THE MYSORE JOURNAL OF AGRICULTURAL SCIENCES

Since 1967

Vol. 57 (1) January - March 2023 ISSN-0047-8539

Online :
Website : www.mjas.co.in
or
https://e-krishiuasb.karnataka.gov.in/MJAS/Home.aspx

UNIVERSITY OF AGRICULTURAL SCIENCES BANGALORE, INDIA

A Peer-Reviewed Journal listed in UGC Care List with a NAAS Score of 4.64

THE MYSORE JOURNAL OF AGRICULTURAL SCIENCES

NAAS Score 4.64

Frequency of Publication : Quarterly

MJAS 57 (1) 2023 : 1-482

EDITORIAL COMMITTEE

Chairman

Dr. S. V. Suresha
Vice-Chancellor, UAS, Bangalore

Members

Dr. K. C. Narayanaswamy, Director of Education, UAS, Bangalore
Dr. K. Narayana Gowda, Director of Extension, UAS, Bangalore
Dr. K. B. Umesh, Director of Research, UAS, Bangalore
Dr. H. C. Prakasha, Dean (PGS), UAS, Bangalore
Dr. S. N. Vasudevan, Dean (Agri.), College of Agriculture, Hassan
Dr. K. H. Nagaraj, Editor, Communication Centre - Member Convenor

SUBSCRIPTION RATES

Membership	Inland (₹)	Foreign (US $) AM*
Annual Membership		
Individual	400.00	80.00
Institution	600.00	
Life Membership		
Individual	3000.00	
Institution	5000.00	
Single copy	100.00	

* AM – Air Mail

Note :

1. All correspondence should be addressed to the Editor, Communication Centre, UAS, GKVK, Bengaluru - 560 065, India. E-mail : editor@uasbangalore.edu.in / editoruasb@gmail.com
2. All the authors of the review article and research article must be the subscribers of MJAS and should also pay a processing fee of Rs.100/- per article
3. Subscription amount drawn in favour of the Editor, Communication Centre, UAS, GKVK, Bengaluru-560 065 may be deposited to the S/B Account No. 0425101030928, IFSC Code CNRB0002737, Canara Bank, GKVK, Bengaluru-560 065. The proof of the payment may be mailed to editor@uasbangalore.edu.in/ editoruasb@gmail.com
4. Authors should submit the articles with the duly signed declaration stating that the contents of the article are not duplicated and has neither been published nor sent for publication elsewhere

This Journal is being indexed in Web of Science, EBSCO and CAB International

Online : **Website : www.mjas.co.in**
or
https://e-krishiuasb.karnataka.gov.in/MJAS/Home.aspx

Edited and Published by Dr. K. H. Nagaraj
Edited and Assisted by Dr. Roopa B. Patil
Communication Centre, University of Agricultural Sciences, GKVK, Bengaluru - 560 065, India

Mysore J. Agric. Sci., 57 (1) : 1-482 (2023)

CONTENTS

ABSTRACTS

Impact of Rootstock *via* Carbohydrate Metabolism and Nutrients on Bearing Habit of Fruit Crops

Hatkari Vittal, Nimisha Sharma and Mukesh Shivran
Division of Fruits and Horticultural Technology, ICAR - Indian Agricultural Research Institute, New Delhi - 110 012
e-Mail : nims17sharma@gmail.com

Authors Contribution

Hatkari Vittal : Collected material for review and drafted the manuscript;
Nimisha Sharma : Conceptualization and editing;
Mukesh Shivran : Editing

Corresponding Author :
Nimisha Sharma
Division of Fruits and Horticultural Technology, ICAR - Indian Agricultural Research Institute, New Delhi

Received : October 2022
Accepted : November 2022

Abstract

Fruits are widely regarded as protective food necessary for maintaining human health. Though growing fruit crops is a highly remunerative enterprise, their cultivation faces many challenges like fluctuations in climatic factors, irregular bearing, pests and diseases *etc.* This causes instability in production and productivity with low economic returns from per unit area. Alternate bearer fruit cultivars are one of the serious economic problems to the fruit growers. Physiological factors like carbohydrate reserves, nutrient metabolism and phytohormones are known to be involved in flowering thereby regulating bearing habit. Draining out of carbohydrate and nitrogen reserves during 'On' year is known to lead to a lean crop in the 'Off' year as they are important for fruit bud initiation *i.e.,* high C/N ratio helps for fruit bud initiation. The developing fruit provides a strong sink for photo assimilates. It was therefore, thought that depletion of photo assimilates, especially carbohydrates from the bud which prevents flowering induction, a hypothesis known as the nutritional theory. Knowledge about impact of carbohydrates and nutrients along with other important factors influencing flowering process is helpful in understanding the phenomena of bearing in fruit crops.

Keywords : Bearing habit, Carbohydrate metabolism, Fruit Crops, Nutrient uptake, Rootstock, Scion

Flower bud initiation is the key developmental stage in plant growth, particularly for horticultural crops such as the fruit trees because it determines the success of commercial orchards by its influence on fruit quantity and quality as well as stability of production from year to year. Fruit crops like mango, apple, citrus, litchi, olive *etc.* show irregular bearing. Improved technologies such as high-density planting, innovations in propagation, micro irrigation, protected cultivation, breeding for regular bearing, rootstock breeding for quality features and so on can help increase fruit yield. Fruit trees with various rootstock and scion combinations exhibit a variety of anatomical, physiological and biochemical characteristics. This will be helpful in understanding the impacts of the rootstock on different horticultural traits in fruit trees (Habibi *et al.,* 2022).

Major Research Gaps in Fruit Breeding for Regular Bearing

The instability in fruit production with good crop during one year and low or no crop in the following year is called as alternate bearing. Commonly used terms related to alternate bearing include biennial bearing and irregular bearing. Monselise and Goldschmidt (1982) reported that this phenomenon is present in many fruit tree crops, *viz.,* nuts (hazelnuts, pecans, pistachios and walnuts), temperate fruits (apple, apricot, pears and prunes), subtropical fruits (avocados, citrus and olives), tropical fruits (litchi and mango). Over the previous few years, India's horticulture production has increased. During last decade, area under horticulture grew by 2.6 per cent per annum with 4.8 per cent increase in production

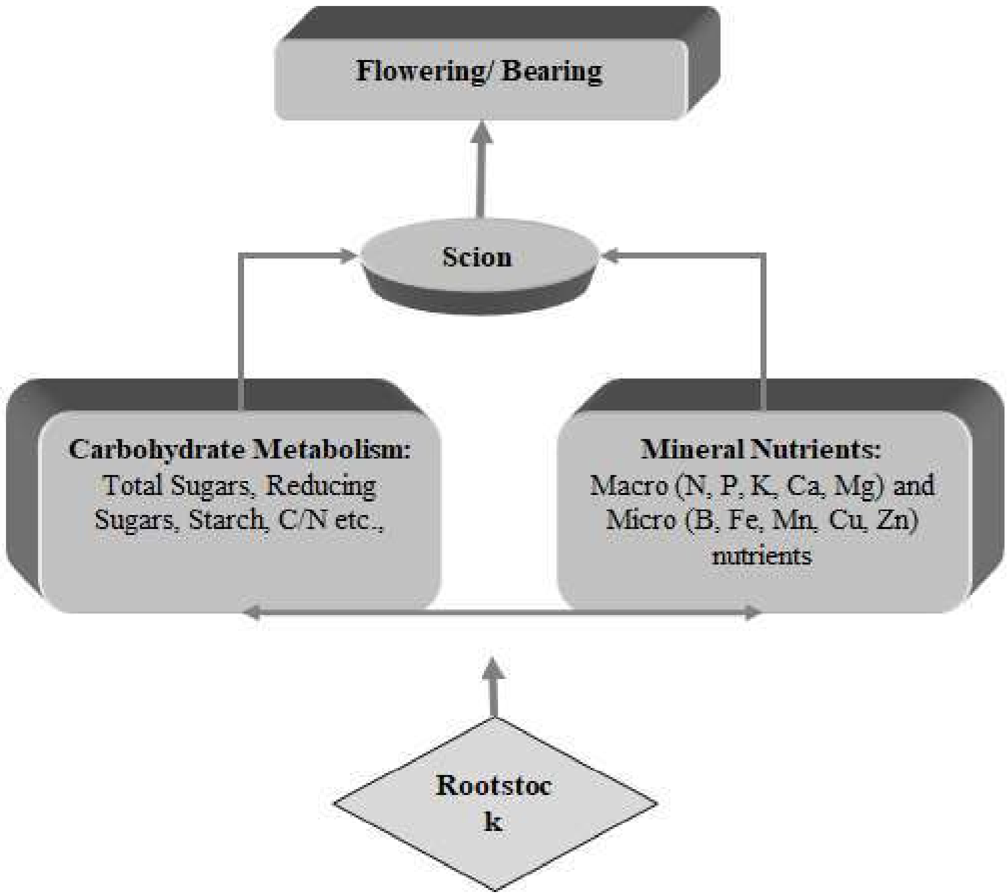


Fig. 1 : Rootstock influence on flowering or bearing habit of fruit crops *via* CHO metabolism and mineral nutrients.

(NHB, 2020-2021). However, variable fruit yield throughout subsequent years is a serious issue that restricts fruit crop productivity. Due to long juvenile phase, heterozygous in nature, breeding methods applicability for regular bearing is very cumber some. Research on perennial crops for regular bearing has been carried out by several workers (Sharma *et al.,* 2019). There are many factors to regulate bearing of crop and carbohydrate metabolism and nutrient up take also play an important role in bearing of crop. Role of rootstock for regular bearing is still meager therefore; present review highlights the role of rootstock in bearing.

Impact of Rootstocks on Physiological Traits of Fruit Crops

Numerous studies (Goncalves *et al.,* 2003 and Hartmann *et al.,* 2011) have shown that scion-rootstock interactions influence the physiological traits of plants like photosynthetic variables (stomatal conductance, rate of transpiration, net rate of photosynthesis), water relations, anti-oxidant enzyme activities, total soluble protein (TSP) concentrations, mineral uptake, plant size, flowering, timing of fruit set, fruit quality and yield efficiency.

In grape, cherry and apple, genotypic effect of the rootstocks has altered the photosynthesis of the scion (Verma *et al.,* 2010). Satisha *et al.* (2007); Singh and Rajan (2009); Koepke and Dhingra (2013); Bavaresco and Lovisolo (2015) found that water use efficiency (WUE), photosynthesis variables *etc.* significantly differed among rootstocks and stress levels in fruit crops. Several studies (Loreti *et al.,* 2002; Haak *et al.,* 2006; Sotiropoulos, 2006; Bosa *et al.,* 2014) on pear and quince rootstocks indicated that scion-rootstock interactions have an impact on gas exchange, tree vigour, fruit set, yield and fruit quality.

Rootstock Influence on Flowering *via* CHO Metabolism

Effect of Rootstock on Carbohydrate Partitioning

Carbon and Nitrogen are the key elements because it is an energy-producing factor and build tissues, respectively. The importance of the Nitrogen Carbon (NC) ratio in flowering concept has been known since 1918. It was documented by the work of Kraus and Kraybill. Foster *et al.* (2017) studied that rootstock affects the partitioning of carbo hydrates on both sides of the graft union in apple. Shu *et al.* (2017); Wang *et al.* (2016) found that plant growth regulators, proteins, mineral nutrients and water, are exchanged between the scion and root stock. Dayal *et al.* (2017) assessed the potential role of polyembryonic rootstocks on tree growth, yield and physiology of five mango cultivars. It is concluded that rootstocks alter most of the physio-chemical parameters of scion cultivars in mango though the extent of regulation of activities was scion specific.

In mango several studies (Reddy *et al.,* 2003; Smith *et al.,* 2003) found that the use of rootstocks has improved the growth, yield and fruit quality of mango. Costes *et al.* (2003); Costes and García-Villanueva, (2007) found that in fruit crops, like apple, rootstock impacts on scion growth habits which can affect the balance between reproductive and vegetative growth. Jover *et al.* (2012) observed that sucrose and starch concentrations in root bark appeared to be related with fruit sink strength. The phloem is main channel in supply of carbohydrates to developing plant tissues, including the flower (Boldingh *et al.,* 2016).

Yang *et al.* (2021) hypothesized that crop load manipulation has long been used to alter source - sink relationship to improve fruit quality and mitigate biennial bearing in fruit crops. Kviklys and Samuoliene (2020) reported that return to bloom was dependent on rootstock, scion and crop load and was negatively correlated to sorbitol in the buds. Abdullah *et al.* (2020) concluded that mango rootstock can affect canopy architecture of scion as early as in the first year of growth following grafting. Fu *et al.* (2016) showed that grafting was associated with significantly increased plant growth, fruit yields and enhanced photosynthetic capacities in melon (Cucumis melo).

Importance of CHO Metabolism in Flowering / Fruiting

Experimental evidence indicates that maturity of terminal shoot and accumulation of carbohydrate in the leaves and shoot apex are in some way associated with the synthesis of the floral stimulus in mango trees (Davenport, 2009). Nath and Singh, (2014) suggested that carbohydrate distribution pattern may serve as an indication for the judging of the floral induction effect in litchi. Barbier *et al.* (2015) investigated how sugar availability modulates the hormonal network during bud outgrowth in Rosa hybrid. Upreti *et al.* (2014) studied the role of carbohydrates in the paclobutrazol induced floral initiation in mango cv. Totapuri. The results indicated that paclobutrazol induced flowering is accompanied by an increase in starch in leaf concomitant with an increase in soluble sugars in the apical buds. Maurel *et al.* (2004) found that vegetative buds of peach (*Prunus persica* L. Batsch.) trees act as strong sinks and their bud break capacity can be profoundly affected by carbohydrate availability during the rest period (November-February). Boldingh (2016) reported that high carbohydrate and boron content in flowers of avocado at anthesis must for fruit setting. Iglesias *et al.* (2002) generated source - sink imbalances by defoliation and sucrose supplementation by stem injection in cv. Okitsu of Satsuma mandarins and reported that sucrose supplementation increased citrus fruit set by more than 10 per cent.

Syvertsen *et al.* (2003) showed that leaves immediately adjacent to fruit were smaller, had lower leaf nitrogen and carbohydrate concentrations, lower leaf dry mass per area (LDM_a) and lower net assimilation of CO2 (A_c) than leaves on non-fruiting branches of the same trees in 'Spring' navel Orange (*Citrus sinensis* (L.) Osbeck). Carbohydrate partitioning also play important role in alternate bearing. Davie *et al.* (1995) emphasized that carbohydrate reserve must be increased in the tree at the flower induction to fruit set stage to modify the alternate bearing. Further, Jyothi *et al.* (1998) studied the biochemical changes in alternate and regular bearing varieties. In regular bearing trees, reducing sugars were highest at flower bud differentiation (FBD). Non-reducing and total sugar levels rise and fall pattern was noted from FBD to maturity.

Slow mobilization of starch reserves may be one limiting factor in citrus. Ulger *et al.* (2004) in their studies found a higher C/N ratio (1.5 times more in 'Off' than 'On' year) during the initiation period and an increased yield in the following year, suggest that sugar levels are associated with floral initiation in olives. Gawankar *et al.* (2019) studied that growth and fruitfulness of a plant is greatly influenced by the relative proportions of carbohydrates and nitrogen. Muñoz-Fambuena *et al.* (2013) did the proteomic analysis of leaves and floral buds from 'On' and 'Off' trees at the time of floral induction in citrus showed the importance of C and N compounds for flowering.

Saxena *et al.* (2014) showed that Amrapali being the regular cultivar, contained higher levels of total and reducing sugar and protein content in all the developmental stages of flowering as compared to biennial cultivars. The forms of sugar, as well as the ratio of reducing to non-reducing sugar and the total sugars, have a significant impact on fruit bud differentiation. Das *et al.* (2019) in their experiment analyzed the carbohydrate levels during flowering in two mango cultivars, Amrapali (regular bearer) and Dashehari (alternate bearer), contrasting for bearing habit. Regular bearer cv. Amrapali has a higher carbohydrate content than alternate bearer Dashehari during the 'Off' year. Capelli *et al.* (2021) investigated the role of hormones and carbohydrates on the negative effects of reproduction on vegetative growth in mango cultivars. Singh and Sharma, (2008) observed that physiological and biochemical changes associated with the flowering in mango. Shivashankara & Mathai, (2000); Urban *et al.* (2008) suggested that the changes in photosynthetic rate associated with flowering are reversible, it is associated with carbohydrate reserves accumulation in reproductive shoot. Vemmos, (2005) reported that reduction in sucrose movement from leaves to inflorescent buds inhibits bud growth and triggers inflorescent bud abscission in pistachio (*Pistacia vera* L.). Goetz *et al.* (2021) showed that during the end of flowering transition, dominance inhibition of inflorescence shoot growth by fruit load is mediated by auxin and sugar signaling in Arabidopsis. Martínez-Alcántara *et al.* (2015) concluded that carbon utilization by fruit limits shoot growth in alternate-bearing citrus tree. In star fruit (*Averrhoa carambola*) drought stress increased the flowering rate in both drooping and water shoots (Pingping *et al.,* 2017). Stress caused increased accumulation of carbo hydrates which may related to flowering.

Rootstocks-CHOs-Alternate Bearing

Fruiting depletes the carbohydrate supply, which is one of the most essential factors for biennial bearing in perennial fruit crops and is connected with floral induction. Diversion of assimilates from shoot apices to floral primordial is required for floral initiation. Off-season, summer flowering and winter fruiting was induced in mango cvs. Dashehari and Totapuri, which normally do not flower out of season, when their defoliated shoots were grafted onto the shoots of the off-season cv Royal Special. Off-season flowering could be readily induced in single flowering cultivars such as Alphonso and Dashehari by veneer grafting their defoliated receptor shoots onto leafy donor shoots of multi-flowering cultivars such as Royal Special (Kulkarni, 1986).

Some rootstocks can affect flowering time by altering the chilling requirement and lead to flowers opening (Atkinson and Else, 2001). Furthermore, the rootstock can influence the alteration of vegetative shoots to flowering buds (Seleznyova *et al.,* 2008). In addition, rootstocks determine the number of flowers on a tree caused by changes in scion architecture, shoot growth, and orientation (Van Hooijdonk *et al.,* 2011). Fruit rootstocks can induce precocious scion flowering. Rootstocks might affect alternate bearing through physiological factors favouring production, such as the amount of photosynthate translocated into parts of the roots (Kriedemann,1969). Dwarf apple rootstocks affect precocity and flowering time due to carbohydrate metabolism and enhanced carbon partitioning to the reproductive areas (Fazio *et al.,* 2014). Dubey *et al.* (2021) observed that rootstock influenced the vigour of scion and yield, but minimal alterations in fruit quality. Cohen *et al.,* (2022) reported that for vegetative rootstocks alternate bearing index (ABI) values were lower than the seedling rootstocks in avocado.

Rootstock Influence on Flowering *via* Nutrient Metabolism

Effect of Rootstock on Mineral Nutrient Uptake

Several reports (Cheng and Raba, 2009; North and Cook, 2006), showed that rootstocks can affect the mineral uptake of tree. According to several research, rootstock selection can have a considerable impact on nutrient uptake (Ibacache and Sierra, 2009; Covarrubias *et al.,* 2016; Habran *et al.,* 2016; Lecourt *et al.,* 2015; Zamboni *et al.,* 2016). Mickelbart *et al.* (2007) studied nutrient concentrations in 'Hass' avocado (*Persea americana* Mill.). In addition, citrus rootstocks affected boron uptake (Guidong *et al.,* 2011; Liu *et al.,* 2013; Mei *et al.,* 2011; Wang *et al.,* 2016). Rootstocks can affect mineral uptake, transport, and use efficiency from the soil through the root to the scion (Amiri *et al.,* 2014; Nawaz *et al.,* 2016). These attributes may be due to root architecture, changing the activities of ion transporters, changes in hormonal levels and miRNAs (Meister *et al.,* 2014; Zeng *et al.,* 2014).

The different architectures of grapevine rootstocks affected nitrogen use efficiency (NUE) and Phosphorus (P) uptake. The total nitrogen accumulation and NUE were affected in various citrus rootstocks, as rough lemon had more potential of NUE than 'Cleopatra' mandarin (Sorgona *et al.,* 2006). Prunus rootstocks significantly affected macro and microelements in leaves of cherry (Hrotko *et al.,* 2014), peach (Mestre *et al.,* 2015; Zarrouk *et al.,* 2005) and plum (Reig *et al.,* 2018), as well as flowers in cherry (Jiménez *et al.,* 2004) and peach (Zarrouk *et al.,* 2005). Consequently, rootstock modifies the transport of nutrients. For example, eight distinct K transporters have been found in 'Carrizo citrange' and 'Cleopatra' mandarins (Caballero *et al.,* 2013). The activities of ferric-related uptake and transport genes (NAS1, FRD3 and NRMAP3) significantly increased ferrous uptake in apple rootstocks under iron-deficient conditions (Zha *et al.,* 2014). Two Prunus rootstocks showed increased expression of Ferric chelate reductase (FCR) and the iron transporter genes grown under iron-deficient conditions (Gonzalo *et al.,* 2011). Different grape rootstocks improved nitrate uptake by affecting the activities of low and high-affinity nitrate transporter genes (Tomasi *et al.,* 2015). In pear rootstocks, transcripts of ammonium transporters have been found to be affected by the rootstock (Li *et al.,* 2016; Mota *et al.,* 2007). Nitrogen uptake and transport in two graft combinations of grapevine, conferring different vigour to the scion. The low vigour rootstock had higher nitrate uptake capacity and assimilation in roots after nitrate resupply than the high vigour rootstock, which is potentially linked to the higher carbohydrate status of the low vigour rootstock. Sarkhosh *et al.* (2021) investigated the effect of rootstock on scion nutritional status and the selection of rootstock-scion combinations for variety development.

Importance of Mineral Nutrients in Flowering/ Fruiting

Role of nutrients in irregular bearing also studied in many fruit crops. Nafees *et al.* (2013); El-Motaium *et al.* (2019) recommended nitrogen fertilizer to mitigate alternate bearing in mango. Fernandez-Escobar *et al.* (1999); Turktas *et al.* (2013), studied mineral nutrients in olive leaves during the alternate-bearing cycle. It was concluded that alternate bearing influenced leaf-nutrient content of olive trees. Pillay *et al.* (2005) observed that lower levels of leaf boron could help identify an 'Off' tree. Thus, signified the role of mineral elements in regulating the flowering. Baninasab *et al.* (2007) demonstrated that N, P and K concentrations were significantly lower in many organs of 'On' trees (presenting major bud abscission) than of 'Off' trees of Pistachio. Okada (2004); Mirsoleimani *et al.* (2014) showed that reserved nutrients status in citrus can predict the fruit productivity. Gundesli *et al.* (2021) studied the seasonal changes in mineral nutrient contents in the leaf and shoot tissues of pistachio trees as well as the relationship between these changes and alternate bearing.

There is some evidence of an interrelationship between transport and metabolism of carbohydrates as well as movement and accumulation of K. It is well established that K acts as an osmoticum for the transport and storage of sugars (Giaquinta *et al.,* 1983). Thus, in 'On' trees there would be an enhanced requirement for K as an osmoticum for the transport of sucrose to the developing fruits. Krishnamurthy *et al.* (2013) investigated the influence of carbohydrates, mineral nutrients and plant hormones in alternate bearing of Black Pepper (*Piper nigrum* L.) and their study indicated that efficient utilization of metabolites in 'On' year may render vine weak in the subsequent year coupled with poor remobilization into developing berries, which could make it an 'Off' year. Physiological and biochemical attributes that help the rootstocks to control plant vigour have generally focused on hormone biosynthesis, nutrient uptake (Khan *et al.,* 2020), carbohydrates (Gemma and Iwahori, 1998).

Molecular Aspects: Bearing

The transport of molecules, mainly miRNA, small RNA and proteins across graft union through the phloem are important communication between rootstock and scion (Harada, 2010; Pant *et al.,* 2008; Xing *et al.,* 2016). The long-distance of mRNA, small RNA and protein as graft-transmissible signals are currently developing as new mechanisms to influence horticultural attributes in rootstock / scion relation ships and play a crucial function in molecular aspects of grafting (Loupit and Cookson, 2020). Guo *et al.,* 2021 did fruit transcriptomics analysis revealed important differences in gene expression between pumpkin-grafted and self-grafted watermelon plants, highlighting a particular impact in ABA-signaling, sucrose transport and carotenoid metabolism related genes associated to the ripening process affected by the pumpkin rootstock.

Goncalves *et al.,* 2019 recommended that the rootstock was responsible for inducing the drought tolerance in scion cultivar by up regulating the transcription of genes associated to the cell wall, biotic as well as abiotic stress resistance, antioxidant systems, soluble carbohydrate, transcription factors (TFs), protein kinases (PKs) and proteins involved in the abscisic acid (ABA) signaling pathway and at the same time by down regulating the activity of genes involved in the light reaction, metabolic processes and biosynthesis of ethylene. Li *et al.* (2003) found that gene expression is related to starch accumulation in all 'Off' tree organs. RNA levels of all the genes examined were high in leaves and bark that accumulated high concentrations of starch and low in roots with declining starch concentrations. Yanik *et al.* (2013) performed a comprehensive study on the olive tree miRNA related to the alternate bearing. Wahl *et al.* (2013) studied the role of carbohydrates especially Trehalose-6-Phosphate in flowering of *Arabidopsis thaliana*. The loss of *TREHALOSE-6-PHOSPHATE SYNTHASE 1 (TPS1)* causes *Arabidopsis thaliana* to flower extremely late. This suggests that TPS1 is required for the timely initiation of flowering. It was concluded that the T6P pathway affects flowering both in the leaves and at the shoot meristem. Nebauer *et al.* (2014) carried out an experiment to find the relation between the seasonal variation of expression and activity of the genes involved in carbon metabolism and the partition and allocation of carbohydrates in 'Salustiana' sweet orange trees with different crop loads. Sharma *et al.* (2020) studied the molecular mechanisms underlying alternate bearing in mango (*Mangifera indica* L.) via transcriptome wide gene expression profiling of both regular and irregular mango varieties. Gould *et al.* (2019) showed differences in sugar delivery rate to the flower reflected by differences in *TPS1* expression. Yang *et al.* (2014) showed that mature leaves had higher expression levels of the floral promoter and florigen in litchi. The enzymes like Sucrose 6 Phosphate Synthase, Trehalose Phosphate Synthase, Citrate Synthase, Alcohol Dehydrogenase involved in the process of carbohydrate metabolism of plants (Brownleader *et al.,* 1997). Micallef *et al.* (1995)

reported the involvement of *Sucrose Phosphate Synthase (SPS)* gene in flowering of transgenic tomato. Role of *Citrate synthase (CS)* gene in flowering of transgenic tobacco and transgenic Arabidopsis plants (Han *et al.* 2013, 2017) was reported. Studies (Eldik *et al.,* 1998 and Gregerson *et al.,* 1991) indicated the involvement of Alcohol dehydrogenase activity in flowering. In plants grown under normal, aerobic conditions, *adh* genes are only transcribed in the anther, whereas ADH enzyme activity is localized in the pollen.

Effective Nutrition Regulation to Mitigate Irregular Bearing

The efficient utilization of metabolites and nutrients in on year may render the shoot week in the subsequent year coupled with poor remobilization into developing fruits, which could make it an 'Off' year.

The nutrients level during critical stages of plant growth plays an important role in production. Therefore, maintaining optimum nutrient balance in plant is essential. Appropriate levels of N, P, K, Mg, S and micronutrients were found necessary along with proper balance of Ca and other cations for flowering and fruit bearing.

The seasonal pattern of nutrient uptake and partitioning is a key component of fertilizer management in orchards. Matching both the time and the rates of fertilizer application with the time of a plant's high nutrient demand, not only maximizes yield, but also increases nutrient-use efficiency and thus, reduces the potential for pollution.

The nutrient management during 'Off' year to obtain higher yields and measures to achieve higher remobilization into developing fruits and enhan cement of hormone levels through exogenous supplement during flower primordial initiation and early flowering stages during 'Off' year are helpful to counter the alternate bearing effect.

Conclusion and Future Thrust

Fruit removal studies have shown that flowering and fruiting are high energy requiring processes and deplete high amounts of stored carbohydrates, nitrogen reserves as well as other mineral nutrients from previous season and there are no reserves to support the next year crop. This knowledge about impact of carbohydrates and nutrients along with other important factors influencing flowering processes helpful in understanding the phenomena of bearing in fruit crops and to take proper actions which will be helpful in reducing the impact of irregular bearing on productivity of fruit crops.

References

Abdullah, F. and Maamun, T. A. M., 2020, Effects of rootstock on the initial growth and development of young 'Chok Anan' mango. *Transactions of the Malaysian Society of Plant Physiology*, pp. : 27.

Amiri, M. E., Fallahi, E. and Safi-Songhorabad, M., 2014, Influence of rootstock on mineral uptake and scion growth of 'Golden delicious' and 'Royal Gala' apples. *J. Plant Nutr.*, **37** (1), 16-29. https://doi.org/10.1080/01904167.2013.792838.

Atkinson, C. and Else, M., 2001, Understanding how rootstocks dwarf fruit trees. *Compact Fruit Tree,* **34** (2) : 46 - 49.

Baninasab, B., Rahemi, M. and Shariatmadari, H., 2007, Seasonal changes in mineral content of different organs in the alternate bearing of pistachio trees. *Commun Soil Sci. Plant Anal.,* **38** (1-2), 241-258. https://doi.org/10.1080/00103620601094197

Barbier, F., Peron, T., Lecerf, M., Perez-Garcia, M. D., Barrière, Q., Rolcik, J., Boutet-Mercey, S., Citerne, S., Lemoine, R. and Porcheron, B., 2015, Sucrose is an early modulator of the key hormonal mechanisms controlling bud outgrowth in *Rosa hybrida*. *J. Exp. Bot.,* **66** (9) : 2569 - 2582. https://doi.org/10.1093/jxb/erv047

Bavaresco, L. and Lovisolo, C., 2015, Effect of grafting on grapevine chlorosis and hydraulic conductivity. *VITIS- J. Grapevine Res.,* **39** (3) : 89.

Boldingh, H. L., Alcaraz, M. L., Thorp, T. G., Minchin, P. E. H., Gould, N. and Hormaza, J. I., 2016, Carbohydrate and boron content of styles of 'Hass' avocado (*Persea americana* Mill.) flowers at anthesis can affect final fruit set. *Sci. Hortic.,* **198** : 125 - 131. https://doi.org/10.1016/j.scienta.2015.11.011

Bosa, K., Jadczuk-Tobjasz, E., Kalaji, M. H., Majewska, M. and Allakhverdiev, S. I., 2014, Evaluating the effect of rootstocks and potassium level on photosynthetic productivity and yield of pear trees. Russ. *J. Plant Physiol.,* **61** (2) : 231 - 237. https://doi.org/10.1134/S1021443714020022

Brownleader, M. D., Harborne, J. B. and Dey, P. M., 1997, Carbohydrate metabolism : Primary metabolism of. plant physiol. *Biochem.,* pp. : 111.

Caballero, F., Garcia-Sanchez, F., Gimeno, V., Syvertsen, J. P., Martínez, V. and Rubio, F., 2013, High-affinity potassium uptake in seedlings of two citrus root stocks carrizo citrange (*'Citrus sinensis'* [L.] Osb. X '*Poncirus trifoliata'* [L.] Raf.) and cleopatra mandarin (*'Citrus reshni'* hort. Ex tanaka). *Aust. J. Crop Sci.,* **7** (5) : 538 - 542.

Capelli, M., Lauri, P. E., Lechaudel, M. and Normand, F., 2021, Hormones and carbohydrates are both involved in the negative effects of reproduction on vegetative bud outgrowth in the mango tree : Consequences for irregular bearing. *Tree Physiol*., **41** (12) : 2293 - 2307. https://doi.org/10.1093/treephys/tpab079

Cheng, L. and Raba, R., 2009, Accumulation of macro and micronutrients and nitrogen demand-supply relationship of 'Gala/ Malling 26' apple trees grown in sand culture. *J. Am. Soc. Hortic. Sci.,* **134** (1) : 3-13. https://doi.org/10.21273/JASHS.134.1.3

Cohen, H., Bar-Noy, Y., Irihimovitch, V. and Rubinovich, L., 2022, Effects of seedling and clonal West Indian rootstocks irrigated with recycled water on 'Hass' avocado yield, fruit weight and alternate bearing. *N. Z. J. Crop Hortic. Sci.,* pp. : 1-13. https://doi.org/10.1080/01140671.2022.2098779

Costes, E. and Garcia-Villanueva, E., 2007, Clarifying the effects of dwarfing rootstock on vegetative and reproductive growth during tree development : A study on apple trees. *Ann. Bot.,* **100** (2) : 347 - 357. https://doi.org/10.1093/aob/mcm114.

Costes, E., Sinoquet, H., Kelner, J. J. and Godin, C., 2003, Exploring within-tree architectural development of two apple tree cultivars over 6 years. *Ann. Bot.,* **91** (1), 91 - 104. https://doi.org/10.1093/aob/mcg010

Covarrubias, J. I., Retamales, C., Donnini, S., Rombola, A. D. and Pastenes, C., 2016, Contrasting physiological responses to iron deficiency in cabernet sauvignon grape vines grafted on two rootstocks. *Sci. Hortic.,* **199** : 1 - 8. https://doi.org/10.1016/j.scienta.2015.12.013

Das, A., Geetha, G. A., Ravishankar, K. V., Shivashankara, K. S., Roy, T. K. and Dinesh, M. R., 2019, Interrelations of growth regulators, carbohydrates and expression of flowering genes (*FT, LFY, AP1*) in leaf and shoot apex of regular and alternate bearing mango (*Mangifera indica* L.) cultivars during flowering. *Sci. Hortic.,* **253** : 263 - 269. https://doi.org/10.1016/j.scienta.2019.04.027

Davenport, T. L., 2009, Reproductive physiology. The mango : botany production and uses. Wallingford, UK : CAB International, pp. : 97 - 169.

Davie, S. J., Van Der Walt, M. and Stassen, P. J. C., 1995, A study of avocado tree carbohydrate cycles to determine ways of modifying alternate bearing. Proceedings of The World Avocado Congress III, pp. : 80 - 83.

Dayal, V., Dubey, A. K., Singh, S. K., Sharma, R. M. and Pandey, R. N., 2017, Effect of poly embryonic rootstocks on leaf mineral composition of five cultivars under Inceptisol. *Indian J. Hortic.,* **74** (2) : 210-213. https://doi.org/10.5958/0974-0112.2017.00044.5

Dubey, A. K., Sharma, R. M. and Kumar, A., 2021, Long term performance of mango varieties on five polyembryonic rootstocks under subtropical conditions : Effect on vigour, yield, fruit quality and nutrient acquisition. *Sci. Hortic.,* pp. : 280, 109944. https://doi.org/10.1016/j.scienta.2021.109944

Eldik, G. V., Ruiter, R. K., Herpen, M., Schrauwen, J. A. M. and Wullems, G. J., 1998, An alcohol dehydrogenase-like gene is specifically expressed in potato pistils. *J. Exp. Bot.,* **49** (325) : 1453 - 1454. https://doi.org/10.1093/jxb/49.325.1453

El-Motaium, R. A., Shaban, A. E. A., Badawy, S. H. and Ibrahim, A. S. A., 2019, Alleviation of alternate bearing phenomenon in mango (*Mangifera indica* L.) trees using boron and nitrogen fertilization. *J. Plant Nutr.,* **42** (20) : 2861 - 2872. https://doi.org/10.1080/01904167.2019.1659319

Fazio, G., Wan, Y., Kviklys, D., Romero, L., Adams, R., Strickland, D. and Robinson, T., 2014, Dw2, a new dwarfing locus in apple rootstocks and its relationship to induction of early bearing in apple scions. *J. Am. Soc. Hortic. Sci.,* **139** (2) : 87 - 98. https://doi.org/10.21273/JASHS.139.2.87

Fernandez-Escobar, R., Moreno, R. and Garcia-Creus, M., 1999, Seasonal changes of mineral nutrients in olive leaves during the alternate-bearing cycle. *Sci. Hortic.,* **82** (1-2) : 25 - 45. https://doi.org/10.1016/S0304-4238(99)00045-X

Foster, T. M., Mcatee, P. A., Waite, C. N., Boldingh, H. L. and Mcghie, T. K., 2017, Apple dwarfing rootstocks exhibit an imbalance in carbohydrate allocation and reduced cell growth and metabolism. *Hort. Res.,* 4. https://doi.org/10.1038/hortres.2017.9

Fu, Q., Zhang, X., Kong, Q., Bie, Z. and Wang, H., 2016, Effects of grafting on carbohydrate metabolism in melon (*Cucumis melo* L.) during stages of fruit development. Cucurbitaceae 2016, XI Eucarpia Meeting on Cucurbit Genetics & Breeding, Warsaw, Poland, pp. : 191 - 196.

Gawankar, M. S., Haldankar, P. M., Salvi, B. R., Parulekar, Y. R., Dalvi, N. V., Kulkarni, M. M., Saitwal, Y. S. and Nalage, N. A., 2019, Effect of girdling on induction of flowering and quality of fruits in horticultural crops - A review. *J. Adv. Agric. Technol.,* **3** : 201 - 215.

Gemma, H. and Iwahori, S., 1998, Partitioning of carbohydrates and development of tissues in the graft union of peaches grafted on *Prunus tomentosa* Thunb. Rootstock. *J. Jpn. Soc. Hortic. Sci.,* **67** (4) : 475 - 482.

Giaquinta, R. T., 1983, Phloem loading of sucrose. *Annu. Rev. Plant Physiol.,* **34** (1) : 347 - 387. https://doi.org/10.1104/pp.72.2.362

Goetz, M., Rabinovich, M. and Smith, H. M., 2021, The role of auxin and sugar signaling in dominance inhibition of inflorescence growth by fruit load. *Plant Physiol.,* **187** (3) : 1189 - 1201. https://doi.org/10.1093/plphys/kiab237

Goncalves, B., Santos, A., Silva, A. P., Moutinho-Pereira, J. and Torres-Pereira, J. M. G., 2003, Effect of pruning and plant spacing on the growth of cherry rootstocks and their influence on stem water potential of sweet cherry trees. *J. Hortic. Sci. Biotechnol.,* **78** (5) : 667 - 672. https://doi.org/10.1080/14620316.2003.11511682

Goncalves, L. P., Boscariol Camargo, R. L., Takita, M. A., Machado, M. A., Dos Soares Filho, W. S. and Costa, M. G., 2019, Rootstock-induced molecular responses associated with drought tolerance in sweet orange as revealed by RNA-Seq. *BMC Genom.,* **20** (1) : 1 - 14. https://doi.org/10.1186/s12864-019-5481-z

Gonzalo, M. J., Moreno, M. A. and Gogorcena, Y., 2011, Physiological responses and differential gene expression in Prunus rootstocks under iron deficiency conditions. *J. Plant Physiol.,* **168** (9) : 887 - 893. https://doi.org/10.1016/j.jplph.2010.11.017

Gould, N., Minchin, P. E., Boldingh, H., Gould, E. M. and Thorp, G., 2019, Biochemical and molecular analyses of potential markers for evaluating the competition for resources between mature fruit and open flowers in 'Hass' avocado trees. *N. Z. J. Crop Hortic. Sci.,* **47** (3) : 143 - 154. https://doi.org/10.1080/01140671.2019.1606020

Gregerson, R., Mclean, M., Beld, M., Gerats, A. G. and Strommer, J., 1991, Structure, expression, chromosomal location and product of the gene encoding ADH1 in Petunia. *Plant Mol. Biol.,* **17** (1) : 37 - 48. https://doi.org/10.1007/BF00036804

GUIDONG, L., CUNCANG, J. AND YUNHUA, W., 2011, Distribution of boron and its forms in young 'Newhall' navel orange (*Citrus sinensis* Osb.) plants grafted on two rootstocks in response to deficient and excessive boron. *Soil Sci. Plant Nutr.,* **57** (1) : 93 - 104. https://doi.org/10.1080/00380768.2010.551299

GUNDESLI, M., KAFKAS, N., GUNEY, M. AND KAFKAS, S., 2021, Seasonal changes in the mineral nutrient concentrations of different plant organs of pistachio trees in alternate bearing. ERWERBS-OBSTBAU.

GUO, S., SUN, H., TIAN, J., ZHANG, G., GONG, G., REN, Y., ZHANG, J., LI, M., ZHANG, H., LI, H. AND XU, Y., 2021, Grafting delays watermelon fruit ripening by altering gene expression of ABA centric phytohormone signaling. *Front. Plant Sci.,* 12. https://doi.org/10.3389/fpls.2021.624319.

HAAK, E., KVIKLYS, D. AND LEPSIS, J., 2006, Comparison of cydonia and pyrus rootstocks in Estonia, Latvia and Lithuania. *SodininkysteIr Darzininkyste,* **25** (3) : 322 - 326.

HABIBI, F., LIU, T., FOLTA, K. AND SARKHOSH, A., 2022, Physiological, biochemical and molecular aspects of grafting in fruit trees. *Hort. Res.,* **9** : 32. https://doi.org/10.1093/hr/uhac032

HABRAN, A., COMMISSO, M., HELWI, P., HILBERT, G., NEGRI, S., OLLAT, N., GOMES, E., VAN LEEUWEN, C., GUZZO, F. AND DELROT, S., 2016, Rootstocks/scion/nitrogen interactions affect secondary metabolism in the grape berry. *Front. Plant Sci.,* **7** : 1134. https://doi.org/10.3389/fpls.2016.01134

HAN, D., WANG, L., WANG, Y., YANG, G., GAO, C., YU, Z., LI, T., ZHANG, X., MA, L., XU, X., AND HAN, Z., 2013, Overexpression of *Malus xiaojinensis CS1* gene in tobacco affects plant development and increases iron stress tolerance. *Sci. Hortic.,* **150** : 65 - 72. https://doi.org/10.1016/j.scienta.2012.10.004

HAN, D., WANG, Y., ZHANG, Z., PU, Q., DING, H., HAN, J., FAN, T., BAI, X. AND YANG, G., 2017, Isolation and functional analysis of MxCS3 : A gene encoding a *citrate synthase* in *Malus xiaojinensis*, with functions in tolerance to iron stress and abnormal flower in transgenic *Arabidopsis thaliana*. *Plant Growth Regul.,* **82** (3) : 479 - 489. https://doi.org/10.1007/s10725-017-0274-3

HARADA, T., 2010, Grafting and RNA transport *via* phloem tissue in horticultural plants. *Sci. Hortic.,* **125** (4) : 545 - 550. https://doi.org/10.1016/j.scienta.2010.05.013

HARTMANN, H. T., KESTER, D. E. AND GENEVE, R. L., 2011, Hartmann & Kester's plant propagation principles and practices. Prentice Hall.

HROTKO, K., MAGYAR, L., BORSOS, G. AND GYEVIKI, M., 2014, Rootstock effect on nutrient concentration of sweet cherry leaves. *J. Plant Nutr.,* **37** (9) : 1395 - 1409. https://doi.org/10.1080/01904167.2014.911317

IBACACHE, A. G. AND SIERRA, C. B., 2009, Influence of rootstocks on nitrogen, phosphorus and potassium content in petioles of four table grape varieties. Chil. *J. Agric. Res.* **4** : 503 - 508. https://doi.org/10.4067/S0718-58392009000400004

IGLESIAS, D. J., LLISO, I., TADEO, F. R. AND TALON, M., 2002, Regulation of photosynthesis through source: Sink imbalance in citrus is mediated by carbohydrate content in leaves. *Physiol Plant*, **116** (4) : 563 - 572. https://doi.org/10.1093/treephys/23.3.199

JIMENEZ, S., GARIN, A., GOGORCENA, Y., BETRAN, J. A. AND MORENO, M. A., 2004, Flower and foliar analysis for prognosis of sweet cherry nutrition: Influence of different rootstocks. *J. Plant Nutr.,* **27** (4) : 701 - 712. https://doi.org/10.1081/PLN-120030376

JOVER, S., MARTINEZ-ALCANTARA, B., RODRÍGUEZ-GAMIR, J., LEGAZ, F., PRIMO-MILLO, E., FORNER, J. AND FORNER-GINER, M. A., 2012, Influence of rootstocks on photosynthesis in navel orange leaves : Effects on growth, yield and carbohydrate distribution. *Crop Sci.,* **52** (2) : 836 - 848. https://doi.org/10.2135/cropsci2011.02.0100

JYOTHI, M. H., SOPPIN, R. AND EKBOTE, S., 1998, Bio chemical changes in the leaf of bearing and non bearing trees of some mango (*Mangifera indica* L.) varieties/hybrids. *Adv Agric.,* **10** : 17 - 23.

KHAN, M. N., HAYAT, F., ASIM, M., IQBAL, S., ASHRAF, T. AND ASGHAR, S., 2020, Influence of citrus rootstocks on growth performance and leaf mineral nutrition of 'Salustiana' sweet orange [*Citrus sinensis* (L.). Obsek]. *J. Pure Appl Agric.,* **5** : 2617 - 8680.

KOEPKE, T. AND DHINGRA, A., 2013, Rootstock scion somatogenetic interactions in perennial composite plants. *Plant Cell Rep.,* **32** (9) : 1321 - 1337. https://doi.org/10.1007/s00299-013-1471-9

KRIEDEMANN, P. E., 1969, 14C translocation in orange plants. *Aust. J. Agric. Res.,* **20** (2) : 291 - 300. https://doi.org/10.1071/AR9690291

KRISHNAMURTHY, K. S., ANKEGOWDA, S. J., SRINIVASAN, V. AND HAMZA, S., 2013, Influence of carbohydrates, mineral nutrients and plant hormones in alternate bearing of black pepper (*Piper nigrum* L.). *Am. J. Plant Sci.,* **4** (10) : 1960.

KULKARNI, V. J., 1986, Graft-induced off-season flowering and fruiting in the mango (*Mangifera indica* L.). *J. Hortic. Sci.,* **61** (1) : 141 - 145. https://doi.org/10.1080/14620316.1986.11515684

KVIKLYS, D. AND SAMUOLIENĖ, G., 2020, Relationships among the rootstock, crop load and sugar hormone signaling of apple tree and their effects on biennial bearing. *Front Plant Sci.,* 1213. https://doi.org/10.3389/fpls.2020.01213

LECOURT, J., LAUVERGEAT, V., OLLAT, N., VIVIN, P. AND COOKSON, S. J., 2015, Shoot and root ionome responses to nitrate supply in grafted grapevines are rootstock genotype dependent. *Aust. J. Grape Wine Res.,* **21** (2) : 311 - 318. https://doi.org/10.1111/ajgw.12136

LI, C.-Y., WEISS, D. AND GOLDSCHMIDT, E. E., 2003, Girdling affects carbohydrate-related gene expression in leaves, bark and roots of alternate-bearing citrus trees. *Ann. Bot.,* **92** (1) : 137 - 143. https://doi.org/10.1093/aob/mcg108

LI, H., HAN, J. L., CHANG, Y. H., LIN, J. AND YANG, Q. S., 2016, Gene characterization and transcription analysis of two new ammonium transporters in pear rootstock (*Pyrus betulaefolia*). *J. Plant Res.,* **129** (4) : 737 - 748. https://doi.org/10.1007/s10265-016-0799-y

LIU, G. D., WANG, R. D., LIU, L. C., WU, L. S. AND JIANG, C. C., 2013, Cellular boron allocation and pectin composition in two citrus rootstock seedlings differing in boron-deficiency response. *Plant Soil.,* **370** (1) : 555 - 565. https://doi.org/10.1007/s11104-013-1659 - 3

LORETI, F., MASSAI, R., FEI, C. AND CINELLI, F., 2002, Performance of conference cultivar on several quince and pear rootstocks : Preliminary results.

LOUPIT, G. AND COOKSON, S. J., 2020, Identifying molecular markers of successful graft union formation and compatibility. *Front. Plant Sci.,* **11** : 610352. https://doi.org/10.3389/fpls.2020.610352

MARTINEZ-ALCANTARA, B., IGLESIAS, D. J., REIG, C., MESEJO, C., AGUSTI, M. AND PRIMO-MILLO, E., 2015, Carbon utilization by fruit limits shoot growth in alternate-bearing citrus trees. *J. Plant Physiol.,* **176** : 108 - 117. https://doi.org/10.1016/j.jplph.2014.12.001

MAUREL, K., LEITE, G. B., BONHOMME, M., GUILLIOT, A., RAGEAU, R., PETEL, G. AND SAKR, S., 2004, Trophic control of bud break in peach (*Prunus persica*) trees : A possible role of hexoses. *Tree Physiol.,* **24** (5) : 579 - 588. https://doi.org/10.1093/treephys/24.5.579

MEI, L., SHENG, O., PENG, S., ZHOU, G., WEI, Q. AND LI, Q., 2011, Growth, root morphology and boron uptake by citrus rootstock seedlings differing in boron-deficiency responses. *Sci. Hortic.,* **129** (3) : 426 - 432. https://doi.org/10.1016/j.scienta.2011.04.012

MEISTER, R., RAJANI, M. S., RUZICKA, D. AND SCHACHTMAN, D. P., 2014, Challenges of modifying root traits in crops for agriculture. *Trends Plant Sci.*, **19** (12) : 779 - 788. https://doi.org/10.1016 j.tplants.2014.08.005

MESTRE, L., REIG, G., BETRAN, J. A., PINOCHET, J. AND MORENO, M. A., 2015, Influence of peach-almond hybrids and plum-based rootstocks on mineral nutrition and yield characteristics of 'Big Top' nectarine in replant and heavy-calcareous soil conditions. *Sci. Hortic.,* **192** : 475 – 481. https://doi.org/10.1016/j.scienta.2015.05.020

Micallef, B. J., Haskins, K. A., Vanderveer, P. J., Roh, K. S., Shewmaker, C. K. and Sharkey, T. D., 1995, Altered photosynthesis, flowering and fruiting in transgenic tomato plants that have an increased capacity for sucrose synthesis. *Planta,* **196** (2) : 327 - 334.

Mickelbart, M. V., Bender, G. S., Witney, G. W., Adams, C. and Arpaia, M. L., 2007, Effects of clonal rootstocks on 'Hass' avocado yield components, alternate bearing and nutrition. *J. Hortic. Sci. Biotechnol.,* **82** (3) : 460 - 466. https://doi.org/10.1080/14620316.2007.11512259

Mirsoleimani, A., Shahsavar, A. R. and Kholdebarin, B., 2014, Seasonal changes of mineral nutrient concentrations of leaves and stems of 'Kinnow' mandarin trees in relation to alternate bearing. *Int. J. Fruit Sci.,* **14** (2) : 117 - 132. https://doi.org/10.1080/15538362.2013.801678

Monselise, S. P. and Goldschmidt, E. E., 1982, Alternate bearing in fruit trees. *Hortic. Rev.,* **4** (1) : 128 - 173.

Mota, M., Neto, C. and Oliveira, C. M., 2007, Identification of genes coding for nh4 + transporters in 'rocha' pear/ba29. X International Pear Symposium, **800** : 365 - 372.

Munoz-Fambuena, N., Mesejo, C., Agusti, M., Tarraga, S., Iglesias, D. J., Primo-Millo, E. and Gonzalez-Mas, M. C., 2013, Proteomic analysis of 'Moncada' mandarin leaves with contrasting fruit load. *Plant Physiol. Biochem.,* **62** : 95 - 106. https://doi.org/10.1016/j.plaphy.2012.10.020

Nafees, M., Ahmad, I. and Ashraf, I., 2013, Sustainable production of mango fruit by managing irregular bearing through foliar spray of urea at critical growth stages. *World Appl. Sci. J.,* **24** (10) : 1368 - 1372.

Nath, V. and Singh, S. K., 2014, Physiology of flowering in litchi in relation to shoot maturity. *Souvenir,* p. : 173.

Nawaz, M. A., Imtiaz, M., Kong, Q., Cheng, F., Ahmed, W., Huang, Y. and Bie, Z., 2016, Grafting : A technique to modify ion accumulation in horticultural crops. *Front. Plant Sci.,* **7** : 1457. https://doi.org/10.3389/fpls.2016.01457

Nebauer, S. G., Renau-Morata, B., Lluch, Y., Baroja-Fernandez, E., Pozueta-Romero, J. and Molina, R. V., 2014, Influence of crop load on the expression patterns of starch metabolism genes in alternate-bearing citrus trees. *Plant Physiol. Biochem.,* **80** : 105 - 113. https://doi.org/10.1016/j.plaphy.2014.03.032

NHB (2021-22). Indian Horticulture Database. Gurugram, India. http://www.nhb.com

North, M. S. and Cook, N. C., 2006, Effect of six rootstocks on forelle pear tree growth, production, fruit quality and leaf mineral content. XXVII International Horticultural Congress-IHC2006: International Symposium on Enhancing Economic and Environmental, **772** : 97 - 103.

Okada, M., 2004, Effectiveness of reserved nutrients for estimating productivity of satsuma mandarin. *J. Jpn. Soc. Hortic. Sci.,* **73** (2) : 163 - 170. https://doi.org/10.2503/jjshs.73.163

Pant, B. D., Buhtz, A., Kehr, J. and Scheible, W. R., 2008, MicroRNA399 is a long-distance signal for the regulation of plant phosphate homeostasis. *Plant J.,* **53** (5) : 731 - 738. https://doi.org/10.1111/j.1365-313X.2007.03363.x

Pillay, A. E., Williams, J. R., El Mardi, M. O., Hassan, S. M. and Al-Hamdi, A., 2005, Boron and the alternate-bearing phenomenon in the date palm (*Phoenix dactylifera*). *J. Arid Environ.,* **62** (2) : 199 - 207. https://doi.org/10.1016/j.jaridenv.2004.11.007

Pingping, W. U., Chubin, W. U. and Biyan, Z., 2017, Drought stress induces flowering and enhances carbohydrate accumulation in Averrhoa Carambola. *Hortic. Plant J.,* **3** (2) : 60 - 66.

Reddy, Y. T. N., Kurian, R. M., Ramachander, P. R., Singh, G. and Kohli, R. R., 2003, Long-term effects of rootstocks on growth and fruit yielding patterns of 'Alphonso' mango (*Mangifera indica* L.). *Sci. Hortic,* **97** (2) : 95 - 108. https://doi.org/10.1016/S0304-4238(02)00025-0

Reig, G., I Forcada, C. F., Mestre, L., Jiménez, S., Betrán, J. A. and Moreno, M. A., 2018, Horticultural, leaf mineral and fruit quality traits of two Greengage plum cultivars budded on plum based rootstocks in Mediterranean conditions. *Sci. Hortic.,* **232** : 84 - 91. https://doi.org/10.1016/j.scienta.2017.12.052

Sarkhosh, A., Shahkoomahally, S., Asis, C. and Mcconchie, C., 2021, Influence of rootstocks on scion leaf mineral content in mango tree (*Mangifera indica* L.). *Hortic. Environ. Biotechnol.,* **62** (5) : 725 - 735.

Satisha, J., Prakash, G. S., Murti, G. S. R. and Upreti, K. K., 2007, Water stress and rootstocks influences on hormonal status of budded grapevine. *Eur. J. Hortic. Sci.,* **72** (5) : 202.

Saxena, P., Singh, V. K. and Pathak, N., 2014, Antioxidative enzymes and biochemical changes in paclobutrazol induced flowering in mango (*M. indica*) cultivars. *J. Environ. Biol.,* **35** (6) : 1061.

Seleznyova, A. N., Tustin, D. S. and Thorp, T. G., 2008, Apple dwarfing rootstocks and interstocks affect the type of growth units produced during the annual growth cycle : Precocious transition to flowering affects the composition and vigour of annual shoots. *Ann. Bot.,* **101** (5) : 679 - 687. https://doi.org/10.1093/aob/mcn007

Sharma, N., Singh, A. K., Singh, S. K., Mahato, A. K., Srivastav, M. and Singh, N. K., 2020, Comparative RNA sequencing-based transcriptome profiling of regular bearing and alternate bearing mango (*Mangifera indica* L.) varieties reveals novel insights into the regulatory mechanisms underlying alternate bearing. *Biotechnol. Lett.,* **42** (6) : 1035 - 1050. https://doi.org/10.1007/s10529-020-02863-8

Sharma, N., Singh, S. K., Mahato, A. K., Ravishankar, H., Dubey, A. K. and Singh, N. K., 2019, Physiological and molecular basis of alternate bearing in perennial fruit crops. *Sci. Hortic.,* **243** : 214 - 225. https://doi.org/10.1016/j.scienta.2018.08.021

Shivashankara, K. S. and Mathai, C. K., 2000, Inhibition of photosynthesis by flowering in mango (*Mangifera indica* L.) A study by gas exchange methods. *Sci. Hortic.,* **83** (3-4) : 205 - 212.

Shu, B., Liu, L., Jue, D., Wang, Y., Wei, Y. and Shi, S., 2017, Effects of avocado (*Persea americana* Mill.) scion on arbuscular mycorrhizal and root hair development in rootstock. *Arch. Agron. Soil Sci.,* **63** (14) : 1951 - 1962. https://doi.org/10.1080/03650340.2017.1317921

Singh, V. K. and Rajan, S., 2009, Changes in photosynthetic rate, specific leaf weight and sugar contents in mango (*Mangifera indica* L.). *Hort. J.,* **2** (1).

Singh, V. K. and Sharma, K., 2008, Physiological and biochemical changes during flowering of mango (*Mangifera indica* L.). *Int. J. Plant Dev. Biol.,* **2** (2) : 100 - 105.

Smith, M. W., Hoult, M. D. and Bright, J. D., 2003, Rootstock affects yield, yield efficiency and harvest rate of 'Kensington Pride' mango. *Hort Science,* **38** (2) : 273 - 276. https://doi.org/10.21273/HORTSCI.43.6.1720

Sorgona, A., Abenavoli, M. R., Gringeri, P. G. and Cacco, G., 2006, A comparison of nitrogen use efficiency definitions in citrus rootstocks. *Sci. Hortic.,* **109** (4) : 389 - 393. https://doi.org/10.1016/j.scienta.2006.06.001

Sotiropoulos, T. E., 2006, Performance of the pear (*Pyrus communis*) cultivar William's Bon Chretien grafted on seven rootstocks. *Aust. J. Exp. Agric.,* **46** (5) : 701 - 705. https://doi.org/10.1071/EA04132

Syvertsen, J. P., Goñi, C. and Otero, A., 2003, Fruit load and canopy shading affect leaf characteristics and net gas exchange of 'Spring' navel orange trees. *Tree Physiol.,* **23** (13) : 899 - 906. https://doi.org/10.1093/treephys/23.13.899

TOMASI, N., MONTE, R., VARANINI, Z., CESCO, S. AND PINTON, R., 2015, Induction of nitrate uptake in sauvignon blanc and chardonnay grapevines depends on the scion and is affected by the rootstock. *Aust. J. Grape Wine Res.,* **21** (2) : 331 - 338. https://doi.org/10.1111/ajgw.12137

TURKTAS, M., INAL, B., OKAY, S., ERKILIC, E. G., DUNDAR, E., HERNANDEZ, P. AND UNVER, T., 2013, Nutrition metabolism plays an important role in the alternate bearing of the olive tree (*Olea europaea* L.). *PloS one,* **8** (3) : e59876.

ULGER, S., SONMEZ, S., KARKACIER, M., ERTOY, N., AKDESIR, O. AND AKSU, M., 2004, Determination of endogenous hormones, sugars and mineral nutrition levels during the induction, initiation and differentiation stage and their effects on flower formation in olive. *Plant Growth Regul.* **42** (1) : 89 - 95. https://doi.org/10.1023/B:GROW.0000014897.22172.7d

UPRETI, K. K., SHIVU PRASAD, S. R., REDDY, Y. T. N. AND RAJESHWARA, A. N., 2014, Paclobutrazol induced changes in carbohydrates and some associated enzymes during floral initiation in mango (*Mangifera indica* L.) cv. Totapuri. *Indian J. Plant Physiol.,* **19** (4) : 317 - 323. https://doi.org/10.1007/s40502-014-0113-8

URBAN, L., JEGOUZO, L., DAMOUR, G., VANDAME, M. AND FRANÇOIS, C., 2008, Interpreting the decrease in leaf photosynthesis during flowering in mango. *Tree Physiol.,* **28** (7) : 1025 - 1036. https://doi.org/10.1093/treephys/28.7.1025

VAN HOOIJDONK, B., WOOLLEY, D., WARRINGTON, I. AND TUSTIN, S., 2011, Rootstocks modify scion architecture, endogenous hormones and root growth of newly grafted 'Royal Gala' apple trees. *J. Am. Soc. Hortic. Sci.,* **136** (2) : 93 - 102. https://doi.org/10.21273/JASHS.136.2.93

VEMMOS, S. N., 2005, Effects of shoot girdling on bud abscission, carbohydrate and nutrient concentrations in pistachio (*Pistacia vera* L.). *J. Hortic. Sci. Biotechnol.,* **80** (5) : 529 - 536. https://doi.org/10.1080/14620316.2005.11511973

VERMA, S. K., SINGH, S. K. AND KRISHNA, H., 2010, The effect of certain rootstocks on the grape cultivar 'Pusa Urvashi' (*Vitis vinifera* L.). *Int. J. Fruit Sci.,* **10** (1) : 16 - 28. https://doi.org/10.1080/15538361003676744

WAHL, V., PONNU, J., SCHLERETH, A., ARRIVAULT, S., LANGENECKER, T., FRANKE, A., FEIL, R., LUNN, J. E., STITT, M. AND SCHMID, M., 2013, Regulation of flowering by trehalose-6-phosphate signaling in Arabidopsis thaliana. *Sci.,* **339** (6120) : 704 - 707. https://doi.org/10.1126/science.1230406

WANG, J., JIANG, L. AND WU, R., 2017, Plant grafting : How genetic exchange promotes vascular reconnection. *New Phytol.,* **214** (1) : 56 - 65. https://doi.org/10.1111/nph.14383

WANG, N., WEI, Q., YAN, T., PAN, Z. AND LIU, Y., 2016, Improving the boron uptake of boron-deficient navel orange plants under low boron conditions by inarching boron-efficient rootstock. *Sci. Hortic.,* **199** : 49 - 55. https://doi.org/10.1016/j.scienta.2015.12.014

XING, L., ZHANG, D., ZHAO, C., LI, Y., MA, J., AN, N. AND HAN, M., 2016, Shoot bending promotes flower bud formation by mi RNA-mediated regulation in apple (*Malus domestica* Borkh.). *Plant Biotechnol. J.,* **14** (2) : 749 - 770. https://doi.org/10.1111/pbi.12425

YANG, H. F., KIM, H. J., CHEN, H. B., RAHMAN, J., LU, X. Y. AND ZHOU, B. Y., 2014, Carbohydrate accumulation and flowering-related gene expression levels at different developmental stages of terminal shoots in Litchi chinensis. *Hort. Science,* **49** (11) : 1381 - 1391. https://doi.org/10.21273/HORTSCI.49.11.1381

YANG, X., CHEN, L. S. AND CHENG, L., 2021, Leaf photosynthesis and carbon metabolism adapt to crop load in 'Gala' Apple trees. *Horticulturae,* **7** (3) : 47. https://doi.org/10.3390/horticulturae7030047

YANIK, H., TURKTAS, M., DUNDAR, E., HERNANDEZ, P., DORADO, G. AND UNVER, T., 2013, Genome-wide identification of alternate bearing-associated microRNAs (miRNAs) in olive (*Olea europaea* L.). *BMC Plant Biol.,* **13** (1) : 1 - 22. https://doi.org/10.1186/1471-2229-13-10

ZAMBONI, M., GARAVANI, A., GATTI, M., VERCESI, A., PARISI, M. G., BAVARESCO, L. AND PONI, S., 2016, Vegetative, physiological and nutritional behavior of new grapevine rootstocks in response to different nitrogen supply. *Sci. Hortic.,* **202** : 99 - 106. https://doi.org/10.1016/j.scienta.2016.02.032

ZARROUK, O., GOGORCENA, Y., GOMEZ-APARISI, J., BETRAN, J. A. AND MORENO, M. A., 2005, Influence of almond\times peach hybrids rootstocks on flower and leaf mineral concentration, yield and vigour of two peach cultivars. *Sci. Hortic.,* **106** (4) : 502 - 514. https://doi.org/10.1016/j.scienta.2005.04.011

ZENG, H., WANG, G., HU, X., WANG, H., DU, L. AND ZHU, Y., 2014, Role of micro RNAs in plant responses to nutrient stress. *Plant Soil.,* **374** (1) : 1005 - 1021. https://doi.org/10.1007/s11104-013-1907-6

ZHA, Q., WANG, Y., ZHANG, X. Z. AND HAN, Z. H., 2014, Both immanently high active iron contents and increased root ferrous uptake in response to low iron stress contribute to the iron deficiency tolerance in *Malus xiaojinensis*. *Plant Sci.,* **214** : 47 - 56. https://doi.org/10.1016/j.plantsci.2013.10.002

Mysore J. Agric. Sci., 57 (1) : 16-24 (2023)

Current Science Insights Concerning Agnihotra Technology - A Review

KANCHAN YADAV AND SHILPA KAUSHAL
Chandigarh University Institute of Agricultural Sciences, Chandigarh, Gharuan, Mohali, Punjab - 140 413
e-Mail : ky242130@gmail.com

AUTHORS CONTRIBUTION

KANCHAN YADAV : Conceptualization ;
SHILPA KAUSHAL : Drafting and editing

Corresponding Author :
KANCHAN YADAV
Chandigarh University Institute of Agricultural Sciences, Chandigarh, Gharuan, Mohali, Punjab

Received : November 2022
Accepted : January 2023

ABSTRACT

Despite the landmark of green revolution, our nation's intensive chemical farming has severely polluted land, food, potable water, and air. When you eat food that was produced in these circumstances, the contaminants are taken into your body. Sustainable agriculture practiced by Agnihotra is the solution to our issues. Agni means 'fire'. According to the Vedas, 'HEAL THE ATMOSPHERE AND IT WILL HEAL YOU', hotra signifies 'going to heal'. The far more important feature of Agnihotra is that it unites the forces of the five variables of earth, air, water, sun and space to bring about tiny differences in biota. It is the vital spark in Homa farming. It is used when all hope is lost and has proven to be useful in raising crop output and minimizing microbial contamination pathogenicity, soil and water decontamination, pest and disease infestation. Regularly incorporating agnihotra will enhance the impact of that activity on the farm.

Keywords : Biota, Dawn and dusk, Pathogenicity, Photochemical

AGNIHOTRA is a traditional domestic solemnity, performed to maintain harmony between living beings and nature, without harming and by giving respect. Agnihotra, the simplest form of 'Yajna' performed at sunset/sunrise in which cow dung is burnt in a copper pot by using cow ghee and brown rice as oblations along with chanting of mantras of sun and fire. Agnihotra is mentioned and explained by traditional Vedic literature, *i.e.,* The Grihya-Sutra (Rules of Vedic domestic ceremonies), (1) 1.2, 1.9 and 1.10 of Asvalayana Grihya-Sutra, (2) 1.1 and 1.3 of Gobhila Grihya-Sutra, (3) 1.5 of Khadira Grihya Sutra, (4) some part of Sankhayana Grihya-Sutra [Muller,2004].

Agnihotra is a purifying fire derived from the Ayurvedic system of medicine. It is a daily procedure of cleansing the environment by lighting a carefully prepared fire at sunrise and dusk. As described in the Rigveda, the holy monks of the Ancient Indus civilization (9500 years ago) practiced Agnihotra yagya in order to purify the atmosphere. The phrase is 'Kramishchmiv rastischmiya gnenkalpt ama'. Chapter 18 of the Yajurveda hymns No. 1 to 29 states that Yajna is the fundamental building block of agricultural, physical, mental and spiritual advancement. It also provides happiness to the kingdom Plantae, boosts metabolism and guards against pollution of the air. Additionally, the Bhagavad Geeta, Krishiparasara Agnipuran and Vriksha Ayurveda have all the reference agnihotra. In the Vedas, it is stated, 'HEAL THE ATMOSPHERE AND IT WILL HEAL YOU'. Any individual from any background is welcome to do agnihotra and improve their home's atmosphere. Millions of persons across the globe have learned that Agnihotra helps in reducing tension, promotes more mental clarity, enhances wellness, boosts vitality and infuses the soul with affection. It is an excellent assistance in the treatment of drug and alcohol addiction. Agnihotra also feeds plant life and protects it from damaging radiation and deadly microorganisms.

Agnihotra is an ancient science that was imparted in sanskrit at the time of creation. Sanskrit was never anyone's native tongue; it is a vibrational language.

With Sanskrit mantras and fire prepared with certain organic compounds and timed to the sunrise/sunset biorhythm, a little copper pyramid of a specified size (2.25 inches *6 inches) and shape is used to prepare the fire. The items which are required for performing agnihotra are brown rice, dried cow dung, and ghee (clarified unsalted butter). Mantras are chanted at sunrise and dusk and a tiny amount of rice and ghee is added to the fire. The beats and chants produce subtle energies in addition to the energy from the flames. These energies are produced or released into the environment by the use of fire. This, together with the properties of the materials burnt, results in the full effect of this restorative HOMA (healing fire) and also known as havan. The Agnihotra pyramid emits a lot of healing energy.

Throughout Agnihotra period, enormous amounts of energy is focused in the surrounding of the copper pyramid of Agnihotra. It creates a magnetic field that balances off detrimental energy while boosting good energy. As a result, the performance of one who does Agnihotra creates a favourable pattern. Agnihotra removes impurities from the environment and neutralizes dangerous radiation. Plant life benefits from the resulting atmosphere.

The ghee after burning with the other materials in the form of heat or as radiation released into the atmosphere and binds to the soil's molecular structure, letting the soil retain more moisture. Plants growing in the Agnihotra environment are more drought resistant. Agnihotra alters the cellular structure of the plant, directing more nutrients to the fruit and less to the leaves, stem and roots. Many practitioners have discovered that fruits and vegetables produced in Agnihotra environment have greater size, flavour, texture and yield. The use of Agnihotra in the garden minimizes insect issues and Homa (healing fire) practises make organic gardening and farming simpler. In the middle of the twentieth century, the Indian teacher Parama Sadguru Shree Gajanan Maharaj and his student, Shree Vasant V. Paranjpe, found historical information on the Agnihotra pyramid fire. Though it is becoming more common in Western Countries, organic farming is now mostly performed by landowners in USA and India [Shinogi *et al.,* 2016].

Agnihotra's medicinal characteristics include the ability to rejuvenate brain cells, invigorate the skin, and purify the blood. It is a comprehensive attitude to life. Many people who are typically allergic to smoke find that sitting in the Agnihotra environment heals them. The therapeutic properties of Agnihotra are imprinted in the resulting ash. Thousands of individuals throughout the world have reported remarkable healings from Agnihotra ash for a variety of diseases.

Why was Agnihotra Chosen

Chemical fertilizers and insecticides needed in increasing doses and intensity or changing formulae over time. Then there comes a point when nothing grows unless you utilize them. They contaminate the soil and sub soil water if used. When we eat food cultivated under these circumstances, we consume hazardous toxins. Then, after a few years, nothing grows at all. These are some of the reasons why certain communities began to consider organic farming and biological pest management. This worked for a while, but when the pollution load of the atmosphere rose and things became more complicated, organic farmers faced enormous challenges. So the only solution to all these problems is agnihotra (Vala, 2021).

Agnihotra Forms

1. *Agnihotrahoma* : This is the most important ritual and ought to be done each day at dawn and sunset.
2. *Vyahruti Homa* : Except for at dusk and dawn, it may be carried out at any point of day or night. Additionally, it is carried out before beginning Om Tryambakam Homa.
3. Om Tryambakam Homa must be performed for a minimum of 4 hours. It needs to be performed for a complete 24 hours on supermoon and non-moon days. Om Tryambakam Homa increased the amount and quality of agricultural crops, as well as their resilience to unfavourable environmental variables and pests (Pathade & Abhang, 2014).

Basic Material Required for Agnihotra

1. *Copper pyramid* : Only copper and gold pyramid containers are utilised for agnihotra fire since they work as an antidote to all our troubles.
2. *Dried cow dung* : cow dung is very much auspicious according to scriptures among the animal faeces on the planet. It is antiseptic, anti-thermal and anti-radioactive. When burned, it emits gases that inhibit the growth of hazardous microbes found in contaminated air and purify the atmosphere.
3. *Pure ghee* : Cow ghee is a natural disinfectant that helps to minimize toxicity in the air. When cow's ghee is burnt with rice, it emits gases such as propylene oxide, ethylene oxide and formaldehyde, which limit the growth of dangerous germs (Shinogi *et al.,* 2016)
4. *Brown rice or unbroken and unpolished rice* : Polished rice loses nutritional value, hence brown rice is used. Only unbroken rises may be employed in agnihotra because if they are fractured, the subtle energy structure is disrupted and hence unsuitable for healing.
5. *Mantras* : Mantras should be said clearly and with complete concentration or completely absorbed inside the chanting of mantras. Mantra chanting generates subtle energy in the surroundings and the human consciousness.

Inverted Copper Pyramid Agnihotra Vessel

The inverted pyramid pot is considered to be a cosmic energy collector. Copper is the finest heat and electromagnetic wave conductor. The Sanskrit Agnihotra mantras produce certain vibrations that are helpful to the mind and the environment. The design of the copper pot allows for better use of incoming air and effective burning of chemicals.

Ghee from Cows (Clarified butter) :

Cow ghee, known as the 'mother of all remedies' in Ayurveda, functions as a transporter of subtle healing forces. Cow ghee, which is applied on the rice grains before oblation, aids in the quick burning of wood cellulose and carbohydrates in rice. When all of the volatile compounds in the surrounding atmosphere are dispersed, they are vulnerable to photochemical reactions in the sunlight the fumes, smoke or vapours produced by the burning components soar to great heights in space. The volatile oils produced by the appropriately lit fire disperse into the surrounding environment together with the air particles

It can be emphasized that the goal of agnihotra is to vaporize the contributions made in the form of burnt offerings or they are heated up to conversion into gaseous form, instead of combusting them. As a result, these compounds spread into the surrounding air and improve air quality.

Cow Dung Cakes

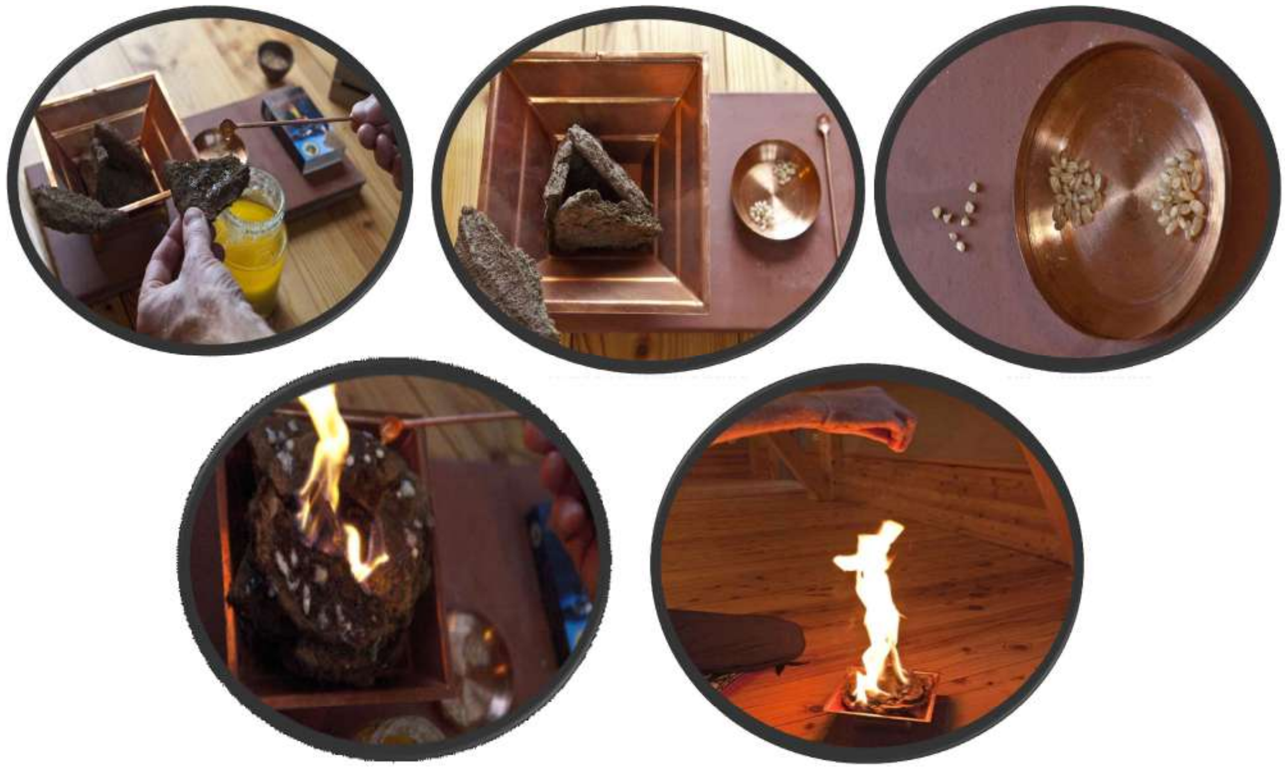
Cow dung cakes extracts have been shown to have antibacterial properties. The fumes generated by Agnihotra have been proved scientifically to posses antibacterial properties as reported earlier. Fumigation by using chemicals like formaldehyde has hazardous effects on the body, but Agnihotra fumes have not only been reported to control microbial load but also to heal the atmosphere and purify the air. The reduction in microbial load may be caused by volatile organic compounds released during the burning of Agnihotra material which is mainly constituted by cow dung cakes (Rajeswari *et al.,* 2016).

Unbreakable Fresh Rice

Because rice is the most plentiful food grain on the planet, raw unbroken complete rice grain is ideal for usage. It is a key part of the Agnihotra ceremony. In Agnihotra, the rice grains burn with a sound. Rice burning emits gases such as ethylene oxide, propylene oxide, formaldehyde and vita propyo lactone. These gases aid in the purification of the atmosphere and the destruction of germs.

Ash of Agnihotra

Certain scientific research have demonstrated the beneficial impact of Agnihotra ash in organic gardening. Phosphorus solubility in soil has been observed to be boosted by Agnihotra ash (Kratz &



Source: homafarming .com

Schnug, 2007). Ash has been demonstrated to have beneficial impacts on rice seed germination and soil fertility (Devi *et al.,* 2004; Sharma *et al.,* 2013).

Agnihotra Procedure

Perform the following steps for the agnihotra fire's preparation just before morning light and dusk:

1. Place a flat piece of dehydrated cow dung cake in the copper pyramid's base. Set up the stack of hardened cow dung so that air may flow across it.

2. Use a small amount of Ghee to ignite a portion of cow dung. Put this glowing bit of cow dung dried piece in the pyramid's middle. The pyramid's waste will soon spontaneously combust. To avoid damaging it with oral germs, do not blow on the flames though.

3. Put some ghee over a few rice kernels and place them on a dish or in your left palm.

4. Chant the first Sutra at aptly sunrise, then add a few kernels of rice to the bonfire after the syllable SWAHA. Add some rice to the fire after reciting the second sutra. The morning Agnihotra is now complete.

5. Redo the mantra also with evening sunset. This brings the evening Agnihotra to an end. Aim to devote far more time as you can for concentration after each Agnihotra. As long as the fire goes itself out, you can sit (Pathade & Abhang, 2014).

What took Place during Agnihotra?

It needs to be underlined that Agnihotra's goal is to vapourize or to heat the contributions given in the type of burnt offerings sufficiently to convert them to vapors, instead of to burn them. The gases and fumes released by the burning parts reach vast altitudes in universe. When all of the volatile compounds in the surrounding atmosphere are dispersed, they are vulnerable to photochemical reactions in the sunshine. When yagya is conducted, the scent may be easily perceived in the surroundings due to the dispersion of compounds such as terpinol, eugenol, ammonia,

(Parkhe Pariwar Trusts, 2020)

indol, formalin and so on. As a result, these compounds spread into the surrounding air and improve air quality (Jani, 2020).

How to Make an Agnihotra Fire

Spread ghee over a few cow dung pieces (arrange them in the Agnihotra pot in such a way to permit free passage on air). Begin the fire a few minutes before sunrise/sunset and chant the agnihotra mantras (after the word SWAHA add a few grains of rice grains coated with ghee to the fire). Agnihotra get finished in 10 minutes and it is best to sit quietly or meditate until the fire is extinguished. The ash residue left after agnihotra is gathered in a cloth on a regular basis. The fine sieved ash is known as 'the miracle powder', and it is used as a fertiliser in homa cultivation as a growth promoter and pesticide (Choudhary *et al.,* 2020).

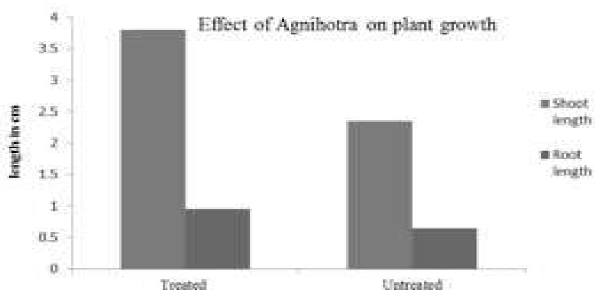
TABLE 1

Homa farming vs conventional farming

Homa agriculture	Conventional agriculture
The environment is regarded as the most essential source of nourishment in Homa farming since it provides 75 percent of the nutrients in plants.	In normal farming the environmental factors are not considered
Production after harvest per hectare is more	Lesser production in the normal agriculture
The shelf life of various perishable goods like vegetables fruits etc. have more	In case of normal agriculture there is not much longer shelf life. To preserve them they require more inputs while storage

Table 1 contd.

Homa agriculture	Conventional agriculture
The cost of production inn homa farming is much lesser than that of other modern techniques	The cost of cultivation in other methods is more than the homa farming (Bhatia et al., 2022).
For example: Homa farming shows a drastic increase in yield of guava with high quality as compared to normal farming and other organic farming systems (Ram and Pathak, 2005)	In a research conducted by (Kumari *et al.,* 2018) to compare the effectiveness of agnihotra fire and regular fire on bacterial count, one plate containing bacteria was placed in the agnihotra room and the other in the control room next to the agnihotra room at some distance. Bacterial count was greatly decreased when compared to regular fire, and bacterial count was also decreased to some extent in plant placed in control room (near agnihotra room) (Berk and Dubey, 2020).



Source : (Pathade & Abhang, 2014)

Fig. 1 : Comparison in the length of plants treated with agnihotra

A Case Study from Australia

(Adhikari, 2015)

Resonance Point

Resonance Technique is a component of HOMA Organic Farming in which basic procedures are utilised to quickly repair huge tracts of unhealthy soil.

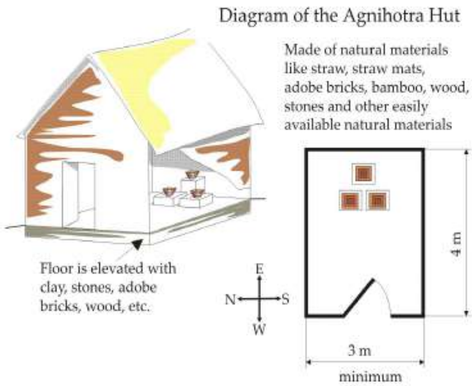
A single RESONANCE POINT has the ability to heal up to 200 acres (80 hectares) of land. It heals the same amount of human work is necessary to mend one acre as it is to heal two hundred acres. Ten new copper pyramids must be installed, activated with Mantra, and placed on the farm in a specified configuration by a volunteer for Homa Treatment who is authorised to place resonance places. In addition, two simple dwellings must be built out of readily accessible, inexpensive natural materials such as wood, earthen blocks, carpets, bamboo, stones, cane, *etc.* These dwellings won't be used as homes. They just serve to protect the person conducting the task. [http://homafarming.com/resonance-point/].

Applications of Homa Farming in Agriculture

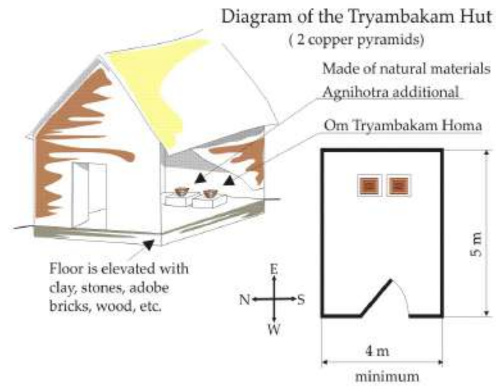
In water purification : One of the primary benefits of doing Yajnya is the use of Agnihotra for water purification. Water is purified only when Agnihotra

Parameters for oil seed crop	Average seed weight per 1000 seeds	Protein content % in seed	Oil content %in seeds	Urease activity* [in average]
Conventional agriculture	103.66g	39.15g	19.54g	7.94g
Homa organic farming	142.60g	39.50g	19.62g	7.86

Agnihotra hut



Trymbkam hut



Every day at dawn and dusk, the AGNIHOTRA bonfire is conducted in the main hut, also known as the Agnihotra hut.	The Agnihotra Hut will be somewhat bigger than the OM TRYAMBAKAM Hut (approximately 4x5m).
If feasible, it would be excellent to construct this cottage in the middle of the farmland.	The HEALING HUT is another name for it. Persons who are ill can sit around and undergo treatment
The dimension must be around 3 × 4 metres, with the larger side pointing in the EAST/WEST direction. To perform the flames, one must enter from the WEST and lid down facing the EAST.	The fire itself is the healer. The region becomes a healing spot for sick people, animals, and plants even if we are lighting the flames for agricultural purposes.
A hole that is 30 cm x 30 cm and around 50 cm deep should be excavated close to and parallel to the EAST wall.	Face EAST while doing HOMA.
Just after primary pyramid has been triggered, it is covered, a stack of sand is erected on top of it, about 50 cm above ground, and a second active pyramid is positioned right above it, perfectly oriented to the east.	Two pyramids—one on the right for OM TRYAMBAKAM HOMA and the other on the left for AGNIHOTRA—are to be erected in this HEALING hut on tiny muddy foundations.
In this position, the individual seated on the floor ahead of the column is at chest level with the pyramid on the column. The pyramid on the column serves as a resonating pyramid.	Om Tryambakam Homa must be conducted for four hours each day and for twenty-four hours on whole and no moon days in order to have the most impact.
Then, on the right and left sides in front of the main column, two more of the triggered pyramids are positioned on small mud slabs. Daily AGNIHOTRA is performed on the left, and other sporadic Homa fires are performed on the right. In this hut, there are a total of four pyramids.	It is preferable to build this hut close to the farm's entry so that visitors may enter and exit without interfering with the secrecy of individuals who live and/or work there.

(Bhatia *et al.,* 2022)

In this hut, Agnihotra must be performed beginning at dusk. It is similar to turning this point on at sunset.	
The Agnihotra hut is a sanctuary of stillness, where only the designated Mantras are chanted. In this manner, the tiny healing forces are not obstructed.	
This hut is the Generator of Healing Energies.	

is performed in an enclosed space, without any physical contact between water and ash or fumes of Agnihotra. Experiments done in Agnihotra environment with water samples stored in Faraday cages (steel, aluminium and copper) reveal less progress in water purification than those not kept in Faraday cages. This is due to variations in the amount of dissolved oxygen caused by the absorption of infrared rays from Agnihotra and the increase in temperature within Faraday cages.

Applications of Agnihotra

Control air pollution : Fumes of Agnihotra are of medicinal use, they control pollution of an ambient air. An Agnihotra fume shows antimicrobial properties by killing or decreasing the growth of microbes which resulted in the reduction of microbial load in the surrounding environment.

Agnihotra Applications for Mitigating Microbial Pathogenicity

Agnihotra's performance demonstrates a reduction in Microbial load in the surrounding environment. Microbes are reduced by direct killing or by inhibiting their growth; this may be due to the production of antimicrobial compounds from burning material or diffusion of microbes with fumes in upper strata in such a way that residual population is kept within nature's tolerable limit. In vitro investigations on the bioenergetics system of *S. aureus* demonstrate that Agnihotra does not kill harmful bacteria but decreases their pathogenicity by decreasing coagulase synthesis. Experiments were carried out on albino mice in vivo demonstrated that when a virus treated with Agnihotra is injected into a mouse, it does not cause any harm. Diseases will not be created as a result of a lesion or an abscess.

Homa farming is a reliable technique to producing plants in a clean and healthy environment. Plants produced in a homa environment germinate quicker, develop earlier, have a longer shelf life and production or yield much higher because when we conduct homa, we make the plants joyful and use all of their energy to boost their output. Homa farming is an efficient agricultural method that increases output by 25-30 per cent. It minimises microbial burden in air and water, lowers SOX (sulphur oxides) and NOx (nitrogen oxides) levels in the atmosphere and is environmentally friendly. Organic farming is a long-term process. Agnihotra ash, it acts as a miracle powder. The raw material reduces the conductivity, hardness, microbial population and biological oxygen requirement of the row water.

Agnihotra ash functions as an antifungal agent, inhibiting the development of fungal hyphae and soil-borne diseases. Agnihotra fumes not only regulate microbial activity, but also cure and purify the air. It is suggested that homa farming be tested in multilocational trials so that this practise may be advocated as a technology and a wide number of farmers become aware of this approach and incorporate it into their everyday farm practises in order to achieve substantial outcomes. It must be spread around the world in order to assist the national economy and farmers.

References

Abhang, P., Patil, M. and Moghe, P., 2015, Beneficial effects of agnihotra on environment and agriculture. *International Journal of Agricultural Science and Research* (IJASR), **5** : 111 - 119.

Abhang, P., Patil, M. and Moghe, P., 2015, Beneficial effects of agnihotra on environment and agriculture, *Int. J. Agr. Sci. Res.,* **5** (2) : 111 - 120.

Adhikari, T., 2015, Agnihotra farming. https://www.slideshare.net/TapanAdhikari/agnihotra-farming

Berk, U. and Dubey, A. K., 2020, Global covid 19 and agnihotra. *International Journal of global science Research,* **7** (1) : 1243 - 1255.

Berk, U. and Sharma, S., 2015, Effect of agnihotra energy field on water purification. *Indian J. Tradit Knowle.,* **1** (1) : 63 - 68.

Bhatia, S., Rohilla, A. and Kaushal, S., 2022, A review on homa farming - A vedic touch to modern agriculture. *International Journal of Advances in Agricultural*

Science and Technology, ***9*** : 14 - 25. https://doi.org/10.47856/ijaast.2022.v09i05.003.

Choudhary, M., Choudhary, S. and Garg, K., 2020, Homa farming - A vedic touch to morden agriculture, pp. : 4.

Devi, H. J., Swamy, N. V. C. and Nagendra, H., 2004, Effect of agnihotra on the germination of rice seeds. Vol. 3(3), July 2004, pp. 231-239.

Golechha, G. R, Sethi, I. G. and Deshpande, U. R., 1991, Agnihotrav in the treatment of alcoholism. *Indian J. Psychiatry,* **33** (1) : 20 - 26.

Jani, C., 2020, Agnihotra : Homa organic farming. *Agrinenv. Com.*, pp. : 67.

Kratz, S. and Schnug, E., 2007, Homa farming - A vedic fire for agriculture : Influence of agnihotra ash on water solubility of soil P. *Land baufors chung Völkenrode*, ***57*** : 207 - 211.

Kumari, A., Sharma, P. M., Yadav, J. and Vaid, P. K., 2018, An urgent need for sustainable agricultural practices : A review of natural, organic ayurvedic and homa farming over chemical farming. *Asian Journal of research in Crop science,* **1** (3) : 1 - 20.

Muller, F. M., 2004, The grihya - sutras part I : The sacred books of the east part twenty-nine, (Kessinger Publishing, USA), pp. : 115-172.

Pathade, G. R. and Abhang, P., 2014, Scientific study of vedic knowledge agnihotra.

Ram, R. A. and Pathak, R. K., 2005, Integration of organic farming practices for sustainable production of guava: A case study. *Int. Guava Sym.,* pp. : 357 - 363.

Rajeswari, S., Poongothai, E. and Hemalatha, N., 2016, Antimicrobial activites of cow dung extracts against human pathogens. *International Journal of Current Pharmaceutical Research, 8*,9. https://doi.org/10.22159/ijcpr.2016v8i4.15268

Sharma, S. K., Sengupta, T., Sunar, K. K., Berk, U., Dave, V. B. M., Gandhi, T. S. and Chaurasia, R., 2013, Ash amended with yellow soil as the growth regulator for *Zea mays*.

Shinogi, K. C., Srivastava, S., Rashmi, K. G., Rosin, 2016, Homa organic farming : Science behind concepts and methodologies. *Indian farmer,* **3** (12) : 850 - 853.

https://www.speakingtree.in/blog/vedic-combustion-science

http://shodhganga.inflibnet.ac.in/bitstream/10603/2491/12/12_chapter%206.pdf

http://homafarming.com/resonance-point/

Trusts, P. P., 2020, *Agnihotra Disciplines* Retrieved 2022/12/15 from https://scontent.fixc4-1.fna.fbcdn.net/v/t1.6435-9119980233_4372529206155000_3507769672311787884 _n.jpg? _nc_cat=110 & ccb=1-7&_nc_sid=9267fe & _nc_ohc=qRvucSYIFd4AX8MjBRI & _nc_ht=scontent. fixc4 1.fna&oh=00_AfBMqYvp8xxOWP8iEOzLM9p2uZVbQZoio GwFrDX-00R9 Ng & oe=63C231B9

Vala, Y. B., 2021, Agnihotra : A vedic touch to modern agriculture. *Just Agriculture,* **1** (8).

Mysore J. Agric. Sci., 57 (1) : 25-32 (2023)

Evaluation of Ashwagandha [*Withania somnifera* (L.) Dunal] Genotypes for Growth and Yield Attributes under Bengaluru Condition

Abdulrazaq Bepari, G. Gopinath, K. N. Srinivasappa and C. Suneetha
Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : abepari94@gmail.com

Authors Contribution

Abdulrazaq Bepari : Conceptualization, data collection and investigation;
G. Gopinath : Data visualization and review;
K. N. Srinivasappa : Conceptualization and supervision;
C. Suneetha : Reviewing

Corresponding Author :
Mr. Abdulrazaq Bepari
Department of Horticulture, College of Agriculture, UAS, GKVK Bengaluru

Received : September 2022
Accepted : November 2022

Abstract

The present investigation was carried-out at the Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru with the aim of evaluating thirty-two genotypes of ashwagandha [*Withania somnifera* (L.) Dunal] for growth and yield parameters under Bengaluru conditions during late *Kharif* 2020 and 2021 by adopting a randomized complete block design with three replications. Various growth and yield parameters, *viz*., days to 50 per cent germination, plant height, branches per plant, days to 50 per cent flowering, length of main root, diameter of main root, dry weight of root plant^{-1} and dry root yield were recorded. Among all genotypes, DWS-319 taken minimum days to 50 per cent germination (11 days), whereas genotype DWS-132 taken maximum days to 50 per cent germination (25 days). Genotype DWS-09 was found as the superior genotype for plant height (74.25 cm), diameter of main root (2.82 cm), dry weight of root plant^{-1} (7.57 g), dry root yield plot^{-1} (416.35 g) and dry root yield ha^{-1} (16.01 q). Among the genotypes, DWS-280 and DWS-279 were superior in branches per plant (17.81) and length of main root (21.67 cm) respectively. The present study indicates that genotype DWS-09 recorded the highest mean performance for growth and yield character under Bengaluru conditions.

Keywords : Ashwagandha, Genotypes, Evaluation, Growth and Yield

Ashwagandha [*Withania somnifera* (L.) Dunal] (2n=48), commonly known as 'Winter cherry,' is an important cultivated medicinal crop of India. It is an erect, evergreen, perennial shrub of the Solanaceae family native to the Indian sub-continent. It is also known as' 'Indian Ginseng' because the roots are compared with the roots of Chinese Ginseng (*Panax ginseng*) for their restorative properties (Devi, 1996). Several types of alkaloids are found in this plant, among which withanine and somniferine are important. The total alkaloid content in Indian type roots has been reported to range between 0.13 and 0.31 per cent. Ashwagandha fruits and seeds are diuretic in nature. The paste prepared out of its leaves is used for curing inflammation of tubercular glands and that of its roots for curing skin diseases, bronchitis and ulcers. In ancient Ayurvedic literature, ashwagandha is mentioned as an important drug. Withaferine-A is used as an antibiotic, anti-stress, neuroprotective, antitumor, anti-arthritic, analgesic and anti-inflammatory drug. The drug is mainly used in Ayurvedic and Unani preparations. Hence, this drug is receiving a great deal of attention. It is also found useful in treating different disorders such as Parkinson's, dementia, memory loss, stress-induced diseases and malignoma. It is commonly used for emaciation of children, debility from old age, rheumatism, leucoderma, constipation, insomnia, nervous breakdown and goitre (Singh *et al*., 2011).

Ashwagandha grows in the dry parts of sub-tropical regions. Rajasthan, Punjab, Haryana, Uttar Pradesh, Gujarat, Maharashtra and Madhya Pradesh are the major Ashwagandha producing states in the country. Recently, it has also been cultivated in the southern states of Karnataka and Andhra Pradesh. India's annual requirement of roots is around 7000 tons while production is hardly 1400 tons since it has potential to grow under rainfed conditions and there is a need to increase its cultivation in newer areas in south India. However, there is an apparent lack of improved genotypes of ashwagandha to increase the yield potential. Therefore, the present investigation was carried out to evaluate the existing variability for higher growth and yield.

Material and Methods

The present investigation, comprising 32 genotypes of ashwagandha, evaluation was carried out during 2020 and 2021 late *kharif* at the Horticulture Research Station, Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru. The treatments included thirty-two genotypes of ashwagandha, with their sources of collection enlisted in Table 1. The experiment was conducted using Randomized Complete Block Design (RCBD) with three replications in Bengaluru conditions following 30 cm x 20 cm spacing with the individual gross plot size of 2.6 m^2. The required area for experiment was marked prior to layout at Horticulture Research Station, Department of Horticulture for the years 2020, 2021 and the experimental plot was ploughed with a tractor followed by levelling and planking with a view to having a fine tilth of the experimental plot. Weeds and debris were removed so as to obtain a clean and fine tilth texture. The recommended doses of organic manures and fertilizers were applied at the time of field preparation. 10-12 tons of FYM, 15 kg of nitrogen and 25 kg of phosphorus per hectare were applied at the time of land preparation of experimental plots. Seeds were sown to a depth of 1 to 2 cm by line sowing method. The crop received regular intercultural operations and irrigation. Standard agronomic practices and plant protection measures were adopted as per the schedule. Five plants from each plot were randomly chosen and tagged in order to record observations.

The observations on various growth parameters were recorded at different growth stages at 45th,

Table 1

List of ashwagandha genotypes along with their sources used in the study

Treatments	Genotypes	Sources
T_1	DWS-05	DMAPR, Boriavi, Anand, Gujarat
T_2	DWS-09	DMAPR, Boriavi, Anand, Gujarat
T_3	DWS-22	DMAPR, Boriavi Anand, Gujarat
T_4	DWS-40	DMAPR, Boriavi, Anand, Gujarat
T_5	DWS-41	DMAPR, Boriavi, Anand, Gujarat
T_6	DWS-132	DMAPR, Boriavi, Anand, Gujarat
T_7	DWS-141	DMAPR, Boriavi, Anand, Gujarat
T_8	DWS-143	DMAPR, Boriavi, Anand, Gujarat
T_9	DWS-144	DMAPR, Boriavi, Anand, Gujarat
T_{10}	DWS-197	DMAPR, Boriavi, Anand, Gujarat
T_{11}	DWS-250	DMAPR, Boriavi, Anand, Gujarat
T_{12}	DWS-252	DMAPR, Boriavi, Anand, Gujarat
T_{13}	DWS-253	DMAPR, Boriavi, Anand, Gujarat
T_{14}	DWS-257	DMAPR, Boriavi, Anand, Gujarat
T_{15}	DWS-258	DMAPR, Boriavi, Anand, Gujarat
T_{16}	DWS-259	DMAPR, Boriavi, Anand, Gujarat
T_{17}	DWS-260	DMAPR, Boriavi, Anand, Gujarat
T_{18}	DWS-262	DMAPR, Boriavi, Anand, Gujarat
T_{19}	DWS-270	DMAPR, Boriavi, Anand, Gujarat
T_{20}	DWS-272	DMAPR, Boriavi, Anand, Gujarat
T_{21}	DWS-279	DMAPR, Boriavi, Anand, Gujarat
T_{22}	DWS-280	DMAPR, Boriavi, Anand, Gujarat
T_{23}	DWS-281	DMAPR, Boriavi, Anand, Gujarat
T_{24}	DWS-284	DMAPR, Boriavi, Anand, Gujarat
T_{25}	DWS-296	DMAPR, Boriavi, Anand, Gujarat
T_{26}	DWS-309	DMAPR, Boriavi, Anand, Gujarat
T_{27}	DWS-315	DMAPR, Boriavi, Anand, Gujarat
T_{28}	DWS-316	DMAPR, Boriavi, Anand, Gujarat
T_{29}	DWS-317	DMAPR, Boriavi, Anand, Gujarat
T_{30}	DWS-319	DMAPR, Boriavi, Anand, Gujarat
T_{31}	Arka Ashwa gandha	IIHR, Bengaluru
T_{32}	Poshita	CIMAP Research Station, Bengaluru

Note : DMAPR –Directorate of Medicinal and Aromatic Plants Research

DWS- Directorate *Withania somnifera*

75th, 105th, 135th days after sowing and at harvest. The yield parameters were recorded after harvest and the replicated mean data was subjected to statistical analysis for interpretation, using Randomized Complete Block Design (Panse and Sukhatme, 1957).

Results and Discussion

Growth Parameters

Days to 50 per cent Germination

Ashwagandha genotypes exhibit variability with respect to various growth parameters (Table 2). Days to 50 per cent germination were recorded and ranged from 11 to 25 days (Table 2). The genotype DWS-132 took the maximum days to 50 per cent germination (25 days), while DWS-143 (24 days) and DWS-144 (23 days) were on par with each other. Minimum days to 50 per cent germination was observed in DWS-319 and DWS-252 (11 days), followed by DWS-141 (12 days). Early germination might be attributed to a soft seed coat, whereas late germination might be attributed to the genotypes hard seed coat. The results from the present investigation are in conformity with the findings of Gami *et al*. (2015) in ashwagandha.

Plant Height

The plant height was found significant among genotypes and the data analysed is presented in Table 2. The data revealed that the significantly maximum plant height was found in genotype DWS-09 (74.25 cm), which was followed by DWS-309 (72.15 cm) and DWS-259 (71 cm) and the lowest plant height (42.42 cm) was recorded in genotype DWS-40. The variations in plant growth phases among different ashwagandha genotypes could be attributed to genetic traits of the individual genotype, genetic heritability and growth variability among genotypes, as well as soil and climatic conditions favourable to vigorous growth and nutrition management. Similar results were obtained by Polaiah *et al*. (2013) and Gami *et al*. (2015) in ashwagandha.

No. of Branches Per Plant

Analysed mean data and its range for the thirty-two genotypes with respect to branches per plant are presented in Table 2. The data revealed that the significantly maximum branches per plant was found in genotype DWS-280 (17.81), which was followed by DWS-296 (16.38) and DWS-270 (15.67) and the lowest branches per plant (6.10) was recorded in genotype DWS-132. The increased number of branches per plant could be attributed to the requirement of developing plants for more carbohydrates, which might have forced the plants of these genotypes to produce more branches. other reason for the increased in branch number might be enhanced cell division, which might have increased the number of vegetative buds on the main stem. The variation in the number of branches among different genotypes was also reported by Sundesha *et al*. (2016) and Gami *et al*. (2015) in ashwagandha.

Days to 50 Per cent Flowering

Data pertaining to days to 50 per cent flowering recorded from different treatments is presented in Table 2. Significant differences were observed between the genotypes for days to 50 per cent flowering during both the years 2020 and 2021. Genotype DWS-252 recorded significantly minimum number of days to 50 per cent flowering (65 days) followed by genotypes DWS-319 and DWS-279 (66 days). The genotypes DWS-143 and DWS-257 were taken maximum number of days to 50 per cent flowering (84 days). The variation might be due to inherited genetic makeup and characteristic features of a genotype. The results from the present investigation agree with the findings of Joshi *et al*. (2014) and Gami *et al*. (2015) in ashwagandha.

Yield Parameters

Length of Main Root

The length of main root was found significant among genotypes and the analysed data is presented in Table 3. The data revealed that the highest length of main root (21.67 cm) was found in DWS-279, which was followed by DWS-09 (19.65 cm) and

TABLE 2

Performance of ashwagandha genotypes for growth and days to 50 per cent flowering

Treatments	Genotypes	Days to 50% germination	Plant height (cm)	No. of branches per plant	Days to 50 % flowering
T_1	DWS-05	17	52.56	10.25	72.00
T_2	DWS-09	14	74.25	12.21	67.00
T_3	DWS-22	16	53.33	12.00	73.00
T_4	DWS-40	18	42.42	11.67	79.00
T_5	DWS-41	15	66.52	14.12	75.00
T_6	DWS-132	25	53.44	6.10	80.00
T_7	DWS-141	12	49.20	12.33	70.00
T_8	DWS-143	24	62.50	11.20	84.00
T_9	DWS-144	23	49.67	11.47	71.00
T_{10}	DWS-197	15	51.85	9.50	72.00
T_{11}	DWS-250	17	47.69	11.64	73.00
T_{12}	DWS-252	11	56.22	13.35	65.00
T_{13}	DWS-253	20	52.54	10.30	79.00
T_{14}	DWS-257	20	53.44	14.00	84.00
T_{15}	DWS-258	16	45.25	8.54	77.00
T_{16}	DWS-259	21	71.00	12.42	75.00
T_{17}	DWS-260	14	55.25	12.69	70.00
T_{18}	DWS-262	18	60.20	12.75	74.00
T_{19}	DWS-270	15	63.70	15.67	68.00
T_{20}	DWS-272	14	54.30	11.90	69.00
T_{21}	DWS-279	13	51.26	14.20	66.00
T_{22}	DWS-280	14	58.67	17.81	73.00
T_{23}	DWS-281	17	48.33	9.84	72.00
T_{24}	DWS-284	13	60.71	10.46	70.00
T_{25}	DWS-296	13	59.50	16.38	71.00
T_{26}	DWS-309	15	72.15	11.85	73.00
T_{27}	DWS-315	19	50.67	10.45	78.00
T_{28}	DWS-316	16	47.55	9.56	71.00
T_{29}	DWS-317	13	59.00	11.61	73.00
T_{30}	DWS-319	11	65.71	14.83	66.00
T_{31}	Arka Ashwagandha	14	54.64	10.64	72.00
T_{32}	Poshita	14	56.59	11.13	70.00
	Mean	16.16	56.25	11.96	72.88
	S. Em (±)	0.07	0.16	0.05	0.10
	C.D. @ 5%	0.21	0.46	0.14	0.28

DWS-41 (18.86 cm) and the least length of main root (10.17 cm) was obtained in DWS-315. The variation in length of the main root among different genotypes may be due to vigour of the plant and other related plant characters. Similar results were reported by Sangwan *et al*. (2013) and Sundesha and Tank (2013) in ashwagandha.

Diameter of Main Root

The analysed mean data with respective diameter of main root was found significant among genotypes (Table 3). The data revealed that the highest diameter of main root (2.82 cm) was found in DWS-09, which was followed by DWS-279 (2.71 cm) and DWS-41 (2.60 cm) and the least diameter of main root (1.44 cm) was obtained in DWS-143. Singh *et al*. (2017) reported that the genetic variability exists in ashwagandha for dry root yield associated with root diameter. The findings are in consistent with the results obtained by Chaudhary *et al*. (2016) and Srivastava *et al*. (2017) in ashwagandha.

Dry Weight of Root Per Plant

The dry weight of root per plant was ranged from 3.34 to 7.57 g (Table 3). The maximum dry weight of root per plant was recorded in DWS-09 (7.57 g), followed by DWS-279 (6.80 g) and DWS-41(6.13 g). The minimum dry weight of root per plant was observed in DWS-22 (3.34 g). The variation in the root yield may be due to variations in the genetic makeup of genotypes. Similar results were obtained by Chaudhary *et al.* (2016) in ashwagandha.

Dry Root Yield Per Plot and Dry Root Yield Per Hectare

Dry root yield per plot ranged from 183.70 to 416.35 g (Table 3). The maximum dry root yield per plot was recorded in DWS-09 (416.35 g), followed by DWS-279 (374 g) and DWS-41 (337.15 g). The minimum dry root yield per plot was observed in DWS-22 (183.70 g). Similarly, dry root yield per hectare ranged from 7.07 to 16.01 q (Table 3). The maximum dry root yield was recorded in DWS-09 (16.01 qha^{-1}), followed by DWS-279 (14.98 qha^{-1}) and DWS-41(12.97 qha^{-1}). The minimum dry root yield was observed in DWS-22 (7.07 qha^{-1}). This variation might be due to differences in the vegetative growth of genotypes which lead to variation in photosynthesis and ultimately effect on dry root weight. The yield of root is directly related with higher number of branches. Similar results were reported by Patel and Desai (2017) in ashwagandha.

Fresh Weight of Per Plant

There was significant variation among genotypes in the analysed mean data with associated fresh weight of per plant (Table 4). Data revealed that DWS-09 had the highest fresh weight per plant (133.58 g), which was on par with DWS-279 (132.19 g) and followed by DWS-41 (131.74 g) and the DWS-132 had showed the lowest fresh weight per plant (45.75 g). The findings are in consistent with the results obtained by Srivastava *et al*. (2017) in ashwagandha.

Dry Weight of Per Plant

The dry weight of per plant was ranged from 16.79 to 45.93 g (Table 4). The maximum dry weight of per plant was recorded in DWS-09 (45.93 g), which was followed by DWS-241 (42.73 g) and DWS-279 (40.80 g). The minimum dry weight of per plant was observed in DWS- 132 (16.79 g). Variations in the genotypes genetic make-up could be the source of the variance in dry weight. Similar results were obtained by Chaudhary *et al.* (2016) and Singh *et al.* (2017) in ashwagandha.

Seed Yield Per Plant and Seed Yield Per Hectare

Seed yield per plant ranged from 2.76 to 13.87 g (Table 4). The maximum seed yield per plant was recorded in DWS-296 (13.87 g), which was followed by DWS-41 (12.23 g) and DWS-280 (12.05 g). The minimum seed yield per plant was noticed in DWS-132 (2.76 g). Similarly, seed yield per hectare ranged from 2.34 to 11.74 q (Table 4). The maximum seed yield was found in DWS-296 (11.74 qha^{-1}), which was followed by DWS-41 (10.34 qha^{-1}) and DWS-280 (10.20 qha^{-1}). The minimum seed yield was noticed in DWS-132 (2.34 qha^{-1}). This might be due

TABLE 3
Performance of ashwagandha genotypes for yield attributes

Treatments	Genotypes	Length of main root (cm)	Diameter of main root (cm)	Dry weight of root plant^{-1} (g)	Dry root yield plot^{-1} (g)	Dry root yield (qha^{-1})
T_1	DWS-05	14.67	1.61	4.07	223.85	8.61
T_2	DWS-09	19.65	2.82	7.57	416.35	16.01
T_3	DWS-22	11.67	1.79	3.34	183.70	7.07
T_4	DWS-40	11.00	1.76	4.60	253.00	9.73
T_5	DWS-41	18.86	2.60	6.13	337.15	12.97
T_6	DWS-132	14.53	1.54	3.95	217.25	8.36
T_7	DWS-141	17.53	2.08	5.42	298.10	11.47
T_8	DWS-143	14.00	1.44	4.80	264.00	10.15
T_9	DWS-144	13.00	1.71	3.59	197.45	7.59
T_{10}	DWS-197	15.48	1.64	4.53	249.15	9.58
T_{11}	DWS-250	12.58	1.51	4.28	235.40	9.05
T_{12}	DWS-252	18.17	2.20	4.57	251.35	9.67
T_{13}	DWS-253	12.34	1.58	3.55	195.25	7.51
T_{14}	DWS-257	14.95	2.18	4.92	270.60	10.41
T_{15}	DWS-258	15.17	1.81	3.96	217.80	8.38
T_{16}	DWS-259	12.17	2.16	5.46	300.30	11.55
T_{17}	DWS-260	17.33	2.10	5.75	316.25	12.16
T_{18}	DWS-262	15.83	1.55	4.16	228.80	8.80
T_{19}	DWS-270	12.67	1.95	5.12	281.60	10.83
T_{20}	DWS-272	16.00	2.14	4.25	233.75	8.99
T_{21}	DWS-279	21.67	2.71	6.80	374.00	14.38
T_{22}	DWS-280	16.33	2.38	5.64	310.20	11.93
T_{23}	DWS-281	11.50	1.69	4.17	229.35	8.82
T_{24}	DWS-284	11.17	1.83	4.49	246.95	9.50
T_{25}	DWS-296	16.85	1.59	4.60	253.00	9.73
T_{26}	DWS-309	14.58	2.00	4.88	268.40	10.32
T_{27}	DWS-315	10.17	1.47	3.89	213.95	8.23
T_{28}	DWS-316	15.67	1.85	3.69	202.95	7.81
T_{29}	DWS-317	15.00	1.92	4.55	250.25	9.63
T_{30}	DWS-319	17.25	2.27	6.00	330.00	12.69
T_{31}	Arka Ashwagandha	13.33	2.04	5.15	283.25	10.89
T_{32}	Poshita	17.90	1.90	5.30	291.50	11.21
	Mean	14.97	1.93	4.79	263.28	10.13
	S. Em (±)	0.06	0.01	0.02	1.10	0.04
	C.D. @ 5%	0.16	0.02	0.06	3.12	0.12

TABLE 4

Performance of ashwagandha genotypes for yield characters

Treatments	Genotypes	Fresh weight of per plant (g)	Dry weight of per plant (g)	Seed yield per plant (g)	Seed yield (qha^{-1})
T_1	DWS-05	99.66	26.67	8.11	6.86
T_2	DWS-09	133.58	45.93	11.83	10.01
T_3	DWS-22	57.50	20.90	2.94	2.49
T_4	DWS-40	63.12	24.76	3.21	2.71
T_5	DWS-41	131.74	42.73	12.23	10.34
T_6	DWS-132	45.75	16.79	2.76	2.34
T_7	DWS-141	70.71	27.42	5.10	4.31
T_8	DWS-143	90.00	26.10	3.21	2.72
T_9	DWS-144	52.71	18.86	3.60	3.04
T_{10}	DWS-197	104.57	27.37	6.51	5.51
T_{11}	DWS-250	78.10	23.54	4.75	4.02
T_{12}	DWS-252	121.92	34.04	9.03	7.64
T_{13}	DWS-253	70.00	18.91	5.88	4.98
T_{14}	DWS-257	97.91	31.47	9.15	7.74
T_{15}	DWS-258	76.24	23.74	4.86	4.11
T_{16}	DWS-259	94.76	26.97	4.50	3.81
T_{17}	DWS-260	99.24	31.41	6.67	5.64
T_{18}	DWS-262	62.20	20.71	5.89	4.98
T_{19}	DWS-270	114.83	33.87	8.61	7.29
T_{20}	DWS-272	87.86	23.03	6.05	5.12
T_{21}	DWS-279	132.19	40.80	11.89	10.06
T_{22}	DWS-280	116.16	39.46	12.05	10.20
T_{23}	DWS-281	81.90	22.59	6.25	5.29
T_{24}	DWS-284	92.22	27.91	7.13	6.03
T_{25}	DWS-296	109.94	40.18	13.87	11.74
T_{26}	DWS-309	71.43	23.50	5.80	4.90
T_{27}	DWS-315	50.66	19.42	4.35	3.68
T_{28}	DWS-316	83.97	21.31	5.28	4.47
T_{29}	DWS-317	88.73	23.81	3.73	3.15
T_{30}	DWS-319	126.46	36.36	9.25	7.83
T_{31}	Arka Ashwagandha	115.34	31.24	7.16	6.06
T_{32}	Poshita	118.22	32.60	6.87	5.81
	Mean	91.86	28.26	6.83	5.78
	S. Em (±)	0.53	0.16	0.47	0.34
	C.D. @ 5%	1.51	0.45	1.32	0.97

to variations in genotypes' reproductive development, which affect seed yield through regulating photosynthesis. The number of berries and branches has a direct impact on seed yield. Patel and Desai (2017) reported similar results in ashwagandha.

Study indicates that DWS-09 showed the highest mean performance in terms of growth and yield characteristics. DWS-279 and DWS-41 were found on par with respective to yield parameters.

REFERENCES

CHAUDHARY, S. B., BAGUL, R. S. AND DODAKE, S. S., 2016, Genotypic association and path coefficient analysis in ashwagandha [*Withania somnifera* (L.) Dunal]. *Int. J. Med. Sci.,* **9** (5) : 81 - 83.

DEVI, P. U., 1996, Ashwagandha potential plant source of a promising drug for cancer chemotherapy. *Indian J. Exp. Biol*., **34** (10) : 927 - 932.

GAMI, R. A., SOLANKA, S. D., PATEL, M. P., KAPIL. T, BHADAURIA, H. S. AND MITHILESH, K., 2015, Enormity of genetic variability in aerial, underground and biochemical traits of ashwagandha [*Withania somnifera* (L.) Dunal]. *Int. J. Agric. Sci*., **5** (5) : 271 - 276.

JOSHI, N. R., PATEL, M. A., PRAJAPATI, K. N. AND PATEL, A. D., 2014, Genetic variability, correlation and path analysis in ashwagandha [*Withania somnifera* (L.) Dunal]. *Electron. J. Plant Breed.,* **5** (4) : 875 - 880.

PANSE, V. G. AND SUKHATME, P. V., 1957, Genetics of quantitative characters in relation to plant breeding. *Indian J. Genet*., **17** (2) : 318 - 328.

PATEL, A. I. AND DESAI, B. S., 2017, Genetic divergence in [*Withania somnifera* (L.) Dunal]. *J. Med. Plants Stud.,* **5** (3) : 119 - 122.

POLAIAH, A. C., LAXMINARAYAN, H. AND VIJAYA, N., 2013, Evaluation of ashwagandha germplasm for growth, yield and quality characters. *Progress Res.,* **8** (2) : 213 - 216.

SANGWAN, O., AVTAR, R. AND SINGH, A., 2013, Genetic variability, character association and path analysis in ashwagandha [*Withania somnifera* (L.) Dunal] under rainfed conditions. *Res. Plant Biol.,* **3** (1) : 32 - 36.

SINGH, G. M., DOIYA, N. S., JOSHI, A. AND KHATIK, C. L., 2017, Variability, character associations and path analysis in ashwagandha [*Withania somnifera* (L.) Dunal] with respect to root yield and biochemical aspects. *Ann. Biol. Res.*, **8** (1) : 129 - 141.

SINGH, N., BHALLA, M., DE JAGER, P. AND GILCA, M., 2011, An overview on ashwagandha rejuvenator of ayurveda. *Afr. J. Tradit. Complement. Altern. Med*., **8** (5) : 208 - 213.

SRIVASTAVA, A., GUPTA, A. K., SHANKER, A., GUPTA, M. M., MISHRA, R. AND LAL, R. K., 2017, Genetic variability, associations and path analysis of chemical and morphological traits in Indian ginseng [*Withania somnifera* (L.) Dunal] for selection of higher yielding genotypes. *J. Ginseng Res*., **4** (1) : 1 - 7.

SUNDESHA, D. L. AND TANK, C. J., 2013, Genetic variability, heritability and expected genetic gain for dry root yield in ashwagandha. *Asian J. Hort.,* **8** (6) : 475 - 477.

SUNDESHA, D. L., TANK C. J. AND TULSANI N. J., 2016, Correlation and path analysis for dry root yield in ashwagandha [*Withania somnifera* (L.) Dunal]. *Electron. J. Plant Breed.,* **8** (5) : 448 - 453.

Relevance of Stomatal Traits in Determining the Water Use and Water Use Efficiency in Rice Genotypes Adapted to Different Cultivation Systems

ABHISHREE RAMACHANDRA, B. MAHADEVA PRABHU AND M. S. SHESHSHAYEE
Department of Crop Physiology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : abhishreeramachandra@gmail.com

AUTHORS CONTRIBUTION

ABHISHREE RAMACHANDRA : Investigation, drafted the manuscript analysis;
B. MAHADEVA PRABHU : Provided technical inputs;
M. S. SHESHSHAYEE : Conceptualization, designing & final aproval

Corresponding Author :
ABHISHREE RAMACHANDRA
Department of Crop Physiology, College of Agriculture, UAS, GKVK Bengaluru

Received : August 2022
Accepted : November 2022

ABSTRACT

Climate change has resulted in a highly unpredictable pattern of rainfall which is often insufficient for agriculture. Rice, being staple food and a water intensive crop, the water conservation strategy without much compromise in yield is always a challenge. The majority of water lost is because of the transpiration process, which is regulated by small opening on the leaf surface called stomata. Studying the stomatal arrangement between the genotypes paves the way to understand physiological responses of stomata to varying moisture regimes. In this study, the spatial variability of stomata existing in three well known rice varieties *viz.,* APO, Dhaksha and IR 64 was studied along with its effect on transpiration. Image J software was used to measure the stomatal size and phenomics facility was used to measure the transpiration. The data on stomatal frequency from both the lower and upper surface showed that APO and IR 64 had considerably higher stomatal frequency in the flag leaf with Dhaksha having higher stomatal frequency among all the three rice varieties. Total dry matter, cumulative water transpired and water use efficiency were significantly higher for Dhaksha followed by APO. The higher stomatal number in flag leaf and second leaf and lower stomatal number and higher size in third and fourth leaf of Dhaksha could be an adaptive strategy of the genotype to reduce the water loss from the leaves under water limited condition. This study indicates that higher stomatal numbers at top leaves and lower stomatal number at lower leaves is best suited for rice under aerobic condition to increase water productivity without decreasing yield.

Keywords : Stomatal traits, Water use efficiency, Rice genotypes

CLIMATE change has a greater impact on agriculture. With the increasing demand for fresh water from civic and industrial sectors, water shortage would have a strong adverse effect on agricultural practices. Thus, there has been an increasing trend towards accessing ground water through tube wells. These anthropogenic interventions have exacerbated water crisis by depleting the water table.

Rice (*Oryza sativa* L.), the staple diet for more than half of the world population, is a water intensive crop. To sustain food security, under the scenario of a changing climate, it is imperative that the water productivity of rice has to be enhanced which can be achieved either by the adoption of specific water saving practices or by genetic enhancement to improve crop tolerance to water limitation stress (Vijayaraghavareddy *et al.,* 2020a). Semi-irrigated aerobic cultivation and upland rice is being practiced under both rainfed and irrigated conditions. However, concomitant reduction in yield is often noticed due to higher spikelet fertility. This led to the adoption of physiological breeding. For example, Dhaksha, has also been developed by introgressing specific physiological traits such as water use and water use efficiency (WUE) to grow under aerobic conditions (Sheshshayee *et al.,* 2019). Other approach was double haploids breeding technique for developing new varieties of crops (Chaitanya and Raju, 2022). It has become necessary to focus on water conservation strategy without much compromise in yield. There is a need to improve the yield of local rice varieties to combat the food demands of the increasing population (Karthika and Shanker, 2022).

Many studies have reported the improvement in water use efficiency (WUE) of the rice crop. The WUE is the function of the amount of dry matter produced per unit of water transpired. In plants, water can be used efficiently by regulating the transpiration process. This transpiration process is regulated by many external factors like light, temperature, humidity and an internal factor *i.e.* stomata. Stomata are extracellular openings present on the leaf surface. These provide access to the mesophyll cells (Zeiger *et al*., 1987; Hetherington and Woodward, 2003). Stomata are not uniform among the plants; their size, shape and number vary within and across different species. They exhibit differences in their development and patterning on the epidermis (Caine *et al.,* 2016).

The stomatal movements are the major driving force for both CO_2 fixation and transpiration. Due to varying response of rice crops to varied climatic conditions, there is differential arrangement of stomata (*i.e.* stomatal density and guard cell size) on leaf surface. These differences have led to the differential response of plants to stress resulting in differences in potential yield. Evolutionarily various stomatal traits have been altered enabling the plants to adopt to new environment (Taylor *et al*., 2012; Drake *et al*., 2013; Haworth *et al*., 2018). The plants with smaller size stomata show fast response to changing environmental conditions unlike the large sized stomata (Franks and Beerling, 2009 and Drake *et al*., 2013 and Lawson & Blatt, 2014). When the ratio of cell surface area to volume of smaller cells is higher, they facilitate faster ion fluxes, leading to faster guard cell turgor changes and a more rapid conductance response (Lawson and Chabrand, 2019).

An investigation was carried out to assess the role of stomatal factors such as number and size, in governing the variability in WUE. These influences were examined in rice cultivars representing the three distinct cultivation ecosystems, *viz.,* irrigated (IR64), rainfed upland (APO) and semi-irrigated aerobic (Dhaksha). Studying the variability of stomatal factors in these genotypes paves the way to understand physiological responses of stomata to varying moisture regimes.

Material and Methods

Plant Material and Environment

The experiment was conducted in the phenomics facility established in the Department of Crop Physiology, University of Agricultural Sciences, GKVK, Bengaluru, during *Rabi* 2022 (Fig. 1A).

Fig. 1 : (A) High throughput phenomics facility established at Department of Crop Physiology, University of Agricultural Sciences, Bangalore. (B) Automated software controlled system enables the measurement of hourly transpiration and cumulative water transpired.

Three well known Rice varieties *viz.,* Dhaksha, IR-64 and APO were used in studying the variability existing in the stomatal traits and water use.

Growing Conditions

The germinated seeds of Dhaksha, IR-64 and APO were directly sown into the pots of 30L capacity. Pots were filled with red soil and FYM in 3:1 ratio. Thinning was carried out at 21 days after sowing (DAS) to maintain two plants per pot. Recommended dose of fertilizers (100N: 50P: 50K) was added in three split doses during sowing, after thinning and at flowering. All the prophylactic measures were taken whenever necessary. The field capacity was calculated as described by Vijayaraghavareddy *et al.,* 2020a. The moisture conditions of 100 per cent Field Capacity (FC) (control) were maintained during the entire crop growth period by gravimetric method using the mini-lysimeter phenomics facility.

Maintaining the Soil Moisture Status with Phenomics Facility

The mini-lysimeter phenomics platform provides the cumulative water transpired by each genotype based on the gravimetric approach (Fig. 1B). The MLM drought simulator platform is capable of gravimetric determination of water loss due to the Evapo-Transpiration of container grown plants on a 'real-time' basis (Vijayaraghavareddy *et al*., 2020b and Lekshmy *et al*., 2021). Combined with a smart transpiration-interfaced automated irrigation facility, it ensures the precise maintenance of a specific water regime in the soil. The most prominent feature of this automated irrigation facility comes from its ability to ensure exactly the same level of soil moisture status for plants irrespective of differences in water used.

Measurement of Stomatal Paramaters

The leaf impressions for stomatal imprints were taken from flag leaf, second leaf, third leaf and fourth leaf from the top during the anthesis stage. The stomatal impressions were made using the nail enamel method. The nail enamel was smeared on the middle portion of leaf surface and allowed to dry for a minute and the smear was imprinted on the microscopic slides using the cello tape. Impressions were made for both the abaxial and adaxial sides of the same leaf for each variety, maintaining four replications for each variety (3 varieties x 2 surfaces x 4 replications x 3 images per slide) (Reddy *et al*., 2020). The imaging was done using automated fluorescent microscope (EVOS M700) at magnification of 400X. The stomatal frequency was calculated by manually counting the number of stomata per microscopic area under 400X magnifaction and was further converted to number of stomata per mm^2 area (Franks and Beerling, 2009). The product of stomatal length and width as taken as stomatal size.

The stomatal length and stomatal width were measured using Image J software, an imaging tool, considering six stomata per microscopic view. From the tool bar the image to be analyzed was opened. Before starting the measurement of length or width of stomata using Image J, the standard scale was set using the scale mentioned in the image taken from the microscope (in the present experiment the scale was set to 75 µm). After setting the scale, the actual measurements were done using straight line tool. After drawing each line to the required length and / or width, the line drawn was measured by the software. The measured data was exported to excel sheets and calculated as stomatal size by multiplying stomatal length and stomatal width.

Measurement of Morpho-Physiological Parameters and Transpiration

When the plants reached physiological maturity (110 DAS), the panicles, leaves, stems and roots were separated from the plants and oven dried at 70°C for 3 days. The total leaf area (TLA) was calculated by multiplying the specific leaf area (SLA) (cm^2/g) with total dry weight of the leaves. The SLA is the ratio of leaf area to leaf dry weight (Garnier *et al.,* 2001). After threshing of panicles, the total weight of filled grains obtained was considered as yield per pot. The TDM was calculated by adding the dry weights of leaf, stem, root and yield.

Cumulative water transpired (CWT) was measured using the phenomics facility. Total water transpired from 20 Days after sowing (DAS) to 100 DAS was computed to arrive at total evapo-transpiration. The soil surface of the pots was covered with beads to avoid the evaporation loss of water. However, empty pots without plants were maintained to arrive at total evaporation loss of water for the crop period. Total evapo-transpiration was deducted with evaporation loss of water to arrive at CWT. Mean transpiration rate (MTR) was calculated as a ratio of CWT to the total leaf area. The WUE was calculated by taking the ratio of total biomass to the CWT by the plant between 20 DAS and 100 DAS.

RESULTS AND DISCUSSION

Measurement of Stomata Using ImageJ

High-throughput phenotyping methods are becoming very crucial for developing genotypes for stress tolerance. Many software-based tools are highly used for measuring morpho-physiological traits (Zang and Zang 2018). However, traits such as stomatal size are not well studied due to lack of

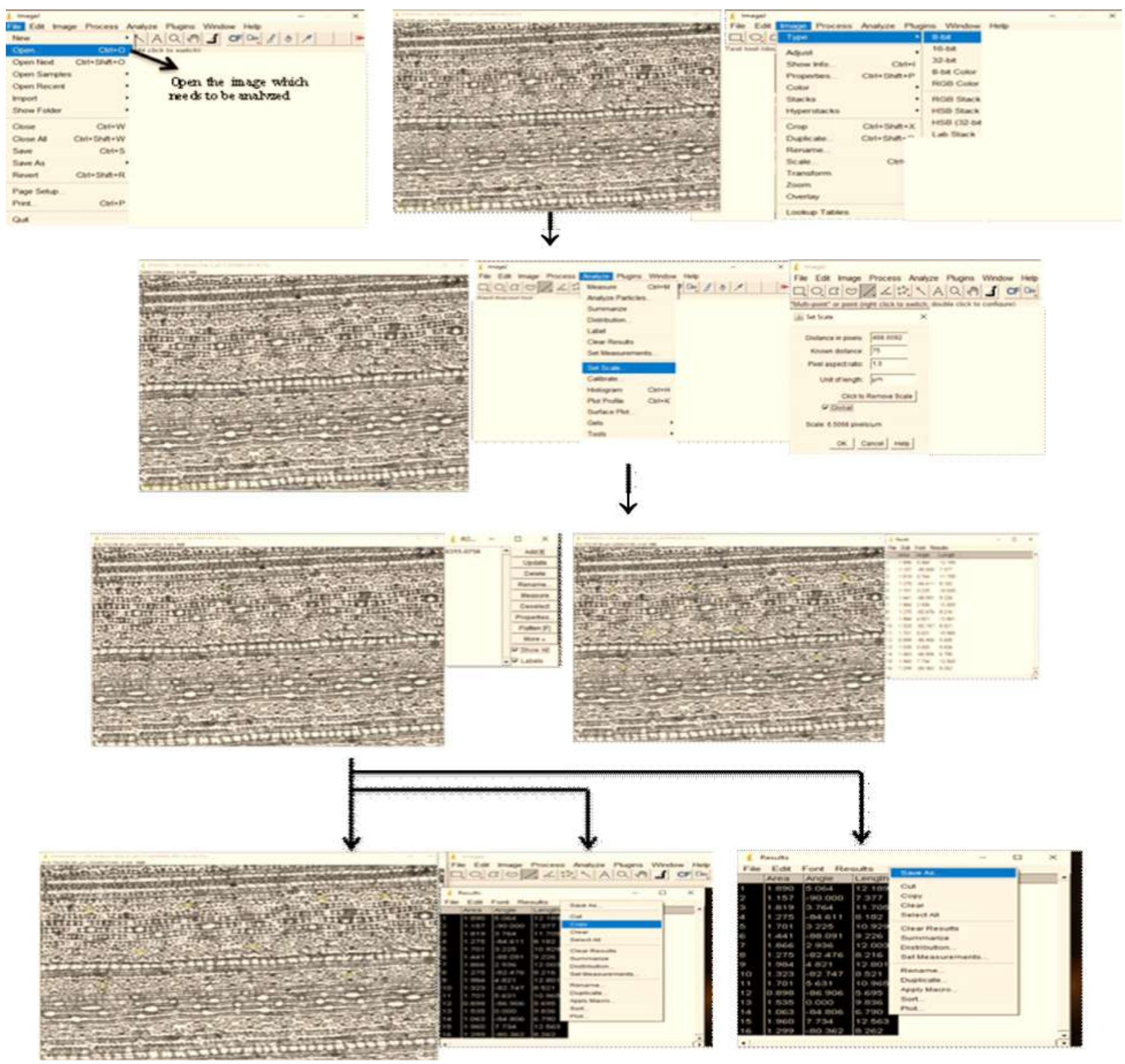


Fig. 2: Detailed illustration of measuring stomatal length and width using ImageJ software

phenotyping tools. Though scanning electron microscopy is highly used, it is not preferable to adopt for large set of genotypes or mapping population due to high cost of the technique. In this study, a quick method was standardized to measure the stomatal size in rice genotypes using ImageJ software. This system needs a clear image taken from the imprint method. In this study, fluorescent microscope was used for taking the images. ImageJ is an open source freeware mainly used for image analysis (Chatterjee *et al*., 2020). Images taken from the microscope were exported to the ImageJ software and the scale was set in µm (Fig. 2). Randomly five stomata were selected and measured for length and width. When the image to be analyzed is opened, in the tool bar, the 'Image' - 'Type' was set to 8 bit. Next, by selecting the straight line tool, the length was drawn on the scale bar in the image opened. By using 'Analyse' tool the scale was set to the same length as the scale bar (75 µm for 400x magnification). After setting the scale, using the same straight line tool, a line was drawn horizontally on the stomatal aperture which indicated the stomatal length and a line drawn vertically in the center of stomata indicated the stomatal width. The length and width of the measured stomata are taken from the results tab and exported to Microsoft excel for further analysis (Fig. 2).

3A

3B

3C

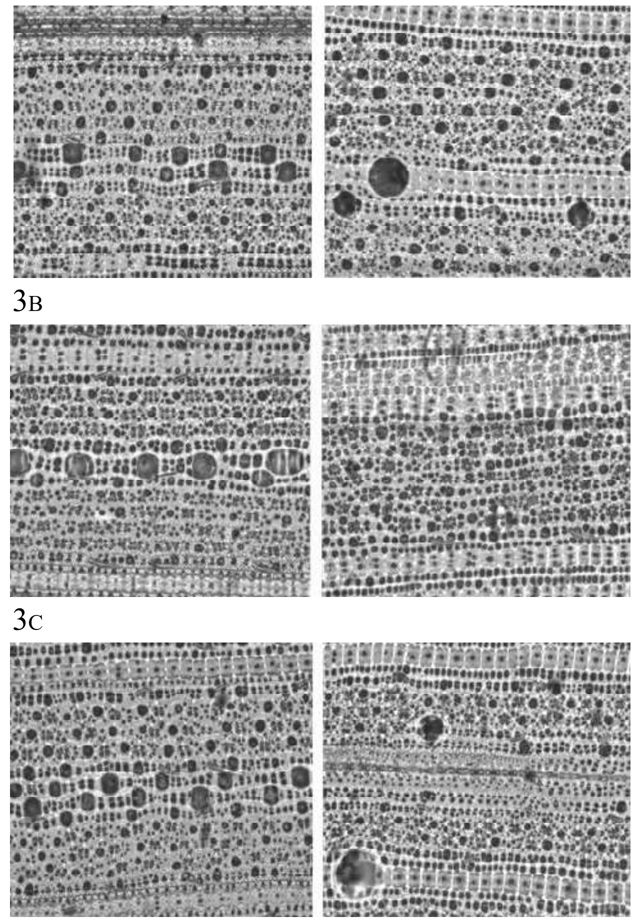


Fig. 3: Impressions of lower (left panel) and upper (right panel) leaf surface under magnification of 400 X. A) APO, B) Dhaksha, C) IR 64. Arrows indicate stomata.

Variability in Stomatal Number and Size among the Rice Genotypes

The stomata in rice are arranged alternatively in parallel rows on both the lower and upper leaf surface (Fig. 3). In APO, the flag leaf had higher stomatal frequency, whereas in Dhaksha both second leaf and flag leaf recorded higher stomatal frequency compared to other leaves (Fig. 4A). IR 64 did not show any difference in stomatal frequency between flag leaf, second and third leaf. In the fourth leaf, stomatal frequency was lower for IR 64 compared to APO and Dhaksha (Fig. 4A). Previous defoliation experiments have shown the importance of flag leaf during grain filling, where plants without flag leaf had a significant reduction in the yield (Acevedo *et al*., 2021). Flag leaf is the major source contributor during grain filling. Hence, higher stomatal frequency attributes to enhanced carbon fixation in the flag leaf (Acevedo *et al*., 2021). Under aerobic conditions, water use efficiency also plays a major role especially in semi aquatic crop plants like rice (Sheshshayee *et al*., 2003). Hence, it could be possible that in both aerobic type genotypes APO and Dhaksha, leaves which has greater light interception (flag leaf and second leaf) had the more number of stomata compared to lower leaves (Fig. 4A). There was no significant difference between the stomatal frequency of upper and lower surface except for fourth leaf of APO and IR 64. The lower surface of the fourth leaf of APO had lower stomatal frequency compared to upper surface. However, the lower surface of the fourth leaf of IR 64 had higher

TABLE 1

Variability in Stomatal frequency of lower and upper leaf surface among Apo, Dhaksha, IR64 through Flourescence microscope with 400X magnification

	Stomatal frequency (per mm^2 area)							
	Lower surface				Upper surface			
	Flag Leaf	Second Leaf	Third Leaf	Fourth Leaf	Flag Leaf	Second Leaf	Third Leaf	Fourth Leaf
APO	645.16 ± 28.71	476.03 ± 8.46	492.83 ± 8.46	380.82 ± 13.99	532.03 ± 13.58	498.43 ± 60.23	435.71 ± 30.49	505.15 ± 5.13
Dhaksha	650.76 ± 46.60	651.88 ± 62.77	493.95 ± 17.78	561.16 ± 26.24	621.64 ± 95.81	776.21 ± 10.08	562.28 ± 83.29	77.15 ± 45.21
IR 64	599.24 ± 19.11	520.83 ± 34.92	539.87 ± 52.52	465.95 ± 102.27	484.99 ± 19.69	516.35 ± 38.95	570.12 ± 25.44	56.50 ± 20.25

stomatal frequency (465.95 per mm^2 area) compared to upper surface (256.50 per mm^2 area). In Dhaksha, second and third leaf had high frequency of stomata in upper surface compared to lower surface (Table 1).

Stomatal size measured using ImageJ showed that, IR64 has the higher stomatal size in the fourth leaf compared to other top leaves. Whereas, Dhaksha had more stomatal size in both third and fourth leaf compared to flag leaf and second leaf (Fig. 4B). Genotype APO did not show any significant difference except for the flag leaf. Many studies have shown that increasing the stomatal size decreases stomatal density (Chatterjee *et al.,* 2020). Between upper and lower surface no significant difference in stomatal size was noticed in any genotype except for fourth leaf of APO (Table 2). Our data also showed a negative association between size and frequency of the stomata (Fig.5A). Size and frequency of the stomata between upper and lower surface did not show a strong association (R^2=0.42 and R^2=0.31 respectively) (Fig. 5B). The cause for variability in stomatal frequency and stomatal size existing between abaxial and adaxial surface and different leaves within same plant and the variability existing between the varieties needs to be further verified.

Difference in the Cumulative Water Transpired Between the Genotypes

The higher stomatal frequencies on all the four leaves in Dhaksha and APO contributed for higher transpiration during the entire growth period (Table 3). Because of higher stomatal frequency and size in APO and Dhaksha, the water transpired measured in term of cumulative water transpired (CWT) was significantly higher. IR64, a lowland cultivar showed significantly lower CWT because of lower stomatal size and frequency. It is well established that stomata is the major internal factor that drives transpiration. Higher stomatal number associates with higher carbon gain to more conductance. This study also confirms that higher stomatal number resulted in higher CWT in both APO and Dhaksha.

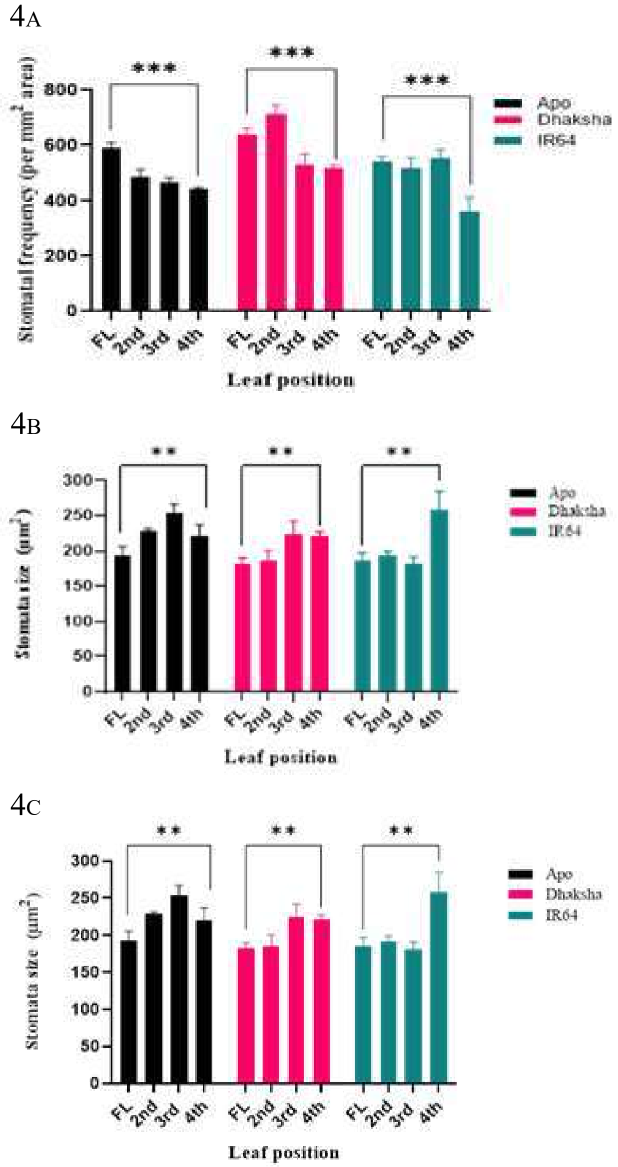


Fig. 4: A) Stomatal frequency and (B) stomatal size in flag leaf, second leaf, third leaf and fourth leaf from top of APO, Dhaksha and IR 64 (mean±SE). Significant difference at *** Pd" 0.01, **Pd" 0.05.

Further, results show that low stomatal frequency and small stomatal size types (IR 64) transpires less. These results would also be due to faster response of the stomata to varying vapor deficit conditions (Lawson and Chabrand, 2019). At the whole plant level, many factors regulate transpiration including the leaf area, canopy architecture and water availability (Caine *et al.*, 2019). It further needs to be studied which type of stomatal arrangement is physiologically important to conserve water without

TABLE 2

Variability in Stomatal size of lower and upper leaf surface among Apo, Dhaksha, IR 64 through ImageJ software

	Stomatal size (µm^2)							
	Lower surface				Upper surface			
	Flag Leaf	Second Leaf	Third Leaf	Fourth Leaf	Flag Leaf	Second Leaf	Third Leaf	Fourth Leaf
APO	190.43 ± 18.01	218.75 ± 7.27	250.46 ± 18.55	245.90 ± 19.63	195.82 ± 13.06	238.61 ± 11.73	256.66 ± 9.78	194.36 ± 14.81
Dhaksha	198.65 ± 9.62	182.71 ± 8.91	233.94 ± 33.23	221.01 ± 14.14	166.98 ± 6.25	188.38 ± 22.83	215.38 ± 16.29	222.59 ± 4.38
IR 64	189.15 ± 15.02	198.15 ± 17.81	177.91 ± 37.55	229.57 ± 45.11	181.92 ± 10.71	186.84 ± 19.57	183.85 ± 18.92	287.13 ± 38.41

5A

5B

5C

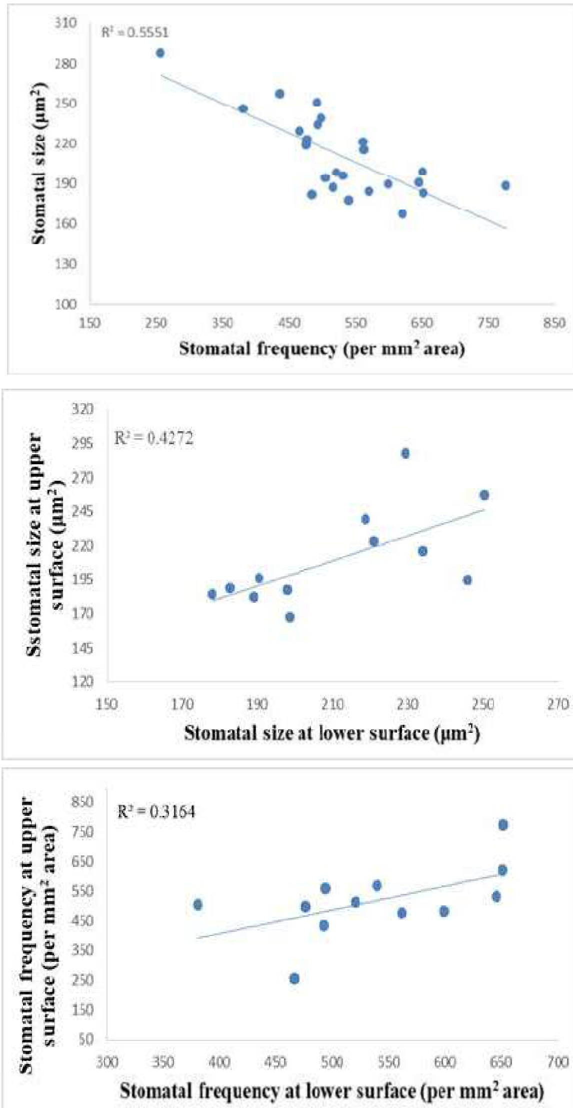


Fig. 5 : Regression analysis showing the relationship between the (A) stomatal frequency at upper and lower surface of the leaf, (B) stomatal size at upper and lower surface of the leaf and (C) stomatal frequency and stomatal size. (*P≤0.1, ns-non significant).

causing any yield penalties under both the well watered and water limited conditions (Caine *et al.*, 2019). It is most important to conserve water without greater compromise in yield to reduce the effects of climate change on future agriculture.

Morpho-Physiological and Transpiration among the Genotypes

Total dry matter (TDM) was significantly higher in Dhaksha and APO. However, yield per pot was significantly higher in Dhaksha compared to APO. The yield was significantly lower in IR 64. (Table 3). This could be due to the experience of mild drought stress under aerobic conditions. It has been well documented that, for lowland cultivars a smaller reduction in water availability causes significant yield loss (Vijayaraghavareddy *et al.,* 2020a). The reduction in yield also depends on the stage of stress occurrence. Since in the plants were maintained in aerobic conditions throughout the crop period, IR 64, the lowland cultivar might have experienced mild stress during all critical growth phases and hence resulted in lower yield. Among the genotypes, Dhaksha had the higher leaf area (5503.40 cm^2) (Table 3). CWT for entire crop period was also significantly higher for APO and Dhaksha. Difference in the CWT could be due to existing differences in the leaf area. Hence we calculated the MTR and it was significantly lower for Dhaksha indicating the lower transpiration per unit leaf area. APO recorded the higher MTR compared to IR 64. The lower MTR in Dhaksha could also be due to lower stomatal frequency in third and fourth leaf (Table 3). Since the lower leaves of the canopy

Table 3

Variability in transpiration and morpho-physiological traits among APO, Dhaksha, IR 64. Cumulative water transpired (CWT), Total dry matter (TDM), Total leaf Area (TLA), Water use efficiency (WUE) and Yield in Apo, Dhaksha and IR 64 respectively.

	CWT (L)	TDM (g/pot)	TLA (cm2/pot)	WUE (g/L)	MTR (ml/cm2)	Yield (g/pot)
APO	116.79 ± 0.70	368.80 ± 35.30	5068.45 ± 209.60	3.16 ± 0.31	23.1 ± 1.0	107.20 ± 8.71
Dhaksha	115.81 ± 0.75	374.37 ± 123.67	5503.40 ± 388.05	3.24 ± 1.09	20.4 ± 1.3	196.78 ± 27.37
IR 64	82.41 ± 0.16	220.12 ± 7.34	3917.29 ± 27.70	2.67 ± 0.09	21.1 ± 1.5	65.60 ± 3.87

experience shade due to overlapping of leaves, carbon assimilation would be substantially low. Hence in Dhaksha, this could be a drought adaptive mechanism to reduce transpiration by minimizing the stomatal frequency in lower leaves. The water use efficiency (WUE) of both aerobic cultivars APO and Dhaksha was significantly higher compared to lowland cultivar IR 64. The genotype Dhaksha has been developed by physiological breeding by crossing high root and high WUE parents (Sheshshayee *et al.,* 2019). Hence despite the higher CWT, higher WUE indicates a better carbon assimilatory capacity.

This study depicts the importance of high through put techniques for measurement of drought adaptive mechanisms and the spatial variations in stomatal number and size indicates a strong G×E interaction. The importance of stomatal traits in determining the WUE explains the need of improving this trait for achieving drought tolerance.

Acknowledgments : AR would like to thank the Department of Science and Technology (DST), Government of India, for the DST-INSPIRE Fellowship. The research is supported by the National Agriculture Science Fund (NASF-2581). The authors also acknowledge the Pathogenomics Lab, Department of Plant Pathology, University of Agricultural Sciences, GKVK for providing microscope facility. The authors wish to thank Dr. Preethi Vijayaraghavareddy for useful suggestions during the experiment and manuscript preparation. The authors also thank the members of Molecular Marker Lab and Phenomics team, Department of Crop Physiology, for providing technical inputs during the experiment.

References

Acevedo-Siaca, L. G., Coe, R., Quick, W. P. and Long, S. P., 2021, Variation between rice accessions in photosynthetic induction in flag leaves and underlying mechanisms. *J. Exp. Bot.*, **72** (4) : 1282 - 1294.

Caine, R. S., Chater, C. C., Kamisugi, Y., Cuming, A. C., Beerling, D. J., Gray, J. E. and Fleming, A. J., 2016, An ancestral stomatal patterning module revealed in the non-vascular land plant Physcomitrella patens. *Development*, **143** (18) : 3306 - 3314.

Caine, R. S., Yin, X., Sloan, J., Harrison, E. L., Mohammed, U., Fulton, T., Biswal, A. K., Dionora, J., Chater, C. C., Coe, R. A. and Bandyopadhyay, A., 2019, Rice with reduced stomatal density conserves water and has improved drought tolerance under future climate conditions. *New Phytol.*, **221** (1) : 371 - 384.

Chaitanya, G. and Mohan Raju, B., 2022, Optimization of *in-vitro* androgenic protocol for development of haploids and double haploids in *indica* rice hybrid, KRH 4. *Mysore J. Agric. Sci.,* **56** (1) : 39 - 48.

Chatterjee, J., Thakur, V., Nepomuceno, R., Coe, R.A., Dionora, J., Elmido-Mabilangan, A., Llave, A. D., Reyes, A. M. D., Monroy, A. N., Canicosa, I. and Bandyopadhyay, A., 2020, Natural diversity in stomatal features of cultivated and wild *Oryza* species. *Rice*, **13** (1) : 1 - 20.

Dharmappa, P. M., Doddaraju, P., Malagondanahalli, M. V., Rangappa, R. B., Mallikarjuna, N. M., Rajendrareddy, S. H., Ramanjinappa, R., Mavinahalli, R. P., Prasad, T. G., Udayakumar, M. and Sheshshayee, S. M., 2019, Introgression of root and water use efficiency traits enhances water productivity : An evidence for physiological breeding in rice (*Oryza sativa* L.). *Rice*, **12** (1) : 1 - 14.

Drake, P. L., Froend, R. H. and Franks, P. J., 2013, Smaller, faster stomata : scaling of stomatal size, rate of response and stomatal conductance. *J. Exp. Bot.*, **64** (2) : 495 - 505.

Franks, P. J. and Beerling, D. J., 2009, Maximum leaf conductance driven by CO_2 effects on stomatal size and density over geologic time. *Proc. Natl. Acad. Sci.*, **106** (25) : 10343 - 10347.

Garnier, E., Shipley, B., Roumet, C. and Laurent, G., 2001, A standardized protocol for the determination of specific leaf area and leaf dry matter content. *Funct. Ecol.,* 688 - 695.

Haworth, M., Marino, G., Brunetti, C., Killi, D., De Carlo, A. and Centritto, M., 2018, The impact of heat stress and water deficit on the photosynthetic and stomatal physiology of olive (*Olea europaea* L.) - A case study of the 2017 heat wave. *Plants*, **7** (4) : 76.

Hetherington, A. M. and Woodward, F. I., 2003, The role of stomata in sensing and driving environmental change. *Nature*, **424** (6951) : 901 - 908.

Karthika, V. and Shanker, A. G., 2022, Efficient callus induction and regeneration protocol for the rice *indica* genotype Sonali. *Mysore J. Agric. Sci.,* **56** (1) : 171 - 179.

Lawson, T. and Blatt, M. R., 2014, Stomatal size, speed and responsiveness impact on photosynthesis and water use efficiency. *Plant Physiol.*, **164** (4) : 1556 - 1570.

Lawson, T. and Vialet Chabrand, S., 2019, Speedy stomata, photosynthesis and plant water use efficiency. *New Phytol.*, **221** (1) : 93 - 98.

Lekshmy, V. S., Vijayaraghavareddy, P., Nagashree, A. N., Ramu, V. S., Ramegowda, V., Makarla, U. and Sreeman, S., 2021, Induction of acquired tolerance through gradual progression of drought is the key for maintenance of spikelet fertility and yield in rice under semi-irrigated aerobic conditions. *Front. Plant Sci.*, pp. : 2275.

Reddy, S. H., Da Costa, M. V. J., Kambalimath, S. K., Rajanna Mavinahalli, P., Muthurajan, R., Chinnusamy, V., Sevanthi, A. M., Neelamraju, S., Gopala Krishnan, S., Singh, A. K. and Singh, N. K., 2020, Relative contribution of stomatal parameters in influencing WUE among rice mutants differing in leaf mass area. *Plant Physiol. Rep.*, **25** (3) : 483 - 495.

Sheshshayee, M. S., Bindumadhava, H., Shankar, A. G., Prasad, T. G. and Udayakumar, M., 2003, Breeding strategies to exploit water use efficiency for crop improvement. *J. Plant Biol.*, **30** (2) : 253 - 268.

Taylor, S. H., Franks, P. J., Hulme, S. P., Spriggs, E., Christin, P. A., Edwards, E. J., Woodward, F. I. and Osborne, C. P., 2012, Photosynthetic pathway and ecological adaptation explain stomatal trait diversity amongst grasses. *New Phytol.*, **193** (2) : 387 - 396.

Vijayaraghavareddy, P., Vemanna, R. S., Yin, X., Struik, P. C., Makarla, U. and Sreeman, S., 2020b, Acquired traits contribute more to drought tolerance in wheat than in rice. *Plant Phenomics*, pp. : 2020.

Vijayaraghavareddy, P., Xinyou, Y. I. N., Struik, P. C., Makarla, U. and Sreeman, S., 2020a, Responses of lowland, upland and aerobic rice genotypes to water limitation during different phases. *Rice Sci.*, **27** (4) : 345 - 354.

Zeiger, E., Farquhar, G. D. and Cowan, I. R., 1987, Stomatal function. *Stanford University Press*, Stanford : pp. : 115.

Zhang, Y. and Zhang, N., 2018, Imaging technologies for plant high-throughput phenotyping : A review. *Front. Agric. Sci. Eng.*, **5** (4) : 406 - 419.

Mysore J. Agric. Sci., 57 (1) : 43-51 (2023)

Effect of Beneficial Micro-organisms on Yield of Quinoa (*Chenopodium quinoa* Wild) Based on Relationship among Nutrients Observed in Semi-arid Alfisols

B. Ameer Pasha[1], N. Lohith Kumar[2], R. M. Salmankhan[3] and L. Krishna Naik[4]
[1,2&4]Department of Agricultural Microbiology; [3]Department of Agronomy, College of Agriculture,
UAS, GKVK, Bengaluru - 560 065
e-Mail : ameerpasha0034@gmail.com

Authors Contribution

B. Ameer Pasha : Conceptualization and investigation;
N. Lohith Kumar : Data analysis ;
R. M. Salmankhan : Experiment design ;
L. Krishna Naik : Supervision and evaluation

Corresponding Author :
B. Ameer Pasha
Department of Agricultural Microbiology,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : September 2022
Accepted : March 2023

Abstract

An assessment was made to identify a superior combination of microbial inoculants for attaining maximum quinoa yield based on the relationships among soil nutrients with different beneficial micro-flora and yield under semi-arid alfisols under green house conditions. Five microbial cultures *viz*., *Azotobacter chroococcum*, *Bacillus megaterium, Fraturia aurantia, Pseudomonas fluorescens* and *Glomus fasciculatum* were tested in the study. Pure cultures of selected isolates were sub-cultured on specific medium and maintained in slants for further studies. Seventeen treatments were tested for identifying a superior treatment for attaining maximum soil nutrients, apart from the beneficial microflora and quinoa yield. The Analysis of Variance indicated that the treatments differed significantly in influencing the different parameters and quinoa yield. Based on Duncan's Multiple Range Test, T_{17} inoculated with *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens* was superior for attaining significantly higher soil N and P nutrients, seed calcium, magnesium and zinc, free living N fixers and phosphorus solubilizing bacteria, while T_{16} was superior for attaining significantly higher soil K, nutrients and potassium solubilizing bacteria. However, T_{15} was superior for chlamydospore count per 50 g of soil.

Keywords : Beneficial micro-organisms, Quinoa, Nutrient obserption

Among different crops, Quinoa (*Chenopodium quinoa* Wild) commonly known as golden grain, is one of the main food crops of the Andean mountains of Latin America. The crop species has been safe guarded for thousands of years by the inhabitants of Andean region and many countries have recently discovered this crop. The species is characterized by an outstanding protein quality, apart from a high content of most of the vitamins and minerals. The Food and Agricultural Organization (FAO) has considered quinoa as one of the crops that is destined to offer food security in the 21stcentury. An increased consumption of quinoa in the western world and also Asia would improve the markets in all countries which have a traditional production of quinoa. There is a necessity of about 300-1000 mm of rainfall during growing season and no rain is required during the seed maturity and harvesting stages. The quinoa crop would grow efficiently in a sandy, well drained soil with low nutrient content, moderate salinity with soil pH value of about 6.0-8.5. The seed bed should be well prepared and also properly drained in order to avoid water logging condition. The crop would respond to fertilizer Nitrogen and requires NPK @ 120:50:50 kg/ha.

As per FAO, the quinoa grain would provide all amino acids that are essential to the human life in optimum quantities and could be comparable with milk. The protein content of quinoa would range from 7.47-22.08 per cent with high concentration of lysine, isoleucine, methionine, histidine, cystine and glycine. The ash content of quinoa would be about 3.4 per cent and contains high amount of calcium, iron, zinc, copper and manganese. The oil content is about 1.8-9.5 per cent and is rich in essential fatty acids like linoleate and linolenate. Quinoa seed is rich in thiamine (0.4 mg), folic acid (78.1 mg), vitamin C (16.4 mg), riboflavin (0.39 mg) and carotene (0.39 mg) in 100 g seed. The calorific value is about 350 cal/100 g grain, which is more than that of other cereal and legume foods. Quinoa contains natural anti oxidants like α-tocopheral (5.3 mg), γ-tocopheral (2.6 mg) in 100 g seed and phytoestrogens which prevent chronic diseases like osteoporosis, breast cancer, heart diseases and other feminine problems caused by lack of oestrogen during menopause stage (Bhargava *et al*., 2006).

The importance of beneficial soil micro-organisms in increasing crop productivity has been well documented. The microbial inoculants includes both symbiotic and asymbiotic Nitrogen fixing bacteria, phosphate solubilizing or mobilizing microorganisms, organic matter degraders *etc*. Many researchers have worked on the fundamental as well as applied aspects of various microbial inoculants in various crops. Soil bio-amendments would provide a promising alternative to reduce the harmful effects of pesticides and chemical fertilizers (Bashan, 1998). The plant growth promotion by PGPB may be either through bio-fertilization, phytostimulation or bio-control of plant pathogens (Bashan and De Bashan, 2005). The ability of microorganisms to release various metabolites affecting the plant health and growth would be considered as one of the most prominent factors in the soil fertility (Ping and Boland, 2004). In addition to the above mentioned traits, PGPB must also be rhizosphere competent to flourish and survive in the soil following inoculation (Cattelan *et al.,* 1999). It would be essential to study the effectiveness of different beneficial microorganisms to maximize the plant growth responses. Based on their adaptability and efficiency, both *in-vitro* and *in-vivo* study, we could use these micro-organisms under real agricultural situations for efficient management of soil health in order to promote plant growth, apart from crop production.

Material and Methods

A research study was conducted at University of Agricultural Sciences (UAS), Bangalore to study the effect of beneficial microorganisms on the free living nitrogen fixers, phosphorus solubilizing bacteria, potassium solubilizing bacteria and Chlamydospore count per 50 g of soil and yield of quinoa under pot culture conditions. Free living nitrogen fixer, phosphate solubilizer and potassium solubilizer were collected, purified, mass multiplied, formulated and used in the study. The procedures and techniques adopted as well as material used in the study are described in the following sections.

Microbial Culture Collection and its Maintenance

Different microbial cultures used in our study are (i) *Azotobacter chroococcum* (ii) *Bacillus megaterium* (iii) *Frateuria aurantia* (iv) *Pseudomonas fluorescens* and (v) *Glomus fasciculatum.* These cultures were obtained from Biofertilizer lab, Department of Agricultural Microbiology, UAS, Bangalore. The 24-h old pure cultures of *Azotobacter chroococcum Bacillus megaterium, Pseudomonas fluorescens* and *Fraturia aurantia* were inoculated aseptically into flasks containing Waksmann No.77 broth, Sperber's broth, King's B broth and Aleksandrow broth medium respectively with the help of inoculation loop and were incubated at 30^{0}C for 3 days for growth. The pure cultures were maintained in the slants for future study (Sahu and Brahmaprakash, 2018).

Azotobacter chroococcum was grown on Waksman No.77 medium, while *Bacillus megaterium* was grown on Sperber's medium. Similarly, *Pseudomonas fluorescens* was grown on king's B medium, while *Frateuria aurantia* was grown on Aleksandrow Agar medium. Pure cultures of *Azotobacter chroococcum*, *Bacillus megaterium, Fraturia aurantia* and *Pseudomonas fluorescens* isolates were subcultured on the specific medium *viz*., Waksman No.77, Pikovskaya's agar medium, Aleksandrow Agar and king's B medium respectively and were maintained in the slants for future study (Gangaraddi and Brahmaprakash, 2018).

TABLE 1

Chemical properties of the soil

Chemical properties	Parameter value	Reference
Soil pH	6.6	pH meter (Piper, 1966)
Electrical conductivity (dS m^{-1})	0.24	Conductometry (Jackson, 1973)
Organic carbon (%)	0.56	Wet oxidation method (Piper, 1966)
Available nitrogen (kg ha^{-1})	342	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available phosphorus (kg ha^{-1})	38.21	Bray's method (Jackson, 1973)
Available potassium (kg ha^{-1})	234.5	Flame photometry method (Jackson, 1973)

Experimental Details

The experiment was conducted with the objective of studying the effect of selected microbial inoculants on the growth and yield of quinoa under greenhouse condition with 17 treatments and each with 3 replications. The soil was sieved with a 4 mm sieve and mixed thoroughly in order to get a homogenous mixture. The pots were filled with well homogenised pot mixture of the soil:sand: FYM in the ratio of 2:1:1 @ 10 kg/pot.

Soil Chemical Properties

The soil samples were analyzed for different parameters *viz*., soil reaction (pH), electrical conductivity (EC), organic carbon (OC), nitrogen (N), phosphorus (P) and potassium (K) by standard procedures as described in Table 1.

Estimation of soil available N was made by using alkaline potassium permanganate method (Subbaiah and Asija, 1956). The soil of 0.5 g was treated with an excess of alkaline 0.32 per cent potassium permanganate (alkaline with 25 % NaOH solution). The liberated ammonia was trapped in the boric acid and was determined by the titration against the standard 1N H_2SO_4. The available N (kg/ha) was computed using the titer value. The available phosphorous in soil (kg/ha) was measured by using Brays-1 reagent. The extracted P was measured by the ascorbic acid method. The intensity of blue colour was measured by using the Spectrophotometer at 660 nm as described by Jackson (1973). The soil K was extracted from air-dried soil samples by shaking with 0.5M ammonium acetate solution for 30 minutes. This was found to effectively displace the potentially available K ions. The K content of the filtered extract was determined by using the flame Photometer (Jackson, 1973).

Treatment Details

Seventeen treatments were considered by including a control (uninoculated) treatment. The treatments were : (i) T_1: Control (only RDF); (ii) T_2: *Azotobacter chroococcum*; (iii) T_3: *Bacillus megaterium*; (iv) T_4: *Glomus fasciculatum*; (v) T_5: *Frateuria aurantia*; (vi) T_6: *Pseudomonas fluorescens*; (vii) T_7: *Azotobacter chroococcum + Bacillus megaterium;* (viii) T_8: *Azotobacter chroococcum + Glomus fasciculatum*; (ix) T_9: *Azotobacter chroococcum + Frateuria aurantia;* (x) T_{10}: *Azotobacter chroococcum + Pseudomonas fluorescens*; (xi) T_{11}: *Bacillus megaterium + Glomus fasciculatum*; (xii) T_{12}: *Bacillus megaterium + Frateuria aurantia*; (xiii) T_{13}: *Bacillus megaterium + Pseudomonas fluorescens*; (xiv) T_{14}: *Glomus fasciculatum + Pseudomonas fluores cens*; (xv) T_{15}: *Glomus fasciculatum + Frateuria aurantia*; (xvi) T_{16}: *Frateuria aurantia + Pseudo monas fluorescens* and (xvii) T_{17}: *Azotobacter chroococcum + Bacillus megaterium + Pseudomonas fluorescens*.

Treatment Imposition / Inoculation

The microbial inoculants of *A. chroococcum*, *B. megaterium, F. aurantia and P. fluorescens* cultures were separately mixed with carrier (talc) and kept for a week for stabilization at room temperature. About 10 g of each carrier based inoculants was applied in each pot just before sowing. Before sowing of quinoa crop, the seed germination (%) test was conducted in laboratory condition by paper towel method. About 90 per cent germination was observed for the given seeds. The different parameters assessed in this study.

Statistical Analysis

Statistical analysis of data was carried out based on Analysis of Variance using WASP 2.0 (Web Agri Stat Package) software (www.icargoa.res.in/wasp/index.php). Based on Duncan's Multiple Range Test (DMRT), the treatments were compared and tested for significant differences. The treatments were ranked for different parameters and superior treatments were identified based on the rank sums. Estimates of correlation between different parameters were derived and tested to assess the importance of different parameters for explaining the variability in data.

Results and Discussion

Effect of Microbial Inoculants on Post-Harvest Soil Nutrients

Based on Analysis of Variance, the treatments were significantly different in influencing the post-harvest soil N, P and K nutrients at $p < 0.05$ level of significance. The soil N ranged from 315.4 - 367.1 kg/ha with mean of 333.7 kg/ha (CV of 4.2%), while the soil P ranged from 30.4 - 48.2 kg/ha with mean of 39.1 kg/ha (CV of 14.9%). The soil K ranged from 146.5-215.4 kg/ha with mean of 168.1 kg/ha (CV of 13.6%).

Significantly higher soil nitrogen of 367.1 kg/ha and soil P of 48.2 kg/ha were attained by T_{17} of *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens*, while lowest soil N of 315.4 kg/ha and soil P of 30.4 kg/ha were attained by T_1. However, significantly higher soil K of 215.4 kg/ha was attained by T_{16} of *Frateuria aurantia* + *Pseudomonas fluorescens*, while lowest soil K of 146.5 kg/ha was attained by T_1. Based on DMRT criteria, T_{17} was superior compared to all other treatments for attaining significantly higher post-harvest soil N and P, while T_{16} was superior for post-harvest soil K (Table 2).

The increase (%) in soil N of a treatment over control ranged from 0.3-14.1 per cent with mean of 5.7 per cent (CV of 65.2%), while the increase in soil P of a treatment over control ranged from 3.3-36.9 per cent with mean of 21.9 per cent (CV of 51.3%). Similarly, the increase in soil K of a treatment over control ranged from 0-32.0 per cent with mean of 12.2 per cent (CV of 90.2%) (Table 2). Highest soil N and P were attained by the triple inoculant receiving treatment. This was due to the microbial inoculants that favour N fixation capacity by *Azotobacter chroococcum* and also PGPR activity. Chandra *et al.*, (2010) reported about an increased dry matter production by application of microbial inoculants, which in turn significantly enhanced the nutrition with respect to N and P supply to the crop, apart from maintaining significantly higher soil N and P under all inoculated treatments. In a study by Bhattacharya (2001), the author has observed about significant response to application of biofertilizers for different crops in agriculture. Das *et al.,* (2007) observed significant effect of microbial inoculants when they applied in *Stevia rebaudiana Bert* commonly grown under the sub-tropics in India.

Effect of Microbial Inoculants on the Beneficial Microflora in Quinoa

Based on Analysis of Variance, the treatments were significantly different in influencing the beneficial microflora (No × $CFUg^{-1}$ of soil) at $p < 0.05$ level of significance. The Free living N fixers (10^3) ranged from 44.60 - 46.28 mg/100 g with mean of 45.15 mg/100 g (CV of 1.0%), while the phosphorus solubilizing bacteria (PSB) ranged from 19.31-37.21 with mean of 20.74 (CV of 16.1%). The potassium solubilizing bacteria (KSB) ranged from 14.12-31.61 with mean of 20.74 (CV of 32.0%), while the chlamydospore count per 50 g of soil ranged from 21.2-58.2 with mean of 34.6 (CV of 28.4%). Significantly higher free living N fixers of 48.31 and PSB of 37.21 were attained by T_{17} of *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens*, while significantly higher KSB of 31.61 was attained by T_{16} of *Frateuria aurantia* + *Pseudomonas fluore scens* and significantly higher chlamydospore of 28.2 was attained by T_{15} of *Glomus fasciculatum* +

TABLE 2

Effect of different treatments on post-harvest soil N, P and K nutrients and their increase over control in quinoa

Treatments	NPK content of soil (Kg/ha)			Increase (%) over control		
	N	P	K	N	P	K
T_1 = Control (only RDF)	315.40^{j}	30.41^{m}	146.46^{j}			
T_2 = *Azotobacter chroococcum* (Ac)	340.40^{b}	39.33^{g}	160.40^{ef}	7.3	22.7	8.7
T_3 = *Bacillus megaterium* (Bm)	332.60^{def}	45.33^{c}	184.32^{d}	5.2	32.9	20.5
T_4 = *Glomus fasciculatum* (Gm)	316.33^{j}	31.55^{l}	146.46^{j}	0.3	3.6	0.0
T_5 = *Frateuria aurantia* (Fa)	325.40^{ghi}	42.45^{f}	159.24^{f}	3.1	28.4	8.0
T_6 = *Pseudomonas fluorescens* (Pf)	334.40^{cde}	44.33^{d}	190.15^{c}	5.7	31.4	23.0
T_7 = *Azotobacter chroococcum* + *Bacillus megaterium*	341.60^{b}	32.08^{l}	147.60^{ij}	7.7	5.2	0.7
T_8 = *Azotobacter chroococcum* + *Glomus fasciculatum*	333.60^{cde}	43.35^{e}	162.22^{e}	5.5	29.9	9.7
T_9 = *Azotobacter chroococcum* + *Frateuria aurantia*	338.24^{bc}	37.26^{i}	184.32^{d}	6.8	18.4	20.5
T_{10} = *Azotobacter chroococcum* + *Pseudomonas fluorescens*	362.33^{a}	31.45^{l}	146.60^{j}	13.0	3.3	0.1
T_{11} = *Bacillus megaterium* + *Glomus fasciculatum*	327.20^{fgh}	46.33^{b}	162.53^{e}	3.6	34.4	9.9
T_{12} = *Bacillus megaterium* + *Frateuria aurantia*	326.26^{gh}	45.60^{c}	189.60^{c}	3.3	33.3	22.7
T_{13} = *Bacillus megaterium* + *Pseudomonas fluorescens*	330.33^{efg}	36.53^{j}	150.60^{gh}	4.5	16.8	2.7
T_{14} = *Glomus fasciculatum* + *Pseudomonas fluorescens*	337.33^{bcd}	35.33^{k}	150.06^{ghi}	6.5	14.0	2.4
T_{15} = *Glomus fasciculatum* + *Frateuria aurantia*	320.40^{ij}	37.33^{i}	210.20^{b}	1.6	18.6	30.3
T_{16} = *Frateuria aurantia* + *Pseudomonas fluorescens*	324.24^{hi}	38.56^{h}	215.40^{a}	2.7	21.2	32.0
T_{17} = *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens*	367.13^{a}	48.20^{a}	152.22^{g}	14.1	36.9	3.8
Minimum	315.4	30.4	146.5	0.3	3.3	0.0
Maximum	367.1	48.2	215.4	14.1	36.9	32.0
Mean	333.7	39.1	168.1	5.7	21.9	12.2
SD 14.1	5.8	22.9	3.7	11.3	11.0	
CV (%)	4.2	14.9	13.6	65.2	51.3	90.2

Frateuria aurantia. The lowest free living N fixers of 16.67, PSB of 19.31 and chlamydospore count per 50g of soil of 21.2 were attained by T_1, while lowest KSB of 14.12 was attained by T_3 of *Bacillus megaterium* (Bm) treatment. Based on DMRT criteria, T_{17} was superior for attaining significantly higher free living N fixers and PSB, while T_{16} was superior for KSB and T_{15} was superior for chlamydospore count per 50 g of soil and compared to all other treatments based on the study (Table 3).

TABLE 3

Beneficial microflora influenced by different treatments and their increase over control in quinoa

Treatments	Beneficial microflora (No × CFUg^{-1} of soil)				Increase (%) over control			
	Free living N fixers (10^3)	PSB (10^2)	KSB (-10^2)	Chlamydospore count per 50g of soil	Free living N fixers (10^3)	PSB (10^2)	KSB (-10^2)	Chlamydospore count per 50g of soil
T_1 =Control (only RDF)	16.67 ^{op}	19.31 ^{l}	15.10 ^{j}	21.20 ^{m}				
T_2	35.10 ^{j}	24.01 ^{k}	16.10 ^{i}	31.08 ^{i}	52.5	19.6	6.2	31.8
T_3	22.05 ^{l}	37.10 ^{a}	14.12 ^{j}	29.11 ^{j}	24.4	48.0	-6.9	27.2
T_4	18.21 ^{n}	36.31 ^{b}	29.81 ^{c}	53.21 ^{b}	8.5	46.8	49.3	60.2
T_5	23.61 ^{k}	35.32 ^{c}	30.81 ^{b}	37.30 ^{f}	29.4	45.3	51.0	43.2
T_6	20.11 ^{m}	27.00 ^{i}	19.20 ^{f}	31.03 ^{i}	17.1	28.5	21.4	31.7
T_7	46.01 ^{c}	37.10 ^{a}	17.30 ^{g}	32.10 ^{h}	63.8	48.0	12.7	34.0
T_8	43.21 ^{d}	30.80 ^{fg}	14.21 ^{j}	35.00 ^{g}	61.4	37.3	-6.3	39.4
T_9	38.33 ^{g}	33.10 ^{d}	16.10 ^{i}	38.30 ^{e}	56.5	41.7	6.2	44.6
T_{10}	47.61 ^{b}	29.21 ^{h}	17.20 ^{g}	29.787 ^{j}	65.0	33.9	12.2	28.8
T_{11}	39.33 ^{f}	30.61 ^{g}	17.31 ^{g}	42.10 ^{c}	57.6	36.9	12.8	49.6
T_{12}	38.32 ^{g}	31.20 ^{ef}	17.41 ^{g}	31.33 ^{hi}	56.5	38.1	13.3	32.3
T_{13}	36.21 ^{i}	31.60 ^{e}	16.61 ^{h}	25.10 ^{k}	54.0	38.9	9.1	15.5
T_{14}	41.21 ^{e}	31.20 ^{h}	19.76 ^{e}	41.07 ^{d}	59.5	38.1	23.6	48.4
T_{15}	37.21 ^{h}	26.31 ^{j}	30.71 ^{b}	58.20 ^{a}	55.2	26.6	50.8	63.6
T_{16}	38.21 ^{g}	35.41 ^{c}	31.61 ^{a}	29.23 ^{j}	56.4	45.5	52.2	27.5
T_{17}	48.31 ^{a}	37.21 ^{a}	29.26 ^{d}	23.07 ^{l}	65.5	48.1	48.4	8.1
Minimum	16.67	19.31	14.12	21.20	8.5	19.6	-6.9	8.1
Maximum	48.31	37.21	31.61	58.20	65.5	48.1	52.2	63.6
Mean	34.69	31.34	20.74	34.60	49.0	38.8	22.2	36.6
SD	10.48	5.06	6.63	9.84	18.2	8.4	21.1	14.8
CV (%)	30.2	16.1	32.0	28.4	37.2	21.7	94.8	40.3

The increase (%) in free living N fixers attained by a treatment over control ranged from 8.5-65.5 per cent with mean of 49.0 per cent (CV of 37.2%), while the increase in PSB of a treatment over control ranged from 19.6-48.1 per cent with mean of 38.8 per cent (CV of 21.7 %). Similarly, the increase in KSB of a treatment over control ranged from -6.9-52.2 per cent with mean of 22.2 per cent (CV of 94.8%), while the increase of chlamydospore count per 50 g of soil of a treatment over control ranged from 8.1-63.6 per cent with mean of 36.6 per cent (CV of 40.3%) (Table 3). Based on the analysis, the treatment T_{17} gave highest increase of free living N fixers and PSB, while T_{16} gave highest increase of KSB and T_{15} gave highest increase of chlamydospore count per 50 g of soil compared to all other treatments. T_4 gave lowest increase of 8.5 per cent of free living N fixers, while T_2 gave lowest increase of 19.6 per cent of PSB. Similarly, T_3 gave lowest increase of -6.9 per cent of KSB, while T_{17} gave lowest increase of 8.1 per cent of chlamydospore count per 50 g of soil compared to all other treatments. In a study by Gu *et al*. (2009), the authors observed similar results on the effects of different amendments on the beneficial urease, invertase, dehydrogenase and polyphenoloxidase activities in a paddy soil.

Effect of Microbial Inoculants on the Yield of Quinoa

Based on Analysis of Variance, the treatments were significantly different in influencing the quinoa grain yield (kg/ha) at $p < 0.05$ level of significance. The grain yield ranged from 1683-2350 kg/ha with mean of 1943 kg/ha (CV of 9.4%). Significantly higher grain yield of 2350 kg/ha was attained by T_{17} involving *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens*, while lowest grain yield of 1683 kg/ha was attained by T_1. The increase (%) of a treatment over control ranged from 2.0-28.4 per cent for grain yield with mean of 13.5 per cent and CV of 55.5 % (Table 4). Thus, significantly higher grain yield (kg/ha) was attained by T_{17} involving *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens* compared to other treatments. Based on DMRT criteria, T_{17} was superior compared to all other treatments for attaining significantly higher quinoa grain yield (kg/ha) (Table 4). Our results are in agreement with the results reported by Shehata *et al*., (2010) on the celeriac plant and also with the results of Erdal Elkoca *et al.,* (2008) in a study on chickpea.

Relationship Between Beneficial Microflora of Free N Fixers, PSB and KSB and Chlamydos Pore count in Quinoa

The relationships between beneficial microflora (No x CFU/g soil) *viz.,* free living N fixers, phosphorus solubilizing bacteria (PSB) and potassium solubilizing

TABLE 4

Effect of beneficial microorganisms on yield and yield increase (%) over control in quinoa

Treatments	Grain yield (kg/ha)	Increase (%) over control
T_1 = Control (only RDF)	1683 ^{q}	
T_2 = Azotobacterchroococcum	2117 ^{c}	20.5
T_3 = Bacillus megaterium	1842 ^{j}	8.6
T_4 = Glomus fasciculatum	1717 ^{op}	2.0
T_5 = Frateuriaaurantia	1883 ^{i}	10.6
T_6 = Pseudomonas fluorescens	1783 ^{m}	5.6
T_7 = Azotobacterchroococcum+Bacillusmegaterium	2050 ^{e}	17.9
T_8 = Azotobacterchroococcum+Glomusfasciculatum	2083 ^{d}	19.2
T_9 = Azotobacterchroococcum + Frateuriaaurantia	2117 ^{c}	20.5
T_{10} = Azotobacterchroococcum + Pseudomonas fluorescens	2183 ^{b}	22.9
T_{11} = Bacillus megaterium + Glomus fasciculatum	1767 ^{n}	4.7
T_{12} = Bacillus megaterium + Frateuriaaurantia	1833 ^{k}	8.2
T_{13} = Bacillus megaterium+Pseudomonas fluorescens	1933 ^{g}	12.9
T_{14} = Glomus fasciculatum+Pseudomonas fluorescens	1967 ^{f}	14.4
T_{15} = Glomus fasciculatum + Frateuriaaurantia	1817 ^{l}	7.4
T_{16} = Frateuriaaurantia + Pseudomonas fluorescens	1900 ^{h}	11.4
T_{17} = Azotobacterchroococcum + Bacillus megaterium + Pseudomonas fluorescens	2350 ^{a}	28.4
Minimum	1683	2.0
Maximum	2350	28.4
Mean	1943	13.5
SD	183	7.5
CV (%)	9.4	55.5

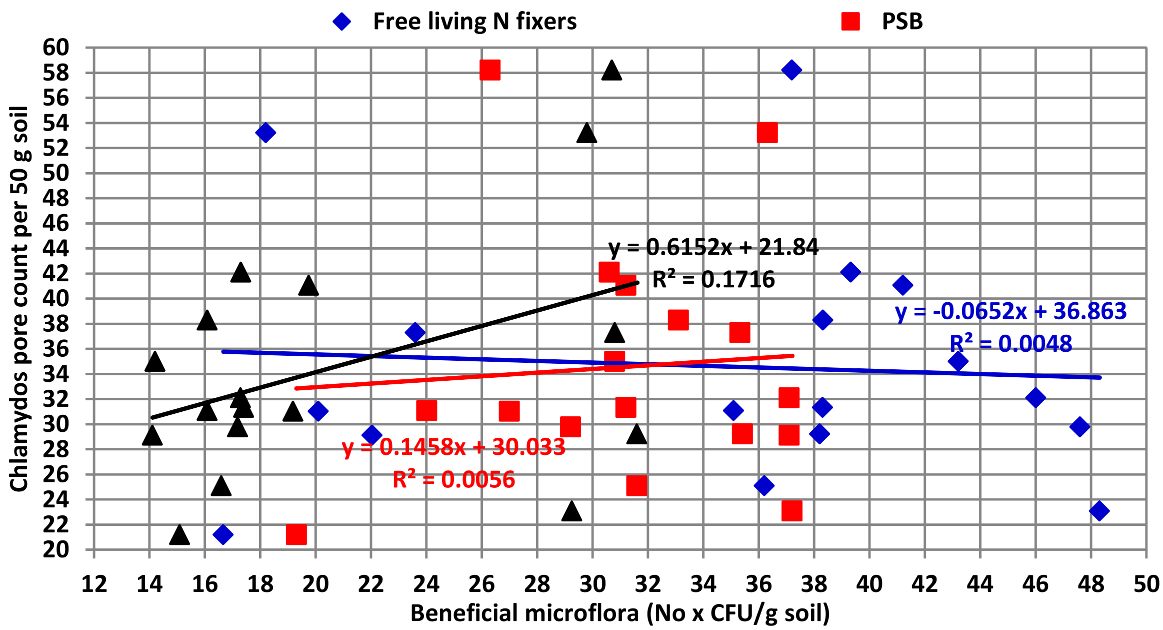


Fig. 1 : Relationship between beneficial microflora and chlamydos pore count of soil in quinoa

bacteria (KSB) with Chlamydos pore count per 50 g of soil are depicted in Fig. 1. The Chlamydos pore count per 50 g of soil was found to decrease with a rate of change of -0.065 for an unit change in free living N fixers, while it increased with a rate of change of 0.145 for an unit change in PSB and 0.615 for an unit change in KSB based on the study. The changes in chlamydos pore count per 50 g of soil occurred with a coefficient of determination values of 0.004, 0.005 and 0.171 for predicting through free living N fixers, PSB and KSB respectively. When VAM fungus was inoculated in cowpea, Thiagarajan and Ahmad (1994) have observed significant relationship between phosphatase activity and cytokinin content in cowpea. In a similar study by Nannipieri *et al.,* (2003), the authors have observed significant relationships based on the different microbial activities on the soil chemical and biological parameters.

An assessment has been made in this paper to identify a superior combination of microbial inoculants based on the soil nutrients with different beneficial micro-flora under semi-arid Alfisols. The study was conducted under glass house conditions in the University of Agricultural Sciences, Bangalore. Five microbial cultures *Viz., Azotobacter chroococcum*, *Bacillus megaterium, Fraturia aurantia, Pseudomonas fluorescens* and *Glomus fasciculatum* were tested in the study. Pure cultures of selected *Azotobacter chroococcum*, *Bacillus megaterium, Fraturia aurantia* and *Pseudomonas fluorescens* isolates were sub-cultured on specific medium and maintained in slants for further studies. Seventeen treatments were tested for identifying a superior treatment for attaining maximum soil, plant and seed nutrients, apart from the beneficial microflora and quinoa yield. The Analysis of Variance indicated that the treatments differed significantly in influencing the different parameters and quinoa yield. Based on Duncan's Multiple Range Test, T_{17} inoculated with *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens* was superior for attaining significantly higher soil N and P nutrients, free living N fixers and phosphorus solubilizing bacteria, while T_{16} was superior for attaining significantly higher soil K nutrients and potassium solubilizing bacteria. However, T_{15} was superior for chlamydospore count per 50 g of soil.

References

Bashan, Y., 1998, Inoculants of plant growth-promoting bacteria for use in agriculture. *Biotechnol. Adv.*, **16** : 729 - 770.

BASHAN, Y. AND DE-BASHAN, L. E., 2005, Bacteria plant growth-promotion. In : *Encyclopedia of Soils in the Environment,* Hillel, D. Oxford, UK, **1** : 103 - 115.

BHARGAVA, A., SUDHIR, S. AND DEEPAK OHRI., 2006, Quinoa (*Chenopodium quinoa* wild.): An Indian perspective, *Ind. Crops. Prod.,* **23** : 73 - 87.

BHATTACHARYYA, P. K., 2011, Use of biofertilizers in agriculture. *J. Mycopathol. Res.,* **49** (2) : 223 - 229.

CATTELAN, A. J., HARTEL, P. G. AND FUHRMANN, J. J., 1999, Screening for plant growth promoting rhizobacteria to promote early soybean growth. *Soil. Sci., Soc. Am. J.,* **63** : 1670 - 1680.

CHANDRA, K. K., KUMAR, N. AND CHAND, G., 2010, Studies on mycorrhizal inoculation on dry matter yield and root colonization of some medicinal plants grown in stress and forest soils. *J. Environ. Biol.,* **31** : 975 - 979.

DAS, K., DANG, R., SHIVANANDA, T. N. AND NAZIM, S., 2007, Influence of bio-fertilizers on the biomass yield and nutrient content in *Stevia rebaudiana Bert*. grown in Indian subtropics. *J. Med. Plant Res.,* **1** (1) : 5 - 8.

ERDAL ELKOCA, FAIK KANTAR AND FIKRETTIN SAHIN, 2008, Influence of nitrogen fixing and phosphorus solubilizing bacteria on the nodulation, Plant growth and yield of chickpea. *J. Plant Nutr.,* **31** (1) : 157 - 171.

GANGARADDI, V. AND BRAHMAPRAKASH, G. P., 2018, Comparative evaluation of selected formulations of a microbial consortium. *Mysore J. Agric. Sci.,* **52** (2) : 255 - 262.

GOMEZ, K. A. AND GOMEZ, A. A., 1984, Statistical procedures for Agricultural Research. John Wiley and Sons, New York.

GU, Y., WONG, P. AND KONG, C. H., 2009, Urease, invertase, dehydrogenase and polyphenol oxidase activities in paddy soil influenced by allelopathic rice variety. *Eur. J. Soil Biol,* **45** : 436 - 441.

JACKSON, M. L., 1973, Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi, pp. : 498.

NANNIPIERI, P., ASCHER, J., CECCHERINI, M. T., LANDI, L. AND RNELLA, G., 2003, Microbial diversity and soil functions. *Eur. J. Soil Sci,,* **54** : 655 - 670.

PING, L. AND BOLAND, W., 2004, Signals from under ground : Bacterial volatiles promote solubilizing ability. *Appl. Soil Ecol.,* **34** : 33 - 41.

PIPER, C. S., 1966, Soil and plant analysis (Hans Publishers: Bombay, India).

SAHU, P. K. AND BRAHMAPRAKASH, G. P., 2018, Modified liquid dual culture methodology for screening bacterial endophytes against fungal pathogens. *Mysore J Agric. Sci.,* **52** (2) : 234 - 240.

SHEHATA, S. M., ABDEL-AZEM, H. S. AND EL-YAZIED, A. A., 2010, Interactive effect of mineral nitrogen and bio fertilization on the growth, chemical composition and yield of celeriac plant. *Eur. J. Sci. Res.*, **47** : 248 - 255.

SUBBAIAH, B. Y. AND ASIJA, G. L., 1956, A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci,* **270** : 223 - 232.

THIGARAJAN, T. R. AND AHMAD, M. H., 1994, Phoshatase activity and cytokinin content in cowpeas (*Vigna unguiculata*) inoculated with a vesicular-arbuscular mycorrhizal fungus. *Biol. Fertil. Soils,* **17** : 51 - 56.

Mysore J. Agric. Sci., 57 (1) : 52-58 (2023)

Antagonistic Effect of Bacterial Endophytes Isolated from Landraces of Finger Millet Against Blast Disease

K. B. Bhagyashree[1], N. Umashankar[2], N. Earanna[3], L. Krishna Naik[4], H. R. Raveendra[5] and P. S. Benherlal[6]

[1,2,3&4]Department of Agril.Microbiology; [6]Plant Biotechnology, College of Agriculture, UAS, GKVK, Bengaluru-560 065

[5]All India Coordinated Research Programme (AICRP) on Small Millets, College of Agriculture, V. C. Farm, Mandya

e-Mail : bhagyakb03@gmail.com

Authors Contribution

K. B. Bhagyashree : Drafting the article, data collection, data analysis & interpretatioin;

N. Umashankar : Conception of the work, critical revision of the article and final approval;

N. Earanna, L. Krishna Naik, H. R. Raveendra & P. S. Benherlal : Design of the work and critical revision of the article

Corresponding Author :

K. B. Bhagyashree
Dept.of Agril. Microbiology, College of Agriculture, UAS, GKVK, Bengaluru

Received : August 2022

Accepted : September 2022

Abstract

Finger millet is an important food crop that is grown in arid and semi-arid parts of Africa and Asia and it serves as a staple food source for millions of people. Blast is the most devastating disease affecting it at every stage of growth and development. In recent years, endophytes received attention because of their potential to increase crop yield without massive application of synthetic chemicals. Landraces are traditional, regional ecotypes that have adapted to their natural environment, some possess resistance to the blast disease. In this study, 42 bacterial endophytes were isolated from fifteen landraces and were screened for their antagonistic activity against *Pyricularia grisea*, causal agent of finger millet blast. Seed constitutes high number of bacterial colonies with the landrace, thenemundaga ragi. The isolates HMS-1 (91.04%), GPRS-1 (92.54%) and GPRR (92.54%) were efficient in inhibiting the pathogen growth in both dual culture plate and biomass assay by means of antibiosis and hyper parasitism. Hence, one can explore the microflora of these landraces and can utilize them as best microbial inoculants for management of blast disease, to improve plant growth and crop yield.

Keywords : Antagonistic activity, Endophytes, Landraces, *Pyricularia grisea*

Finger millet [*Elusine coracana* (L.)] is grown widely in different agroecosystems and is an important crop for its diverse nutritional value and well suited to adverse growing conditions. It is cultivated in more than 25 countries of Africa and Asia, occupies about 12 per cent of the total global millet area (Vetriventhan *et al*., 2015). It can withstand biotic and abiotic stresses, therefore it is considered as one of the important cereal crops grown under rainfed conditions (Chandra *et al.,* 2016).

Biotic constrains affecting the crop are mainly diseases such as blast, foot rot, smut, leaf blight *etc.* Among them blast is one of the predominant disease, caused by *Magnaporthe grisea* (anamorph: *Pyricularia grisea*), the fungus infects all stages of plant growth, attacking different plant parts like stem, leaf, neck and fingers, causing yield loss of about 28-36 per cent (Nagaraja *et al*., 2010).

There are many strategies to manage the blast disease, like use of resistant cultivars, fungicide application, optimum fertilizer application and appropriate planting dates (Bonman, 1992). Fungicides like carbendazim, mancozeb and tricyclazole are effective in controlling blast disease (Netam *et al*., 2014), but these synthetic fungicides are hazardous to human health, leaves a negative impact on the environment (Budnik and Baur, 2009) and also repeated application of chemicals may induce resistance in the pathogen. In this perspective, it is desirable to identify eco-friendly, economical and farmer-friendly approaches to control the blast, one of the methods can be use of microbial agents.

In recent decades, the novel research on biological control of plant diseases demonstrated the role of a particular class of microbes that colonize the internal tissues of the host plant, referred to as endophytes, and hypothesized that they confer host plant resistance against fungal pathogens (Mousa and Raizada, 2013). Endophytes are living entities which may be either fungi or bacteria living within the plant tissues for at least a part of their life cycle without causing any apparent symptoms with more beneficial effect on their host plants (Pablo *et al.,* 2015).

Wild plants grow and resist pathogens without the use of fungicides, a landrace is a dynamic population or populations of a cultivated plant that has historical origin, distinct identity and lacks formal crop improvement, as well as often being genetically diverse, locally adapted and associated with traditional farming systems. Plant defences are stronger in landraces in modern varieties (Davila-Flores *et al*., 2013 and Camacho Villa *et al*., 2005). Plant growth promoting bacteria (PGPB) elicit induced systemic resistance (ISR) to secure plants against aerial pathogens, where chances of direct contact between the pathogen and biocontrol agent are very rare (Afroz *et al*., 2017). Thus in the present study we hypothesized that cross inoculation of endophytes from landraces to susceptible variety will impart resistance to the pathogen, in turn results in higher yield in an eco-friendly manner. Hence, study was taken up to isolate bacterial endophytes from landraces of finger millet and screen against blast disease caused by *Pyricularia grisea*.

TABLE 1

Landraces used for endophytes isolation

Sample	Abbreviation
Guppe Ragi Seeds	GPRS
Haaluguli Ragi Seeds	HGRS
Guppe Ragi Root	GPRR
Thenemundaga Ragi Seeds	TMRS
Hasirumundaga Ragi Seeds	HMS
Dodda Ragi Shoot	DRP
Hasirumundaga Ragi	HMS
Haaluragi Root	HRR
Biliragi Shoot	BRP
Keenya Ragi Root	KRR
Thenemundaga Ragi Seeds	TMRS
Hasirumundaga Ragi	HMS
Hasirumundaga Ragi	HMS
Keenya Ragi Seeds	KRS
Dodda Ragi Seeds	DRS

MATERIAL AND METHODS

Isolation of Endophytes from Landraces of Finger Millet

Isolation was carried from different parts of plant like root, shoot, leaf and seeds. Landraces seeds were collected from All India Coordinated Research Programme on Millets (AICRP), Zonal Agricultural Research Station (ZARS), V. C. Farm, Mandya, Karnataka, as listed in Table 1 and Plate 1. The plant

Plate 1 : Finger millet landraces

samples were washed and cut into 2-3 cm and the pieces were surface-sterilized by immersing in 70 per cent ethanol for 1 minute, followed by dipping plant samples in 1.5 per cent sodium hypochlorite. The plant samples were washed with distilled water to remove traces of sodium hypochlorite. Washing was repeated with sterile distilled water 5-6 times. The surface sterilized samples were blot-dried using sterile filter paper and were cut into 2 halves and each half was impregnated on nutrient agar plates in triplicate and plating was done from the final wash, which serves as the control. The plates were incubated at room temperature for 24 - 48 hours (Bacon *et al.,* 2002).

Isolation of Pathogen

Diseased plant samples were collected from finger millet fields located in ZARS, UAS, GKVK, Bangalore. Samples were thoroughly washed and infected specimen was cut into small pieces measuring 2-3 cm in size with sterile blade. These bits were surface sterilized by dipping them in 2 *per cent* sodium hypochlorite solution (Riker and Riker, 1936) for 30 seconds and then washed thrice in sterilized distilled water for 45 seconds each to remove the traces of sodium hypochlorite. These bits were incubated in a humid chamber at 28 ºC for 24 h to induce sporulation. The spore mass from individual lesion was streaked on 4 per cent water agar and then transferred to ragi yeast lactose agar (RYLA) medium under aseptic conditions and incubated at 25±2 ºC (Jabbar and Nagaraja, 2018).

Pathogenicity Test

Pathogenicity test was performed on finger millet plants (Variety - udurumallige), by using modified procedure described by Jia *et al.* (2003). Plants were grown in controlled conditions at 24-30 ºC with sufficient day light and high humidity. Plants were inoculated with 2 ml of spore suspension with sufficient spore density by piercing slightly with sterile needle and were sealed with plastic bag as high humidity was required for fungal penetration in to host plant. Disease symptoms were monitored daily and plants were maintained till symptoms were noticed (Laxman, 2017).

Pure axenic form of fungus was obtained and morphological characteristics of blast fungus showed greyish colony with circular smooth margin and concentric ring pattern on RYLA (Plate 2). Isolated culture could infect the same variety of finger millet from where organism was isolated. Hence, the Koch's postulates were proved. The characteristic feature of pyriform shaped conidial pattern confirms the pathogen as *Pyricularia grisea* (Kulkarni and Peshwe, 2019).

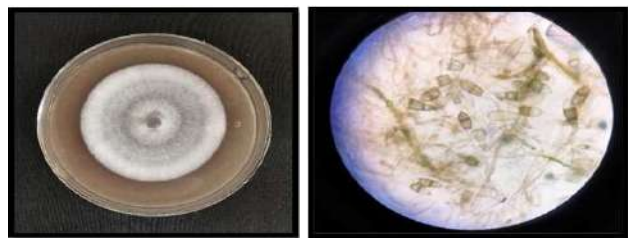


Plate 2 : a) Culture of *Pyricularia grisea,* b) Microscopic view of *P. grisea* spores

Screening for Biocontrol Activity of Endophytic Bacteria Against Blast Pathogen

Dual culture plate assay : Endophytic isolates were screened for their antagonist activity against blast pathogen, *Pyricularia grisea*, according to dual culture plate assay (Dennis and Webster, 1971), in which both endophytic bacterial isolate and pathogen were inoculated on single potato dextrose agar (PDA) plate. The pathogen (5 mm diameter disc) was inoculated at the centre of PDA plate and 24-hour old culture of endophytic bacteria (10^8 cfu/ml) was streaked at corner of the plate and incubated at 27 °C for four to eight days in triplicates. Observations were recorded when there was a full growth of pathogen in the control plate. The *per cent* inhibition on growth of the test pathogen was calculated using formula as suggested by Vincent (1927).

$$I = \frac{(C-T)}{C} \times 100$$

Where,

I = Per cent inhibition,

C = Growth of fungal plant pathogens in control (mm),

T = Growth of fungal plant pathogens in dual culture plate (mm)

Biomass Method

Fungal growth inhibition by endophytic isolates was measured using mycelial mat weight determination method (Opgenorth and Endo, 1983). Both pathogenic fungus and the antagonistic bacterial endophyte were Co-inoculated to the culture flasks. To each flask containing 100 ml broth, 8 mm disc of the pathogenic fungi along with 1 ml of 24-hrs old endophytic bacterial culture (10^5 cfu/ ml) was inoculated and flasks inoculated with only pathogen was used as control. The flasks were incubated at 30 ºC for 10 days, then the contents were filtered through a pre-weighed Whatman filter paper and were dried in oven at 105 ºC for 48 hrs. The reduction in weight of co-inoculated flasks was determined in comparison with the control flasks.

Results and Discussion

Isolation of Endophytic Bacteria from Landraces of Finger Millet

Forty-two bacterial endophytes were isolated from the fifteen landraces and number of bacteria isolated were more from the landrace thenemundaga ragi (6), followed by keenya ragi (4), guppe ragi (4), mundaga ragi (4) and hasirumundaga ragi (4) the isolates from each landrace is represented in Fig. 1. Number of bacteria isolated from seeds (16) were more compared to other parts suggesting that a large population of endophytic bacteria reside inside the finger millet seeds. Higher number of endophytic bacteria indicates their possible contribution in promoting seed germination and establishment or modulating other physiological functions since a given plant species normally harbours a wide range of microbial species, the specific composition of which is shaped by complex interactions with the host plant and the environment (Pan *et al.*, 2008). Different studies demonstrated that the seed microbiome plays an important role in seed germination and seedling development. Thus endophytes play a positive role in root and shoot development, in the formation of root hairs and help to increase the chlorophyll content of seedlings (Shearin *et al*., 2018).

Screening for Biocontrol Activity

The most commonly reported mechanism for biocontrol by rhizospheric bacteria and endophytic bacteria is antagonism through predation, competition, and production of enzymes or chemicals that are antagonist in nature. Unlike rhizospheric microbes, the endophytes have an alternative mechanism of biocontrol known as Induced Systemic Resistance (ISR) where bacterial metabolites affect the plant in such a way as to increase the plants resistance to pathogens (Kloepper and Ryu, 2006). Among 42 endophytic isolates, based on their different morphological and colony characteristics, 33 isolates were selected for antagonistic activity screening.

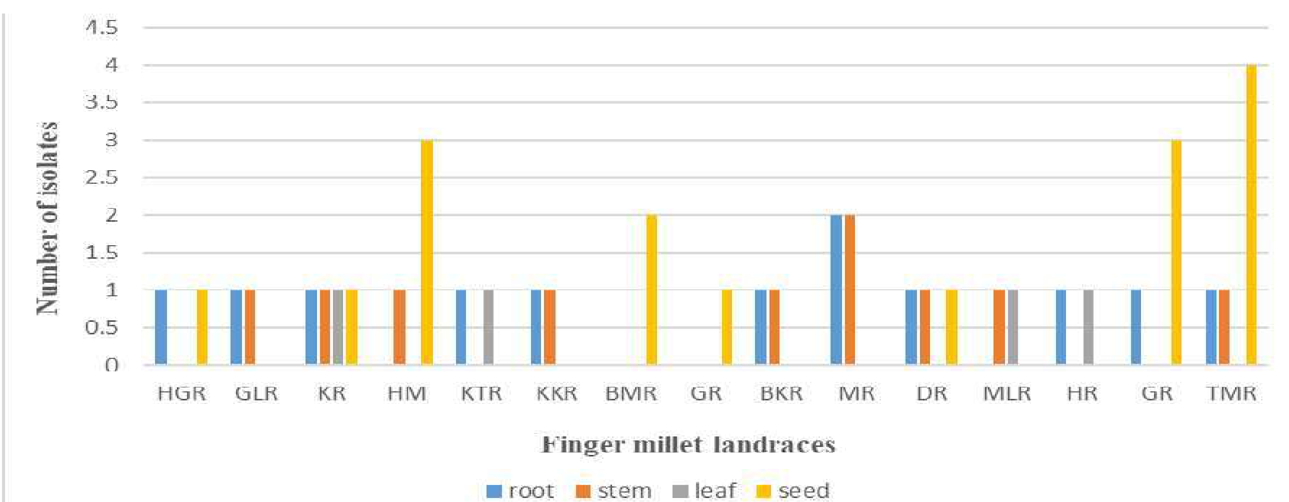


Fig. 1 : Endophytic bacterial isolates from different plant parts of finger millet landraces

The Mysore Journal of Agricultural Sciences

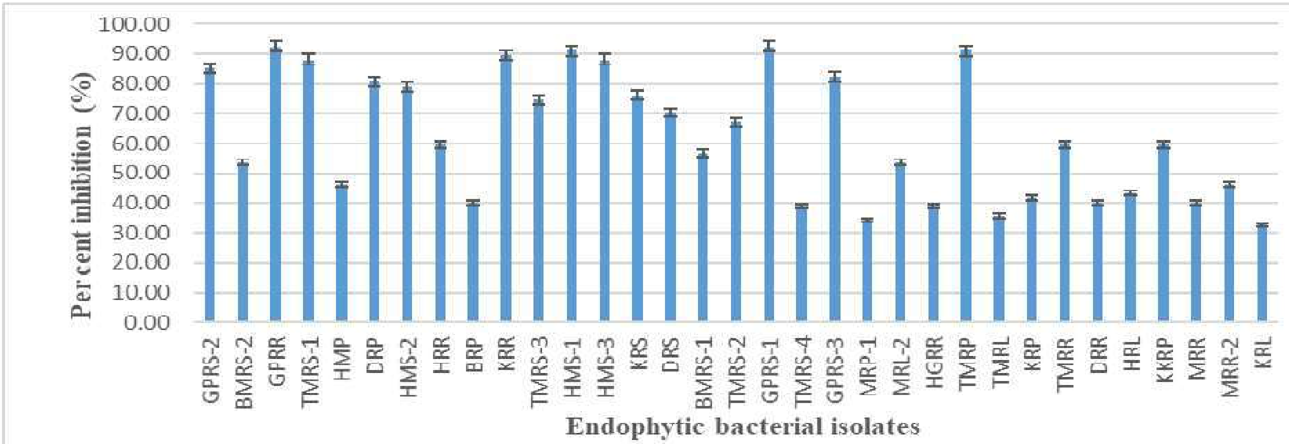


Fig. 2 : Antagonistic activity of bacterial endophytes in dual plate assay

In dual culture plate assay, zone of inhibition by isolates were measured and per cent inhibition was calculated by comparing control. The results are summarized in the Fig. 2. The per cent inhibition by bacterial isolates were between 32 and 93 per cent. Highest antagonistic activity was shown by isolates GPRR and GPRS-1 (92.54%) from landrace Guppe ragi followed by HMS-1 (91.04%) and lowest activity was reported in isolate KRL (32.84 %) of Keenya ragi.

It is clearly observed that the growth of fungal mycelium was inhibited by bacterial endophyte that is due to the hyper parasitism and production of antagonistic substances and also different locality and inherent microflora of landraces can be the reason for their difference in biocontrol activity (Misganaw *et al.,* 2019). Endophytes from GPU, blast resistant variety, *Stenotrophomonas maltophilia* and *Lactobacillus aerocolonigenes* were reported to hold a strong antagonistic activity against *M. grisea*. The production of alkaline serine proteolytic enzyme, induction of host systemic acquired resistance and thiobutacin production by *S. maltophilia* and *L. aerocolonigenes* respectively might play a key role in its biocontrol activity against oomycetes and some ascomycetes fungi. The high abundance of these species in GPU might have a potential role in the resistant reaction of this cultivar against the blast pathogen (Prasanna kumar *et al.,* 2020).

In biomass assay, the per cent reduction in dry weight of the mycelium mat of plant pathogens by the bacterial endophytes is presented in Fig.3. The highest per cent reduction of dry weight of mycelium was shown by isolate GPRS-1 (96.02%) isolated from seeds of landrace Guppe Ragi and lowest activity was found with the isolate GRS (24.77 %). Pathogen growth was inhibited due to the microbial activity by production of enzymes, secondary metabolites and by competing for limited nutrients or space (Suman *et al*., 2016). The filtrates of *S. globisporus* JK-1 suppressed the growth of *M. oryzae* in dual culture as well as inhibited conidial germination and appressorial formation as demonstrated by detached leaf assay. Kumar *et al*. (2020) evaluated the antifungal activity of bacterial seed endophytes showed inhibition of growth of tested fungal pathogens *Alternaria* sp., *Curvularia* sp., *Fusarium oxysporum* and *Rhizoctonia solani* by *Paenibacillus dendritiformis* with per centage inhibition 54.54, 58.33, 30.43 and 50 per cent respectively. Bacterial endophytic isolates from minor millets, KMS 5 (62.22 %) and PML 3 (82.05 %) were able to inhibit the growth of *Rhizoctonia solani* (Raveendra and Shivaprakash, 2018), the suppression of mycelial growth of fungal pathogen by bacterial endophytes may be due to the production of inhibitory allelochemicals, volatile and non-volatile compounds, hydrogen cyanide and cell wall degrading enzymes. .

Thirty-three bacterial isoloates were screened against blast pathogen under *in vitro* conditions.

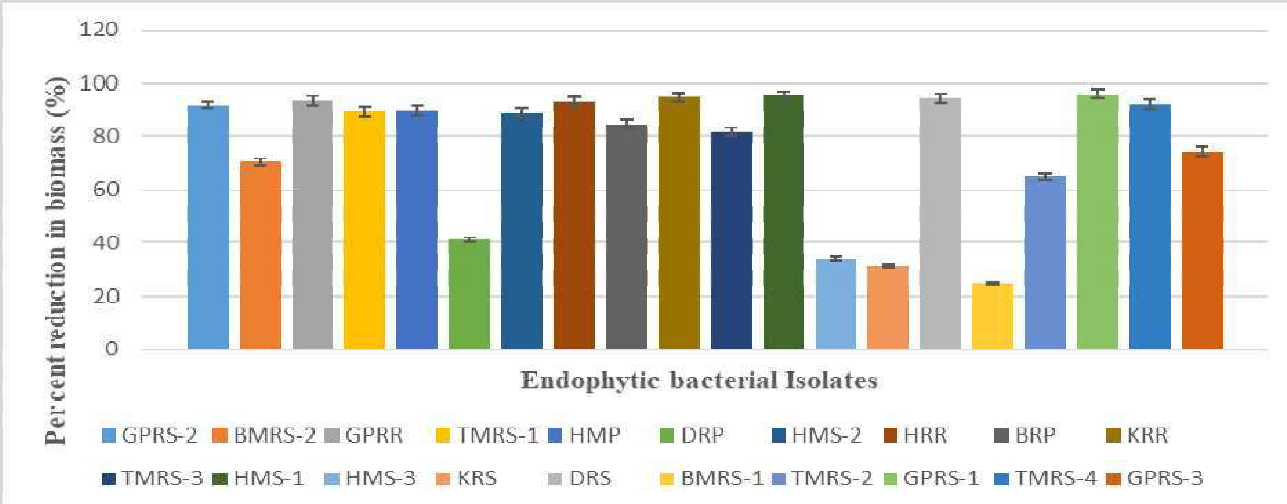


Fig. 3 : Antagonistic activity of bacterial endophytes in biomass assay

Based on dual culture assay, 20 isolates were selected and screened in biomass method. Among 15 landraces, thenemundaga ragi had harboured high endophytic bacteria and finger millet seed contributed for higher population. Three isolates HMS-1, GPRS-1 and GPRR were efficient in inhibiting growth of the pathogen *P. grisea*. Efficiency of these isolates from landraces can be exploited as a bio agent in controlling blast.

References

Afroz, R., Zahra, J., Faluk, S., Fauzia, Y. H., Muhammad and Nadeem, H., 2017, *Bacillus* spp., a bio-control agent enhances the activity of antioxidant defense enzymes in rice against *Pyricularia oryzae. Plos One*, **12** (11) : 0187412.

Bacon, C. W., Glenn A. E. and Hinton, D. M., 2002, Isolation, in planta detection and culture of endophytic bacteria and fungi. In: Hurst, C. J., Crawford, R. L., Mc Inroy, M. J., Knudsen, G. R. and Stetzenbach, L. D. (eds) Manual of Microbiology, 2nd edn. ASM, Washington D. C., pp. : 543 - 553.

Bonman, J, 1992, Durable resistance to rice blast disease - environmental influences. *Euphytica*, **63** : 115 - 123. https://doi.org/10.1007/BF00023917.

Budnik, L. T. and Baur, X., 2009, The assessment of environmental and occupational exposure to hazardous substances by biomonitoring. *Dtsch. Arztebl. Int*., **106** : 91 - 97.

Camacho, V., Maxted, N., Scholten, M. and Ford-Lloyd, B. V., 2005, Defining and identifying crop landraces. *Plant Genet. Resour.,* **3** (3) : 373 - 384.

Chandra, D., Chandra, S., Pallavi and Sharma, A. K., 2016, Review of finger millet [*Eleusine coracana* (L.) Gaertn]: A powerhouse of health benefiting nutrients. *Food Sci. Hum. Well*, **5** : 149 - 155.

Davila-Flores, A., Dewitt, T. and Bernal, J., 2013, Facilitated by nature and agriculture : Performance of a specialist herbivore improves with host-plant life history evolution, domestication and breeding. *Oecologi*a, **173** : 1425 - 1437.

Dennis, C. and Webster, J., 1971, Antagonistic properties of species groups of *Trichoderma* production of non-volatile antibiotics. *Trans. Br. Mycol. Soc*., **57** : 25 - 39.

Jabbar Sab and Nagaraja, A., 2018, Assessment of morphological and cultural variability of *Pyricularia grisea* (Cooke) Sacc. isolates associated with finger millet blast disease. *Mysore J. Agric. Sci*., **52** (2) : 391 - 401.

Jia, Y., Valent, B. and Lee, F. N., 2003, Determination of host responses to *Magnaporthe grisea* on detached rice leaves using a spot inoculation method. *Plant Dis.,* **87** : 129 - 133.

Kulkarni, K. and Peshwe, S., 2019, Screening, isolation and molecular identification of rice pathogen *Magnaporthe oryzae*. *Int. J. Adv. Res.*, **7** (3) : 428 - 433.

Kumar, K., Pal, G., Verma, A. and Verma, S. K., 2020, Seed inhabiting bacterial endophytes of finger millet (*Eleusine coracana* L.) promote seedling growth and development and protect from fungal Disease. *S. AFR. J. Bot.*, **134** : 91 - 98.

Kloepper, J. W. and Ryu, C. M., 2006, Bacterial endophytes as elicitors of induced systemic resistance. In: Schulz, B., Boyle, C., Sieber, T. N. (eds) Microbial root endophytes, Soil Biology, Springer-Verlag Berlin Heidelberg, **9** : 33 - 52.

Laxman Singh Rajput, T. S., 2017, Effect of temperature on rice blast infection process with emphasis on appressoria formation by *Magnaporthe oryzae*. *Int. J. Curr. Microbiol. Appl. Sci.,* **6** (4) : 1931 - 1939.

Misganaw, G., Simachew, A. and Gessesse, A., 2019, Endophytes of finger millet (*Eleusine coracana*) seeds. *Symbiosis,* https://doi.org/10.1007/s13199-019-00607-5.

Mousa, W. K. and Raizada, M. N., 2013, The diversity of anti-microbial secondary metabolites produced by fungal endophytes : An interdisciplinary perspective. *Front. Microbiol.*, **4** : 1 - 18.

Nagaraja, A., Nanja, Y. A., Anjaneya, B., Patro, T. S. S. K., Kumar, B., Kumar, J. and Krishne, K. T., 2010, Reaction of finger millet recombinant inbred lines to blast. *Crop Res.,* **39** : 120 - 122.

Netam, R. S., Tiwari, R. K. and Bahadur, A. N. D. S., 2014, *In vitro* and *in vivo* efficacy of fungicides against *Pyricularia grisea* causing finger millet blast disease. *Int. J. Plant Prot.*, **7** : 137 - 142.

Opgenorth, D. C. and Endo, R. M., 1983, Evidence that antagonistic bacteria suppress *Fusarium* wilt of celery in neutral and alkaline soils. *Phytopathol.,* **73** : 703 - 708.

Pablo, C., Maria, P. M., Rodriguez, J. A. N. and Rafael, M. J. D., 2015, Interactions of *Pratelenchus thornei* and *Fusarium oxysporum* f. sp. *ciceris* on Chickpea. *Phytopathol.*, **88** : 828 - 836.

Pan, J. J., Baumgartenam and May, G., 2008, Effects of host plant environment and *Ustilago maydis* infection on the fungal endophyte community of maize (*Zea mays*). *New Phytol.*, **178** : 147 - 156. https://doi.org/10.1111/j.1469-8137.2007.02350.x

Prasannakumar, M. K., Mahesh, H. B., Radhika, U., Desai, Bharath Kunduru, Karthik, S., Narayan, Kalavati Teli, Puneeth, M. E. and Rajadurai, R. C., 2020, Metagenome sequencing of finger millet associated microbial consortia provides insights into structural and functional diversity of endophytes. *Biotech.*, **10** : 15.

Raveendra Reddy, M. and Shivaprakash, M. K., 2018, Antagonistic activity of bacterial endophytes isolated from millets against *Rhizoctonia solani* in foxtail millet. *Mysore J. Agric. Sci.,* **52** (2) : 241 - 247.

Ricker, A. J. and Ricker, R. S., 1936, Introduction to research on plant disease. John S. S. wit Co., No.4, New York, USA.

Shearin, Z. R. C., Filipek, M., Desai, R., Bickford, W.A., Kowalski, K. P. and Clay, K., 2018, Fungal endophytes from seeds of invasive, non-native *Phragmites australis* and their potential role in germination and seedling growth. *Plant Soil*, **422** : 183 - 194. https://doi.org/10.1007/s11104-017-3241-x.

Suman, A., Yadav, A. N. and Verma, P., 2016, Endophytic microbes in crops : Diversity and beneficial impact for sustainable agriculture. In: Singh DP, Abhilash PC, Ratna P (eds) Microbial inoculants in sustainable agricultural productivity. Springer, Dordrecht, pp. : 117 - 143.

Vetriventhan, M., Upadhyaya, H. D. and Dwivedi, S. L., 2015, Finger and foxtail millets. Elsevier Inc., Amsterdam, pp. : 291 - 319.

Vincent, J. M., 1927, Distortion of fungal hyphae in the presence of certain inhibitors. *Nature*, **59** : 850.

Mysore J. Agric. Sci., 57 (1) : 59-70 (2023)

Optimization of Photoperiod, Carbon Source and Plant Hormones for Effective Micro-Tuberization in Potato

S. R. Bharath and B. Mohan Raju
Department of Crop Physiology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : bmohanraju@uasbangalore.edu.in

Authors Contribution

S. R. Bharath :
Carried out the experiment, performed the statistical analysis and participated in sequence alignment;
B. Mohan Raju :
Conceived the idea, design and coordinated the experiments, drafting the manuscript and final approval

Corresponding Author :
B. Mohan Raju
Dept.of Crop Physiology, College of Agriculture, UAS, GKVK, Bengaluru

Received : Octomber 2022
Accepted : December 2022

Abstract

Potato micro-tuberization is an effective and efficient in-vitro technique for production of micro tubers through single node cuttings. This technique accelerates the production of high quality disease free potato seeds faster and cheaper than the other methods. However, micro-tuberization is regulated by several key factors such as photoperiod, lower temperature, carbon sources and plant hormones. In the present study, we showed that, short day condition induces tuberization with more efficiency when sucrose is used as a source of carbon than maltose. Further, 50g/l of sucrose was found to be very effective, while increased concentration was rather lethal for growth and micro-tuberization in potato. Although, both BAP @ 2ppm and kinetin @ 1ppm were found to be effective as a source of cytokinin to induce micro-tuberization, kinetin can be a better source of cytokinin as its requirement is only 1 ppm as against 2 ppm of BAP. Taken together, single node cuttings cultured on MS media supplemented with 50g/l sucrose and 1 ppm of kinetin and exposed to a short day condition of 8 hrs. light with 16 hrs. of dark period would be an ideal situation for efficient induction of micro-tubers in potato.

Keywords : Micro-tuberization, Carbon source, Plant hormones, Short days, Sucrose, Kinetin

In-vitro production of tubers through culturing of nodal cuttings is often referred to as Micro-tuberization (Badoni and Chauhan, 2010). Micro tubers have many advantages that make them ideal planting material for producing high quality seed potatoes. Compared with in-vitro plantlets, micro tubers are more robust, easier to handle and can be stored for a longer period (Mc-Cown and Joyce, 1991). In fact, micro tuber production technology offers a wide range of advantages of small space requirement, ease of transport and storage and accelerates the production of high quality disease free potato seeds faster and cheaper than other methods (Ranalli, 1997; Nistor *et al.*, 2010 and Raveesha, 2014). In India, the advances in micro tuber productionare considered as second 'green revolution' in agriculture and are expected to make farming more efficient, profitable and environmentally safe in addition to helping the farmers economically, socially and commercially.

Potato micro-tuberization is rather influenced by several *in-vitro* tuber inducing factors like media composition, short day photoperiodic conditions (8h/16h) (Nistor *et al.*, 2010), low temperature (18-21^0 C), sucrose or maltose, phyto-hormones like 6-BAP, kinetin and others (Mamiya *et al.*, 2020). Many researchers have reported that, MS basal medium is quite effective and efficient for micro-propagation and micro-tuberization in potato (Hussey and Stacey, 1981; Roselli *et al.,* 1987; Aburkhes *et al.,* 1991; Gopal *et al.*, 1998 and Ozkaynak and Samanci, 2005). In addition, the short day photoperiods highly influence potato micro-tuberization and would promote aerial stolons and tubers from axillary meristems (Macwan *et al.*, 2017;

Ali *et al*., 2018 and Kondhare *et al*., 2021). Besides photoperiod, low temperature (18-21 ^{0}C) seems to be very crucial factor that promotes miro-tuberization in potatoes under in-vitro conditions (Nistor *et al*., 2010 and Macwan *et al*., 2017). A slight increase in temperature would inhibit potato micro tuber formation (Wang and Hu, 1982 and Salem and Hossain, 2017). In addition, altering the media composition with sucrose will further increase the micro-tuberization process. Sucrose is the main tuber inducing stimulus and signaling molecule for micro tuber induction in potato. Therefore, supplying a sufficient amount of sucrose as a carbon source would stimulate plant growth and development, tissue proliferation and increases micro tuber weight and diameter (Perl *et al*., 1991; Khuri and Moorby, 1995; Yu *et al*., 2000; Donnelly *et al*., 2003 and Nistor *et al*., 2010). Maltose is also serving as another important carbon source for the development of a healthy and vigorous plantlets from the nodal explants (Rahman *et al*., 2015). Like sucrose, maltose would also regulate the formation of micro tuber number, tuber weight and micro tuber diameter (Altindal and Karadogan, 2010). However, which carbon source would favor micro-tuberization more effectively needs further examination.

Phytohormones like BAP and kinetin also play a major role in micro-tuberization in potatoes. BAP is the potential option to increase micro tuber number, size, weight and tuber diameter (Fufa and Diro, 2014; Rahman *et al*., 2015; Dessoky *et al*., 2016; Borna *et al*., 2019 and Meenakshi, 2020). However, even kinetin also shown to regulate micro-tuberization under *in-vitro* conditions from single nodal cuttings (Dessoky *et al*., 2016 and Olga *et al*., 2022). The sucrose and kinetin together play a critical role in micro tuber size and tuber weight (Ali *et al*., 2018). Therefore, the main objective of the present study is to standardize the photoperiodic conditions with most effective carbon source and hormonal combination for effective plant growth and micro-tuberization in potato. As many factors regulate micro-tuberization in potato, it is necessary to standardize each of these factors for effective micro-tuberization.

Material and Methods

Planting Material

The experiments were conducted at the Plant Tissue Culture Laboratory, Department of Crop Physiology, UAS, GKVK, Bangalore. The virus-free planting material was procured from the Central Potato Research Institute (CPRI), Shimla and the College of Horticulture, Bengaluru campus, UHS, Bagalkot.

In-vitro Micro-Propagation of Potato and Induction of Micro-Tuberization

Potato micro-propagation is a very important tissue culture technique to multiply plantlets within a short period of time (Pruski *et al.,* 2002). However, multiplication of plantlets in-vitro requires standardization of media, carbon source, plant hormones including regulation of photoperiod. In this context, the said conditions / parameters were standardized. Towards multiplication of plantlets, five important potato cultivars namely, Kufri-Jyoti (KJ), Kufri-Himalini (KH), Kufri-Chipsona-1 (KC-1), Kufri-Chipsona-3 (KC-3) and Kufri-Chipsona-4 (KC-4) were used. As standardization of micro-propagation protocol is a pre requisite for micro tuber production in potato, the micro-propagation protocol was standardized with an overall objective of producing micro tubers in potato.

Standardization of Media Composition

Single nodal explants made from 21 days old potato plantlets were inoculated into a growing MS media. The media composition for micro - tuberization of potato plantlets consist of 75 per cent of basal MS medium supplemented with standardized concentration of sucrose and the plant hormone and the pH was adjusted to 5.8. To this, 5g/l agar was added which served as a solidified agent. The media was autoclaved at 121 ^{0}C for 15 min and after two hours, media was poured into the tissue culture bottles to inoculate the single nodal explants. After solidification of media, single nodal explants were inoculated under the laminar air flow chamber (LAF) and the inoculated bottles were kept exposed to standardized photoperiodic treatment. After

21 days of inoculation, the bottles were observed for *in-vitro* grown plantlets and the growth parameters were recorded in them. Towards inducing micro-tubers, the plantlets were allowed to grow in the same growing condition for some more days and finally, the number of tuber inducing plants and the micro tuber number and size were recorded under each treatment.

Carbon Sources for Induction of Micro-Tuberization in Potato

Carbon source is very important for robust plant growth and micro-tuberization. In this regard, two carbon sources namely, sucrose and maltose @ 50g/l of each was used in the media separately to examine which carbon source favoring robust plant growth and micro-tuberization. Our preliminary experiment indicated that, sucrose is a better source of carbon than maltose and hence, the sucrose concentration was further standardized to examine whether or not the altered carbon source brings in better micro-tuberization in potato. As sucrose is serving as an important carbon source and also a micro tuber inducing stimulus (Nistor *et al.,* 2010), different concentrations of sucrose were used which include 30g/l (T1), 40g/l (T2), 50g/l (T3), 60g/l (T4), 80g/l (T5) and 100g/l (T6) along with the normal MS media.

Standardization of Hormone Source for Effective Micro-Tuberization

Besides media, carbon source and photoperiod, plant hormone is also equally important for effective micro-tuberization. In this context, different cytokinin sources namely, kinetin and BAP were used in the MS media and examined which cytokinin source induces effective micro-tuberization in potato. Accordingly, the cytokinin source which induced more micro tuber was considered as standardized hormone source.

Standardization of Photoperiodic Conditions

Different photoperiodic treatments were given to the cultured single node cuttings to standardize the photoperiodic condition. These treatments include complete dark (T1), complete light (T2), short days (T3) and long days (T4). Complete dark treatment was given in a dark chamber where, complete darkness was maintained all through the day and during the entire growing / culturing period. However, complete light treatment was given through light chambers using LED lights with an intensity of 4000 Lux. Short days were created for about 8 hours of light treatment with 16 hours of darkness using an automatic timer. Similarly, long days were also created by exposing the bottles to artificial light for 16hrs and dark for 8hrs through timer regulation.

Multiplication of Potato Plantlets *In-vitro*

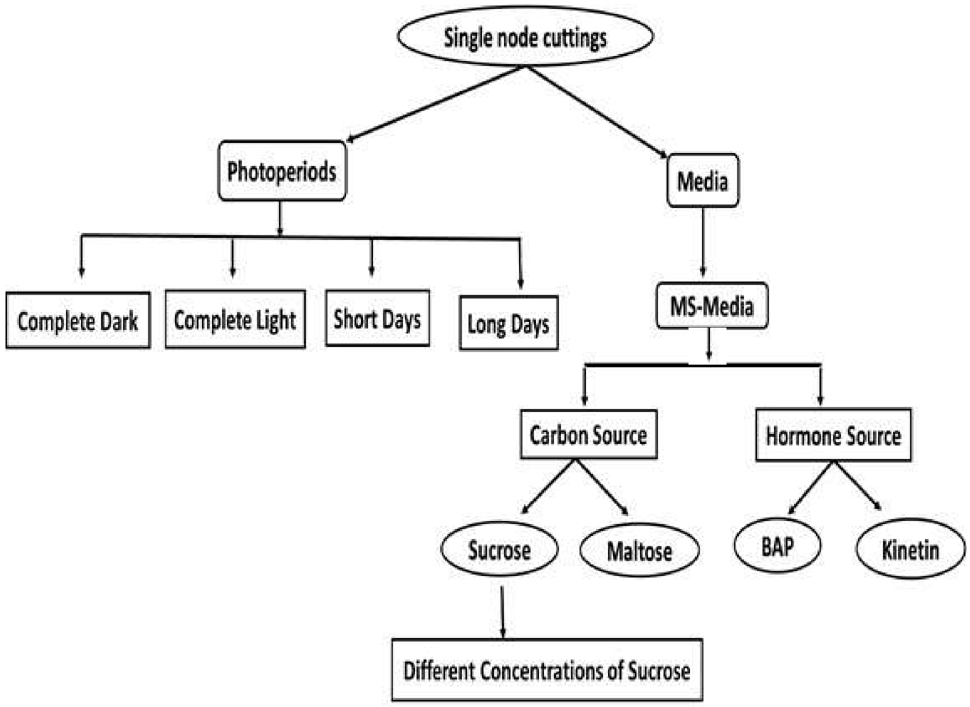
After standardizing various elements of micro-propagation in potato, five different cultivars as mentioned above were cultured in-vitro and plantlets were multiplied. A flowchart depicting the standardization of various elements of micro-propagation of potato under in-vitro condition is given in flowchart 1.

Induction of Micro-Tuberization in Potato

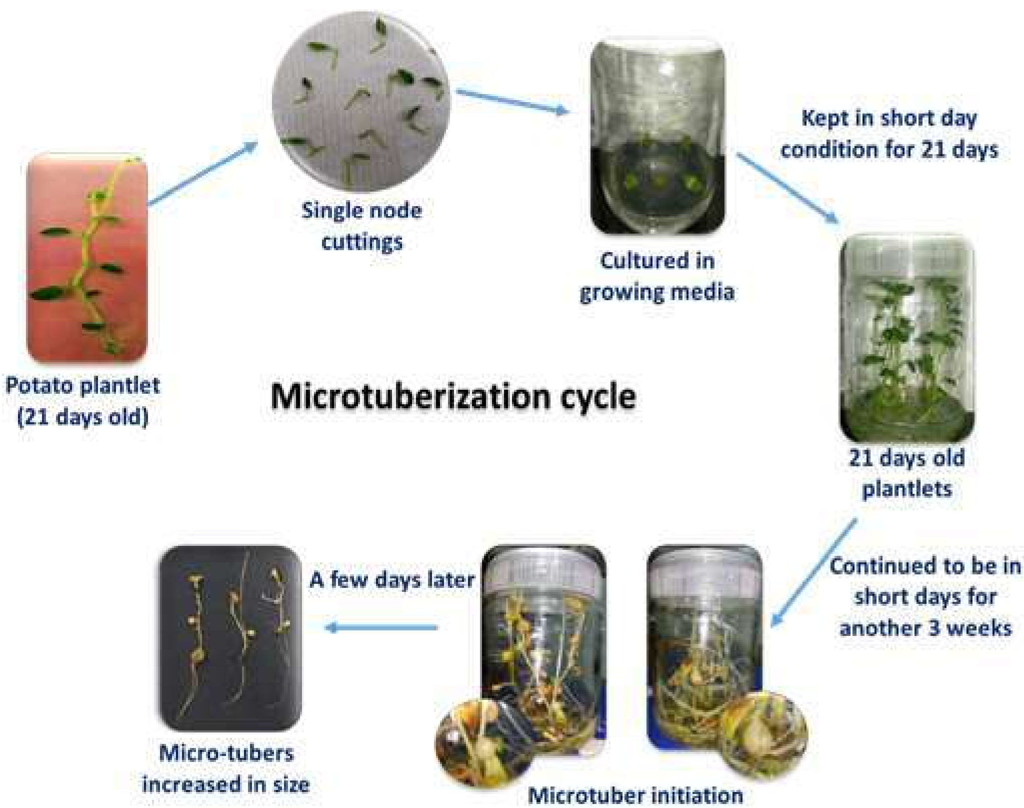
As our main objective is to produce micro tubers in potato, single node cuttings of Kufri Jyoti, one of the leading cultivars of potato in India with high multiplication rate, robust growth and wider adaptability including disease resistance was used. Single node cuttings made from 21 days old plantlets were inoculated into the MS-media supplemented with 50g/l of sucrose and 1 ppm kinetin. Later, the cultured bottles were kept in short day condition of 8h photoperiod (4000 lux) and 16 hr. of dark all through the experimental period and observed for micro-tuberization. The inoculated bottles were kept inside the BOD incubator where the temperature was maintained at 18 ^{0}C with an RH of 80 per cent. At the end of 45 days, initiation of micro tubers was observed and recorded. The flowchart depicting the steps followed for micro-tuberization is given in flowchart 2.

Statistical Analysis

Data on plant height, number of nodes, no. of leaves, micro-tuber number, weight and tuber diameter were collected during harvest. Further, all the collected data



Flowchart 1: A Flowchart depicting standardization of various elements for micro-propagation in potato



Flowchart 2: Schematic representation of different steps involved in micro-tuber production in potato

were analyzed by analysis of variance and the means were compared according to DMRT (Duncan's Multiple Range Test) and the mean separation was done at 5 and 1 per cent level of significance.

Results and Discussion

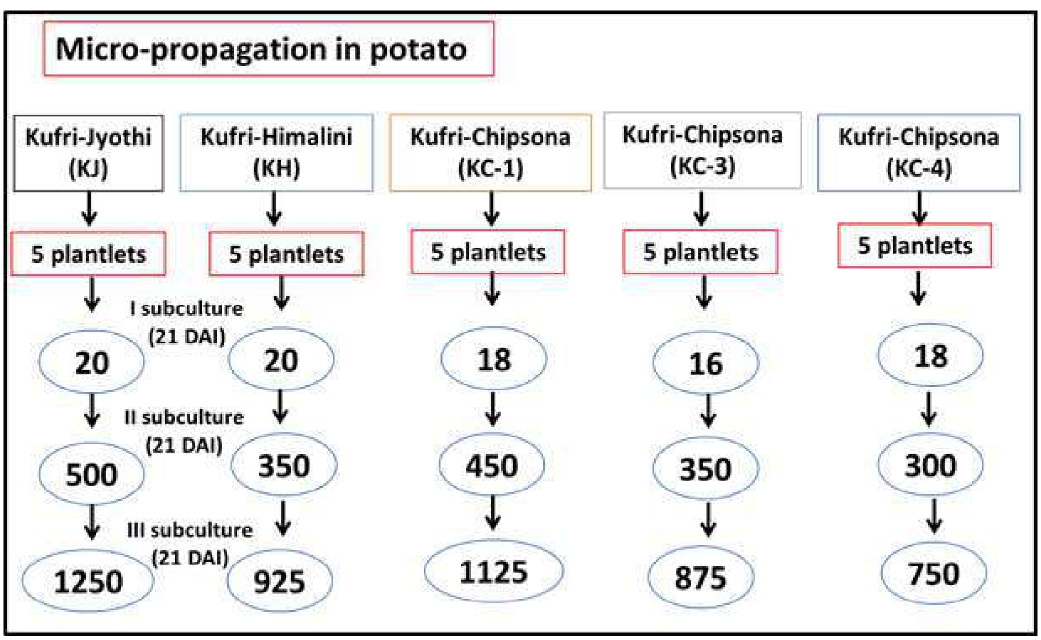
Potato micro-propagation is regulated by several factors which include photoperiod, media composition, carbon source and even plant hormones. Therefore, in the present study, the influence of the said parameters was evaluated for micro tuber induction in potato.

Mass Multiplication of Potato Plantlets

Initially, mass multiplication of potato plantlets free from pests and diseases were taken up to generate the required number of plantlets for inducing micro-tuberization. Accordingly, mass multiplication was taken up in 5 varieties of potato. Initially, 5 plants each were taken from each of the varieties and sub cultured the single node cuttings for 21 days and end of which, the plantlets generated were again sub cultured to produce more number of plantlets (Flowchart 3). Accordingly, at the end of 3rd sub culturing, sufficient number of plantlets were produced. Interestingly, Kufri Jyoti, one of the leading varieties (Srikant Tengli and Mohan Raju, 2022) produced significantly higher number of plantlets of 1250 while, Kufri Chipsona had only 750 plantlets to suggest the variation in number of plantlets generated at the end of each sub culturing. It appears that, Kufri Jyoti responds very well to sub culturing and mass multiplication compared to the other varieties (Flowchart 3). Such differential response was also noticed by Pavithra (2020) while working with different cultivars of potato, where she found significant variation in number of plantlets generated at each cycle due to higher rate of mortality in some cultivars (Flowchart 3).

Effect of Carbon Sources on Growth and Micro-Tuberization in Potato

Although maltose and sucrose serve as carbon source for in vitro grown plantlets, sucrose seems to be very effective as a source of carbon as it is not only triggered the vegetative growth, but even the micro-tuberization in potato. Single node cuttings cultured under in-vitro media with sucrose as a



Flowchart 3: Mass multiplication of different cultivars of potato under in-vitro conditions and their success rate

Note: Single node cuttings were used in every sub-culturing steps
DAI-Days after inoculation

source of carbon showed significantly higher number of nodes, leaf number and even the root length. In addition, more than 80 per cent of the plantlets produced micro tubers as against only 25 per cent with maltose as carbon source. Further, the number of micro tubers per plant and also the fresh weight of micro tuber was significantly higher when sucrose was used as a carbon source instead of maltose. The results therefore suggest that, sucrose seems to be the ideal carbon source than maltose for effective growth and micro-tuberization in potato (Table 1 and Plate 1).

The importance of sucrose as a source of carbon for effective micro-tuberization has been reported by several other workers. Accordingly, increased biomass, micro tubers, micro tuber dry matter was promoted with sucrose as a source of carbon compared to the other sources of carbon (Gopal *et al.,* 2004 and Altindal and karadogan, 2010). In several earlier studies, it has been reported that, concentration of sucrose decides the efficiency of micro-tuberization in potato. In one of the studies, Hossain *et al.* (2017) have reported that, the micro-tuberization and micro tuber number was highest in 8 per cent sucrose and as the sucrose concentration increased, they observed decreased micro-tuberization. Similar observation was also made by others where they showed improved micro-tuberization when the sucrose concentration increased from 3-8 per cent in the media (Omokolo *et al.,* 2003 and Macwan *et al.,* 2017).

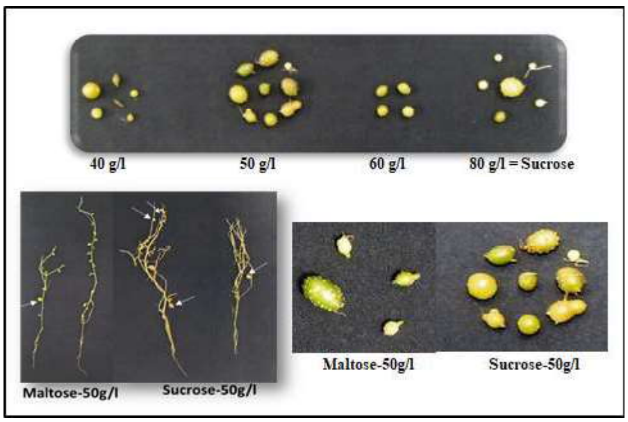


Plate 1: Plant growth and micro-tuberization as influenced by different carbon source

Sucrose is rather serving as energy source and osmotically active compound and at higher concentration, it serves as a signaling molecule for micro tuber formation (Perl *et al*., 1991, Donnelly *et al*., 2003 and Gibson, 2005). According to Garner and Blake (1989), the use of 8 per cent sucrose would increase the tuber initiation, number and weight of micro-tubers compared to 4 per cent sucrose concentration. However, further increase in the concentration of sucrose up to 12 per cent caused a delay in tuber initiation resulting in smaller tubers.

In this direction, when we examined the concentration of sucrose on plant growth and micro-tuberization, we found that, the plant growth, number of nodes, number of leaves and root length increased up to a

TABLE 1

Effect of different sources of carbon on growth and micro-tuberization in potato (Var. Kufri Jyoti)

Treatments	Plant height (cm)	No. of nodes	No. of leaves	Root length (cm)	% Micro-tuberizing plants	Number of micro tubers /plant	Micro tuber fresh weight (g)
Maltose-50g/l	13.67 [a]	21.89 [b]	19.89 [b]	7.39 [b]	25.00 [b]	0.31 [b]	0.09 [b]
Sucrose-50g/l	12.33 [b]	36.56 [a]	32.78 [a]	8.10 [a]	83.33 [a]	1.18 [a]	0.18 [a]
CD ($P<0.01$)	0.67 **	0.32 **	0.44 **	0.23 **	1.14 **	0.038 **	5.37 **
SE(m)	0.17	0.08	0.11	0.06	0.28	0.009	1.33
SE(d)	0.24	0.12	0.15	0.08	0.40	0.013	1.89
CV (%)	2.22	0.48	0.72	1.28	2.71	2.197	2.70

** Significant at 1% level

TABLE 2

Effect of different concentrations of sucrose on various growth parameters in in-vitro grown potato plantlets (Var. Kufri Jyoti)

Treatments	Plant height (cm)	No. of nodes (no.)	No. of leaves (no.)	Root length (cm)
T_1-Sucrose-30g/l	8.28 [d]	19.11 [d]	15.67 [e]	6.78 [bc]
T_2-Sucrose-40g/l	10.17 [b]	25.73 [c]	20.89 [c]	6.50 [c]
T_3-Sucrose-50g/l	11.83 [a]	34.67 [a]	32.74 [a]	7.78 [a]
T_4-Sucrose-60g/l	9.29 [c]	33.67 [b]	33.44 [a]	6.93 [b]
T_5-Sucrose-80g/l	8.22 [d]	34.50 [ab]	31.44 [b]	6.67 [bc]
T_6-Sucrose-100g/l	7.78 [d]	16.54 [e]	18.78 [d]	6.12 [d]
CD (P<0.01)	0.68 **	0.85 **	1.23 **	0.33 **
SE(m)	0.22	0.28	0.40	0.11
SE(d)	0.31	0.39	0.56	0.15
CV (%)	4.13	1.74	2.69	2.74

** Significant at 1% level

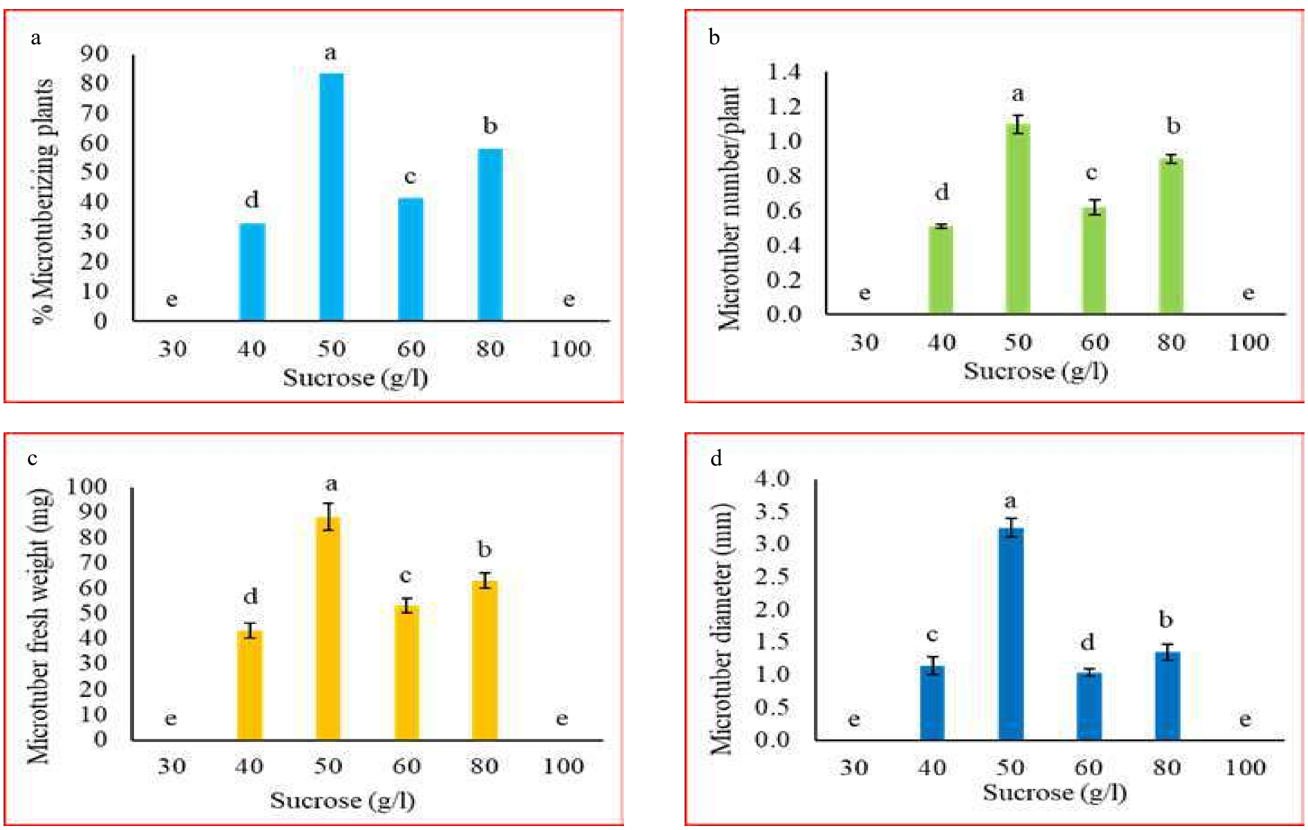


Fig. 1: Effect of different concentrations of sucrose on micro-tuberization in potato (Var. Kufri Jyoti); a) % Micro-tuberizing plants b) Micro tuber number/ plant, c) micro tuber fresh weight and d) Micro tuber diameter

concentration of 50 g/l from 30g/l (Table 2). Further, the number of tuberizing plants and the number of micro tubers per plant with tuber fresh weight and diameter increased gradually with increased concentration of sucrose (Plate 1 and Fig.1). However, with increase in sucrose concentration in the media beyond 50g/l, a reduction in said parameters was observed which corroborates with the results of earlier workers. Very interestingly, significantly very high number of micro tuberizing plants coupled with increased micro tubers per plant as well as fresh weight and diameter observed in plants grown in a media supplemented with 50g/l of sucrose compared with the rest of the concentrations. However, at a very high concentration of 100 mg/l of sucrose, we did not observe any tuberizing plants suggesting that, the higher concentration of sucrose becomes lethal for micro-tuberization in potato (Fig.1).

Effect of Cytokinin on Micro-Tuberization in Potato

Cytokinin plays an important role in micro-tuberization in potato. In this regard, different sources of cytokinins namely, BAP and kinetin were included in the growth media separately. While the BAP was used at a concentration of 1, 2, 4 and 6 ppm, the kinetin was used at a concentration of 0.5 and 1.0 ppm separately. The results of the study indicated that, 2 ppm BAP was found to be effective in increasing the micro-tuberization with higher number of micro tubers per plant coupled with more fresh weight and diameter compared to control and other concentrations of BAP (Fig 2). Similarly, 1 ppm of kinetin was found to be effective than 0.5 ppm and interestingly, the response was similar to that of BAP at 2 ppm. At 1 ppm of kinetin, nearly 79 per cent

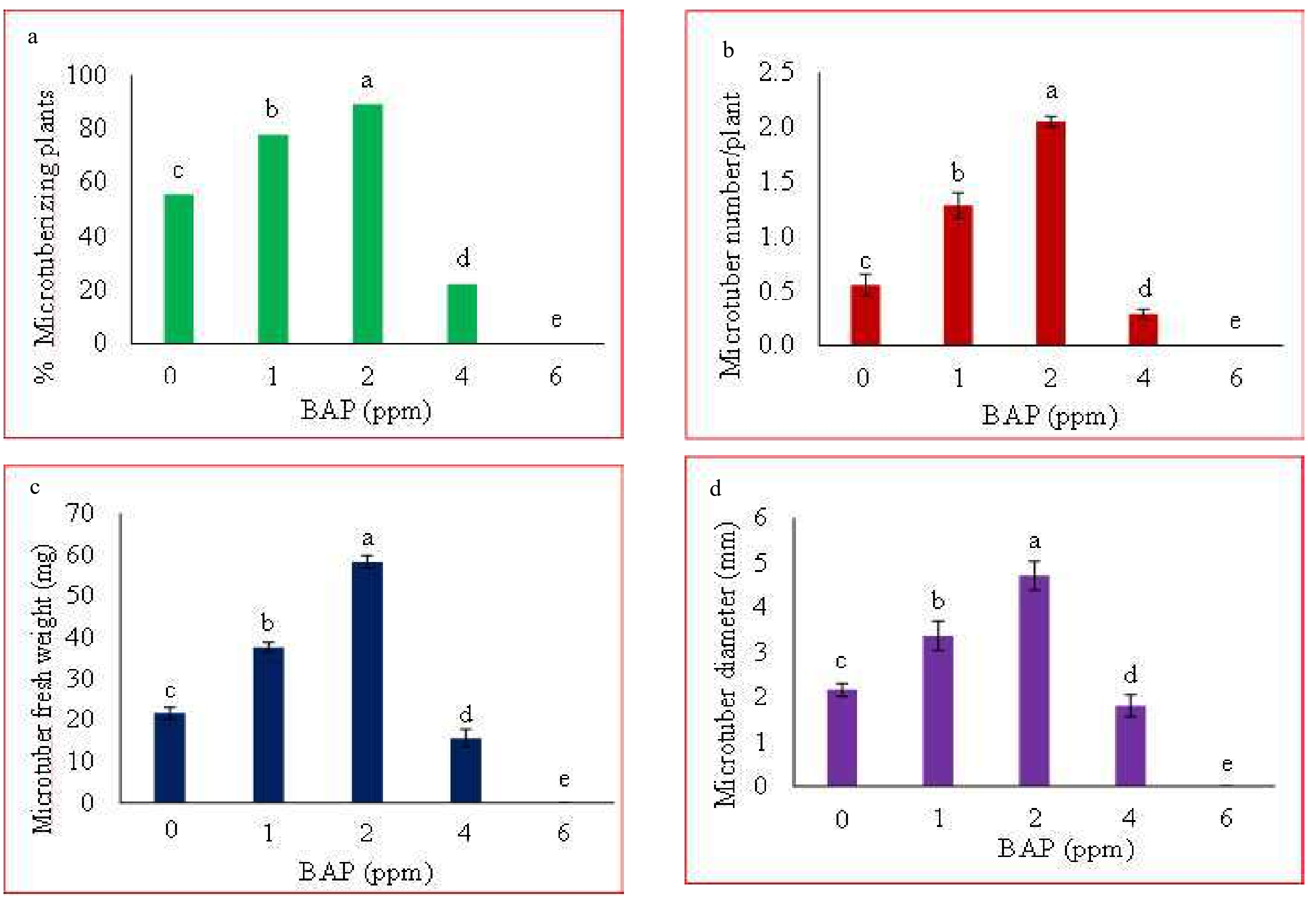


Fig. 2: Effect of 6-BAP on micro-tuberization in potato; a) % Micro-tuberizing plants b) Micro tuber number per plant c) Micro tuber fresh weight and d) Micro tuber diameter

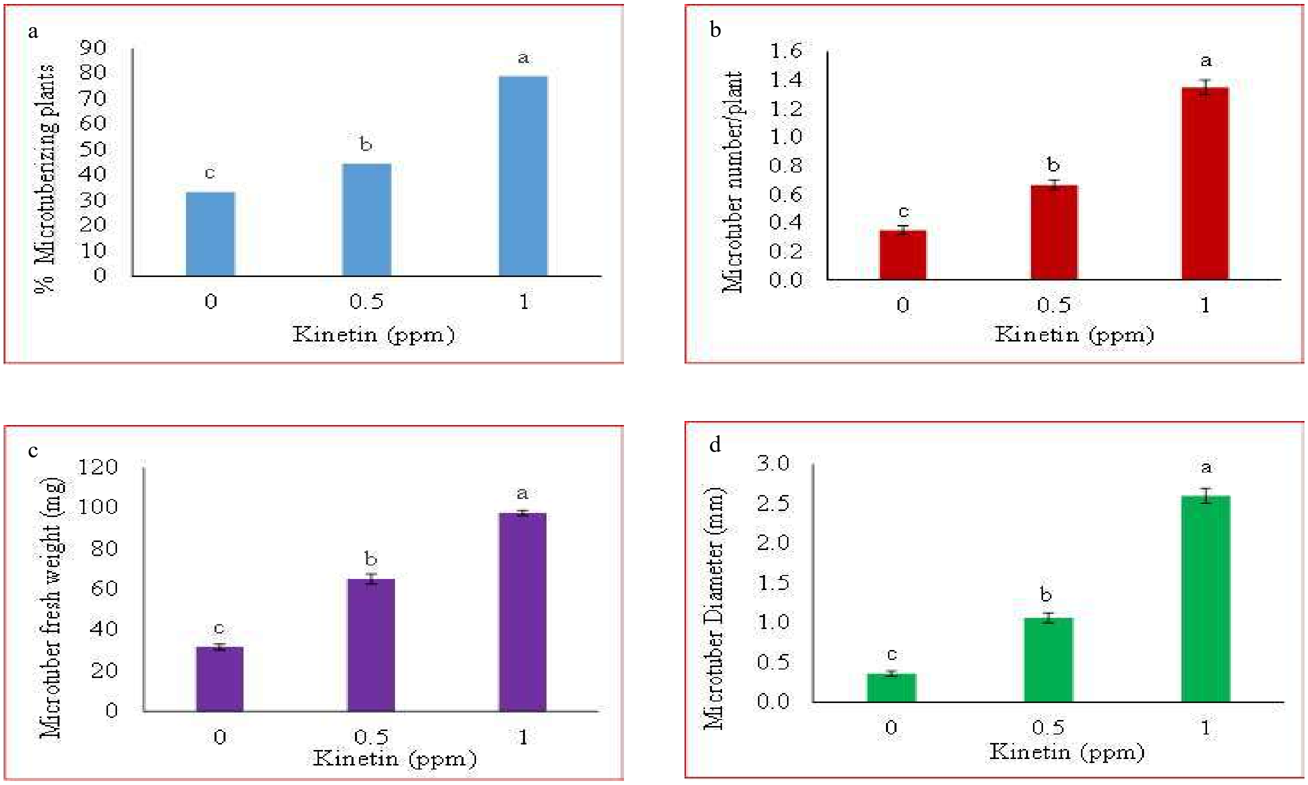


Fig. 3: Effect of Kinetin on micro-tuberization in potato; a) % Micro tuberizing plants b) Micro tuber number per plant c) Micro tuber fresh weight and d) Micro tuber diameter

of micro-tuberizing plants was observed with significantly higher fresh weight and diameter of micro tubers compared to 0.5 ppm of kinetin (Fig 3). The results therefore suggest that, 1 ppm of kinetin is effective for micro-tuberization in potato.

In contrast to our observations, others have found BAP as a good source of cytokinin for effective micro-tuberization. Accordingly, cultured medium supplemented with 2.25 mg/l (Meenakshi, 2020) and 5 mg/l of BAP (Dessoky *et al*., 2016) showed higher percentage of tuberizing plants as well as micro tubers suggesting the other sources of cytokinin would also do the job of inducing micro tubers in potato. Our study however indicates that, 1 ppm of kinetin would be sufficient to bring in the desired effect on micro tuberization in potato.

Effect of Photoperiod on Micro-Tuberization in Potato

Micro-tuberization in potato is influenced by photoperiod. While some reports indicated a good response in complete darkness, yet others showed the requirement of short days or longer days for micro-tuberization. In this regard, the effect of photoperiod on micro-tuberization was examined by exposing the single node cuttings of potato under *in-vitro* condition to either complete darkness or complete light or short days or long days. The results indicated that, both complete darkness or complete light for 24 hours a day did not show any response for micro-tuberization although they put on some plant height. However, short day photoperiod of 8 hrs. of light and 16hrs of dark period showed a higher micro-tuberization under hormonal treatment. Accordingly, under control condition without hormone treatment, the number of micro tubers produced per plant was 0.56 as against 1.29 tubers observed under hormonal treatment which is significant. Further, the average fresh weight and diameter of micro tubers was 108 mg and 3.88 mm respectively for the micro tubers produced under hormonal treatment, while, it was 81.6 mg and 1.92 mm respectively for control (Table 3).

TABLE 3

Effect of photoperiod on micro-tuberization in potato (Var. Kufri Jyoti)

Treatments	Plant height (cm)		No. of micro tubers/plant		Average fresh weight of micro tubers (mg)		Average diameter of micro tubers (mm)	
	Control	Hormone	Control	Hormone	Control	Hormone	Control	Hormone
T_1- Complete Dark	19.10 [a]	9.26 [b]	0.00 [b]	0.00 [c]	0.00 [b]	0.00 [c]	0.00 [b]	0.00 [c]
T_2- Complete Light	8.56 [c]	9.43 [a]	0.00 [b]	0.00 [c]	0.00 [b]	0.00 [c]	0.00 [b]	0.00 [c]
T_3- Short Days	9.02 [b]	8.50 [c]	0.56 [a]	1.29 [a]	81.6 [a]	108.0 [a]	1.92 [a]	3.88 [a]
T_4- Long Days	9.24 [b]	5.92 [d]	0.00 [b]	0.69 [b]	0.00 [b]	98.0 [b]	0.00 [b]	3.06 [b]
CD (P<0.01)	0.33 **	0.11 **	0.004 **	0.012 **	0.37 **	1.35 **	0.037 **	0.08 **
C X H	1.046		0.037		0.016		0.491	
SE (m)	0.11	0.04	0.001	0.004	0.12	0.45	0.012	0.03
SE (d)	0.16	0.06	0.002	0.005	0.17	0.63	0.017	0.04
CV (%)	2.15	1.06	1.97	1.74	1.34	1.94	5.65	3.53

** Significant at 1% level

Under long day conditions, micro-tuberization did not take place in control treatment. However, with the intervention of hormones, tuberization did take place with low efficiency both in number of micro-tuberizing plants as well as fresh weight and tuber diameter. The results therefore suggest that, short day condition induces micro-tuberization in potato. Very interestingly, when micro-tuberization is not possible under long day conditions, with the intervention of cytokinin, the plants could be made to induce micro-tuberization although the number and fresh weight and diameter is significantly lower compared to the plants exposed to short day conditions (Table 3).

Induction of tuberization in dark or at low light intensities with a light period of 8 hrs has been shown by several earlier workers (Struik and Wiersema, 1999; Dobrfinski, 2000 and Martlnez-Garcfa *et al*., 2002). However, in contrary to this, Macwan *et al*., (2017) have reported that, light conditions of 16 hrs. photoperiod was found to be the best at a temperature of 18 °C for tuberization with micro tubers showing increased weight and size. Similarly, cultures incubated at 20 °C either in dark for 8 weeks or two weeks in 16-h photoperiod followed by 6 weeks in dark, a combination of both dark and 16h-photoperiods promoted micro-tuberization in potato (Salem and Hassanein, 2016) suggesting both short days and long days would influence micro-tuberization in potato. However, in our study, we found that, short days favored micro-tuberization with no tuberization under long days.

In-vitro micro-tuberization is an effective way of producing disease free quality planting material in potato which not only saves space significantly, but tubers can also be stored for longer time. However, it is influenced by several factors and the present study revealed that, micro-tuberization was found to be effective when single node cuttings were cultured on MS media supplemented with 50g/l of sucrose and 1mg/l of kinetin and keeping the cultured bottles in short day conditions of 8 hrs. light with 16 hrs. of dark period.

Acknowledgement : Authors profusely thank Late Prof. M. Udaya Kumar for having served as major mentor to carry out the work. The authors highly acknowledge the help rendered by Dr. Srikant, Dr. Raghavendra, Mr. Vishwas and the entire potato team who helped directly or indirectly. The fund provided by Indian Council of Agricultural Research, New Delhi, under National Agricultural Science Fund (NASF) is highly acknowledged.

References

ABURKHES, M., FAHMI, N., BENHMEDA, A., NAFFATI, M. AND ZIGLAM, A., 1991, Virus free potatoes by tissue culture in Libya. *Acta Horticulturae,* **289** : 77 - 79.

ALI, S., KHAN, N., NOUROZ, F., ERUM, S. AND NASIM, W., 2018, Effects of sucrose and growth regulators on the microtuberization of cip potato (*Solanum tuberosum*) germplasm. *Pak. J. Bot.,* **50** (2) : 763 - 768.

ALTINDAL, D. AND KARADOGAN, T., 2010, The effect of carbon sources on *in vitro* microtuberization of potato (*Solanum tuberosum* L.). *Turkish J. Field Crops*, **15** (1) : 7 - 11.

BADONI, A. AND CHAUHAN, J. S., 2010, *In vitro* sterilization protocol for micro propagation of *Solanum tuberosum* cv. 'Kufri Himalini'. *Academia Arena*., **2** (4) : 24 - 27.

BORNA, R. S., HOQUE, M. I. AND SARKER, R. H., 2019, *In vitro* microtuber induction and regeneration of plantlets from microtuber discs of cultivated potato *(Solanum tuberosum* L.). *Plant Tissue Cult. and Biotech*., **29** (1) : 63 - 72.

DESSOKY, E. L. D. S., ATTIA, O. A., ISMAIL, A. I. AND EHAB EL-HALLOUS, I., 2016, *In vitro* propagation of potato under different hormonal combination. *Int. J. Advanced Research*, **4** (1) : 684 - 689.

DOBRÁNSZKI, J., 2000, Effects of light and genetic origin on *in vitro* tuberization of potato. *Acta Agronomica Hungarica*., **48** (1) : 1 - 10.

DONNELLY, D. J., COLEMAN, W. K. AND COLEMAN, S. E., 2003, Potato microtuber production and performance : A review. *Amer. J. Potato Res*., **80** : 103 - 115.

FUFA, M. AND DIRO, M., 2014, Microtuber induction of two potato *(Solanum tuberosum* L.) varieties. *Adv. Crop. Sci. Tech.*, **2** : 2329 - 8863.

GARNER, N. AND BLAKE, J., 1989, The induction and development of potato microtubers *in vitro* on media free of growth regulating substances. *Ann. Bot.*, **63** : 663 - 674.

GIBSON, S. I., 2005, Control of plant development and gene expression by sugar signaling. *Current Opinion in Plant Biology*., **8** : 93 - 102.

GOPAL, J., CHAMAIL A. AND SARKAR, D., 2004, *In vitro* production of microtubers for conservation of potato germplasm : Effect of genotype, abscisic acid and sucrose. *In vitro Cell. Dev. Biol. Plant*, **40** : 485 - 490.

GOPAL, J., MINOCHA, J. L. AND DHALIWAL, H. S., 1998, Micro tuberization in potato (*Solanum tuberosum* L.). *Plant Cell Rep*., **1** (10) : 794 - 798.

HOSSAIN, S. M. D., HOSSAIN, M., HAQUE, M., HAQUE, M. D. AND SARKAR, M. D., 2017, Varietal evaluation of potato microtuber and plantlet in seed tuber production. *Int. J. Agronomy*, **10** : 1 - 5.

HUSSEY, G. AND STACEY, N. J., 1981, *In vitro* propagation of potato (*Solanum tuberosum* L.). *Ann. Bot*., **48** (6) : 787 - 796.

KHURI, S. AND MOORBY, J., 1995, Investigations into the roles of sucrose in potato cv. Estima microtuber production *in vitro*. *Ann. Bot.,* **75** : 295 - 303.

KONDHARE, K. R., KUMAR, A., NIKITA, S. P., MALANKAR, N. N., SAHA, K. AND BANERJEE, A. K., 2021, Development of aerial and below ground tubers in potato is governed by photoperiod and epigenetic mechanism. *Plant physio*., **1** : 1 - 16.

MACWAN, S. J., VAISHNAV, P. R., UPADHYAY, N. V. AND SHUKLA Y. M., 2017, Effect of photoperiod and different growth substances on microtuber production of potato (*Solanum tuberosum* L.). *Int. J. Agri. Sci*., **9** (27) : 0975 - 9107.

MAMIYA, K., TANABE, K. AND ONISHI, N., 2020, Production of potato (*Solanum tuberosum* L.) microtubers using plastic culture bags. *Plant Biotechnology*, **37** : 233 - 238.

MARTINEZ-GARCIA, F. J., ARIADNA VIRGOS-SOLER AND SALOME PRAT, 2002, Control of photoperiod-regulated tuberization in potato by the Arabidopsis flowering-time gene CONSTANS. *PNAS*., **99** (23) : 15211 - 15216.

MC-COWN, B. H. AND JOYCE, P. J., 1991, Automated propagation of microtubers of potato. In: Vasil IK (ed) Scale-Up and Automation in Plant Propagation. *Academic Press, San Diego*, pp. : 95 - 110.

MEENAKSHI, K., 2020, Modulation in growth and development of potato (*Solanum tuberosum* L.) microtubers by different concentration of 6-benzyl amino-purine. *African J. Plant Sci*., **14** (2) : 102 - 107.

NISTOR, A., CAMPEANU, G., ATANASIU, N., CHIRU, N., N. AND KARACSONYI, D., 2010, Influence of genotype on microtuber production. *Not. Bot. Hort. Agrobot. Cluj*., **38** (1) : 209 - 212.

OLGA, V. G., EUGENY, S. P. B., GAFITSKAYA IRINA, V. A., VERESHCHAGINA YULIA, V. A., BURKOVSKAYA ELENA, V. A., KHROLENKO YULIA, A. A., GRIGORCHUK VALERIA, P. A., NAKONECHNAYA OLGA, V. A., BULGAKOV VICTOR, P. A. AND KULCHIN YURI, N. B., 2022, Growth of micro-propagated *Solanum tuberosum* L. Plantlets under Artificial Solar Spectrum and Different Mono- and Polychromatic LED Lights. *Horticultural Plant J*., **8** (2) : 205 - 214.

OMOKOLO, N. D., BOUDJEKO, T. AND TSAFACK TAKADONG, J. J., 2003, *In vitro* tuberization of *Xanthosoma sagittifolium* L. Schott: effects of phytohormones, sucrose, nitrogen and photoperiod. *Scientia Horticulturae*, **98** : 337 - 345.

OZKAYNAK, E. AND SAMANCI, B., 2005, Yield and yield components of greenhouse, field and seed bed grown potato (*Solanum tuberosum* L.) plantlets. *Mediterranean Agricul. Sci*., **18** (1) : 125 - 129.

PAVITHRA, 2020, *In vitro* propagation of potato and characterization of *in vitro* grown plants. *M.Sc (Agri) thesis* submitted to the University of Agricultural Sciences, Bangalore.

PERL, A., AVIV, D. AND GALUN, E., 1991, Ethylene and in vitro culture of potato : Suppression of ethylene generation vastly improves protoplast yield, planting efficiency and transient expression of an alien gene. *Plant Cell Rep*., **7** (6) : 403 - 406.

PRUSKI, K, T., ASTATKIE, M., MIRZA. AND NOWAK, J., 2002, Photoautotrophic micropropagation of russet burbank potato (*Solarium tuberosum* L.). *Plant Cell Tissue and Organ Culture*, **69** (2) : 197 - 200.

RAHMAN, Z. M., ISLAM, S. M., CHOWDHURY, A. N. AND SUBRAMANIAM, S., 2015, Efficient microtuber production of potato in modified nutrient spray bioreactor system. *Scientia Horticulturae*, **192** : 369 - 374.

RANALLI, P., 1997, Innovative propagation methods in seed tube multiplication programmes. *Potato Res*., **40** (4) : 439 - 453.

RAVEESHA, K. A., 2014, Incidence of pests and diseases and storage behavior of early maturing genotypes of potato (Solanum tuberosum L.) in southern transition zone of Karnataka. *Mysore J. Agric. Sci.,* **48** (4) : 522 - 528.

ROSELLI, G., DE BESTOLDI, F. G. AND TIZIO, R., 1987, *In-vitro* mass tuberization as a contribution to potato micro propagation. *Potato Res*., **30** (1) : 111 - 116.

SALEM J. AND HASSANEIN A, M., 2016, In vitro propagation, microtuberization and molecular characterization of three potato cultivars. *Biologia plantarum*., **2** : 1 - 11.

SRIKANT TENGLI AND MOHAN RAJU, 2022, Optimizing nutrients formulation and spray schedule for aeroponically grown potato. *Mysore J. Agric. Sci.*, **56** (2) : 1 - 13.

Struik, P., C. and Wiersema, S., G., 1999, Seed Potato Technology. Wageningen Pers, Wageningen Academic Publishers, Netherlands., pp. : 383.

WANG, P. AND HU, C, 1982, *In vitro* mass tuberization and virus-free seedpotato production in Taiwan. *Amer. Potato J*.**,** **59** : 33- 37.

YU, W. C., JOYCE, P. J., CAMERON, D. C. AND MCCOWN, B, H., 2000, Sucrose utilization during potato microtuber growth in bioreactors. Plant Cell Report. **19** : 407 - 413.

Mysore J. Agric. Sci., 57 (1) : 71-81 (2023)

Perception of Farmers towards Koramangala - Challagatta (K. C.) Valley Project in Kolar District of Karnataka

J. Chithrashree[1], Y. N. Shivalingaiah[2] and T. L. Mohankumar[3]

[1&2]Department of Agricultural Extension; [3]Agricultural Statistics, Applied Mathematics and Computer Science, College of Agriculture, UAS, GKVK, Bengaluru - 560 065

e-Mail : chaithrashreej@gmail.com

Authors Contribution

J. Chithrashree & Y. N. Shivalingaiah : Conceptualization, Investigation, data analysis and draft prepration

T. L. Mohankumar : Data curation, sampling methods and methodology

Corresponding Author :

J. Chithrashree

Department of Agricultural Extension, College of Agriculture, UAS, GKVK, Bengaluru

Received : August 2022

Accepted : December 2022

Abstract

The present investigation was undertaken in Kolar district of Karnataka state during 2021-22 to analyse the farmer's perception about the Koramangala-Challaghatta Valley project (K.C. Valley Project), which is deemed to be a unique project in the country. It's a rare irrigation project and first of its kind in the country. Under this project, treated sewage water is used to fill irrigation tanks in Kolar and Chikkaballapura districts. Data was collected personally by the researcher through pretested interview schedule from 180 respondents. It was found that 40.00 per cent of marginal farmers belonged to better perception category followed by average (38.33%) and good (21.67%) perception category respectively. More than half of the small farmers (55.00%) belonged to average perception category followed by good (31.67%) and better perception (13.33%). Nearly two third of the big farmers (63.33%) belonged to good perception category followed by better (26.67 %) and average perception (10.00 %) category respectively. Relative importance index of perception as expressed by farmers is mentioned in this paper.

Keywords : K. C.Valley project, Perception, Treated water

The sustenance of life depends on the natural resources. Burgeoning growth in population exerting tremendous pressure on the land and other water resources. Due to rapid industrialization, the effluents are discharging into the lakes and water bodies. In most of the metropolitan cities it is a common phenomenon. Due to lack of drainage system, sometimes water will over flows and stagnates in puddles. Today, an estimated 80.00 per cent of global wastewater is being discharged untreated into the world's waterways (Anonymous, 2017). This affects the biological diversity of aquatic ecosystems and disrupts the fundamental web of our life support systems, on which a wide range of sectors from urban development to food production and industry depend.

In India, our capacity to treat sewage water is low as there is a low underground sewerage to transport wastewater and low number of Sewage Treatment Plants (STPs). Only two per cent towns in the country have both these facilities. Overall, there is capacity to treat only about 37 per cent of the 62 billion litres of sewage water generated daily by urban India. Currently, Bangalore generates 1400 Million Liters waste water per day (MLD), as per Bangalore Water Supply and Sewerage Board conservative estimates. The city has total treatment capacity of 721 MLD, but only 520 MLD gets treated on an average.

Globally, area under groundwater irrigation is highest in India (38 million ha) followed by China (19 million ha) and USA (17 million ha). In Karnataka, total replineshable groundwater potential for the state is estimated at 17.03 Billion Cubic Meters (BCM) received from both monsoon and non-monsoon seasons rainfall constitutes 9.48 BCM and recharge of 7.55 BCM from other sources (Krishna Raj and Chandrakanth, 2015). Kolar district has 26,144 hectares gross irrigated area, of which 17,135 (10.22%) hectares was net irrigated and remaining area was rainfed. Total number of wells in the district were 29,936 and ground water availability with the depth of 1,150 feet. Major irrigation sources include wells, bore wells and ponds etc. during the year 2012. The Central Ground Water Board (CGWB) assessment team reported about the groundwater situation of Kolar district. During 2016, the Kolar district falls in over exploited category across all blocks. There is a possibility to improve area under irrigation by augmenting groundwater recharge in all taluks as these blocks have exceeded the safer limits and fall in over-exploited category (Anonymous, 2020).

Considering the significance of waste water on production and productivity of agriculture and to meet the escalated demand for water, Karnataka Government's ambitious project of supplying treated water from Bengaluru to the arid districts came into existence during 2016 as Koramangala - Challagatta (K.C.) valley project aimed at increasing the groundwater table in Kolar district. Kolar is a drought prone area and ground water level is depleting over the years. A farmer used to spend up to Rs.5 lakh to sink a borewell with the hope of finding water. Often, the water used to dry up very soon and he would be left with a huge debt to repay. This K.C. Valley needs to be emulated across the Kolar to solve the problem of dry borewells and poor groundwater level. In K.C. Valley project, Bangalore sewage treated water is supplying to Kolar district. In this regard, it is essential to analyze the farmer's perception, acceptance and any religious barriers in utilization of sewage treated water for domestic as well as irrigation purpose. The present paper has been conceptualized with the objective of measuring perception of farmers towards K.C. Valley project.

Perception

According to Ray (1991), perception is an activity through which an individual becomes aware of objects around him and of events taking place. He considers perception as selective and we perceive what we want to perceive. Individual differs in perceiving the things and it is crucial to study the perception of people when a new project is implemented. Researcher operationally defined the Perception as 'process of awareness, comprehension or understanding and interpretation of KC valley project by the farmers'.

Methodology

The present study was purposively carried out in Kolar district of Karnataka State. Kolar and Srinivaspura taluks were selected purposively for the study as the numbers of tanks filled were more in these two taluks. The ex-post facto research design was used. Random sampling method was employed for the selection of respondents. The primary data were collected from 180 farm households, consisting of 90 farm households in Kolar taluk and 90 from Srinivaspura taluk. From each taluk, 30 marginal, 30 small and 30 big farmers were selected. The data were collected from the respondents through personal interview method using pre-tested and well-structured schedules. The responses were scored, classified, analyzed to calculate the mean score, Standard deviation and Relative importance Index using Microsoft excel -2019 and Kruskal-Wallis H test using SPSS.

Relative Importance Index

Relative Importance Index is calculated for each of the indicators of perception and ranked accordingly.

The RII derived to summarize the importance of each indicator:

$$RII = \frac{\sum W}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$$

Where,

W = weighting as assigned on Likert's scale by each respondent in a range from 1 to 5, where 1=Strongly disagree, 2=Disagree, 3=Undecided, 4=Agree and 5=Strongly Agree.

A = Highest weight (here it is 5)

N = Total number in the sample.

Kruskal - Wallis H test

The Kruskal - Wallis H test is a non-parametric one-way ANOVA on ranks used for testing whether samples originate from the same distribution. It was used in the study for comparing more than two independent samples of equal or different sample sizes.

Results and Discussion

Overall Perception of Farmers towards K.C. Valley Project

The data presented in the Table 1 depicts the overall perception of farmers towards K. C. Valley project. It is evident that two fifth of marginal farmers (40.00 %) belonged to better perception category followed by average (38.33%) and good (21.67%) perception category. Majority of the marginal famers had better to good perception. The probable reason is that, farmers might have availed irrigation facilities all round the year due to implementation of K.C. Valley project which enabled them to practice different cropping system, that resulted in securing better returns. The results are in line with the findings of Rajvendra and Kinjulck (2012).

It is clear from the Table 1, that more than half of the small farmers (55.00%) belonged to average perception category followed by good (31.67%) and better (13.33%) perception. More than three fifth of the big farmers (63.33%) belonged to good perception category followed by better (26.67 %) and average (10.00 %) perception category. The results are in conformity with the Younus (2013).

Majority of the small and big farmers had average to good perception; the probable reason for average and good perception may be that small and big farmers were not satisfied with the water quality. Further, they were more cosmopolite and educated, had knowledge regarding the importance of water quality, effects in agriculture. Majority of them also expressed their views during interview that because of the increase in water availability, marginal farmers and labourers working in their field are also started cultivating crops all-round the year and competing with small and big farmers. Further, In addition to this, they expressed that due to increased supply of produce they are not getting better prices for the produce in the market. This may be the reason for having average to good perception.

Overall, it is apparent from the table that almost equal number of farmers spread over into better (36.11%), good (32.22%) and average perception (36.11%) categories. The results are in line with Gopika and Lalitha (2018).

The farmers in the K.C. Valley region are having both positive as well as negative perception towards the project in their own way with so many benefits as well as lacunas. Hence, farmers were distributed over different perception categories.

Table 1

Overall perception of farmers towards K.C. valley project

Categories	Marginal farmers (n_1 = 60)		Small farmers (n_2 = 60)		Big farmers (n_3 = 60)		Total No. of farmers (n = 180)	
	No	%	No	%	No	%	No	%
Average (< 67.11)	23	38.33	33	55.00	6	10.00	57	31.67
Good (67.11 - 83.99)	13	21.67	19	31.67	38	63.33	58	32.22
Better (> 83.99)	24	40.00	8	13.33	16	26.67	65	36.11

Mean = 75.55 ; SD = 16.87

Statement Wise Perception of Farmers towards K.C. Valley Project based on Relative Importance Index

Marginal Farmer's Perception towards K. C. Valley Project based on Relative Importance Index

The data presented in Table 2 indicates that, marginal farmers strongly perceived the statement K.C. Valley project helped in increasing ground water table as relatively important (Rank I) followed by treated water reduces the demand and stress on fresh water supply (Rank II), treated water is harmful for consumption (Rank III), treated water will be an alternative to fresh water irrigation sources (Rank IV), cropping pattern has been changed after increased availability of ground water (Rank V), increasing in livestock farming by cultivation of more pasture through treated water (Rank VI) and treated water smells and it is unhygienic (Rank VII).

Marginal farmers expressed the following statement as moderately important: groundwater contamination after implementation of project (Rank VIII), cropping intensity has been increased after the implementation of K.C. Valley project (Rank IX) followed by use of treated water can leads to lower production cost and is economical (Rank X). The statement irrigation with waste water allows you to produce high value crops (Rank XI), income has been increased after the implementation of project (Rank XII), use of treated water will affect the health of the farmers and animals (Rank XIII) and the statement project helps in effective utilization of waste water (Rank XIV).

Relatively least important statements as perceived by marginal farmers were irrigation with treated water will act as insurance against drought and seasonal variability (Rank XV), willing to pay for the waste water (Rank XVI), treated water increases the nutrient availability to the crop (Rank XVII), Increase in ground water availability will increase the agricultural production as well as productivity (Rank XVIII) followed by the statement sewage treated water helps in increasing the speed of growth of crop (Rank XIX) and trust in the technology for making water safe for reuse (Rank XX).

The statement K.C. Valley project helped in increasing ground water table treated water reduces the demand and stress on fresh water supply was perceived as relatively important. Probable reason might be that treated water supply in Kolar region has enhanced the ground water recharge through deep percolation, water table has been increased and farmers are getting water at lowest feet as well. Treated water is used by the farmers for domestic as well as agricultural purposes. So by utilization of freely available water for irrigation as well as consumption, it is acting as an alternative source for fresh water.

Small Farmer's Perception towards K.C. Valley Project based on Relative Importance Index

The data presented in the Table 2 elicit the relative importance of small farmer's perception towards K.C. Valley project. Relatively most important statements as expressed by small farmers were K.C. Valley project helped in increasing ground water table (Rank I), treated water is harmful for consumption (Rank II), treated water reduces the demand and stress on fresh water supply (Rank III), treated water smells and it is unhygienic (Rank IV) followed by the statement cropping pattern has been changed after increase in groundwater table and cropping intensity has been increased after the implementation of K.C. Valley project (Rank V), project helps in effective utilization of waste water (Rank VII).

Moderately important statements as expressed by small farmers are increasing in livestock farming by cultivation of more pasture through treated water (Rank VIII), waste water will be an alternative to fresh water irrigation sources (Rank IX) groundwater contamination after implementation of project (Rank X). The statement treated water increases the nutrient availability to the crop (Rank XI), willing to pay for treated waste water and improved drainage facilities as (Rank XII), the use of treated water will affect the health of the farmers and animals (Rank XIII) use of treated water can leads to lower production cost and is economical

TABLE 2

Statement wise perception of farmers towards K.C. valley project based on relative importance index

(n=180)

Statements	Marginal farmers (n_1 = 60)		Small farmers (n_2 = 60)		Big farmers (n_3 = 60)	
	RII	Rank	RII	Rank	RII	Rank
Do you perceive treated water is harmful for consumption	0.790	III	0.847	II	0.793	XII
Do you perceive treated water smells and it is unhygienic	0.750	VII	0.793	IV	0.840	VII
Do you perceive, the use of treated water will affect the health of the farmers and animals	0.681	XIII	0.690	XIII	0.797	XI
K.C. valley project helped in increasing ground water table	0.950	I	0.977	I	0.970	I
Do you find groundwater contamination after implementation of project	0.713	VIII	0.720	X	0.677	XIX
Increase in ground water availability will increase the agricultural production as well as productivity	0.623	XVIII	0.617	XVII	0.690	XVIII
Do you have trust in the technology for making water safe for reuse	0.417	XX	0.460	XIX	0.397	XX
Irrigation with waste water allows you to produce high value crops	0.688	XI	0.663	XV	0.729	XVI
Do you perceive that project helps in effective utilization of waste water	0.680	XIV	0.763	VII	0.847	VI
Do you perceive that because of increase in ground water availability cropping pattern has been changed	0.780	V	0.767	V	0.863	V
Cropping intensity has been increased after the implementation of K.C. valley project	0.710	IX	0.767	V	0.877	III
Do you perceive that treated water reduces the demand and stress on fresh water supply	0.793	II	0.810	III	0.747	XIV
Do you perceive that treated water increases the nutrient availability to the crop	0.647	XVII	0.700	XI	0.900	II
Do you perceive that use of treated water can leads to lower production cost and is economical	0.703	X	0.680	XIV	0.757	XIII
Irrigation with treated water will act as insurance against drought and seasonal variability	0.677	XV	0.653	XVI	0.873	IV
Is there is increasing in livestock farming by cultivation of more pasture through treated water	0.751	VI	0.760	VIII	0.813	X
Sewage treated water helps in increasing the speed of growth of crop	0.540	XIX	0.280	XX	0.737	XV
Do you perceive, waste water will be an alternative to fresh water irrigation sources	0.783	IV	0.747	IX	0.823	IX
Are you willing to pay for treated waste water and improved drainage facilities	0.670	XVI	0.693	XII	0.830	VIII
Do you perceive that your income has been increased after the implementation of project	0.683	XII	0.590	XVIII	0.720	XVII

(Rank XIV), irrigation with waste water allows you to produce high value crops (Rank XV).

Small farmers perceived the following statements as relatively least important. The statement irrigation with treated water will act as insurance against drought and seasonal variability (Rank XVI), Increase in ground water availability will increase the agricultural production as well as productivity (Rank XVII), income has been increased after the implementation of project (Rank XVIII), trust in the technology for making water safe for reuse (Rank XIX) followed by sewage treated water helps in increasing the speed of growth of (Rank XX).

The statement K.C. Valley project helped in increasing ground water table treated water is harmful for consumption is perceived as relatively important. The probable reason treated water may remove contaminants but leave behind some of the by products, when they enter in the distribution system they might to harmful for consumption. Farmers expressed the statement sewage treated water helps in increasing the speed of growth of crop as least. Irrigation with treated water has proven beneficial effects on plant health and soil quality in countries having low water resources such as Middle East, United Arab emirates, Israel, Kuwait, Malta, Qatar and Saudi Arabia (Hashem and Xuebin, 2021). Lack of knowledge regarding these beneficial effects of using water may be the probable reason for this.

Big Farmer's Perception towards K.C. Valley Project based on Relative Importance Index

The data presented in Table 2, throws the light on the Relative importance of big farmer's perception towards K.C. Valley Project. Big farmers perceive the following statements as relatively important. The statement K.C. Valley project helped in increasing ground water table (Rank I) treated water increases the nutrient availability to the crop (Rank II), cropping intensity has been increased after the implementation of K.C. Valley project (Rank III), irrigation with treated water will act as insurance against drought and seasonal variability Rank (IV), cropping pattern has been changed due to increase in ground water availability (Rank V). The project helps in effective utilization of waste water (Rank VI)

Moderately important statement as perceived by big farmers are sewage treated water smells and it is unhygienic (Rank VII), willing to pay for treated waste water and improved drainage facilities (Rank VIII), waste water will be an alternative to fresh water irrigation sources (Rank IX) and increasing in livestock farming by cultivation of more pasture through treated water (Rank X). The statement the use of treated water will affect the health of the farmers and animals (Rank XI), treated water is harmful for consumption (Rank XII) treated water can leads to lower production cost and is economical (Rank XIII), treated water reduces the demand and stress on fresh water supply (Rank IV), Sewage treated water helps in increasing the speed of growth of crop (Rank XV).

The statement irrigation with waste water allows you to produce high value crops (Rank XVI), income has been increased after the implementation of project (Rank XVII), ground water availability will increase the agricultural production as well as productivity (Rank XVIII) followed by groundwater contamination after implementation of project (XIX) and trust in the technology for making water safe for reuse (Rank XX).

The statement K.C. Valley project helped in increasing ground water table as highly important and ranked first important. Kolar district ground water table is plummeted below ground level over past few years. The supply of K.C. Valley water has helped in increasing the water table as well as water availability. The statement groundwater contamination after implementation of project and trust in the technology for making water safe for reuse is perceived as least important by farmers. The probable reason might be in long range the soil quality and water quality may deteriorate by accumulation of impurities if water is not treated properly and farmers lacks knowledge and awareness about the water treatment process as well as treatment plant.

Statement wise Overall Farmers Perception towards K.C. Valley Project based on Relative Importance Index

The data presented in Table 3, depicts the relative importance of farmers perception towards K.C. Valley project. Relatively most important statements as expressed by overall farmers are K.C. Valley project helped in increasing ground water (Rank I), treated water is harmful for consumption (Rank II), treated water smells and it is unhygienic (Rank III), the use of treated water will affect the health of the farmers and animals (Rank IV) followed by increase in livestock farming by cultivation of more pasture through treated water (Rank V). The statement treated water reduces the demand and stress on fresh water supply (Rank VI), cropping intensity has been increased after the implementation of K.C. Valley project (Rank VII).

Moderately important statements as expressed by overall farmers are project helps in effective utilization of waste water (VIII), cropping pattern has been changed due to increase in groundwater availability (Rank IX), irrigation with treated water will act as insurance against drought and seasonal variability (Rank X), treated water increases the nutrient availability to the crop ranked (Rank XI), willing to pay for treated waste water and improved drainage facilities (Rank XII), treated water can leads to lower production cost and is economical (XIII), waste water will be an alternative to fresh

TABLE 3

Statement wise overallfarmersperception towards K. C. valley project based on relative importance index

(n=180)

Statements	RII	Rank
Do you think treated water is harmful for consumption	0.810	II
Do you think treated water smells and it is unhygienic	0.799	III
Do you think, the use of treated water will affect the health of the farmers and animals	0.794	IV
KC valley project helped in increasing ground water table	0.824	I
Do you find groundwater contamination after implementation of project	0.724	XV
Increase in ground water availability will increase the agricultural production as well as productivity	0.666	XVIII
Do you have trust in the technology for making water safe for reuse	0.391	XX
Irrigation with waste water allows you to produce high value crops	0.714	XVI
Do you think, project helps in effective utilization of waste water	0.757	VIII
Do you think , because of increase in ground water availability cropping pattern has been changed	0.750	IX
Cropping intensity has been increased after the implementation of KC valley project	0.763	VII
Do you think, treated water reduces the demand and stress on fresh water supply	0.790	VI
Do you think , treated water increases the nutrient availability to the crop	0.747	XI
Do you think use of treated water can leads to lower production cost and is economical	0.743	XIII
Irrigation with treated water will act as insurance against drought and seasonal variability	0.749	X
Is there is increasing in livestock farming by cultivation of more pasture through treated water	0.791	V
Sewage treated water helps in increasing the speed of growth of crop	0.568	XIX
Do you think , waste water will be an alternative to fresh water irrigation sources	0.730	XIV
Are you willing to pay for treated waste water and improved drainage facilities	0.744	XII
Do you think, your income has been increased after the implementation of project	0.693	XVII

*RII- Relative Importance Index

water irrigation sources (Rank IV), groundwater contamination after implementation of project (Rank XV).

Relatively least important statement as expressed by overall farmers were waste water allows you to produce high value crops (Rank XVI), income has been increased after the implementation of project (Rank XVII), Increase in ground water availability will increase the agricultural production as well as productivity (Rank XVIII) and sewage treated water helps in increasing the speed of growth of crop (Rank XIX) and trust in the technology for making water safe for reuse (Rank XX).

The statement K.C. Valley project helped in increasing ground water table perceived as highly important by marginal, small and big farmers. The farmers in Kolar district were facing severe droughts and decline in groundwater table over the past few years. K.C. Valley becomes relevation to farmers in building confidence among them and K.C. Valley project has been implemented with the objective of groundwater recharge and it has successfully accomplishing the objective.

The statement trust in the technology for making water safe for reuseranked relatively least important by the farmers the probable reason may be that authorities might not create any awareness regarding the treatment process, frequent servicing needs to be done in treatment plant which may not be visible to farmers, farmers having limited knowledge on wastewater management.

Statement wise Perception of Farmers towards K.C. Valley Project

The data presented in the Table 4, indicates the statement wise perception of farmers towards K.C. Valley project. Table 4, portrays that more than three fourth (86.11%) of the farmers strongly agreed the statement K.C. Valley project helped in increasing ground water table. The farmers in Kolar district were facing severe droughts and decline in groundwater table over the past few years. K.C. Valley becomes relevation to farmers in building confidence among them. K.C. Valley project has been implemented with the objective of groundwater recharge and the purpose has been achieved. Hence, they opinioned that it helped in increasing the ground water table. The results are in conformity with the findings of Ramesh (2020).

The statement the use of treated water will affect the health of the farmers and animal was strongly agreed by 43.89 per cent of respondents. The probable reason might be that, during the interview farmers expressed that there was a occurrence of death of animals by direct consumption of water from the lake. So, farmers were afraid about that and if water is used for drinking purpose without filtering it might cause diarrhea and other health issues.

It is evident from the table that two-fifth (42.78%) of the respondents strongly agreed that cropping pattern has been changed due to increase in groundwater availability after the implementation of the project and agreed the statement cropping intensity has been increased after the implementation of K.C. Valley project (48.33%). The results of Pavithra and Gaddi (2022) also revealed that crop diversification in K.C. Valley region was comparatively higher compare to Non K.C. Valley region. After implementation of project, there is an increased water availability, which made farmers to cultivate more number of vegetable crops in K.C. Valley region. Thus, there was an increased cropping intensity in the project area irrespective of farmer's category. The respondents are cultivating vegetables in all the three agriculture seasons due to increased water table as well as water availability. Further, they adopted multiple cropping as well as sequential cropping in that region which could be the probable reason for the same. Apart from this, particularly marginal farmers started cultivating vegetables and flower crops instead of cereal crops because of availability of water.

Equal number of the respondents (43.89%) strongly agreed on the statement that use of treated water will affect the health of farmers, found groundwater contamination after the implementation of project the treated water sometime consists of human fecal waste,

TABLE 4

Statement wise perception of farmers towards K.C. valley project

(n=180)

Statements	SA	A	UD	DA	SDA	Mean score	Rank
Do you perceive treated water is harmful for consumption	65 (36.11)	59 (32.78)	56 (31.11)	0 (0.00)	0 (0.00)	4.05	III
Do you perceive treated water smells and it is unhygienic	42 (23.33)	101 (56.12)	31 (17.22)	6 (3.33)	0 (0.00)	3.99	IV
Do you perceive, the use of treated water will affect the health of the farmers and animals	79 (43.89)	60 (33.33)	24 (13.33)	17 (9.44)	0 (0.00)	4.12	II
KC valley project helped in increasing ground water table	155 (86.11)	19 (10.56)	6 (3.33)	0 (11.11)	0 (0.00)	4.83	I
Do you find groundwater contamination after implementation of project	79 (43.89)	12 (6.67)	32 (17.78)	57 (31.67)	0 (0.00)	3.63	XV
Increase in ground water availability will increase the agricultural production as well as productivity	36 (20.00)	29 (16.11)	77 (42.78)	34 (18.89)	4 (2.22)	3.33	XVIII
Do you have trust in the technology for making water safe for reuse	0 (0.00)	7 (3.89)	43 (23.89)	65 (36.11)	65 (36.11)	1.96	XX
Irrigation with waste water allows you to produce high value crops	50 (27.78)	55 (30.56)	33 (18.33)	30 (16.67)	12 (6.67)	3.56	XVII
Do you perceive, project helps in effective utilization of waste water	72 (40.00)	40 (22.22)	34 (18.89)	26 (14.44)	8 (4.44)	3.79	IX
Do you perceive , because of increase in ground water availability cropping pattern has been changed	77 (42.78)	38 (21.11)	17 (9.44)	40 (22.22)	8 (4.44)	3.76	XI
Cropping intensity has been increased after the implementation of KC valley project	57 (31.68)	87 (48.33)	23 (12.78)	4 (2.22)	9 (5.00)	3.99	IV
Do you perceive, treated water reduces the demand and stress on fresh water supply	59 (32.78)	32 (17.78)	70 (38.89)	15 (8.33)	4 (2.22)	3.71	XIII
Do you perceive, treated water increases the nutrient availability to the crop	77 (42.78)	30 (16.67)	45 (25.00)	21 (11.67)	7 (3.89)	3.83	VIII
Do you perceive use of treated water can leads to lower production cost and is economical	61 (33.89)	54 (30.00)	15 (8.33)	44 (24.44)	6 (3.33)	3.67	XIV
Irrigation with treated water will act as insurance against drought and seasonal variability	63 (35.00)	70 (38.89)	12 (6.67)	27 (15.00)	8 (4.44)	3.85	VII
Is there is increasing in livestock farming by cultivation of more pasture through treated water	64 (35.56)	34 (18.89)	37 (20.56)	40 (25.56)	5 (2.78)	3.62	XVI
Sewage treated water helps in increasing the speed of growth of crop	35 (19.44)	62 (34.44)	16 (8.89)	46 (25.56)	21 (11.67)	3.24	XIX
Do you perceive , waste water will be an alternative to fresh water irrigation sources	61 (33.89)	62 (34.44)	21 (11.67)	24 (13.33)	12 (6.67)	3.76	XI
Are you willing to pay for treated waste water and improved drainage facilities	69 (38.33)	41 (22.78)	40 (22.22)	23 (12.78)	7 (3.89)	3.79	IX
Do you perceive, your income has been increased after the implementation of project	54 (30.00)	66 (36.67)	46 (25.56)	11 (6.11)	3 (1.67)	3.87	VI

medicinal and industrial wastages; if the water is not treated properly it may cause harmful effect on human beings. Direct consumption of water by humans as well as animals for drinking purpose has caused diarrhea and vomiting. Direct release of improperly treated water may contaminate the groundwater. Hence they perceive that in the long run treated water will affect the health of the farmers. Due to increased water availability to farmers, farmers started fodder crops in the waste land, when water flows through the channel pasture growth has become more prominent in that area that has given chance for rearing more livestock animals in that area. While informal discussion with the researcher some of the respondents expressed that some of the animals died by consumption of sewage water directly from the lake. So, people might have negative opinion about water quality.

More than fifty percent of the respondents (56.12%) agreed that treated water smells and it is unhygienic. Some bacterial growth occurs in the drains, some anaerobic decomposition of organic compounds will takes place. More than two fifth of the respondents (43.89%) agreed that waste water will be an alternative to fresh water irrigation sources. The probable reason may be that, famers are using treated water as alternative for all the domestic as well as irrigation purposes as a result they perceive waste water is an alternative to freshwater irrigation source.

Nearly fifty percent of the respondents (42.78%) were undecided about the statement ground water availability will increase the agricultural production as well as productivity. About 40.00 per cent of the respondents disagreed the statement that sewage treated water helps in increasing the speed of growth of crop.

None of them strongly disagreed on the statement that do you have trust in the technology for making water safe for reuse. Famers are not having trust in the technology, because sometime water color is not good, it smells and they feel that it is unhygienic. Hence, frequent checking of the quality of water as well as soil needs to be done in project area to make water safe for reuse.

Significant per cent of farmers perceived that their income has been increased after the implementation of project, irrigation with treated water acts as insurance against drought and seasonal variability, use of treated water can leads to lower production cost and economical

Comparison of Perception of Marginal, Small and Big Farmers about K.C. Valley Project

Kruskal wallies test was applied to test the significant difference between marginal, small and big farmers. (Table 5). The mean rank obtained from the test for big farmers is 108.78 followed by small farmers (mean rank = 95.73) and marginal farmers (mean rank = 108.78) respectively. It is found that there is a significant difference in perception of marginal, small and big farmers about K.C. Valley project at one per cent of probability. Perception depends on individual and vary from one person to another person, small farmers perceive the things in one way, marginal farmers perceive in another way and big farmers perceive in different way. Hence, there exists a significant difference between them.

Majority of the respondents had both positive as well as negative perception about K.C. Valley project. Significant per centage of farmers expressed that the use of treated water will affect the health of the farmers and animals, treated water is harmful for

Table 5

Comparison of perception of marginal, small and big farmers about K.C.valley project

Category	Sample size	Mean Rank	H-Value	P
Marginal farmers	60	66.99	20.239	0.001
Small farmers	60	95.73		
Big farmers	60	108.78		

consumption in the long run as its smells and unhygienic. It indicates that people lacks trust and confidence in public agencies as well as decline in belief that best technologies can remove impurities and germs. In this regard, there is a need of multidisciplinary action in educating farmers to develop trust and confidence. Frequent water quality testing and monitoring is needed at the grass root level by concerned agencies so that in the long run farmers develops confidence about the technology followed to treat sewage water and use the water effectively and efficiently for agricultural and other purposes.

REFERENCES

ANONYMOUS, 2017, Waste water: the untapped resource, UN World water development report.

ANONYMOUS, 2020, Ground water year book, Government of Karnataka, India.

GOPIKA, M. H. AND LALITHA, K. C., 2018, Perception of beneficiary and non-beneficiary farmers towards integrated farming system demonstration (IFSD). *Mysore J. Agric. Sci.,* **52** (2) : 227 - 233.

HASHEM, S. M. AND XUEBIN QI., 2021, Treated water irrigation : A review. *Water*, **13** : 1527

KRISHNA RAJ AND CHANDRAKANTHA, M. G., 2015, Water resources and irrigation management, State of environment report for karnataka 2015. Government of Karnataka, Environmental Management & Policy Research Institute (EMPRI), pp. : 10.

PAVITHRA, K. N. AND GADDI, G. M., 2022, Drivers of crop diversification : An empirical evidence from eternally drought prone area of Karnataka. *Mysore J. Agric. Sci*., **56** (1) : 244 - 251.

RAJVENDRA, B. AND KINJULCK, C., 2012, Perception of farmers towards seed village programme in Madhya Pradesh. *Mysore J. Agric. Sci.,* **46** (3) : 628 - 633.

RAMESH, N., 2020, An economic impact assessment of supplying treated sewage water to irrigation tanks on farming in Kolar district under KC valley project. *M.Sc. (Agri.) Thesis* (Unpub.), Univ. Agric. Sci., Bangalore.

SHWETHA, N. V., 2016, Performance and perception about different farming systems adopted by farmers of Chickaballapura district of Karnataka. *M.Sc. (Agri.) Thesis* (Unpub.), Univ. Agric. Sci., Bangalore.

YOUNUS, M. D., 2013, Awareness and perception of integrated farming system by SC/ST farmers. *M.Sc. (Agri.) Thesis,* (Unpub.), Univ. Agric. Sci., Dharwad, Karnataka, India.

Mysore J. Agric. Sci., 57 (1) : 82-88 (2023)

Phenological Studies on Parental Lines of Promising Maize Hybrids for their Seed Production Potentiality

T. N. DEEPAK AND S. N. VASUDEVAN
Department of Seed Science & Technology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : deepak.tn01@gmail.com

AUTHORS CONTRIBUTION
T. N. DEEPAK : Investigation, methodology, orginal draft;
S. N. VASUDEVAN : Conceptualization, supervision, review and editing

Corresponding Author :
T. N. DEEPAK
Dept. of Seed Science and Technology, College of Agriculture, UAS, GKVK, Bengaluru

Received : August 2022
Accepted : February 2023

ABSTRACT

The field and laboratory experiments were conducted at ZARS, V. C. Farm, Mandya, during *kharif* 2020 to study the phenology of parental lines of promising maize hybrids for their seed production potentiality. The results revealed that mean sum of squares due to parental lines indicated significant differences for growth and yield parameters *viz.,* field emergence, plant height, cob length, cob weight, number of rows per cob, number kernels per row and seed yield per hectare and quality parameters *viz.,* hundred seed weight, seed germination, mean seedling length and seedling vigour index I and II. Among the parental lines MAI-729 has showed significantly higher cob weight (114.33 g), hundred seed weight (29.11 g), seed yield per hectare (45.71 q ha^{-1}) and seed vigour index-I and II (3550 and 7673, respectively). Therefore, MAI-729 line could be recommended for breeding and seed production programmes.

Keywords : Parental lines, Days to 50 per cent flowering, Seed yield, Quality

MAIZE (*Zea mays* L.) is one of the important versatile and staple cereal crops of the world and ranks next to wheat and rice. Maize has been an important cereal because of its great production potential and adaptability under wide range of environments. Maize occupies an important place in Indian economy, like rice, wheat and millets. Besides being a potential source of food for human being, it is also used for feeding cattle, poultry and industries for the production of starch, syrup, alcohol, acetic acid, lactic acid *etc*.

Globally, maize is cultivated on an area of 193.7 million hectares with production of 1147.7 million ton with productivity of 5750 kg ha^{-1} (FAO, 2020). In India, maize is grown over an area of 9.89 million hectares with a production of 31.65 million ton and productivity of 3199 kg ha^{-1}. In Karnataka, it is cultivated in an area of 1.34 million hectares with production of 3.98 million ton accounting the productivity of 3305 kg ha^{-1} (DES., 2021).

Maize is the only cereal crop which will be grown in various seasons and requires moderate climate for their growth. Being a C_4 plant, it is physiologically more efficient and has higher yield potential and wider adaptability over environmental conditions. The production and utilization potential of maize in the recent times is not only attracting the attention of research scientists, but also evolving major National and International Research thrusts, with a view to provide solutions to various problems of maize particularly in terms of poor genetic potential, low seed yield, poor adaptation to various agro ecologies and overall poor performance of some varieties. For achieving the successes of crop improvement programme not only depend on amount of genetic variability present in the population but also, it can be achieved through selection of genotypes based on phenological parameters *viz.,* days to 50 per cent tasseling and silking days to maturity, plant height, number of rows per cob, grain number per cob, seed yield traits and seed quality traits (germination, seedling length and seedling vigour index).

The study of phenology is one of the most important functions that determines the crop growth and development of any crop and is essential to acquire knowledge on the physiological response of the crop under different field conditions. The phenology of the crop is influenced by parameters like the crop genotype, nutrient, biotic, abiotic, yield potential and weather parameters (Chakravarthy and Jagannathan, 2014). Hence, study of phenological characters would make possible to selection of varieties for future breeding, propagation and production purpose.

Methodology

The experiment was laid out in randomized complete block design during *kharif* 2020 to study the crop growth, days to flowering, seed yield and quality in parental lines of promising maize hybrids with three replications at ZARS, V.C. Farm, Mandya and Department of Seed Science and Technology, UAS, GKVK, Bengaluru. Seeds of each parental lines were sown on a 3 m long row with an inter-plant spacing of 30 cm and an inter- row spacing of 60 cm. Normal agronomic practices were followed to raise the crop. The experiment consists of ten treatments (parental lines) *viz.* P_1: MAI 729, P_2: MAI 105, P_3: NAI 137, P_4: SKV 50, P_5: CAL 1443, P_6: CML 451, P_7: DH 388, P_8: DH 371, P_9: DH 376, P_{10}: DH 545. Observations on growth and yield attributes were recorded on five randomly selected plants from each plot during *kharif* 2020 season. Freshly harvested seeds of parental lines were collected and an observation on seed quality attributes was recorded as per the ISTA rules (ISTA., 2019).

Results and Discussion

Growth and Yield Parameters

The results of phenology of parental lines of maize hybrids examined on field emergence were significant (Table 1). However, NAI-137 had significantly highest field emergence (90.50%) followed by MAI-729, MAI-105, SKVV-50, CAL-1443 and CML-451, while DH-376 had the lowest (65.00%). The ultimate test of seed vitality is field emergence. This variation in field emergence among parental lines could be attributed to their genetic makeup, as reported by Sharma *et al.* (2020) in maize.

Significant difference was observed among the parental lines for plant height at harvest. The plant

Table 1

Mean performance of parental lines of maize hybrids for their growth parameters

Parental lines	Field emergence (%)	Plant height (cm)	Days to 50 % tasseling	Days to 50 % silking	Days to maturity	Cob length (cm)
P_1 : MAI-729	85.27	152.33	55.00	57.00	102.00	13.36
P_2 : MAI-105	83.33	149.33	57.00	58.00	104.00	13.48
P_3 : NAI-137	90.50	151.00	56.00	58.00	106.00	11.89
P_4 : SKV-50	82.90	142.67	54.00	54.00	97.00	9.42
P_5 : CAL-1443	80.00	133.00	58.00	59.00	113.00	13.83
P_6 : CML-451	83.33	127.67	63.00	65.00	114.00	12.50
P_7 : DH-388	75.00	147.00	57.00	57.00	95.00	9.83
P_8 : DH-376	65.00	146.33	62.00	64.00	97.00	8.83
P_9 : DH-371	79.17	161.67	57.00	57.00	97.00	14.67
P_{10} : DH-545	70.00	137.00	57.00	57.00	108.00	10.17
Mean	79.45	144.80	57.60	58.60	103.30	11.80
SEm±	3.62	5.19	2.55	2.61	4.58	0.63
CD (P= 0.05)	10.84	15.57	NS	NS	NS	1.87

height ranged from 127.67 cm (CML-451) to 161.67 cm (DH-371) with a mean of 144.80 cm (Table 1). Significantly higher plant height was noticed in DH-371 followed by MAI-729, MAI-105, NAI-137, DH-388 and DH-376. The lowest plant height was found in CML-451. Plant height is an important trait because it is often associated with logging and lodging of plants under unfavorable situations. This variation may be attributed to their genetic background. Higher plant height may be attributable to earlier field emergence, which boosted the plant's resistance to heat and drought, resulting in higher plant height at harvest. The similar findings reported by Hidayat *et al.* (2008) and Manjunath *et al.* (2018) in maize.

Days to 50 per cent tasseling and silking did not differ significantly among parental lines (Table 1). However, SKV-50 had taken lesser days for flowering (54.00 and 54.00 days, respectively) and CML-451 has taken longer days to flowering (63.00 and 65.00 days, respectively). Furthermore, all the parental lines come under medium and late flowering groups as per the DUS guidelines. These parental populations were noted to be quite earlier than the checks and could be used as germplasm source in developing varieties with early maturity. Variability may be attributed to their differential genetic constitution and also due to speed of emergence, improved field stand and vigorous growth of plant. The above results are in line with previous findings of Hidayat *et al.* (2008) and Kiran and Channakeshava. (2017) in maize.

Non-significant difference was noticed for number of days taken to maturity among parental lines. CML-451 matured in 114 days while, CAL-1443 and DH-545 taken 113 and 108 days for maturation, respectively. The earliest maturation was noticed in DH-388 (Table 1). Flowering and maturity period are essential qualities that are typically taken into account before a variety is released for commercial use. Early flowering and maturity ensure the visible uniformity of a crop field which is always preferred by farmers. This might be due to better utilization nutrients and moisture among the parental lines populations. Similar results were also reported by Ibrahim and Mukhtar (2016) and Anil kumar (2018).

The phenotypic character pertaining to cob length varied significantly among the parental lines (Table 1). It was found that higher cob length recorded in DH-371 (14.67cm) followed by MAI-729, MAI-105 and CAL-1443. Whereas the parental line DH-376 (8.83 cm) recorded lower cob length. The trait cob weight also differed significantly among the parental lines (Table 2 and Fig. 1). It was ranged from 54.27 grams (DH-376) to 114.33 grams (MAI-729) with a mean of 85.79 grams. However, higher cob weight recorded in MAI-729 followed by MAI-105 and DH-371 while, lowest cob weight was noticed in DH-376.

Significant differences were observed among parental lines of promising maize hybrids for number of rows per cob. The number of rows per cob ranged from 11.33 (DH-388 and DH-376) to 16.67 (CAL-1443) with a mean of 13.78. Similarly, the trait number of kernels per row also differed significantly among parental lines. The number of kernels per row was ranged from 16.33 (DH-376) to 23.94 (MAI-729) with a mean of 19.44 (Table 2).

Wietholter *et al.* (2008) concluded that, the traits contributed majorly to the classification of Brazilian corn landraces were plant height, ear insertion, female flowering, male flowering and kernel row number per ear, cob length and cob diameter. Though both qualitative and quantitative characters could be a better descriptive for grouping the maize genotypes, but high heritable traits are much useful in selection of inbreds for further breeding programme. Similar results were in line with Shashibhaskar (2015) in maize, Madhukeshwara and Sajjan (2015) in maize and Arjun *et al.* (2021) in white maize.

Seed yield per cob and seed yield per hectare showed significant differences among the parental lines of promising maize hybrids (Table 2). Among parental lines, MAI-729 lines showed highest seed yield per cob and seed yield per hectare (94.61 g and 45.71 q ha^{-1}, respectively) which was followed by MAI-105. Whereas lower seed yield per cob and

TABLE 2

Mean performance of parental lines of maize hybrids for yield parameters

Parental lines	Cob weight (g)	Number of rows per cob	Number of kernels per row	Seed yield per cob (g)	Seed yield (q ha^{-1})
P_1 : MAI-729	114.33	15.45	23.94	94.61	45.71
P_2 : MAI-105	113.44	16.58	20.67	90.08	43.37
P_3 : NAI-137	93.40	14.73	22.07	72.60	37.96
P_4 : SKV-50	71.33	12.72	16.39	58.72	28.94
P_5 : CAL-1443	80.67	16.67	21.00	66.33	30.96
P_6 : CML-451	86.67	14.67	17.33	69.67	33.54
P_7 : DH-388	63.60	11.33	16.67	53.33	24.63
P_8 : DH-376	54.27	11.33	16.33	43.00	17.89
P_9 : DH-371	106.82	12.67	23.00	90.00	38.25
P_{10} : DH-545	73.33	11.67	17.00	63.67	23.21
Mean	85.79	13.78	19.44	70.20	32.45
SEm±	3.96	0.62	1.37	3.39	1.66
CD(P= 0.05)	11.87	1.85	4.11	10.15	4.97

seed yield per hectare was recorded in DH-376 (43.00 g and 17.89 q ha^{-1}).

The variation in the yield potential is probably due to the diverse background of parental lines (Fig. 1). Positive and significant association of cob weight and hundred seed weight contribute to more seed yield. The significant positive correlation between seed yield to hundred seed weight and cob weight implies that the selection of these traits is important to improve the seed yield of the parental lines (Prasad and Shrestha, 2020). The above findings were in accordance with Daniel (2014) and Dhakal *et al.* (2017) in maize genotypes.

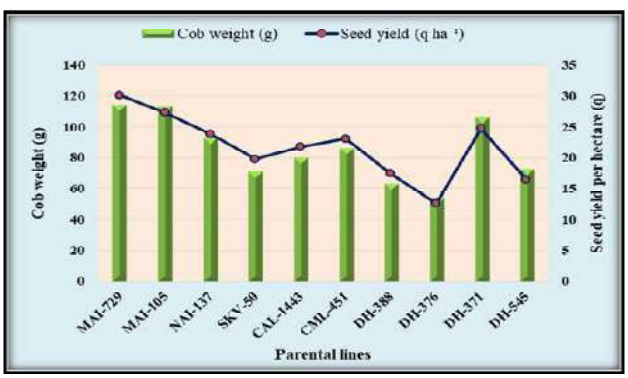


Fig. 1: Variation of cob weight (g) and seed yield (q ha^{-1}) in parental lines of maize hybrids

Seed Quality Parameters

Hundred seed weight is one of the important distinguishing features used by several scientists to differentiate several crop varieties. The study revealed that hundred seed weight was differed significantly among the parental lines (Table 3). Significantly higher hundred seed weight was observed in MAI-729 (29.11 g) followed by NAI-137, CAL-1443 and CML-451. Whereas lower hundred seed weight was observed in DH-376 (19.18 g). The variation among the parental lines might be due to inherent genotypic differential conditions that had existed during the crop growth, seed development and maturation stage. The genotypic variation in hundred seed weight may also be due to the reserved food material accumulated in the genotypes. Similar pattern of classification was reported earlier by Pinnisch *et al.* (2012) in maize and Bhusal *et al.* (2017) in sorghum.

Among the parental lines no significant differences were observed for seed germination percentage. The seed germination percentage ranged from 91.33 to 98.33 with a mean of 95.93 per cent (Table 3). However maximum seed germination percentage

TABLE 3

Mean performance of parental lines of maize hybrids for seed quality parameters

Parental lines	Hundred seed weight (g)	Germination (%)	Shoot length (cm)	Root length (cm)	Mean seedling length (cm)	Seedling dry weight (mg)	Seedling vigour Index-I	Seedling vigour Index-II	Electrical conductivity of seed leachate (µSm^{-1})
P_1 : MAI-729	29.11	98.33	17.07	19.03	36.10	78.03	3550	7673	188.00
P_2 : MAI-105	24.75	97.33	16.03	18.00	34.03	73.20	3313	7125	217.15
P_3 : NAI-137	27.63	97.67	16.56	18.41	34.97	74.60	3415	7286	198.14
P_4 : SKV-50	22.71	96.00	14.60	16.86	31.46	65.72	3020	6309	231.71
P_5 : CAL-1443	27.54	97.00	16.20	18.11	34.31	67.00	3338	6499	219.59
P_6 : CML-451	28.12	97.00	16.34	18.28	34.62	76.40	3358	7411	244.84
P_7 : DH-388	21.46	94.33	14.80	15.67	30.47	64.28	2874	6064	277.33
P_8 : DH-376	19.18	91.33	13.16	16.35	29.52	63.12	2696	5765	317.33
P_9 : DH-371	24.72	96.00	15.47	17.21	32.68	73.28	3137	7035	239.83
P_{10} : DH-545	20.60	94.33	13.76	16.46	30.22	63.60	2851	6000	295.49
Mean	24.58	95.93	15.40	17.44	32.84	69.92	3154	6717	242.94
SEm±	0.67	1.89	0.42	0.47	0.63	1.66	84.44	161.54	5.54
CD(P=0.05)	1.97	NS	1.23	1.38	1.84	4.90	249.09	476.55	16.33

was observed in MAI-729 (98.33%) and minimum seed germination percentage was observed in DH-376 (91.33%). This is due to increase in activity of enzymes such as amylase, protease and lipase which have great role in breakdown of macromolecules for growth and development of embryo that ultimately resulted in higher seedling emergence. Similar findings were reported by Hidayat *et al.* (2008) and Manjunatha *et al.* (2018) in maize genotypes.

Significant differences were observed among the parental lines of promising maize hybrids for shoot, root and mean seedling length (Table 3). The results showed that highest shoot, root and mean seedling length was recorded in MAI-729 (17.07, 19.03 and 36.10 cm, respectively) which was followed by NAI-137, CAL-1443 and CML-451. Whereas lowest shoot, root and mean seedling length was recorded in DH-376 (13.16, 16.35 and 29.52 cm, respectively).

Mean seedling dry weight was differed significantly among the parental lines (Table 3). Higher mean seedling dry weight was observed in MAI-729 (78.03 mg) which was followed by MAI-105, NAI-137 and CML-451 and lower seedling dry weight was observed in DH-376 (63.12 mg).

Among the parental lines significant differences were observed for seedling vigour index I and II (Table 3 and Fig. 2). Significantly higher seedling vigour index-I and II was recorded in MAI-729 (3550 and 7673, respectively) and lower seedling vigour index-I and II was recorded in DH-376 (2696 and 5765, respectively).

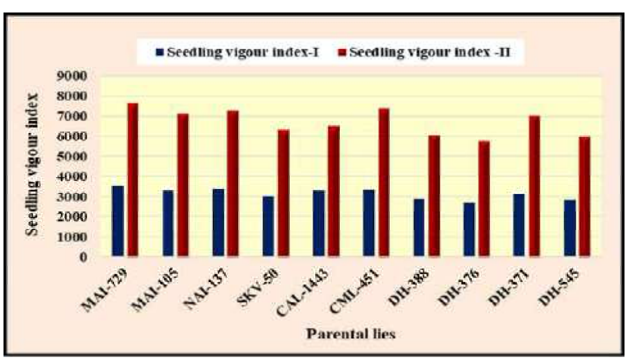


Fig. 2 : Variation of seedling vigour index-I and II in parental lines of maize hybrids

Significant variation was found among parental lines for seed quality parameters *viz.,* shoot, root and mean seedling length, seedling dry weight and seed vigour index except germination percentage. Variation among the parental lines might be due to accumulation reserve food material *viz.* carbohydrates, protein and soluble sugars that existed during seed formation, development and maturation stage. The mean seedling length, seedling dry weight and seedling vigour index were all positively correlated with hundred seed weight. Similar findings were reported by Ahammad *et al.* (2014), Anil Kumar (2018) and Vijay Lakshmi and Siddaraju (2021) in maize.

Electrical conductivity of seed leachate was differed significantly among the parental lines of promising maize hybrids (Table 3). The results revealed that MAI-729 recorded significantly lower electrical conductivity of seed leachate (188.00 μSm^{-1}) and higher electrical conductivity of seed leachate was recorded in DH-376 (317.33 μSm^{-1}). The reduction in the value of electrical conductivity of seed leachate with diversity of parental lines or genotypes may be because of critical maintains of structural integrity and cell membranes permeability. The results were in accordance with the findings of Kiran and Channakeshava (2018) and Omar *et al.* (2022) in maize.

Based on the above experimental results, it can be inferred that MAI-729 is the better performer among the parental lines in terms of growth, higher seed yield and good quality aspects. Therefore, it was suggested that study of phenological characters would be most supporter for selection of parental lines in breeding and seed production programmes.

References

Ahammad, K. U., Rahman, M. M. and Ali. M. R., 2014, Effect of hydropriming method on maize (*Zea mays* L.) seedling emergence. *Bangladesh J. Agric. Res.,* **39** (1) : 143 - 150.

Anil Kumar, G. S., 2018, Staggering and optimization of planting ratios to maximize the seed yield and quality of single cross hybrid maize MAH-14-5 (*Zea mays* L.).

M. Sc. Thesis, Univ. Agric. Sci., Bangalore, Karnataka, India.

Arjun, B., Ankit, S., Pandey, U., Mausami, R., Manoj, K. and Shrestha, J., 2021, Evaluation of white grain maize varieties for growth, yield and yield components. *J. Agric. Natural Res.,* **4** (1) : 265 - 272.

Bhusal, N., Pahuja, S. K. Akshay Kumar, V., Srivastava, A. and Ravi Kumar, 2017, Morphological characterization of forage sorghum genotypes for its various DUS traits. *J. Appl & Natural Sci.,* **9** (2) : 912 - 919.

Chakravarthy, K. S. and Jagannathan, R., 2014, Phenological studies on five maize hybrids under higher nitrogen levels in western zone of Tamil Nadu. *Madras Agric. J.,* **101** (7 - 9) : 235 - 238.

Daniel, T., 2014, Evaluation of improved maize genotypes for grain yield and yield components in Chilga district, North Western Ethiopia. *Int. J. Sci. Res.,* **3** (10) : 1362-1364.

Dhakal, B., Keshav, P. S., Joshi, B. P. and Jiban, S., 2017, Evaluation of early maize genotypes for grain yield and agro morphological traits. *J. Maize Res. Develop.,* **3** (1) : 67 - 76.

Directorate of Economics and Statistics (DES), Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare. Retrieved March, 2021, from https://www.india.gov.in/official-website-directorate-economics-and-statistics

Food and Agriculture Organization (FAO), FAOSTAT: Suite of Food Security Indicators. Retrieved July 2020, from https://www.fao.org/faostat/en/#data/FS

Hidayat, U. R., Sajid, A., Syed, M. A. S., Syed, S. S., Naveed, U. R., Amin, I. K., Hussain, I. and Fehmida, A., 2008, Diversity for morphological and maturity traits in maize populations from upper dir. *Sarhad J. Agric.,* **24** (3) : 2007 - 2011.

Ibrahim, A. K. and Mukhtar, Y., 2016, Evaluation of the performance of maize genotypes (*Zea mays* L.) for yield and other agronomic traits. *Bayero J. Pune and Appl. Sci.,* **9** (2) : 61 - 65.

International Rules for Seed Testing (ISTA). Retrieved January 1, 2019, from https://doi.org/10.15258/istarules.2019.F

Kiran, S. P. and Channakeshava, B. C., 2017, Influence of seed treatments and foliar spray on crop growth and seed yield in maize hybrid (*Zea mays* L.) - Hema. *Mysore J. Agric. Sci.,* **51** (3) : 644 - 649.

Madhukeshwara, B. P. and Sajjan, A., 2015, Morphometric characterization of maize hybrids and their parents using dus guidelines. *I-scholar,* **6** (2) : 178 - 182.

Manjunatha, B., Niranjana, K. and Jagadesh, G. B., 2018, Performance evaluation of maize hybrids (*Zea mays* L.). *Int. J. Curr. Microbiol. App. Sci.,* **7** (11) : 1198 - 1203.

Omar, S., Tarnawa, A., Kende, Z., Ghani, R. A., Kassai, M. K. and Jolankai, M., 2022, Germination characteristics of different maize inbred hybrids and their parental lines. *Cereal Res. Communi.,* pp. : 1 - 8.

Pinnisch, R., Mowers, R., Trumpy, H., Walejko, R. and Bush, D., 2012, Evaluation of maize (*Zea mays* L.) inbred lines for yield component traits and kernel morphology. *Maydica,* **57** (2) : 1 - 5.

Prasad, K. B. and Shrestha, K., 2020, Performance evaluation of maize hybrids in inner-plains of Nepal. *Heliyon.,* **6** : 1 - 6.

Sharma, V., Bhushan, A., Deepak, K., Mishra, S. and Kumar., R., 2020, Single cross hybrid of QPM maize seed production as influenced by row ratio and spacing in north western Himalayan region. *Int. J. Curr. Microbiol. App. Sci.,* **9** (8) : 1491 - 1496.

Shashibhaskar, M. S., 2015, Investigation on seed production techonology for single cross maize hybrids (*Zea mays* L.). *Ph.D. Thesis,* Univ. Agric. Sci., Bangalore, Karnataka, India.

Vijayalakshmi, N. and Siddaraju, R., 2021, Optimization of spacing and mother plant nutrition on growth potential of parental lines of maize hybrid MAH-14-5. *The Pharma Innovation J.,* **10** (4) : 581 - 586.

Wietholter, P., Melo Sereno, M. J., De Freitas Terra, T., Silva, D. A. E., Delmar, S. and Barbosa, J., 2008, Genetic variability in corn landraces from Southern Brazil. *Maydica*, **53** (2) : 151 - 159.

Mysore J. Agric. Sci., 57 (1) : 89-95 (2023)

How Social Media Savvy are Krishi Vigyan Kendra Scientists of South India?

DISHANT JOJIT JAMES[1] AND R. MINITHRA[2]
[1]Wyzsza Szkola Bankowa University, Gdansk, Poland
[2]Karunya Institute of Technology and Sciences, Coimbatore, India
e-Mail : dishantjj@gmail.com

AUTHORS CONTRIBUTION

DISHANT JOJIT JAMES : Data collection, data analysis and manuscript preparation;
R. MINITHRA : Conceptualization and editing of manuscript

Corresponding Author :
DISHANT JOJIT JAMES
Wyzsza Szkola Bankowa University, Gdansk, Poland

Received : January 2023
Accepted : February 2023

ABSTRACT

The present research study was conducted in Andhra Pradesh, Karnataka, Kerala, Lakshadweep, Puducherry, Tamil Nadu and Telangana during 2019-2020 to analyze the knowledge of Krishi Vigyan Kendra (KVK) scientists regarding social media. The sample consisted of 161 scientists out of a population of 542 scientists from 117 Krishi Vigyan Kendras in the above mentioned states. The results revealed that a greater proportion of KVK scientists (39.14%) had high knowledge regarding social media, whereas slightly more than one-third (36.64%) of KVK scientists had medium level of knowledge regarding the social media and nearly one-fourth, *i.e.,* 24.22 per cent of respondents had low knowledge regarding social media. The independent variables, namely, education, e-readiness, innovative proneness and trainings that were received by the KVK scientists seemed to have positive and also a relationship that was significant, with knowledge level of the KVK agricultural scientists with the level of probability being one per cent. Twenty-one independent variables contributed to the tune of 87.15 per cent to the knowledge of KVK scientists regarding social media. Sixteen of the independent variables screened for the path analysis had a positive and direct effect on knowledge of the agricultural scientists of KVKs regarding social media.

Keywords : Knowledge, Social media, KVK scientists, Agricultural development

THE growth in significance of social media among professionals and researchers of agriculture, over the past few years, has been remarkable. Capturing millions of users from all over the world, social media has become one of the most popular means of interacting and information-sharing. Social media can be defined as web based tools of electronic communication that allow users to interact, create, share, retrieve and exchange information and ideas in any form (text, pictures, video, *etc.*) that can be discussed upon, archived and used by anyone in virtual communities and networks (Suchiradipta and Saravanan, 2016). The annual growth rate of social media users worldwide is 13 per cent whereas in India it is 31 per cent. In the agricultural sector, there is an increasing rate of social media usage amongst stakeholders. Today, farmers are using Facebook, Twitter and other tools to access and disseminate the news. Farmers are sharing pictures of their farms on Facebook; selling products on Twitter and connecting with experts on WhatsApp. The scientists of Krishi Vigyan Kendras (KVKs) play a pro-active role in transferring latest technologies with beneficial impacts to the farmers at grassroots level. They continuously improve their knowledge and skills by updating themselves regarding latest information and technologies. Social media speeds up connections between scientists in the virtual space and it can be used effectively by the KVK scientists for agricultural development (Jayashree, 2018). In this backdrop, the present study has been carried out with the following specific objectives :

1. To analyse the knowledge of KVK Scientists regarding social media and

2. To know the relationship between personal, socio-economic, psychological and communication characteristics of KVK scientists and their knowledge regarding social media.

Material and Methods

The present study was carried out in Andhra Pradesh, Karnataka, Kerala, Lakshadweep, Puducherry, Tamil Nadu and Telangana during 2019-2020. One hundred and sixty one scientists working in 117 Krishi Vigyan Kendras were purposively selected as the sample of the study. Ex post-facto research design was adopted for conducting the study. Knowledge level of KVK scientists in the present study was operationalized as the quantum of scientific information known to the scientists about the tasks that can be performed using selected social media.

A list of eleven selected social media was enlisted and the scientists had to tick the activities/ tasks that the particular social media could be used for. A preliminary survey was conducted using Google forms to know the usage of social media by KVK scientists under the jurisdiction of University of Agricultural Sciences, Bengaluru, as well as from scientists working in other KVKs of Karnataka, Central Silk board, ISEC (Institute for Social and Economic Change, Bengaluru), IGFRI (Indian Grassland and fodder Research institute, Jhansi) and CICR (Central Institute for Cotton Research, Nagpur). Based on the preliminary survey, 11 social media platforms were selected for the study, namely: Facebook, WhatsApp, YouTube, Instagram, Twitter, Telegram, LinkedIn, Skype, Messenger, Quora and Research Gate.

The correct responses were awarded a score of one. The wrong answers were allotted a score of 0. If no attempt was made against a particular social media, a total score of 0 was allotted for knowledge regarding that particular social media. Also, if a respondent scored nine or more than nine for a particular social media, he/she was considered to have complete knowledge regarding that social media. If the respondent scored one to eight for a particular social media, he/she was considered to have partial knowledge regarding that social media. The summation of scores for a particular respondent indicated his/her knowledge level about social media. Based on the total score obtained, the respondents were classified into three categories namely, 'low', 'medium' and 'high' using mean (42.00) and half standard deviation (11.82) as a measure of check. The collected data was scored, tabulated and analysed using frequency, mean, standard deviation, correlation test and path analysis.

Results and Discussion

1. Personal, Socio-Economic, Psychological and Communication Characteristics of KVK Scientists

Larger proportion of KVK scientists were of middle age (70.19%), studied up to Ph.D. (Agri.) degree (45.96%), having more job experience (47.20%) with semi-urban background (41.61%), as depicted in Table 1 A. Larger number of KVK scientists were

Table 1A

Personal characteristics of KVK scientists

(n=161)

Characteristics	Category	KVK Scientists	
		Number	Per cent
Age	Young	29	18.01
	Middle	113	70.19
	Old	19	11.80
Education	M.Tech. (Agri. Engineering)	5	3.11
	MHSc.	7	4.35
	MVSc.	12	7.45
	M.Sc.(Agri)	63	39.13
	Ph.D. (Agri.)	74	45.96
Rural urban background	Rural	41	25.47
	Semi-urban	67	41.61
	Urban	53	32.92
i) Job experience	Less	45	27.95
	Moderate	76	47.20
	More	40	24.85
ii) Social media experience	Less	65	40.37
	Moderate	54	33.54
	More	42	26.09

noticed as having high level of job satisfaction (37.27%), high job performance level (39.75%), low achievement motivation level (42.24%), medium level of innovative proneness (54.04%), scientific orientation (63.98%), perceived work load (37.89%) and job involvement (40.99%), high level of e-readiness (44.72%), organisational climate (46.58%) and finally, low level of competition orientation (44.10%) as depicted in Table 1 B. Comparatively, a

TABLE 1B

Psychological characteristics of KVK scientists

(n=161)

Characteristics	Category	KVK Scientists	
		Number	Per cent
Job satisfaction	Low	47	29.19
	Medium	54	33.54
	High	60	37.27
Job performance	Low	40	24.85
	Medium	57	35.40
	High	64	39.75
Achievement motivation	Low	68	42.24
	Medium	42	26.09
	High	51	31.67
Innovative proneness	Low	44	27.33
	Medium	87	54.04
	High	30	18.63
Scientific orientation	Low	28	17.39
	Medium	103	63.98
	High	30	18.63
Perceived work load	Low	39	24.22
	Medium	61	37.89
	High	61	37.89
Job involvement	Low	35	21.74
	Medium	66	40.99
	High	60	37.27
e-readiness	Low	41	25.47
	Medium	48	29.81
	High	72	44.72
Organizational climate	Low	48	29.82
	Medium	38	23.60
	High	75	46.58
Competition Orientation	Low	71	44.10
	Medium	50	31.06
	High	40	24.84

TABLE 1C

Socio-economic and communication characteristics of KVK scientists

(n=161)

Characteristics	Category	KVK Scientists	
		Number	Per cent
Awards/ recognition received	Low	63	39.13
	Medium	72	44.72
	High	26	16.15
Abroad exposure	Low	103	63.98
	Medium	30	18.63
	High	28	17.39
Field activities conducted	Less	96	59.63
	Moderate	29	18.01
	More	36	22.36
Mass media utilization	Low	77	47.83
	Medium	35	21.74
	High	49	30.43
Trainings received	Less	70	43.48
	Moderate	54	33.54
	More	37	22.98
Number of publications	Less	43	26.71
	Moderate	84	52.17
	More	34	21.12
Participation in seminars/ conferences	Low	64	39.75
	Medium	65	40.37
	High	32	19.88

higher proportion of scientists were in the medium level in obtaining awards/ recognition (44.72%), had low level of abroad exposure (63.98%), had conducted less number of field activities (59.63%), with low utilization pattern of mass media utilization (47.83%), with less number of trainings received (43.48%), moderate number of publications (52.17%) and medium participation in seminars/ conferences (40.37%) as shown in Table 1 C.

2. Knowledge of KVK Scientists Regarding Individual Social Media

The results in Table 2 provide conclusive evidence regarding knowledge of KVK scientists regarding selected individual social media. A great majority (67.70%) of the KVK scientists possessed complete knowledge regarding WhatsApp whereas 55.90 per

TABLE 2

Knowledge of KVK scientists regarding individual social media

(n= 161)

Social media	Knowledge level					
	Complete knowledge		Partial knowledge		No knowledge	
	Number	Per cent	Number	Per cent	Number	Per cent
Facebook	85	52.80	68	42.24	8	4.96
WhatsApp	109	67.70	47	29.19	5	3.11
YouTube	90	55.90	53	32.92	18	11.18
Instagram	33	20.50	56	34.78	72	44.72
Twitter	67	41.61	39	24.23	55	34.16
Telegram	48	29.81	59	36.65	54	33.54
LinkedIn	65	40.37	55	34.16	41	25.47
Skype	42	26.09	62	38.51	57	35.40
Messenger	54	33.54	41	25.67	66	40.99
Quora	24	14.91	44	27.33	93	57.76
ResearchGate	78	48.45	43	26.71	40	24.84

cent respondents had complete knowledge regarding YouTube, 52.80 per cent respondents had complete knowledge regarding Facebook, 48.45 per cent respondents had complete knowledge regarding ResearchGate, 41.61 per cent had complete knowledge regarding Twitter, 40.37 per cent had complete knowledge regarding LinkedIn, 33.54 per cent complete knowledge regarding Messenger, 29.81 per cent had complete knowledge on Telegram, 26.09 per cent had complete knowledge on Skype, 20.50 per cent respondents had complete knowledge on Instagram and only 14.91 per cent KVK scientists had complete knowledge regarding Quora.

A close view at the results of Table 2 also reveals that 42.24 per cent respondents had partial knowledge regarding Facebook, followed by Skype (38.51%), Telegram (36.65%), Instagram (34.78%), LinkedIn (34.16%), YouTube (32.92%), WhatsApp (29.19%), Quora (27.33%), ResearchGate (26.71%), Messenger (25.67%) and Twitter (24.23%). The results in Table 2 further revealed that 57.76 per cent KVK scientists had no knowledge regarding Quora, whereas 44.72 per cent had no knowledge regarding Instagram, 40.99 per cent had no knowledge regarding Messenger, 35.40 per cent respondents had no knowledge regarding Skype, 34.16 per cent scientists had no knowledge regarding Twitter, 33.54 per cent respondents had no knowledge regarding Telegram, 24.84 per cent of them had no knowledge regarding ResearchGate, 11.18 per cent KVK scientists did not have knowledge regarding YouTube, 4.96 per cent had no knowledge regarding Facebook and only 3.11 per cent KVK scientists didn't have knowledge regarding WhatsApp.

Overall Knowledge of KVK Scientists Regarding Social Media

The bird's eye perusal of Table 3 shows that greater proportion of the KVK scientists (39.14%) had high knowledge regarding social media, whereas slightly more than one-third (36.64%) of respondents possessed medium level of knowledge regarding social media and finally, 24.22 per cent KVK scientists possessed low knowledge regarding social media. It may be inferred from findings that 75.78 per cent KVK scientists possessed medium to high knowledge level regarding social media. Majority of the respondents have good amount of knowledge with regard to social media as it is imperative as educated scientists, to have know-how regarding such useful

TABLE 3

Overall knowledge of KVK scientists regarding social media

(n=161)

Categories	KVK Scientists	
	Number	Per cent
Low (< 30.19 score)	39	24.22
Medium (30.19 – 53.82 score)	59	36.64
High (> 53.82 score)	63	39.14
Total	161	100.00

Mean= 42.00; Standard deviation = 23.63

information sharing and communication platforms as social media. Findings akin were put forth by Aisar *et al.* (2015), Rashmi and Sapna (2016) and Ayushi (2018).

Since there is difference in respect of knowledge level among KVK scientists regarding social media, the set forth hypothesis, that is, there's no difference in knowledge level regarding social media among KVK scientists, is rejected.

3. Relationship between Personal, Socio-Economic, Psychological and Communication Characteristics of KVK Scientists and their Knowledge Regarding Social Media

The results in Table 4 reveal that education, innovative proneness, e-readiness and trainings received had positive and significant relationship with knowledge of KVK scientists at one per cent level of probability. Whereas, job experience, job performance, achievement motivation, scientific orientation, job involvement, competition orientation, awards/ recognition received, abroad exposure/ countries visited, field activities conducted, mass media utilization, number of publications and participation in seminars/ conferences were found to have a significant relationship with knowledge of KVK scientists regarding social media at five per cent level of probability. Age was the only independent variable that had negative but significant relationship with their knowledge regarding social media, at level of probability being five per cent. The remaining four variables, namely, rural urban background, job satisfaction, perceived workload and organizational climate were not having significant relationship with knowledge regarding social media.

TABLE 4

Relationship of personal, socio-economic, psychological and communication characteristics with knowledge of KVK Scientists regarding social media

(n=161)

Independent Variables	Correlation coefficient
Age	-0.211 *
Education	0.4012 **
Rural urban background	0.092 NS
Job experience	0.201 *
Job satisfaction	0.192 NS
Job performance	0.199 *
Achievement motivation	0.216 *
Innovative proneness	0.313 **
Scientific orientation	0.202 *
Perceived work load	0.099 NS
Job involvement	0.222 *
e-readiness	0.300 **
Organizational climate	0.062 NS
Competition Orientation	0.239 *
Awards/ recognition received	0.248 *
Abroad exposure/ countries visited	0.226 *
Field activities conducted	0.210 *
Mass media utilization	0.251 *
Trainings received	0.410 **
Number of publications	0.244 *
Participation in seminars/ conferences	0.233 *

NS=Non-significant, * Significant at 5 per cent level, ** Significant at 1 per cent level

4. Direct, Indirect and the Largest Indirect Effect of Selected Personal, Socio-Economic, Psychological and Communication Characteristics of KVK Scientists on their Knowledge Regarding Social Media

Path co-efficient of the personal, socio-economic, psychological and communication characteristics of KVK scientists with respect to direct effects, the total indirect effects and the largest indirect effects that were channelled through other independent variables on knowledge regarding social media are presented in Fig. 1. For path analysis, sixteen variables were considered that having positive, significant relationship with the knowledge of KVK scientists regarding social media. All the sixteen independent variables selected for path analysis did have a positive, direct effect on knowledge of KVK scientists regarding social media.

Ranking of variables based on the total direct effects on knowledge of KVK scientists regarding social media reveals that trainings received (X14) had highest direct effect (0.497) on knowledge of KVK scientists regarding social media, followed by e-readiness (X8) with direct effect value of 0.412 and education (X1) with direct effect value of 0.312.

With respect to total indirect effect of the personal, psychological, socio-economic, and communication characteristics on knowledge of KVK scientists regarding social media, it was found to be quite substantial. The ranking of these effects revealed that trainings received (X14) ranked highest with the total indirect effect of 0.389, followed by e-readiness (X8) with total indirect effect of 0.381, education (X1) with a total indirect effect value of 0.333, innovative proneness (X5) with a total indirect effect value of 0.331, achievement motivation (X4) with a total indirect effect value of 0.296.

Further, it's evident from results that first largest indirect effect channelled was through trainings received (X14) in case of seven variables namely, education (X1), job experience (X2), achievement motivation (X4), e-readiness (X8), competition orientation (X9), abroad exposure/ countries visited (X11) and mass media utilization (X13).

Training on social media helps the agricultural scientists to gain valuable knowledge on integration

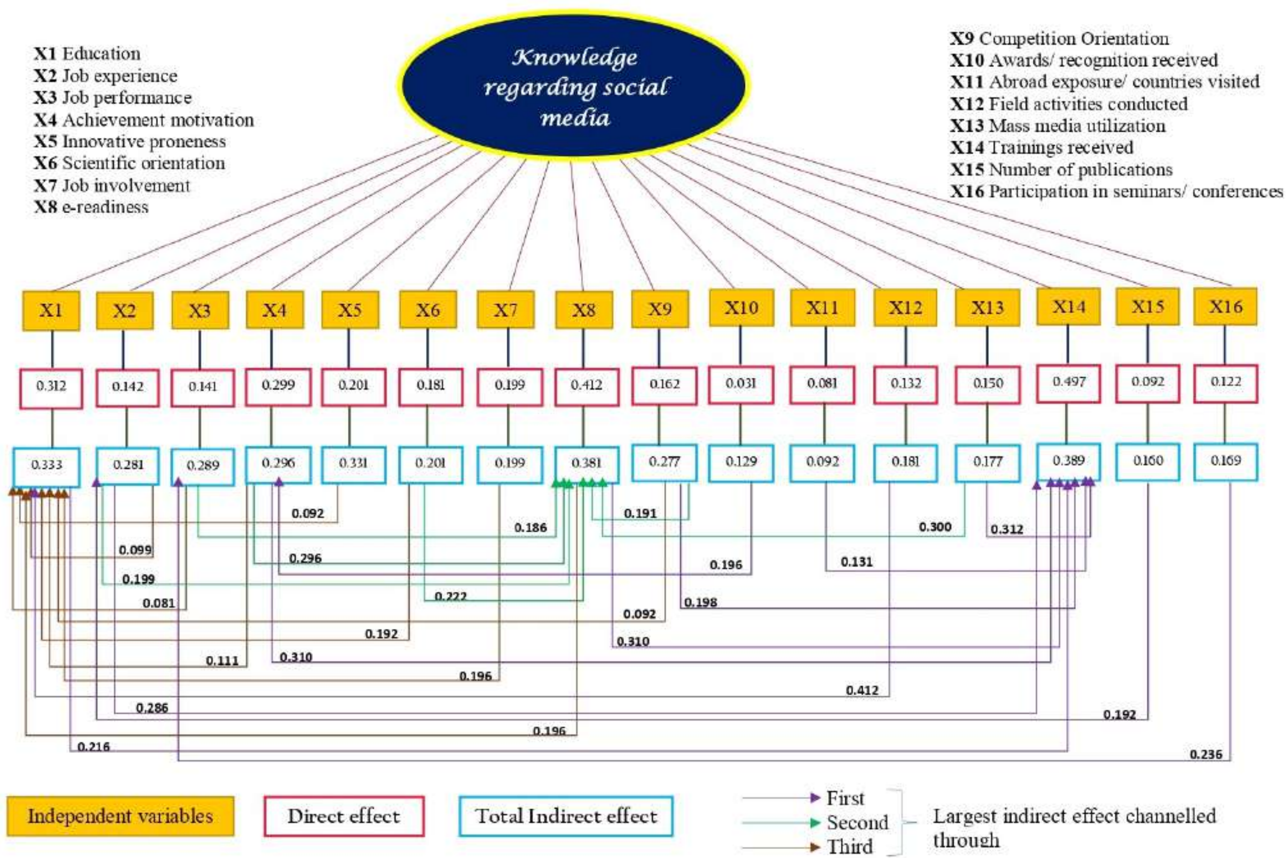


Fig. 1 : Path Analysis showing the effects of profile of KVK scientists on their knowledge regarding social media

of different types of social media, technicalities of social media, content creation and use of social media in general. Training will help the scientists to handle social media effectively and in the process, know more about the intricacies of social media. This is the reason why training can be considered the forerunner of knowledge of KVK scientists regarding social media as it had highest direct effect on knowledge regarding social media. Training was followed by e-readiness, education, achievement motivation, innovative proneness, job involvement, scientific orientation, competition orientation, mass media utilization, job experience and job performance.

Majority of the KVK scientists were seen to have complete knowledge regarding two to three popular social media only. They have no knowledge regarding several social media listed specifically in the study and the possibly unlisted social media platforms available in the ever-growing virtual world. Thus, it is essential that all the KVK scientists who need more knowledge regarding social media have to attend online webinars or e-courses on social media, its uses and features, in order to gain better knowledge regarding social media.

References

Aisar Salihu Musa, Mohd Nazri Latiff Azmi and Nur Salina Ismail, 2015, Awareness and usage of social media : A study of mass communication students of Kano state polytechnic. International Conference on Languages, Kuala Lumpur.

Ayushi Pal, 2018, Perception of farmers towards use of social media for seeking agricultural information : A study in Udham Singh Nagar district of Uttarakhand. *M.Sc. Thesis* (Unpub.), G. B. Pant University of Agriculture and Technology, Pantnagar.

Jayashree, 2018, Social media and communication by scientists : M. S. Swaminathan on Twitter. *Current Science,* **114** (9) : 1840 - 1846.

Rashmi Gopinathan and Sapna Suri, 2016, A study of awareness and usage of social media in HR practices and its impact on organizations especially with reference to pharma industry. *Int. J. Management,* **7** (5) : 164 - 172.

Suchiradipta, B. and Saravanan, R., 2016, Social Media: Shaping the future of agricultural extension and advisory services. GFRAS Interest Group on ICT4RAS Discussion Paper, GFRAS: Lindau, Switzerland: 9.

Mysore J. Agric. Sci., 57 (1) : 96-101 (2023)

Effect of New Generation Mesotrione Herbicide on Growth and Yield of Maize (*Zea mays* L.)

S. Harisha, C. Seenappa, K. N. Kalyanamurthy, M. N. Thimmegowda, N. Krishnamurthy, Umashankar and D. C. Hanumanthappa
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : harishs27666@gmail.com

Authors Contribution

S. Harisha : Conceptualization, investigation, data analysis; C. Seenappa & K. N. Kalyana Murthy : Conceptualization, draft correction & data curation; M. N. Thimmegowda : Data curation and analysis of data; N. Krishnamurthy, Umashankar & D. C. Hanumanthappa : Supervision and guidance

Corresponding Author :
S. Harisha
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru

Received : July 2022
Accepted : October 2022

Abstract

The field experiment was conducted at Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK, Bengaluru during *summer* 2021 to evaluate the effect of new generation mesotrione herbicide on growth and yield of maize (*Zea mays L.*). The experiment consists of application of different doses of mesotrione herbicide as early post emergent (EPoE) and weed free check and unweeded control were replicated thrice in RCBD. Major weeds observed were *Alternanthra sessilis, Borreria articularis, Euphorbia geniculata, Cynodon dactylon, Dactyloctenium aegyptium, Echinochloa colonum, Eleusine indica* and *Cyperus rotundus.* Post-emergent application of mesotrione 48 per cent SC @ 120 ml a.i. ha^{-1} recoded higher kernel yield, stover yield of maize and lower weed index value (6273 kg ha^{-1}, 7583.7 kg ha^{-1} and 4.07%, respectively) and it was on par with mesotrione 48 per cent SC @ 144 ml a.i. ha^{-1} (6075 kg ha^{-1}, 7430 kg ha^{-1} and 7.08%, respectively). Weedy check recorded a kernel yield (3090.7 kg ha^{-1}), lower stover yield (4096.3 kg ha^{-1}) of maize and higher weed index value (52.72%) compared to other treatments.

Keywords : Mesotrione, Weed flora, Growth, Yield and Weed index

Maize (*Zea mays* L.) is the world's third most important cereal grain after wheat and rice. It is grown primarily for grain and secondarily for fodder. Globally, maize is cultivated on an area of 193.7 m ha with production of 1147.7 m t and a productivity of 5750 kg ha^{-1}. In India, it is cultivated on an area of 9.89 m ha with a production of 31.65 m t and the productivity of 3199 kg ha^{-1} (Anonmous., 2021a). The predominant maize growing states that contributes more than 80 per cent of the total maize production are Andhra Pradesh (20.9%), Karnataka (16.5%), Rajasthan (9.9%), Maharashtra (9.1%), Bihar (8.9%), Uttar Pradesh (6.1%), Madhya Pradesh (5.7%) and Himachal Pradesh (4.4%). In Karnataka, it is cultivated on an area of 1.3 m ha with a production of 3.96 m t and an average productivity of 3305 kg ha^{-1} (Anonmous., 2021b). Recently with the release of improved cultivars and hybrids, the grain yield has been increased but still the maize crop faces many problems.

Weeds are one of the most important factor affecting maize production. Because of higher quantity of fertilizer application, wider spacing and initial slow growth, maize is more susceptible for weed competition, being maximum during initial 2 to 6 weeks after sowing. This suggests the importance of maintaining the fields weed free during this critical period of weed competition. The extent of reduction in grain yield of maize has been reported to be in the range of 33 to 50 per cent depending on the intensity and persistence of weed density in standing crop

(Sharma *et al*., 2000). Atrazine has been found to be the most effective pre emergence herbicide and is widely used in maize, but its usage does not control late emerged weeds and there are reports of persistence of atrazine in soil resulting in residual effects. To manage complex and dynamic weed flora in maize during later stages of crop growth, the new generation herbicides needs to be evaluated.

Presently, efficacy of mesotrione herbicide has not been tested for wide spectrum weed control in maize under Eastern Dry Zone of Karnataka. Therefore, to study the efficacy of new generation mesotrione herbicide on maize, the present investigation was undertaken.

Material and Methods

A field experiment was conducted during Summer-2021 at the field unit of Agronomy, Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK, Bengaluru. The experimental site is situated in the Eastern Dry Zone (Zone - V) of Karnataka which is situated between 12º 51' N Latitude and 77º 35' E Longitude at an altitude of 930 m above Mean Sea Level (MSL). The soil of the experimental site was sandy loam in its texture. The moisture content at field capacity was 18.63 per cent with a bulk density of 1.43 g cc^{-1}. The soil of the site is slightly acidic in reaction (pH 5.8) with medium electrical conductivity (0.32 dS m^{-1}) and organic carbon content (0.50%). It has low available nitrogen (253.60 kg ha^{-1}), medium phosphorus (32.24 kg ha^{-1}) and potassium (283.2 kg ha^{-1}), respectively. The experiment included eight treatments laid out in randomized complete block design with three replications. Treatments involved of early post emergence application of different doses of mesotrione herbicide. T_1-Mesotrione 48 per cent SC @ 72 ml a.i. ha^{-1}, T_2-Mesotrione 48 per cent SC @ 96 ml a.i. ha^{-1}, T_3-Mesotrione 48 per cent SC @ 120 ml a.i. ha^{-1}, T_4-Mesotrione 48 per cent SC @ 144 ml a.i. ha^{-1}, T_5-Mesotrione 48 per cent SC @ 288 ml a.i. ha^{-1}, T_6-2,4-D Amine Salt 58 per cent SL @ 500 g a.i. ha^{-1}, T_7 -Weed free Check and T_8-Weedy Check. Treatment imposition was done at two to three leaf stage of weeds. The maize hybrid MAH 14-5 seeds were sown in lines at the rate of 15 kg ha^{-1} at a depth of 4-5 cm, maintaining 60 cm row and 30 cm plant spacing. The crop was fertilized with 100 kg N, 75 kg P_2O_5 and 40 kg K_2O ha^{-1} through urea, single super phosphate and muiate of potash, respectively. The crop was sown during 19th January 2021 and harvested at 13th May 2021.Weed index (WI) was calculated as per standard formulae as:

$$\text{WI (\%)} = \frac{\text{Yield of weed free plot} - \text{Yield of treated plot}}{\text{Yield of weed free plot}} \times 100$$

Results and Discussion

Effect on Weed Flora

The dominated weed flora observed in the experimental plots were *Cyperus rotundus*, the grasses were *Cynodon dactylon, Dactyloctenium aegyptium, Digitaria marginata, Echinochloa colonum, Eleusine indica* and the broad leaf weeds were *Alternanthra sessilis, Amaranths viridis, Borreria articularis* and *Euphorbia geniculata*. Application of mesotrione 48 per cent SC @ 288 ml a.i. ha^{-1} recorded lower total weed density and weed dry weight (10.73 m^{-2} and 14.53 g m^{-2}) and at par with mesotrione 48 per cent SC @ 144 ml a.i. ha^{-1} (15.80 m^{-2} and 18.83 g m^{-2}) and mesotrione 48 per cent SC @ 120 ml a.i. ha^{-1} (20.53 m^{-2} and 21.43 g m^{-2}). Whereas, weedy check recorded highest total weed density and dry weight (78.33 m^{-2} and 100.53 g m^{-2}) at 45 days of the crop stage (Table. 1). The application of mesotrione inhibits the enzyme 4-hydroxyphenylpyruvate dioxygenase (HPPD) activity. In plants, HPPD is necessary for the biosynthesis of tocopherols and plastoquinone, which is essential to carotenoid production. Inhibition of the pathway ultimately leads to bleaching of leaves as chlorophyll is degraded, followed by plant death as a result of achieving higher weed control efficiency. Whereas, weedy check recorded the higher weed density and dry weight due to the non-interruption for growth of weeds. Similar results were reported by Ahmed and Susheela (2012) at Hyderabad, Geetha Kumari (2014) at Hebbal, Bengaluru, Veeresh (2015) and Poojitha *et al.* (2021)

Effect on Maize Growth

Early post emergence (EPoE) application of mesotrione 48 per cent SC @ 120 ml a.i. ha^{-1} herbicide significantly recorded higher values of growth attributes and at par with mesotrione 48 per cent SC @ 144 ml a.i. ha^{-1} and mesotrione 48 per cent SC @ 288 ml a.i. ha^{-1}. Whereas, weed free plot was significantly superior to all other treatments with respect of growth attributes like plant height, leaf area and dry matter production.

Plant Height

The data pertaining to plant height (cm) at different growth stages of maize as influenced by different doses of mesotrione herbicide are presented in Table 1.

At 30 days after sowing (DAS), application of mesotrione 48 per cent SC @ 144 ml a.i. ha^{-1} was recorded higher plant height (44.3 cm) and it was on par with all other treatments except weed free check (38.6 cm).

Among herbicide treatments, significantly higher plant height at 60, 90 DAS and at harvest (154, 180.7 and 183.8 cm, respectively) was recorded in mesotrione 48 per cent SC @ 120 ml a.i. ha^{-1} and it was on par with mesotrione 48 per cent SC @ 144 ml a.i. ha^{-1} (145.3, 178, and 181.1 cm, respectively) and

TABLE 1

Category wise weed density and weed dry weight at 45 DAS of maize as influence by different doses of mesotrione herbicide

Treatments	Weed density at 45 DAS (Number m^{-2})				Weed dry weight at 45 DAS (g m^{-2})			
	Sedges$^+$	Grasses$^+$	BLW$^+$	Total$^+$	Sedges$^+$	Grasses$^+$	BLW$^+$	Total$^+$
T_1	2.20	3.95	4.13	5.97	2.58	4.40	4.46	6.63
	(4.0)	(14.6)	(16.33)	(35.00)	(5.83)	(18.40)	(19.00)	(43.23)
T_2	1.99	3.85	3.79	5.59	2.12	4.15	4.26	6.16
	(3.0)	(14.0)	(13.33)	(30.33)	(3.53)	(16.40)	(17.13)	(37.07)
T_3	1.72	3.14	3.25	4.63	1.95	3.18	3.20	4.74
	(2.0)	(9.0)	(9.53)	(20.53)	(2.83)	(9.23)	(9.37)	(21.43)
T_4	1.82	2.63	2.91	4.09	1.93	3.04	2.97	4.45
	(2.3)	(6.0)	(7.47)	(15.80)	(2.73)	(8.23)	(7.87)	(18.83)
T_5	1.49	2.38	2.37	3.42	1.69	2.60	2.75	3.93
	(1.3)	(4.7)	(4.67)	(10.73)	(2.10)	(5.87)	(6.57)	(14.53)
T_6	3.13	5.4	2.87	6.63	3.28	4.71	3.39	6.54
	(9.0)	(26.6)	(7.27)	(42.93)	(9.80)	(21.53)	(10.50)	(41.83)
T_7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	(0.0)	(0.0)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
T_8	3.39	5.79	5.96	8.90	3.77	6.74	6.57	10.07
	(11.0)	(32.6)	(34.67)	(78.33)	(13.53)	(44.67)	(42.33)	(100.53)
S.Em±	0.27	0.15	0.18	0.22	0.21	0.22	0.20	0.18
C. D. at 5%	0.81	0.44	0.56	0.66	0.64	0.66	0.61	0.56

Data within parentheses are original values; + - square root (x+1) transformation, BLW- Broad leaved weeds

TABLE 2

Plant height (cm) of maize at different growth stages as influenced by different doses of mesotrione herbicide

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1 : Mesotrione 48% SC @ 72 ml a.i. ha^{-1} as EPoE	40.7	135.3	155.3	159.4
T_2 : Mesotrione 48% SC @ 96 ml a.i. ha^{-1} as EPoE	41.5	136.0	160.7	163.1
T_3 : Mesotrione 48% SC @ 120 ml a.i. ha^{-1} as EPoE	43.2	154.0	180.7	183.8
T_4 : Mesotrione 48% SC @ 144 ml a.i. ha^{-1} as EPoE	44.3	145.3	178.0	181.1
T_5 : Mesotrione 48% SC @ 288 ml a.i. ha^{-1} as EPoE	43.5	145.7	177.3	182.0
T_6 : 2,4-D Amine Salt 58% SL @ 500 g a.i. ha^{-1} as EPoE	41.3	121.3	143.0	146.1
T_7 : Weed free check	46.1	165.3	195.3	210.4
T_8 : Weedy check	38.6	112.3	125.3	130.1
S.Em±	1.72	5.40	7.21	7.35
C. D. @ 5%	5.22	16.37	21.87	22.29

EPoE- Early post emergence application, SE-Soluble concentrate

mesotrione 48 per cent SC @ 288 ml a.i. ha^{-1} (145.7, 177.3, and 182 cm, respectively). Whereas, lower plant height was recorded in weedy check (112.3, 125.3 and 130.1 cm, respectively).

Leaf Area

The data relating to the leaf area (cm^2 $plant^{-1}$) as influenced by different doses of mesotrione herbicide are presented in Table 2. Significantly higher leaf area $plant^{-1}$ was recorded in weed free check at all the stages of crop growth.

Among herbicide treatments, significantly higher leaf area at 30, 60 and 90 DAS was recorded in mesotrione 48 per cent SC @ 120 ml a.i. ha^{-1} (1905, 1322 and 5444 cm^2, respectively) and it was on par with mesotrione 48 per cent SC @ 288 ml a.i. ha^{-1} (1874, 5120 and 5176 cm^2, respectively) and mesotrione 48 per cent SC @ 144 ml a.i. ha^{-1} (1857, 5060, and 5249 cm^2, respectively). Whereas, lower leaf area was recorded in weedy check (1232, 3958, and 3780 cm^2, respectively).

Dry Matter Production

The data relating to dry matter production (g $plant^{-1}$) as influenced by different doses of mesotrione herbicide are presented in Table 3.

TABLE 3

Leaf area (cm^{-2} $plant^{-1}$) of maize at different growth stages as influenced by different doses of mesotrione herbicide

Treatments	30 DAS	60 DAS	90 DAS
T_1 : Mesotrione 48% SC @ 72 ml a.i. ha^{-1} as EPoE	1481	4173	4296
T_2 : Mesotrione 48% SC @ 96 ml a.i. ha^{-1} as EPoE	1604	4310	4432
T_3 : Mesotrione 48% SC @ 120 ml a.i. ha^{-1} as EPoE	1905	5322	5444
T_4 : Mesotrione 48% SC @ 144 ml a.i. ha^{-1} as EPoE	1857	5060	5249
T_5 : Mesotrione 48% SC @ 288 ml a.i. ha^{-1} as EPoE	1874	5120	5176
T_6 : 2,4-D Amine Salt 58% SL @ 500 g a.i. ha^{-1} as EPoE	1583	4032	4154
T_7 : Weed free check	2109	5857	6013
T_8 : Weedy check	1232	3958	3780
S.Em±	77.0	196.3	195.6
C. D. @ 5%	233.8	595.5	593.5

TABLE 4

Total dry matter production (g plant^{-1}) of maize at different growth stages as influenced by different doses of mesotrione herbicide

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1 : Mesotrione 48% SC @ 72 ml a.i. ha^{-1} as EPoE	7.3	44.9	149.0	202.9
T_2 : Mesotrione 48% SC @ 96 ml a.i. ha^{-1} as EPoE	7.6	49.8	153.0	222.3
T_3 : Mesotrione 48% SC @ 120 ml a.i. ha^{-1} as EPoE	8.5	54.5	193.0	258.9
T_4 : Mesotrione 48% SC @ 144 ml a.i. ha^{-1} as EPoE	8.3	53.3	173.9	232.8
T_5 : Mesotrione 48% SC @ 288 ml a.i. ha^{-1} as EPoE	8.1	51.6	172.1	234.7
T_6 : 2,4-D Amine Salt 58% SL @ 500 g a.i. ha^{-1} as EPoE	7.4	45.9	151.5	208.4
T_7 : Weed free check	8.8	57.7	197.3	272.5
T_8 : Weedy check	7.1	38.9	129.4	112.0
S.Em±	0.46	2.80	8.77	11.42
C. D. @ 5%	1.39	8.49	26.61	34.65

Among herbicide treatments application of mesotrione 48% SC @ 120 ml a.i. ha^{-1} recorded higher dry matter production at 30, 60, 90 DAS and at harvest (8.5, 54.5, 193 and 258.9 g plant^{-1}, respectively) and it was on par with mesotrione 48 per cent SC @ 144 ml a.i. ha^{-1} (8.3, 53.3, 173.9 and 232.8 g plant^{-1}, respectively) and mesotrione 48 per cent SC @ 288 ml a.i. ha^{-1} (8.1, 51.6, 172.1 and 234.7 g plant^{-1}, respectively). Whereas, lower leaf area was recorded in weedy check (7.1, 38.9, 129.4 and 112 g plant^{-1}, respectively)

Among the herbicide treatments, significantly higher plant height, leaf area, and total dry matter production per plant at all stages of plant growth was recorded with the application of mesotrione 48 per cent SC @ 120 ml a.i. ha^{-1} due to broad spectrum weed control during critical period of crop weed competition through which leads to better growth and development of plant parts and ultimately produced higher plant height, leaf area and total dry matter production plant^{-1}. These results are in confirmity with the findings of Chhokar *et al.* (2019), Veeresh *et al.* (2014) and Poojitha *et al.* (2021).

Maize Crop Yield

The data pertaining to yield attributes of maize as influenced by different doses of mesotrione herbicide are presented in Table 4.

TABLE 5

Kernel weight per cob, kernel yield, stover yield, harvest index and weed index in maize as influenced by different doses of mesotrione herbicide

Treatments	Kernel weight per cob (g)	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Weed index(%)
T_1 : Mesotrione 48% SC @ 72 ml a.i. ha^{-1}as EPoE	104.7	5286	6529	19.14
T_2 : Mesotrione 48% SC @ 96 ml a.i. ha^{-1}as EPoE	108.3	5502	6746	15.83
T_3 : Mesotrione 48% SC @ 120 ml a.i. ha^{-1}as EPoE	131.7	6273	7583	4.07
T_4 : Mesotrione 48% SC @ 144 ml a.i. ha^{-1}as EPoE	126.0	6075	7430	7.08
T_5 : Mesotrione 48% SC @ 288 ml a.i. ha^{-1}as EPoE	122.7	5737	7016	12.25
T_6 : 2,4-D Amine Salt 58% SL @ 500 g a.i. ha^{-1} as EPoE	89.3	4730	6278	27.65
T_7 : Weed free check	142.3	6538	7695	0
T_8 : Weedy check	66.0	3090	4096	52.72
S.Em±	5.0	99.3	146.6	-
C. D. @ 5%	15.1	301.2	444.6	-

Weed free plot was significantly superior to all other treatments with respect of yield attributes. Among herbicide treatments, application of mesotrione 48 per cent SC @ 120 ml a.i. ha^{-1} recorded significantly higher kernel weight per cob, kernel yield and stover yield (131.7 g, 6273 kg ha^{-1} and 7583.7 kg ha^{-1}) and it was on par with mesotrione 48 per cent SC @ 144 ml a.i. ha^{-1} (126 g, 6075 kg ha^{-1} and 7430 kg ha^{-1}). However, lower values were recorded in weedy check (66 g, 3090.7 kg ha^{-1} and 4096.3 kg ha^{-1}). Lower weed index was noticed in the treatment with mesotrione 48% SC @ 120 ml a.i. ha^{-1} (4.07%) followed by mesotrione 48 per cent SC @ 144 ml a.i. ha^{-1} (7.08%) and higher weed index value was recorded in weedy check (52.72%). This is due to broad spectrum control of weeds effectively during the critical period of crop weed competition, which otherwise quite notorious for imposing competition for light, space and nutrients with the crop. It has provided a congenial environment for better expression of growth and yield attributes. The cumulative effect of all these yield components resulted in increased seed yield. These results document with the findings of Zhang *et al.* (2013) and Swetha *et al.* (2015).

References

AHMED, A. M. A. AND SUSHEELA, R., 2012, Weed management studies in *kharif* maize. *The J. Res. ANGRAU*, **40** (3) : 121 - 123.

ANONYMOUS, 2021a, Ministry of Agriculture, GoI.

ANONYMOUS, 2021b, *www.indiastat.com.*

CHHOKAR, R. S., SHARMA, R. K., GILL, S. C. AND SINGH. R. K., 2019, Mesotrione and atrazine combination to control diverse weed flora in maize. *Indian J. Weed Sci.,* **51** (2) : 145 - 150.

GEETHA KUMARI, A., 2014, Bio-efficacy of new herbicide molecules for weed management in maize (*Zea mays* L.). *M. Sc. (Thesis)*, University of Agricultural Sciences, Bangalore.

VEERESH, H., SANJAY, M. T., RAMACHANDRA, T. V., KALYANA MURTHY, K. N., BASAVARAJ, K. AND SHRUTHI, M. K., 2014, Effect of new herbicide molecules on yield, soil microbial biomass and their phytotoxicity on maize (*Zea mays* L.) under irrigated conditions. *Int. J. Life Sci.,* **9** (3) : 1127 - 1130.

POOJITHA, K., SANJAY, M. T., MURTHY, K. K. AND DHANAPAL, G. N., 2021, Bioefficacy and phytotoxicity of different new herbicide molecules on weed growth, crop growth and yield parameters of maize. *India J. Plant Protec.,* **49** (1) : 142 - 145.

SHARMA, A. R., TOOR, A. S. AND SUR, H., 2000, Effect of intercultural operations and scheduling of atrazine application on weed control and productivity of rainfed maize (*Zea mays* L.) in Shiwalik foot hills of Punjab. *Indian J. Agril. Sci.,* **70** (1) : 757 - 761.

SWETHA, K., MADHAVI, M., PRATIBHA, G. AND RAMPRAKASH, T., 2015, Weed management with new generation herbicides in maize. *Indian J. Weed Sci.,* **47** (4) : 432 - 433.

VEERESH, H., RAMACHANDRAPPA, B. K. AND MUDALAGIRIYAPPA, 2015, Studies on effect of different tillage and nutrient management approaches on growth, yield and weed index in finger millet. *Mysore J. Agric. Sci.,* **50** (2) : 301 - 304.

ZHANG, J., LI, Z., JÄCK, O., DAYU Y., ZONGJIAN, Z., ROLAND, G. AND HANWEN, N., 2013, Efficacy of four post-emergence herbicides applied at reduced doses on weeds in summer maize (*Zea mays* L.) fields in North China Plain. *Crop Protection*, **52** : 26 - 30.

Mysore J. Agric. Sci., 57 (1) : 102-108 (2023)

Perception of Beekeepers Towards Bee Keeping in Coastal Zone of Karnataka State

V. Jagadeesh, M. T. Lakshminarayan, B. Krishnamurthy and K. Shivaramu
Department of Agricultural Extension, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : jagadeeshsharana@gmail.com

Authors Contribution

V. Jagadeesh : Conceptualization, investigation, data collection, data analysis, original draft preparation ; M. T. Lakshminarayan : Conceptualization, data correction & data curation; B. Krishnamurthy & K. Shivaramu : Data curation, draft correction, supervision

Corresponding Author **:**
V. Jagadeesh
Department of Agricultural Extension, College of Agriculture, UAS, GKVK, Bengaluru

Received : August 2022
Accepted : December 2022

Abstract

The present study was conducted in Dakshina Kannada district of Coastal zone in Karnataka state during 2022 to analyze the perception of bee keepers towards bee keeping and to find out the association and extent of contribution of the profile characteristics of bee keepers on their perception towards bee keeping. The data were collected randomly from 60 bee keepers from five taluks of Dakshina Kannada using a pre-tested interview schedule. Expost-factor research design was employed in the present study. The results revealed that a high percentage (48.34%) of bee keepers had better perception towards beekeeping. The chi square test revealed that 17 out of 22 independent variables shown significant association with their perception towards beekeeping, where in, number of bee hives, experience in beekeeping, innovativeness. training on bee keeping and extension participation had highly significant association with their perception towards bee keeping. Further, all the 22 profile characteristics of beekeepers contributed to the tune of 73.10 per cent in developing better perception towards beekeeping.

Keywords : Bee keeping, Beekeepers, Dakshina Kannada, Perception, Ecological Benefits, Economic benefits

Beekeeping is an art and a mesmerizing science and it offers an immense potential for providing employment to the rural folk in India, where many evergreen and moist deciduous forests, orchards *etc.* constitute good beekeeping areas. The unique feature of beekeeping is that the capital investment required is small and unlike many other industries, it does not need raw material, as nature offers the same in the form of nectar and pollen. Beekeeping is a very fascinating occupation and it can be practiced equally by men, women, grown up children and even by physically handicapped and old persons. The investment required is low and the economic returns are comparatively very high. Beekeeping improves the economic condition of the farmers; restrict the migration of rural youth to urban areas and helps in holistic development of rural society. It is a subsidiary, complementary, supplementary and a family business enterprise which is pollution free (Tarakini *et al.,* 2020).

India is an exclusive country which habitats four bee species. Of these: two domesticated species, *viz. Apis cerana* (oriental honey bee) and *A. mellifera* (occidental or European honeybee) and two wildspecies, *viz,. Apis dorsata* (giant/rock honeybee or dumna) and *A. florea* (dwarf honeybee). Honey harvesting by smoking away the honeybees and squeezing out their combs for honey has been traditional in India for the last several thousand years. Honeybees are special gift to mankind because beekeeping can be done for both their pollination services and their cherished products such as honey, beeswax, propolis, bee venom, *etc*. These products have their wide spread use in different small and large scale industries in India.

Honey has been traditionally used in various diet preparations, medicines, cosmetics, ointments and house-hold items. Honeybee apiaries, thus, prove of great value in terms of food and medicinal security. More than 2.50 lakh farmers in India are involved in beekeeping. The average quantity of honey produced per beehive per year in our country was 8.5 kg in 2014, as compared to 1.50 kg during 1953-54. During 2017-18, the global market for apicultural products was estimated at USD $8,819 million. In India, currently the total number of bee hives is estimated at 12 lakhs. The country's apiculture market size was worth Rs. 16,818 million in 2018, is further projected to reach Rs.33,128 million by 2024, with 12 per cent average growth rate per year during (Jagadeesh *et al.,* 2022). Thus, keeping in view the importance of bee keeping, In view of the importance of bee keeping, the present study was undertaken with the following specific objectives:

1. To analyze the perception of bee keepers towards beekeeping and
2. To find out the association and extent of contribution of profile characteristics of beekeepers on the perception towards beekeeping

Methodology

The present study was conducted in the purposively selected Dakshina Kannada district of Coastal zone in Karnataka state during 2022. The list of beekeepers who were maintaining at least five *Apis cerena* colonies for the past three years and were members and regular honey suppliers to the Beekeeper's Co-operative Society, Puttur of Dakshina Kannada district was prepared by employing simple random technique. Twelve beekeepers from all the five taluks (Mangalore, Bantval, Puttur, Belatangadi and Sullya) of Dakshina Kannada district were randomly selected to constitute 60 bee keepers for the study.

The perception of beekeepers towards bee keeping was considered as dependent variable for the study. Perception of beekeepers towards bee keeping in the present study is operationally defined *'as the extent of mental awareness of bee keepers about the ecological and economic benefits of beekeeping'*. Summated rating scale suggested by Likert (1932) and Edwards (1969) was followed to develop a standardized scale for analyzing the perception of beekeepers towards beekeeping. Fourteen and eighteen statements originally selected under ecological benefits and economic benefits. The developed perception scale was found to be highly reliable (0.771) and valid (0.8430). The developed perception scale consists of 21 statements categorized under ecological benefits (10 statements) and economic benefits (11 statements) of rearing honey bees. The response was collected on a five-point continuum, namely, strongly agree, agree, undecided, disagree and strongly disagree with an assigned score of 5, 4, 3, 2 and 1 for positive statements and reverse scoring for negative statements, respectively. The perception score of this scale ranges from a minimum of 21 to a maximum of 110 score. Based on the mean (78.66) and half standard deviation (12.02), the respondents were categorized as poor, good and better perception. Higher score on this scale indicates that the respondent has better perception towards bee keeping and the lower perception score indicates that the respondent has poor perception towards bee keeping.

Information regarding 22 profile characteristics (independent variables) of beekeepers were collected using a structured schedule with suitable scales. The collected data were scored, tabulated and analyzed using frequency, mean, percentage, chi-square test and multiple regression analysis.

Results and Discussion

Perception of Beekeepers towards Beekeeping in Coastal Zone of Karnataka

The results in Table 1 reveals the data on the perception of beekeepers towards the ecological and economic benefits of beekeeping.

Ecological Benefits of Rearing Honey Bee

It is observed from Table 1 that among the ten perception statements with respect to the ecological benefits of rearing honey bee, the statement 'Bees play a key role in pollination of agri-horticultural and other crops 'obtained perception score of 241 and was accorded the first rank, while the statement

TABLE 1

Perception of beekeepers towards beekeeping in coastal zone of Karnataka

(n=60)

Perception statements	Beekeepers	
	Perception score	Rank
Ecological benefits of rearing honey bee		
Bees play a key role in pollination of agri-horticultural and other crops	241	I
Beekeeping is an environmentally friendly subsidiary income generating activity	236	II
Beekeeping has been a skillful low impact technologies to deliver great benefits to people and biodiversity	231	III
Bees contribute to complex and interconnected ecosystems that allow a diverse number of different species to co-exist	208	IV
Closer the relationship between life forms and apiculture is realized, the much higher will be the consciousness of conservation of forest and crop species	205	V
Bees are responsible for the production of many seeds, nuts, berries, and fruit, which serve as a vital food source for wild animals and man	201	VI
Honey bee is a unique pollinator as it provides multiple by-products in addition to pollination services	199	VII
Bees are the vital part of food chain and they act as a food source for predators	188	VIII
Beekeeping requires least land area and even, backyard is sufficient, hence it releases people from land demanding activities and reduces pressure on land	181	IX
Bee hive fences are used as multi-dimensional conflict mitigation tool in protecting crops against elephants raids - a livestock wild interface	161	X
Economic benefits of rearing honey bees		
Apiculture is a non-farm income generating activity to increase income of the rural and urban households	226	I
Apiculture can be integrated into already existing agriculture enterprises such as piggery, diary, horticulture and field crops	224	II
Beekeeping is not labour intensive activity	202	III
Beekeeping is a cash crop	200	IV
Apiculture uses inexpensive, locally available resources, with quick returns	189	V
The growing market potential for honey and its products has resulted in bee keeping emerging as a viable enterprise	187	VI
Beekeepers can be better organized by enrolling themselves in Beekeeping Associations for adopting improved techniques, increasing production and strengthening their position in the market	185	VII
Bee keeping requires relatively lower levels of investment and is a non-physically demanding work	180	VIII
Beekeeping is easy to manage even by women and children	169	IX
By practicing beekeeping the farmer family becomes less vulnerable to economic pressure strengthening their ability to look into the future	153	X
Selling a secondary product such as bee wax, royal jelly, bee venom etc., brings a far better return for the producer than selling the raw commodity	151	XI

'Beekeeping is an environmentally friendly subsidiary income generating activity' received a score of 236 and was ranked second. The statement 'Beekeeping has been a skillful low impact technology to deliver great benefits to people and biodiversity' obtained a perception score of 231 and was ranked third by the beekeepers, whereas the statement 'Bees contribute to complex and interconnected ecosystems that allow a diverse number of different species to co-exist' was ranked fourth with apperception score of 208. The statement 'Closer the relationship between life forms and apiculture is realized, the much higher will be the consciousness of conservation of forest and crop species' received a perception score of 205 and was ranked fifth, while the statement 'Bees are responsible for the production of many seeds, nuts, berries and fruits, which serve as a vital food source for wild animals and man' obtained a perception score of 201 and was ranked sixth.

The perception statement 'Honey bee is a unique pollinator as it provides multiple by-products in addition to pollination services' obtained an perception score of 199 and was ranked seventh, while the remaining three statements, namely, 'Bees are the vital part of food chain and they act as a food source for predators', 'Beekeeping requires least land area and even, backyard is sufficient, hence it releases people from land demanding activities and reduces pressure on land' and 'Bee hive fences are used as multi-dimensional conflict mitigation tool in protecting crops against elephants raids - a livestock wild interface' were ranked eighth (188 score), ninth (181 score) and tenth (161 score), respectively.

Economic Benefits of Rearing Honey Bees

In respect of the perception of beekeepers towards the economic benefits of rearing honey bee, the statement 'Beekeeping is a non-farm income generating activity to increase income of the rural and urban households' obtained perception score of 226 and was assigned the first rank while the statement 'Beekeeping can be integrated into already existing agriculture enterprises such as piggery, diary, horticulture and field crops' received a score of 224 and was ranked second (Table 1). The perception statement 'Beekeeping is not a labour intensive activity' obtained a perception score of 202 and was ranked third by the bee keepers, while the statement 'Beekeeping is a cash crop' was ranked fourth with a perception score of 200. The statement 'Beekeeping uses inexpensive, locally available resources, with quick returns' received a perception score of 189 and was ranked fifth, whereas the statement 'The growing market potential for honey and its products has resulted in bee keeping emerging as a viable enterprise' obtained a perception score of 187 and was ranked sixth. The statement 'Beekeepers can be better organized by enrolling themselves in Beekeeping Associations for adopting improved techniques, increasing production and strengthening their position in the market' obtained a perception score of 199 and was ranked seventh.

The perception statement 'Bee keeping requires relatively lower levels of investment and is a non-physically demanding work' was ranked eighth with the score of 180, while the remaining three statements, namely, 'Beekeeping is easy to manage even by women and children', 'By practicing beekeeping the farmer family becomes less vulnerable to economic pressure strengthening their ability to look into the future' and 'Selling a secondary product such as bee wax, royal jelly, bee venom *etc.,* brings a far better return for the producer than selling the raw commodity were ranked ninth (169 score), tenth (153 score) and eleventh (151 score), respectively.

Beekeeping is an environmentally friendly activity helping in the pollination of crops and is vital part of the food chain requiring least land area. Besides, beekeeping is also a non-farm activity which uses locally available resources and family labour for obtaining quick returns. The beekeepers are well aware of the ecological and economic benefits of beekeeping; hence they possess better perception towards beekeeping.

Overall Perception of Beekeepers towards Beekeeping

The results in Table 2 reveals that nearly half of the beekeepers had better perception (48.34%)

TABLE 2

Overall perception of beekeepers towards beekeeping in coastal zone of Karnataka

(n=60)

Perception categories	Beekeepers	
	Number	Per cent
Poor (Below 72.65 score)	13	21.66
Good (72.65 to 84.67score)	18	30.00
Better (Above 84.67score)	29	48.34
Total	60	100.00
Mean	78.66	
Standard deviation	12.02	

Mean = 191.89; Standard deviation = 28.08

towards beekeeping, while 30.00 and 21.66 per cent of the bee keepers had good and poor perception towards beekeeping, respectively. The beekeepers are well aware of the ecological and economic benefits of beekeeping, hence more than three-fourth of the beekeepers had good to better perception (78.34%) towards beekeeping. The present findings are in line with the findings of the study conducted by Preethi *et. al.* (2017), Yehual *et. al.* (2013) and Sharma and Das (2018).

Association between the Profile Characteristics of Bee Keepers and their Perception towards Beekeeping

The Chi square test was applied to find out the association between profile characteristics of beekeepers and their perception towards beekeeping (Table 3). The results revealed that 17 out of 22 independent variables exhibited significant to highly significant association with the perception of bee keepers towards beekeeping. The variables such as number of bee hives, experience in beekeeping, innovativeness, training on bee keeping and extension participation of bee keepers had a highly significant association with their perception towards bee keeping at one per cent level of probability, whereas education, farming experience, annual income, achievement motivation, scientific orientation, risk orientation, cosmopoliteness, decision making ability, market orientation, economic motivation, mass media

TABLE 3

Association between profile characteristics of bee keepers with their perception towards beekeeping

(n=60)

Characteristics	df	Chi-square value	Contingency coefficient
Age	4	2.367 NS	0.122
Education	4	11.673 *	0.267
Family size	4	6.812 NS	0.187
Farm size	4	7.816 NS	0.189
Farming experience	4	11.888 *	0.266
Number of bee hives	4	13.968 **	0.269
Experience in beekeeping	4	14.891 **	0.287
Annual income	4	10.689 *	0.265
Innovativeness	4	15.061 **	0.342
Achievement motivation	4	12.619 *	0.311
Scientific orientation	4	11.692 *	0.268
Risk orientation	4	12.692 *	0.309
Cosmoploiteness	4	11.600 *	0.268
Decision making ability	4	12.692 *	0.310
Credit orientation	4	5.692 NS	0.111
Market orientation	4	10.888 *	0.262
Economic motivation	4	11.692 *	0.265
Social participation	4	6.991 NS	0.188
Mass media exposure	4	12.620 *	0.308
Training on beekeeping	4	15.699 **	0.343
Extension agency contact	4	13.612 *	0.312
Extension participation	4	14.001 **	0.313

NS=Non-significant; *=Significant at 5%; **= Significant at 1%; df=degrees of freedom

exposure and extension agency contact of bee keepers were found to be having a significant association with their perception towards bee keeping at five per cent level of probability. Variables such as age, family size, farm size, credit orientation and social participation of bee keepers had a non-significant association with their perception towards beekeeping, For every unit increase in the education, farming experience, annual income, achievement motivation, scientific orientation, risk orientation, cosmopoliteness, decision making ability, market orientation, economic motivation, number of bee hives, experience in beekeeping, innovativeness, mass media exposure,

TABLE 4

Extent of contribution of profile characteristics of beekeepers on the perception towards beekeeping

Characteristics	Regression coefficient	SE of Regression coefficient	't' value
Age	0.374	0.4161	1.110 NS
Education	0.276	0.5550	2.010 *
Family size	0.1936	01861	0.9610 NS
Farm size	0.7550	0.6161	0.8160 NS
Farming experience	0.3128	0.7879	2.5181 **
Number of bee hives	0.2507	0.6816	2.718 **
Experience in beekeeping	0.3295	0.9281	2.816 **
Annual income	0.3702	0.7816	2.111 *
Innovativeness	0.4009	0.9618	2.399 *
Achievement motivation	0.3283	0.6928	2.110 *
Scientific orientation	0.3401	0.8100	2.381 *
Risk orientation	0.3884	0.8192	2.109 *
Cosmopoliteness	0.2410	0.5892	2.444 *
Decision making ability	0.3885	0.8128	2.108 *
Credit orientation	0.3399	0.6666	1.961 NS
Market orientation	0.3371	0.7866	2.333 *
Economic motivation	0.2412	0.5986	2.481 *
Social participation	0.7523	0.8961	1.191 NS
Mass media exposure	0.3591	0.7981	2.222 *
Training on beekeeping	0.3263	0.9191	2.8160 **
Extension agency contact	0.3860	0.8181	2.119 *
Extension participation	0.3228	0.9681	2.999 **

NS= Non-significant; *=Significant at 5%; **= Significant at 1%; R^2=.731; F=22.66**

training on bee keeping, extension agency contact and extension participation of bee keepers there will be an increase in developing better perception towards bee keeping. The above findings are in line with the findings reported by Darshan *et. al*, (2019) and Meghajit Sharma Shijagurumayum *et al.,* (2022).

Extent of Contribution of Profile Characteristics of Beekeepers on the Perception towards Bee keeping

The results in Table 4 revealed that education, farming experience, annual income, achievement motivation, scientific orientation, risk orientation, cosmopolite ness, decision making ability, market orientation, economic motivation, number of bee hives, experience in beekeeping, innovativeness, mass media exposure, training on bee keeping, extension agency contact and extension participation of bee keepers have significantly contributed in developing better perception towards bee keeping, while age, family size, farm size, credit orientation and social participation of bee keeper have not significantly contributed in developing better perception towards bee keeping. All the 22 profile characteristics of beekeepers had contributed to the tune of 73.10 per cent (R^2 = 0.731) in developing better perception towards beekeeping and the 'F' value (22.66) indicated significant differences at one per cent level. Similar findings were reported by Sharma *et. al*, (2022).

It could be concluded from the results of the research study that more than three fourth (78.34%) of the beekeepers possessed good to better level of perception towards beekeeping. Mass media exposure, training on bee keeping, extension agency contact and extension participation of beekeepers had significant association with their perception towards beekeeping. Therefore, the apiculturists and extension personnel may conduct education activities (discussion meeting, demonstration, farmers field school and training programmes) to the beekeepers regarding the scientific bee keeping practices for developing better perception of beekeepers towards beekeeping in getting increased honey yield and higher returns. The mass media may also publish case studies of successful beekeepers for motivating the beekeepers to adopt sustainable beekeeping practices for utilizing locally available resources and family labour to get quick returns from beekeeping.

References

EDWARDS A. L., 1969, Techniques of attitude scale construction. VIkils, Feger and Dimons Pvt. Ltd., Sport Road, Ballard Estate, Bombay, **9** : 34 - 37.

DARSHAN, M. E., LAKSHMINARAYAN, M. T., SHIVAMURTHY, M., PATIL, S. S. AND BANUPRAKASH, K. G., 2019, Perception of farmers about the functioning of Raitha Samparka Kendras. *Mysore J. Agri. Sci*., **53** (2) : 73 - 81.

JAGADEESH,V., LAKSHMINARAYAN. M. T. AND JAGADISH, K. S., 2022, A scale to analyse the perception of farmer-bee keepers towards Beekeeping, *The Pharma Innovation Journal*, **11** (3) : 1471 - 1474.

LIKERT, R. A., 1932, A technique for assessing attitudes. *Archives of Psychology,* New York : 140.

MEGHAJIT SHARMA SHIJAGURUMAYUM, LAKSHMINARAYAN, M. T. AND KRISHNAMURTHY, B., 2022, Perception of aromatic black rice growers towards mission organic value chain development scheme. *Mysore J. Agric. Sci*., **56** (1) : 221 - 230.

PREETHI, NATARAJU, M. S. AND LAKSHMINARAYAN, M. T., 2017, Perception of farm youth towards agriculture. *Mysore J. Agric. Sci.,* **51** (1) : 139 - 144.

SHARMA, S. AND DAS, D., 2018, Factors affecting the adoption of beekeeping and associated technologies in Kamrup (rural) District, Assam State, India. *Biodiversity International Journal,* **2** (3) : 35 - 41.

YEHUAL, A. S., MALEDE BIRHAN AND DEGSEW MELAK, 2013, Perception of farmers towards the modern beehives technology in Amhara Region, Ethiopia. *European Journal of Biological Science,* **5** (1) : 01 - 08.

TARAKINI, G., ABEL CHEMURA AND ROBERT MUSUNDIRE, 2020, Farmers knowledge and attitudes towards pollination and bees in a maize-producing region of Zimbabwe implications for pollinator conservation, *Tropical Conservation Science,* **13** (3) : 1 - 13.

Mysore J. Agric. Sci., 57 (1) : 109-119 (2023)

Assessment of Genetic Variability Based on Morphometric Characteristics in Soybean (*Glycine max* L. Merrill) Germplasm

Kaveri Chawan, P. Ravishankar, S. Ramesh and T. Onkarappa
Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : kaverichawan1@gmail.com

Authors Contribution

Kaveri Chawan : Conceptualization, investigation and original draft preparation;
P. Ravishankar : Conceptualization and draft correction;
S. Ramesh : Conceptualization, original draft preparation and analysis;
T. Onkarappa : Supervision and editing

Corresponding Author :
Kaveri Chawan
Department of Genetics and Plant Breeding,
College of Agriculturre,
UAS, GKVK, Bengaluru

Received : September 2022
Accepted : December 2022

Abstract

The present study is aimed at assessing the extent and pattern of genetic variability present among soybean germplasm accessions (2000) obtained from IISR (Indian Institute of Soybean Research), Indore, Madhya Pradesh. It was studied at University of Agricultural Sciences (UAS), Bangalore for 7 quantitative traits and 13 qualitative traits. The germplasm accessions along with three check entries were sown in augmented design in 21 compact blocks during 2021 summer season at the experimental plots of Zonal Agricultural Research Station (ZARS), UAS, GKVK, Bengaluru. Substantial variability among the accessions for quantitative traits and polymorphism for qualitative traits were documented. The germplasm accessions could be grouped into 10 clusters following K-means clustering approach. The variability parameters like mean, range of variation, GCV, PCV, heritability and genetic advance were estimated for all traits. The differences between GCV and PCV estimates were narrow for all traits indicating less contribution of environmental factors in traits expression. High estimates of heritability coupled with high genetic advance were observed in all traits. The traits with higher heritability and GA value may indicate their variability and high selective value. Some of the germplasm accessions were superior to the check KBS 23, JS 335 and DSB 21. The accessions contrasting for individual and multiple traits were identified. These results are discussed in relation to suitable strategies to be adopted for breeding soybean for improved productivity.

Keywords : GCV, Genetic advance, K-means clustering, Heritability, PCA, PCV

Soybean (*Glycine max* L. Merril) is an annual self -pollinated diploid legume (subfamily Fabaceae), which is an important source of high quality protein and oil in the world. It contains about 42 per cent protein, 20 per cent oil and 33 per cent carbohydrate (Zhang *et al.,* 2001). Cultivated soybean has a genome size of 1.1 to 1.15 GB with chromosome pair of twenty (2n=40). Owing to its amino acids composition, the protein of soybean is called a complete protein. Among the various soybean growing countries in the world, USA stands first in both production and productivity with 96.62 m.t. and 3157 kg/ha respectively from 306.03 lakh ha of area. Whereas, India in the fifth position produces 9.00 m.t. with productivity of 800 kg/ha from 112.5 lakh ha of area (USDA Foreign agricultural service, 2020). India's contribution to the world soybean area is 10 per cent, but the contribution to total world soybean grain is only 4 per cent indicating the poor level of productivity of the crop in India as compared to other courtiers (world average 2.2 t/ha). Hence it necessitates broadening the genetic base through enhanced use of diverse germplasm accessions.

Precise information on genetic variability and diverse sources of germpalsm for traits of economic importance is a prerequisite for enhanced use of germplasm for continued genetic improvement and to cater to the needs of changing consumer preferences. The remarkable progress made in plant genetic resource management in recent days has resulted in the collection of a huge set of plant germplasm that hinders the very purpose for which they exist (Odong *et al.,* 2013). Frankel and Brown (1984) proposed the concept of core collection that could be established from an existing collection for better management and utilization of plant genetic resources. Characterization of a core set is an efficient approach for exploring and capturing the genetic diversity of large populations, as it represents the maximum genetic diversity of the whole collection and become a powerful tool for evaluation and identification of trait-specific accessions in germplasm (Gireesh *et al.,* 2015).

Therefore, an investigation was carried out to assess the variability for morpho-metric traits among germplasm accessions at the University of Agricultural Sciences (UAS), Bangalore which in turn helps in understanding the limitations of the domesticated germplasm and potential use of its wild relatives in crop improvement.

Material and Methods

The material for the study comprised of 2000 germplasm accessions obtained from IISR (Indian Institute of Soybean Research), Indore, Madhya Pradesh and three check entries (KBS 23, JS 335 and DSB 21). The 2000 germplasm accessions and three check entries were sown in an augmented design (Federer 1956) in 21 compact blocks during 2021 summer season in the experimental plots of Zonal Agricultural Research Station (ZARS), UAS, GKVK, Bengaluru (930 m above mean sea level; 12°C 58' north latitude and 77°C 35' east longitude). Each block consisted of 100 germplasm accessions and three checks (replicated twice). The seeds of each entry were dibbled in a single row of 1.5-meter length, using a row spacing of 45 X 10 cm. At the time of sowing, a basal dose of 25:50:25 Kg NPK ha^{-1} was applied to the experimental plot. Recommended agronomic and plant protection practices were followed to raise a healthy crop.

Using five randomly tagged plants, data were recorded on 13 qualitative traits (hilum color, seed coat color, early plant vigour, hypocotyl color, flower color, leaf shape, leaflet color, plant pubescence, plant pubescence color, plant pubescence density, plant pubescence type, stem determination, pod color) visually. Data were also recorded on 7 quantitative traits *viz.* days to 50 per cent flowering, plant height (cm), number of secondary branches^{-1}, number of pods^{-1}, days to 80 per cent maturity, 100 seed weight (g), seed yield^{-1} (g) based on counting/measurement using appropriate scale depending on the trait following the descriptors developed by IISR. Quantitative trait means of each of the 2003 accessions were adjusted for block effect. Block effect was estimated as difference between trait mean of check entries included in the ith block and trait mean of check entries of all the blocks (Federer, 1956). The number and per cent accessions belonging to each class were counted and computed.

Statistical Analysis

Adjusted mean values of quantitative traits data recorded on five random plants were subjected to statistical analysis. Descriptive statistics such as range and variance and their standardized values standardized range (maximum-minimum/mean), coefficient of variation (standard deviation/mean) x 100 were estimated (Snedecor and Cochran, 1994) to quantify variability and compare across traits. The 2003 soybean accessions were grouped into 10 clusters following model-based 'K means' clustering (Mac Queen, 1967) approach. The significance of difference among the clusters for means and variances of 7 quantitative traits was examined using't' and Levene's (Levene, 1960) tests, respectively.

Results and Discussion

An attempt was made to study the variability in the soybean germplasm accessions by using 20 morph metric characteristics and substantial variability was documented for both qualitative and quantitative traits.

TABLE 1

Variability for qualitative characteristics and their frequency in soybean germplasm

Traits	Score	Class	Frequency	Percentage
Hypocotyl color	1	Green	498	24.86
	2	Purple	1505	75.14
Early plant vigour	1	Poor	89	4.44
	2	Good	1608	80.28
	3	Very good	306	15.28
Leaf shape	1	Broad	500	24.96
	2	Indeterminate	1015	50.67
	3	Narrow	488	24.36
Leaf color	1	White	561	28.01
	2	Light green	959	47.88
	3	Green	254	12.68
	4	Dark green	229	11.43
Plant pubescence	0	Absent	51	2.55
	1	Present	1952	97.45
Plant pubescence color	0	Absent	51	2.55
	1	Grey	146	7.29
	2	Light tawny	502	25.06
	3	Tawny	1304	65.1
Plant pubescence density	0	Absent	51	2.55
	1	Glaborus	100	4.99
	3	Sparse	535	26.71
	5	Semi-sparse	380	18.97
	7	Normal	922	46.03
	9	Dense	15	0.75
Plant pubescence type	0	Absent	51	2.55
	1	Errect	1109	55.37
	3	Semi-appressed	436	21.77
	5	Appressed	277	13.83
	7	Curly	113	5.64
	9	Retrose tip	17	0.85
Stem determination	1	Determinate	1205	60.16
	2	Semi-determinate	369	18.42
	3	Indeterminate	429	21.42
Flower color	1	White	393	19.62
	2	Light purple	233	11.63
	3	Purple	1067	53.27
	4	Dark purple	310	15.48

Table 1 contd....

Traits	Score	Class	Frequency	Percentage
Pod color	1	Light brown	625	31.2
	2	Brown	600	29.96
	3	Dark brown	778	38.84
	4	Black	0	0
Hilum color	1	Yellow	34	1.7
	2	Buff	66	3.3
	3	Brown	626	31.25
	4	Green	2	0.1
	5	Grey	187	9.34
	6	Imperfect black	153	7.64
	7	Black	935	46.68
Seed coat color	1	Yellowish white	266	13.28
	2	Yellow	1246	62.21
	3	Green	126	6.29
	4	Buff	3	0.15
	5	Reddish brown	81	4.04
	6	Grey	0	0
	7	Imperfect black	69	3.44
	8	Black	212	10.58

Qualitative traits

Determinate type of accessions dominated the collection (60.16%) followed by indeterminate (21.42%) and semi-determinate (18.42%) types (Table 1). Although an indeterminate growth habit is attractive to develop high-yield soybean varieties with higher number of pods, lodging in indeterminate varieties remains a problem in India. As the determinate and semi-determinate varieties have shorter main stem length than the indeterminate varieties, this trait can be useful to improve varieties with high yield and low lodging risk hence determinate growth habit always had an advantage. Predominance of determinate types of accessions and lower frequency of semi determinate or indeterminate accessions in the USDA Soybean Germplasm Collection database at National Plant Germplasm System (NPGS) of 89 soybean germplasm accessions have been documented (Zhixi *et al.,* 2010).

Soybean is now being cultivated extensively for commercial purpose, determinate type cultivars are gaining popularity among the farmers. Determinate type cultivars have more compact growth habit, reduced branching, shorter internodes, reduced above ground biomass and accelerated and synchronized flowering and reduced period of pod production leading to more uniform pod maturity and stable harvest index. Further, determinate types do not require support system (in contrast to indeterminate types which require staking) enabling high density planting to harness complete productivity potential of cultivars. Hence, breeding for determinacy is one of the major objectives of soybean breeding to optimize allocation between vegetative and reproductive phases. Shannon *et al.,* (1971) and Weaver *et al*., (1991) have reported a higher yield of determinate type soybean lines.

Purple flowers (53.27%) dominated the collection followed by white (19.62%), dark purple (15.48%) and light purple (11.63%) flowers (Table 1). Genotypes with purple hypocotyl (75.14%) were highest compared to green hypocotyl (24.86%).

Indeterminate leaf shape (50.67%) with light green (47.88%) leaves type of accessions dominated the collection followed by broad leaves (24.96%) and narrow leaves (24.36%) with white (28.01%), green (12.68%) and dark green (11.43%) leaves. Good plant vigour type of accessions dominated the collection (80.28%) followed by very good plant vigour (15.28%) and poor plant vigour (4.44%) types. High seedling vigour is considered a decisive factor for the success of most field crops, as these parameters contribute to uniform plant growth maturity, better competition with weeds and high productivity (Bewley *et al.,* 2013 and Schuch *et al.,* 2009).

Accessions bearing pubescent (97.45%) pods which of tawny (65.1%) and light tawny (25.06%) colored pubescence were higher compared to non-pubescent pods (2.5%) and grey colored pubescence (7.29%). Dark brown pod color type of accessions dominated the collection (38.84%) followed by light brown (31.2%) and brown (29.96%) types. Genotypes with yellow (62.21%), yellowish white (13.28%) colored seed coat were found to be prominent over black (10.58%), green (6.29%), reddish brown (4.04%), imperfect black (3.44%) and buff (0.15%) colored seed coat accessions. Further, seeds with black colored hilum (46.68%) were higher followed by brown (31.25%), imperfect black (7.64%), grey (9.34%), buff (3.3%) and yellow (1.7%) hilum colored genotypes. The dominance of yellow seeded genotypes in the collection may be due to higher directional selection for yellow seeded ones owing to their high yield potential and consumer preference (Akito Kaga *et al.,* 2012).

Quantitative Traits

Analysis of variance represents the variability among the germplasm accessions and it exhibited a highly significant mean sum of square values for all quantitative traits (Table 2). Mean squares due to check varieties were significant for all traits except for number of pods plant^{-1}, while those due to 'accessions vs. check varieties' were significant for all traits except for days to 80 per cent maturity. These results suggested significant differences among the accessions and they differ from the checks.

TABLE 2

Analysis of variance of Soybean germplasm accessions for quantitative traits

Sources of variation	df	Mean sum of squares (MSS)						
		Days to 50% flowering	Plant height (cm)	Number of secondary branches plant^{-1}	Number of pods plant^{-1}	Days to 80% maturity	100 seed weight (g)	Seed yield plant^{-1} (g)
Blocks	19	895.89 **	988.00 **	1.48 **	749.22 **	1277.91 **	49.00 **	14876.25 **
(Accessions + Checks)	2002	69.21 **	90.65 **	0.43 **	155.06 **	87.53 **	7.56 **	2397.24 **
Accessions	1999	76.97 **	93.33 **	0.43 **	160.04 **	98.11 **	7.87 **	2531.20 **
Checks	2	112.90 **	5707.96 **	7.45 **	17.05	939.15 **	142.19 **	5985.45 **
Accessions vs Checks	1	1280.87 **	1934.45 **	7.27 **	4437.68 **	157.12	41.14 **	9159.47 **
Error	38	12.44	10.2	0.13	7.95	46.65	0.41	38.38

*Significant at P= 0.05 level, **Significant at P= 0.01 level

Descriptive Statistics of Quantitative Characters

It indicated the components of genetic variability, heritability and genetic advance and it was computed using first and second-degree statistics. Presence of genetic variability *per se* is of less significance in crop breeding programmes. Knowledge on relative contribution of genetic and non-genetic sources on the quantitative trait variability is useful in formulating appropriate selection strategies to breed improved soybean cultivars. The estimates of standardized range provide clues about the occurrence of accessions with extreme expression which varied with the trait. However, standardized range *per se* does not reflect variability in the expression of all the accessions. The estimates of GCV and PCV which reflect average inter-accession differences are more useful statistics to understand variability among the germplasm accessions.

The accessions were highly variable for plant height (cm), number of pods plant^{-1}, 100 seed weight (g), seed yield plant^{-1}(g), hilum color, seed coat color, early plant vigour, hypocotyl color, flower color, leaf shape, leaf color, plant pubescence, plant pubescence color, plant pubescence density, plant pubescence type, stem determination, pod color traits as indicated by the estimates of PCV (>20%) (Table 3), the accessions were moderately variable (10.1% < PCV < 19.9%) for days to 50 per cent flowering and number of secondary branches plant^{-1} traits. The accessions were least variable for days to 80 per cebt maturity (PCV=8.29%). Relatively narrow difference between PCV and GCV estimates for these traits has amply reflected in higher broad-sense heritability estimates. The differences between GCV and PCV estimates were narrow for all the traits indicating less contribution of environmental factors in character expression (Karnwal and Singh, 2009 and Aditya *et al.,* 2011). Thus selection based on the phenotypic performance of these characters would be an effective way to bring about considerable improvement of these characters (Akram *et al.,* 2016).

TABLE 3

Descriptive statistics for quantitative traits in Soybean germplasm

Traits	Mean ± Std. Error	Range		Standardized Range	Coefficient of variablility		Broad-sense h^2 (%)	Expected genetic advance as % mean
		Min	Max		GCV%	PCV%		
Days to 50% flowering	58.37 ± 0.2	43.73	77.39	33.67	13.62	14.9	83.56	21.92
Plant height (cm)	46.81 ± 0.22	31.65	83.31	51.67	19.29	20.46	88.86	31.97
Number of secondary branches plant^{-1}	4.94 ± 0.01	3.4	7	3.6	10.98	13.26	68.37	16.08
Number of pods plant^{-1}	41.92 ± 0.28	22.38	93.44	71.07	29.13	29.9	94.94	49.94
Days to 80% maturity	118.81 ± 0.22	94.91	138.58	43.67	5.98	8.29	51.95	7.58
100 seed weight (g)	13.28 ± 0.06	6.01	23.29	17.29	20.36	20.93	94.6	34.85
Seed yield plant^{-1} (g)	110.02 ± 1.12	36.5	294.77	258.27	44.92	45.27	98.45	78.45

*Significant at P= 0.05 level, **Significant at P= 0.01 level

Broad-sense heritability was higher (> 60%) for all the traits, except for days to 80 per cent maturity (51.95%), hypocotyl color (38.24%), leaf shape (39.8%) and plant pubescence (39.94%). Plant pubescence density (99.93%) followed by seed yield plant^{-1} (98.45%) and hilum color (98.16%) were more heritable than the other traits. Soybean is predominantly a self-pollinated crop. Hence the accessions used in the study are a mixture of pure lines whose expression predominantly determined by additive genetic effects and additive x additive type of epistasis. Consequently, broad-sense heritability is a reflection of narrow-sense herit ability Thus selection of desired accessions for any of the traits considered in the present investigation would be effective as all the traits were highly heritable.

In the present study, the estimates of expected GAM were higher for seed yield plant^{-1} and plant pubescence density (78.45 and 72.22%, respectively), hilum color (63.21%), seed coat color (59.99%), plant pubescence type (59.71%), stem determination (54.37%), number of pods plant^{-1} (49.94%), while they were lower for number of secondary branches plant^{-1} (16.08%) and days to 80 per cent maturity (7.58%). Thus higher estimates of expected genetic advance which takes into account of variability and heritability are conformity evidence for scope and effectiveness of a selection of genotypes (Patil *et al.,* 2011). One of the major applications of estimating heritability and the genetic parameters that compose the heritability estimate is to compare the expected genetic gains from selection based on alternative selection strategies and different experimental designs (Falconer and Mackay, 1996). The information elicited from such comparisons could be used to design optimal breeding strategies (Milligan *et al*., 1990).

Organization of Variability

The efficiency and pace of soybean improvement programmes hinges on the precise information on magnitude of fixable (additive and additive based epitasis) component of genetic variability, g×e (both spatial and temporal) interaction and DNA marker-assisted chromosomal localization and mode of action of genes controlling traits of economic importance. The identification of accessions contrasting for traits of economic importance is a prerequisite for eliciting such information. Cluster analysis helps in grouping of accessions sharing similar characters in different clusters and to identify genetically diverse and desirable genotypes.

The quantitative traits mean differences between clusters were significant for all the traits (Table 4). The trait variances among six clusters were significant for all traits (Table 5). These results suggested K-means clustering approach was efficient to minimize with-in cluster variance and maximize between-cluster variance as a result of inclusion of diverse accessions into different clusters. The estimates of the means of the quantitative traits such as Days to 50 per cent flowering, plant height, secondary branches plant^{-1}, number of pods plant^{-1}, days to 80 per cent maturity, 100 seed weight, seed yield plant^{-1} (g) were highest among the accessions included in cluster X and Cluster VI and were least among the accessions included in cluster VIII. It is desirable to choose germplasm accessions from among those included in Cluster X and Cluster VI for various applications in soybean breeding research such as those already indicated.

Significant variability among the accessions for quantitative traits was expected as they are landraces which have evolved over millennia through a combination of natural and human selection on the variation originated by mutations and distributed by recombination (Allard, 1999). These landraces poses different combination of traits and hence have better adaptability to different production environment and / or a combination of production environments. Through increased use of landraces, efficiency of breeding soybean cultivars that are suitable for diverse production constraints especially that of terminal drought, a most frequently occurring abiotic stress in regions where soybean is extensively grown could be maximized.

TABLE 4

Estimates of quantitative traits means of the soybean accessions belonging to different clusters

Size of the cluster	Mean of clusters										F Statis-tic	Proba-bility
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}		
	221	284	170	340	141	182	231	209	154	71		
Days to 50% flowering	61.26	54.15	69.97	54.51	70.28	60.5	53.54	53.05	58.16	59.47	29.65	0.00
Plant height (cm)	49.54	42.12	56.14	42.74	53.72	49.11	41.81	41.19	52.05	55.98	25.39	0.00
Number of secondary branches plant^{-1}	4.99	4.83	5.03	4.9	5.12	4.91	4.92	4.89	5	5.05	177.44	0.00
Number of pods plant^{-1}	48.48	43.24	39.66	37.18	28.5	54.23	31.1	25.82	63.11	76.08	8.82	0.00
Days to 80% maturity	121.48	115.24	127.78	115.93	129.1	119.86	115.04	112.56	119.97	122.16	69.32	0.00
100 seed weight (g)	13.09	13.89	11.94	13.58	11.89	13.57	14.11	13.59	12.78	12.61	53.07	0.00
Seed yield plant^{-1} (g)	135.52	105.52	93.31	86.73	61.36	167.55	70.75	53.44	203.04	242.05	6.05	0.00

TABLE 5

Estimates of quantitative traits variances among the soybean accessions belonging to different clusters

Size of the cluster	Variance of clusters										F Statis-tic	Proba-bility
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}		
	221	284	170	340	141	182	231	209	154	71		
Days to 50% flowering	77.27	28.59	42.61	29.54	43	67.91	28.28	34.56	62.09	46.65	8.32	0.00
Plant height (cm)	108.3	33.57	103.63	35.73	79.39	109.78	25.53	18.85	114.88	104.84	5.79	0.00
Number of secondary branches plant^{-1}	0.47	0.33	0.47	0.43	0.39	0.56	0.42	0.41	0.47	0.44	22.89	0.00
Number of pods plant^{-1}	2.86	4.68	22.71	7.63	7.53	3.65	4.12	4.03	9.92	30.07	3.33	0.00
Days to 80% maturity	75.97	80.32	34.26	80.64	39.7	80.14	83.72	85.67	80.12	69.39	12.13	0.00
100 seed weight (g)	7.25	7.32	5.68	7.51	7.77	5.96	10.67	8.81	5.6	4.06	12.01	0.00
Seed yield plant^{-1} (g)	103.2	56.82	98.91	38.67	82.42	107.75	23.49	40.1	86.43	324.67	3.55	0.00

TABLE 6

Trait-specific accessions for seven quantitative traits from 2000 germplasm accessions of soybean

Characters	Accessions with lowest value	Mean value	Accessions with highest value	Mean value
Days to 50% flowering	SQL 32	44	UPSV 45	77
	EC 308327	44	JS 82-780	77
	TGX 844-313E	44	UPSL 28	77
	EC 456650	44	UPSL 254	77
	IC 501637	44	UPSM 858	77
	JS 335 (Check)	47.54		
Plant height (cm)	N 928	33.02	GP 519	84.328
	EC 39376	35.052	GC-60115-8	82.804
	CAT 2086 A	35.052	JS 99-76	81.28
	VP 1156	35.052	TGX 560-200	80.264
	TGX 86-24-6F	35.052	HIMSO 1597	79.756
	JS 335 (Check)	39.67		
Number of secondary branches plant^{-1}	SEHORE 1	3.4	WT 89	7
	UPSL 54	3.4	PS 1337	7
	UPSL 750 A	3.4	PS 1347	7
	EC 381884	3.4	EC 245986	7
	UPSM 42	3.4	TGX 352-3D	6.8
	JS 335 (Check)	5.86		
Number of pods plant^{-1}	NRC 2755	22.4	JS 99-76	93.4
	EC 457181	22.4	MACS 693	91.6
	JS 80-39	23	TGX 825-3D	86.2
	DT-21	23	V 31	84.4
	LEE 75	23	GP-434	82.4
	JS 335 (Check)	54.36		
Days to 80% maturity	AGS-116	95	EC 39508	138
	UPSL-77	95	UPSL 736	138
	PS-1336	95	KB 19	138
	NB 208	95	UPSL 758	138
	EC 572126	95	UPSL 750 A	138
	JS 335 (Check)	103.5		
100 seed weight (g)	EC 251356	6	TGX 1016-19 F	23.3
	EC 250601	6	B 160-3	22.2
	MACS 57	6.3	JS 20-82	21.59
	JS 79-82	6.3	SQL 7	21.38
	EC 572087	6.3	EC 25196	21.3
	JS 335 (Check)	15.19		
Seed yield plant^{-1} (g)	EC 457181	36.84	JS 99-76	295
	IC 501785	37.04	MACS 693	292
	EC 457211	42	TGX 825-3D	274.1
	DT-21	42.7	V 31	268.1
	IC 501785	42.75	GP-434	266.5
	JS 335 (Check)	118.09		

Traits-Specific Accessions

Exploitation of natural genetic variability aim to meet short-term objectives as very often breeders are forced to meet immediate requirement of the farmers, consumers and end-users. Continued crop genetic improvement to meet medium - and / long-term requirements requires availability of variability induced through deliberately planned crosses among the genotypes *harbouring* desired combination of traits. Evaluation of germplasm provides information about the accessions / genotypes with desired combination of traits.

TABLE 7

Superior accessions for multiple traits

Accessions	Number of pods plant^{-1}	Seed yield plant^{-1} (g)
TGX 825-3D	86.2	274.1
V 31	84.4	268.1
GP-434	82.4	266.5
JS 335 (Check)	54.36	118.09

Some of the germplasm accessions were superior to the check JS 335 for 7 quantitative traits and the top five accessions for these traits along with contrasting lines are listed in Table 6. Three lines among the top performing accessions exhibited superiority for multiple traits and is listed in Table 7.

REFERENCES

ADITYA, J. P., PUSHPENDRA, B. P. AND ANURADHA, B., 2011, Genetic variability, heritability and character association for yield and component characters in soybean. *J. Central European Agric*., **12** (1) : 27 - 34.

AKITOKAGA, TAKEHIKO SHIMIZU, SATOSHI WATANABE, YASUTAKA TSUBOKURA, YUICHI KATAYOSE, KYUYA HARADA, DUNCAN, A. V. AND NORIHIKO TOMOOKA, 2012, Evaluation of soybean germplasm conserved in NIAS genebank and development of mini core collections. *Breed Sci.,* **61** (5) : 566 - 592.

AKRAM, S., HUSSAIN, B. M. N., BARI, M. A. A., BURRITT, D. J. AND HOSSAIN, M. A., 2016, Genetic variability and association analysis of soybean (*Glycine max* L. Merrill) for yield and yield attributing traits. *Plant Gene and Trait*, **7** (13) : 1 - 11.

ALLARD, R. W., 1999, Principles of plant breeding. 2nd Ed. John Wiley and Sons, INC, Newyork, USA, pp. : 81.

BHANDARKAR, S., 1999, Studies on genetic variability and correlation analysis in soybean (*Glycine max* L. Merrill). *Mysore J. Agric. Sci.,* **33** (3) : 130 - 132.

BEWLEY, J. D., BRADFORD, K. J., HILHORST, H. W. M. AND NONOGAKI, H., 2013, Seeds: physiology of development, germination and dormancy. New York: Springer.

FALCONER, D. S. AND MACKAY, T. F. C., 1996, Introduction to quantitative genetics. 4th Ed. Addison Wesley Longman Ltd., England, pp. : 356 - 357.

FEDERER, W. T., 1956, Augmented (or hoonuiaku) designs. Hawaii. *Plant Res.,* **2** : 191 - 208.

FRANKEL, O. H. AND BROWN, A. H. D., 1984, Plant genetic resources today : A critical appraisal. CISRO, Div. of Plant industry, Canberra, Austrelia, pp. : 249 - 257.

GIREESH, C., HUSAIN, S. M., SHIVAKUMAR, M. AND SATPUTE, G. K., 2015, Integrating principal component score strategy with power core method for development of core collection in Indian soybean germplasm. *Plant Genetic Resources*, pp. : 1 - 9.

KARNWAL, M. K. AND SINGH, K., 2009, Studies on genetic variability, character association and path coefficient for seed yield and its contributing traits in soybean (*Glycine max* L. Merrill). *Legume Res*., **32** : 70 - 73.

LEVENE, H., 1960, Robust tests for equality of variances. In: Olkin *et al.* (ed.). Contributions to probability and statistics : Essays in honour of Harold Hotelling. Stanford University Press, Stanford, pp. : 278 - 292

MACQUEEN, J. B., 1967, Some methods for classification and analysis of multivariate observations, Proceedings of 5th Berkeley Symposium on Mathematical Statistics and Probability, Berkeley, University of California Press, **1** : 281 - 297.

MILLIGAN, S. B., GRAVOIS, K. A., BISCHOFF, K. P. AND MARTIN, F. A., 1990, Crop effect on broad-sense heritabilities and genetic variances of sugarcane yield components. *Crop Science*, **30** : 344 - 349.

ODONG, T. L., JANSEN, J., EEUWIJK, F. A. AND HINTUM, T. J. L., 2013, Quality of core collections for effective utilisation of genetic resources review, discussion and interpretation. *Theor. Appl. Genet.,* **126** : 289 - 305.

PATIL, S. S., NAIK, M. R., PATIL, P. P. AND SHINDE, D. A., 2011, Genetic variability, correlation and path analysis in soybean. *Legume Research*, **34** (1) : 36 - 40.

SCHUCH, L. O. B., KOLCHINSKI, E. M. AND FINATTO, J. A., 2009, Seed physiological quality and individual plants performance in soybean. *Rev. Bras. Sementes*, **31** : 144 - 149.

SHANNON, J. G., WILCOX, J. R. AND PROBST, A. H., 1971, Response of soybean genotypes to spacing in hill plots. *Crop Sci.,* **11** : 38 - 40.

SHARMA, S. M., RAO, S. K. AND GOSWAMI, U., 1983, Genetic variation, correlation and regression analysis and their implications in selection of exotic soybean. *Mysore J. Agric. Sci.,* **17** : 26 - 30.

SNEDECOR, G. W. AND COCHRAN, W. G., 1994, Statistical methods. 8th edition, Iowa state university press, Ames, Iowa, USA.

USDA Foreign agricultural service, 2020, https://www.fas.usda.gov/.

WEAVER, D. D., AKRIDGE, R. L. AND THOMAS, C. A., 1991, Growth habit, planting date and row-spacing effects on late planted soybean. *Crop Sci.*, **31** : 805 - 810.

ZHANG, J., MUNGARA, P. AND JANE, J., 2001, Mechanical and thermal properties of extruded soy protein sheets. *Polymer.*, **42** : 2569 - 2578.

ZHIXI TIAN., XIAOBO WANG., RIAN LEE., YINGHUI LI., JAMES E. SPECHT, RANDALL L. NELSON, PHILLIP E. MCCLEAN, LIJUAN QIU AND JIANXIN, M. A., 2010, Artificial selection for determinate growth habit in soybean, *Proc. Natl. Acad. Sci.,* U S A., **107** (19) : 8563 - 8568.

Mysore J. Agric. Sci., 57 (1) : 120-126 (2023)

Studies on Yield, Yield Attributes and Nutrient uptake of Cowpea as Influenced by Integrated Nutrient Management

KUSHAL, M. R. ANAND, GANGADHAR ESHWAR RAO, VIGHNESH AND C. SEENAPPA
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : kushalrathod321@gmail.com

AUTHORS CONTRIBUTION

KUSHAL :
Carried out experiment ;
M. R. ANAND :
Guidance ;
GANGADHAR ESHWAR RAO & C. SEENAPPA :
Conceptualization;
VIGHNESH :
Data analysis

Corresponding Author :
KUSHAL
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru

Received : September 2022
Accepted : January 2023

ABSTRACT

The field experiment entitled 'Studies on yield, yield attributes and nutrient uptake of cowpea as influenced by integrated nutrient management' was conducted during *kharif*-2020 at AICRP on Arid Legumes, Gandhi Krishi Vigyan Kendra, University of Agricultural Sciences, Bangalore. Experiment consists combined application of nutrients (Urea, SSP, MOP used as a NPK sources) along with the seed treatment at the time of sowing. Totally there are nine treatments replicated thrice in randomized block design. The yield and yield attributes were significantly varied with the combined application of 100 per cent RDF + seed treatment with *Rhizobium* + PSB + 1 per cent 19:19:19 spray recorded higher number of pods plant^{-1} (27.1), pod length (17.0 cm) and number of seeds pod^{-1} (16.9) and it was on par with 100 per cent RDF + seed treatment with *Rhizobium* + PSB + 2 per cent urea spray and 100 per cent RDF + seed treatment with *Rhizobium* + PSB, respectively. Whereas, lower number of pods plant^{-1} (21.4), pod length (10.4 cm) and number of seeds pod^{-1} (10.3) were recorded with the application of 100 per cent RDF(Control). Higher seed yield, net returns and BC ratio (1384 kg ha^{-1}, Rs.38952 ha^{-1} and 2.53, respectively) recorded with application of 100 per cent RDF + seed treatment with *Rhizobium* + PSB + 1 per cent 19:19:19 spray. Whereas, lower seed yield, net returns and BC ratio (735 kg ha^{-1}, Rs.9584 ha^{-1} and 1.39, respectively) were recorded with 100 per cent RDF (Control).

Keywords : Cowpea, RDF, Rhizobium, Phosphate solubilizing bacteria, Urea, 19:19:19

COWPEA (*Vigna unguiculata* L. Walp) is one of the most important pulse crop native to Central Africa, belongs to family fabaceae. Cowpea is called as 'vegetable meat' due to high content of protein in grain with better biological value on dry weight basis. It is mainly grown in tropical and subtropical regions in the world for vegetable and grains and to lesser extent as a fodder crop. Apart from this, it produces heavy vegetative growth and covers the ground so well that it checks the soil erosion. It serves as a cover crop and improves soil fertility by fixing atmospheric nitrogen. Cowpea yield remains low (less than 1 t ha^{-1}) in majority of the areas mainly due to lack of high yielding varieties, low soil fertility and inappropriate farming techniques (Salih, 2013).

Nutritionally, cowpea grains contain 23-25 per cent of protein, 50-67 per cent of starch and several vitamins and minerals, while immature green cowpea pods are reported to contain 17-25 per cent of protein and abundant essential minerals. Green cowpea pods are often harvested and consumed as fresh vegetables.

Cowpea production worldwide is estimated to be about 6.5 million metric tons annually from an area of 14.5 million hectares. Over the last three decades, global cowpea production grew at an average rate of 5 per cent, with 3.5 per cent annual growth in area and 1.5 per cent growth in yield and the area expansion accounting for 70 per cent of the total growth during this period (Anonymous., 2013).

Nutrients are directly related with the growth and yield of cowpea. Application of nutrients through integrated approach reduce the cost of cultivation and also maintain as well as improve soil health by increasing the fertility (Mahajan and Sharma, 2005), whereas, non-monetary inputs like spacing also play an important role for boosting the yield by increasing the plant population per unit area.

Integrated Nutrient Management (INM) is a phenomenon that involves the use of chemical fertilizers in conjunction with organic manures and bio-fertilizers (Mahajan and Sharma, 2005). The basic concept of integrated nutrient management is supply of required plant nutrients for sustaining the anticipated crop productivity with a minimum harmful effect on soil health and environment (Balasubramanian, 1999). The combined effect of organic and inorganic nutrient sources used as integrated nutrient management has been proved superior to the use of each component separately (Palaniappan and Annadurai, 2007).

For boosting crop production, nutrient balance in the soil is the key component. Scientists have been concentrating their efforts on the efficient and sensible use of available resources to boost the total productivity and profitability per unit area in order to meet the food and other demands of an ever-increasing population.

Keeping these points in view, the present investigation on 'Studies on yield, yield attributes of cowpea as influenced by integrated nutrient management under changing climate' was under taken during *kharif* 2020 at All India Co-ordinated Research Project on Arid Legumes, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru.

Material and Methods

A field experiment was conducted during *kharif* 2020 at All India Coordinated Research Project (AICRP) on Arid Legumes, Gandhi Krishi Vigyana Kendra (GKVK), University of Agricultural Sciences (UAS), Bangalore, the centre is situated in the Agro-climatic Zone-V: Eastern Dry Zone of Karnataka at 12°58' North latitude and 77°35' East longitude with an altitude of 924 m above mean sea level (MSL). Soil of the experiment was red sandy loam soil (pH 6.2; OC 0.46%) with low available nitrogen (239.04 kg ha^{-1}), phosphorus (26.2 kg ha^{-1}) and potassium (248.3 kg ha^{-1}) respectively. The experiment was laid out in randomized complete block design (RCBD), replicated thrice with nine treatments. In the experimental site Horsegram (PHG-9) was grown during the *kharif* season of year 2019 and later kept fallow in *rabi* and *summer* seasons.

The land was prepared by using tractor drawn disc plough once followed by cultivator twice. The seeds were treated with *Rhizobium* and PSB culture and shade dried before sowing. The treated seeds were dibbled 2-3 cm in the furrows opened at 45 cm spacing with the help of hand hoe. Two seeds were dibbled per hill at 10 cm spacing. Sowing was done on 5th August, 2020 by using UAS Bangalore released variety KBC-9 (Arka Garima × VS389) and maintaining spacing as per the treatments using seed rate of twenty-five kg ha^{-1}. FYM was applied before 15 days of sowing to all the treatment plots at the rate of 2.5 tonnes ha^{-1}. Urea, single super phosphate and muriate of potash were used as a source of NPK. Fertilizers were applied 25:50:25 kg N, P_2O_5 and K_2O ha^{-1} and 2.5 t ha^{-1} FYM was applied as per the recommendation of package of practices (UAS, Bangalore). Thinning was done at 15 DAS by pulling out the extra seedlings in each hill and retaining only one seedling per hill. Hand weeding was done at 25 DAS to keep plots free from weeds. Earthing up was done at 30 DAS to encourage for rapid growth and to prevent lodging. Dimethioate @ 2 ml L^{-1} of water was given as spray to manage aphids and others sucking pests, during the period of 50 per cent of flowering stage at 55 DAS foliar nutrients were sprayed to the respective plots in three replications. The crop has attained the maturity at 85 DAS, the crop was harvested on 11th November, 2020 Subsequently, the pods from net plot area was harvested and allowed for sun drying for about a 4-5 days. After five days of sun-drying, threshing was done manually by beating the pods with a stick their after seeds were cleaned manually. Plot wise seed and haulm weight were recorded separately from each net plot after completion of threshing.

By using Fisher's method of analysis of variance technique which was given by Gomez and Gomez (1984) the analysis and interpretation of data were done.

Treatment details include, $T_{1:}$100 per cent RDF (Control), $T_{2:}$ 100 per cent RDF + foliar spray of urea @ 2 per cent, $T_{3:}$ 100 per cent RDF+ seed treatment with *Rhizobium* + PSB, $T_{4:}$ 100 per cent RDF + seed treatment with *Rhizobium* + PSB + 2 per cent urea spray, $T_{5:}$ 100 per cent RDF + seed treatment with *Rhizobium* + PSB+ 1 per cent 19:19:19 spray, $T_{6:}$ 100 per cent RDF + 1 per cent 19:19:19 spray, $T_{7:}$ 50 per cent RDF + 2.5 tonnes ha^{-1} FYM + 2 per cent urea spray, $T_{8:}$ 50 per cent RDF + 2.5 tonnes ha^{-1} FYM + 1 per cent 19:19:19 spray, $T_{9:}$ 50 per cent RDF +2.5 tonnes ha^{-1} FYM.

The Recommended dose of fertilizer is 25 kg N + 50 kg P_20_5 + 25 kg K_2O, for seed treatment 200 gram of *Rhizobium* and PSB used for 10 kg of seeds. All the foliar sprays were given at 50 per cent flowering stage.

Results and Discussion

Yield Attributes

The data presenting in (Table 1 and Fig. 1, respectively) revealed that maximum number of yield attributes *viz.,* No. of pods plant^{-1} (27.1), No. of seeds pod^{-1} (16.9), Pod length (17.0 cm) and Test weight (10.9 grams) were recorded with the application of 100 per cent RDF + seed treatment with

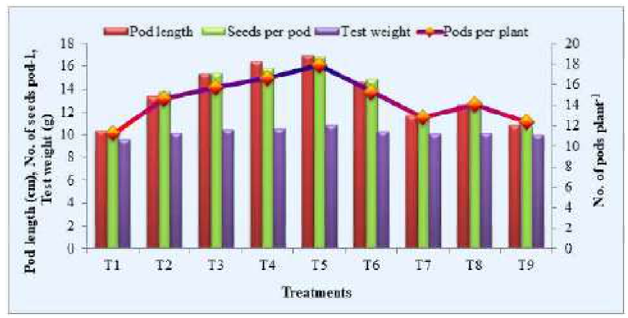


Fig. 1: Yield attributes of cowpea as influenced by integrated nutrient management

Table 1

Yield attributes of cowpea as influenced by integrated nutrient management

Treatments	No. of pods plant^{-1}	Pod length (cm)	No. of seeds pod^{-1}	Test weight (g)
T_1: 100% RDF (Control)	21.4	10.4	10.3	9.6
T_2: 100% RDF + foliar spray of urea @ 2%	24.8	13.4	13.8	10.2
T_3: 100% RDF+ seed treatment with *Rhizobium* + PSB	25.9	15.4	15.4	10.5
T_4: 100% RDF+ seed treatment with *Rhizobium* + PSB+ 2% urea spray	26.7	16.4	15.8	10.6
T_5: 100% RDF + seed treatment with *Rhizobium* + PSB + 1% 19:19:19 spray	27.1	17.0	16.9	10.9
T_6: 100% RDF + 1% 19:19:19 spray	25.2	14.6	14.8	10.3
T_7: 50% RDF + 2.5 tonnes ha^{-1} FYM + 2% urea spray	23.0	11.7	11.3	10.1
T_8: 50% RDF + 2.5 tonnes ha^{-1} FYM + 1% 19:19:19 spray	23.9	12.7	13.0	10.2
T_9: 50% RDF +2.5 tonnes ha^{-1} FYM	22.6	10.9	10.7	10.0
S. Em. ±	0.62	0.70	0.67	0.61
C.D. (P=0.05)	1.85	2.10	2.08	-

Rhizobium + PSB + 1 per cent 19:19:19 spray it is statistically on par with the application of 100 per cent RDF + seed treatment with *Rhizobium* + PSB + 2 per cent urea spray (26.7, 15.8, 16.4 and 10.6, respectively) and 100 per cent RDF + seed treatment with *Rhizobium* + PSB (25.9, 15.4, 15.4 cm and 10.5 g, respectively), Whereas minimum number of yield attributes *viz.,* No. of pods plant^{-1} (21.4), No. of seeds pod^{-1} (10.3 cm), Pod length (10.4) and Test weight (9.6 g.) were recorded in 100 per cent recommended dose of fertilizer (control).

The yield attributes are the symbol of vigorous plant growth and development. The optimum application of nutrients through soil as well as foliar nutrition offered easy availability for the absorption of macro nutrients in cowpea. It might be due to the efficient utilization of nitrogen helped for chlorophyll metabolism and boost of the production of carbohydrate. Phosphorus is essential for respiratory mechanism, which favoured more photosynthesis and vital for seed formation. Potassium plays important role in translocation of starch and protein synthesis. This was reflected in production of higher number of pods per plant of cowpea. The results are in closely associated with the findings of Manasa (2013), Malesha *et al.* (2014) and Sharma *et al.* (2015).

A reference to data in (Table 2 and Fig. 2), shows that, the maximum seed yield (1384 kg ha^{-1}), haulm yield (3267 kg ha^{-1}) and harvest index (29.8%) were recorded in treatment T_5 it is significantly on par with the treatment T_4 (1343,3176 and 29.7%) and T_3 (1291,3067 and 29.6%). However, minimum number of seed yield (735 kg ha^{-1}), haulm yield (1904 kg ha^{-1}) and harvest index (27.9%) were recorded in

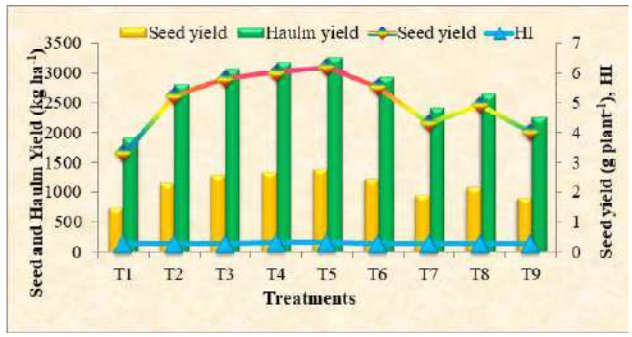


Fig. 2: Seed yield and haulm yield of cowpea as influenced by integrated nutrient management

TABLE 2

Seed yield, haulm yield and harvest index of cowpea as influenced by integrated nutrient management

Treatments	Seed yield (g plant^{-1})	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest Index (%)
T_1: 100% RDF(Control)	3.3	735	1904	27.9
T_2: 100% RDF + Foliar spray of urea @ 2%	5.2	1157	2804	29.2
T_3: 100% RDF+ seed treatment with *Rhizobium* + PSB	5.8	1291	3067	29.6
T_4: 100% RDF+ Seed treatment with *Rhizobium* + PSB + 2% urea spray	6.0	1343	3176	29.7
T_5: 100% RDF + seed treatment with *Rhizobium* + PSB + 1%19:19:19 spray	6.2	1384	3267	29.8
T_6: 100% RDF + 1% 19:19:19 spray	5.5	1222	2926	29.5
T_7: 50% RDF + 2.5 tonnes ha^{-1} FYM + 2% urea spray	4.3	945	2409	28.2
T_8: 50% RDF + 2.5 tonnes ha^{-1} FYM + 1% 19:19:19 spray	4.9	1083	2641	29.1
T_9: 50% RDF +2.5 tonnes ha^{-1} FYM	4.0	896	2265	28.4
S. Em. ±	0.23	50.3	115.2	
C.D. (P=0.05)	0.68	150.7	345.3	

control. It might be due to the dual seed inoculation benefited the plants by providing atmospheric N, increased the root nodulation through better root development and more nutrient availability and rendering the insoluble Phosphorus into available form also the entry of nutrients through foliar spray resulted in the entry of water into the cell causing cell elongation and cell division which leads to better growth and development of a plant. At critical stages of the crop growth macronutrients were effectively absorbed and translocated to the developing pods which lead to the better filling of seeds in the pod as a result increase in seed yield. The similar findings were reported by Vighnesh *et al.* (2022), Verma *et al.* (2009) and Amany (2007).

Nutrient Uptake

From the data presented in (Table 3 and Fig. 3), significantly higher nitrogen, phosphorous and potassium uptake (134.9 kg N ha^{-1},30.9 kg P_2o_5 and 125.9 K_2o kg ha^{-1}) as well as higher crude protein content (27.5%) were observed with the application of 100 per cent RDF + seed treatment with *Rhizobium* + PSB + 1 per cent 19:19:19 spray and it was statistically on par with the combined application of

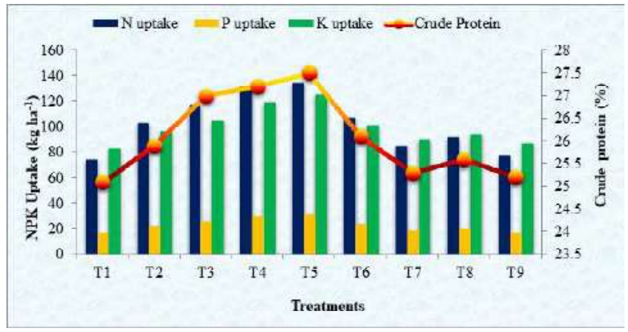


Fig. 3: Nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) uptake by cowpea as influenced by integrated nutrient management

100 per cent RDF+ seed treatment with *Rhizobium* + PSB + 2 per cent urea (131.7, 29.5 and 119.7 kg NPK ha^{-1}, respectively) followed by 100 per cent RDF+ seed treatment with *Rhizobium* + PSB (117.2, 25.7 and 104.9 kg NPK ha^{-1}, respectively). However, the lower nitrogen, phosphorous and potassium uptake (74.3, 16.1 and 83.2 kg NPK ha^{-1}, respectively) recorded in application with the 100 per cent recommended dose of fertililizer alone.

The increased nutrient uptake with integrated nutrient management because of increased balance supply of nutrients and good response by the plants resulted in

TABLE 3

Nutrient uptakes Nitrogen (N), Phosphorous (P_2o_5) and Potassium (K_2o) of cowpea as influenced by integrated nutrient management

Treatments	Nutrient uptakes		
	N uptake (kg ha^{-1})	P_2o_5 uptake (kg ha^{-1})	K_2o uptake (kg ha^{-1})
T_1: 100% RDF(Control) 25:50:25 kg ha^{-1} NPK	74.3	16.1	83.2
T_2: 100% RDF + foliar spray of urea @ 2%	103.2	22.1	96.9
T_3: 100% RDF+ seed treatment with Rhizobium + PSB	117.2	25.7	104.9
T_4: 100% RDF + seed treatment with Rhizobium + PSB + 2% urea spray	131.7	29.5	119.7
T_5: 100% RDF + seed treatment with Rhizobium+ PSB + 1% 19:19:19 spray	134.9	30.9	125.9
T_6: 100% RDF + 1% 19:19:19 spray	107.4	23.6	101.2
T_7: 50% RDF + 2.5 tonnes ha^{-1} FYM + 2% urea spray	84.9	17.8	90.6
T_8: 50% RDF + 2.5 tonnes ha^{-1} FYM + 1% 19:19:19 spray	92.0	19.4	94.2
T_9: 50% RDF + 2.5 tonnes ha^{-1} FYM	77.2	16.6	87.7
SE(m)±	3.83	0.24	4.32
C.D. (P=0.05)	11.49	0.73	12.94

TABLE 4

Economics of cowpea as influenced by integrated nutrient management

Treatments	Cost of cultivation (A)	Gross returns (Rs. ha^{-1}) (B)	Net return (Rs. ha^{-1}) (C=B-A)	B:C Ratio (D=B/A)
T_1: 100% RDF (Control)	24602	34186	9584	1.39
T_2: 100% RDF + foliar spray of urea @ 2% spray	25202	53797	28595	2.13
T_3: 100% RDF + seed treatment with *Rhizobium* + PSB	24782	60021	35239	2.42
T_4: 100% RDF+ seed treatment with *Rhizobium* + PSB + 2% urea	25382	62431	37049	2.46
T_5: 100% RDF + seed treatment with *Rhizobium* + PSB +1% 19:19:19 spray	25382	64334	38952	2.53
T_6 : 100% RDF + 1% 19:19:19 spray	25202	56833	31631	2.26
T_7: 50% RDF + 2.5 tonnes ha^{-1} FYM + 2% urea spray	27789	43937	16148	1.58
T_8: 50% RDF + 2.5 tonnes ha^{-1} FYM + 1% 19:19:19 spray	27789	50364	22575	1.81
T_9: 50% RDF + 2.5 tonnes ha^{-1} FYM	27189	41678	14489	1.53

enhanced translocation of nutrients to reproductive structure *viz*., pods, seeds and other plant parts as well as continuous availability of N, P and nutrients throughout the crop growth period as the nutrients from inorganic sources were available to the crop in the early stages and the nutrients released from the organic sources become available in the later stages of crop growth. It also might be due to dual inoculation of seed treatments with *Rhizobium* and PSB. This dual inoculation benefited the plants by providing atmospheric N and rendering the insoluble phosphorus into available form which also resulted in improved nodulation and higher leghemoglobin content of root nodules along with an increase in nitrogen uptake, available soil nitrogen content and dry matter production in cowpea. And entry of nutrients through foliar spray resulted in the entry of water into the cell causing cell elongation and cell division which leads to better growth and development of plant. The results were in colloboration with Venkatesh and Basu (2011), Bhoye (2016) and Mudalagiriyappa *et al*. (2016).

Economics

It is evident from the data presented in (Table 4 and Fig. 4), that the B:C ratio was found maximum in

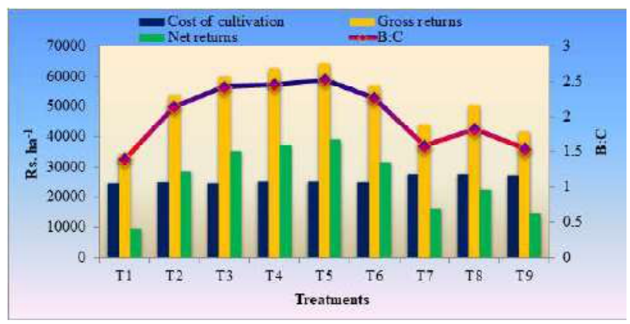


Fig. 4: Economics of cowpea cultivation influenced by integrated nutrient management

treatment T_5 (2.53). Whereas the minimum B:C ratio was recorded in treatment T_1 (1.39). It might happen due to high cost of cultivation. The benefit cost ratio is the result of higher seed yield with the combined application of different nutrients in integrated manner because of greater availability of essential nutrients to plant, better translocation of photosynthates leads to higher haulm and seed yield. The results are in close vicinity with the findings of Sangamesh (2020), Jadhav and Kulkarni (2016) and Channabasavanna *et al.* (2017).

REFERENCES

AMANY, A. B., 2007, Effect of plant density and urea foliar application on yield and yield components of chickpea (*Cicer arietinum* Linn.). *Res. J. Agric. & Biol. Sci.,* **3** (4) : 220 - 223.

ANONYMOUS, 2013, Ministry of Agriculture, Govt. of India. www. Indiastat.com.

BALASUBRAMANIAN, V., 1999, Managing soil quality for sustainable rice production. *Tamilnadu Rice Res. Insti.,* Anduthrai, pp. : 11 - 24.

BHOYE, S. R., 2016, Effect of foliar nutrition on growth, yield, uptake and quality of chickpea *M.Sc. (Agri), Thesis,* Vasantrao Naik Marathwada Agril. Univ., Parbhani (India*)*.

CHANNABASAVANNA, A. S., KITTURMATH, M. S. AND RAJKUMAR, H., 2017, Effect of soil and foliar application of micronutrients and fertilizers on growth and yield of pigeonpea [*Cajanus cajan* (L.) Mill sp]. *J. Agric. Sci.,* **30** (3) : 424 - 425.

GOMEZ, K. A. AND GOMEZ, A. A.,1984, Statistical procedures for agricultural research, Second edition, John Willey, New York, pp. 693.

JADHAV, R. L. AND KULKARNI, S., 2016, Effect of foliar spray of nutrients on productivity of greengram (*Vigna radiata*) in North Eastern Transitional Zone of Karnataka, India. *Legume Res.,* **39** (5) : 817 - 819.

MAHAJAN, A. AND SHARMA, R., 2005, Integrated nutrient management (INM) system- concept, need and future strategy, *Agro bios Newsletter*, **3** (6) : 29 - 32.

MALESHA, PATIL, K., MURALI BASAVARAJ, MADHU, G. K. AND SHRUTI, M. K., 2014, Effect of foliar application of water soluble fertilizer on growth and yield of pigeonpea. *Quarterly J. Life Sci.,* **11 (**4) : 229 - 232.

MANASA, 2013, Effect of water soluble fertilizers on growth, yield and oil quality of groundnut in a *Vertisol* of northern transition zone of Karnataka. *M. Sc. (Agri.) Thesis,* Univ. Agric. Sci., Dharwad.

MUDALAGIRIYAPPA, ALI, M. S., RAMACHANDRAPPA, B. K., NAGARAJU AND SHANKARALINGAPPA, B. C., 2016, Effect of foliar application of water soluble fertilizers on growth, yield and economics of chickpea (*Cicer arietinum* L.). *Legume Res.,* **39** (4) : 610 - 613.

PALANIAPPAN, S. P. AND ANNADURAI, K., 2007, Organic farming: theory and practices. Scientific Publishers, Jodhpur, India, pp. : 169.

SALIH, H. O., 2013, Effect of foliar fertilization of Fe, B and Zn on nutrient concentration and seed protein of cowpea (*Vigna unguiculata*). *J. Agri. Vet. Sci.,* **6** : 42 - 46.

SANGAMESH, K., BHAIRAPPANAVAR, S. T. AND PRAKASH, K., 2020, Response of foliar nutrition on growth, yield and B: C ratio of hybrid maize (*Zea mays* L.) in southern transition zone of Karnataka. *Mysore J. Agric. Sci.,* **54** (3) : 5 - 72.

SHARMA, S. K., PRAJAPATI, S. AND RAGHUWANSHI, O., 2015, Effect of organic manures and inorganic fertilizers on yield and economics of cowpea production [*Vigna unguiculata* (L.)] *Indian Res. J. Biotech.,* **7** (1) : 152 - 155.

VENKATESH, M. S. AND BASU, P. S., 2011, Effect of foliar application of urea on growth, yield and quality of chickpea under *rainfed* conditions. *J. Food legume*, **24** (2) : 110 - 112.

VERMA, C. B., YADAV, R. S., SINGH, I. J. AND SINGH, A. K., 2009, Physiological traits and productivity of *rainfed* chickpea in relation to urea spray and genotypes. *Legume Res.,* **32** (1) : 103 - 107.

VIGHNESH, SEENAPPA, C., HARISHA, S. AND KALYANAMURTHY, K. N., 2022, Effect of foliar nutrition on yield and economics of cowpea (*Vigna unguiculata*). *Mysore J. Agric. Sci.,* **56** (1) : 401 - 406.

Mysore J. Agric. Sci., 57 (1) : 127-138 (2023)

Effect of Nitrogen, Copper and Zinc Liquid Nano Fertilizers on Soil Properties, Nutrient Concentration, Uptake and Nutrient Use Efficiency of Potato (*Solanum tuberosum* L.)

B. Manikanta, S. Channakeshava and B. Mamatha
Department of Soil Science & Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : manikanta974377@gmail.com

Authors Contribution

B. Manikanta : Conceptualization, investigation, original draft preparation and analysis;
S. Channakeshava : Conceptualization, supervision, data curation and draft correction;
B. Mamatha : Draft correction

Corresponding Author :
B. Manikanta
Department of Soil Science & Agricultural Chemistry, College of Agriculturre, UAS, GKVK, Bengaluru

Received : September 2022
Accepted : January 2023

Abstract

A field experiment was conducted in farmer's field at Madenur village of Hassan district during *rabi* 2020, to study the 'Effect of nano-nitrogen, copper and zinc liquid fertilizers on nutrient concentration, uptake and efficiency in potato (*Solanum tuberosum* L.)'. The experiment was laid out in randomized complete block design comprising ten treatments replicated thrice. The treatment includes combined and individual application of nano fertilizers *i.e.* nitrogen, copper and zinc liquid fertilizers at 0.4 per cent to see the release of the nutrients, uptake and its efficiency compared with a conventional fertilizer. The results revealed that significantly higher nitrogen, copper and zinc concentration in potato haulm and tuber, uptake and efficiency of applied nutrients was observed in treatment T_{10} which received 50 per cent N, 50 per cent Zn and 100 per cent PK application to soil inorganically along with 1st spray of Nano N at 25-30 DAP + 2nd spray of nano Zn after 10-15 days of 1st spray + 3rd spray of nano Cu after 10-15 days of 2nd spray, although the release of N, Zn and Cu was higher for applied nano fertilizer than the conventional one. Analysis showed higher accumulation of N, Zn and Cu in plants applied with nano fertilizer. Post-effect of nano fertilizer concentration and uptake increased in plant with nano fertilizer treatment than the conventional fertilizer.

Keywords : Nano fertilizers, Foliar spray, Micronutrients, Potato haulm

The potato (*Solanum tuberosum* L.) is a starchy tuber and a root vegetable native to the Americas. The plant is a perennial in the night shade family Solanaceae. Potato (*Solanum tuberosum* L.) is widely used for many industrial and food applications and considered one of the most important vegetable crops in India and it is most economically valuable vegetable crop, after tomato (Birch *et al*., 2012). The vegetative and fruiting parts of the potato contain the toxin solanine which is dangerous for human consumption. Normal potato tubers that have been grown and stored properly produce glyco alkaloids in amounts small enough to be negligible to human health but if green sections of the plant are exposed to light, the tuber can accumulate a high enough concentration of glycoalkaloids to affect human health.

Modern agriculture depends mostly on inorganic fertilizers, a greater portion of which is readily removed from soil after harvesting. Nowadays growers are striving to overcome the nutrient deficiency and approach the genetic limit of plants. Resorting to replace these nutrients is the ultimate choice. Because of agricultural development, different parts of the world have evidenced that fertilizer application is the most efficient measure for increasing crop production, sustainable yield growth and food security. Fertilization increases crop yields at a rate of 30 to 50 per cent, globally. About

40 - 70 per cent of the nitrogen and 80 - 90 per cent of the phosphorus of the applied fertilizers either are lost into the environment or become unavailable for crops. It not only causes major economic and resource loss but also is responsible for serious environmental pollution.

To overcome the problem of fertilizer use and increase economical use, number of approaches have been made. Among them: application of adequate amount of fertilizer; deep placement of fertilizer; use of granular urea; improving crop response knowledge and use of slow release nano fertilizer are notable (Ahmed *et al*. 2012).

Nano fertilizer, the most important field of agriculture, has drawn the attention of the soil scientists as well as the environmentalists due to its capability to increase yield, improve soil fertility, reduce pollution and make a favourable environment for microorganisms. Nano particles with small size and large surface area are expected to be the ideal forms for use as a fertilizer in plants. Farmers are applying different fertilizers for soil and as foliar applications; however, the efficacy is low (Uma *et al.*, 2019). So that, application of nano fertilizers in minute quantity improves crop growth and reduces environmental pollution (Pruthviraj *et al*., 2022). According to the present study, the rate of release of nutrients from laboratory synthesized nano fertilizer and its effects on crop production have been compared with ordinary chemical fertilizer.

Material and Methods

The experiment was conducted during *rabi* 2020 to study effect of nitrogen, copper and zinc liquid nano fertilizers on soil properties, nutrient concentration, uptake and nutrient use efficiency of potato (*Solanum tuberosum* L.) at farmers field Madenur, College of Agriculture, Hassan, Karnataka. Experiment was laid out in a randomised complete block design with ten treatments and three replicates. Treatments of this research comprised of three nano fertilizers (Nano nitrogen, nano copper and nano zinc at 0.4 per cent concentration) under field conditions, potato crop uptake and use efficiency of nano fertilizers were studied.

Treatments Involved

T_1 - Control (0% N and Zn, 100% P & K fertilizers)

T_2 - Control + 2 sprays of water,

T_3 - Control + 2 sprays of Nano Nitrogen @ 0.4%

T_4 - Control + 2 sprays of Nano Zinc @ 0.4%

T_5 - Control + 2 sprays of Nano Copper @ 0.4%

T_6 - RDF (100% NPK and $ZnSO_4$ @ 6 kg ha^{-1}); 125:100:125 NPK kg ha^{-1} soil application

T_7 - RDF (50% N 100% PK) soil application + 2 sprays of Nano Nitrogen

T_8 - RDF (50% Zn 100% NPK) soil application + 2 sprays of Nano Zinc

T_9 - RDF + 2 sprays of Nano Copper

T_{10} - RDF (50% N, 50% Zn & 100% PK) + 1st spray of Nano N at 25-30 DAP + 2nd spray of nano Zn after 10-15 days of 1st spray + 3rd spray of nano Cu after 10-15 days of 2nd spray.

Where, RDF was recommended dose of fertilizers (125:100:125 NPK kg ha^{-1}) and 100 per cent P and K is common for all treatment.

Collection of Soil and Plant Samples

The initial soil samples were collected from different sites of experimental field and a composite sample was prepared. The initial soil sample was analysed for various chemical properties. Treatment wise soil samples were collected after harvest and were air dried, the clods were gently broken using wooden mallet, sieved through 2 mm sieve and stored in polythene bags for further analysis. The initial soil samples before treatment imposition was collected and subjected for analysis physico-chemical properties such as soil texture, pH and EC by Jackson (1973), OC (Walkley and Black, 1934), DTPA extractable available micro (Lindsay and Norvell, 1978) and macro nutrients.

The nutrient composition of the plant species is not a fixed entity. It varies from time to time in plants, soil to soil and even species to species. Hence, a specific plant part should be selected at a definite stage of the plant growth. The physiologically matured plant part should be selected as it will not undergo rapid changes in nutrient composition. The haulms were collected at 75 days after planting and the tubers were collected after harvest. The collected samples were first air dried, then oven dried at 65 ^{0}C for 48 hours, grounded in a Wiley mill and stored in brown paper covers for chemical analysis. Representative plant samples were collected treatment wise and analysed for total NPK nutrients in haulm and tuber. The uptake of these nutrients by potato crop was computed and the results were expressed in kg ha^{-1} on dry weight basis by using below formula.

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Percentage of nutrients x Total dry matter production (kg/ha)}}{100}$$

Nutrient Use Efficiency (NUE) is a critically important concept in the evaluation of crop production systems. NUE was calculated by using partial factor productivity (Dua *et al.*, 2007).

$$\text{Partial factor productivity (kg/kg)} = \frac{\text{Total yield (kg / ha)}}{\text{Amount of nutrient applied (kg / ha)}}$$

Results and Discussion

Soil Characteristics of the Experimental Site

Some common physicochemical properties of the soil were analysed before the experimental setup in order to know the initial nutrient status of the soil

Table 1

Soil initial properties

Soil properties	Values obtained
pH (1:2.5) soil water suspension	6.13
EC (dS m^{-1}) soil water extract	0.23
Organic carbon (%)	0.82
Available N (kg ha^{-1})	274.45
Available P_2O_5 (kg ha^{-1})	27.30
Available K_2O (kg ha^{-1})	156.50
Exchangeable Ca and Mg (cmol kg^{-1})	2.95 & 1.18
Available S (mg kg^{-1})	10.21
DTPA Extractable Fe, Zn, Mn and Cu (mg kg^{-1})	37.53, 0.95, 10.31 & 0.32 respectively
Hot water-soluble Boron (mg kg^{-1})	0.25

and represented in Table 1. The experimental soil was silty loam in texture, slightly acidic in reaction (pH 6.13). The soil having organic carbon 0.82 per cent, electrical conductivity 0.23 dS m^{-1}, available Nitrogen 274.45 kg ha^{-1}, available Phosphorous 27.30 kg ha^{-1}, available potassium 156.50 kg ha^{-1}, Exchangeable Ca and Mg 2.95 and 1.18 cmol kg^{-1}, respectively, Available Sulphur 10.21 mg kg^{-1}, DTPA Extractable Fe, Zn, Mn and Cu 37.53, 0.95, 10.31 and 0.32 mg kg^{-1} respectively, Hot water-soluble Boron 0.25 mg kg^{-1}.

Soil Chemical Properties and Nutrient Status after the Harvest of Potato Crop

Initial Soil Chemical Properties : The data on effect of nano nitrogen, copper and zinc liquid fertilizers on potato is presented in Table 1. The soil parameters like pH, EC, Soil organic carbon and organic matter of soil did not show any significant difference. However, the higher pH, EC and OC (6.22, 0.44 dSm^{-1} and 0.83 %, respectively) was found in the treatment T_{10}. Here it is observed that there is a slight increase in pH, EC and OC compare to initial values, it may be due to basal application of fertilizers, FYM and crop residues. Elumalai and Velmurugan in 2015, recorded similar observations in red soils of Tamil Nadu, they also reported that higher buffering capacity of soils will resist the minute change in pH and EC.

Post-Harvest Nutrient Status of the Soil : The nutrient status *viz*., available N, P_2O_5, K_2O, S, exchangeable Ca and Mg, DTPA extractable Zn, Cu, Mn, Fe and B of the soil after harvest of potato are presented in Table 2.

Among the macro nutrients the available nitrogen content of the soil after harvest of potato crop was found significant over the control but with respect to available phosphorus and potassium content of the soil after harvest of potato crop did not show any significant difference between the treatments imposed. It might be due to uniform application of phosphorous and potassium fertilizers with same amount of fertilizer to all the treatments. The presence of nitrogen in the available form leads to early growth, improves the quality of the yield and increases protein content. promotes absorption of other nutrients including potassium and phosphorus and promotes

TABLE 2

Effect of nano nitrogen, copper and zinc liquid fertilizers on soil chemical properties and nutrient status of the soil after the harvest of potato crop

Treat-ments	pH	EC (dSm^{-1})	OC (%)	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Mn	Zn	Cu	B
				($kg\ ha^{-1}$)			($cmol\ (p^+)\ kg^{-1}$)			($mg\ kg^{-1}$)				
T_1	6.20	0.38	0.79	272.42	28.02	162.68	1.27	2.80	8.41	39.33	13.92	0.91	0.53	0.41
T_2	6.21	0.37	0.81	272.52	29.55	164.85	1.43	3.17	10.73	45.47	14.03	0.92	0.57	0.43
T_3	6.20	0.41	0.84	277.34	29.43	163.63	1.35	3.09	13.64	41.30	15.16	0.91	0.55	0.42
T_4	6.18	0.36	0.83	276.53	30.45	163.08	1.42	3.30	12.33	41.67	15.12	0.93	0.54	0.44
T_5	6.20	0.36	0.80	277.22	29.73	165.83	1.41	3.18	11.37	45.57	14.97	0.93	0.58	0.42
T_6	6.21	0.39	0.89	305.73	31.35	169.46	1.37	3.51	13.74	44.77	14.81	1.16	0.57	0.40
T_7	6.22	0.43	0.81	287.26	31.64	171.88	1.38	3.23	12.3	41.13	14.18	1.15	0.56	0.42
T_8	6.19	0.42	0.82	283.80	33.51	174.97	1.44	3.23	13.97	43.37	14.26	1.08	0.58	0.40
T_9	6.18	0.36	0.79	294.47	34.41	172.28	1.36	3.17	14.23	46.50	15.36	1.13	0.57	0.43
T_{10}	6.22	0.44	0.83	290.15	35.39	176.55	1.43	3.29	13.58	46.90	15.46	1.10	0.59	0.45
S. Em ±	0.04	0.02	0.02	13.35	3.03	34.52	0.047	0.115	1.190	2.02	0.71	0.07	0.02	0.01
CD @ 5%	NS	NS	NS	26.15	NS	NS	NS	NS	NS	NS	NS	0.20	NS	NS

Note:

T_1 : Control (0% N and Zn, 100% P and K fertilizers);
T_2 : Control + 2 sprays of water;
T_3 : Control + 2 sprays of Nano Nitrogen @ 0.4 %;
T_4 : Control + 2 sprays of Nano Zinc @ 0.4%;
T_5 : Control + 2 sprays of Nano Copper @ 0.4%;
T_6 : RDF (100% NPK and $ZnSO_4$ @ 6 kg ha^{-1}); 125:100:125 NPK kg ha^{-1};
T_7 : RDF (50% N 100% PK) + 2 sprays of Nano Nitrogen;
T_8 : RDF (50% Zn 100% NPK) + 2 sprays of Nano Zinc;
T_9 : RDF + 2 sprays of Nano Copper;
T_{10} : RDF (50% N, 50% Zn and 100% PK) + 1st spray of Nano N at 25-30 DAP + 2nd spray of nano Zn after 10-15 days of 1st spray + 3rd spray of nano Cu after 10-15 days of 2nd spray

total plant growth (Hemerly, 2016). Potassium has a catalytic effect in the main step of protein synthesis. The production of proteins and enzymes that regulate all growth processes, *i.e.* K deficiency in the plant, may affect the synthesis of proteins despite the availability of nitrogen (N). In respect of available nitrogen treatment T_6 worst significantly superior over T_1, T_2, T_3, T_4,T_5 and at par with T_7, T_8, T_9 and T_{10}.

With respect to secondary nutrients, there was no significant difference among different treatments with respect to Ca, Mg and S content in haulm and tuber of potato. It may be due to potato plants requires higher secondary nutrients throughout its growth and development and applied fertilizers supplies some proportion of all these nutrients in addition to the nano fertilizers, hence there was an increased secondary nutrient contents in the leaves over control though not significant. The present study is in compliance with the findings of Halemani *et al.* (2004).

Crop did not show any significant difference between treatments imposed with respect to micronutrients Cu, Fe, Mn and B content except Zn in soil after harvest of potato crop due to different treatments imposed. Among the micro nutrients, higher DTPA extractable zinc content was found in T_6 (1.10 mg kg^{-1}) followed by and T_7 (1.15 mg kg^{-1}) lowest DTPA extractable zinc content (0.91 mg kg^{-1}) of soil was found in both T_1 and T_3.

Increase in zinc is due to application of zinc sulphate fertilizers as a basal dose, the application of nano fertilizers to soil increased the soil available Zn and Fe as compared to control, Similar results were reported by Bala *et al*., (2019) and they also reported a significant increase in soil Zn content on foliar application of ZnO-NPs. Different concentrations of ZnO-NPs and days after treatments significantly affected other micro-nutrients also, *i.e*., Cu, Fe and Mn.

Effect on Nutrients Content (%) and Uptake (kg ha^{-1}) by Potato

The content and uptake of macro and micro nutrients in potato haulm and tuber at harvest are presented in Tables 3, 4, 5, 6 and 7.

Nutrient Content (%)

The nitrogen content in potato haulm and tuber differed significantly due to different treatments imposed (Table 3). Significantly higher nitrogen content in haulm and tuber (1.30 % and 1.34 %, respectively) was recorded in $T_{10,}$ followed by T_7 (1.26 % and 1.28). Among all the treatments, lowest N content in haulm and tuber (1.13 % and 1.07 %, respectively) was recorded in (T_1) Control. These results are in harmony with those found by Kisan *et al.* (2015) who studied the effect of nano-zinc on the leaf physical and nutritional status of spinach in nitrogen and phosphorous content of leaves. Manikandan and Subramanian (2015) also reported that highest N content was registered in roots of maize plants fertilized with nanozeourea (0.32 %).

The zinc content in potato haulm and tuber differed significantly due to different treatments imposed (Table 5). Significantly highest zinc content in haulm and tuber (73.45 and 15.64 mg kg^{-1}, respectively) was recorded in T_8. It was found significant over all the treatments except T_{10} (73.01 and 14.22 mg kg^{-1}, respectively), these treatments found on par with each other in haulm and tuber zinc content. Significantly higher copper content in haulm and tuber of potato (46.91 and 26.34 mg kg^{-1}, respectively) was recorded in T_9 which received RDF + 2 sprays of Nano Copper. It was found significant over all the treatments including control (25.61 mg kg^{-1}) except T_{10} (44.64 mg kg^{-1}) and T_5 (44.39 mg kg^{-1}) in copper content of haulm. However, these treatments were found on par with each other in copper content in haulm. Whereas, in tuber it was significant over control (17.15 mg kg^{-1}). Among the all treated plots lower copper content in both haulm and tuber (25.61 and 17.15 mg kg^{-1}, respectively) was found in (T_1) Control 0 per cent N and Zn, 100 per cent P and K fertilizers, which was found on par with T_2 (18.26 mg kg^{-1}) in tuber copper content. The role of Cu in flower formation is thought to be related to its activation of polyphenol and Indole Acetic Acid (IAA) oxidases, enzymes involved in the oxidation of IAA (Bhakuni *et al.,* 2009).

TABLE 3

Effect of nano nitrogen, copper and zinc liquid fertilizers on nutrient content of N, P_2O_5, K_2O, Ca, Mg and S (%) in haulm and tuber of potato after harvest.

Treat-ments	Nitrogen (%)		Phosphorous (%)		Potassium (%)		Calcium (%)		Magnesium (%)		Sulphur (%)	
	Haulm	Tuber	Haulm	Tuber	Haulm	Tuber	Haulm	Tuber	Haulm	Tuber	Haulm	Tuber
T_1	1.13	1.07	0.21	0.23	1.71	1.34	0.95	0.23	0.97	0.21	0.23	0.40
T_2	1.15	1.19	0.23	0.25	1.94	1.45	1.06	0.25	1.06	0.23	0.26	0.41
T_3	1.26	1.23	0.25	0.29	2.05	1.53	1.18	0.32	1.12	0.26	0.29	0.48
T_4	1.17	1.25	0.23	0.25	1.88	1.50	1.09	0.30	1.05	0.25	0.28	0.47
T_5	1.21	1.22	0.24	0.26	1.96	1.41	1.10	0.29	1.1	0.23	0.28	0.51
T_6	1.23	1.24	0.25	0.29	2.12	1.53	1.13	0.29	1.14	0.25	0.29	0.49
T_7	1.26	1.28	0.24	0.26	1.97	1.48	1.20	0.31	1.10	0.25	0.30	0.50
T_8	1.19	1.25	0.22	0.25	2.18	1.44	1.17	0.30	1.14	0.27	0.31	0.50
T_9	1.16	1.24	0.24	0.27	2.17	1.45	1.16	0.28	1.11	0.26	0.30	0.49
T_{10}	1.30	1.34	0.25	0.31	2.2	1.58	1.23	0.34	1.21	0.30	0.32	0.53
S. Em. ±	0.030	0.025	0.013	0.015	0.113	0.044	0.06	0.02	0.04	0.02	0.02	0.03
CD @ 5%	0.09	0.07	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note:

T_1 : Control (0% N and Zn, 100% P and K fertilizers);
T_2 : Control + 2 sprays of water;
T_3 : Control + 2 sprays of Nano Nitrogen @ 0.4 %;
T_4 : Control + 2 sprays of Nano Zinc @ 0.4%;
T_5 : Control + 2 sprays of Nano Copper @ 0.4%;
T_6 : RDF (100% NPK and $ZnSO_4$ @ 6 kg ha^{-1}); 125:100:125 NPK kg ha^{-1};
T_7 : RDF (50% N 100% PK) + 2 sprays of Nano Nitrogen;
T_8 : RDF (50% Zn 100% NPK) + 2 sprays of Nano Zinc;
T_9 : RDF + 2 sprays of Nano Copper;
T_{10} : RDF (50% N, 50% Zn and 100% PK) + 1st spray of Nano N at 25-30 DAP + 2nd spray of nano Zn after 10-15 days of 1st spray + 3rd spray of nano Cu after 10-15 days of 2nd spray

TABLE 4

Effect of nano nitrogen, copper and zinc liquid fertilizers on nutrient uptake of N, P_2O_5, K_2O, Ca, Mg and S (kg ha^{-1}) in haulm and tuber of potato after harvest

Treat-ments	Nitrogen (kg ha^{-1})			Phosphorous (kg ha^{-1})			Potassium (kg ha^{-1})			Calcium (kg ha^{-1})			Magnesium (kg ha^{-1})			Sulphur (kg ha^{-1})		
	H	T	To	H	T	To	H	T	To	H	T	To	H	T	To	H	T	To
T_1	9.87	25.32	35.20	1.98	5.48	7.46	14.87	31.83	46.71	8.25	5.54	13.79	8.45	4.91	13.36	1.98	9.40	11.37
T_2	10.06	27.74	37.80	1.99	5.93	7.92	17.12	33.82	50.94	9.31	5.77	15.08	9.28	5.38	14.66	2.25	9.51	11.76
T_3	15.65	34.36	50.01	3.14	7.63	10.76	25.39	41.12	66.51	14.03	7.80	21.83	13.66	6.70	20.37	3.55	12.85	16.40
T_4	14.25	31.12	45.37	2.55	6.30	8.85	22.87	37.40	60.27	13.32	7.38	20.70	12.75	6.23	18.98	3.40	11.71	15.11
T_5	13.89	29.72	43.61	2.76	6.26	9.02	22.53	34.14	56.67	12.68	7.10	19.78	12.62	5.50	18.12	3.17	12.31	15.49
T_6	15.29	34.70	49.99	3.10	8.04	11.14	26.32	42.79	69.11	14.91	8.52	23.44	14.17	7.02	21.19	3.60	13.83	17.43
T_7	17.02	46.03	63.04	3.18	10.70	13.88	25.77	54.42	80.19	16.10	11.68	27.78	15.75	10.33	26.08	3.92	17.29	21.20
T_8	15.19	39.38	54.57	2.85	7.77	10.62	28.09	45.32	73.41	14.94	9.78	24.72	14.58	8.64	23.23	3.95	15.74	19.69
T_9	14.77	38.26	53.03	3.17	8.22	11.40	27.51	44.61	72.12	14.77	8.62	23.40	14.09	8.03	22.12	3.85	15.21	19.06
T_{10}	18.54	43.48	62.01	3.47	9.35	12.83	32.05	52.47	84.52	17.31	11.24	28.55	16.39	9.31	25.69	4.69	18.80	23.49
S. Em ±	0.34	1.41	3.09	0.17	0.56	0.69	1.38	2.18	4.11	0.68	0.68	1.61	0.48	0.51	1.41	0.22	0.83	1.30
CD @ 5%	1.00	4.20	9.17	0.50	1.68	2.06	4.11	6.49	12.20	2.02	2.02	4.78	1.41	1.52	4.20	0.64	2.45	3.86

H-haulm, T-tuber, To-total uptake

Note :

T_1 : Control (0% N and Zn, 100% P and K fertilizers);
T_2 : Control + 2 sprays of water;
T_3 : Control + 2 sprays of Nano Nitrogen @ 0.4 %;
T_4 : Control + 2 sprays of Nano Zinc @ 0.4%;
T_5 : Control + 2 sprays of Nano Copper @ 0.4%;
T_6 : RDF (100% NPK and $ZnSO_4$ @ 6 kg ha^{-1}); 125:100:125 NPK kg ha^{-1};
T_7 : RDF (50% N 100% PK) + 2 sprays of Nano Nitrogen;
T_8 : RDF (50% Zn 100% NPK) + 2 sprays of Nano Zinc;
T_9 : RDF + 2 sprays of Nano Copper;
T_{10} : RDF (50% N, 50% Zn and 100% PK) + 1st spray of Nano N at 25-30 DAP + 2nd spray of nano Zn after 10-15 days of 1st spray + 3rd spray of nano Cu after 10-15 days of 2nd spray

TABLE 5

Effect of Nano nitrogen, copper and zinc liquid fertilizers on Fe, Mn, Zn, Cu and B content ($mg\ kg^{-1}$) in potato

Treat-ments	Iron		Manganese		Zinc		Copper		Boron	
	Haulm	Tuber	Haulm	Tuber	Haulm	Tuber	Haulm	Tuber	Haulm	Tuber
T_1	203.03	133.16	179.91	34.68	32.07	10.75	25.61	17.15	9.42	21.47
T_2	234.22	149.43	204.6	39.40	38.34	11.62	35.07	18.26	10.42	25.56
T_3	235.15	155.37	224.93	46.47	53.18	13.04	37.72	21.04	10.85	29.87
T_4	247.86	152.77	217.93	39.08	68.17	13.75	40.43	20.30	10.57	29.15
T_5	253.56	153.10	210.23	38.24	55.56	12.83	44.39	22.81	11.25	29.07
T_6	248.40	155.40	223.30	46.30	56.75	12.82	41.90	21.71	11.49	30.61
T_7	245.90	155.82	236.73	46.19	67.38	13.54	42.92	22.54	11.21	30.77
T_8	253.63	153.70	210.10	46.10	72.01	14.22	39.62	20.18	10.61	30.00
T_9	251.21	155.43	215.46	45.73	53.55	13.35	44.64	23.03	10.85	29.13
T_{10}	250.00	161.90	243.36	47.31	73.45	15.64	46.91	26.34	11.54	31.22
S. Em ±	10.20	4.82	11.30	3.08	2.86	0.46	1.51	0.75	0.40	1.92
CD @ 5%	NS	NS	NS	NS	8.48	1.36	4.48	2.23	NS	NS

Note:
T_1 : Control (0% N and Zn, 100% P and K fertilizers);
T_2 : Control + 2 sprays of water;
T_3 : Control + 2 sprays of Nano Nitrogen @ 0.4 %;
T_4 : Control + 2 sprays of Nano Zinc @ 0.4%;
T_5 : Control + 2 sprays of Nano Copper @ 0.4%;
T_6 : RDF (100% NPK and $ZnSO_4$ @ 6 kg ha^{-1}); 125:100:125 NPK kg ha^{-1};
T_7 : RDF (50% N 100% PK) + 2 sprays of Nano Nitrogen;
T_8 : RDF (50% Zn 100% NPK) + 2 sprays of Nano Zinc;
T_9 : RDF + 2 sprays of Nano Copper;
T_{10} : RDF (50% N, 50% Zn and 100% PK) + 1st spray of Nano N at 25-30 DAP + 2nd spray of nano Zn after 10-15 days of 1st spray + 3rd spray of nano Cu after 10-15 days of 2nd spray

Nutrient Uptake (kg ha^{-1})

The total uptake of nitrogen by potato crop differed significantly due to different treatments imposed (Table 4). Significantly highest nitrogen uptake (63.04 kg ha^{-1}) was recorded in T_7, over all other treatments including control (35.20 kg ha^{-1}) but except T_{10} (62.01 kg ha^{-1}) and T-$_8$ (54.57 kg ha^{-1}). However, these treatments found on par with each other. Among the all treatments imposed, lower uptake (35.20 kg ha^{-1}) was found in (T_1) Control. When a nanoengineered composite which consists of N, P, K, micronutrients, mannose and amino acids was applied to grain crops, it appeared to enhance the uptake and use of nutrients (Abdel-Aziz *et al.*, 2018). Mohamad Yatim *et al.* (2016) also reported that N fertilizer uptake was recorded for UF-MWCNT's treatment which recorded which was higher than that of control.

The total uptake of zinc content by potato differed significantly due to different treatments imposed (Table 6). Significantly the higher zinc uptake was recorded in T_{10} (161.21 g ha^{-1}) over all other treatments including control (53.56 g ha^{-1}) except T_7 (134.67 g ha^{-1}) and T_8 (138.66 g ha^{-1}). However, these treatments found on par with each other and lower total uptake of Zn (53.56 g ha^{-1}) was found in T_1 with Control 0 per cent N and Zn, 100 per cent P and K fertilizers, which was found non significant over T_2 (60.84 g ha^{-1}). Zinc is the precursor of IAA, due to these enzymes in oxidation of IAA and increased the concentration and uptake of zinc and in most of studies indicated that Nitrogen addition results in significant increases in the availabilities of micronutrients, such as the available concentrations of Cu, Mn and Fe in soils (Wang *et al*. 2017).

The total uptake of copper by potato haulm and tuber was found significant by the application of

TABLE 6

Effect of Nano nitrogen, copper and zinc liquid fertilizers on Fe, Mn and Zn uptake (g ha^{-1}) by potato

Treat-ments	Iron (g ha^{-1})			Manganese (g ha^{-1})			Zinc (g ha^{-1})		
	Haulm	Tuber	Total	Haulm	Tuber	Total	Haulm	Tuber	Total
T_1	176.88	316.95	493.84	156.75	82.38	239.13	27.94	25.62	53.56
T_2	205.64	349.46	555.11	179.11	92.00	271.11	33.69	27.15	60.84
T_3	291.19	417.93	709.12	278.55	125.14	403.69	65.84	35.08	100.93
T_4	301.01	379.82	680.82	264.62	97.10	361.72	82.79	34.08	116.87
T_5	291.24	372.47	663.71	241.37	92.38	333.75	63.72	31.12	94.85
T_6	307.86	436.39	744.25	276.74	129.59	406.32	70.38	35.95	106.33
T_7	326.42	557.32	883.74	317.73	162.99	480.72	87.97	46.70	134.67
T_8	324.14	484.71	808.85	268.27	145.78	414.05	93.85	44.81	138.66
T_9	319.00	479.77	798.78	273.64	141.12	414.77	67.99	41.19	109.18
T_{10}	361.09	552.47	913.55	347.45	163.73	511.18	105.67	55.54	161.21
S. Em ±	14.38	22.73	44.70	12.79	9.71	28.33	3.51	1.83	11.10
CD @ 5%	42.72	67.54	132.81	37.99	28.86	84.18	10.44	5.45	32.97

Note:

T_1 : Control (0% N and Zn, 100% P and K fertilizers);
T_2 : Control + 2 sprays of water;
T_3 : Control + 2 sprays of Nano Nitrogen @ 0.4 %;
T_4 : Control + 2 sprays of Nano Zinc @ 0.4%;
T_5 : Control + 2 sprays of Nano Copper @ 0.4%;
T_6 : RDF (100% NPK and $ZnSO_4$ @ 6 kg ha^{-1}); 125:100:125 NPK kg ha^{-1};
T_7 : RDF (50% N 100% PK) + 2 sprays of Nano Nitrogen;
T_8 : RDF (50% Zn 100% NPK) + 2 sprays of Nano Zinc;
T_9 : RDF + 2 sprays of Nano Copper;
T_{10} : RDF (50% N, 50% Zn and 100% PK) + 1st spray of Nano N at 25-30 DAP + 2nd spray of nano Zn after 10-15 days of 1st spray + 3rd spray of nano Cu after 10-15 days of 2nd spray

nano nitrogen, copper and zinc liquid fertilizers on potato crop (Table 7). Significantly higher copper uptake was recorded in T_{10} (161.43 g ha^{-1}) and it is superior over all other treatments including control (63.11 g ha^{-1}). Among all the treatments imposed the lower total uptake of Copper (63.11 g ha^{-1}) was found in T_1 which received 0 per cent N and Zn, 100 per cent P and K fertilizers, which was found on par with T_2 with (73.47 g ha^{-1}) in copper uptake by potato crop. Higher uptake might be due to nano fertilizers are excellent alternatives for soluble conventional chemical fertilizers where the nutrients are released at slower rates throughout the growth cycle and uptake of nutrients before leaching (Sohair *et al.,* 2018 and Eissa, 2019).

Nutrient Use Efficiency (NUE)

The data obtained on nutrient use efficiency of nitrogen, phosphorous and potassium was presented in terms of partial factor productivity in the Table 8.

The higher nutrient use efficiency of nitrogen, phosphorous and potassium was recorded in the treatment T_{10} (462, 289 and 231 kg kg^{-1}, respectively). Nano fertilizer have large surface area and particle size less than the pore size of root and leaves of the plant which can increase penetration into the plant from applied surface and improve uptake and nutrient use efficiency of the nano fertilizer. Reduction of particle size results in increased specific surface area and number of particles per unit area of a fertilizer that provide more opportunity to contact of nano-fertilizers which leads to more penetration and uptake of the nutrient. Fertilizers encapsulated in nano-particles will increase availability and uptake of nutrient to the crop plants (Tarafdar *et al*., 2012).

Based on the experiment conducted and results obtained it is concluded that, combined application of nano nitrogen, copper and zinc liquid fertilizers

TABLE 7

Effect of Nano nitrogen, copper and zinc liquid fertilizers on Cu and B uptake (g ha^{-1}) by potato

Treatments	Copper (g ha^{-1})			Boron (g ha^{-1})		
	Haulm	Tuber	Total	Haulm	Tuber	Total
T_1	22.32	40.79	63.11	8.21	51.16	59.37
T_2	30.77	42.70	73.47	9.15	59.81	68.96
T_3	46.70	56.60	103.30	13.44	80.57	94.01
T_4	49.09	50.47	99.56	12.84	72.48	85.32
T_5	50.95	55.49	106.43	12.92	70.68	83.60
T_6	51.93	60.93	112.85	14.31	87.69	102.00
T_7	56.04	77.82	133.86	15.00	105.83	120.84
T_8	50.66	63.59	114.25	13.54	94.73	108.27
T_9	59.56	71.12	130.68	13.77	89.99	103.76
T_{10}	67.72	93.71	161.43	16.45	108.51	124.96
S. Em ±	1.91	3.78	9.54	0.46	6.56	7.06
CD @ 5%	5.67	11.23	28.34	1.37	19.50	20.98

Note :

T_1 : Control (0% N and Zn, 100% P and K fertilizers);
T_2 : Control + 2 sprays of water;
T_3 : Control + 2 sprays of Nano Nitrogen @ 0.4 %;
T_4 : Control + 2 sprays of Nano Zinc @ 0.4%;
T_5 : Control + 2 sprays of Nano Copper @ 0.4%;
T_6 : RDF (100% NPK and $ZnSO_4$ @ 6 kg ha^{-1}); 125:100:125 NPK kg ha^{-1};
T_7 : RDF (50% N 100% PK) + 2 sprays of Nano Nitrogen;
T_8 : RDF (50% Zn 100% NPK) + 2 sprays of Nano Zinc;
T_9 : RDF + 2 sprays of Nano Copper;
T_{10} : RDF (50% N, 50% Zn and 100% PK) + 1st spray of Nano N at 25-30 DAP + 2nd spray of nano Zn after 10-15 days of 1st spray + 3rd spray of nano Cu after 10-15 days of 2nd spray

TABLE 8

Effect of Nano nitrogen, copper and zinc liquid fertilizers on nutrient use efficiency of N, P_2O_5 and K_2O (kg kg^{-1}) by potato

Treatments	Yield (kg ha^{-1})	Nutrient applied (kg ha^{-1})			Nutrient use efficiency (kg kg^{-1})		
		N	P_2O_5	K_2O	N use efficiency	P_2O_5 use efficiency	K_2O use efficiency
T_1	18614	0	100	125	0	186	149
T_2	18805	0	100	125	0	188	150
T_3	23069	0	100	125	0	231	185
T_4	22619	0	100	125	0	226	181
T_5	20336	0	100	125	0	203	163
T_6	25625	125	100	125	205	256	205
T_7	27697	62.82	100	125	441	277	222
T_8	26847	125	100	125	215	268	215
T_9	26553	125	100	125	212	266	212
T_{10}	28931	62.66	100	125	462	289	231

Note :

T_1 : Control (0% N and Zn, 100% P and K fertilizers);
T_2 : Control + 2 sprays of water;
T_3 : Control + 2 sprays of Nano Nitrogen @ 0.4 %;
T_4 : Control + 2 sprays of Nano Zinc @ 0.4%;
T_5 : Control + 2 sprays of Nano Copper @ 0.4%;
T_6 : RDF (100% NPK and $ZnSO_4$ @ 6 kg ha^{-1}); 125:100:125 NPK kg ha^{-1};
T_7 : RDF (50% N 100% PK) + 2 sprays of Nano Nitrogen;
T_8 : RDF (50% Zn 100% NPK) + 2 sprays of Nano Zinc;
T_9 : RDF + 2 sprays of Nano Copper;
T_{10}: RDF (50% N, 50% Zn and 100% PK) + 1st spray of Nano N at 25-30 DAP + 2nd spray of nano Zn after 10-15 days of 1st spray + 3rd spray of nano Cu after 10-15 days of 2nd spray.

shows increased nutrient content and efficiency of potato crop and also improved the uptake of that particular nutrient. But these nano fertilizers did not influence the soil chemical and nutrient status. Buffering capacity of soil resists the small changes in the chemical properties and application of nano fertilizers in lesser quantity did not show any significant difference on soil chemical properties and nutrient status of soil. Application of nano fertilizers in a very small quantity improves crop growth and reduces environmental pollution. It is also concluded that nano fertilizers in general, and Nano-N in particular, will successfully help in reducing the consumption of urea to 50 per cent by applying 2 sprays of Nano-N. Other products *viz.,* Nano-Zinc and Nano-Copper would show their effectiveness depending upon the magnitude of deficiencies of these nutrients in soils.

REFERENCES

ABDEL-AZIZ, H., HASANEEN, M. N. AND OMAR, A., 2018, Effect of foliar application of nano chitosan NPK fertilizer on the chemical composition of wheat grains. *Egypt. J. Bot.,* **58** (1) : 87 - 95.

AHMED, S., NIGER, F., KABIR, M. H., CHAKRABARTI, G., NUR, H. P. AND IMAMUL HUQ, S. M., 2012, Development of slow release nano fertilizer. *Proc. of the International Workshop on Nanotechnology*, Dhaka, Bangladesh.

BALA, R., KALIA, A. AND DHALIWAL, S. S., 2019, Evaluation of efficacy of ZnO nanoparticles as remedial zinc nano fertilizer for rice. *J. Soil Sci. Plant Nutr*., **19** (2) : 379 - 389.

BHAKUNI, G., DUBE, B. K., SINHA, P., CHATTERJEE, C., 2009, Copper stress affects metabolism and reproductive yield of chickpea. *J. Plant Nutr.,* **32** (4) : 703 - 711.

BIRCH, P. R., BRYAN, G., FENTON, B., GILROY, E. M., HEIN, I., JONES, J. T., PRASHAR, A., TAYLOR, M. A., TORRANCE, L. AND TOTH, I. K., 2012, Crops that feed the world 8 : potato : are the trends of increased global production sustainable?. *Food Security*, **4** (4) : 477 - 508.

DUA, V. K., GOVINDAKRISHNAN, P. M., LAL, S. S. AND KHURANA, S. P., 2007, Partial factor productivity of nitrogen in potato. *Better Crops*, **91** (4) : 26 - 27.

EISSA, M. A., 2019, Efficiency of P fertigation for drip-irrigated potato grown on calcareous sandy soils. *Potato Res.*, **62** (1) : 97 - 108.

ELUMALAI, K. AND VELMURUGAN, S., 2015, Green synthesis, characterization and antimicrobial activities of zinc oxide nanoparticles from the leaf extract of (*Azadirachta indica* L.). *Appl. Surf. Sci.*, **34** : 329 - 336.

HALEMANI, H. L., HALLIKERI, S. S., NANDAGAVI, R. A. AND NOOLI, S. S., 2004, November. Response of mahyco Bt cotton hybrids to levels of fertilizer under protective irrigation. In *Int. Symp. Strat. Sust. Cotton Prodn - A Global Vision* (23 - 25).

HEMERLY, A., 2016, Genetic controls of biomass increase in sugarcane by association with beneficial nitrogen-fixing bacteria, In *Plant and Animal Genome XXIV Conference. Plant and Animal Genome, during month of January.*

JACKSON, M. L., 1973, *Soil Chemical Analysis,* prentice hall of India Pvt. Ltd., New Delhi, pp. : 498.

KISAN, B., SHRUTHI, H., SHARANAGOUDA, H., REVANAPPA, S. B. AND PRAMOD, N. K., 2015, Effect of nano-zinc oxide on the leaf physical and nutritional quality of spinach. *Agrotechnol.,* **5** (1) : 135 - 139.

LINDSAY, W. L. AND NORVELL, W. A., 1978, Development of a DTPA-soil test for Zn, Fe, Mn and Cu. *Soil Sci. Soc. America J.*, **42** : 421 - 428.

MANIKANDAN, A. AND SUBRAMANIAN, K. S., 2015, Evaluation of zeolite-based nitrogen nano-fertilizers on maize growth, yield and quality on inceptisol and alfisols. *Int. J. plant soil sci.*, **1** (1) : 1 - 9.

MOHAMAD YATIM, N., SHAABAN, A., DIMIN, M. F., YUSOF, F. AND ABD RAZAK, J., 2016, Application of response surface methodology for optimization of urea grafted multiwalled carbon nanotubes in enhancing nitrogen use efficiency and nitrogen uptake by paddy plants. *J. Nanotechnol*, Vol, 2016.

PRUTHVIRAJ, N., GEETHA, K., PRAKASH, S., JAYADEVA, H., PUSHPA, K. AND SHANKAR, A., 2022, Impact of different methods of nano fertilizers application on soil chemical properties and fertility status in sunflower growing soils. *Mysore J. Agric. Sci.,* **56** (1) : 275 - 284.

SOHAIR, E. E. D., ABDALL, A. A., AMANY, A. M. AND FARUQUE HMD, H. R., 2018, Evaluation of nitrogen, phosphorus and potassium nano-fertilizers on yield, yield components and fiber properties of egyptian cotton (*Gossypium barbadense* L.). *J. Plant. Sci. Crop. Protec.*, **1** (2) : 208.

TARAFDAR, J. C., XIANG, Y., WANG, W. N., DONG, Q. AND BISWAS, P., 2012, Nanoparticle synthesis characterization and application to solve some chronic agricultural problems. *Appl. Biol. Res.*, **14** : 138 - 144.

UMA, V., JAYADEVA, H. M., REHAMAN, H. M. A., KADALLI, G. G. AND UMASHANKAR, N., 2019, Influence of nano zinc oxide on yield and economics of maize (*Zea mays* L.). *Mysore J. Agric. Sci.,* **53** (4) : 44 - 48.

WALKLEY, A. J. AND BLACK, C. A., 1934, An examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.,* **37** (1) : 29 - 38.

WANG, R., DUNGAIT, J. A. J., BUSS, H. L., YANG, S., ZHANG, Y. AND XU, Z., 2017, Base cations and micro nutrients in soil aggregates as affected by enhanced nitrogen and water inputs in a semi-arid steppe grassland. *Sci. Total Environ.*, **57** (5) : 564 - 572.

Mysore J. Agric. Sci., 57 (1) : 139-151 (2023)

Sensory Studies of Safflower Seed Milkshake Analogue using Fuzzy Logic

MANSURKHAN TADAKOD[1], SAGAR DESHAMNI[2], T. HARSHITHA[3], C. KAVITHA[4] AND SATISH R. DESAI[5]
[1,2,3&5]Department of Food Engineering, [4]Department of Food Processing and Technology,
College of Community Science, UAS, Dharwad - 580 005
e-Mail : harshitha.t@uasd.com

AUTHORS CONTRIBUTION

MANSURKHAN TADAKOD : Methodology and Writing original draft;
SAGAR DESHAMNI : Investigation and formal analysis ;
T. HARSHITHA : Conceptualization, visualization, validation, supervision and reviewing ;
C. KAVITHA & SATISH R. DESAI : Proof reading

Corresponding Author :
T. HARSHITHA
Department of Food Engineering,
College of Community Science, UAS, Dharwad

Received : October 2022
Accepted : January 2023

ABSTRACT

The fuzzy logic technique was used to evaluate the acceptability of the safflower seed milkshake analogue with the conventional bovine milkshake. The sensory evaluation of four different milkshake formulations *viz.,* T_1 = Bovine milk (60%) + Banana pulp (30%) + Sugar (10%) + Cardamom powder (0.1%), T_2 = Safflower seed extract (60%) + Banana pulp (30%) + Sugar (10%) + Cardamom powder (0.1%), T_3 = Bovine milk (60%) + Sapota pulp (30%) + Sugar (10%) + Cardamom powder (0.1%), T_4 = Safflower seed extract (60%) + Sapota pulp (30%) + Sugar (10%) + Cardamom powder (0.1%) was conducted. The sensory panel was comprised of semi-trained, individuals of 18-45 years age. Study found T_4 sample as more acceptable and taste as the most salient sensory parameter followed by mouth feel, flavour and colour in determining the acceptability of the milkshake.The experiment evident the potential of safflower seed to use as an ingredient in the production of milkshake analogues. This milkshake analogue prepared from safflower seed was acceptable and on par with a bovine milkshake. The industry can use safflower seed extracts like soya bean, peanut, almond, cashew and oat extracts to provide a variety of beverages. Consumer's demand for vegan, lactose-free or novel drinks could be met by this novel milkshake analogue from safflower seed.

Keywords : Milkshake, Plant based milk analogue, Safflower seed, Sensory evaluation, Fuzzy logic

MILKSHAKE is a beverage prepared by blending milk, flavourings, fruit syrup, whole fruit pulp, sweeteners, and ice cream. The globe news wire released a report on the Global Packaged Milkshake Industry stating the growth of milkshake sales at a CAGR of 5.9 per cent from 2020-27 (Report Linker 2021). The milkshake market is driven by a shift in consumer preferences from carbonated drinks to healthy and nutritious drinks. The product development in the beverage sector has changed from standard sugary formulations to functional beverages with added novel ingredients and the removal of undesirable components with satisfying tastes and prices (Tireki, 2021). Recent market research concerns about functional and newer beverage development indicate a faster growth phase. The trends may be due to the growing population, changing dietary patterns and increased consumer knowledge. (Chughtai *et al.,* 2022). Bovine milk allergies, lactose intolerance, calorie concerns, hypercholesterolemia incidence and the desire for vegetarianism seek consumers for bovine milk substitutes. Plant-based alternatives to bovine milk are favourable among developing countries due to their lesser cost. The increasing number of plant-based dairy analogues offer numerous options in the food and beverage industry for similar taste, flavour and functionality on par with conventional bovine milk. Dairy Alternatives Market Overview (2022) reported that the sales of dairy alternatives in the global market are estimated to increase at the rate of 14.7 per cent from 2022-32.

The plant-based dairy analogues have been reported to have an unacceptable beany flavour and this can be masked by the incorporation of fruits/spices. Fruits are a good source of bioactive components and the most suitable choice to incorporate into beverages. The Food Safety and Standards Authority of India (2011) defines a thermally processed beverage as an unfermented but fermentable product which is prepared from juice or pulp/puree or concentrated juice or pulp of sound mature fruit. The substances that may be added to fruit juice or pulp are water, peel oil, fruit essences or flavours, salt, sugar, inverted sugar, liquid glucose, milk and other ingredients appropriate to the product and processed by heat, in an appropriate manner, before or after being sealed in a container, to prevent spoilage.

The consumer acceptance or preference of any food significantly depends upon the sensory impressions it creates in one's mind. The sensory attributes like appearance, colour, flavour, taste, mouth feel and consistency were checked by vision, olfactory, and gustatory in milkshake. The sensory panel may comprise trained, semi-trained or untrained individuals to express their results with more subjectivity, ambiguity and vagueness (Martinez, 2007). Human evaluation of sensory attributes is inaccurate, imprecise and uncertain repeatability (Das, 2005 and Routray, W. and Mishra, H. N., 2012). Fuzzy logic is a statistical tool for concluding ambiguous and vague data. The Fuzzy modelling uses linguistic variables (e.g., not satisfactory, good, excellent) to develop the relationship between independent (*e.g.,* colour, flavour, taste, mouth-feel, convenience) and dependent (*e.g.,* acceptance, rejection, ranking, strong and weak attributes of food) variables (Das, 2005). The fuzzy techniques are helpful in ranking samples based on specific quality characteristics & quality attributes with clarity over the acceptance of the product and compare the usefulness of the sensory parameters (Kumar *et al.,* 2021).

Safflower (*Carthamus tinctorius* L.) is an annual oilseed crop belonging to the Asteraceae family. It is a xerophilous species native to Asia and the Mediterranean basin and grown in arid and semi-arid regions. It is a minor, underutilized oilseed crop. The safflower seeds contain 38 g of fat, 17.6 g of protein, 1.3 g of mono and disaccharides, 35.8 g of dietary fiber, 7.1 g of minerals *viz*., 687 mg of potassium, 78.2 mg of calcium, 353 mg of magnesium, 644 mg of phosphorus, 5 mg of iron, 1 mg of selenium & the total proportion of essential amino acids in safflower seeds as 15 - 22 per cent of protein content and 74.4 per cent biological value (Kutsenkova *et al*., 2020). The nutritional value of safflower oil is, in fact, like that of olive oil and for this reason, the species has gained importance in recent years as a result of human consumption in arid and semi-arid regions (Bella *et al*., 2019). Safflower seed extracts may be useful for lactose intolerant people and infants allergic to bovine milk as these seeds are rich in their chemical composition.

Manilkara zapota, Sapodilla also known as sapota belongs to the Sapotaceae family. These are brown-coloured ranging from 5-10 cm diameter. India is a leading producer of fruit. Sapodilla fruits are a rich source of nutrients (sugars, ascorbic acids, protein, amino acids), minerals (potassium, calcium, and iron) and comprise bioactive compounds (ellagitannins, gallotannins, phenolic acids and flavonoids (anthocyanins and flavanols)). Punia *et al*., (2022) suggested that the nutritional profile of sapodilla fruit makes it a potential source of nutraceutical compounds. Banana fruit is one of the important staple foods in the world across different ethnicities and has been an extensively studied fruit for edible purposes. The pulp of banana fruit is rich in bioactive compounds like dietary fibre, low glycaemic carbohydrates, natural sugars, vitamins, minerals and antioxidants. Suriyamoorthy *et al*., (2022) reported that, these beneficial compounds are responsible for the proper functioning of the immune system and enhance the prevention of various diseases and metabolic disorders like cancer, diabetes and heart diseases. Hence, the current study was conducted to evaluate the sensory acceptance of fruit beverages from safflower seed extract in comparison to fruit beverage from bovine milk using fuzzy logic.

Material and Methods

Preparation of Safflower Seed Extract

The safflower seed extract was prepared as explained by Kashid *et al*., (2007). The cleaned, washed, de-husked safflower seeds were soaked in 0.05 per cent NaCl solution (1:5 Safflower seeds : 0.05 per cent NaCl Solution) for 10 hours. Safflower seeds were drained, washed using potable water and further soaked in boiling water for 10 min. Twice-soaked safflower seeds were ground by adding water (1:2 Safflower Seed : Water ratio) and filtered through a muslin cloth. The filtrate obtained was used in the preparation of safflower seed extract beverage.

Preparation of Fruit Pulp

Fruits *viz*., sapota and banana were washed, peeled, & ground in a mixer separately and filtered using a muslin cloth. The prepared sapota and banana pulp were packed separately in PET jars and stored in a refrigerator at - 4 °C until further use.

Preparation of Safflower Milkshake Analogue and Bovine Milkshake

The safflower milkshake analogue and bovine milkshake were prepared with 60 per cent safflower seed extract/ bovine milk as base and 30 per cent fruit pulp, 10 per cent sugar and 0.1 per cent of cardamom powder were added and mixed uniformly (Ubale *et al*., 2014). The experiment was conducted using following formulations *viz*.,

T_1 = Bovine milk (60%) + Banana pulp (30%) + Sugar (10%) + Cardamom powder (0.1%)

T_2 = Safflower seed extract (60%) + Banana pulp (30%) + Sugar (10%) + Cardamom powder (0.1%)

T_3 = Bovine milk (60%) + Sapota pulp (30%) + Sugar (10%) + Cardamom powder (0.1%)

T_4 = Safflower seed extract (60%) + Sapota pulp (30%) + Sugar (10%) + Cardamom powder (0.1%)

The ingredients according to the formulation were mixed well and homogenized. The prepared milkshake analogue and milkshake were filled in a presterilized 200 ml glass bottle and pasteurized in boiling water for 20 min, further bottles were cooled in a water bath and stored at room temperature.

Sensory Evaluation of Safflower Milkshake Analogue and Bovine Milkshake using Fuzzy Logic

A panel of eleven judges who are non-beetle leaf chewers and non-smokers were selected in the age group between 21 and 40 years. The quality attributes colour, flavour, taste and mouthfeel of the milkshake sample were selected for the sensory evaluation. The judges were detailed about the quality attributes, score card (as shown in fig. 1) and method of scoring for the sensory evaluation. They were instructed to judge the samples quickly but not in hurry and to take two short sniffs of the samples before 'tasting' the sample and give the score for the 'Flavour and colour' first on the score card and rinse their mouth with water between tasting the consecutive samples (Ranganna, 1987). The ratings *viz.,* Excellent, Good, Medium, Fair and Not satisfactory were assigned as fuzzy scale factors and the judges were instructed to give a tick mark (✓) in the respective fuzzy, the scale factor for each of the quality attributes of the sample after evaluating the samples.

Sensory quality attributes of milkshake samples	Sensory scale factors				
	Not satisfactory	Fair	Medium	Good	Excellent
Color					
T1					
T2					
T3					
T4					
Flavor					
T1					
T2					
T3					
T4					
Taste					
T1					
T2					
T3					
T4					
Mouthfeel					
T1					
T2					
T3					
T4					
Quality attributes of milkshakes in general	Sensory scale factors				
	Not at all important	Somewhat important	Important	Highly important	Extremely important
Color					
Flavor					
Taste					
Mouthfeel					

Fig. 1: Fuzzy sensory score card (Das, 2005)

The milkshake samples were evaluated for their sensory attributes using the Fuzzy logic method referred to (Das, 2005; Jaya and Das, 2003; Routray and Mishra, 2012; and Kumar *et al.,* 2021). The sensory scores of beverage samples were collected from fuzzy score cards, which were used for the estimation of similarity values for ranking by converting them into triplets. The steps followed were: (1) Estimation of triplets for the sensory score of the milkshake sample; (2) Estimation of triplets for general sensory attributes of the milkshake sample; (3) Estimation of triplets for relative weightage of sensory attributes of milkshake samples; (4) Estimation of triplets for the overall sensory score of milkshake samples; (5) Estimation of values of the overall membership function of sensory scores of milkshake samples using the standard fuzzy scale; (6) Estimation of similarity values of milkshake samples and (7) The ranking of the general sensory attributes of milkshake samples.

Estimation of Triplets for the Sensory Score of the Score of Milkshake Samples

The triplets of sensory attributes, *i.e.,* colour, flavour, taste, and mouth feel of each milkshake sample were calculated using equation 1 with the triplets associated with the sensory scale using equation 1.

$$T_X(SA) = \frac{n_1(0\ 0\ 25)+n_2\ (25\ 25\ 25)+n_3(50\ 25\ 25)+n_4(75\ 25\ 25)+n_5(100\ 25\ 0)}{n_1+n_2+n_3+n_4+n_5} \quad \text{....(1)}$$

Where 'X' represents the treatment number, SA represents the sensory attribute of the treatment, n_1, n_2, n_3, n_4 and n_5 represent the sensory score associated with sensory scale factors, not satisfactory, fair, medium, good and excellent respectively of that sample.

Estimation of Triplets for General Sensory Attributes of Milkshake Samples

The triplets of the general sensory attributes colour, flavour, taste and mouthfeel of the milkshake sample were calculated using equation 2:

$$Q_{SA} = \frac{n_1(0\ 0\ 25)+n_2\ (25\ 25\ 25)+n_3(50\ 25\ 25)+n_4(75\ 25\ 25)+n_5(100\ 25\ 0)}{n_1+n_2+n_3+n_4+n_5} \quad \text{....(2)}$$

Where SA represents the sensory attribute of the milkshake sample and n_1, n_2, n_3, n_4 and n_5 represent the sensory score associated with sensory scale factors of the sensory attribute.

Estimation of Triplets for Relative Weightage of Sensory Attributes of Milkshake Samples

The triplets of the relative weightage of sensory attributes for each sample were determined using equation 3.

$$Q\ (SA)_{Rel} = \frac{Q_{SA}}{Q_{SUM}} \quad \text{.......(3)}$$

Where SA represents the sensory attribute, Q_{SA} represents the triplets of the general sensory attribute of the milkshake sample; Q_{SUM} represents the sum of all first digits of the triplets of each sensory attribute of the milkshake sample.

Estimation of Triplets for the Overall Sensory Score of Milkshake Samples

The sensory scores of the milkshake samples are represented in the form of a triplet for each sensory attribute and these triplets of each sensory attribute are to be compiled to form a single triplet which will represent the overall sensory score of the milkshake sample. The overall sensory score of the milkshake sample in the form of a triplet is calculated using equation 4.

$$SO_X = T_X(C) \times Q(C)_{Rel} + T_X(F) \times Q(F)_{Rel} + T_X(T) \times Q(T)_{Rel} + T_X(MF) \times Q(MF)_{Rel} \quad \text{.......(4)}$$

Where SO represents the overall sensory score of the milkshake sample, X represents the sample number, $T_X(C)$, $T_X(F)$, $T_X(T)$ and $T_X(MF)$ represents the triplet of sensory attributes 'Colour, Flavour, Taste and Mouthfeel' of that sample respectively and $Q(C)_{Rel,}$ $Q(F)_{Rel,}$ $Q(T)_{Rel,}$ and $Q(MF)_{Rel}$ represents the triplets of general relative weightage score of sensory attributes 'Colour, Flavour, Taste and Mouthfeel' respectively.

The multiplication of triplets of sensory attributes with triplets of the general relative weightage score of the sensory attribute was performed using equation 5.

$$(a, b, c) \times (d, e, f) = [(a \times d), (a \times e) + (d \times b)], [(a \times f) + (d \times c)] \quad \text{.......(5)}$$

Where a, b & c represents the triplets of sensory attributes and d, e & f represents the triplets of the general relative weightage score of the sensory attribute of sample.

Estimation of Values of Overall Membership Function of Sensory Scores of Milkshake Samples on the Standard Fuzzy Scale

The standard fuzzy scale for a 6-point sensory scale in a triangular distribution pattern is shown in fig. 2. In the fig. 2, the sensory scales *viz.,* Not satisfactory/ Not at all necessary, Fair/Somewhat necessary, Satisfactory/Necessary, Good/Important, Very good/ Essential and Excellent/Essential are marked as Fl, F2, F3, F4, F5 and F6 (Das, 2005). The value of the fuzzy membership function of each sensory scale is between a minimum and maximum value of 0 and 1, respectively (Sarkar *et al*., 2020). The values of the membership function of the sensory scale are defined by a set of 10 numbers as explained by Das (2005). The values of the membership function of the standard fuzzy scale are:

Fl = (1, 0.5, 0, 0, 0, 0, 0, 0, 0, 0)

F2 = (0.5, 1, 1, 0.5, 0, 0, 0, 0, 0, 0)

F3 = (0, 0, 0.5, 1, 1,0.5, 0, 0, 0, 0)

F4 = (0, 0, 0, 0, 0.5, 1, 1, 0.5, 0, 0)

F5 = (0, 0, 0, 0, 0, 0, 0.5, 1, 1, 0.5)

F6 = (0, 0, 0, 0, 0, 0, 0, 0, 0.5, 1)

The values of membership function (B_X) of the overall sensory score of milkshake samples were calculated in association with the standard fuzzy scale as given in fig. 3. For a given value of Y, B_X can be calculated using the following equation

$$B_X = \frac{Y - (a-b)}{b} \quad \text{if } (a-b) < Y < a$$

$$= \frac{(a+c)\ Y}{c} \quad \text{if } a < Y < (a+c)$$

$$= 0 \text{ for all other values of Y} \quad \text{............. (6)}$$

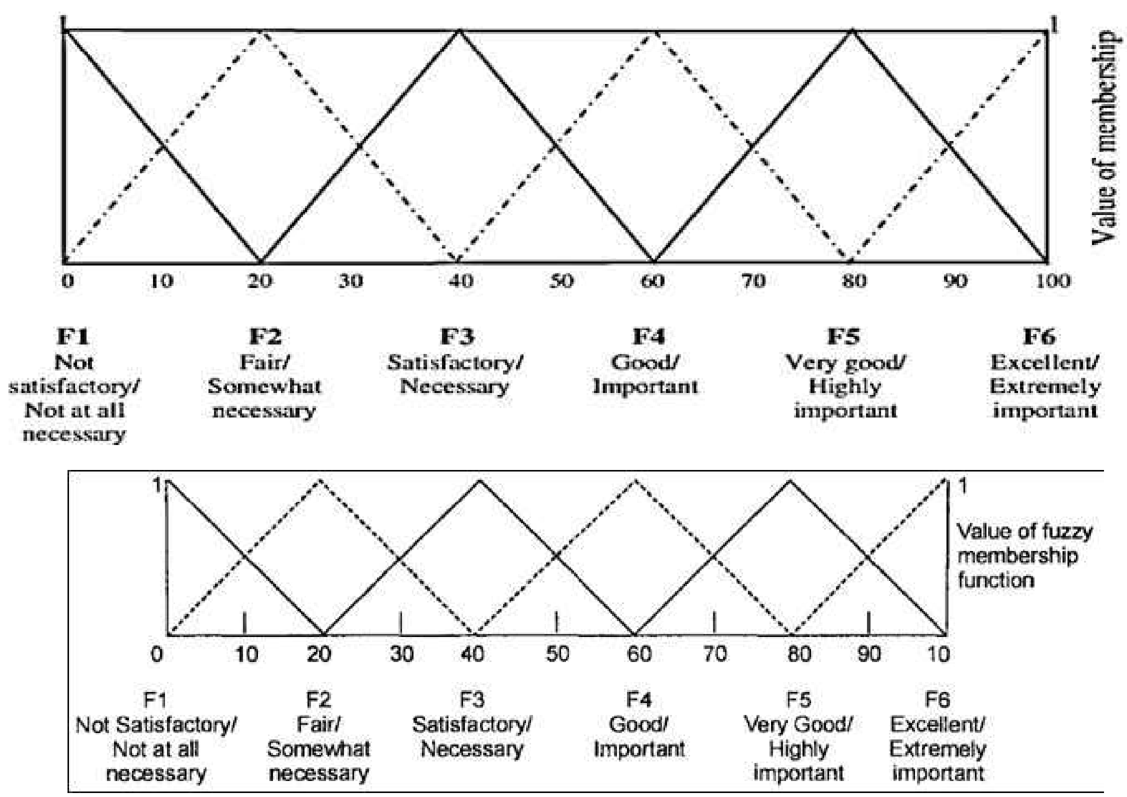


Fig. 2: Standard Fuzzy Scale (Das, 2005)

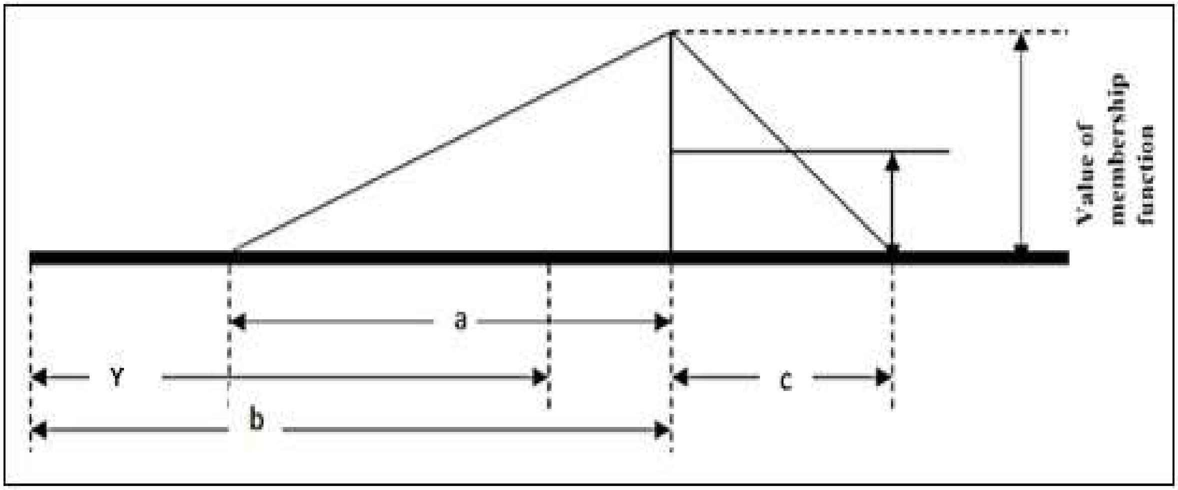


Fig. 3 : Representation of the triplet (a b c) and its membership function (Das, 2005)

Where,

B_X = Value of membership function of 'X' sample

Y = 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100

(a, b, c) = triplet values of the overall sensory score of samples

Estimation of Similarity Values of Milkshake Samples

To estimate the similarity values of milkshake samples, first the value of $(F_Z \times F_Z^1)$, $(F_Z \times B_X^1)$ and $(B_X \times B_X^1)$ have to be calculated. The F_Z represents a matrix of 10 rows and 1 column with Z being the number of standard fuzzy scales. Similarly, B_X represents a matrix of 1 row and 10 columns with X being the number of samples. The values F_Z^1 and B_X^1 represent the transpose of matrices F_Z and B_X. The matrix multiplication was carried out as shown in fig. 4.

The similarity values (S_m) of the milkshake sample were obtained by comparing the values of the membership function of the milkshake sample (B_X) and the values of the standard fuzzy scale (F_1 to F_6). These values were calculated using the following equation :

$$S_m\,(F_Z\,B_X) = \frac{(F_Z \times B_X^1)}{\text{Maximum of } (F_Z^1 \times F_Z^1) \text{ and } (B_X^1 \times B_X^1)} \quad ....(7)$$

$$\begin{pmatrix} R_1 & R_2 & R_3 & R_4 & R_5 & R_6 & R_7 & R_8 & R_9 & R_{10} \end{pmatrix} X \begin{pmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \\ C_{10} \end{pmatrix} = \begin{pmatrix} (R_1 X C_1) + (R_2 X C_2) + (R_3 X C_3) + \\ (R_4 X C_4) + (R_5 X C_5) + (R_6 X C_6) + \\ (R_7 X C_7) + (R_8 X C_8) + (R_9 X C_9) + \\ (R_{10} X C_{10}) \end{pmatrix}$$

Fig. 4: Matrix multiplication

The similarity values for sample 1 Sm (F_1 B_1), Sm (F_2 B_1), Sm (F_3 B_1), Sm (F_4 B_1), Sm (F_5 B_1) and Sm (F_6 B_1) were calculated using equation 7. Similarly, the similarity values of all samples were calculated. Referring to the similarity values, the milkshake samples were ranked by locating the sensory factor with the highest similarity value. The milkshake sample that exhibited the highest similarity value on the superior sensory scale was ranked highest.

The Ranking of the General Sensory Attributes of Milkshake Samples

The ranking of the general sensory attributes of the milkshake sample was done by calculating the similarity values of the general sensory attributes of the milkshake sample. These values were calculated similarly with the similarity values of the milkshake sample using equation 8.

$$S_m (F_Z Q_{SA}) = \frac{(F_Z \times B^1_{SA})}{\text{Maximum of } (F_Z \times F^1_Z) \text{ and } (B_{SA} \times B^1_{SA})} \quad .....(8)$$

Where B_{SA} is a matrix of 1 row and 10 columns of the quality attributes and B^1_{SA} is the transpose of the matrix. The sensory attribute with the highest value on the superior scale was ranked highest.

Results and Discussion

The safflower milkshake analogue and bovine milkshake were prepared as explained and given for

Table 1

Sensory score for sensory attributes and triplet values of milkshake samples

Sensory attribute	Not satisfactory	Fair	Medium	Good	Excellent	Triplets for the sensory score			
							a	b	c
Sample T_1									
Colour	0	0	0	5	6	T_1C	88.64	25.00	11.36
Flavour	0	0	1	6	4	T_1F	81.82	25.00	15.91
Taste	0	0	1	5	5	T_1T	84.09	25.00	13.64
Mouthfeel	0	0	0	6	5	T_1M	86.36	25.00	13.64
Sample T_2									
Colour	0	0	0	3	8	T_2C	93.18	25.00	6.82
Flavour	0	0	1	5	5	T_2F	84.09	25.00	13.64
Taste	0	0	0	3	8	T_2T	93.18	25.00	6.82
Mouthfeel	0	0	0	5	6	T_2M	88.64	25.00	11.36
Sample T_3									
Colour	0	0	1	8	2	T_3C	77.27	25.00	20.45
Flavour	0	0	1	5	5	T_3F	84.09	25.00	13.64
Taste	0	0	0	6	5	T_3T	86.36	25.00	13.64
Mouthfeel	0	0	0	9	2	T_3MF	79.55	25.00	20.45
Sample T_4									
Colour	0	0	0	6	5	T_4C	86.36	25.00	13.64
Flavour	0	0	0	3	8	T_4F	93.18	25.00	6.82
Taste	0	0	0	3	8	T_4T	93.18	25.00	6.82
Mouthfeel	0	0	0	6	5	T_4M	86.36	25.00	13.64

T_1: Bovine Milk (60%) + Banana Pulp (30%) + Sugar (10%) + Cardamom Powder (0.1%); T_2: Safflower seed extract (60%) + Banana Pulp (30%) + Sugar (10%) + Cardamom Powder (0.1%); T_3: Bovine Milk (60%) + Sapota Pulp (30%) + Sugar (10%) + Cardamom Powder (0.1%); T_4: Safflower seed extract (60%) + Sapota Pulp (30%) + Sugar (10%) + Cardamom Powder (0.1%); T_1C, T_1F, T_1T, and T_1M represent triplets associated with sensory attribute Colour, Flavour, Taste, and Mouthfeel respectively for sample T_1; T_2C, T_2F, T_2T, and T_2M represents triplets associated with sensory attribute Colour, Flavour, Taste, and Mouthfeel respectively for sample T_2; T_3C, T_3F, T_3T, and T_3M represents triplets associated with sensory attribute Colour, Flavour, Taste, and Mouthfeel respectively for sample T_3, and T_4C, T_4F, T_4T, and T_4M represents triplets associated sensory attribute Colour, Flavour, Taste, and Mouthfeel respectively for sample T_4

Table 2

Sensory score for general sensory attributes and triplet values of general sensory attributes and relative weightage of sensory attributes of milkshake samples

Quality attributes in general	NI	SI	I	HI	EI	Triplets for the general sensory attributes	a	b	c	Triplets for relative weightage of sensory attributes	a	b	c
Colour	0	0	3	4	4	Q_C	77.27	25.00	15.91	QC_{Rel}	0.2267	0.0733	0.0467
Flavour	0	0	1	5	5	Q_F	84.09	25.00	13.64	QF_{Rel}	0.2467	0.0733	0.0400
Taste	0	0	0	1	10	Q_T	97.73	25.00	2.27	QT_{Rel}	0.2867	0.0733	0.0067
Mouthfeel	0	0	2	4	5	Q_M	81.82	25.00	13.64	QM_{Rel}	0.2400	0.0733	0.0400

NI: Not at all important, SI: Somewhat important, I: Important, HI: Highly important, EI: Extremely important, Q_C, Q_F, Q_T, and Q_M represent the triplet for the sensory score of Colour, Flavour, Taste, and Mouthfeel respectively; QC_{Rel}, QF_{Rel}, QT_{Rel}, and QM_{Rel} represent the triplet for relative weightage of Colour, Flavour, Taste, and Mouthfeel respectively.

sensory evaluation to eleven judges using fuzzy score cards. The score cards after evaluation were collected and the preferences of the judges were summed and tabulated in Table 1 and Table 2 for milkshake samples and general quality attributes of milkshake, respectively.

From Table 1, it can be observed that with respect to the sample T_1 the colour, flavour, taste and mouth feel were preferred as Excellent, Good, Good/Excellent and Good, respectively, by most judges. The highest number of judges preferred the colour and taste of the sample T_2 as excellent. The highest number of judges ranked the colour, flavour, taste and mouthfeel of sample T_3 as Good, Good/Excellent, Good and Good, respectively. The Flavour and taste of sample T_4 were preferred as Excellent whereas the colour and mouthfeel were preferred as Good by the highest number of judges.

The sensory score preferences were used to calculate the triplet values for the milkshake samples and the general quality attributes of the milkshake using equation 1 and tabulated in Table 1 and Table 2, respectively.

The triplets for relative weightage of sensory attributes (QC_{Rel}, QF_{Rel}, QT_{Rel} and QM_{Rel}) were calculated using triplets for the sensory score, in general, using equation 3. Where in Q_{SUM} = 340.91, which is the sum of all first digits of triplets for the general sensory score and tabulated in Table 2.

Triplets for the Overall Sensory Score of Milkshake Samples

The triplets for the overall sensory score of milkshake samples were calculated using the values of triplets for the sensory score of milkshake samples and the triplets of relative weightage of the general sensory attributes of the milkshake sample using equation 4 and referring equation 6.

The triplets for the overall sensory score of the sample T_1 can be calculated as follows :

$$SO_1 = T_1C \times QC_{Rel} + T_1F \times QF_{Rel} + T_1T \times QT_{Rel} + T_1MF \times QMF_{Rel}$$

Triplet a $(88.64 \times 0.2267) + (81.82 \times 0.2467) + (84.09 \times 0.2867) + (86.36 \times 0.2400) = 85.1058$

Triplet b $[(88.64 \times 0.0733) + (25 \times 0.2467)] + [(81.82 \times 0.0733) + (25 \times 0.2467)] + [(84.09 \times 0.0733) + (25 \times 0.2867)] + [(86.36 \times 0.0733) + (25 \times 0.2400)] = 49.9999$

Triplet c $[(88.64 \times 0.0467) + (11.36 \times 0.2267)] + [(81.82 \times 0.0400) + (15.91 \times 0.2467)] + [(84.09 \times 0.0067) + (13.64 \times 0.2867)] + [(86.36 \times 0.0400) + (13.64 \times 0.2400)] = 25.1060$

Similarly, the triplets for the overall sensory scores for the remaining milkshake samples were calculated and tabulated in Table 3.

TABLE 3

Triplets for the overall sensory score of milkshake samples

Milkshake samples	A	b	c
SO_1	85.1058	49.9999	25.1060
SO_2	89.8482	51.3332	21.4696
SO_3	82.1058	48.9999	27.5454
SO_4	89.9998	51.3332	21.8333

SO_1, SO_2, SO_3 & SO_4 represent the triplet of the overall sensory score of milkshake sample, T_1, T_2, T_3, and T_4, respectively

Overall Membership Function for Sensory Scores of the Milkshake Sample on the Standard Fuzzy Scale

The values of the overall membership function B_1, B_2, B_3 and B_4 for milkshake samples on the standard fuzzy scale were calculated using equation 6 for a value of X varying from 0 to 100. The overall membership function for the T_1 beverage sample using the triplet values of overall sensory score SO_1 can be calculated as shown in Table 4.

From the above table, it can be observed that the value of B_1 satisfies the first condition of Equation 6 when the value of X is 40, 50, 60, 70 and 80, the second condition when the value of X is 90 and 100. Furthermore, the value of B_1 is zero when the value of X is 0, 10, 20 and 30 as per the third condition of equation 6. It can also be noted that when the value of X is $80 < X < 90$, the value of B_1 is 1, thus the values of the overall membership function B_1 for sample T_1 are as follows

B_1 = 0.0000, 0.0000, 0.0000, 0.0000, 0.0979, 0.2979, 0.4979, 0.6979, 0.8979, 1.0000, 0.8051

Similarly, the values of B_2, B_3 and B_4 were calculated and tabulated in Table 5 in the form of matrix.

The similarity values of the milkshake samples were calculated using the values of the overall member ship function (B_1 to B_4) and the values of the standard fuzzy scale (F_1 to F_6) were considered as a matrix of order (1 × 10) and (10 × 1) respectively and the transpose of these matrices were formed as B_1^1 to B_4^1 and F_1^1 to F_6^1. The matrix multiplication was carried out as shown in fig. 4 and the values of $(F_Z \times F_Z^1)$, $(F_Z \times B_X^1)$ and $(B_X \times B_X^1)$ were calculated as given in Table 5.

TABLE 4

Calculation for overall membership function of T_1 beverage sample

a	b	C	a-b	Y	a	(Y-(a-b))/b	a	Y	a+c	((a+c)-Y) /c
85.1058	49.9999	25.1060	35.1060	0	85.1058	-0.7021	85.1058	0	110.2118	4.3899
85.1058	49.9999	25.1060	35.1060	10	85.1058	-0.5021	85.1058	10	110.2118	3.9915
85.1058	49.9999	25.1060	35.1060	20	85.1058	-0.3021	85.1058	20	110.2118	3.5932
85.1058	49.9999	25.1060	35.1060	30	85.1058	-0.1021	85.1058	30	110.2118	3.1949
85.1058	49.9999	25.1060	35.1060	40	85.1058	0.0979	85.1058	40	110.2118	2.7966
85.1058	49.9999	25.1060	35.1060	50	85.1058	0.2979	85.1058	50	110.2118	2.3983
85.1058	49.9999	25.1060	35.1060	60	85.1058	0.4979	85.1058	60	110.2118	2.0000
85.1058	49.9999	25.1060	35.1060	70	85.1058	0.6979	85.1058	70	110.2118	1.6017
85.1058	49.9999	25.1060	35.1060	80	85.1058	0.8979	85.1058	80	110.2118	1.2034
85.1058	49.9999	25.1060	35.1060	90	85.1058	1.0979	85.1058	90	110.2118	0.8051
85.1058	49.9999	25.1060	35.1060	100	85.1058	1.2979	85.1058	100	110.2118	0.4067

TABLE 5

The values of the overall membership function and the values of the standard fuzzy scale in the form of matrix

The values of the overall membership function and the values of the standard fuzzy scale in form of Matrix

B_1	0.0000	0.0000	0.0000	0.0979	0.2979	0.4979	0.6979	0.8979	1.0000	0.8051
B_2	0.0000	0.0000	0.0000	0.0289	0.2237	0.4185	0.6133	0.8082	1.0000	0.9929
B_3	0.0000	0.0000	0.0000	0.1407	0.3448	0.5489	0.7529	0.9570	1.0000	0.7134
B_4	0.0000	0.0000	0.0000	0.0260	0.2208	0.4156	0.6104	0.8052	1.0000	0.5420
F_1	1	0.5	0	0	0	0	0	0	0	0
F_2	0.5	1	1	0.5	0	0	0	0	0	0
F_3	0	0	0.5	1	1	0.5	0	0	0	0
F_4	0	0	0	0	0.5	1	1	0.5	0	0
F_5	0	0	0	0	0	0	0.5	1	1	0.5
F_6	0	0	0	0	0	0	0	0	0.5	1

Transpose of the Matrix

B_1^1	B_2^1	B_3^1	B_4^1	F_1^1	F_2^1	F_3^1	F_4^1	F_5^1	F_6^1
0.0000	0.0000	0.0000	0.0000	1	0.5	0	0	0	0
0.0000	0.0000	0.0000	0.0000	0.5	1	0	0	0	0
0.0000	0.0000	0.0000	0.0000	0	1	0.5	0	0	0
0.0979	0.0289	0.1407	0.0260	0	0.5	1	0	0	0
0.2979	0.2237	0.3448	0.2208	0	0	1	0.5	0	0
0.4979	0.4185	0.5489	0.4156	0	0	0.5	1	0	0
0.6979	0.6133	0.7529	0.6104	0	0	0	1	0.5	0
0.8979	0.8082	0.9570	0.8052	0	0	0	0.5	1	0
1.0000	1.0000	1.0000	1.0000	0	0	0	0	1	0.5
0.8051	0.9929	0.7134	0.5420	0	0	0	0	0.5	1

The values of $(F_Z \times F_Z^1)$, $(F_Z \times B_X^1)$, and $(B_X \times B_X^1)$

$F_1*B_1^1$	0.0000	$F_1*B_2^1$	0.0000	$F_1*B_3^1$	0.0000	$F_1*B_4^1$	0.0000	$F_1*F_1^1$	1.2500	$B_1*B_1^1$	3.2875
$F_2*B_1^1$	0.0489	$F_2*B_2^1$	0.0145	$F_2*B_3^1$	0.0703	$F_2*B_4^1$	0.0130	$F_2*F_2^1$	2.5000	$B_2*B_2^1$	3.2413
$F_3*B_1^1$	0.6447	$F_3*B_2^1$	0.4619	$F_3*B_3^1$	0.7599	$F_3*B_4^1$	0.4546	$F_3*F_3^1$	2.5000	$B_3*B_3^1$	3.4317
$F_4*B_1^1$	1.7936	$F_4*B_2^1$	1.5478	$F_4*B_3^1$	1.9527	$F_4*B_4^1$	1.5390	$F_4*F_4^1$	2.5000	$B_4*B_4^1$	2.5368
$F_5*B_1^1$	2.6493	$F_5*B_2^1$	2.6113	$F_5*B_3^1$	2.6902	$F_5*B_4^1$	2.3814	$F_5*F_5^1$	2.5000		
$F_6*B_1^1$	1.3051	$F_6*B_2^1$	1.4929	$F_6*B_3^1$	1.2134	$F_6*B_4^1$	1.0420	$F_6*F_6^1$	1.2500		

B_1, B_2, B_3 & B_4 represent the triplet of the overall membership function for samples T_1, T_2, T_3, and T_4, respectively; F_1 to F_6 values of the standard fuzzy scale

Using the above values of $(F_Z \times F_Z^1)$, $(F_Z \times B_X^1)$, and $(B_X \times B_X^1)$ the similarity values of milkshake samples with respect to the scale factor were calculated using equation 7.

The similarity values for sample 1 can be calculated as follows :

S_m (F_1 B_1) Not satisfactory, F1	$\dfrac{(F_1 \times B_1^1)}{\text{Maximum of } (F_1 \times F_1^1) \text{ and } (B_1 \times B_1^1)}$	$\dfrac{0.0000}{3.2875}$	**0.0000**
S_m (F_2 B_1) Fair, F2	$\dfrac{(F_2 \times B_1^1)}{\text{Maximum of } (F_2 \times F_2^1) \text{ and } (B_1 \times B_1^1)}$	$\dfrac{0.0489}{3.2875}$	**0.0149**
S_m (F_3 B_1) Satisfactory, F3	$\dfrac{(F_3 \times B_1^1)}{\text{Maximum of } (F_3 \times F_3^1) \text{ and } (B_1 \times B_1^1)}$	$\dfrac{0.6447}{3.2875}$	**0.1961**
S_m (F_4 B_1) Good, F4	$\dfrac{(F_4 \times B_1^1)}{\text{Maximum of } (F_4 \times F_4^1) \text{ and } (B_1 \times B_1^1)}$	$\dfrac{1.7936}{3.2875}$	**0.5456**
S_m (F_5 B_1) Very good, F5	$\dfrac{(F_5 \times B_1^1)}{\text{Maximum of } (F_5 \times F_1^1) \text{ and } (B_1 \times B_1^1)}$	$\dfrac{2.6493}{3.2875}$	**0.8059**
S_m (F_6 B_1) Excellent, F6	$\dfrac{(F_6 \times B_1^1)}{\text{Maximum of } (F_6 \times F_6^1) \text{ and } (B_1 \times B_1^1)}$	$\dfrac{1.3051}{3.2875}$	**0.3970**

Similarly, the similarity values associated with other milkshake samples were calculated and tabulated in Table 6.

TABLE 6

The similarity values of milkshake samples

Scale Factor	Sample T_1	Sample T_2	Sample T_3	Sample T_4
Not satisfactory, F_1	0.0000	0.0000	0.0000	0.0000
Fair, F_2	0.0149	0.0045	0.0205	0.0051
Satisfactory, F_3	0.1961	0.1425	0.2214	0.1792
Medium, F_4	0.5456	0.4775	0.5690	0.6067
Good, F_5	0.8059	0.8056	0.7839	0.9387
Excellent, F_6	0.3970	0.4606	0.3536	0.4107

From Table 6, it can be observed that for sample T_1 the similarity values (Sm) are 0.0000, 0.0149, 0.1961, 0.5456, 0.8059 and 0.3970 with respect to scale factors Not satisfactory, Fair, Satisfactory, Medium, Good and Excellent respectively. Since the similarity value associated with the scale factor 'GOOD' is the highest, the overall quality of the sample T_1 is considered as 'GOOD'. Exercising the same analogy, the overall quality of samples T_2, T_3, and T_4 can be considered 'GOOD'.

As the values of all milkshake samples are associated with the scale factor 'GOOD', the sample with the maximum score should be ranked highest. Thus, the order of ranking for milkshake samples will be :

Sample T_4 (GOOD) > Sample T_1 (GOOD) > Sample T_2 (GOOD) > Sample T_3 (GOOD)

TABLE 7

The overall membership function for general quality attributes of the milkshake samples

B_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.3091	0.7091	1.0000	0.8286	0.2000
B_F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0364	0.4364	0.8364	1.0000	0.5667
B_T	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2909	0.6909	1.0000
B_M	0.0000	0.0000	0.0000	0.0000	0.0000	0.1273	0.5273	0.9273	1.0000	0.4000

$B_{C,}$ $B_{F,}$ B_T & B_M represents the triplet of the overall membership function for general quality attributes of the milkshake sample

Overall Membership Function for General Sensory Scores of the Milkshake Sample on the Standard Fuzzy Scale

The values of the overall membership function for general sensory attributes of the milkshake sample on the standard fuzzy scale were calculated similarly to the overall membership function of sensory scores of the beverage samples using the triplets of general quality attributes of the beverage sample and the triplets of the standard fuzzy scale referring equation 6 and tabulated in Table 7.

The Similarity Values for General Sensory Attributes of Milkshake Samples

The similarity values for general sensory attributes of milkshake samples were estimated using values of the overall membership function for general sensory attributes of milkshake samples similar to the similarity values of the milkshake samples.

Using the values of ($FZ \times F^1Z$), ($FZ \times B^1X$) and ($BX \times B^1X$) the similarity values of general sensory attributes of the milkshake sample with respect to the scale factor were calculated using equation 7 similarly to that of the similarity values of the beverage samples and tabulated in Table 8.

TABLE 8

The similarity values of general sensory attributes of milkshake samples

Scale Factor	Colour	Flavour	Taste	Mouth-feel
Not at all necessary, F_1	0.0000	0.0000	0.0000	0.0000
Somewhat necessary, F_2	0.0000	0.0000	0.0000	0.0000
Necessary, F_3	0.0618	0.0073	0.0000	0.0255
Important, F_4	0.6073	0.3564	0.0582	0.4473
Highly important, F_5	0.9132	0.9352	0.5927	0.9564
Extremely important, F_6	0.2642	0.4821	0.8614	0.3889

From Table 8, the highest similarity value associated with supreme scale factor can be observed for the sensory attribute 'Taste' associated with the scale factor 'Extremely important' (0.8614), followed by Sensory attributes Mouthfeel, Flavour and Colour which are associated with scale factor Highly important with similarity values 0.9564, 0.9352 and 0.9132 respectively. Thus, the general sensory attributes of the milkshake sample can be ranked in the order as follows.

TASTE (Extremely Important) > MOUTHFEEL (Highly important) > FLAVOUR (Highly Important) > COLOUR (Highly Important)

The current study ranks taste as the most salient sensory aspect compared to mouth feel, flavour and colour in determining the acceptability of the milkshake used in this experiment. Among the two milkshakes and their analogues compared in this experiment employing fuzzy logic, the safflower milkshake analogue with sapota pulp is the most acceptable. The study suggests safflower seed extract as a potential choice over bovine milk for use in the beverage processing industry to fulfil the needs of consumers with lactose intolerance and a vegan mindset.

Declaration of interest : There is no conflict of interest in this study.

REFERENCES

BELLA, S. L, TUTTOLOMONDO, T., LAZZERI, L., MATTEO, R., LETO, C. AND LICATA, M., 2019, An agronomic evaluation of new safflower (*Carthamus tinctorius* L.) germplasm for seed and oil yields under Mediterranean climate conditions. *Agronomy,* **9** : 468.

Chughtai, M. F. J., Khaliq, A., Zahoor, T., Mehmood, T., Ahsan, S., Liaqat, A., Nadeem, M., Bin, T. A, Sammed, N. and Aziz, S., 2022, Plant protein based beverages. In : A. Manickavasagan, LT. Lim, A. Ali, (eds) *Plant Protein Foods,* pp. : 251-270. Springer, Cham. https://doi.org/10.1007/978-3-030-91206-2_9

Dairy Alternatives Market Overview. (n.d.). Future market insights. Com. Retrieved July 29, 2022, from https://www.futuremarketinsights.com/reports/dairy-alternatives-market

Das, H., 1st Ed., 2005, *Food Processing Operations Analysis,* pp. : 383 - 402. Asian Books, New Delhi, India.

Food Safety and Standards Authority of India, 2011, Food Safety and Standards (Food Products Standards and Food Additives) Regulations, 2011 (2.3.10)

Jaya, S. and Das, H., 2003, Sensory evaluation of mango drinks using fuzzy logic. *Journal of Sensory Studies,* **18** (2) : 163 - 176.

Kashid, U. B., Sontakke, A. T. and Shinde, D. B., 2007, Manufacture of golden milk shake from cow milk blended with safflower milk. *Asian Journal of Dairy and Food Research,* **26** : 159 - 163.

Kumar, R., Ghosh, P., Rao, P. S., Rana, S. S., Vashishth, R. and Kambhampati, V., 2021, Sensory evaluation of microwave-assisted ultrasound treated soymilk beverage using fuzzy logic. *Journal of the Saudi Society of Agricultural Sciences,* **20** : 257 - 264. https://doi.org/10.1016/j.jssas.2021.02.005

Kutsenkova, V. S., Nepovinnykh, N. V. and Qingbin Guo, 2020, Using of safflower seeds as a protein fortifier for shortbread, *Food Hydrocolloids*, **105** : 105808 https://doi.org/10.1016/j.foodhyd.2020.105808.

Martinez, L., 2007, Sensory evaluation based on linguistic decision analysis. *Int. J. Approximate Reasoning,* **44** (2) : 148 - 164.

Punia, B. S., Sharma, N., Kaur, H., Kaur, M., Sandhu, K. S., Maqsood, S. and Ozogul, F., 2022, A review of Sapodilla (Manilkara Zapota) in human nutrition, health and industrial applications. *Trends in Food Science & Technology*, **127** : 319-334. doi: https://doi.org/10.1016/j.tifs.2022.05.016.

Ranganna, S., 1987, *Handbook of Analysis and Quality Control for Fruit and Vegetable Products* (2nd ed.). Tata McGraw-Hill Publications, New Delhi.

Report Linker., 2021, January 15. *Global Packaged Milkshakes Industry*. Globe News Wire. Retrieved July 29, 2022, from https://www.globenewswire.com/news-release/2021/01/15/2159233/0/en/Global-Packaged-Milkshakes-Industry.html

Routray, W. and Mishra, H. N., 2012, Sensory evaluation of different drinks formulated from Dahi (Indian yogurt) powder using fuzzy logic. *Journal of Food Processing and Preservation,* **36** : 1 - 10.

Sarkar, T., Bhattacharjee, R., Salauddin, M., Giri, A., and Chakraborty, R., 2020, Application of fuzzy logic analysis on pineapple rasgulla. *Procedia Computer Science,* **167** *:* 779 - 787.

Suriyamoorthy, P., Madhuri, A., Tangirala, S., Michael, K. R., Sivanandham, V., Rawson, A. and Anandharaj, A., 2022, Comprehensive review on banana fruit allergy : Pathogenesis, diagnosis, management and potential modification of Allergens through food processing. *Plant Foods Hum Nutrition,* **77** (2) : 159 - 171. doi: 10.1007/s11130-022-00976-1.

Tireki, S., 2021, A review on packed non-alcoholic beverages : Ingredients, production, trends and future opportunities for functional product development. *Trends in Food Science & Technology,* **112** : 442 - 454

Ubale, P. J., Hembade A. S. and Choudhari, D. M., 2014, Sensory and chemical quality of sapota milk shake. *Research Journal of Animal Husbandry and Dairy Science,* **5** (2) : 116 - 122.

Diversity of Floral Resources of Stingless Bee, *Tetragonula* nr. *pagdeni* (Hymenoptera : Apidae : Meliponini)

M. R. Moulya[1], K. S. Jagadish[2], V. V. Belavadi[3], G. Eswarappa[4] and A. N. Sringeswara[5]
[1&3]Department of Agricultural Entomology, [2&4]Department of Apiculture, [5] Department of Forestry and Environmental Sciences, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : moulyamr533@gmail.com

Authors Contribution

M. R. Moulya : Conceptualization, investigation, original draft preparation and analysis;
K. S. Jagadish : Conceptualization, framing research proposal, data curation & draft correction ;
V. V. Belavadi, G. Eswarappa & A. N. Sringeswara : Supervision and editing

Corresponding Author :
M. R. Moulya
Department of Agricultural Entomology,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : September 2022
Accepted : January 2023

Abstract

Stingless bees, play an important role as pollinators of many flowering plants. The present study was aimed to know the floral resources foraged by stingless bee, *Tetragonula* nr. *Pagdeni* in Bengaluru, Karnataka through visual observations. Roving surveys were conducted and observation on the stingless bees visiting flowering plants were recorded from June 2021 to May 2022. A Total of 258 bee floral plant species, belonging to 68 different botanical families were documented. Most frequently foraged families were Asteraceae (28 species) and Fabaceae (27 species) followed by Bignoniaceae (14 species), Acanthaceae (11 species), Lamiaceae (10 species), Poaceae (10 species), Cucurbitaceae (9 species) and Solanaceae (8 species), besides 141 plant species coming under 60 other families. The flower colour, shape and size also influenced the foraging efficiency. Greater bee visitation was evident in white and yellow coloured flowers with open shape and small and medium sized flowers as compared to other. These results suggested that the studied site can provide floral resources to stingless bees throughout the year which is an important pre - requisite for maintaining stingless bee populations.

Keywords : Bee flora, Flower anatomy, Flowering period, Nectar source, Pollen source, Pollination, Stingless bees

Pollinators have co-evolved with flowering plants and many species have a mutualistic relationship. Plant-pollinator interactions bind together food webs, within complex ecosystems and drive co-adaptive evolution among several insect-plant species (Gilbert and Raven, 1980; Williams *et al.,* 1983). Pollination is a crucial ecological service rendered by pollinators that indirectly determines the agricultural productivity (Robacker and Erickson*,* 1988). More than 85 per cent of the flowering plants depend on insects for pollination (Ollerton *et al*., 2011). Among non-*Apis* bee species, stingless bees, being eusocial, populated this planet 65 million years ago, are considered efficient pollinators of angiosperms with very small flowers, particularly in tropics. Stingless bees are amongst the longest evolved bees and have been found preserved inside pieces of 80-million-year old amber. 22 species of stingless bees belonging to 3 genera namely, *Tetragonula*, *Lepidotrigona* and *Lisotrigona* have been recorded in India (Viraktamath and Roy, 2022). In kannada, stingless bees are known as Nasarujenu or Mujentijenu or Ralajenu or Sollejenu. They are the smallest (4.0 to 5.0 mm length) of the honey bees, which are distributed in most parts of India and form an important group of pollinators in agricultural and natural ecosystems. Stingless bee forage in order to collect valuable floral resources needed for their survival and these include, nectar for energy requirement, pollen for protein and other nutritional needs, water for cooling hives and for metabolic processes, resins and other plant materials for nest building (Vazhacharickal *et al.,* 2020). The stingless bees have a flight range of only around 500-800m radius from their nest for collecting pollen and nectar which makes them suitable for controlled conditions like green houses, poly houses and precision - horticultural ecosystems which often lack insect pollinators. These are potentially the most promising pollinator species because of their small size hence they can visit even the smallest flowers. They can survive under varying temperatures between 18-36 °C and can build their nest with low cost, easily available materials. Their hives could be placed hanging on the sunshades of houses, open porches or in the farm by using bee hive stands (Dollin and Heard, 1999).

The present study aims to understand the availability of various bee floral resources for stingless bees, their flowering period and source of rewards (pollen or nectar or both) and to know whether the shape, colour and size of flowers influence their foraging behaviour.

Material and Methods

The present study was conducted at the Gandhi Krishi Vigyana Kendra (GKVK) campus, UAS, Bengaluru (13.0713 - 13.0801^{0} N, 77.5785 - 77.5905^{0} E), which represents Eastern - Dry Zone of Karnataka, India during June 2021 to May 2022 with an objective to understand the diversity of floral resources available for stingless bees.

Periodic surveys on flowering plants was conducted and documented at fortnightly intervals for one year, with a view to identify the major nectar and pollen yielding plants in the study area. The plant samples were collected and their botanical features were documented, besides the bee flora was identified with the technical help of Botanist at the Department of Forestry and Environmental Sciences, UAS, GKVK, Bengaluru.

The plants were classified as a nectar source, when the bees insert the proboscis into the flower for sipping the nectar and as a pollen source, when the corbiculae got loaded with pollen during foraging. When both the activity was observed on the same plant, the plant was categorised as a source for both nectar and pollen. The richness of the source was judged by observing the number of bees involved and time spent by the bees to collect one load.

The plant was judged as bee flora based on field observations and as per the methodology suggested by Waykar and Baviskar (2015). Blooming periods of the plants were also recorded. In relation to the visitation by stingless bee foragers, data was recorded at fortnightly intervals for one-year period during June 2021 to May 2022 for construction of a floral calendar. This bee floral calendar comprising of flowering period, colour of the flower, shape and size of flower, its family and richness of the source (whether nectar source or pollen or both nectar and pollen source) was prepared in order to document the availability of food sources of stingless bees in the study area year round. Flower size was categorized based on visual observation: if the flower size was >3cm it was considered as large flower, if the flower size ranged from 1-3cm it was considered as medium flower and if it was <1 cm, then it was categorized into small flower group Waykar and Baviskar (2015).

Results and Discussion

The present study revealed that *Tetragonula* nr. *pagdeni* was found to forage on 258 bee floral species in UAS, GKVK, Bengaluru. The bee flora included 103 ornamental plant species (39.92%), 29 medicinal and aromatic plant species (11.24%), 21 vegetable crop species (8.14%), 13 fruit and plantation crop species (5.04%), 38 weed species (14.73%), 40 tree species (15.50%), 11 oilseed and pulse crop species (4.26%) and 3 field crops (1.16%) (Table 1 & Fig. 1). These findings are in accordance with those of Vijayakumar and Jeyaraaj (2016) who reported that 45 plant taxa belonging to 29 families and non-floral sources were utilized by *Tetragonula iridipennis* for pollen, nectar and resin. The families Arecaceae and Fabaceae had a significant importance amongst the samples. Coconut, sunflower and banana pollen types occurred most constantly among the samples collected from Nellithurai Village, Tamilnadu. About 140 plant species were recorded as bee forage sources in Dharwad, Karnataka, India,

TABLE 1

Category-wise abundance and distribution of bee floral resources available for *Tetragonula* nr. *pagdeni*

Categories of the plant	No. of plants species foraged by *T.* nr. *pagdeni*	Percentage abundance
Vegetables	21	8.14
Oilseeds and Pulses	11	4.26
Field Crops	3	1.16
Weeds	38	14.73
Fruits and Plantations	13	5.04
Trees	40	15.50
Medicinal and Aromatic plants	29	11.24
Ornamentals	103	39.92
Total	258	

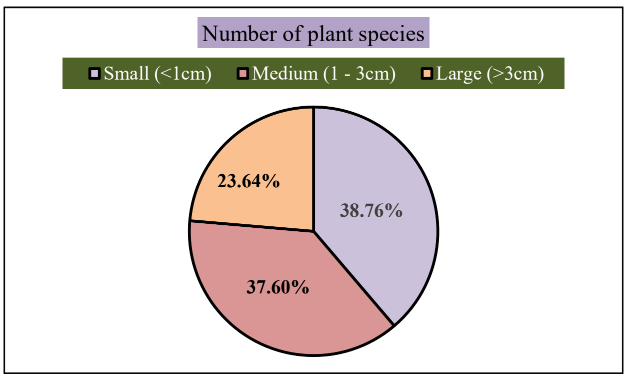


Fig. 1 : Foraging activity of *Tetragonula* nr. *pagdeni* in relation to the size of the flowers

14 were identified as major food sources (Bhat *et al.*, 1990) who gave the details of their frequency of occurrence, whether nectar or pollen source and main flowering period.

Of the 68 botanical families recorded, Asteraceae topped the list accounting for 28 species, followed by the Fabaceae (27 species), Bignoniaceae (14 species), Acanthaceae (11 species), Lamiaceae (10 species), Poaceae (10 species), Cucurbitaceae (nine species), Solanaceae (eight species), Amaranthaceae , Euphorbiaceae and Myrtaceae 6 species each; Amaryllidaceae and Rubiaceae five species each; four species each of Apiaceae, Arecaceae, Asparagaceae and Moraceae, three species each of Anacardiaceae, Combretaceae, Convolvulaceae, Lythraceae, Malvaceae, Oleaceae and Rosaceae, two species each of Asclepiadaceae, Balsaminaceae, Brassicaceae, Cannaceae, Crassulaceae, Geraniaceae, Nyctaginaceae, Proteaceae, Verbanaceae and Vitaceae; one species each of Annonaceae, Apocyanaceae, Araceae, Araliaceae, Basellaceae, Berberidaceae, Bixaceae, Cacicaceae, Caprifoliaceae, Celestraceae, Chenopodiaceae, Commelinaceae, Costaceae, Dilleniaceae, Heliconiaceae, Magno laceae, Malpighiaceae, Meliaceae, Mimosaceae, Moringaceae, Muntingeaceae, Musaceae, Nymph aeceae, Papavaraceae, Passifloraceae, Pedaliaceae, Plumbaginaceae, Polygonaceae, Rutaceae, Sapota ceae, Scrophulariaceae, Simaroubaceae, Strelitziaceae and Zingiberaceae (Table 2). The present findings are also supported by those of Waykar and Baviskar (2015) who studied the diversity of bee flora and developed a floral calendar for Paithan taluka of Aurangabad district, Maharashtra, where 63 plant species were useful to honeybees as floral resources, out of which 41 were wild and 22 were agri-horticultural cultivated plant species. Vamshikrishna *et al.* (2021) conducted surveys at the College of Horticulture, Udyanagiri and Haveri Campus of University of Horticultural Sciences, Bagalkot, Karnataka and observed the stingless bees floraging on different flowering plant species from September 2019 to March 2020 during peak foraging time. They recorded a total of 30 plant species belonging to 20 different families of which the most preferred families included Apiaceae, Fabaceae, Asteraceae, Amaryllidaceae, Anacardiaceae and Euphorbiaceae.

Flower colour, shape and size acts as visual cues and a structure that allows a specific, co-evolved pollinator to contact the flower's anthers and stigma. In study area we have encountered various coloured flowers having different shapes and sizes and one or the other species of plants are present throughout the year which are rich sources of pollen and nectar and help in bee survival. The present studies revealed white coloured flowers (95 species) constituted about 31.35 per cent and was predominant, followed by flowers with

TABLE 2

Familywise distribution of bee pasturage resources of *Tetragonula* nr. *pagdeni*

Botanical family	No. of bee floral species
Asteraceae	28
Fabaceae	27
Bignoniaceae	14
Acanthaceae	11
Lamiaceae	10
Poaceae	10
Cucurbitaceae	9
Solanaceae	8
Amaranthacea	6
Euphorbiaceae	6
Myrtaceae	6
Amaryllidaceae	5
Rubiaceae	5
Apiaceae	4
Arecaceae	4
Asparagaceae	4
Moraceae	4
Anacardiaceae	3
Combretaceae	3
Convolvulaceae	3
Lythraceae	3
Malvaceae	3
Oleaceae	3
Rosaceae	3
Asclepiadaceae	2
Balsaminaceae	2
Brassicaceae	2
Cannaceae	2
Crassulaceae	2
Geraniaceae	2
Nyctaginaceae	2
Proteaceae	2
Verbanaceae	2
Vitaceae	2
Annonaceae	1
Apocyanaceae	1
Araceae	1
Araliaceae	1
Basellaceae	1
Berberidaceae	1
Bixaceae	1
Cacicaceae	1
Caprifoliaceae	1
Celestraceae	1
Chenopodiaceae	1
Commelinaceae	1
Costaceae	1
Dilleniaceae	1
Heliconiaceae	1
Magnoliaceae	1
Malpighiaceae	1
Meliaceae	1
Mimosaceae	1
Moringaceae	1
Muntingeaceae	1
Musaceae	1
Nymphaeceae	1
Papavaraceae	1
Passifloraceae	1
Pedaliaceae	1
Plumbaginaceae	1
Polygonaceae	1
Rutaceae	1
Sapotaceae	1
Scrophulariaceae	1
Simaroubaceae	1
Strelitziaceae	1
Zingiberaceae	1

yellow colour (65 species) which constituted 21.45 per cent, 45 species of red coloured flowers (14.85 %), 40 species of pink coloured flowers (13.20 %), 26 species of purple colour flowers (8.58 %), 23 species of orange colour flowers (7.59 per cent), violet colour (6 species) constituted 1.98 per cent and blue colour (3 species) contributed 0.99 per cent attracting stingless bee visitation (Table 3). Bosch *et al.* (1997) studied the flowering

TABLE 3

Foraging activity of *Tetragonula* nr. *pagdeni* in relation to the colour of flowers

Colour of the flower	Number of plant species	Percentage
White	95	31.35
Yellow	65	21.45
Red	45	14.85
Pink	40	13.20
Purple	26	8.58
Orange	23	7.59
Violet	6	1.98
Blue	3	0.99

phenology, floral traits and pollinator composition in an herbaceous Mediterranean plant community and stated that yellow coloured flowers attracted more pollinators than the other colour flowers. Sajjanar and Eswarappa (2015) reported that stingless bee foraging in sesamum (2.26 bees / plant / 5min) increased the qualitative and quantitative parameters in sesamum when it has caged with bees as compared to open pollination.

Flower shapes create a distinct design when they bloom. It ranges from open, tubular, trumpet, funnel, bell, star and various other shapes. The shape of flowers is important in facilitating the pollinators they need. Out of 258 plants visited by stingless bees, open shape flowers constituted 58 bee floral species (22.48%), followed by tubular shaped flowers which constituted 31 species (12.02%), trumpet shaped flowers contributed 30 species (11.63%), 25 species had cup shaped flowers (9.69%), 20 species had star shaped flowers (7.75%), 18 species exhibited pea shaped flowers (6.98%), 15 species showed ligulate flowers (5.81%), 11 species each of funnel shaped and salverform shaped (4.26%), 10 species were labiate flowers (3.88%), seven species had bell shaped flowers (2.71%), five species of bee flora had urceolate and saucer shaped flowers and each contributed 1.94 per cent, each of the four species had campanulate and cruciform flowers which constituted 1.55 per cent, three species had bowl shaped flowers (1.16%) and one species of bee flora had coronate flowers contituting 0.39 per cent (Table 4).

TABLE 4

Foraging activity of *Tetragonula* nr. *pagdeni* in relation to the shape of the flowers

Shape of the flower foraged	Number of plant species	Percentage
Open	58	22.48
Tubular	31	12.02
Trumpet	30	11.63
Cup	25	9.69
Star	20	7.75
Pea	18	6.98
Ligulate	15	5.81
Funnel	11	4.26
Salverform	11	4.26
Labiate	10	3.88
Bell	7	2.71
Urceolate	5	1.94
Saucer	5	1.94
Campanulate	4	1.55
Cruciform	4	1.55
Bowl	3	1.16
Coronate	1	0.39
Total	258	100.00

Among the 258 plant species that were encountered, 100 species had smaller sized flowers (38.76 %), 97 plant species had medium sized flowers (37.60%) and 61 plant species had large sized flowers (23.64%) contributed stingless bee visitation. It clearly implied that > 70 per cent of the flowers which were small and medium sized ones were more preferred for visitation by stingless bees as compared to large sized flowers (Fig. 2).

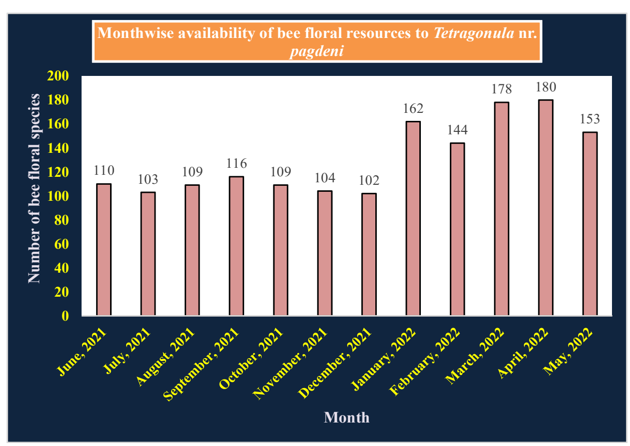


Fig. 2 : Monthwise availability of flowering plants for

Availability of nectar and pollen, the main food source for honey bees are the two chief nutritional resources affecting survival, abundance and distribution of bees. The plants which provide both nectar and pollen are known as 'bee floral plants' or 'bee pasturage'. The interaction between bees and the food plants needs to be properly understood for better management and commercial exploitation of bee colonies to fulfill the human needs. Among the forage plants, in vegetables three species offered only pollen and 18 species provided both; among ornamentals 24 species offered nectar, eight species provided pollen and the remaining 71 provided both; 21 species of medicinal and aromatic plants provided both nectar and pollen; seven species were offered nectar and only one species was a pollen source; 19 species of weeds provided both nectar and pollen, 11 weed species give only nectar and eight weed species provided only nectar; two species of field crops provided only pollen and only one species offered both pollen and nectar, 28 species of trees provided both pollen and nectar, four species gave only pollen and eight species provided only nectar; 10 species of fruit and plantation crops provided both pollen and nectar, two species of fruit and plantation crops gave only pollen and one species provided only nectar and 11 species of oilseeds and pulses provided both pollen and nectar to the stingless bee (Table 5).

TABLE 5

Floral rewards for *Tetragonula* nr. *pagdeni* from different bee flora

Bee floral category	Only pollen source (P)	Only nectar source (N)	Both P + N
Vegetables	3	0	18
Medicinal and Aromatic crops	1	7	21
Ornaments	8	24	71
Field Crops	2	0	1
Weeds	11	8	19
Trees	4	8	28
Fruits and Plantation	2	1	10
Oilseeds and Pulses	0	0	11

Bee pasturage was available for stingless bees throughout the year at GKVK, Bengaluru. From June 2021 to May 2022, 110, 103, 109, 116, 109, 104,102, 162, 144, 178, 180 and 153 bee floral were recorded, respectively. This figure indicated that the maximum visitation of stingless bees was during April, March, January, February and May, where the maximum sunshine hours and less rainfall conditions are present. These bees were active during sunny days. Due to the availability of bee flora during the entire year will be greatly congenial for maintaining stingless bee colonies at GKVK campus which in turn helps in pollination and ensuring the bio-diversity of this campus besides giving honey which is rich in medicinal value. The current findings are also supported by those of Basari *et al.* (2021) revealed that both nectar concentration and flower morphology are important factors for the bees in choosing their food sources. Gadhiya and Pastagia (2015) studied the flowers visited by stingless bees, *Tetragonula laeviceps* Smith and reported that 34 different plant species were visited by stingless bees including cucumber, onion, radish, cauliflower, tomato, brinjal and chilli, fruit crops like coconut, papaya, banana, mango, guava, muskmelon and watermelon; oilseed crops like mustard, castor, sunflower, niger and sunhemp; pulse crops namely greengram, blackgram and cowpea. The ornamental flower plants visited by stingless bees were hibiscus, hamelia, gardenia, ixora, chrysanthemum, turnera, gaillardia and gultora.

From the present study, it could be inferred that the stingless bees have an ability to visit a wide range of flowers like, vegetable crops, fruit crops, plantation crops, oilseed crops, pulse crops, ornamentals, weeds, trees, medicinal and aromatic crops. For bee visitation flower structure like shape, colour and size are one of the major criteria. The present findings prove that flower architecture is crucial while ensuring continuous availability of bee floral resources for sustenance of meliponiculture at a particular geographical location.

Acknowledgement : The authors are thankful to the Department of Agricultural Entomology/ Apiculture/ Forestry and Environmental Sciences, UAS, Bangalore for providing research facilities, besides Department of Science and Technology for financial support in the form of DST-INSPIRE fellowship awarded to the first author to conduct this study.

References

Basari, N., Ramli, S. N., Abdul-Mutalid, N. A., Shaipulah, N. F. M. and Hashim, N. A., 2021, Flowers morphology and nectar concentration determine the preferred food source of stingless bee, *Heterotrigona itama*. *J. Asia Pac. Entomol.*, **24** (2) : 232 - 236.

Bhat, N. S., Manjunath, M. and Lingappa, S., 1990, Studies on bee flora of transitional zone of Karnataka. *Mysore J. Agric. Sci*., **24** (4) : 463 - 470.

Bosch, J., Retana, J. and Cerda, X., 1997, Flowering phenology, floral traits and pollinator composition in a herbaceous Mediterranean plant community. *Oecologia,* **109** (4) : 583 - 591.

Dollin, A. and Heard, T. A., 1999, Tips on stingless beekeeping by Australian beekeepers, *Native Bees of Australia,* **7** (1) : 1 - 17.

Gadhiya, V. C. and Pastagia, J. J., 2015, Flowers visited by stingless bees, *Tetragonula laeviceps* Smith. *AGRES,* **4** (4) : 323 - 330.

Gilbert, L. E. and Raven, P. H., 1980, Coevolution of animals and plants. *Symposium V, First Inter national Congress of Systematic and Evolutionary Biology*. University of Texas Press, 1973.

Ollerton, J., Winfree, R. and Tarrant, S., 2011, How many flowering plants are pollinated by animals? *Oikos*, **120** (3) : 321 - 326.

Robacker, D. C. and Erickson, E. H., 1988, Floral aroma: How far will plants go to attract pollinators? *Biosci.*, **38** (6) : 390 - 398.

Sajjanar, S. M. and Eswarappa, G., 2015, Bee pollination in crop production of sesame (*Sesamum indicum* L.). *Mysore J. Agric. Sci*., **49** (4) : 703 - 707.

Vamshikrishna, N., Vinaykumar, M. M., Venkateshalu, J. B. and Ajjappalavara, P. S., 2021, Foraging flora of stingless bees, *Tetragonula* spp. in Bagalkot, Karnataka, India. *J. Exp. Zool.,* **24** (2) : 1449 - 1453.

Vazhacharickal, P. J., Jagadish, K. S., Eswarappa, G. and Anil, G. B., 2020, An overview of global meliponi culture with a special focus to Kerala, India, *Int. J. Curr. Res.,* **8** : 2347 - 3215.

Vijayakumar, K. and Jeyaraaj, R., 2016, Floral sources for stingless bees in Nellithurai village, Tamilnadu, India. *Ambient. Sci.*, **3** (2) : 22 - 25.

Viraktamath, S. and Roy, J., 2022, Description of five new species of *Tetragonula* (Hymenoptera : Apidae : Meliponini) from India. *Biologia*, **77** : 1769 - 1793.

Waykar, B. and Baviskar, R. K., 2015, Diversity of bee foraging flora and floral calendar of Paithan taluka of Aurangabad district (Maharashtra), India. *J. Appl. Hortic.,* **17** (2) : 155 - 159.

Williams, K. S., Lincoln, D. E. and Ehrlich, P. R., 1983, The co-evolution of *Euphydryas chalcedona* butterflies and their larval host plants. *Oecologia,* **56** (2) : 323 - 329.

Mysore J. Agric. Sci., 57 (1) : 159-167 (2023)

Isolation and Screening of Arbuscular Mycorrhizal Fungi for Drought Tolerance in Green Gram (*Vigna radiata* L.)

R. Mythra and L. Krishna Naik
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : mythrarj@gmail.com

Authors Contribution

R. Mythra :
Design of the work, data collection, data analysis and interpretation;
L. Krishna Naik :
Critical revision of the article and final approval of version to be published

Corresponding Author :
R. Mythra
Department of Agricultural Microbiology,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : August 2022
Accepted : January 2023

Abstract

The climate change over the years has led to the occurrence of abiotic stresses in crops. Drought stress has become the main limiting factor for crop growth, development and production. Arbuscular mycorrhizal fungi (AMF) establish symbiotic interaction with 80 per cent of known land plants. It has good impact on plant growth, water absorption and protection from abiotic stresses. In this view, a total of forty AM fungal isolates were isolated from the drought prone areas of Karnataka. Isolates were mass produced by using maize as host plant. MPN method was carried out to determine the number of infective propagules in each isolate. The efficient isolates were screened for drought tolerance in green gram at different levels of field capacity (FC) (25, 50, 75 and 100% FC). Plants were grown in polythene bags for 30 days under greenhouse condition and based on performance of mycorrhizal parameters and plant parameters, the efficient drought tolerant isolates were selected.

Keywords : Arbuscular mycorrhizal fungi, Drought tolerance, Green gram, Field capacity

The climate change over the years has led to abiotic stresses around the world. Drought stress is one of the major constraints for pulse production which negatively affecting its growth and production. It interferes with photosynthesis, plant water status, enzyme structure, biomass distribution, reduces nutrient uptake and causes nutritional imbalance in the plant. Water deficit condition also affects osmotic balance that can lead to changes in cell wall permeability and increased leakage of solutes across membranes (Kumar and Verma, 2018). In addition, drought stress triggers the production of reactive oxygen species (ROS). ROS disrupts normal metabolism through oxidative damage to carbohydrates, protein synthesis, peroxidation of membrane lipids and cell death in plant tissues (Xie *et al*., 2018). These factors ultimately affect plant growth and reduce the yield.

Recently there has been a great interest in miti gating drought stress by the use of beneficial micro organisms. Plants depend on root-associated microrganisms to overcome various environmental stresses. A number of Plant Growth Promoting Bacteria (PGPB) can also mitigate the impact of abiotic stresses on plants through a process called induced systemic tolerance (IST), which includes bacterial production of cytokinins, production of antioxidants and degradation of ethylene precursor 1-aminocyclopropane 1-carboxylate (ACC) by bacterial ACC deaminase. (Glick *et al.,* 2007).

The association of plant roots with arbuscular mycorrhizal fungi (AMF) is the most abundant symbiosis for 80 per cent of land plants. The symbiosis between AMF and plants enhances the plant growth, nutrient uptake and stress resistance. (Bi *et al,* 2019; Gupta 2020). Arbuscular mycorrhizal symbiosis improves plant performance under drought stress through various mechanisms such as, water/nutrient uptake through extraradical hyphae, increased photosynthesis and stomatal conductance, production of glomalin for soil aggregate stability, protect the plant from oxidative damage by producing antioxidant enzymes and regulate the metabolic activity through osmotic adjustment (He *et al*., 2019; Wu *et al*., 2019; Zou *et al*., 2019). Therefore, use of AM fungi for drought tolerance in plants would be a better option.

Green gram is one of the important leguminous crop in India with high nutritional value. It contains 23 per cent of protein and very low levels of oligosaccharides (Ihsan *et al*., 2013). India is the largest producer and consumer of green gram in the world, with an area of 4.58 M ha, production of 2.50 Mt and productivity of 548 kg / ha (Gopakumar *et al*., 2022). This crop is a source of food, animal feed and income in arid and semi-arid regions, the amount of water available to the crop is the major limiting factor for crop growth and yield. In India, about 68 per cent of net sown area (140 million hectares) is reported to be vulnerable to drought conditions. In legume crops, mycorrhizal fungi were found to increase the vegetative growth and seed yield under drought stress conditions (Hashem *et al.,* 2019, Musyoka *et al.,* 2020). In this view, the present study was aimed to isolate and screen AM fungi for drought tolerance in green gram.

Material and Methods

The present investigation on isolation and screening of arbuscular mycorrhizal fungi for drought tolerance in green gram (*Vigna radiata* L.) was conducted in the Department of Agricultural Microbiology, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra (GKVK), Bengaluru.

Soil Sample Collection and Extraction of AM Spores from the Soil

The soil samples were collected from rhizosphere region of the plants in the drought prone areas of Karnataka (Table 1). From soil samples, AM spores were extracted by wet sieving and decanting method given by Gerdemann and Nicholson (1963). The sievings were collected from each sieve separately in beakers. The collected sievings for recovering AM spores were subjected to the sucrose density gradient centrifugation method (Ohms, 1957).

Funnel Technique

Morphologically similar spores were picked and a single spore as representation of each morphotype (as distinguished by colour or size) and those spores were brought in to funnel technique (Fig. 1a). Sand and soil were mixed in 1:1 proportion and the isolated spores were placed inside the mixture, ragi (*Finger millet*) seeds were sown and maintained for 45 days. Hoagland's solution was applied at weekly intervals (Nicolson, 1967).

Table 1

Geographical details of the soil sample collection

Place (District)	Location	Latitude (N)	Longitude (E)	Number of isolates
Chitradurga	JN Kote	14° 17' 8420''	76° 54' 0783''	5
	Vaddikere	14° 11' 6572''	76° 59' 7156''	4
	Ramajogihalli	14° 17' 5931''	76° 62' 7469''	6
	Sanikere	14° 18' 0814''	77° 64' 3092''	6
	Challakere	14° 30' 1398''	76° 61' 7712''	4
Tumkur	Sira	13° 73' 5175''	76° 89'1865''	2
	Changavara	13° 93' 9765''	76° 85' 3383''	4
Bellary	Marammanhalli	14° 29' 5285''	77° 12' 8695''	3
	Karur	14° 56' 5754''	75° 73' 6439''	2
Raichur	Chilkaragi	16° 05' 3083''	76° 76' 5729''	4
			Total	40

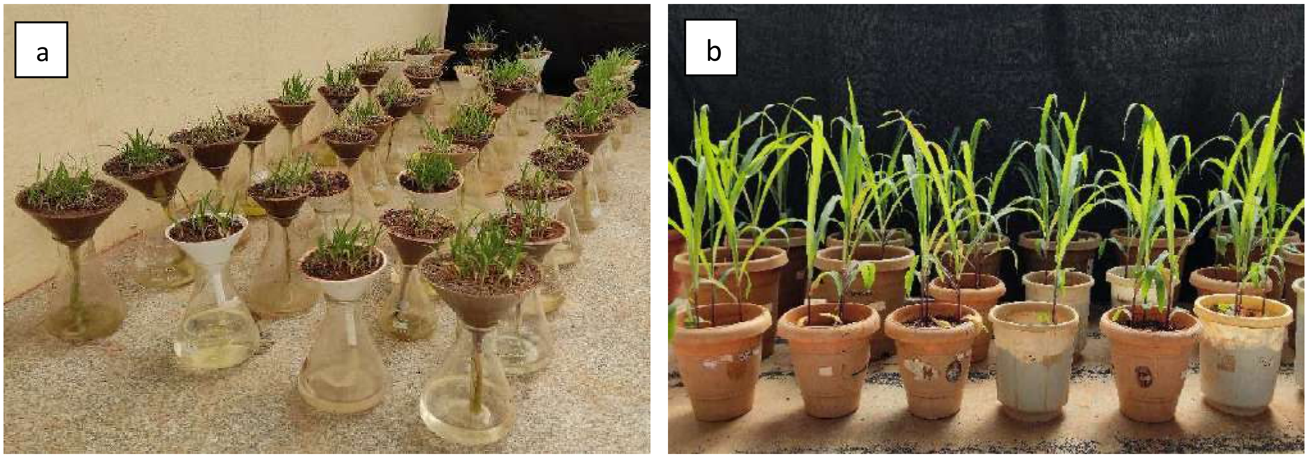


Fig.1 : (a) Funnel technique for isolation of fungal isolates; (b) Mass multiplication of AM fungal isolates

Mass Multiplication

Once the roots of plants started emerging from the stem-tips of the funnels, the contents were transferred to small plastic pots containing sterilized sand: soil substrate (1:1) after confirming the roots for AM colonization. The spores were multiplied up to 45 days using maize as host plant (Fig. 1b). After 45 days of growth, substrate containing spores, hyphae and root bits (cut into about 1 cm pieces) were used as inoculum.

Estimation of Infective Propagules of AM Fungi by MPN Method

The infective propagule (IP) numbers of the AM fungal isolates were estimated by the most probable number (MPN) method as described by Porter (1979). For this, 30 g of substrate based individual inoculum was mixed with 270g of sterile diluents *i.e.,* soilrite, perlite and vermiculite (each 90 g) in cups (4×2''). The mixture was mixed thoroughly to get 10^{-1} dilution. Then 30 g of this 10^{-1} dilution mixture was weighed and placed into another cup containing 270 g of sterile diluents to get 10^{-2} dilution. Likewise, up to 10^{-5} dilutions were made. Each dilution was distri buted into five plastic cups with five replications. Ragi (*Finger millet*) seeds were sown as host into each cup and watered regularly. After 45 days, the roots collected from each cup were stained with acid fuchsin and the presence or absence of mycorrhizal colonization for each replicate was determined under microscope. Counts of positive cups (those containing AM fungal structures) in different dilutions were used to calculate MPN values using the table.

Screening of AM Fungi for Drought Tolerance in Green Gram

Drought stress significantly reduces plant growth and development by inducing oxidative stress, disturbing membrane integrity, plant water relations, nutrient uptake and photosynthetic activity. AM fungal isolates were evaluated based on the ability of mycorrhizal fungi to colonize the plants and growth under drought stress in green house condition. To evaluate for drought stress tolerance, polythene bags were filled with soil and were inoculated with AM fungi prior to sowing of seeds. Seeds were sown and different field capacity levels (25, 50, 75 and 100% FC) were maintained during plant growth. Ability of AM fungal isolates to perform under drought stress conditions were recorded after 30 days of sowing.

Determination of AM Fungal Root Colonization

Staining of root segments was carried out as per the procedure proposed by Philips and Hayman (1970). Fresh root samples were collected after harvesting, roots were washed in tap water to remove the soil debris. Then the roots were cut into pieces of 1cm and the root segments were transferred to glass test tubes containing 10 per cent KOH solution and autoclaved at 121 °C for 15 minutes to soften the root pieces. The root pieces were then rinsed in water and 1 per cent HCl was added and kept aside to neutralize them for five minutes. The roots in the test tube were immersed in 0.05 per cent acid fuchsin in lacto glycerol staining solution for 24h. Then excess stain was removed by immersing the roots in lacto glycerol solution. The stained roots were arranged on grid-line plates and observed using microscope. Number of roots with AM fungal colonization was recorded and the per cent of mycorrhizal colonization was calculated by using formula.

$$\%\ \text{root colonization} = \frac{\text{Number of root fragments +ve for AM fungal colonization}}{\text{Total number of root fragments observed}} \times 100$$

Total Biomass

The plant materials after harvest were dried in a hot air oven at 60 ^{o}C for 48 hours to a constant weight. Later the weight of shoot and root of each replication was weighed and expressed in grams (g) plant^{-1}.

Statstical Analysis

The data were subjected to two way Analysis of Variance by factorial complete block design and means were separated by the Duncan's Multiple Range Test (DMRT).

Results and Discussion

Isolation of AM Fungi from Soil

The soil samples were collected from rhizosphere region of the plants in the drought prone areas of Karnataka (Table 1). A total of forty AM fungal isolates were obtained from ten soil samples. This shows that rhizosphere soils of drought prone areas harbor a vast diversity of AM fungi. Earlier studies have revealed that in drought condition, highest external AM fungal development, fungal mycelium length, root mycorrhization rates and fungal diversity were observed (Benabdellah *et al.,* 2011; Calvo-Polanco *et al*., 2016). This diversity is due to AM fungi that evolved characteristics that are advantageous in dry environments. Some of the AMF can tolerate drought stress were extensively distributed and adapted to the soils of extreme environments. A number of investigations reported that *Glomus* species are dominant in arid and semi-arid regions and are able to grow under water deficit conditions (Opik *et al*., 2006 and Verma *et al*., 2008).

Estimation of Infective Propagules of AM Fungi by MPN Method

This method reveals all living infective propagules capable of colonizing with plant roots (Porter 1979). According to the fertilizer control order (FCO) specifications in India, AM fungal biofertilizers should contain 10 viable spores and 1200 infective propagules (IP) per gram of inoculum according to fertilizer fifth amendment order, July 2021(Agnihotri *et al*., 2022). The MPN method was carried out for forty AM fungal isolates to determine the number of infective propagules. Results revealed that the infective propagule number ranges from 120-1800 IP/g (Fig. 2). Among forty AM fungal isolates, twenty eight isolates showed more than 1000 IP/g and the isolates which showed less than 1000 IP/g were rejected. Total of twenty eight AM fungal isolates were selected for further analysis. Abinaya *et al.* (2018) reported that the MPN assay is considered to be the best for determining the quality of AM fungal inoculum.

Screening of AM Fungi for Drought Tolerance

Determination of per cent root colonization : Ability of AM fungal isolates to colonize with plant roots at different levels of field capacity (FC) were recorded by determining the per cent root colonization. The results revealed that the extent of the mycorrhizal colonization was significantly decreased in green gram roots as the level of the drought stress raised. Root mycorrhizal colonization was significantly higher under 100 per cent FC (without stress) than under 25, 50 and 75 per cent FC (with stress) conditions. The highest percentage of mycorrhizal colonization was recorded at 100 per cent FC with an average of 87.95 per cent and the lowest percentage of mycorrhizal colonization was recorded at 25 per

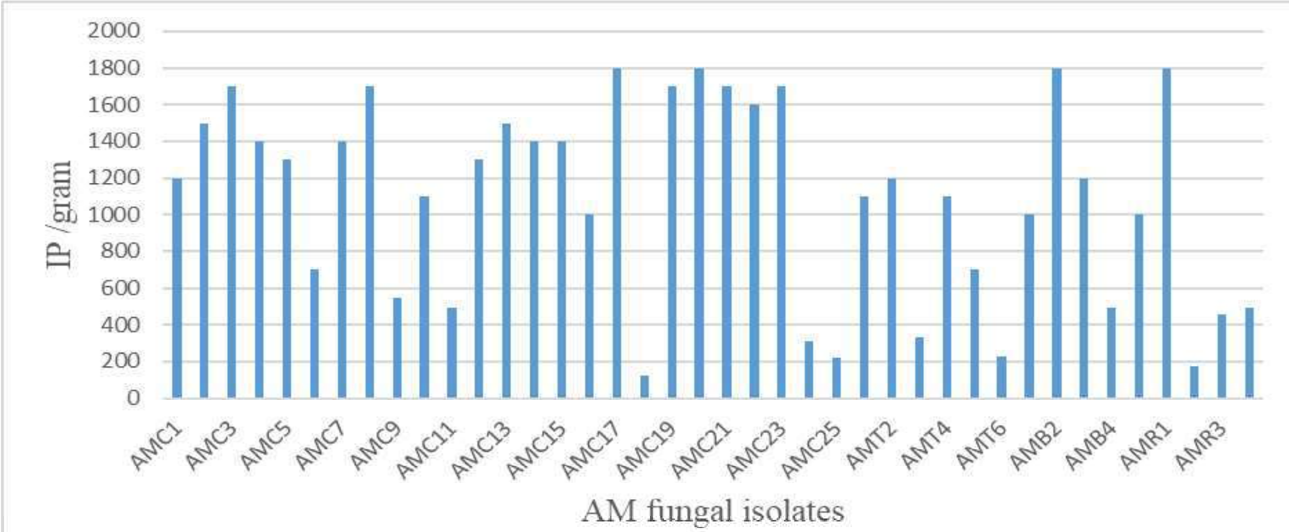


Fig. 2 : Infective propagule (IP) numbers in AM fungal isolates

cent FC with an average of 32.47, 50 and 75 per cent FC levels were recorded the root colonization with an average of 67.86 and 80.11 per cent respectively (Table 2). 50 per cent FC level significantly increased the per cent root colonization by 35.39 per cent as compared to 25 per cent FC. Likewise, From 50 to 75 per cent FC and 75 to 100 per cent FC levels increased the per cent root colonization by 12.25 and 7.84 per cent respectively.

These results depict that AM fungi are able to colonize the plant roots under water deficit conditions to protect the plants from stress but the extent of colonization differs with stress levels. The results were due to the influence of water availability on mycorrhizal colonization to plant roots. In water deficit condition, water shortage interferes with AMF development cycle, which affects the AMF spore germination, colonization capacity, sporulation and extra-radical hyphal elongation (Zhang *et al*., 2018).

Present results were similar with the result obtained by Abdel-Salam *et al.* (2018), who studied the levels of drought stress (100, 75, 50 and 25% FC) on mycorrhizal damask rose (*Rosa damascena* Mill.) plants and found a decrease in root colonization of damask plants by AMF under water deficit conditions from 83.67 to 54.17 per cent. The results were also consistent with the results of Musyoka *et al.* (2020), who performed the studies in green gram (*Vigna radiata* L.) and obtained the highest percentage of mycorrhizal colonization in watering regime R3 (irrigation after interval of 4 days) 36.93 per cent and the lowest percentage of mycorrhizal colonization of 31.73 per cent was recorded in watering regime R1 (irrigation after interval of 12 days). Treatment M3 (*Rhizophagus irregularis*) was recorded highest percentage colonization of 77.01 per cent.

In the present study, among twenty eight AM fungal isolates, AMC3 isolate was recorded the highest percentage mycorrhizal colonization at 75 and 100 per cent FC levels with 89.05 and 97.25 per cent respectively. AMB2 isolate was recorded the highest percentage mycorrhizal colonization at 25 and 50 per cent FC levels with 45.25 and 79.66 per cent respectively. At all the FC levels, AMB2 and AMC3 isolates were recorded highest percentage of root colonization with an average of 77.33 and 76.85 per

Fig.3 : Spores of AM fungal isolates (a) AMB2 (b) AMC3

TABLE 2

Mycorrhizal colonization of green gram plants grown under different field capacity levels

Isolates	Mycorhizal colonization (%)				
	25% FC	50% FC	75% FC	100% FC	Mean
AMC1	26.37 l	61.74 k	74.33 ij	82.50 k	61.23 i
AMC2	31.37 h	71.00 gh	82.1 de	89.08 f	68.39 e
AMC3	44.11 b	77.00 b	89.05 a	97.25 a	76.85 a
AMC4	29.39 ij	66.96 i	77.09 h	87.28 g	65.18 f
AMC5	36.29 f	72.59 ef	82.08 def	92.34 bcde	70.82 d
AMC7	25.86 l	59.65 l	73.73 j	77.26 n	59.12 jk
AMC8	39.28 d	75.05 m	84.13 c	91.40 e	72.46 c
AMC10	28.82 jk	64.4 lj	76.66 h	84.94 i	63.71 g
AMC12	30.23 i	66.03 i	76.90 h	87.98 g	65.28 f
AMC13	32.15 h	70.83 gh	80.99 g	92.11 cde	69.02 e
AMC14	31.90 h	70.53 h	80.53 g	91.32 e	68.57 e
AMC15	34.15 g	72.60 ef	82.33 d	93.40 b	70.62 d
AMC16	21.95 o	58.53 mnop	71.43 kl	78.82 m	57.68 l
AMC17	40.93 c	73.95 cd	84.72 c	93.10 bc	73.18 bc
AMC19	41.86 c	73.48 de	85.22 bc	92.32 bcde	73.22 bc
AMC20	37.84 e	73.33 de	85.11 c	92.18 cde	72.12 c
AMC21	37.06 ef	74.97 c	89.00 a	91.6 de	73.17 bc
AMC22	36.06 f	71.78 fg	80.77 g	89.20 f	69.45 e
AMC23	41.22 c	74.60 c	87.92 a	92.73 bcd	74.11 b
AMT1	23.17 no	58.41 nopq	74.15 ij	80.64 l	59.09 jk
AMT2	23.37 n	59.02 mn	73.86 j	83.36 jk	59.90 j
AMT4	27.98 k	64.16 j	75.09 i	84.02 ij	62.81 gh
AMB1	28.46 jk	60.66 l	74.33 ij	86.02 h	62.37 h
AMB2	45.25 a	79.66 a	88.08 a	96.33 a	77.33 a
AMB3	24.27 mn	57.41 oq	74.04 ij	80.49 l	59.05 jk
AMB5	26.04 l	55.84 r	71.03 l	82.35 k	58.81 jkl
AMR1	41.11 c	76.38 b	86.25 b	93.42 b	74.29 b
AMR2	24.76 m	58.56 mno	72.42 k	79.03 m	58.69 kl
Mean	32.47 d	67.86 c	80.11 b	87.95 a	

Note : Means with same superscrit, in a column do not differ significantly at P=<0.05 as per Duncan Multiple Range Test (DMRT); FC-field capacity

cent respectively. This is due the ability of plant species to be colonized by specific group of AM fungi (Grman, 2012).

Total Plant Biomass

AM fungal isolates were evaluated based on the plant performance of drought tolerance at different levels of field capacity. The results revealed that total dry biomass of plant had significantly increased with the level of reduction in drought stress. As the level of drought stress reduced from 25 FC to 100 per cent FC, the average values of total dry biomass of plant ranged from 0.62 to 1.21 g/plant respectively. From 25 to 100 per cent FC levels, two fold increase in total biomass of plant was observed. 50 per cent FC was recorded the total biomass of plant with an average of 0.86 g/plant and 75 per cent FC was recorded the total biomass of plant with an average of 1.09 g/plant (Fig. 4).

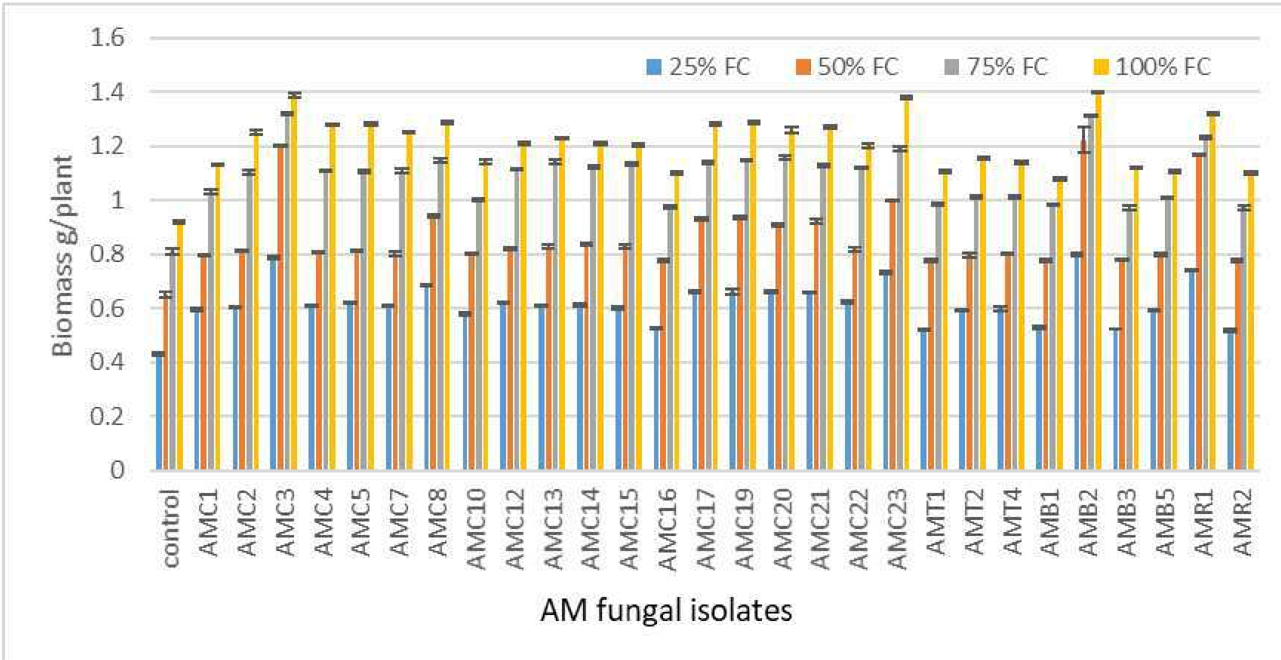


Fig. 4 : Total biomass of green gram plants as influenced by different AM fungi grown under different field capacity levels

These results were due to higher percentage of mycorrhizal colonization under well watered condition campared to water stress conditions and the higher AMF colonization has positive effect on the plant growth traits. Under well watered condition, the biomass of plant was 3.29 g/plant while under drought stress condition biomass of plant was 2.75 g/ plant as reported by Zhang *et al*. (2020) in trifoliate orange (*Poncirus trifoliate*) which support the results of present study.

AMF inoculated plants showed maximum biomass of plant compared to uninoculated control (0.70g/plant) under different field capacity (25, 50, 75 and 100% FC) levels. Among twenty eight AM fungal isolates, AMB2 and AMC3 isolates recorded highest biomass of plant with an average of 1.165 and 1.16 g/plant. These results were due to the AM fungal colonization to plant roots under water deficit conditions, can able to protect the plant and increase the growth of plant through various mechanisms such as, water/nutrient uptake through extraradical hyphae, increased photosynthesis, stomatal conductance, root hydraulic conductivity and root architecture, protect the plant from oxidative damage by producing antioxidant enzymes and regulate the metabolic activity through osmotic adjustment, root hydraulic conductivity and root architecture (He *et al*., 2019 and Wu *et al*., 2019). The effect of AM fungal colonization in increasing the plant performance has been well documented by many researchers in many plant species (Nagarathna *et al*., 2013; Musyoka *et al*., 2020; Azizi *et al*., 2021 and Jabborova *et al*., 2021) augment these results.

REFERENCES

ABDEL-SALAM, A., ALATAR, A. AND EL-SHEIKH, M. A., 2018, Inoculation with arbuscular mycorrhizal fungi alleviates harmful effects of drought stress on damask rose. *Saudi J. Biol. Sci.,* **25** : 1772 - 1780.

ABINAYA, T., BAGYARAJ, D. J, THILAGAR, G. AND ASHWIN, R., 2018, Time reduction for determination of infective propagule numbers of arbuscular mycorrhizal fungi by most probable number assay. *Curr. Sci*., **114** : 729 - 730.

AGNIHOTRI, R., SHARMA, M. P., BUCKING, H., DAMES, J. F. AND BAGYARAJ, D. J., 2022, Methods for assessing the quality of AM fungal bio-fertilizer: Retrospect and future directions. *World J. Microbiol. Bio technol*., **38** (97) : 1 - 14.

Azizi, S., Kouchaksaraei, M. T., Hadian, J., Abad, A. F. N., Sanavi, S. A. M. M., Ammer, C. and Bader, M. K. F., 2021, Dual inoculations of arbuscular mycorrhizal fungi and plant growth-promoting rhizobacteria boost drought resistance and essential oil yield of common myrtle. *For. Ecol. Manag.,* **497** : 119478.

Benabdellah, K., Abbas, Y., Abourouh, M., Aroca, R. and Azcon, R., 2011, Influence of two bacterial isolates from degraded and non-degraded soils and arbus cular mycorrhizae fungi isolated from semi-arid zone on the growth of *Trifolium repens* under drought conditions: Mechanisms related to bacterial effectiveness. *Eur. J. Soil Biol*., **47** : 303 - 309.

Bi, Y., Xiao, L. and Sun, J., 2019, An arbuscular mycorrhizal fungus ameliorates plant growth and hormones after moderate root damage due to simulated coal mining subsidence: A microcosm study. *Environ. Sci. Pollut. Res*., **26** : 11053 - 11061.

Calvo-Polanco, M., Sanchez-Castro, I., Cantos, M, García, J., Azcón, R., Ruiz-Lozano, J. M., Beuzón, C. and Aroca, R., 2016, Effects of different arbuscular mycorrhizal fungal background sand soils on olive plants growth and water relation properties under well-watered and drought conditions. *Plant Cell Environ.,* **39** : 2498 - 2514.

Gerdemann, J. W. and Nicholson, T. H., 1963, Spores of mycorrhizal endogone species extracted from soil by wet sieving and decanting. *Trans. Br. Mycol. Soc*., **46** : 235 - 244.

Glick, B. R., Todorovic, B., Czarny, J., Cheng, Z., Duan, J. and Mcconkey, B., 2007, Promotion of plant growth by bacterial ACC deaminase. *Crit. Rev. Plant Sci.,* **26** : 227 - 242.

Gopakumar, S., Menon, M. V. and Gopal, S. K., 2022, Weed management practices for yield and sustain ability in green gram. *Mysore J. Agric. Sci*., **56** (1) : 313 - 319.

Grman, E., 2012, Plant species differ in their ability to reduce allocation to non-beneficial arbuscular mycorrhizal fungi. *Ecol.*, **93** (4) : 711 - 718.

Hashem, A., Kumar, A., Al-Dbass, A. M., Alqarawi, A. A., Al-Arjani, A. F., Singh, G., Farooq, M. and Allah, E. F. A., 2019, Arbuscular mycorrhizal fungi and biochar improves drought tolerance in chickpea. *Saudi J. Biol. Sci*., **26** : 614 - 624.

He, J. D., Dong, T., Wu, H. H., Zou, Y. N., Wu, Q. S. and Kuca, K., 2019, Mycorrhizas induce diverse responses of root TIP aquaporin gene expression to drought stress in trifoliate orange. *Sci. Hortic*., **243** : 64 - 69.

Ihsan, M. Z., Shahzad, N., Kanwal, S., Naeem, M., Khaliq, A., El-Nakhlawy, F. S. and Matloob, A., 2013, Potassium as foliar supplementation mitigates moisture induced stresses in mung bean (*Vigna radiata* L.) as revealed by growth, photosynthesis, gas exchange capacity and Zn analysis of shoot. *Int. J. Agron. Plant Prod*., **4** : 3828 - 3835.

Jabborova, D., Annapurna, K., Al-Sadi, A. B., Alharbi, S. A., Datta, R. and Zuan, A. T., 2021, Biochar and arbuscular mycorrhizal fungi mediated enhanced drought tolerance in okra (*Abelmoschus esculentus*) plant growth, root morphological traits and physiological properties. *Saudi J. Biol. Sci*., **28** : 5490 - 5499.

Kumar, A. and Verma, J. P., 2018, Does plant-microbe interaction confer stress tolerance in plants: A review. *Microbiol. Res.,* **207** : 41 - 52.

Musyoka, D. M., Njeru, E. M., Nyamwange, M. M. and Maingi, J. M., 2020, Arbuscular mycorrhizal fungi and *Bradyrhizobium* co-inoculation enhances nitrogen fixation and growth of green gram (*Vigna radiata* L.) under water stress. *J. Plant Nutr*., **78** : 1 - 13.

Nagarathna, T. K., Shadakshari, Y. G. and Pandurang, 2013, Influence of mycorrhizal association on photosynthetic rate in sunflower (*Helianthus annuus* L.) *Mysore J. Agric. Sci*., **47** (2) : 296 - 300.

Nicolson, T. H., 1967, Vesicular arbuscular mycorrhiza - a universal plant symbiosis. *Sci. Progr*., **55** : 561 - 568.

Ohms, R. E., 1957, A floatation method for collecting spores of a phycomycetous mycorrhizal parasite from soil. *Phytopathol*., **47** : 751 - 752.

OPIK, M., MOORA, M., LIIRA, J. AND ZOBEL, M., 2006, Composition of root-colonizing arbuscular mycorrhizal fungal communities in different ecosystems around the globe. *J. Ecol.,* **94** : 778 - 790.

PHILIPS, J. H. AND HAYMAN, D. S., 1970, Improved procedures for cleaning roots and staining parasitic and vesicular arbuscular mycorrhizal fungi for rapid assessment of infection. *Trans. Br. Mycol. Soc.*, **55** : 158 - 161.

PORTER, W. M., 1979, The 'Most probable number' method for enumerating infective propagules of vesicular arbuscular mycorrhizal fungi in soil. *Soil Res.*, **17** (3) : 515 - 519.

VERMA, N., TARAFDAR, J. C., SRIVASTAVA, K. K. AND PANWAR, J., 2008, Arbuscular mycorrhizal (AM) diversity in *Prosopis cineraria* (L.) Druce under arid agro ecosystems. *Agric. Sci*., **7** : 754 - 761.

WU, Q. S., HE, J. D., SRIVASTAVA, A. K., ZOU, Y. N. AND KUCA, K., 2019, Mycorrhizas enhance drought tolerance of citrus by altering root fatty acid compositions and their saturation levels. *Tree Physiol*., **39** : 1149 - 1158.

XIE, W., HAO, Z., ZHOU, X., JIANG, X., XU, L., WU, S., ZHAO, A., ZHANG, X. AND CHEN, B., 2018, Arbuscular mycorrhiza facilitates the accumulation of glycyrrhizin and liquiritin in *Glycyrrhiza uralensis* under drought stress. *Mycorrhiza*, **28** : 285 - 300.

ZHANG, F., ZOU, Y. N. AND WU, Q. S., 2018, Quantitative estimation of water uptake by mycorrhizal extraradical hyphae in citrus under drought stress. *Sci. Hortic*., **229** : 132 - 136.

ZHANG, F., ZOUA, Y. N., WUA, Q. S. AND KUCAB, K., 2020, Arbuscular mycorrhizas modulate root polyamine metabolism to enhance drought tolerance of trifoliate orange. *Environ. Exp. Bot.,* **171** : 103926.

ZOU, Y. N., WU, H. H., GIRI, B., WU, Q. S. AND KUCA, K., 2019, Mycorrhizal symbiosis down regulates or does not change root aquaporin expression in trifoliate orange under drought stress. *Plant Physiol. Biochem*., **144**: 292-299.

Mysore J. Agric. Sci., 57 (1) : 168-175 (2023)

Screening of Bacterial Endophytes for Osmotolerance and Improvement of Maize Seed Germination under Water Deficit Condition

NAKUL KALE, N. EARANNA AND TASMIYA IMTIYAZ
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : shivajiputral@gmail.com

AUTHORS CONTRIBUTION

NAKUL KALE :
Design of the work, data collection, data analysis and interpretation;
N. EARANNA :
Critical revision and final approval;
TASMIYA IMTIYAZ :
Data analysis, interpretation and drafting

Corresponding Author :
NAKUL KALE
Department of Agricultural Microbiology,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : August 2022
Accepted : December 2022

ABSTRACT

Bacterial endophytes present within plant tissues play an important role in maintaining host plant fitness, nutrient supply and mainly to mitigate water deficit stress. In this investigation, it was hypothesized that bacterial endophytes inhabiting the tissues of drought tolerant plants would ameliorate drought stress in maize seed germination. In this study 54 bacterial endophytes were isolated from drought adopted plants collected across different drought prone areas of Karnataka. These endophytes were screened for Osmotolerance using Polyethylene glycol (PEG MW-8000) at 15 and 20 per cent. Out of 54 isolates, five bacterial isolates (P7L1, P2L2, P6R1, P3L2 and P7R1) showed growth in the presence of 20 per cent PEG. These five bacterial isolates were inoculated to pre-germinated maize seeds and incubated in paper towel dipped with 15 per cent PEG. All the five endophytes inoculated seedlings showed increased growth of maize seedlings compared to un-inoculated seedling. However, the P7L1 isolate inoculated seedlings showed significantly increased seedling length than other isolates inoculated seedlings indicating its efficiency against water deficit stress This bacterium isolate was identified as *Pseudomonas tolaasii* using 16S rRNA gene sequence and its presence in the inoculated seedling was confirmed by re-isolation of bacterium after 10 days of seedling growth and comparing culture with inoculated mother culture both morphologically as well as by 16Sr RNA.

Keywords : Bacterial endophytes, *Pseudomonas tolaasii*, Drought stress, Polyethylene glycol (PEG MW-8000)

IN nature all plants have shown to inhabit diverse group of microbes, among which bacteria exists as dominant group. The bacteria inhabit within the tissues of healthy plant are referred to as bacterial endophytes (Hallmann *et al.,* 1997). Inside plant system these bacteria do not normally cause any substantial morphological changes like root-nodule as symbionts do. However they have significant impact on plant growth and survival under adverse conditions. In recent past drought stress has been one of the major crucial problem that negatively affects plant growth, development and more importantly yield (Ullah *et al.,* 2017). It has been reported that up to 40 per cent yield reduction in maize is mainly due to drought stress worldwide (Daryanto *et al.,* 2016). These effects of drought on plant system also depend on the duration and intensity of exposure. Under stress condition, plants execute a series of reactions in terms of stress responsive genes, activation or inactivation of functional proteins by secreting stress hormones and ROS, which functionally regulate physiology of the cell for its normal functioning in plant system.

Endophytes are microorganisms (bacteria and fungi) that infiltrate plants without creating disease symptoms. They populate practically every part of the plant, including the leaves, stems, roots, flowers and fruits. They found in a broad variety of plants, from grasses to higher order plants. They live symbiotically inside plant tissue could impart stress tolerance by various mechanisms. Many of them create vital biochemical components that aid in the defence of plants against insect assault (Rabiey *et al.,* 2019) and diseases (Raveendra Reddy and Shivaprakash, 2018). Endophytes are extensively exploited for plant growth promotion and imparting stress tolerance when plants are exposed to a variety of abiotic stresses. Bacterial endophytes can confer benefit to plant fitness including increased biomass (root and shoot), yield and tolerance to abiotic stresses such as heat, salt and drought (Lata *et al*., 2018). In this context use of bacterial endophytes is the most feasible, reliable and sustainable option for enhancing growth of plants under drought stress conditions. Present study intended to screen and characterize the bacterial endophytes efficient against drought stress in maize crop.

Material and Methods

Isolation of Bacterial Endophytes from Drought Adapted Grasses

Grasses growing in the drought prone area of Koppal (Northern dry zone), Bellary (Northern dry zone), Chikkaballapur (Eastern dry zone) and Chitradurga districts (Central dry zone) of Karnataka were collected and the endophytic bacteria were isolated from root and leaf bits. The samples were surface sterilized using sodium hypochlorite (4%) solution followed by 70 per cent ethanol. Surface sterilized root and leaf bits were repeatedly washed using sterile water and last wash water was analyzed for lack of microbial growth by spread plate technique, this confirms surface sterilization of plant bits. These bits were placed on the petriplates dispensed with Nutrient Agar (NA) and incubated at 30 ºC for two days. The bacterial colonies developed were purified and maintained on nutrient agar slants in the refrigerator for further use.

Screening of Bacterial Endophytes for Drought Tolerance

The isolated bacteria were tested for their drought tolerance in liquid cultures. Ten ml of Nutrient broth (NB) supplemented with polyethylene glycol (PEG MW-8000) at 15 and 20 per cent concentrations which corresponds to -0.70 MPa, and -0.81 MPa (Control being -0.39 MPa) respectively were inoculated with each bacterial isolates. For the control nutrient broth was used. The plates were incubated for two days at 30 °C and the bacterial population was enumerated by serial dilution plate method.

Influence of the Bacterial Isolates on Maize Growth Under Drought Stress

Maize seeds (MAH 14-5) were surface sterilized and pre-germinated on sterile moist blotters. The pre-germinated seeds were treated with 48 h old bacterial cultures (~ 10^7 CFU) by soaking for 3 h as described by Wellington and Marcela (2004). The corresponding control was treated with sterile distilled water. These seeds were then subjected to drought stress by placing them on blotter paper dipped in the solution of 14.6 per cent (LC_{50}) PEG, LC stands for 'Lethal Concentration' value which refer to the concentration of a PEG chemical were at least 50 per cent of the seedlings can germinate during observation period (Roopashree, 2022). The growth of the seedling was recorded after 10 days.

Analysis of Plant Growth Promoting Traits of Bacterial Endophytes

Quantification of Indole acetic acid Gibberellic acid and Abscisic acid production using HPLC. The 24 h old cultures were inoculated in 20 mL nutrient broth containing with stress (15% PEG-8000) and without stress. For IAA, tryptophan was amended in the broth and incubated at 30 °C for 7 days. After incubation they were centrifuged at 6000 rpm for 10 minutes and the supernatant was collected, which was adjusted to a pH of 2.8 using 1 N HCl solution. The acidified supernatant was taken in 100 mL conical flask and equal volume of diethyl ether was added and incubated for 4 h at 4 °C. The solvent phase (upper layer) formed was collected and allowed to evaporate. To the evaporated samples 2-3 mL of HPLC grade methanol was added and stored at -20°C after membrane filtration to perform high performance liquid chromatography (Patten and Glick, 2002).

Confirmation of the Endophytes in Inoculated Maize Seedlings

The inoculated maize seedlings were cut into one cm bits (root, stem and leaf), surface sterilized and placed on nutrient agar. The plates were incubated at 30 °C for 48 h. The bacterial colony emerged out of cut ends were sub-cultured and confirmed by comparing with the original colonies of respective mother culture.

Identification of Selected Isolate using 16S rRNA Gene Sequence

Total genomic DNA of the isolate was extracted by alkaline lysis method (Sambrook and Maniatis, 1989).The universal primers already reported (26 bp forward primer 5' GTTAGATCTTGGCTCA GGACGAACGC 3' and 24 bp reverse primer 5' GATCCAGCCGCACCTTCCGATACG 3') for 16S rRNA sequence from the NCBI (http:// www.ncbi.nlm.nih.gov) were custom synthesized by Sigma-Aldrich (Sigma, USA) and diluted accordingly for the Polymerase Chain Reaction (PCR). PCR was performed in 20 µl reaction mixture containing 2.0 µl of 1X PCR Taq buffer with $MgCl_2$ (1.5 mM), 2.0 µl of 10 mM dNTP's mix (200 µM), 0.5 µl of primers (both forward and reverse), 0.3 µl of Taq DNA Polymerase (1U Genei Bengaluru), 1.0 µl of Template DNA, 14.2 µl of Sterile distilled water. Amplification was carried out with an initial denaturation at 96 °C for four minutes followed by 35 amplification cycles consisting of 94 °C for one minute, 60 °C for 30 seconds and 72 °C for one minute and a final extension at 72 °C for 10 minutes. Then the amplified product of DNA was electrophoresed using one per cent agarose gel and documented using gel documentation system. The DNA was eluted by using gel elution kit (The Gene JET™ Gel Extraction Kit, Thermo Scientific) and the amplified product was got sequenced by Chromgene Biotech Pvt. Ltd., Bengaluru, Karnataka. The sequences obtained were analysed for homology using NCBI Gen Bank.

Statistical Analysis

The data was statistically analysed using WASP: 2.0 (Web Agri Stat Package 2) statistical tool (www.icargoa.res.in/wasp2/index.php) and means were separated by Duncan Multiple Range Test (DMRT).

Results and Discussion

The details of the location and the plants used for isolation of endophytic bacteria are presented in Table 1. A total of 54 bacterial isolates were obtained from ten grasses. These isolates were designated serially based on the part of the plant tissue used (P=plant, L=leaf, R=root). Maximum number of isolates were obtained from the plant *Digitaria ciliaaris* (9) and minimum in the *Cyperus* sp. (3), in other plant samples number of isolates ranged from 4 to 7.

Screening of Bacterial Endophytes for Drought Tolerance

The isolated bacteria were tested for their drought tolerance ability in nutrient broth supplemented with PEG (MW-8000) at 15 and 20 per cent concentrations. All the 54 bacterial isolates showed growth at 15 per cent PEG (MW-8000). But at 20 per cent PEG concentration, only five isolates such as P7L1, P2L2, P6R1, P3L2 and P7R1 showed growth after 36 to 48 h. The population of these bacteria were 2.4×10^7, 1.2×10^7, 1.2×10^7, 1.6×10^7 and 1.2×10^7 (Colony forming units) CFU/ml respectively. The bacterial colonies developed were further purified by three way streaking (Fig. 1). This indicated that these bacteria can withstand drought stress at 20 per cent PEG. The ability of these isolates to serve under drought stress can be attributed to accumulation of osmolytes, which include amino acids like proline, glutamate, glutamine, alanine and sugars like sucrose, trehalose and quarternary amines like glycine betaine and polyglucosyl granules that improve cell growth under adverse osmotic conditions, as osmoprotectants (Potts, 1994). These osmolytes lowers the water potential in the cyto plasm, and maintains the cell turgor thus preventing cell death (Aswathy *et al.*, 2020).

TABLE 1
Details of location of plants and endophytic bacterial isolates

District	Location	Longitude (N)	Latitude (E)	Plant sample	Number of isolates
Koppal (Northern dry zone)	Achalapur	15^0 25’ 039"	76^0 34‘ 005"	*Brachiariamutica*	P1L1,P1L2,P1R1, P1R2,P1R3,P1R4
	Raghunata Halli	15^0 22’ 045”	75^0 95’ 016”	*Fimbristylis miliacea*	P2L1,P2L2,P2R1, P2R2,P2R3
Bellary (Northern dry zone)	Tondehal	15^0 38’ 036”	76^0 59’ 014”	*Panicum repens*	P3L1,P3L2,P3L3,P3R1, P3R2,P3R3,P3R4
	Desanur	15^0 36’ 057”	76^0 50’ 045”	*Digitaria ciliaaris*	P4L1,P4L2,P4L3,P4L4, P4R1,P4R2,P4R3, P4R4,P4R5
Chikkaballapur (Eastern dry zone)	Chintamani	13^0 23’ 005”	78^0 03’ 028”	*Dichanthium* sp.	P5L1,P5L2,P5L3,P5R1, P5R2
	Kurubur	13^0 19’ 020”	78^0 04’ 044”	*Eleusine indica*	P6R3,P6L1,P6L2,P6R1, P6R2
	Shidlaghatta	13^0 24’ 009”	77^0 52’ 007”	*Sorghum halepense*	P7L1,P7L2,P7L3,P7R1
Chitradurga (Central dry zone)	Hiryuru	13^0 56’ 001”	76^0 37’ 005”	*Tragus* sp.	P8L1,P8L2,P8L3,P8R1, P8R2
	Ramajogihalli	14^0 17’ 019”	76° 32’ 036”	*Cyperus* sp.	P9L1,P9R1,P9R2
	Challakere	14^0 18’ 038”	76^0 39’ 026”	*Urochloa* sp.	P10L1,P10L2,P10R1, P10R2,P10R3
				Total isolates	54

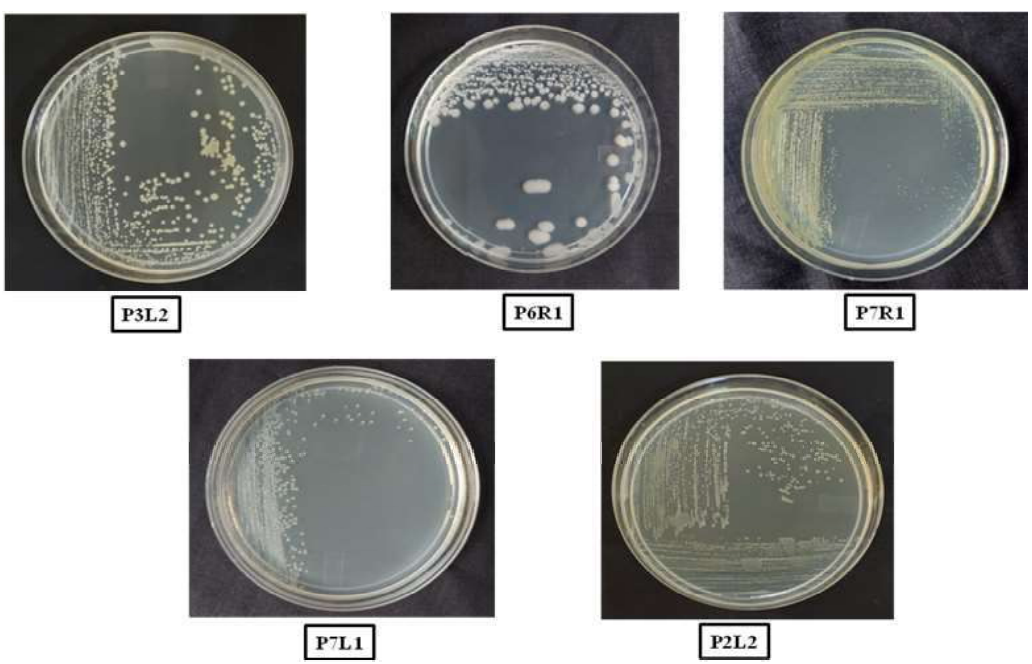


Fig. 1 : Pure cultures of selected bacterial isolates

TABLE 2

Bacterial growth at 20 per cent PEG in Nutrient broth medium

Sl.No.	Isolate	CFU/ml	Sl.No.	Isolate	CFU/ml	Sl.No.	Isolate	CFU/ml
1	P1L1	0.0	19	P4L1	0.0	37	P6R3	0.0
2	P1L2	0.0	20	P4L2	0.0	38	P7L1	2.4×10^{7}
3	P1R1	0.0	21	P4L3	0.0	39	P7L2	0.0
4	P1R2	0.0	22	P4L4	0.0	40	P7L3	0.0
5	P1R3	0.0	23	P4R1	2.0×10^{6}	41	P7R1	1.2×10^{7}
6	P1R4	2.0×10^{6}	24	P4R2	0.0	42	P8L1	0.0
7	P2L1	0.0	25	P4R3	1.0×10^{6}	43	P8L2	0.0
8	P2L2	1.2×10^{7}	26	P4R4	0.0	44	P8L3	0.0
9	P2R1	5.3×10^{6}	27	P4R5	0.0	45	P8R1	0.0
10	P2R2	2.3×10^{6}	28	P5L1	0.0	46	P8R2	0.0
11	P2R3	0.0	29	P5L2	0.0	47	P9L1	0.0
12	P3L1	3.0	30	P5L3	0.0	48	P9R1	0.0
13	P3L2	1.6×10^{7}	31	P5R1	4.5×10^{6}	49	P9R2	0.0
14	P3L3	0.0	32	P5R2	4.0	50	P10L1	4.6×10^{6}
15	P3R1	6.0	33	P6L1	0.0	51	P10L2	0.0
16	P3R2	2.0	34	P6L2	0.0	52	P10R1	1.0×10^{6}
17	P3R3	0.0	35	P6R1	1.2×10^{7}	53	P10R2	0.0
18	P3R4	0.0	36	P6R2	0.0	54	P10R3	0.0

Note: The values are presented as mean. CFU=Colony forming unit.

Influence of Bacterial Endophytes on Maize Seedling Growth Under Drought Stress

The drought stress mainly leads to over production of ROS (Reactive oxygen species) and it must be managed homeostatically therwise it results in denaturation of protein structure, lipid peroxidation, nucleotide disruption by affecting plant physiology which ultimately leads to death of plants. In the present study, five selected bacterial endophytes (P7L1, P2L2, P6R1, P3L2 and P7R1) were inoculated to surface sterilised pre-germinated maize seeds and then subjected to drought stress by placing them on blotter paper dipped in polyethy lene glycol (PEG MW-8000) solution of 14.6 per cent (LC_{50}) concentration. Among the five bacterial endophytes, the P7L1 inoculated seedlings showed significantly higher growth (34.1 cm) which is followed by P7R1, P2L2, P3L2 and P6R1 (Table 3). The least growth was observed in un-inoculated seedlings (Fig. 2). These endophytes also increased the growth of maize under normal conditions compared to control and this may be attributed to plant growth promoting substances produced by the endophytes (Santoyo *et al.,* 2016). Naveed *et al*. (2014) reported the improved seedling growth and water availability in maize cultivars inoculated with *Burkholderia phytofirmans* and *Enterobacter* sp. under drought stress. Similarly, Tasmiya and Earanna (2021) also reported that the bacterial endophyte

TABLE 3

Effect of bacterial endophytes on seedling growth of maize

Treatments	Seedling length (cm)	
	Without drought stress	Drought stress (-0.69MPa)
Control	36.3 [b]	22.3 [c]
P7L1	41.7 [a]	34.1 [a]
P2L2	41.46 [a]	28.9 [b]
P6R1	41.8 [a]	25.8 [bc]
P7R1	41.22 [a]	29.1 [b]
P3L2	37.5 [b]	28.4 [b]
C.D. (5%)	2.416	3.6

Note: Means with the same superscript in a column do not differ significantly as per uncan Multiple Range Test (DMRT) @ p=0.05

Fig. 2 : Effect of bacterial endophytes on seedling length of maize under normal as well as in drought condition

Stenotrophomonas maltophilia isolated from Himalayan cold desert plants increased the seedling length of rice (var. IR-64) compared to uninoculated seedlings.

Determination of Indole Acetic Acid, Gibberellic Acid and Abscisic Acid Production by Endophytes

Phytohormones play a vital role on growth and development of plants. The quantified data of Indole acetic acid (IAA), gibberellic acid (GA) and abscisic acid (ABA) production using high performance liquid chromatography (HPLC) is presented in the Table 4. The bacterial endophytes grown on the medium amended with precursor L-tryptophan showed the highest production of IAA under abiotic (Water deficit) stress compared to bacteria grown under normal medium. This envisaged that the tryptophan amendment in medium can enhance the IAA production. Indole acetic acid is the most prevalent kind of auxin, that influences many aspects of plant growth and development. Many bacteria generate and release IAA as a secondary metabolite by exploiting L-tryptophan found in root exudates (Fu *et al*., 2015). Gibberellic acid helps plant in stimulating cell division and elongation. Abscisic acid also regulates abiotic stress by stomatal closure and lowering transpiration water loss and inducing acquired resistance in plants against diseases. In this study, bacterial endophytes P7L1 and P7R1 grown under abiotic (Water deficit) stress condition

TABLE 4

Plant growth promoting traits of bacterial endophytes (HPLC data)

Treatments	IAA mg/l		GA mg/l		ABA mg/l	
	Without stress	With stress	Without stress	With stress	Without stress	With stress
P7L1	2.87 ^{a}	0.53 ^{a}	86.96 ^{a}	49.11 ^{a}	0.62 ^{c}	2.67 ^{a}
P2L2	1.00 ^{b}	0.20 ^{b}	20.26 ^{d}	17.43 ^{c}	3.79 ^{a}	1.2 ^{b}
P6R1	0.41 ^{c}	0.28 ^{b}	9.10 ^{e}	5.85 ^{e}	1.44 ^{b}	0.79 ^{bc}
P3L2	0.22 ^{c}	0.27 ^{b}	36.77 ^{c}	13.14 ^{d}	1.33 ^{b}	0.64 ^{c}
P7R1	0.76 ^{b}	0.56 ^{a}	63.31 ^{b}	33.68 ^{b}	0.68 ^{c}	1.13 ^{bc}
C.D(1%)	0.35	0.077	0.759	0.76	0.489	0.5

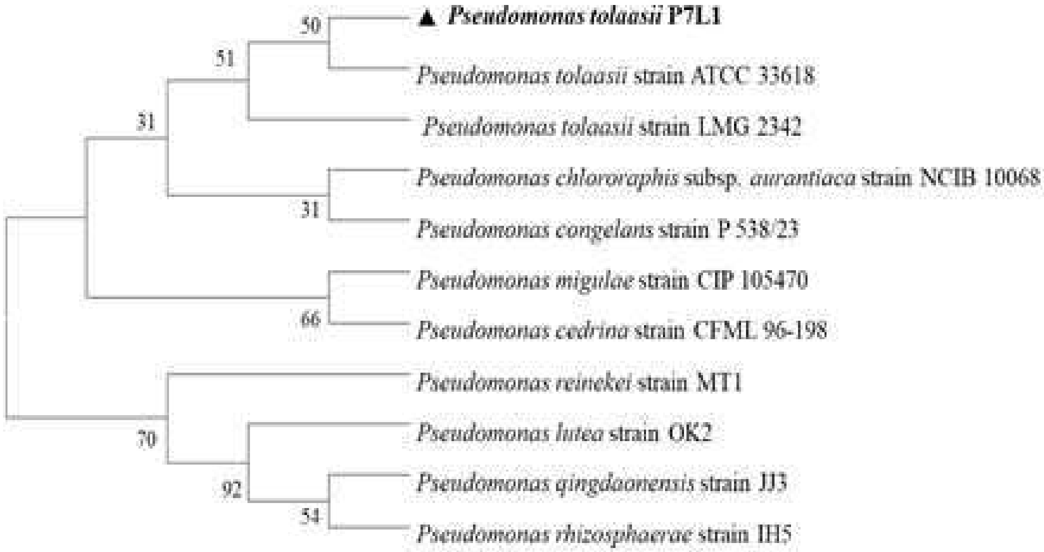


Fig. 3 : Phylogenetic tree of *Pseudomonas species*

showed the significantly difference in production of IAA, GA and ABA (Table 4). These results are in agreement with those of Goswami *et al.* (2014) who reported bacteria *Kocuria turfanensis* produced the IAA in presence of tryptophan under abiotic stress. Pathade (2015) reported that *Bacillus siamensis* BE 76 isolated from the banana plant (Musa spp.) produce gibberellic acid of 0.108 µg mL^{-1}.

Identification of the Selected Bacterial Endophyte using 16S rRNA Gene Sequence

Bacteria can be identified using morphological as well as molecular tools. The genes encoding for 16S rRNA in prokaryotes have been used extensively for sequence based evolutionary analysis because, they are (1) Universally distributed, (2) Functionally constant, (3) sufficiently conserved and (4) Have adequate length to provide a view of evolution encompassing all living microorganisms (Madigan *et al.,* 2009). Molecular methods such as 16S rRNA/ 18S rRNA gene sequence is extensively used for identification of microorganisms (Nandan *et al.,* 2021). In the present study, drought tolerant bacterial endophyte (isolate P7L1) was identified by 16S rRNA gene sequence. The amplified product having sequence length of 1130 bp showed 99.4 per cent homology with *Pseudomonas tolaasii* available at NCBI database. The phylogenetic tree constructed with the sequences of 10 *Pseudomonas species* revealed that the isolate P7L1 is closely related to *Pseudomonas tolaasii* ATCC 33618 and the bacterium was confirmed as *Pseudomonas tolaasii* (Fig. 3).

This study envisaged that the, *Pseudomonas tolaasii* as an efficient bacterium for mitigating drought stress in maize can be used for seed biopriming.

Acknowledgement : Authors are thankful to the Karnataka Science and Technology Promotion Society (KSTePS), Department of Science and Technology, Government of Karnataka for awarding Karnataka DST-Ph.D. fellowship for Science and Engineering for the Ph.D. research.

REFERENCES

AMBAWADE, M. S. AND PATHADE, G. R., 2015, Production of gibberellic acid by *Bacillus siamensis* BE 76 isolated from banana plant (*Musa* spp.). *Int. J. Sci. Res.*, **4** (7) : 394 - 398.

ASWATHY, J., POOJA, P., INDU, C. N. AND RADHAKRISHNAN, E. K., 2020, Drought tolerant bacterial endophytes with potential plant probiotic effects from Ananas comosus. *Biologia.*, **75** : 1769 - 1778.

DARYANTO, S., WANG, L. AND JACINTHE, P. A., 2016, Global synthesis of drought effects on maize and wheat production. *PLoS One,* **11** : 156 - 162.

FU, SHIH-FENG, WEI, J., CHEN, H., LIU, Y., LU, H. AND CHOU, J., 2015, Indole-3-acetic acid : A widespread physiological code in interactions of fungi with other organisms. *Plant Signal. Behav*., **10** (8) : e1048052.

GOSWAMI, D., PITHWA, S., DHANDHUKIA, P. AND THAKKER, J. N., 2014, Delineating Kocuria turfanensis 2M4 as a credible PGPR: a novel IAA-producing bacteria isolated from saline desert. *J. Plant Interact*., **9** (1) : 566 - 576.

HALLMANN, J., QUADT-HALLMANN, A., MAHAFEE, W. F. AND KLOEPPER, J. W., 1997, Bacterial endophytes in agricultural crops. *Can. J. Microbiol*., **43** : 895 - 914.

LATA, R., CHOWDHURY, S., GOND, S. K. AND WHITE, J. F., 2018, Induction of abiotic stress tolerance in plants by endophytic microbes. *Lett. Appl. Microbiol.*, **66** : 268 - 276.

MADIGAN, M. T., BROCK T. D., MARTINKO, J. M. AND PARKER, J., 2009, Biology of microorganisms, 12th edn. *Prentice Hall*, Upper Saddle River, NJ, USA, pp. : 320 - 321.

NAVEED, M., MITTER, B., REICHENAUER, T. G. WIECZOREK, K. AND SESSITSCH, A., 2014, Increased drought stress resilience of maize through endophytic colonization by *Burkholderia phytofirmans* PsJN and *Enterobacter* sp. FD17. *Environ. Exp. Bot.,* **97** : 30 - 39.

NANDAN, N. H. D., VINAY, K., SHRIDHAR, H. AND MANTESH, M., 2021, Molecular characterization and phylogenetic analysis of *Rhizoctonia solani* Kuhn. infecting Tomato. *Mysore J. Agric. Sci*., **55** (2) : 45 - 50.

PATTEN, C. L. AND GLICK, B. R., 2002, Role of *Pseudomonas putida* indoleacetic acid in development of the host plant root system. *Appl. Environ. Microbiol*., **68** (8) : 3795 - 3801.

POTTS, M., 1994, Desiccation tolerance of prokaryotes. *Microbiol. Rev.,* **58** : 755 - 805.

RAVEENDRA REDDY, M. AND SHIVAPRAKASH, M. K., 2018, Antagonistic activity of bacterial endophytes isolated from millets against *Rhizoctonia solani* in foxtail millet. *Mysore J. Agric. Sci.,* **52** (2) : 241 - 247.

RABIEY, M., HAILEY, L. E., ROY, S. R., GRENZ, K., AL-ZADJALI, M. A., BARRETT, G. A. AND JACKSON, R. W., 2019, Endophytes vs tree pathogens and pests: can they be used as biological control agents to improve tree health?. *Eur. J. Plant Pathol.,* **155** (3) : 711 - 729.

ROOPASHREE, B., 2022, Endophytes : A potent seed bio-priming agents for abiotic stress mitigation in selected crops. *Ph.D. Thesis* (Unpub.), Univ. Agric. Sci., Bangalore.

SAMBROOK, J. E. F. AND FRISTSOL MANIATIS, T., 1989, Molecular cloning - A laboratory manual, 2nd edn. *Cold Spring Harbor*, New York. pp. : 17 - 18.

SANTOYO, G., MORENO-HAGELSIEB, G., DEL CARMEN OROZCO - MOSQUEDA, M. AND GLICK, B. R., 2016, Plant growth-promoting bacterial endophytes. *Microbiol. Res.,* **183** : 92 -99.

TASMIYA IMTIYAZ AND EARANNA, N., 2021, Characterization of bacterial endophyte imparting drought tolerance in rice (*Oryza sativa* L.). *Mysore J. Agric. Sci.,* **55** (4) : 364 - 370.

ULLAH, A., SUN, H., YANG, X. AND ZHANG, X., 2017, Drought coping strategies in cotton: increased crop per drop. *Plant Biotechnol J.,* **15** : 271 - 284.

WELLINGTON, B. AND MARCELA, T. B., 2004, Delivery methods for introducing endophytic bacteria into maize. *Bio Control*, **49** : 315 - 322.

Mysore J. Agric. Sci., 57 (1) : 176-185 (2023)

Plant Growth Promoting Traits of Rhizospheric Actinobacteria

B. S. NALINI AND R. MUTTHURAJU
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : nalnibs90@gmail.com

AUTHORS CONTRIBUTION

B. S. NALINI : Conceptualization, investigation, data analysis and original draft preparation;
R. MUTTHURAJU : Supervision and draft correction

Corresponding Author :
R. MUTTHURAJU
Department of Agricultural Microbiology,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : August 2022
Accepted : January 2023

ABSTRACT

Plant growth-promoting rhizomicroflora inhabit the rhizosphere of plants, enhance plant growth with the release of metabolites and also inhibit soil-borne plant pathogens. In the present study, a total of sixty actinobacterial isolates were obtained from soil samples collected from the rhizosphere of cowpea and finger millet crop fields at the University of Agricultural Sciences, Bangalore. All the isolates were screened for their plant growth promoting activities *viz*, ammonia production, indole acetic acid (IAA), gibberellic acid (GA_3) production, HCN production and phosphate solubilization. The results showed that the actinobacterial isolates differed in the levels of plant growth-promoting activities. Screening of the isolates for plant growth promoting traits, 26 isolates produced IAA and GA_3, out of which the most active IAA and GA_3 producers were UASBA46 and UASBA50, which produced 59.26 and 61.73 $\mu g ml^{-1}$ IAA, 24.28 and 25.31 $\mu g ml^{-1}$ GA_3, respectively. UASBA46 (21.48%) and UASBA50 (22.63%) isolates showed the highest phosphate solubilization. Most of the actinobacterial isolates were positive for siderophore and ammonia production. UASBA46 and UASBA50 isolates produced the highest concentration of ACC-deaminase activity of 0.12 and 0.13mmol α-ketobutyrate mg^{-1} h^{-1}, respectively. Further, these actinobacterial isolates were identified as *Streptomyces antibioticus* (UASBA50) and *Streptomyces* sp. (UASBA46) based on 16s rRNA partial genome sequencing.

Keywords : Actinobacteria, Plant growth hormones, IAA, GA_3, ACC deaminase, 16s rRNA

PLANTS are extensively colonized by a range of beneficial microorganisms and acquire a variety of plant-microbe interactions. Some of these interactions are beneficial, whereas some are detrimental to the plant. The microorganisms grow on plants as a resource of nutrients or habitat niche. In one such symbiotic interaction, the roots of many plants are infected by specific fungi (mycorrhizal association), rhizobia and actinobacteria (particularly streptomycetes) that help the plant to acquire nutrients from the soil.

Plant growth promoting rhizobacteria (PGPR) is a group of naturally occurring, free-living rhizosphere colonizing bacteria that improve plant growth, increase yield, enhance soil fertility and reduce pathogens as well as biotic or abiotic stresses (Vessey, 2003 and Kumar *et al*., 2014). PGPR helps the plants by producing plant growth phytohormones such as indole acetic acid (IAA), cytokinins and gibberellins (Marques *et al*., 2010), solubilization of inorganic phosphate (Jeon *et al*., 2003), asymbiotic nitrogen fixation (Khan, 2005), antagonistic effect against phytopathogenic micro organisms by producing siderophore, antibiotics and fungicidal compounds (Lucy *et al*., 2004; Barriuso *et al*., 2008 and Majeed *et al*., 2015).

Actinobacteria have been and remain the most fruitful source of microorganisms for all types of bioactive metabolites, including agroactive types. Over one thousand secondary metabolites from actinobacteria were discovered during 1988-1992. Most of these compounds are produced by various species of the genus *Streptomyces*. About 60 per cent of the new insecticides and herbicides reported in the past 5 years originate from Streptomyces. It is also estimated that as many as three-quarters of all streptomycete species are capable of antibiotic production. Actinobacteria produce a variety of antibiotics with diverse chemical structures such as polyketides, b-lactams and peptides in addition to a variety of other secondary metabolites that have antifungal, anti-tumor and immunosuppressive activities.

Actinobacteria are present extensively in the plant rhizosphere and produce various agroactive compounds. In the last few years, this group of bacteria, due to its strong antimicrobial potential and soil-dominant saprophytic nature, gained much attention as plant growth promoters (PGP; Franco-Correa *et al*., 2010). Actinobacteria can actively colonize plant root systems, can degrade a wide range of biopolymers by secreting several hydrolytic enzymes and tolerate hostile conditions by forming spores (Alexander, 1977). Actinobacteria, especially *Streptomyces*, also exhibit immense biocontrol action against a range of phytopathogens (Wang *et al*., 2013). Actinobacteria can produce phytohormones (IAA) and siderophore as well as solubilize phosphate and promote plant growth (Jeon *et al*., 2003).

Cowpea and finger millet plays a very important role in providing nutritious food. Cowpea kernel contains essential amino acids, with high nutritional value food having minerals and vitamins, which are essential for good health. Their seeds contain carbohydrates (53%), crude protein (24%) and fat (2%). Besides the fruit, leaves, and flowers of cowpea are also consumed. Cowpea is also utilized as forage, hay and silage. Finger millet (*Eleusine coracana* L.) commonly known as 'nutritious millet' is the fourth most important small millet crop grown globally after sorghum, pearl millet and foxtail millet.

The main objectives of the present study are to isolate indigenous actinobacteria from the cowpea and finger millet rhizosphere, characterize these isolates based on morphological and physiological characteristics as well as by 16SrRNA gene sequence analysis, to screen actinobacteria for various plant growth promoting activities (PGPAs), such as IAA production, phosphate solubilization, siderophore production and *in-vitro* 1 - aminocyclopropane - 1 - carboxylate (ACC) deaminase activity.

Material and Methods

In-vitro screening of actinobacteria for their plant growth promoting activities.

Indole Acetic Acid (IAA) Production

The production of indole acetic acid (IAA) by actinobacteria isolates was determined as per the method outlined by Gordon and Weber (1951). Mycelial discs (8 mm) obtained from colonies grown at 28 ± 2 ºC for 5 days on YMEA (Yeast malt extract agar) were inoculated into 5 ml yeast malt extract broth containing 0.2 per cent L tryptophan, having a pH of 7.0 and the inoculated tubes were kept on shaking incubator at 125 rpm for 7 days at 28 ± 2 ºC. The culture tubes were then centrifuged at 11,000 rpm for 15 minutes. One milliliter of the supernatant was mixed with 2 ml of Salkowski reagent (one ml of 0.5 M $FeCl_3$ in 50 ml of 35% $HClO_4$) (Glickmann and Dessaux, 1995). The appearance of pink color indicated the IAA production. Optical density (OD) values were measured at 530 nm using a spectrophotometer. The amount of IAA produced was estimated against a standard curve of IAA and expressed as µg/ml of the culture filtrate.

Gibberellic Acid (GA) Production

Gibberellic acid (GA) production by the cultures was estimated as per the procedure of Paleg (1965). 25 ml of the culture filtrate was taken in a flask to which 2 ml of zinc acetate was added. After two minutes, two ml of potassium ferrocyanide was added and centrifuged at 10,000 rpm for 15 minutes. From this 5 ml of supernatant was taken and to this 5 ml of 30 per cent, HCl was added and incubated at 20 ^{0}C for 75 minutes. The blank sample was treated only with 5 ml of 30 per cent HCl and the absorbance of the sample and the blank was measured at 254 nm in a

UV-visible spectrophotometer. The amount of GA present in the extract was calculated from the standard curve and expressed as µg/ ml of the medium. The standard curve of GA was prepared by using graded concentrations of GA.

Phosphate Solubilization

Actinobacteria were purified on SCA agar and then cultivated on an NBRIP medium containing tri-calcium phosphate (TCP) as an insoluble P source. The development of a clear zone around the colony on the culture plates was taken as a zone of phosphate solubilization.

Quantitative Estimation of P

The isolates showing a zone of solubilization on Pikovaskaya's agar were further examined for their ability to release Pi from TCP in a broth medium. One ml of three days grown culture of each isolate was inoculated into 50 ml of Pikovskaya's broth. One ml of the culture supernatant was taken in a 50 ml volumetric flask to which 10 ml of chloromolybdic acid was added and mixed thoroughly. The volume was made upto three fourth with distilled water and 0.25 ml chlorostannous acid was added and the volume was made to 50 ml with distilled water and mixed thoroughly. After 15 minutes, the blue colour developed was read in a spectrophotometer at 610 nm. Simultaneously, a standard curve was prepared using various concentrations of standard KH_2PO_4 (two ppm solution). The amount of phosphorous solubilized by the isolates was calculated from the standard curve and expressed as percent Pi released from the culture filtrate.

Potassium Solubilization

Actinobacteria were purified on starch casein agar and then cultivated on Aleksandrov agar containing potassium source. The development of a clear zone around the colony on the culture plates was taken as a zone of potassium solubilization.

Quantitative Estimation of Potassium Released from Insoluble Potash-Bearing Mineral

The isolates showing K solubilization zone on Aleksandrov's agar were further examined for their ability to release K in the broth. One ml of three days old culture of each isolate was inoculated into 25 ml of Aleksandrov's broth (Hu *et al.,* 2006).

Zinc Solubilization

Zinc solubilization was checked using zinc oxide as an insoluble zinc source. Spot inoculation of the isolates was done in the center of the modified Pikovskaya's agar medium. These plates were then incubated at 37° for 48 to 72 hrs. The development of a clear zone around the colony on the culture plates was taken as a zone of zinc solubilization.

Ammonia Production

Freshly grown actinobacterial cultures will be inoculated into one ml of peptone water and incubated at 28° for 7-12 days with shaking at 120 rpm. After incubation, 0.5ml of Nessler's reagent was added to each culture tube. The development of yellow to brown color indicated a positive result for ammonia production (Cappuccino and Sherman, 2005).

Siderophore Production

Actinobacterial isolates were inoculated to chromeazurol-S medium (CAS) agar plates. Plates were incubated at 28 ± 2 ºC for seven days. The orange halo zone surrounding the colonies indicated a positive for siderophore production.

ACC Deaminase Activity

Actinobacterial isolates were screened for their ability to utilize ACC (aminocyclopropane-1-carboxylic acid) as a sole N source by using MDF (modified nitrogen free-Dworkin and Foster) medium (Jacobson *et al.,* 1994). The actinobacterial isolates were inoculated to MDF agar plates and incubated at 28 ± 2 ºC for seven days. Growth indicated the ability of the isolates to utilize ACC as the sole N source.

Quantitative Estimation of ACC Deaminase Activity

ACC deaminase activity was assayed according to the modified protocol of Honma and Shimomura (1978) and Penrose and Glick (2003) which measures the amount of α-ketobutyrate produced by the cleavage of ACC in the presence of ACC deaminase. The number of millimoles of α- ketobutyrate produced by this reaction is determined by comparing the absorbance at 540 nm of a sample to a standard curve of α- ketobutyrate ranging between 0.1 and 1.0 mmol.

Genomic DNA Isolation, PCR Amplification and Sequencing of the 16SrRNAGene

Total genomic DNA was isolated according to the alkaline lysis method. Universal Primers 27F52 AGAGTTTGATCMTGGCTCAG3 and 1492R2 TACGGYTACCTTGTTACGACTT32 were used for the PCR amplification of the 16SrRNA gene of the selected strains. Agarose gel electrophoresis (1%) was used for analyzing PCR product and the remaining mixture was purified by using a PCR Purification kit Purified PCR products were sequenced commercially by got sequenced by Chromegene Pvt. Ltd., Bengaluru, Karnataka. The obtained gene sequences were compared with others in the GenBank databases using the NCBI Nucleotide BLAST at http://blast.ncbi.nlm.nih. gov/Blast.cgi. Sequences were submitted to NCBI Gene Bank database and accession numbers were obtained.

Results and Discussion

IAA Production and Gibberellic acid by Selected Actinobacteria : Qualitative analysis of cultures supernatant of selected actinobacterial isolates revealed the production of variable amounts of IAA. Twenty-five actinobacterial isolates were observed to produce the phytohormone indole-acetic acid ranging from 23.10-61.73 µg ml^{-1}. Maximum IAA production was reported in actinobacterial isolate UASB A50 (61.73 µg ml^{-1}) and UASBA46 (59.26 µg ml^{-1}). Khamna *et al.* (2010) also reported 36 actinobacterial isolates producing IAA, from rhizosphere soils of 14 Thai medicinal plants ranging from 5.5 to 144 µg/ml. Gibberellic acid is a plant growth regulator of economic importance (Gelmi *et al.,* 2002). For instance, maximum gibberellic acid production was observed in UASB A50-25.31 µg ml^{-1}.

Table 1

Indole Acetic Acid (IAA) and Gibberellic Acid (GA) production by the actinobacterial isolates

Actinobacterial isolates	IAA production µg ml^{-1})	GA production µg ml^{-1})
UASBA1	34.95 ^{l}	18.28 ^{g}
UASBA3	46.73 ^{f}	13.28^{l}
UASBA5	20.36 ^{r}	11.27 ^{n}
UASBA7	50.79 ^{d}	21.19 ^{d}
UASBA12	48.53 ^{e}	11.49 ^{mn}
UASBA13	37.43 ^{k}	14.29 ^{k}
UASBA18	40.34 ^{i}	14.31 ^{k}
UASBA21	43.80 ^{g}	11.29 ^{n}
UASBA22	51.23 ^{d}	21.57 ^{d}
UASBA24	43.88 ^{g}	14.60 ^{jk}
UASBA26	23.10 ^{op}	13.24 ^{l}
UASBA27	48.49 ^{e}	15.27 ^{i}
UASBA28	32.57 ^{m}	11.24 ^{n}
UASBA30	43.80 ^{g}	15.33 ^{i}
UASBA31	38.78 ^{j}	14.74 ^{j}
UASBA32	52.54 ^{c}	23.32 ^{c}
UASBA34	47.98 ^{e}	16.27 ^{h}
UASBA35	41.99 ^{h}	15.33 ^{i}
UASBA36	46.68 ^{f}	11.73 ^{m}
UASBA39	37.72 ^{k}	11.76 ^{m}
UASBA46	59.26 ^{b}	24.28 ^{b}
UASBA47	21.68 ^{q}	12.96 ^{l}
UASBA50	61.73 ^{a}	25.31 ^{a}
UASB A60	24.35 ^{n}	19.99 ^{e}
UASBA62	22.62 ^{op}	18.96 ^{f}

Note: Mean values followed by the superscript in each column do not differ significantly at Pd”0.05 level by DMRT

Phosphate, Potassium and Zinc Solubilization : Screening of actinobacterial isolates for P-solubilization potential revealed that 25 actinobacterial isolates solubilized tricalcium phosphate in the medium. P-solubilization index ranged from 0.20-1.50 cm, highest P solubilization recorded with isolate UASBA50 - 1.50 cm followed by UASBA46 - 1.30 cm. The isolates which were able to solubilize phosphate on Pikovskayas's medium were further evaluated for the amount of phosphate solubilized. The amount of phosphate solubilized by

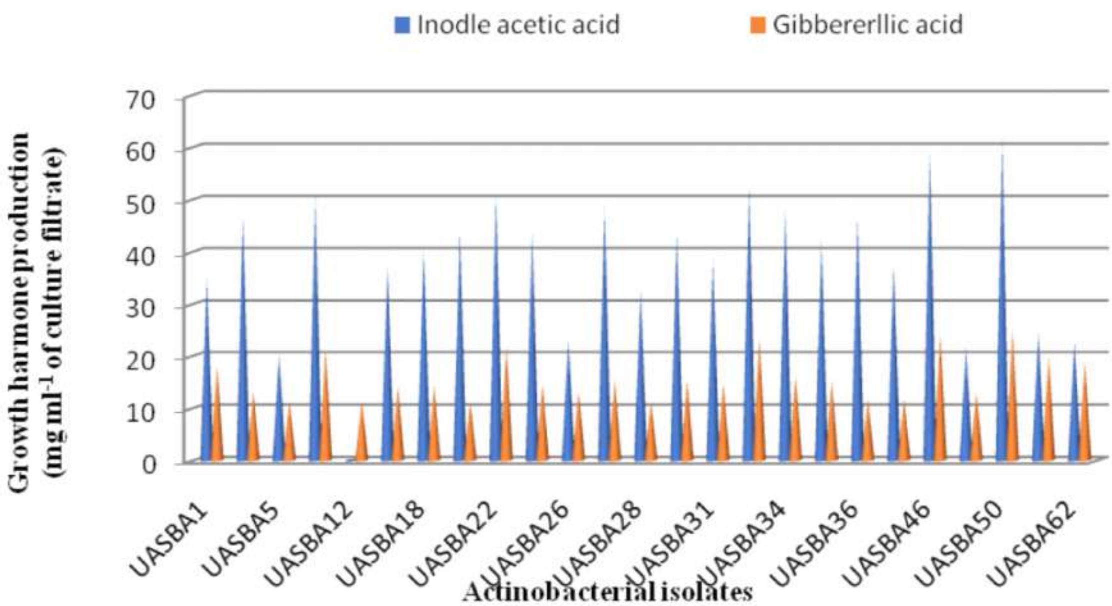


Fig.1: IAA and GA production (µg ml^{-1}) by actinobacterial isolates

actinobacterial isolates remained in the range of 6.66 to 22.63 per cent. The highest percent Pi solubilized was recorded in isolate UASB A50-22.63 per cent followed by UASB A46-21.48 per cent. Anwar *et al.* (2016) screened the phosphate solubilizing ability of actinobacterial isolates, among which six *Streptomyces* were able to solubilize phosphate. *Streptomyces* sp. WA-1 showed the highest phosphate solubilization index. The Highest K solubilization zone was observed in UASB A50 - 1.30 cm and quantitative estimation of potassium revealed actinobacterial isolate UASB A50 (6.30 µg ml^{-1}) which was isolated from cowpea rhizosphere. Archana (2007) isolated 30 K mobilizing bacterial isolates (mica as insoluble K source) from the soils of Belgaum and Dharwad districts of Karnataka and found that K mobilization by the actinobacterial isolates ranged from 2.41 µg/ml to 44.49 µg/ml. The Zn-solubilizing potential varied among these actinobacterial isolates as evidenced by the diameter of the halo or clear zone formed on Luria-Bertani agar plates. Zn-solubilization index ranged from 0.30 - 1.30 cm, maximum being recorded with isolate UASBA50 followed by UASBA46.

Ammonia, Siderophore Production and ACC Deaminase : Among twenty-five actinobacterial isolates screened for ammonia production, twenty-two

TABLE 2

Phosphate potassium and zinc solubilization efficiency of actinobacterial isolates under *in-vitro* condition

Actinobacterial isolates	Zone of solubilization (cm)	P*i* (%)at 10th day	Zone of solubilization K (cm)	Solubilization of K(µg ml^{-1})	Zone of solubilization Zn (cm)
UASBA1	0.80 ^{f}	14.21 ^{g}	0.60 ^{f}	3.60 ^{e}	-
UASBA3	0.40 ^{i}	7.53 ^{k}	0.20 ^{j}	1.00 ^{ijk}	-
UASBA5	0.40 ^{i}	6.66 ^{l}	0.20 ^{j}	0.90 ^{jkl}	-
UASBA7	1.00 ^{d}	19.48 ^{d}	0.80 ^{e}	4.30 ^{d}	0.60 ^{e}
UASBA12	0.50 ^{h}	8.32 ^{i}	0.30 ^{i}	1.20 ^{hi}	0.50 ^{f}
UASBA13	0.40 ^{i}	6.50 ^{l}	0.20 ^{j}	1.00 ^{ijk}	-

Actinobacterial isolates	Zone of solubilization (cm)	P*i* (%)at 10th day	Zone of solubilization K (cm)	Solubilization of K(µg ml^{-1})	Zone of solubilization Zn (cm)
UASBA18	0.20 ^{k}	3.90 ^{q}	0.10 ^{k}	0.80 ^{kl}	-
UASBA21	0.30 ^{j}	5.52 ^{mn}	0.10 ^{k}	0.80 ^{kl}	-
UASBA22	1.00 ^{d}	19.35 ^{d}	0.90 ^{c}	5.90 ^{bc}	0.80 ^{d}
UASBA24	0.30 ^{j}	5.67 ^{m}	0.20 ^{j}	0.80 ^{kl}	-
UASBA26	0.40 ^{i}	7.98 ^{ij}	0.30 ^{i}	1.30 ^{h}	0.40 ^{g}
UASBA27	0.80 ^{f}	14.78 ^{ef}	0.60 ^{f}	3.70 ^{e}	-
UASBA28	0.90 ^{e}	15.19 ^{e}	0.50 ^{g}	3.30 ^{fg}	0.50 ^{f}
UASBA30	0.60 ^{g}	9.62 ^{h}	0.40 ^{h}	3.10 ^{g}	-
UASBA31	0.40 ^{i}	7.69 ^{jk}	0.20 ^{j}	1.10 ^{hij}	-
UASBA32	1.20 ^{c}	21.01 ^{c}	0.90 ^{d}	5.80 ^{c}	0.90 ^{c}
UASBA34	0.30 ^{j}	5.16 ^{nop}	0.20 ^{j}	1.00 ^{ijk}	-
UASBA35	0.30 ^{j}	5.06 ^{op}	0.10 ^{k}	0.70 ^{l}	-
UASBA36	0.40 ^{i}	7.79 ^{jk}	0.30 ^{i}	1.10 ^{hij}	-
UASBA39	0.20 ^{k}	3.29 ^{r}	0.20 ^{j}	1.00 ^{ijk}	-
UASBA46	1.30 ^{b}	21.48 ^{b}	1.10 ^{b}	6.10 ^{ab}	1.20 ^{b}
UASBA47	0.20 ^{k}	3.65 ^{qr}	0.20 ^{j}	0.90 ^{jkl}	-
UASBA50	1.50 ^{a}	22.63 ^{a}	1.30 ^{a}	6.30 ^{a}	1.30 ^{a}
UASBA60	0.80 ^{f}	14.57 ^{fg}	0.60 ^{f}	3.50 ^{ef}	-
UASBA62	0.50 ^{h}	9.53 ^{h}	0.50 ^{g}	3.20 ^{g}	0.30 ^{h}

Note: Mean values followed by the same superscript in each column do not differ significantly at the Pd”0.05 level by DMRT

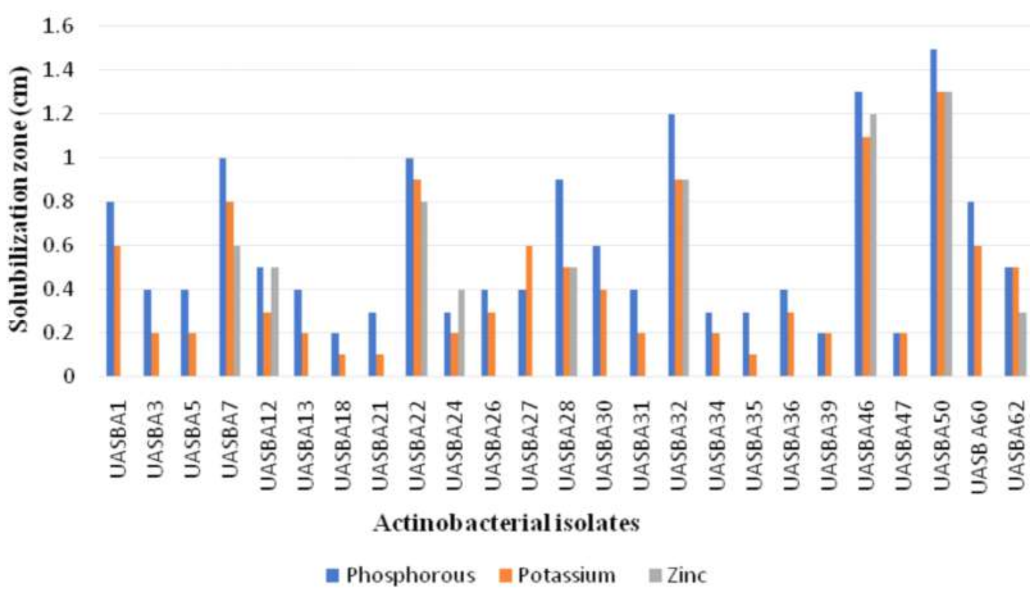


Fig.2: Solubilization of phosphorous, potassium and zinc by actinobacterial isolates (cm)

isolates were found to be ammonia producers and most of the isolates were strong producers as indicated by the intensity of the color developed. Out of 25 isolates, 6 produced distinct orange halo on chrome azurol S (CAS) plates indicating siderophore production. Prasad *et al.* (2014) isolated 116 microorganisms from the rhizospheric soil of rice from nine different locations to understand the diversity of the microorganisms. Among these microorganisms, 110 were bacterial and only 6 were actinomycetes. All 6 actinobacteria showed positive results for the production of siderophore by forming orange-yellow halo zones on the CAS agar media plate. ACC deaminase production potential of actinobacterial isolates, 3 isolates (12%) were positive for ACC deaminase activity as they had a growth on DF-ACC agar plates with ACC as the sole source of nitrogen. The ACC deaminase enzymatic activity ranged from 0.04 mmol mg^{-1} h^{-1} to 0.13mmol mg^{1} h^{-1}, indicating wide variations among the isolates. It is evident that among the 3 ACC deaminase positive actinobacterial isolates, two isolates (UASBA46 and UASBA50) recorded significantly higher ACC deaminase activity (0.12 and 0.13 mmol mg^{-1} h^{-1} respectively). Siddikee *et al.* (2010) isolated several halotolerant actinobacterial strains with ACC deaminase activity from the soil of barren fields and the rhizosphere of naturally growing halophytic plants and found that they can increase canola plant growth.

Identification of Selected Actinobacterial Strains by 16srRNA Gene Sequencing : Two promising isolates were selected based on their ability to produce phytohormone IAA, solubilization of inorganic phosphates, ACC deaminase activity, siderophore and ammonia. For selected actinobacteria, single-band PCR products were achieved with universal primers. The sequences of the 16S rRNA gene were analyzed by comparison with sequences in GenBank through Nucleotide BLAST (http://www.ncbi.nlm.nih.gov/BLAST). After comparison, strains UASBA46 showed 96.71% similarity with *Streptomyces* sp. While the strains UASBA50 showed 99 per cent similarity with *Streptomyces antibioticus.* The sequences from strains UASBA46 and UASBA50 have been deposited in the NCBI GenBank and accession numbers were obtained (Table 4). A total of 15 actinobacteria from the East Black Sea Region plateau soil were isolated by using the sucrose gradient method and different growth media. In the light of phylogenetic analysis, it was determined that out of 15 organisms, two belong to *Actinomadura*, three *Kribbella*, three *Nocardia*, six *Micromonospora* and an organism of *Microbacterium*. Elaborate the discussion by adding recent literature.

Microbes and plants are keys to the sustenance of life on the planet earth. They are the drivers of natural processes, like biogeochemical cycles, maintenance of various ecological habitats (supporting specific

TABLE 3

Ammonia, siderophore production and ACC deaminase activity by actinobacterial isolates

Actinobacterial isolates	Ammonia production	Siderophore production	ACC deaminase activity			ACC deaminase activity (mmol α-ketobutyrate mg^{-1} h^{-1})
			+N	-N	+ACC	
UASBA1	-	-	-	-	-	-
UASBA3	+	-	+	-	-	-
UASBA5	+	+	+	-	-	-
UASBA7	+	+	+	-	-	-
UASBA12	+	+	-	-	-	-
UASBA13	-	-	+	-	-	-
UASBA18	+	-	-	-	-	-

Actinobacterial isolates	Ammonia production	Siderophore production	ACC deaminase activity			ACC deaminase activity (mmol α-ketobutyrate mg^{-1} h^{-1})
			+N	-N	+ACC	
UASBA21	-	-	+	-	-	-
UASBA22	-	-	+	-	-	-
UASBA24	+	-	-	-	-	-
UASBA26	+	-	+	-	-	-
UASBA27	+	-	+	-	+	0.04
UASBA28	+	-	-	-	-	-
UASBA30	+	-	+	-	-	-
UASBA31	+	-	+	-	-	-
UASBA32	+	-	+	-	-	-
UASBA34	+	-	+	-	-	-
UASBA35	+	-	-	-	-	-
UASBA36	+	-	-	-	-	-
UASBA39	+	+	+	-	-	-
UASBA46	+	+	+	+	+	0.12
UASBA47	+	-	-	-	-	-
UASBA50	+	+	+	-	+	0.13
UASBA60	-	-	-	-	-	-
UASBA62	+	-	+	-	-	

Note: + : Positive, - : Negative

Plate 1: IAA production

Plate 2: GA solubilization

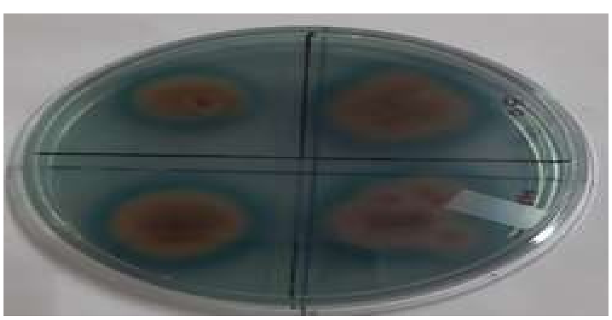


Plate 3: Siderophore production

Plate 4: Phosphate solubilization

TABLE 4
Actinobacterial isolates and their nearest match identity by 16S rRNA partial genome sequencing

Actinobacterial isolate	Closest match	NCBI number accession	Percent Identity	Accession
UASB A46	*Streptomyces* sp. strain A2 16s ribosomal RNA gene, partial sequence	MT967491	96.71%	KX641026.1
UASB A50	*Streptomyces antibioticus* strain 66 1 6s ribosomal RNA gene, partial sequence	MT967490	97.63%	MK430540.1

flora and fauna under such special niches), production of oxygen, utilization of carbon dioxide, production of organic compounds used as food, feed and medicine. These naturally thriving and beautifully maintained biosystems have come under serious threat due to deleterious consequences of rampant industrialization and unthoughtful use of a myriad of chemicals for human, animal and agricultural purposes. These problems have drawn the attention of the researchers to find the appropriate remedy. It is during such endeavors that we are learning more about various biotic and abiotic factors, which interact in a very rationale and scientific manner to balance and sustain each other. Actinobacteria and their host plants provide an exciting model to explore and understand their biology and chemistry to develop suitable, non-deleterious applications for human health, agriculture and the environment.

The study revealed that the soil rhizospheric actinobacteria are potential microbial inoculants because of the intense PGP activities such as IAA production, phosphate solubilization, siderophore and HCN production and ACC deaminase production. The strains reported in this study are promising candidates to be developed as commercial biofertilizer formulations and can also be exploited for the production of various agro-active compounds like auxin.

REFERENCES

ALEXANDER, M., 1977, *Introduction to Soil Microbiology*. 2nd Edn., Malabar, FL: Krieger Publishing Company.

ANWAR, S., ALI, B. AND SAJID, I., 2016, Screening of rhizospheric actinomycetes for various *in vitro* and *in-vivo* plant growth promoting (PGP) traits and for proactive compounds. *Front. Microbiol.,* **7** :1334-1339.

ARCHANA, D. S., 2007, Studies on potassium solubilizing bacteria, *M.Sc. (Agri.)Thesis,* Univ. Agric. Sci., Dharwad, pp. : 64.

BARRIUSO, J., RAMOS SOLANO, B. AND GUTIERREZ MANERO, F. J., 2008, Protection against pathogen and salt stress by four plant growth-promoting rhizobacteria isolated from *Pinus* sp. on *Arabidopsis thaliana*. *Biol. Control.* **98** : 666 - 672.

CAPPUCCINO, J. G. AND SHERMAN, N., 2005, In: *Microbiology: a laboratory manual*, 6th Edn. Pearson Education, Singapore.

FRANCO- CORREA, M., QUINTANA, A., DUQUE, C., SUAREZ, C., RODRIGUEZ, M. X. AND BAREA, J. M., 2010, Evaluation of actinomycete strains for key traits related with plant growth promotion and mycorrhiza helping activities. *Appl. Soil Ecol.,* **45** : 209 - 217.

GELMI, C., CORREA, R. P. AND AGOSIN, E., 2002, Modelling *Gibberella fujikuroi* growth and GA3 production in solid-state fermentation. *Process Biochem.,* **37** : 1033 - 1040.

GLICKMANN, E. AND DESSAUX, Y., 1995, A critical examination of the specificity of the salkowski reagent for indolic compounds produced by phytopathogenic bacteria. *Appl. Environ. Microbiol*., **61** : 793 - 796.

GORDON, S. A. AND WEBER, R. P., 1951, Colorimetric estimation of indole acetic acid. *Plant Physiol*., **26** : 192 - 195.

HONMA, M. AND SHIMOMURA, T., 1978, Metabolism of 1-aminocyclopropane-1- carboxylic acid. *Agric. Biol. Chem.,* **42** (10) : 1825 - 1831.

HU, X. F., CHEN, J. AND GUO, J. F., 2006, Two phosphate and potassium solubilizing bacteria isolated from Tiannu mountain, Zhejiang, China. *World J. Microbiol. Biotech.,* **22** : 983 - 990.

JACOBSON, C. B., PASTERNAK, J. J. AND GLICK, B. R., 1994, Partial purification and characterization of ACC deaminase from plant growth promoting rhizobacterium *Pseudomonas putida* GR 12-2. *Can. J. Microbiol.,* **40** : 1019 - 1025.

JEON, J. S., LEE, S. S., KIM, H. Y., AHN, T. S. AND SONG, H. G., 2003, Plant growth promotion in soil by some inoculated microorganisms. *J. Microbiol.* **41** : 271 - 276.

KHAMNA, S., YOKOTA, A., PEBERDY, J. F. AND LUMYONG, S., 2010, Indole-3- acetic acid production by *Streptomyces* spp. isolated from some Thai medicinal plant rhizosphere soils. *Eur. Asia J. Bio Sci.*, **4** : 23 - 32.

KHAN, A. G., 2005, Role of soil microbes in the rhizospheres of plants growing on trace metal contaminated soils in phytoremediation. *J. Trace Elem. Med. Biol.,* **18** : 355 - 364.

KUMAR, A., MAURYA, B. R. AND RAGHUWANSHI, R., 2014. Isolation and characterization of PGPR and their effect on growth, yield and nutrient content in wheat (*Triticum aestivum* L.). *Biocatal. Agric. Biotechnol.,* **3** : 121 - 128.

LUCY, M., REED, E. AND GLICK, B. R., 2004, Application off reliving plant-promoting rhizobacteria. *Antonie van Leeuwenhoek,* **86** : 1 - 25.

MAJEED, A., ABBASI, M. K., HAMEED, S., IMRAN, A. AND RAHIM, N., 2015, Isolation and characterization of plant growth-promoting rhizobacteria from wheat rhizosphere and their effect on plant growth promotion. *Front. Microbiol.,* **6** : 198.

MARQUES, A. P. G. C., PIRES, C., MOREIRA, H., RANGEL, A. O. S. S. AND CASTRO, P. M. L., 2010, Assessment of the plant growth promotion abilities of six bacterial isolates using *Zea mays* as indicator plant. *Soil Biol. Biochem.,* **42** : 1229 - 1235.

PALEG, L. G., 1965, Physiological effects of gibberellins. *Ann. Rev. Plant Physiol.,* **16** : 291 - 322.

PENROSE, D. M. AND GLICK, B. R., 2003, Methods for isolating and characterizing ACC deaminase containing plant growth promoting rhizobacteria. *Physiol. Plant,* **118** (1) : 10 - 15.

PRASAD, M. P. AND SINGH, R., 2014, Isolation and screening of rice rhizosphere soil microorganisms for the production of IAA. *Int. J. Curr. Microbiol. Appl. Sci.,* **3** : 993 - 998.

SIDDIKEE, M. A., CHAUHAN, P. S., ANANDHAM, R., HAN, G. H. AND SA, T., 2010, Isolation, characterization and use for plant growth-promotion under salt stress of ACC deaminase-producing halotolerant bacteria derived from coastal soil. *J. Microbiol. Biotechnol.,* **20** : 1577 - 1584.

VESSEY, J. K., 2003, Plant growth promoting rhizobacteria as biofertilizers. *Plant Soil,* **2** : 571 - 586.

WANG, X. J., ZHANG, J., WANG, J. D., QIAN, P. T., LIU, C. X. AND XIANG, W. S., 2013, Novel cyclopentenone derivatives produced by a rare actinobacterial strain *Actinoalloteichus nanshanensis* sp. nov. NEAU119. *Nat. Prod. Res.,* **27** : 1863 - 1869.

Mysore J. Agric. Sci., 57 (1) : 186-196 (2023)

Induction of Embryogenesis in Anthers of *Capsicum annuum* var. Arka Meghana

Ninitha Vijayan[1], Swapna Alex[2], K. B. Soni[3], K. P. Sindura[4], S. Sarada[5] and Manjushri Dinkar Dongare[6]

[1,2,3,4,&6]Department of Plant Biotechnology, Kerala Agricultural University, College of Agriculture, Vellayani Thiruvananthapuram, Kerala - 695 522 & [5]Department of Vegetable Science, KAU

e-Mail : swapna.alex@kau.in

Authors Contribution

Ninitha Vijayan : Investigation & manuscript preparation;

Swapna Alex : Supervision;

K. B. Soni, K. P. Sindura & S. Sarada : Interpretation & data analysis;

Manjushri Dinkar Dongare : Manuscript preparation

***Corresponding Author* :**
Swapna Alex
Dept. of Plant Bio. Tech., Kerala Agricultural University, CoA, Vellayani Thiruvananthapuram,Kerala

Received : October 2022

Accepted : February 2023

Abstract

Arka Meghana is a high yielding hybrid variety of chilli suitable for cultivation in South India and is tolerant to powdery mildew and chilli mosaic disease. The present study is the first report on successful embryogenic induction during anther culture of Arka Meghana. The suitable stage for culture establishment was buds collected at six and nine days after bud initiation. Sterilization with 70 per cent ethanol for 30 seconds followed by 4 per cent sodium hypochlorite for 15 minutes was optimum for establishing aseptic cultures. The best growth regulator combinations for indirect embryogenesis and direct embryogenesis were MS + 4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25 per cent activated charcoal + 10 mgL^{-1} $AgNO_3$ and MS + 4.00 mgL^{-1} NAA + 0.50 mgL^{-1} BA + 0.25 per cent activated charcoal + 15 mgL^{-1} $AgNO_3$ respectively at culture conditions of 35°C initial incubation temperature for two days in darkness followed by incubation at 25°C with 12 hour photoperiod.

Keyword : Anther culture, Arka meghana, Callogenesis, Embryogenesis, Incubation conditions

Chilli (*Capsicum annuum* L.) is an important horticultural crop which belongs to the family Solanaceae. Chilli is consumed all around the world and is a source of a wide number of phytochemicals, minerals, dietary fiber and vitamins like vitamin C and A *i.e.,* beta-carotene and other carotenoid pigments like lycopene and zeaxanthin, which have anticancer properties (Anilkumar & Rao, 2018 and Olatunji & Afolayan, 2018). The active compound, capsaicin, responsible for the pungency of chilli is also proved to have medicinal uses.

Chilli possesses a high susceptibility to fungal and viral pathogens which constricts the production in a huge way to meet the current demand. The development of pure homozygous plant material is a significant step in the development of high yielding hybrids. Conventional breeding methods are tedious and will take 5-6 generations of continuous selfing for homozygous production. Moreover, the pure lines produced by conventional breeding need not be 100 per cent homozygous (Germana, 2006).

Doubled haploid production can introduce homozygosity in a single generation. Doubled haploids can be produced in a single generation by chromosome doubling of haploid plants by colchicine treatment. Haploids can be induced in plants using a variety of techniques like wide species hybridization and chromosome elimination, androgenesis, gynogenesis *etc.* (Forster *et al.,* 2007). Haploid induction through *in vitro* techniques can accelerate the plant breeding studies and plays an important role in the development of new cultivars and early release of varieties (Mityko & Fari, 1997 and Kele *et al.,* 2015). But there are many factors influencing *in vitro* haploid induction and subsequent production of plantlets like genotype, developmental stage of gametes, pre-treatment, physical environmental factors (temperature, humidity, dark and light period) and the composition of the culture medium (Touraev *et al.,* 1996 and Debina *et al.,* 2016). Hence, a standard protocol is required for large-scale haploid production in crop plants.

Arka Meghana is a high yielding hybrid variety of chilli suitable for cultivation in South India. It is tolerant to powdery mildew and chilli mosaic disease. A successful protocol for haploid production in Arka Meghana is not yet established. Hence the present study was undertaken with the objective to induce embryogenesis in *Capsicum annuum var.* Arka Meghana by anther culture.

Material and Methods

Standardization of Microspore Stage Suitable for Androgenesis

F1 hybrid seeds of Arka Meghana were procured from IIHR, Bangalore. The seeds were germinated in protrays filled with 1:1 mixture of soil and composted coir pith. Two week old seedlings were transplanted into pots of 30 cm diameter and 45 cm height filled with potting mixture consisting of vermicompost, cow dung manure and soil in 1:1:1 ratio. The pots were maintained in open field conditions.

Buds of different stages were collected at three day intervals from Arka Meghana plants grown in open condition and anthers isolated from these buds were used as explants. Determination of the stage of microspores was carried out by aceto-orcein staining (1%) (Fig.1). The number of microspores at the late uninucleate stage and early binucleate stage per hundred microspores were counted and the percentage was calculated for each stage of bud (Table 1).

Surface Sterilization of Flower Buds

The buds were treated with 70 per cent ethanol followed by 4 per cent sodium hypochlorite for different time intervals. The treated buds were washed with autoclaved double distilled water three times, five minutes each.

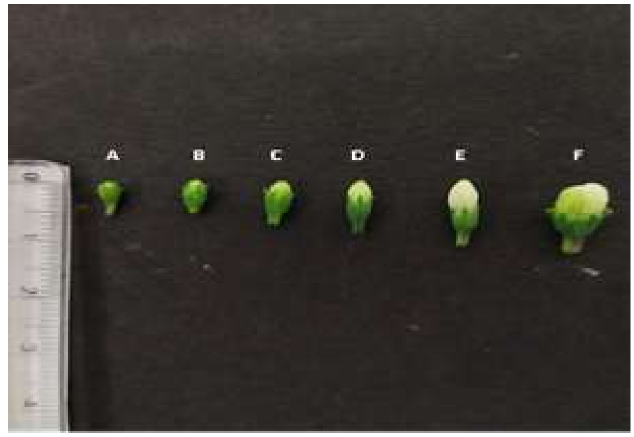


Fig. 1 : Flower buds of Arka Meghana collected at three day intervals after bud initiation: (A) Three days after bud initiation (B) Six days after bud initiation (C) Nine days after bud initiation (D) Twelve days after bud initiation (E) Fifteen days after bud initiation (F) Eighteen days after bud initiation

Table 1

Percentage of uninucleate and binucleate microspores in different stages of bud

Stage of bud	Late uninucleate microspore (%)	Early binucleate microspore (%)
3 days after bud initiation	5	0
6 days after bud initiation	57	34
9 days after bud initiation	21	49
12 days after bud initiation	7	12
15 days after bud initiation	0	6
18 days after bud initiation	0	0

Inoculation

The flower buds after surface sterilization were transferred to autoclaved petri plates and blotted with sterile blotting paper. Sterile forceps were used to remove the sepals from the bud and open the petals. Care was taken to remove the filament from the anthers.

The anthers were placed onto the media with their concave face touching the medium. The anthers (maximum of four) from the same buds were cultured in a petri plate. Anthers were inoculated onto nine media combinations *viz.,* full strength MS [Murashige and Skoog (1962)] medium and CP [De Vaulx- (1981)] media with different concentrations of plant growth

TABLE 2

Composition of media used for the study

Treatment	Basal Medium	Supplements	Reference
T_1	MS	0.10 mgL^{-1} kinetin + 0.004 mgL^{-1} 2,4-D	Irikova and Rodeva (2004)
T_2	MS	2.00 mgL^{-1} IAA + 0.30 mgL^{-1} BA	Gonzalez -Garcia (2002)
T_3	MS	4.00 mgL^{-1} NAA + 1.00 mgL^{-1} BA + 0.25% Activated charcoal	Ciner and Tipirdamaz (2002)
T_4	MS	4.00 mgL^{-1} NAA + 1.00 mgL^{-1} BA	Comlekcioglu and Ellialtioglu (2018)
T_5	MS	4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% Activated charcoal + 10mgL^{-1} $AgNO_3$	Comlekcioglu and Ellialtioglu (2018)
T_6	MS	4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% Activated charcoal + 15mgL^{-1} $AgNO_3$	Buyukalaca *et al.* (2004)
T_7	MS	4.00 mgL^{-1} NAA + 0.50 mgL^{-1} BA+ 0.25% Activated charcoal + 15 mgL^{-1} $AgNO_3$	Keles *et al.* (2015)
T_8	CP	2.00 mgL^{-1} Kinetin + 0.10 mgL^{-1} 2,4-D	Irikova *et al.* (2011)
T_9	CP	0.01 mgL^{-1} Kinetin + 0.01 mgL^{-1} 2,4-D	De Vaulx *et al.* (1981)

regulators such as kinetin, BA, NAA, IAA and 2, 4-D along with silver nitrate and activated charcoal as additives (T_1 - T_9) under varying culture conditions (Table 2).

Incubation

The anthers inoculated in MS media (T_1-T_7) were retained in the same media for regeneration. Anthers inoculated in CP medium (T_8 and T_9) were transferred after 12 days to CP medium supplemented with 0.01 mgL^{-1} kinetin for regeneration. Culture conditions are detailed in Table 3. The cultures were initially incubated at 25°C for 2/8 days in nine media combinations. The six media combinations that showed good response were tried in initial incubation condition of 35°C for 2 days also. After initial incubation, all the cultures were transferred to the culture room at 25 ± 2 °C with 12 hours light photoperiod.

TABLE 3

Incubation conditions

Incubation Temperature	Days in Darkness
25°C	2
25°C	8
35°C	2

RESULTS AND DISCUSSION

Standardisation of Microspore Stage Suitable for Androgenesis

The flower buds collected at six days after bud initiation had 57 per cent late uninucleate and 34 per cent early binucleate microspores whereas, the flower buds collected at nine days after bud initiation had 21 per cent late uninucleate and 49 per cent early binucleate microspores. The buds collected at six and nine days after bud initiation were observed to be most suitable for anther culture in our study. This was in accordance with the results obtained by Supena *et al.* (2006) in Indonesian hot chilli genotypes and Lantos *et al.* (2009) in Hungarian and Spanish chilli genotypes.

It is essential to correlate the microspore stage with the size and morphology of the flower buds for ease of explant collection. Morphological observation of the flower buds collected at six days after bud initiation, had most of the microspores in the late uninucleate stage with an almost uniform length of calyx and corolla. Similar results are reported by Buyukalaca *et al.* (2004) in U-247 and U-238 genotypes of *Capsicum annuum* L. and Nowaczyk *et al.* (2014) in hybrids of cross between *Capsicum frutescens* L. and *Capsicum annuum* L. The flower buds collected at nine days after bud initiation had the corolla slightly longer than the calyx and the majority of the microspores in the early binucleate stage. Ciner and Tipirdamaz (2002) in Malatya genotype of chilli observed that, buds with petals slightly longer than sepals had most of the microspores in the uninucleate stage while Testillano *et al.* (1995) by immunolocalization and cytological studies reported that in American variety of *Capsicum annuum* L., the buds with petals slightly longer than sepals had a majority of microspores in the early binucleate stage. Microspore stage and corresponding morphology of flower buds in *Capsicum annuum* appears to be genotype dependent and need to be verified for each genotype in anther culture.

Surface Sterilization of Flower Bud

Standardisation of optimum surface sterilization of flower buds of Arka Meghana grown in pots under open condition was carried out by treating the buds with 70 per cent ethanol followed by 4 per cent sodium hypochlorite for different time intervals as given in Table 4. Treatment of the buds with 70 per cent ethanol for 30 seconds followed by 4 per cent sodium hypochlorite for 15 minutes gave the highest percentage of uncontaminated culture without browning. Ciner and Tipirdamaz (2002), Rodeva *et al.* (2004), Supena *et al.* (2006), Lantos *et al.* (2011) and Barroso *et al.* (2015) have also reported the use of sodium hypochlorite for effective surface sterilization of buds for anther culture.

TABLE 4

Response of anthers to different surface sterilization treatments

Treatment	70% ethanol (seconds)	4% sodium hypochlorite (minutes)	Uncontaminated culture (%)
T_1	30	10	77.28
T_2	30	12	88.00
T_3	30	15	96.25
T_4	45	10	82.20
T_5	45	12	90.00
T_6	45	15	98.53 *

*Browning of anthers observed

Anther Culture

On incubation at 25 °C with initial darkness for two days, callogenesis (3.17%) was observed only in one treatment with MS medium *viz.,* T_5 (MS + 4.00 mg L^{-1} NAA + 0.10 mgL^{-1} BA + 0.25 per cent activated charcoal + 10 mgL^{-1} $AgNO_3$)at sixth week of inoculation (Table 5). All the treatments incubated

Fig. 2 : Callogenesis in anthers six weeks after inoculation at 25°C incubation temperature and eight days darkness: (A) T_1 (MS medium + 0.10 mgL^{-1} Kinetin + 0.004 mg L^{-1} 2,4-D) (B) T_2 (MS medium + 2.00 mgL^{-1} IAA + 0.30 mgL^{-1} BA) (C) T_3 (MS medium + 4.00 mgL^{-1} NAA + 1.00 mgL^{-1} BA + 0.25% activated charcoal) (D) T_4 (MS medium + 4.00 mgL^{-1} NAA + 1.00 mgL^{-1}BA) (E) T_5 (MS medium + 4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 10mg L^{-1} $AgNO_3$) (F) T_6 (MS media + 4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 15mg$L^{-1}$$AgNO_3$) (G) T_7 (MS media + 4.00 mgL^{-1} NAA + 0.50 mgL^{-1} BA + 0.25% activated charcoal + 15 mg$L^{-1}$$AgNO_3$) (H) T_8 (CP Media + 2.00 mgL^{-1} Kinetin + 0.10 mgL^{-1} 2,4-D) (I) T_9 (CP Media + 0.01 mgL^{-1} Kinetin + 0.01 mgL^{-1} 2,4-D)

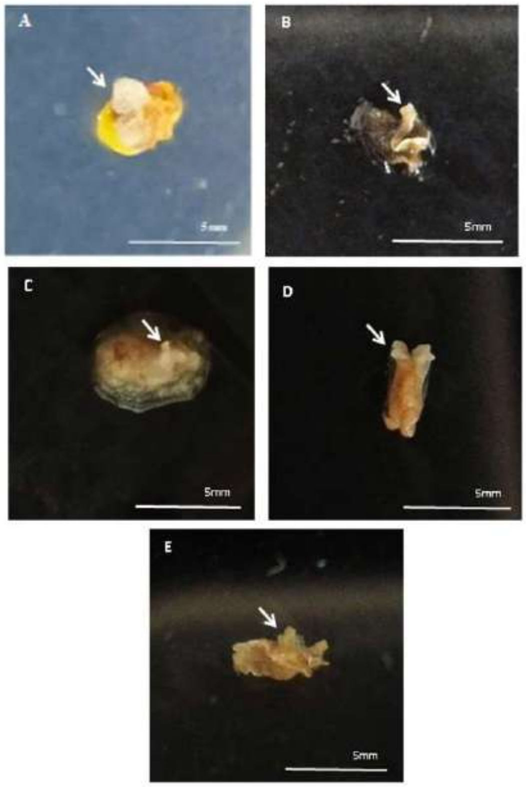


Fig. 3 : Direct embryogenesis from anthers of *Capsicum annuum* var. Arka Meghana (A) Globular embryo in T_1 (MS media + 0.10 mgL^{-1} Kinetin + 0.004 mgL^{-1} 2,4-D) incubated at 25°C and eight days darkness (B) Embryo in T_5(MS media + 4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 10mgL^{-1} $AgNO_3$) incubated at 35°C and two days darkness (C) Heart shaped embryo in T_6 (MS media + 4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 15$mgL^{-1}$$AgNO_3$) incubated at 35°C and two days darkness (D) Heart shaped embryos in T_7 (MS media + 4.00 mgL^{-1} NAA + 0.50 mgL^{-1} BA+ 0.25% activated charcoal + 15 $mgL^{-1}$$AgNO_3$) incubated at 35°C and two days darkness (E) Embryo in T_7(MS media + 4.00 mgL^{-1} NAA + 0.50 mgL^{-1} BA+ 0.25% activated charcoal + 15 mgL^{-1} $AgNO_3$) incubated at 35°C and two days darkness (Bar = 5mm)

at 25 °C for eight days in darkness showed a response at sixth week of inoculation with callogenesis varying from 3.75 to 15.38 per cent. (Fig.2). Among the nine treatments, the highest callogenesis of 15.38 per cent was observed in the treatment T_5 at the sixth week of inoculation (Table 6). Embryogenesis (1.25%) was observed in the treatment T_4 (MS + 4.00 mgL^{-1} NAA + 1.00 mgL^{-1} BA) at sixth week of inoculation (Fig.3).

All the treatments with initial incubation at 35 °C in two days darkness showed callogenesis at the second week of inoculation with responses varying from 4 to 15.54 per cent. Callogenesis varying from 10.66 to 34.48 per cent and embryonic calli induction varying from 3.17 to 17.24 per cent was observed in the fourth week of inoculation (Fig.4). At the sixth week of inoculation callogenesis varied from 11.11 to 37.93 per cent and embryonic callus induction varied from 3.17 to 19.54 per cent. Among the treatments, the maximum callogenesis of 37.93 per cent and embryonic calli induction of 19.54 per cent was observed in the treatment T_5 at sixth week of inoculation (Table 7).

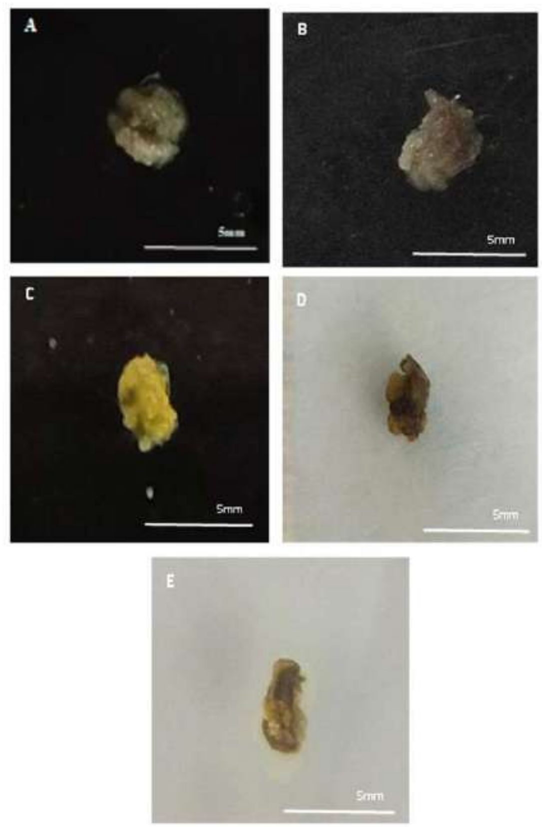


Fig. 4 : Embryonic calli induced from anther culture at 35°C incubation temperature and two days darkness (A) T_5 (MS media + 4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 10mgL^{-1} $AgNO_3$ (B) T_5 (MS media + 4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 10mgL^{-1} $AgNO_3$) (C) T_5 (MS media + 4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 10mgL^{-1} $AgNO_3$) (D) T_4 (MS media + 4.00 mgL^{-1} NAA + 1.00mgL^{-1} BA) (E) T_8 (CP medium +2.00 mg L^{-1} Kinetin + 0.10 mgL^{-1} 2,4-D) (Bar = 5mm)

TABLE 5

Response of anthers to different media combinations at 25 °C incubation temperature and two days darkness

Treatment	Basal medium	Supplements	Reference	Number of anthers inoculated	Callogenesis/ Embryogenesis (%)								
					2nd week			4th week			6th week		
					C	EC	E	C	EC	E	C	EC	E
T_1	MS	0.10 mgL^{-1} Kinetin + 0.004 mgL^{-1} 2,4-D	Irikova and Rodeva (2004)	50	0	0	0	0	0	0	0	0	0
T_2	MS	2.00 mgL^{-1} IAA + 0.30 mgL^{-1} BA	Gonzalez -Garcia (2002)	52	0	0	0	0	0	0	0	0	0
T_3	MS	4.00 mgL^{-1} NAA + 1.00 mgL^{-1} BA + 0.25% activated charcoal	Ciner and Tipirdamaz (2002)	51	0	0	0	0	0	0	0	0	0
T_4	MS	4.00 mgL^{-1} NAA + 1.00 mgL^{-1} BA	Comlekcioglu and Ellialtioglu (2018)	56	0	0	0	0	0	0	0	0	0
T_5	MS	4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 10mgL^{-1} $AgNO_3$	Comlekcioglu and Ellialtioglu (2018)	63	0	0	0	0	0	0	3.17	0	0
T_6	MS	4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 15mgL^{-1} $AgNO_3$	Buyukalaca *et al*. (2004)	55	0	0	0	0	0	0	0	0	0
T_7	MS	4.00 mgL^{-1} NAA + 0.50 mgL^{-1} BA+ 0.25% activated charcoal + 15 mgL^{-1} $AgNO_3$	Keles *et al*. (2015)	53	0	0	0	0	0	0	0	0	0
T_8	CP	2.00 mgL^{-1} Kinetin + 0.10 mgL^{-1} 2,4-D	Irikova *et al*. (2011)	57	0	0	0	0	0	0	0	0	0
T_9	CP	0.01 mgL^{-1} Kinetin + 0.01 mgL^{-1} 2,4-D	De Vaulx *et al*. (1981)	51	0	0	0	0	0	0	0	0	0

*C = Callus; EC = Embryogenic callus; E = Embryo

TABLE 6

Response of anthers to different media combinations at 25°C incubation temperature and eight days darkness

Treatment	Basal medium	Supplements	Reference	Number of anthers inoculated	Callogenesis/ Embryogenesis (%)								
					2nd week			4th week			6th week		
					C	EC	E	C	EC	E	C	EC	E
T_1	MS	0.10 mgL^{-1} Kinetin + 0.004 mgL^{-1} 2,4-D	Irikova and Rodeva (2004)	74	0	0	0	0	0	0	5.40	0	0
T_2	MS	2.00 mgL^{-1} IAA + 0.30 mgL^{-1} BA	Gonzalez -Garcia (2002)	70	0	0	0	0	0	0	4.28	0	0
T_3	MS	4.00 mgL^{-1} NAA + 1.00 mgL^{-1} BA + 0.25% activated charcoal	Ciner and Tipirdamaz (2002)	66	0	0	0	1.51	0	0	4.54	0	0
T_4	MS	4.00 mgL^{-1} NAA + 1.00 mgL^{-1} BA	Comlekcioglu and Ellialtioglu (2018)	80	0	0	0	0	0	0	3.75	0	1.25
T_5	MS	4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 10mgL^{-1}$AgNO_3$	Comlekcioglu and Ellialtioglu (2018)	65	0	0	0	3.07	0	0	15.38	0	0
T_6	MS	4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 15mgL^{-1}$AgNO_3$	Buyukalaca *et al.* (2004)	58	0	0	0	0	0	0	8.62	0	0
T_7	MS	4.00 mgL^{-1} NAA + 0.50 mgL^{-1} BA+ 0.25% activated charcoal + 15 mgL^{-1}$AgNO_3$	Keles *et al.*(2015)	81	0	0	0	2.46	0	0	8.64	0	0
T_8	CP	2.00 mgL^{-1} Kinetin + 0.10 mgL^{-1} 2,4-D	Irikova *et al.* (2011)	59	0	0	0	1.69	0	0	6.78	0	0
T_9	CP	0.01 mgL^{-1} Kinetin + 0.01 mgL^{-1} 2,4-D	De Vaulx *et al.* (1981)	54	0	0	0	1.85	0	0	7.40	0	0

*C = Callus; EC = Embryogenic callus; E = Embryo

TABLE 7

Response of anthers to different media combinations at 35°C incubation temperature and two days darkness

Treatment	Basal medium	Supplements	Reference	Number of anthers inoculated	Callogenesis/ Embryogenesis (%)								
					2nd week			4th week			6th week		
					C	EC	E	C	EC	E	C	EC	E
T_4	MS	4.00 mgL^{-1} NAA + 1.00 mgL^{-1}BA	Comlekcioglu and Ellialtioglu (2018)	63	4.76	0	0	11.11	3.17	0	11.11	3.17	0
T_5	MS	4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 10$mgL^{-1}AgNO_3$	Comlekcioglu and Ellialtioglu (2018)	87	13.79	0	0	34.48	17.24	0	37.93	19.54	1.15
T_6	MS	4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 15$mgL^{-1}AgNO_3$	Buyukalaca *et al*. (2004)	75	4.00	0	0	10.66	0	1.33	13.33	0	1.33
T_7	MS	4.00 mgL^{-1} NAA + 0.50 mgL^{-1} BA+ 0.25% activated charcoal + 15 $mgL^{-1}AgNO_3$	Keles *et al*. (2015)	110	15.54	0	0	31.81	0	1.82	33.63	0	2.72
T_8	CP	2.00 mgL^{-1} Kinetin + 0.10 mgL^{-1} 2,4-D	Irikova *et al*. (2011)	72	12.50	0	0	26.38	6.94	0	26.38	9.72	0
T_9	CP	0.01 mgL^{-1} Kinetin + 0.01 mgL^{-1} 2,4-D	De Vaulx *et al*. (1981)	103	6.79	0	0	12.62	0	0	13.59	0	0

*C = Callus; EC = Embryogenic callus; E = Embryo

Embryogenesis of 1.33 and 1.82 per cent were observed in the treatments T_6 (MS + 4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25% activated charcoal + 15mg L^{-1} $AgNO_3$) and T_7 (MS + 4.00 mgL^{-1} NAA + 0.50 mgL^{-1} BA+ 0.25% activated charcoal + 15 mgL^{-1} $AgNO_3$) respectively at fourth week of inoculation. At sixth week of inoculation, treatment T_5 exhibited 1.15 per cent embryogenesis whereas T_7 exhibited 2.72 per cent embryogenesis.

Among the different hormones tried, embryogenesis was observed only in media supplemented with NAA and BA. The results are in accordance with the reports by Ciner and Tipirdamaz (2002), where a combination of NAA and BA in the MS medium induced embryogenesis in Malatya genotype of chilli. Cheng *et al.* (2013) and Phuong (2021) also reported the significant influence of NAA and BA on embryogenesis in Chinese chilli genotypes and Vietnam local chilli varieties respectively.

The treatments T_6 and T_7 varied only in the concentration of BA. T_6 recorded 1.33 per cent of embryogenesis whereas T_7 recorded 2.72 per cent embryogenesis. Thus, increased concentration of BA exhibited comparatively better embryogenesis in Arka Meghana variety of chilli. This result is concordant to the report by Kele *et al.* (2015) in Charleston, Bell, Capia and Green genotypes of chilli. However, Buyukalaca *et al.* (2004) in U-247 and U- 238 genotypes of chilli and Ozsan and Onus (2017) in Benino, Kanyon, Belissa and Filinta cultivars of chilli have reported better embryogenesis in the medium with a lower concentration of BA.

The influence of silver nitrate on embryo induction in Arka Meghana was dependent on culture condition. Percentage of embryo induction in the presence of silver nitrate was better in T_6 compared to T_5. Increased concentration of silver nitrate exhibited a better response. Similar results are reported by Nervo *et al.* (1995), Buyukalaca *et al.* (2004) and Keles *et al*. (2015) in *Capsicum annuum* L.

Initial incubation at 35 °C in darkness for two days exhibited better response to embryonic calli induction and embryogenesis compared to incubation at 25 °C for two and eight days darkness. Incubation temperature of 25 °C exhibited only 1.25 per cent direct embryogenesis and no indirect embryogenesis was observed. According to Morrison *et al.* (1986) and Rajakaruna *et al.* (2018), initial incubation at 35 °C was better for embryo initiation than incubation temperature of 25 °C. Buyukalaca *et al.* (2004), Keles *et al.* (2015) and Atasoy *et al.* (2021) have also reported embryogenesis in anthers of *Capsicum annuum* L. inoculated at 35 °C and one or two days in darkness.

To conclude, among the treatments tried in *Capsicum annuum var.* Arka Meghana the best treatment for indirect embryogenesis and direct embryogenesis was MS + 4.00 mgL^{-1} NAA + 0.10 mgL^{-1} BA + 0.25 per cent activated charcoal + 10 mgL^{-1} $AgNO_3$ (T_5) and MS + 4.00 mgL^{-1} NAA + 0.50 mgL^{-1} BA + 0.25 per cent activated charcoal + 15 mgL^{-1} $AgNO_3$ (T_7) respectively at culture conditions of 35 °C initial incubation temperature for two days darkness followed by incubation at 25 °C with 12 hour photoperiod. The most suitable initial incubation condition was determined to be 35 °C initial incubation temperature in two days darkness. It was observed that the hormonal combination of NAA and BA was better suited for embryogenesis and the increased concentration of silver nitrate in the medium supplemented the embryogenic potential. The embryos induced could be further used for regeneration of haploid plantlets of Arka Meghana for doubled haploid production and crop improvement.

Acknowledgements : The facilities provided by Kerala Agricultural University for the conduct of the work is gratefully acknowledged.

References

Anilkumar, C. and Rao, A. M., 2018, Genetics of fruiting habit traits in chilli (*Capsicum annuum* L.). *Mysore J. Agric. Sci.,* **52** (2) : 293 - 299.

Atasoy, D., Baktemur, G. and Taokin, H., 2021, Bazy biber (*Capsicum annuum* L.) Geno tiplerininanter kulturu perform anslarynynbelirlen mesi. Yuzuncu Yýl Universites Tarým Bilimleri Dergisi, **31** (2) : 282 - 293.

Barroso, P. A., Rego, M. M., Rego, E. R. and Soares, W. S., 2015, Embryogenesis in the anthers of different ornamental pepper (*Capsicum annuum* L.) genotypes. *Genet. Mol. Res.,* **14** (4) : 13349 - 13363.

Buyukalaca, S., Comlekcioglu, N., Abak, K., Ekbic, E. and Kilic, N., 2004, Effects of silver nitrate and donor plant growing conditions on production of pepper (*Capsicum annuum* L.) haploid embryos *via* anther culture. *Europ. J. Hort. Sci.,* **69** (5) : 206 - 209.

Cheng, Y., Ma, R. L., Jiao, Y. S., Qiao, N. and Li, T. T., 2013, Impact of genotype, plant growth regulators and activated charcoal on embryogenesis induction in microspore culture of pepper (*Capsicum annuum* L.). *S. Afr. J. Bot.,* **88** : 306 - 309.

Ciner, D. O. and Tipirdamaz, R., 2002, The effects of cold treatment and charcoal on the *in vitro* andro genesis of pepper (*Capsicum annuum* L.). *Turk. J. Bot.,* **26** (3) : 131 - 139.

Comlekcioglu, N. and Ellialtioglu, S. S., 2018, Review on the research carried out on *in vitro* androgenesis of peppers (*Capsicum annuum* L.) in Turkey. *Res. J. Biotechnol.*, **13** (6) : 75 - 84.

De Vaulx, R. D., Chambonnet, D. and Pochard, E., 1981, Culture *in vitro* d antheres de piment (*Capsicum annum* L.) : amelioration des taux d obtention de plantes chez different genotypes par des traitements a^{+}35 °C. *Agron.,* **1** (10) : 859 - 864.

Debina, S., Udayakumar, M., Shivakumar, N., Sheshshayee, M. S. and Raju, B. M., 2016, Anther derived haploid production in rice and identification of true haploids by markers and flow cytometry. *Mysore J. Agric. Sci.,* **50** (2) : 305 - 308.

Forster, B. P., Heberle, B. E., Kasha, K. J. and Touraev, A., 2007, The resurgence of haploids in higher plants. *Trends Plant Sci.,* **12 (8)** : 368 - 375.

Germana, M. A., 2006, Doubled haploid production in fruit crops, *Plant Cell Tissue Organ Cult.,* **86** : 131 - 146.

Gonzalez-Garcia, J., 2002, Plant induction by anther culture of jalapeno pepper (*Capsicum annuum* L.). *Yeast Genet. Mol. Biol.*, **93** (9) : 15 - 21.

Irikova, T. and Rodeva, V., 2004, Anther culture of pepper (*Capsicum annuum* L.): the effect of nutrient media. *Capsicum and Eggplant News letter*, **23** : 101 - 104.

Irikova, T., Grozeva, S. and Rodeva, V., 2011, Anther culture in pepper (*Capsicum annuum* L.) *in vitro*. *Acta Physiol. Plant,* **33** : 1559 - 1570.

Kele, D., Pinar, H., Ata, A., Taskin, H., Yildiz, S. and Buyukalaca, S., 2015, Effect of pepper types on obtaining spontaneous doubled haploid plants *via* anther culture. *Hort. Sci.,* **50** (11) : 1671 - 1676.

Lantos, C., Juhasz, A. G., Vagi, P., Mihaly, R., Kristof, Z. and Pauk, J., 2011, Androgenesis induction in microspore culture of sweet pepper (*Capsicum annuum* L.). *Plant Biotechnol. Rep.,* **6** (2) : 123 - 132.

Lantos, C., Juhasz, A., Somogyi, G., Otvos, K., Vagi, P., Mihaly, R. Z., Kristof, Z., Somogyi, N. and Pauk, J., 2009, Improvement of isolated microspore culture of pepper (*Capsicum annuum* L.) *via* co-culture with ovary tissues of pepper or wheat. *Plant Cell Tissue Organ Cult.,* **97** : 285 - 293.

Mityko, J. and Fari, M., 1997, Problems and results of doubled haploid plant production in pepper (*capsicum annuum* L.) *via* anther and microspore culture. *Acta Hortic.,* **447** : 281 - 288.

Morrison, R. A., Koning, R. E. and Evans, D. A., 1986, Anther culture of an interspecific hybrid of capsicum. *J. Plant Physiol.,* **126** (1) : 1 - 9.

Murashige, T. and Skoog, F., 1962, A revised medium lor the rapid growth and bioassay with tobacco tissue cultures. *Physiol. Plant,* **15** : 73 - 497.

Nervo, G., Carannante, G., Azzimonti, M. T. and Rotino, G. L., 1995, Use of anther culture method in pepper breeding: factors affecting plantlets production. *Curr. Plant Sci. Biotechnol. Agric.,* **22** : 155 - 160.

Nowaczyk, L., Banach-Szott, M., Olszewska, D. and Nowaczyk, P., 2014, Androgenic response of Capsicum interspecific hybrids and capsaicinoid characteristics of DH lines. *Herba Pol.,* **60** (4) : 50 - 59.

OLATUNJI, T. L. AND AFOLAYAN, A. J., 2018, The suitability of chili pepper (*Capsicum annuum* L.) for alleviating human micronutrient dietary deficiencies a review. *Food Sci. Nutr.,* **6** (3) : 1 - 13.

OZSAN, T. AND ONUS, A., 2017, *In vitro* pepper (*Capsicum annuum* L.) anther culture: can be affected *via* vitamins B. *Biotechnol. J. Int.,* **20** (1) : 1 - 13.

PHUONG, N. T. D., 2021, Direct embryogenesis from anther culture of hot chilli (*Capsicum annuum* L.). *Ho Chi Minh City Open University J.Sci. Eng. Technol.,* **11** (1) : 3 - 10.

RAJAKARUNA, R. H. M. S. V., KUMARI, H. M. P. S. AND SERAN, T. H., 2018, Callus induction in anther culture of selected *Capsicum annuum* L. varieties. *Research Symposium on Pure and Applied Sciences*, Faculty of Science, University of Kelaniya, Sri Lanka. pp. : 19.

RODEVA, V. N., IRIKOVA, T. P. AND TODOROVA, V. J., 2004, Anther culture of pepper (*Capsicum annuum* L.): comparative study on effect of the genotype. *Biotechnol. Biotechnol. Equip.,* **18** (3) : 34 - 38.

SUPENA, E. D., SUHARSONO, S., JACOBSEN, E. AND CUSTERS, J. B., 2006, Successful development of a shed-microspore culture protocol for doubled haploid production in Indonesian hot pepper (*Capsicum annuum* L.). *Plant Cell Rep.,* **25** : 1 - 10.

TESTILLANO, P. S., GONZALEZ-MELENDI, P., AHMADIAN, P., FADON, B. AND RISUENO, M. C., 1995, The immuno localization of nuclear antigens during the pollen developmental program and the induction of pollen embryogenesis. *Exp. Cell Res.,* **221** (1) : 41 - 54.

TOURAEV, A., INDRIANTO, A., WRATSCHKO, I., VICENTE, E. AND HEBERLE-BORS, E., 1996, Efficient microspore embryogenesis in wheat (*Triticum aestivum* L.) induced by starvation at high temperature. *Sex. Plant Repdn.,* **9** : 209 - 215.

Mysore J. Agric. Sci., 57 (1) : 197-205 (2023)

Fungal Endophytes Isolated from Drought Adapted Plants Improve Maize (*Zea mays* L.) Seedling Growth under PEG induced Drought Stress

NEEKSHITHA SHETTY AND N. EARANNA
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : neekshithashetty94@gmail.com

AUTHORS CONTRIBUTION

NEEKSHITHA SHETTY :
Design of the work, data collection, data analysis & interpretation and drafting the article ;
N. EARANNA :
Conception, critical revision of the article and final approval

Corresponding Author :
NEEKSHITHA SHETTY
Department of Agricultural Microbiology,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : August 2022
Accepted : January 2023

ABSTRACT

Endophytes are one of the symbiotic associations which can be successfully utilized to mitigate negative effects of abiotic stress in agricultural crops**.** Habitat adapted symbiotic fungal endophytes are known to impart drought tolerance in host plants. This study aimed at evaluating fungal endophytes of drought adapted plants against drought stress in maize. Fungal endophytes were isolated from arid and semi-arid regions of Karnataka and screened for their ability to grow in matric modified media using Polyethylene glycol (PEG 8000). Out of 65 isolates, six isolates (P1R1, P4L5, P6R3, P6R4, P10R1 and P12R2) showed increased mycelial growth up to -10.31 MPa (30 % PEG). The six fungal endophytes were evaluated for their ability to alleviate drought stress and improve growth of maize seedlings at PEG induced drought stress under *in vitro* condition. Maize seedlings inoculated with fungal endophytes showed significant increase in shoot length under drought stress after 10 days compared to control. Among six endophytes, the isolate P10R1 significantly enhanced shoot and root length of maize. The fungus was identified as *Alternaria burnsi* by using ITS region sequences. This study revealed that the fungal endophyte, *Alternaria burnsi* isolated from drought adapted plant has ability to mitigate drought stress and improve the maize growth under drought condition.

Keywords : Fungal endophyte, PEG 8000, Drought, Maize

FUNGAL endophytes colonize plant tissues in intercellular spaces without causing any disease symptoms. Mutualistic or symbiotic association of plant with endophytic fungi confer fitness benefits to host plant which include tolerance to biotic and abiotic stresses (Sherameti *et al.,* 2008 and Rocha *et al.,* 2011). Among abiotic stresses, drought is one of the important abiotic factors expected to cause reduced growth and yield. It is estimated that more than 50 per cent of arable land may be affected with drought by 2050 (Vinocur and Altman, 2005). Plants response to the drought stress is a complex phenomenon. Plants adapt various metabolic and physiological mechanisms to tolerate or avoid stresses. Plant associated microbial community, particularly the fungal endophytes play a critical role in assisting host plant to overcome abiotic stresses. Fungal endophytes are known to impart drought tolerance in host plant by activating host defense systems such as osmotic adjustment, increasing plant growth by producing growth hormones, scavenging reactive oxygen species (ROS) and producing antioxidant enzymes (Ali *et al.*, 2018; Moghaddam *et al.,* 2021; Khan *et al*., 2016). Rodriguez *et al.* (2009) classified fungal endophytes into 4 classes where clavicipitaceous endophytes were grouped into class I fungal endophytes and non clavicipitaceous endophytes into Class II, III and IV. Fungi colonizing above and below-ground plant tissues and being horizontally and vertically transmitted were grouped as class II fungal endophytes. Class III endophytes were defined to contain mostly members of the *Dikaryomycota* (*Ascomycota* or *Basidiomycota*), which are particularly well studied in trees, but also in other plant taxa and in various ecosystems. Class IV endophytes comprise dark, septate endophytes, which, similar to mycorrhizal fungi, are restricted to roots, where they reside inter and intracellularly in the cortical cell layers. The Class II endophytes have broad host range and are readily culturable on artificial media and are thought to colonize all plants in natural ecosystems. Many studies have been reported the benefits of habitat adapted endophytes in plants against abiotic stresses which includes drought, heat and salinity (Rodriguez *et al.* 2008; Redman *et al.,* 2002 and Manasa *et al*., 2015). Ghaffari *et al.* (2019) reported *Piriformospora indica* colonization readjusts plant metabolites and sustains the presence of aquaporins in drought-stressed plants. Moghaddam *et al.* (2021) reported fungal endophyte *Periconia macrospinosa* induce drought tolerance in tomato and cucumber by increasing proline content and antioxidant activities in host plant. Therefore, fungal endophytes isolated from drought adapted plants can impart drought stress tolerance in crop plants. This study is intended to screen and evaluate efficient fungal endophytes against drought stress in maize.

Material and Methods

Isolation of Fungal Endophytes

From arid and semi-arid regions *viz.,* Bellary, Koppal, Chinthamani, Chithradurga, twelve grass species were collected which belong to different agro-climatic zones *viz.,* North eastern dry zone, Central dry zone and eastern dry zone of Karnataka (Table 1). Root and leaf samples were cut in to 1cm bits and surface sterilized using 4 per cent sodium hypochlorite for 45 seconds followed by 70 per cent alcohol for one minute. The sterilized bits were repeatedly washed using sterile water to remove residual chemicals. The surface sterilized root and leaf bits were placed on Potato Dextrose Agar (PDA) medium dispensed plates and incubated at 28 °C for 7 days. The fungal mycelia emerged from the medium were purified and preserved under refrigerator for further study.

Screening of Fungal Endophytes for Drought Tolerance

Under matric induced water stress, sixty one fungal isolates were screened. Actively growing mycelial

Table 1

Details of location of plant samples collected and designated endophytic fungal isolates

Place (Agro climatic zones of Karnataka)	Location	Plant sample	Isolate codes
Koppal (Northern dry zone)	Achalapur	*Brachiaria mutica*	P1R1, P1R2, P1R3
	Raghunatahn halli	*Fimbristylis miliacea*	P2R1, P2R2, P2R3, P2R4, P2L1, P2L2, P2L3, P2L4, P2L5
Bellary (Northern dry zone)	Tondehal	*Panicum repens*	P3R1, P3R2, P3R3, P3L1, P3L2, P3L3, P3L4, P3L5
	Desanur	*Digitaria ciliaris*	P4R1, P4R2, P4R3, P4L1, P4L2, P4L3, P4L4, P4L5
Chikkaballapura (Eastern dry zone)	Chinthamani	*Dichanthium* spp	P5R1, P5R2, P5R3, P5R4
	Kurubur	*Eleusine indica*	P6R1, P6R2, P6R3, P6R4, P6R5, P6L1, P6L2
	Shidlaghatta	*Sorghum halepense*	P7R1
Chitradurga (Central dry zone)	Hiryuru	*Tragus* spp.	P8R1, P8R2, P8L1
	Hiryuru	*Digitaria* spp.	P9R1
	Ramajogihalli	*Cyperus* spp.	P10R1, P10R2, P10L1, P10L2
	Ramajogihalli	*Arthraxon* spp.	P11R1, P11R2, P11R3, P11R4, P11R5, P11L1, P11L2, P11L3
	Challakere	*Urochloa* spp.	P12R1, P12R2, P12L1, P12L2, P12L3

Note: P-Plant, R-Root, L-leaf

discs (5mm) were made using sterile cork borer. These discs were inoculated into Erlenmeyer flask containing Potato Dextrose broth amended with Polyethylene glycol (PEG 8000) at 15, 20, 25 and 30 per cent concentrations which corresponds to -2.88, -4.85, -7.33 and -10.31 MPa water potential respectively (Michel, 1983). The inoculated flasks were placed in a shaker (90 rpm) at 25 °C for 7 days. Fungal mycelia were separated by passing the culture broth through pre-weighed Whatman - No.1 filter paper. The filter paper was rinsed in distilled water to remove broth residue. The filter paper with mycelium was dried at 60 °C in hot air oven for 48 hrs to attain constant weight and the final weight of filter paper with mycelium was recorded. The dry weight of the fungal mycelium recorded was the final weight of the filter paper with mycelium minus weight of the filter paper. Fungal growth types were assessed as reported by Hutton *et al*. (1996).

Morphological Characters of Selected Drought Tolerant Fungal Isolates

The fungal growth was observed for their colony morphology and the fruiting body and spore characters were studied under microscope using agar slide culture technique (Harris, 1986).

Evaluation of Selected Fungal Endophytes for Induction of Drought Stress Tolerance in Maize

Maize seeds (MAH 14-5) were surface sterilized using sodium hypochlorite (4%) solution followed by 70 per cent ethanol and repeatedly washed with sterile water to remove residual chemicals on the seeds. Then these seeds were pre-germinated in sterile moist blotters. The pre-germinated seeds were treated with fungal spore suspension (10^6 spores/mL) prepared from 10 days old culture for 3 hours (Zhang *et al*., 2014). The control seeds were treated with sterile distilled water. The pre-germinated seeds were subjected to drought stress by placing them on a sterile paper towel soaked in 14.6 per cent (LC_{50}) PEG (Roopashree, 2022) and incubated at 27 ºC in the growth chamber for 10 days. There were three replications and each replication comprised with fifteen seedlings. Root and shoot lengths were recorded after incubation for 10 days.

Confirmation of Fungal Endophytes in the Tissue of Inoculated Maize Seedlings

The fungal endophytes were re-isolated from the inoculated seedlings on PDA medium and confirmed by comparing their colony morphology and spore characteristics with the mother cultures.

Identification of the Efficient Drought Tolerant Fungal Isolate P10R1

The genomic DNA of the fungal isolate was extracted by CTAB (Cetyl trimethyl ammonium bromide) method (Lee *et al.,* 1988). The fungal mycelia (500 mg) were macerated using sterile pestle and mortar in liquid nitrogen and a pinch of Poly vinyl pyrolidone (PVP) to obtain a fine powder. The powder was added to 3mL extraction buffer (50 mM Tris-HCl of pH 8.0, 50 mM EDTA, 0.7 M NaCl, pinch of PVP and 2 µl of β-mercaptoethanol), mixed gently and incubated at 65 ºC for 45 min with intermittent shaking. The lysate was extracted by adding an equal volume of chloroform: isoamyl alcohol (24:1) and centrifuging at 10,000 rpm for 10 min. The supernatant was transferred to new tube and further chloroform: isoamyl alcohol (24:1) was added and centrifuged again. This step was repeated, until the middle layer disappeared. The genomic DNA was precipitated by adding chilled isopropanol (600 µL) and incubated at -20°C overnight. After incubation, the tubes were centrifuged at 10,000 rpm for 10 min and the aqueous layer was discarded and the pellet was washed by using 500 µl of 70 per cent chilled ethanol. The pellet so obtained was air dried and dissolved in 20 µl of deionized sterile water. The dissolved pellet was treated with five µl RNase A enzyme and incubated at 37°C for one hour. The DNA was subjected to electrophoresis using 0.8 per cent agarose gel, gel documented and purity was checked using Nano drop. This DNA was used as template for amplification.

Polymerase Chain Reaction (PCR)

The internal transcribed spacer (ITS) region of genomic DNA was amplified using universal primer ITS1-F (5[TCCGTAGGTGAACCTGCGG 3[) and ITS4-R (5[TCCTCCGCTTATTGATATGC 3]) by polymerase chain reaction (PCR). PCR amplification was performed using thermocycler (Mater cycler Nexus gradient, Eppendrof, India) with a 20 µL reaction mixture that comprised of 2 µL 1X taq buffer with $MgCl_2$ (1.5 mM), 2µL dNTP's (10mM), 0.5 µL each primer (10 pmol), 0.3 µL Taq DNA polymerase (3U) and 1µL template DNA (100 ng). The PCR was carried out with an initial denaturation at 96 °C for 4 min, followed by 35 cycles at 94 °C for 30s, 55 °C for 1 min and 72 °C for 30s and a final extension at 72 °C for 12 min. Then the amplified product of DNA was electrophoresed using one per cent agarose gel. The DNA band was visualized under UV light and documented using a gel documentation unit (Vilber, E-Box CX5.TS, France). The amplified DNA was eluted by using gel extraction kit to obtain purified PCR product. The eluted DNA was sequenced by Barcode bioscience pvt. Ltd., Bangalore, India. The sequence data received from the company was analysed for homology using NCBI GenBank.

Sequence Analysis and Homology Search

Sequence results were analysed using the online software National Centre for Biotechnology Information (NCBI), USA. The BLAST (Basic Local Alignment Search Tool) search was done for partial length sequence homology with NCBI data (http// www. Ncbi.nlm.nih.gov/BLAST/) (Altschul *et al.*, 1990). Phylogenetic analysis was done by using MEGA10 software and a phylogenetic tree was generated using neighbour-joining algorithm.

Statistical Analysis

The data was statistically analysed using WASP: 2.0 (Web Agri Stat Package 2) statistical tool (www.icargoa.res.in/wasp2/index.php) and the means were separated by Duncan Multiple Range Test (DMRT).

Results and Discussion

Screening of Fungal Endophytes Drought Tolerance

Sixty one endophytes were isolated from 12 plant species of arid and semi-arid regions of Karnataka and screened for drought tolerance (Fig. 1 & Table 1) using different concentrations of PEG. The isolates grown in PEG amended medium showed 3 different types (Type-I, Type-II and Type-III) of growth response as defined by Hutton *et al*. (1996) which include: Type I- overall minimal growth after 7 days; Type II- maximum growth at control with decreased growth as matric water stress increased; Type III- maximum growth under some degree of matric induced water stress. Out of sixty-one isolates (Fig.1 & Fig.2), 38 isolates showed decreased mycelial dry weight with increased PEG concentration indicating that they possess type-II growth response. Seventeen isolates showed no

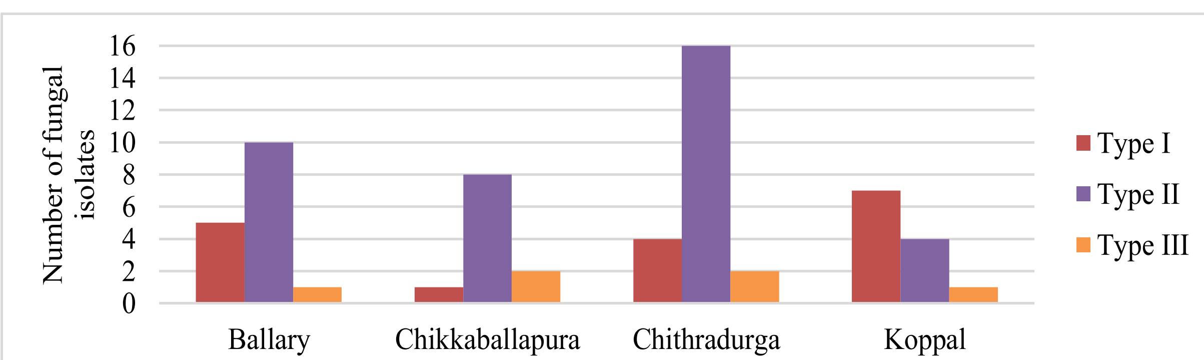


Fig. 1: Number of fungal endophytes isolated from drought adapted plants from various parts of Karnataka showing different growth type response

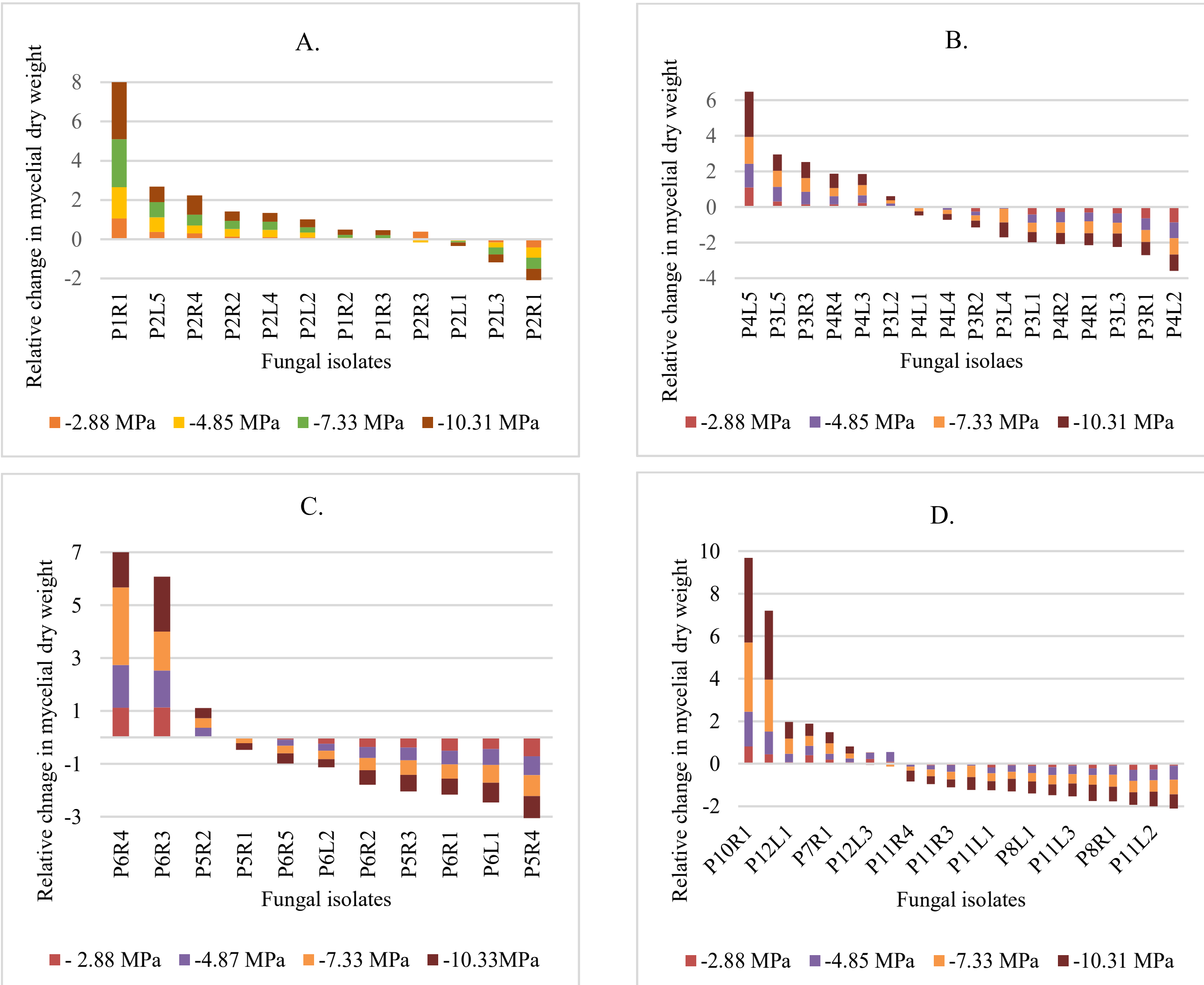


Fig. 2: Relative change in mycelial dry weight of fungal endophytes with respect to control (mycelial dry weight of isolates grown in PD broth) at different water potential
Locations: A) Bellary B) Chikkaballapura C) Chitradurga D) Koppal districts of Karnataka

response to increased PEG concentration (decreased water potential) indicating that they are belong to type I growth response. Remaining 6 fungal endophytes (P1R1, P4L5, P6R3, P6R4, P10R1 and P12R2) showed increased mycelial dry weight with increased concentration of PEG (-10.31MPa) compared to control and belong to the Type III indicating that they are more tolerant to matric-induced water stress (Ramirez *et al.,* 2004). The preference of these six endophytes for low water potentials in the study might be due to their arid habitats and the low water potential of host plants in arid regions (Moghaddam *et al.,* 2021). Osmotic potential and matric potential could be considered two important components of water potential which influence the water availability for the microorganisms (Aujla and Paulitz, 2017). Osmotic potential is contributed by the solutes in the water and matric potential by the interaction of water with solid phase (Papendick and Campbell, 1981). Most fungi tolerate osmotic-induced water stress better than matric-induced water stress (Ramirez *et al.,* 2004). This suggests that the matric induced water stress tolerance would be an important factor that could be considered to screen drought tolerant fungal endophytes. Polyethylene glycol (PEG) is a high

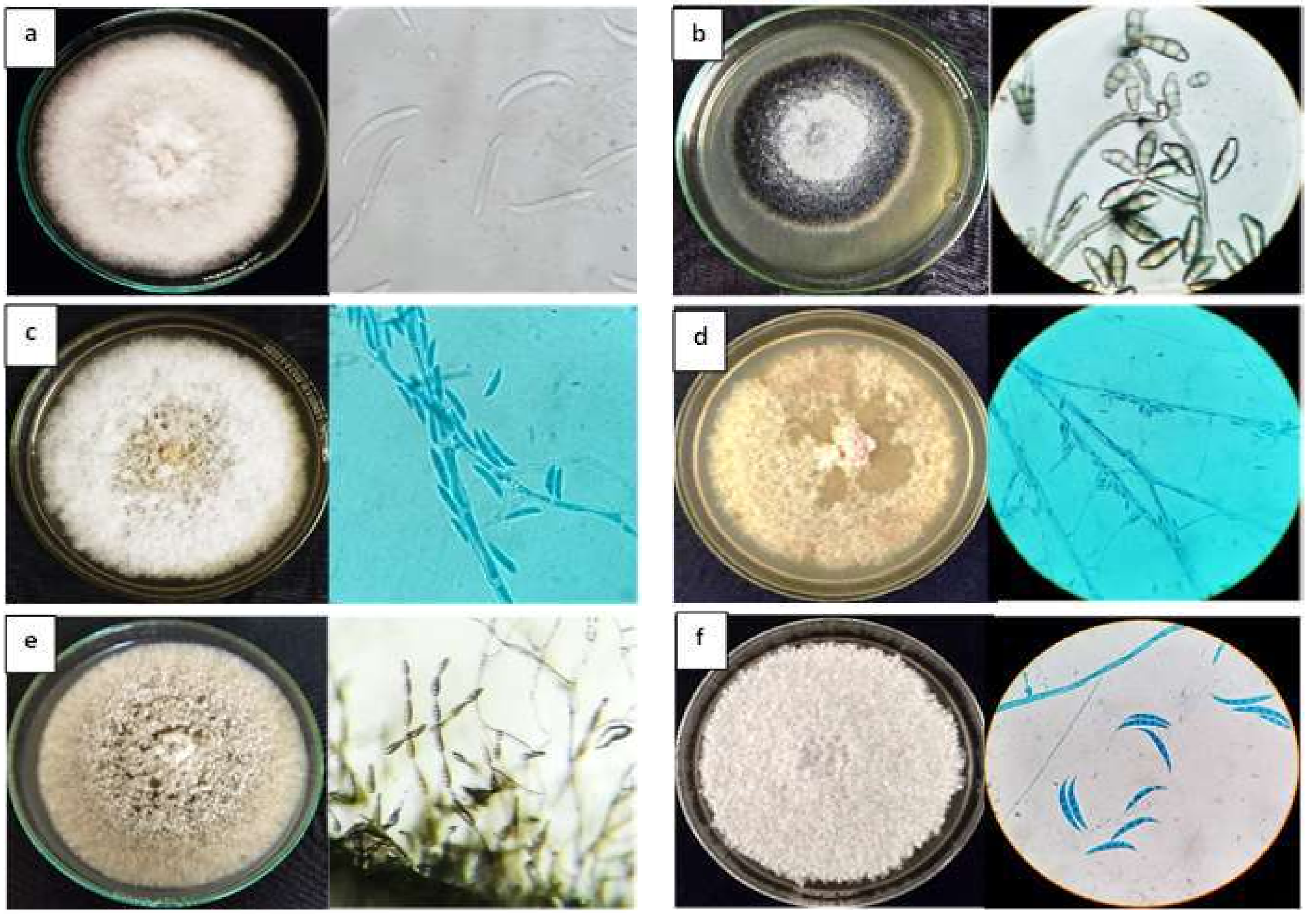


Plate 1: Mycelial growth of endophytic fungi on PDA and spore structures under microscope (40x) a. *Fusarium* P1R1, b. *Curvularia* P4L5, c. *Fusarium* P6R3, d. *Fusarium* P6R4, e. *Alternaria* P10R1, f. *Fusarium* P12R2

molecular weight compound which is impermeable through both cell wall and cell membrane of microorganisms and contributes to the matric induced water stress (Harris, 1981). Hence, growth media was amended with polyethylene glycol (PEG) with different concentration which corresponds to various matric induced water potential. Roopashree and Rajendra Prasad (2021) demonstrated the Type III growth response (-7.41 MPa PEG) in the fungal endophyte isolated form the plants grown in extreme climatic conditions. The six selected fungal endophytes (P1R1, P4L5, P6R3, P6R4, P10R1 and P12R2) when examined for their cultural, microscopic and morphological characteristics (Plate1, a,b,c,d,e and f) revealed that four isolates P1R1, P6R3, P6R4 and P12R2 belong to the genera of *Fusarium*, P10R1 to *Alternaria* and P4L5 to *Curvularia* (Watanabe, 2010).

In vitro Evaluation of Selected Fungal Endophytes on Growth of Maize under PEG Induced Drought

The six isolates (Fig. 2) having maximum mycelial dry weight at -10.31MPa water potential were further evaluated for their ability to influence on early seedling growth of maize (MAH 14-5). The seedlings inoculated with fungal endophytes showed significant increase in shoot length compared to un-inoculated seedlings under stress. The fungal endophytes did not influence on the root length of maize seedlings which are not treated with PEG. But, significant increase in root length was observed in maize seedlings grown under PEG induced drought conditions (Table 2). In addition, root hair development was observed in endophyte inoculated seedlings. This indicates that the fungal endophytes might have influenced

TABLE 2

Influence of fungal endophytes on shoot and root length of maize under without and with drought stress

Treatments	Without drought stress		Drought stress (-2.74 MPa)	
	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)
Control	13.70 [e]	23.20	5.60 [e]	15.10 [e]
P1R1	17.60 [b]	20.80	7.90 [d]	16.50 [cde]
P4L5	15.24 [d]	23.50	8.24 [cd]	17.70 [cd]
P6R3	16 [cd]	24.26	8.90 [bcd]	16.10 [de]
P6R4	18.98 [a]	24.86	10.18 [b]	21.10 [b]
P10R1	19.04 [a]	24.90	12.36 [a]	23.02 [a]
P12R2	17.30 [bc]	24.40	9.90 [bc]	18.26 [c]
C.D (0.05)	1.32	NS	1.75	1.77
C.D (0.01)	1.79	NS	2.36	2.39

Note: Means of same superscript in a column do not differ significantly at p=0.05 as per DMRT; NS= Non significant

root architecture by producing plant growth hormones (Verma *et al.,* 2018). Among the six selected fungal endophytes, the isolate $P_{10}R_1$ showed the highest shoot and root length compared to others. Li *et al*. (2019) reported the increased root length of maize inoculated with fungal isolate (*Paraphoma* sp., *Embellisia chlamydospore* and *Cladosporium oxysporum*) under moderate drought stress. The fungal endophytes were re-isolated from the inoculated seedlings and confirmed by comparing with respective mother cultures.

Identification of Efficient Drought Tolerant Fungal Isolate $P_{10}R_1$

Ribosomal DNA Internal Transcribed Spacer (ITS) sequence analysis is widely used for the identification of microorganisms. The use of ITS region sequences was proved to be a valuable source of evidence to resolve phylogenetic relationships at lower levels, such as among genera or species. The ITS region sequences of selected fungal isolates were compared with already published sequences in the NCBI data base and fungal endophytes were identified. The ITS partial gene sequence of the $P_{10}R_1$ isolate having the sequence length 505 base pair (bp) showed 99.80 per cent homology with *Alternaria burnsii* available in the NCBI database. The phylogenetic tree (Fig. 3)

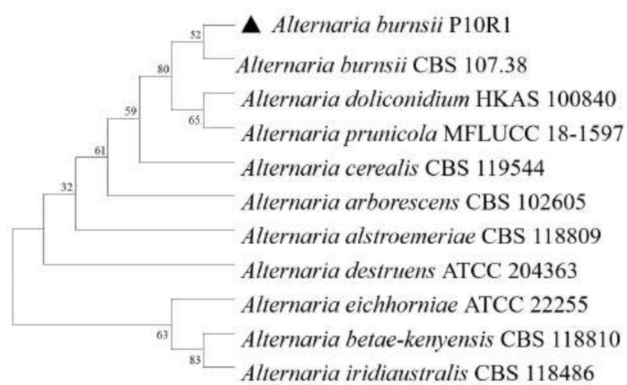


Fig. 3: Phylogenetic tree of *Alternaria* species

constructed using the sequences of 10 *Alternaria* species available in the NCBI GenBank showed that the isolate $P_{10}R_1$ is closely related to *Alternaria burnsii* CBS 107.38. Thus, the fungus $P_{10}R_1$ was identified as *Alternaria burnsii*. The ITS region has the highest probability of successful identific ation for the broadest range of fungi with the most clearly defined gap between inter and intra specific variation (Schoch *et al*., 2012), the above said fungal endophyte was identified using sequence homology. It can be concluded from the study that *Alternaria burnsii* as the efficient drought tolerant fungal endophyte which has the ability to impart drought tolerance in maize.

Acknowledgement : Authors are thankful to the Department of Science and Technology (DST), GOI, New Delhi, for awarding INSPIRE fellowship (DST/INSPIRE Fellowship/2019/IF190203) for the Ph.D. research.

References

Ali, A. H., Abdelrahman, M., Radwan, U., El-Zayat, S. and El-Sayed, M. A., 2018, Effect of thermomyces fungal endophyte isolated from extreme hot desert-adapted plant on heat stress tolerance of cucumber. *Appl. Soil Ecol.,* **124** : 155 - 162.

Altschul, S. F., Gish, W., Miller, W., Myers, E. W. and Lipman, D. J., 1990, Basic local alignment search tool. *J. Mol. Biol.,* **215** (3) : 403 - 410.

Aujla, I. S. and Paulitz, T. C., 2017, An improved method for establishing accurate water potential levels at different temperatures in growth media. *Front. Microbiol.,* **8** : 1497.

Ghaffari, M. R., Mirzaei, M., Ghabooli, M., Khatabi, B., Wu, Y., Zabet-Moghaddam, M., Mohammadi-Nejad, G., Haynes, P. A., Hajirezaei, M. R., Sepehri, M. and Salekdeh, G. H., 2019, Root endophytic fungus *Piriformospora indica* improves drought stress adaptation in barley by metabolic and proteomic reprogramming. *Environ. Exp. Bot.,* **157** : 197 - 210.

Harris, J. L., 1986, Modified method for fungal slide culture. *J. Clin. Microbiol.,* **24** (3) : 460 - 461.

Harris R. F., 1981, Effect of water potential on microbial growth and activity. In : Water potential relations in soil microbiology. [(Eds.) J. F Parr, WR Gardner and LF Elliot], *Soil Science Society of America, Inc.,* Madison, U.S.A, pp. : 23 - 95.

Hutton, B. J., Sivasithamparam, K., Dixon, K. W. and Pate, J. S., 1996, Pectic zymograms and water stress tolerance of endophytic fungi isolated from Western Australian heaths (*Epacridaceae*). *Ann. Bot.*, **77** (4) : 399 - 404.

Khan, Z., Rho, H., Firrincieli, A., Hung, S. H., Luna, V., Masciarelli, O., Kim, S. H. and Doty, S. L., 2016, Growth enhancement and drought tolerance of hybrid poplar upon inoculation with endophyte consortia. *Curr. Plant Biol.*, **6** : 38 - 47.

Lee, S. B., Milgroom, M. G. and Taylor, J. W., 1988, A rapid, high yield mini-prep method for isolation of total genomic DNA from fungi. *Fungal Genet. Newslett.*, **35** : 23 - 24.

Li, X., He, C., He, X., Su, F., Hou, L., Ren, Y. and Hou, Y., 2019, Dark septate endophytes improve the growth of host and non-host plants under drought stress through altered root development. *Plant Soil*, **439** (1) : 259-272.

Manasa, K. M., Ravikanth, G., Nataraja, K. N. and Umashaanker, R., 2015, Isolation and characterization of endophytic fungi from saline habitat adapted plants. *Mysore J. Agric. Sci*., **49** (2) : 299 - 301.

Michel, B. E., 1983, Evaluation of the water potentials of solutions of polyethylene glycol 8000 both in the absence and presence of other solutes. *Plant Physiol*., **72** (1) : 66 - 70.

Moghaddam, M. S. H., Safaie, N., Soltani, J. and Hagh-Doust, N., 2021, Desert adapted fungal endophytes induce salinity and drought stress resistance in model crops. *Plant Physiol. Biochem.*, **160** : 225 - 238.

Papendick, R. I. and Campbell, G. S., 1981, Theory and measurement of water potential. In : Water potential relations in soil microbiology. [(Eds.) J. F. Parr, WR Gardner and LF Elliot], *Soil Science Society of America, Inc.,* Madison, U.S.A, pp. : 1 - 22.

Ramirez, M. L., Chulze, S. N. and Magan, N., 2004, Impact of osmotic and matric water stress on germination, growth, mycelial water potentials and endogenous accumulation of sugars and sugar alcohols in *Fusarium graminearum*. *Mycologia,* **96** : 470 - 478.

Redman, R. S., Sheehan, K. B., Stout, R. G., Rodriguez, R. J. and Henson, J. M., 2002, Thermotolerance conferred to plant host and fungal endophyte during mutualistic symbiosis. *Sci.*, **298** : 1581.

Rocha, A. C. S., Garcia, D., Uetanabaro, A. P. T., Carneiro, R. T. O., Araujo, I. S., Mattos, C. R. R. and Goes-Neto, A., 2011, Foliar endophytic fungi from *Hevea brasiliensis* and their antagonism on *Microcyclusulei*. *Fungal Divers*, **47** : 75 - 84.

Rodriguez, R. J., Henson, J., Van Volkenburgh, E., Hoy, M., Wright, L., Beckwith, F., Kim, Y. O. and Redman, R. S., 2008, Stress tolerance in plants *via* habitat-adapted symbiosis. *ISME J.*, **2** (4) : 404 - 416.

Rodriguez, R. J., White Jr, J. F., Arnold, A. E. and Redman, A. R. A., 2009, Fungal endophytes: diversity and functional roles. *New Phytol*., **182** (2) : 314 - 330.

Roopashree, B. and Rajendra Prasad, S., 2021, Drought tolerant endophytic fungi for enhancing early seedling growth under stressful conditions in selected crops. *Mysore J. Agric. Sci*., **55** (4) : 289 - 295.

Roopashree, B., 2022, Endophytes: a potent seed bio-priming agents for abiotic stress mitigation in selected crops. *Ph.D. Thesis* (Unpub.), Univ. Agric. Sci., Bangalore.

Schoch, C. L., Seifert, K. A., Huhndorf, S., Robert, V., Spouge, J. L., Levesque, C. A. and Chen, W., 2012, Fungal barcoding consortium, nuclear ribosomal internal transcribed spacer (ITS) region as a universal DNA barcode marker for Fungi. *Proc. Natl. Acad. Sci.,* U.S.A., **109** (16) : 6241 - 6246.

Sherameti, I., Tripathi, S., Varma, A. and Oelmuller, R., 2008, The root-colonizing endophyte *Pirifomo spora indica* confers drought tolerance in Arabidopsis by stimulating the expression of drought stress related genes in leaves. *Mol. Plant Microbe Interact.,* **21 (6)** : 799 - 807.

Verma, S. K., Kingsley, K., Bergen, M., English, C., Elmore, M., Kharwar, R. N. and White, J. F., 2018, Bacterial endophytes from rice cut grass (*Leersia oryzoides* L.) increase growth, promote root gravitropic response, stimulate root hair formation and protect rice seedlings from disease. *Plant Soil*, **422** (1) : 223 - 238.

Vinocur, B. and Altman, A., 2005, Recent advances in engineering plant tolerance to abiotic stress: achievements and limitations. *Curr. Opin. Biotechnol.,* **16** : 123 - 132.

Watanabe, T., Kanno, M., Tagawa, M., Tamaki, H. and Kamagata, Y., 2010, Pictorial atlas of soil and seed fungi pictorial atlas of soil and seed fungi. *Mycoscience*, **53** (1) : 45 - 48.

Zhang, Q., Zhang, J., Yang, L., Zhang, L., Jiang, D., Chen, W. and Li, G., 2014, Diversity and biocontrol potential of endophytic fungi in *Brassica napus*. *Biol. Control.,* **72** : 98 - 108.

Mysore J. Agric. Sci., 57 (1) : 206-210 (2023)

Acaricide Resistance in Field Populations of Broad Mite, *Polyphagotarsonemus latus* (Banks) (Acari : Tarsonemidae)

NEENU AUGUSTINE[1], M. MOHAN[2] AND N. SRINIVASA[3]
[1&3]Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
[2]Division of Genomic Resources, ICAR-NBAIR, Bengaluru - 560 024
e-Mail : neenuaugustine93@gmail.com

AUTHORS CONTRIBUTION

NEENU AUGUSTINE : Conceptualization, investigation, data analysis and draft preparation ;
M. MOHAN : Conceptualization, resources supply and data curation;
N. SRINIVASA : Conceptualization, framing research proposal and draft correction

Corresponding Author :
NEENU AUGUSTINE
Department of Agricultural Entomology,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : September 2022
Accepted : December 2022

ABSTRACT

The broad mite, *Polyphagotarsonemus latus* (Banks), has assumed a key pest status in several crops like chilli, capsicum, mulberry, jute, tea, sesame and cotton in recent years. In spite of the increasing cases of outbreaks and reports of chemical control failures, the prevalence of acaricide resistance in broad mite remains under studied. In this context, five major acaricides were used to ascertain the resistance development in three field-collected populations of broad mite from Karnataka. A laboratory strain (NBAIR-GR-TAR-01a) of broad mite being maintained at ICAR-NBAIR showed high susceptibility to propargite 57 per cent EC (LC_{50} of 0.37 ppm), diafenthiuron 50 per cent WP (0.40 ppm), fenazaquin 10 per cent EC (0.44 ppm), spiromesifen 22.9 per cent SC (0.58 ppm) and dicofol 18.5 per cent EC (0.70 ppm). Among the field populations screened, the Haveri population showed higher resistance to the tested acaricides as compared to Chikkaballapur and Tumkur populations. Upon categorizing the resistance levels, resistance to spiromesifen was observed to be extremely high (162.55folds) in broad mites collected from Haveri on chilli crop. The acaricide which recorded the lowest levels of resistance was propargite (8.81 folds) in Tumkur population. Dicofol and fenazaquin registered moderate to high levels of resistance, while diafenthiuron recorded high levels of resistance across the populations studied.

Keywords : Resistance, Acaricides, Broad mite, Field populations

THE broad mite also called as yellow mite, *Polyphagotarsonemus latus* (Banks), is an important pest infesting several crops around the globe. It is reported to have more than 250 hosts including plants of agricultural and horticultural importance like chilli, capsicum, jute, mulberry, tea, sesame, cotton, potato, eggplant, beans, melons, celery, cotton, pears, guava, passion fruit, tea, flower crops like chrysanthemum, dahlia etc. In recent years, the infestation of *P. latus* (Banks) on several crops has significantly increased in India with a severe reduction in the quality and quantity of economic parts (Rai *et al*., 2007).

Among vegetables, chilli and capsicum are the most affected by *P. latus* often compromising the entire crop in massive infestations. On these crops, they habituate and multiply on the lower leaf surface causing curling of leaf margins downwards (Rao *et al*., 2020). The damage due to mites in chilli had been estimated to the tune of 60 per cent (Srinivasan *et al*., 2003) and can cause cent per cent yield loss under polyhouse conditions. Several bio-ecological factors of *P. latus* like microscopic nature, cryptic habitat, abundant progeny production, monoculture of host plants and their ability to reach damaging densities within a very short time demand the repeated application of pesticides in a prophylactic fashion both under open as well as polyhouse conditions that can lead to the rapid development of resistance (Leeuwen *et al*., 2010). Despite these facts, there are no studies on acaricide resistance in broad mite populations in India and abroad. Hence, the present study was undertaken to monitor the resistance development to major acaricides in field populations of *P. latus* in Karnataka.

Material and Methods

The isofemale susceptible population of *P. latus* (national accession number NBAIR-GR-TAR-01a) is being maintained on potted mulberry plants in nethouse at ICAR-National Bureau of Agricultural Insect Resources for more than 70 generations without exposure to chemicals. The population has reached the inbred stage and is used in comparative studies with the field populations.

In order to assess the status of acaricide resistance in field populations, roving surveys were conducted in chilli and capsicum fields both under open fields and polyhouses in three districts of Karnataka. Samples of *P. latus* were collected from Hosahalli, Chikkaballapur (13.1432° N, 77.6428° E); Hedigonda, Haveri (14.6834° N, 75.3849° E) and Koratagere, Tumkur (13.4489° N, 76.1678° E). The collected mites were released in large numbers on fresh uninfested mulberry plants and allowed to multiply. The mite progeny from the F_1 generation were used for bioassay studies.

Five acaricides recommended by the Central Insecticide Board for the control of broad mites were used for assessing the resistance level, *viz*., diafenthiuron 50 per cent WP, dicofol 18.5 per cent EC, fenazaquin 10 per cent EC, propargite 57 per cent EC and spiromesifen 22.9 per cent SC. The leaf dip bioassay recommended by the Insecticide Resistance Action Committee (IRAC, 2009) was used with suitable modifications. Different concentrations were established on the basis of preliminary bioassays to determine five and 95 per cent mortality concentrations and a minimum of five required concentrations were prepared by serial dilution from the stock solution of respective acaricides.

Freshly cut mulberry leaf discs devoid of mite infestation were immersed in the respective test chemical solutions for 30 seconds. The discs were allowed to air dry at room temperature and then placed on a wet cotton wad in petri plates. Adult female mites were chosen for bioassays on account of their comparative larger size and female-biased sex-ratio. Thirty adult females were transferred onto the treated leaf discs and incubated in a BOD chamber at 25±1 °C and RH 75±5 per cent. Each concentration and the control treatments had three such replications and mite mortality was recorded under a stereo binocular microscope. Mites that were not able to make any movement when poked with a brush after 24 hours of acaricide treatment were considered dead.

The median lethal concentrations (LC_{50}) were determined by Probit analysis (Finney, 1971) using Polo Plus 2.0 software and resistance ratios (RR) were computed by dividing the LC_{50} of the field population by that of the susceptible population. On the basis of RR values, the intensity of resistance was grouped as low (RR less than 10), moderate (RR between 10 and 40), high (RR between 40 and 160) and extremely high (RR greater than 160) (Kim *et al*., 2004).

Results and Discussion

The laboratory susceptible mite population (NBAIR-GR-TAR-01a) was highly susceptible to propargite with an LC_{50} of 0.37 ppm, followed by diafenthiuron (0.40 ppm), fenazaquin (0.44 ppm), spiromesifen (0.58 ppm) and dicofol (0.70 ppm). The resistance level to different acaricides varied among the three field populations.

The LC_{50} values for diafenthiuron were 26.00 ppm, 32.38 ppm and 32.00 ppm for Chikkaballapur, Haveri, and Tumkur populations, respectively. All the populations showed significantly high level of resistance as compared to the susceptible strain, based on non-overlapping of 95 per cent fiducial limits (Table 1). All the field populations were highly resistant to diafenthiuron with the highest RR for the populations collected from Haveri (80.95 folds), followed by Tumkur (80.00 folds) and Chikkaballapur (65.00 folds). Ranjeethkumar (2008) and Mohin (2020) also reported high levels of resistance to diafenthiuron in *Tetranychus urticae* populations on tomato.

TABLE 1

Dose-response mortality of *Polyphagotarsonemus latus* populations to diafenthiuron

Population	LC_{50} (ppm)	95% fiducial limits (ppm)	Slope ± SEM	χ^2 (df)	Hetero-geneity	RR	Class
Chikkaballapur	26.00	3.48 - 44.04	1.45 + -0.17	5.88 (3)	1.96	65.00	High
Haveri	32.38	25.80 - 40.52	1.48 ± 0.17	4.42 (3)	1.47	80.95	High
Tumkur	32.00	26.34 - 38.57	1.78 + -0.18	1.03 (3)	0.34	80.00	High
NBAIR-GR-TAR-01a	0.40	0.68 - 0.95	2.02 ± 0.18	1.17 (4)	0.39	-	-

df- degrees of freedom, RR- resistance ratio

TABLE 2

Dose-response mortality of *Polyphagotarsonemus latus* populations to dicofol

Population	LC_{50} (ppm)	95% fiducial limits (ppm)	Slope ± SEM	χ^2 (df)	Hetero-geneity	RR	Class
Chikkaballapur	34.65	20.45 - 60.27	2.52 ± 0.19	4.97 (3)	1.66	49.50	High
Haveri	58.68	47.17 - 72.70	1.61 + -0.19	1.88 (3)	0.63	83.83	High
Tumkur	19.23	11.47 - 37.29	1.45 ± 0.18	5.18 (4)	1.73	27.47	Moderate
NBAIR-GR-TAR-01a	0.70	0.59 - 0.83	1.72 ± 0.16	2.42 (3)	0.81	-	-

df- degrees of freedom, RR- resistance ratio

TABLE 3

Dose-response mortality of *Polyphagotarsonemus latus* populations to fenazaquin

Population	LC_{50} (ppm)	95% fiducial limits (ppm)	Slope ± SEM	χ^2 (df)	Hetero-geneity	RR	Class
Chikkaballapur	14.64	11.87 - 17.77	1.68 ± 0.18	2.31 (3)	0.77	33.27	Moderate
Haveri	19.90	16.18 - 24.38	2.84 ± 0.21	0.84 (4)	0.28	45.22	High
Tumkur	13.48	10.81 - 16.47	1.77 + -0.18	0.970(3)	0.32	30.63	Moderate
NBAIR-GR-TAR-01a	0.44	0.37 - 0.51	1.84 ± 0.17	0.34 (3)	0.11	-	-

df- degrees of freedom, RR- resistance ratio

The bioassays with dicofol indicated high level of resistance development in Haveri (LC_{50} 58.68 ppm) and Chikkaballapur populations (34.65 ppm). However, there was a lower level of resistance in case of Tumkur population (LC_{50} 19.23 ppm). The RRs varied from 27.47 to 83.83 folds indicating moderate to high levels of resistance (Table 2). Extremely high resistance of upto 1038.70 and 2231.8 folds were recorded by Najeer-E-Noor and Srinivasa (2018) and Mohin (2020) respectively in *T. urticae* populations on tomato. This might be because of the intensive use and high persistence of dicofol or related chemicals in tomato fields of Karnataka.

The LC_{50} values for fenazaquin ranged from 13.48 ppm to 19.90 ppm in the field populations and they differed significantly from the susceptible strain. The RR values of Chikkaballapur (33.27 folds), Haveri (45.22 folds) and Tumkur (30.63 folds) indicated moderate to high levels of resistance to fenazaquin in the tested populations (Table 3). Similar trend was observed (12.00 to 75 folds) in *T. urticae* populations on tomato by Najeer-E-Noor and Srinivasa (2018). Nevertheless, extremely high levels of resistance (988.77 to 1028.05 folds) were reported by Mohin (2020) from Chikkamagaluru and Shivamogga districts of Karnataka.

TABLE 4

Dose-response mortality of *Polyphagotarsonemus latus* populations to propargite

Population	LC_{50} (ppm)	95% fiducial limits (ppm)	Slope ± SEM	χ^2 (df)	Hetero-geneity	RR	Class
Chikkaballapur	5.75	4.52 - 7.18	2.45 ± 0.17	2.87 (3)	0.96	15.54	Moderate
Haveri	5.05	1.97 - 9.35	1.40 ± 0.18	6.42 (3)	2.14	13.64	Moderate
Tumkur	3.26	2.63 - 4.04	1.55 ± 0.17	1.64 (3)	0.55	8.81	Low
NBAIR-GR-TAR-01a	0.37	0.23 - 0.55	1.20 ± 0.13	4.95 (4)	1.24	-	-

df- degrees of freedom, RR- resistance ratio

TABLE 5

Dose-response mortality of *Polyphagotarsonemus latus* populations to spiromesifen

Population	LC_{50} (ppm)	95% fiducial limits (ppm)	Slope ± SEM	χ^2 (df)	Hetero-geneity	RR	Class
Chikkaballapur	53.90	30.19 -103.44	1.85 ± 0.19	9.07 (3)	3.02	92.93	High
Haveri	94.28	64.93 -136.55	1.97 + -0.19	4.68 (4)	1.56	162.55	Extremely high
Tumkur	58.45	28.09 -149.49	1.51 ± 0.18	9.17 (3)	3.06	100.78	High
NBAIR-GR-TAR-01a	0.58	0.49 - 0.68	1.91 + -0.18	0.60 (3)	0.20	-	-

df- degrees of freedom, RR- resistance ratio

For propargite, the highest LC_{50} was observed in Chikkaballapur population (5.75 ppm) followed by Haveri (5.05 ppm) and the least was in Tumkur population (3.26 ppm) (Table 4). The range of RRs was comparatively narrow (8.81 to 15.54 folds) and indicated low to moderate levels of resistance. Roy *et al*. (2018) and Titiksha and Sood (2019) reported low resistance to propargite in *Oligonychus coffeae* (11.94 folds) and *T. urticae* (3.54 to 5.63 folds), respectively which are in line with the present findings. However, high resistance (43.80 to 60.63 folds) was recorded by Naveena *et al*. (2022) and extremely high resistance upto 164 and 3,725 folds were recorded by Mohin (2020) and Hany *et al*. (2020), respectively on different *T. urticae* populations.

Spiromesifen was observed to have the widest LC_{50} range from 53.90 ppm to 94.28 ppm across the tested populations (Table 5). Chikkaballapur and Tumkur populations recorded RRs of 92.93 and 100.78 folds, respectively, indicating high resistance levels while Haveri population evidenced extremely high levels of resistance to spiromesifen, with RR being 162.55 folds. The results are in accordance with the findings of Najeer-E-Noor and Srinivasa (2018), Naveena *et al*. (2022) and Mohin (2020) who reported extremely high resistance to spiromesifen in *T. urticae* populations.

The successful management of a pest requires effective monitoring of the levels of resistance and examining the possible mechanisms involved. The present investigation is the first report of acaricide resistance in various field populations of broad mite. The results of the present study forewarn the rapid development of resistance in field populations of *P. latus* to various groups of acaricides. The variations in resistance levels in field populations depend on the nature and extent of acaricides usage by the farmers in different areas. The high level of resistance in the Haveri population might be because of mono-cropping of chilli year-round and frequent treatments with insecticide/acaricides.

REFERENCES

FINNEY, D. J., 1971, Probit analysis : A statistical treatment of the sigmoid curve, *Cambridge University Press*, London, pp. : 333.

HANY, H. M., BRAR, B. M. AND PARAMJIT, K., 2020, Acaricide resistance in field collected two spotted spider mite, *Tetranychus urticae* from Okra in Punjab. *Indian J. Ecol*., **47** (2) : 590 - 593.

IRAC, 2009, Susceptibility test method series, Method No. 004. http://www.irac-online.org.

KIM, Y. J., LEE, S. H., LEE, S. W., AHN, Y. J., 2004, Fenpyroximate resistance in *Tetranychus urticae* (Acari : Tetranychidae): cross-resistance and biochemical resistance mechanisms. *Pest Manag. Sci*., **60** : 1001 - 1006.

LEEUWEN, V. T., VONTAS, J., TSAGKARAKOU, A., DERMAUW, W. AND TIRRY, L., 2010, Acaricide resistance mechanisms in the two spotted spider mite *Tetranychus urticae* and other important Acari : A review. *Insect Biochem. Mol. Biol*., **40** : 563 - 572.

MOHIN, M., 2020, Studies on acaricidal resistance in two-spotted spider mite, *Tetranychus urticae* Koch (Acarina : Tetranychidae) infesting tomato. *M.Sc. (Agri.) Thesis* (Unpub.), Univ. Agric. Sci., Shivamogga.

NAJEER-E-NOOR, S. K. AND SRINIVASA, N., 2018, Resistance of two spotted spider mite, *Tetranychus urticae* Koch to major acaricides and its consequences on biological characteristics of mites. *Mysore J. Agric. Sci*., **52** (2) : 179 - 185.

NAVEENA, K., SHANTHI, M., CHINNIAH, C., JAYARAJ, J., RAMASUBRAMANIAN, T., MINI, M. L. AND RENUKA, R., 2022, Acaricide resistance in field-collected two-spotted spider mite *Tetranychus urticae* Koch. *Indian J. Entomol*., e21228.

RAI, A. B., SATPATHY, S., GRACY, G. R., SWAMY, T. M. S. AND MATHURA, R., 2007, Yellow mite *Polyphagotar sonemus latus* (Banks) menace in chilli crop. *Veg. Sci.*, **34** (1) : 1 - 13.

RANJEETHKUMAR, B. V., 2008, Monitoring acaricide resistance in two spotted spider mite, *Tetranychus urticae* Koch (Acari : Tetranychidae) infesting tomato. *M.Sc. (Agri.) Thesis* (Unpub.), Univ. Agric. Sci., Bangalore.

RAO, A. M., GANESH, P. AND BALARAJU, S., 2020, The leaf curling in capsicum species: a review. *Mysore J. Agric. Sci*, **54** (2) : 1 - 13.

ROY, S., PRASAD, A. K., HANDIQUE, G. AND DEKA, B., 2018, Susceptibility to acaricides and detoxifying enzyme activities in the red spider mite, *Oligonychus coffeae* Nietner (Acari : Tetranychidae). *Acarologia,* **58** (3) : 647 - 654.

SRINIVASAN, M. R., NATARANJAN, N. AND PALANISWAMY, S., 2003, Evaluation of buprofezin 25 SC and fenpyroximate 5 SC against chilli mite, Polyphagotar sonemus latus (Banks). *Int. J. Pl. Prot*., **31** : 116 - 117.

TITIKSHA, R. AND SOOD, A. K., 2019, Determining resistance level to acaricides in field populations of two spotted spider mite, *Tetranychus urticae* in Himachal Pradesh. *Himachal J. Agri. Res*., **45** (1&2) : 62 - 65.

Mysore J. Agric. Sci., 57 (1) : 211-219 (2023)

Assessment of Productivity Potential of Doubled Haploid Lines in Maize (*Zea mays* L.) for Suitability as Parents in Hybrid Development

Noor E. Mujjassim[1], H. C. Lohithaswa[2], Kalmeshwer Gouda Patil[3], A. Mohan Rao[4], Sunil Kumar Biradar[5], Nataraj N. Karaba[6], N. Mallikarjuna[7], K. V. Shalini[8] and S. Mamatha[9]
[1,2 &4]Department of Genetics & Plant Breeding; [6]Department of Crop Physiology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
[3,5,8 & 9]Bayer Cropscience; [7]AICRP on Maize, ZARS, Mandya
e-Mail : mujjassim28@gmail.com

Authors Contribution

Noor E. Mujjassim : Conceptualization, design, material preparation and draft writing;
H. C. Lohithaswa & Kalmeshwer Gouda Patil: Editing and prepration;
S. Mamatha & K.V. Shalini: Curation, analysis of data and tabulation of results;
Sunilkumar Biradar, A. Mohan Rao, Karaba N. Nataraja and N. Mallikarjuna : Supervision and experiment

Corresponding Author :
Noor E. Mujjassim
Department of Genetics and Plant Breeding,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : July 2022
Accepted : December 2022

Abstract

The present study was performed to quantify the amount of variation present in 275 doubled haploid lines developed from the cross CV-29073758 × CV-29073679 and also to understand the distribution pattern for seven yield related traits in maize. Analysis of variance revealed mean squares attributable among and between the DHs and the checks were significant for all the traits. These results suggested significant differences among the maize doubled haploid lines. All the quantitative traits exhibited less than three kurtosis value indicating that the tails of the distribution of these traits are platykurtic. It indicated that genetic control of these traits was influenced by many genes, with the majority of them displaying complementary epistasis with increasing effects. Correlation studies revealed that kernel weight per cob had a significant positive correlation with cob length, cob girth, kernel rows per cob ($p<0.001$) followed by plant height ($p<0.01$) and ear height ($p<0.05$). It indicated that kernel weight per cob can be increased by giving importance to these traits while formulating selection criteria in yield improvement programmes. In the Principal Component Analysis, the first principal component (PC1) showed 30.85 per cent while, PC2 and PC3 exhibited 21.25 per cent and 15.10 per cent variation respectively, among the doubled haploid lines for the traits under study. As indicated by the principal component analysis, the K-mean clustering resulted in three clusters with the cluster B consisted of 118 DH lines followed by cluster A with 110 DH lines. The DH lines with highest values for plant height, ear height, cob girth, cob length, kernel weight per cob and test weight were formed in cluster C. The study was helpful in identifying several superior DH lines which can be used as parents in hybrid development programmes.

Keywords : Maize, Doubled haploids, Correlation, Complementary epistasis, Platykurtic distribution, Principal component analysis, K- means clustering

Maize is one of the most important cereal crops of the world and contributes to food security in most of the developing countries. In India, maize is the third most important crop after rice and wheat. Currently, nearly 1147.7 million MT of maize is being produced together by over 170 countries from an area of 193.7 million ha with average productivity of 5.75 t/ha. As a rapid generation advancement tool, doubled haploid (DH) has decreased the time needed to create maize inbreds from six to seven selfing generations to just two generations. The rapid development of DH lines helps in more reliable selection than lines obtained through consecutive self-pollination because in DH whole genome is duplicated and all its genetic loci are homozygous (Couto *et al.,* 2019).

Morphological characterization and grouping of germplasm is very important to study relationships among cultivars and to identify accessions with desirable traits and also it helps the breeders to avoid duplication in sampling populations. Among the most statistical tools, skewness and kurtosis are more powerful which help us to understand relative mean performance, nature of distribution of traits and for characterizing the nature of epistasis. Fasoulas (1981) considered that departure from normal distribution is an indication of the presence of unfavourable genes that a breeder has to remove during the selection procedure. Yield is a complex trait and is influenced by several component traits and we need to identify those characters that contribute to improvement of kernel yield. Correlation studies provide knowledge of association among different characters and kernel yield (Greveniotis *et al*., 2017).

The principal component analysis is used to evaluate the magnitude of genetic diversity among the germplasm (Guedira, 2000) and cluster analysis is used to classify maize (*Zea mays* L.) accessions and can be used by breeders and geneticists to identify subsets of accessions which have the potential utility for specific breeding or genetic purposes (Rincon *et al*., 1996). The present study was carried out to quantify the genetic variability in maize DH lines, to work out the contribution of different characters to divergence and to classify the DH lines employing K-means clustering.

Material and Methods

Basic Genetic Material and Development of Doubled Haploid Population

The basic genetic material consisted of 275 maize doubled haploid lines developed from the cross CV-29073758 × CV-29073679 along with parental inbreds. The susceptible inbred line (CV-29073758) was crossed with resistant line (CV-29073679) during *kharif* 2020 and F_1 was selfed to obtain F_2 plants. These F_2 plants were crossed with male haploid inducer inbred. The dominant grain purple colour marker gene (R1-nj marker) was employed to separate haploid kernels without pigmentation on embryo and those with pigmentation as regular diploids. The haploid kernels thus separated were placed in the paper towels for germination. When the coleoptiles were about 2-cm long the tip was cut-off and submerged in colchicine solution with Dimethyl Sulphoxide (DMSO). The seedlings were washed under tap water and planted in biodegradable ellepots filled with peat pellets. These pots were kept in the shade house till three-leaf stage and then transplanted in the DH nursery net house and selfed to obtain doubled haploids (DH_1). This process resulted in 275 doubled haploid lines from F_2 plants of the cross CV-29073758 × CV-29073679.

Field Layout

The 275 maize inbred lines and their respective parents as checks were evaluated in the augmented design and checks were repeated after every 20th row of test entries. All the entries were planted in rows spaced 0.60 m apart with an intra-row spacing of 0.20 m at the Mega Breeding Station, Bayer Crop Science Pvt. Ltd., Kallinayakanahalli, Gauribidanur (T), Chikkaballapur (D) 13.464013^0 N, 77.519178^0 E during, 2021 *kharif.* The observations were recorded on five plants in all 275 doubled haploid lines for plant height (PH), ear height (EH), cob girth (CG), cob length (CL), number of kernel rows per cob (KR), kernel weight per cob (KW) and test weight (TW).

Statistical Analysis

The mean of five plants was used to perform the analysis of variance as per augmented design. Descriptive statistics was employed to study the distribution pattern of DH lines with respect to quantitative traits and analysed using R software. Skewness was worked out by using Agostino test and kurtosis and that of fourth-degree statistics by using Anskombi test.

Three types of kurtosis recognised based on the values which depends on the distribution curve.

If kurtosis value = 3 = Normal curve = Mesokurtic

If kurtosis value > 3 = leaping curve = Leptokurtic

If kurtosis value < 3 = Flat curve = Platykurtic

Similarly, the lack of symmetry *i.e.,* skewness was recognised based on the coefficient of skewness values which ranged from -3 to +3. The type of distribution based on the skewness values are as follows.

If skewness value is zero = symmetrical distribution

If skewness value is negative = negatively skewed distribution

If skewness value is positive = positively skewed distribution

Correlation, principal component analysis and K means clustering were performed by using factoshiny and factoextra packages in R software. (Pauline Vaissie, 2021 not found in references).

Results and Discussion

Analysis of variance revealed highly significant differences among doubled haploid lines for all the traits (Table 1). Similarly, a significant mean square due to doubled haploid lines vs checks was also observed. These results suggested the existence of wide variability among the maize doubled haploid lines for all the traits under study. Non-significance of mean squares due to blocks indicated the poor evidence for a detectable effect of edaphic factors and / or micro-environments associated with the blocks for all the traits.

Box and Whisker Plots

Box plot is the way to represent range of numerical data of several traits by constructing box and whisker plots (Tukey, 1977). A box plot can provide information about a sample's range, median, normality of the distribution and skewness of the distribution (Kumar *et al*., 2019). It can also identify and plot extreme cases within the sample. The distribution properties of seven quantitative parameters estimated in doubled haploid population derived from crossing CV-29073758 × CV-29073679 are presented in box plots (Fig.1) depicting the degree of dispersion in the population. Bold lines within boxes indicate median value and box limits indicate interquartile range (*i.e*., 50% of values lie within the box) and whiskers indicate highest and lowest excluding outliers or extremes. In our data set, among seven traits, only cob length, number of kernel rows per cob and cob girth showed very few outliers as indicated by the points outside the whisker.

Test for Skewness and Kurtosis

The results of phenotypic statistics which includes mean, skewness, kurtosis, minimum, maximum are shown in Table 2. The genetic expectation of coefficient of skewness for the distribution of DH lines for plant height, ear height and cob length was positively skewed (Table 2, Fig. 2). Positive skewness indicated the involvement of complementary gene

Table 1

Analysis of variance for seven quantitative traits in 275 maize doubled haploid lines

Source	df	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob girth (cm)	Number of kernel rows/ cob	Kernel weight / cob (g)	Test weight (g)
Blocks	13	178.8 ns	53.53 ns	2.1 ns	0.16 ns	7.56 ns	192 ns	5.72 ns
Checks	2	4657.14 **	1616.67 **	35.41 **	26.60 *	43.76 ns	921.56 *	1832.55 **
Doubled haploids	274	442.9 **	143.23 **	19.28 *	22.65 **	63.09 *	1007.69 **	21.77 **
Doubled haploids vs checks	272	411.92 **	132.4 **	25.34 **	20.27 *	52.12 ns	1008.32 **	20.87 **
Error	26	61.63	33.33	5.12	0.29	4.37	186.06	7.05

ns-non-significant; *, **significant at $P<0.05$, $P<0.01$

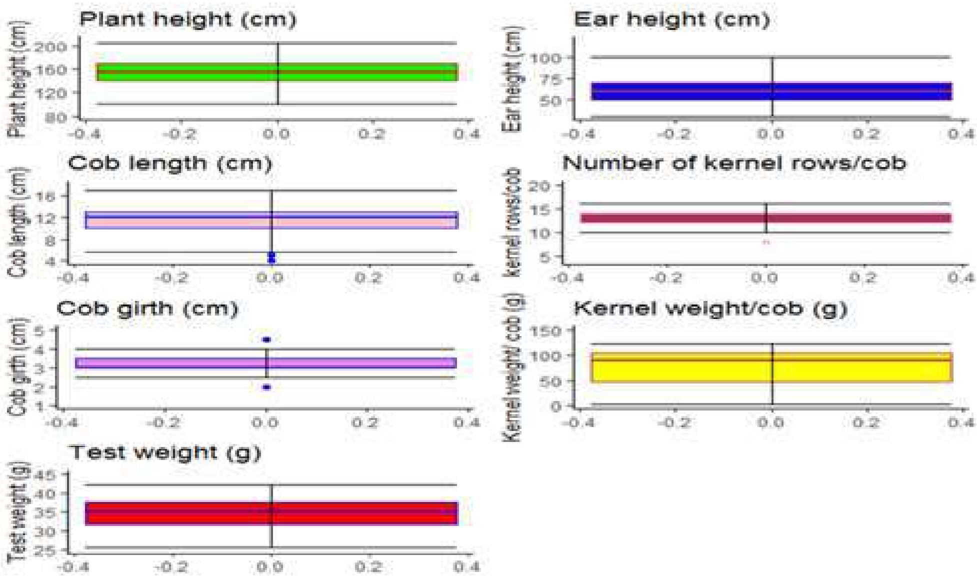


Fig. 1: Box plot depicting the distribution properties of seven quantitative traits in maize doubled haploid population

interactions predominantly in the same direction (Snape and Riggs, 1975).

Similarly, all the quantitative traits exhibited platykurtic distribution (<3.0). It indicated the involvement of many genes, with the majority of them displaying complementary epistasis with increasing effects (Table 2, Fig. 2). Thus, expected genetic gain in such a condition would be slow under mild selection while it is rapid with intense selection. From these statistical values, it was concluded that the seven quantitative traits were controlled by multiple genes. Whereas, platykurtic and negatively skewed distribution recorded for cob length, number of kernel rows per cob, kernel weight per cob and test weight revealed large number of genes displaying duplicate dominant epistasis. Sumathi *et al.* (2018) also has reported positive skewness for cob diameter, 100 grain weight and grain yield per plant in Maize.

Correlation Studies for Yield and Yield Component Traits in Doubled Haploid Population

Selection based on the correlation studies gives an idea about magnitude and direction of association between yield and its attributes. Phenotypic correlations between kernel weight per cob and

Table 2

Descriptive statistics on seven quantitative traits in maize doubled haploid lines

Traits	Mean	Std. Error	Skewness	Kurtosis	Median	Min	Max	Variance
Plant height (cm)	153.4234	1.278	0.0494	-0.1127	155	100	205	445.9668
Ear height (cm)	59.9088	0.765	0.238	-0.1383	60	30	100	160.1194
Cob girth (cm)	3.1989	0.033	0.1794	-0.3335	3	2	4.5	0.3154
Cob length (cm)	11.6204	0.143	-0.4034	0.0307	12	4	16	5.637
Number of kernel rows per cob	12.9781	0.11	-0.4545	-0.1313	14	8	16	3.4229
Kernel weight per cob (g)	75.56	1.99	-0.605	-1.013	89.6	1.9	122.7	1089.91
Test weight (g)	34.5599	0.22	-0.2829	-0.5937	35.025	25.6	42.33	14.3694

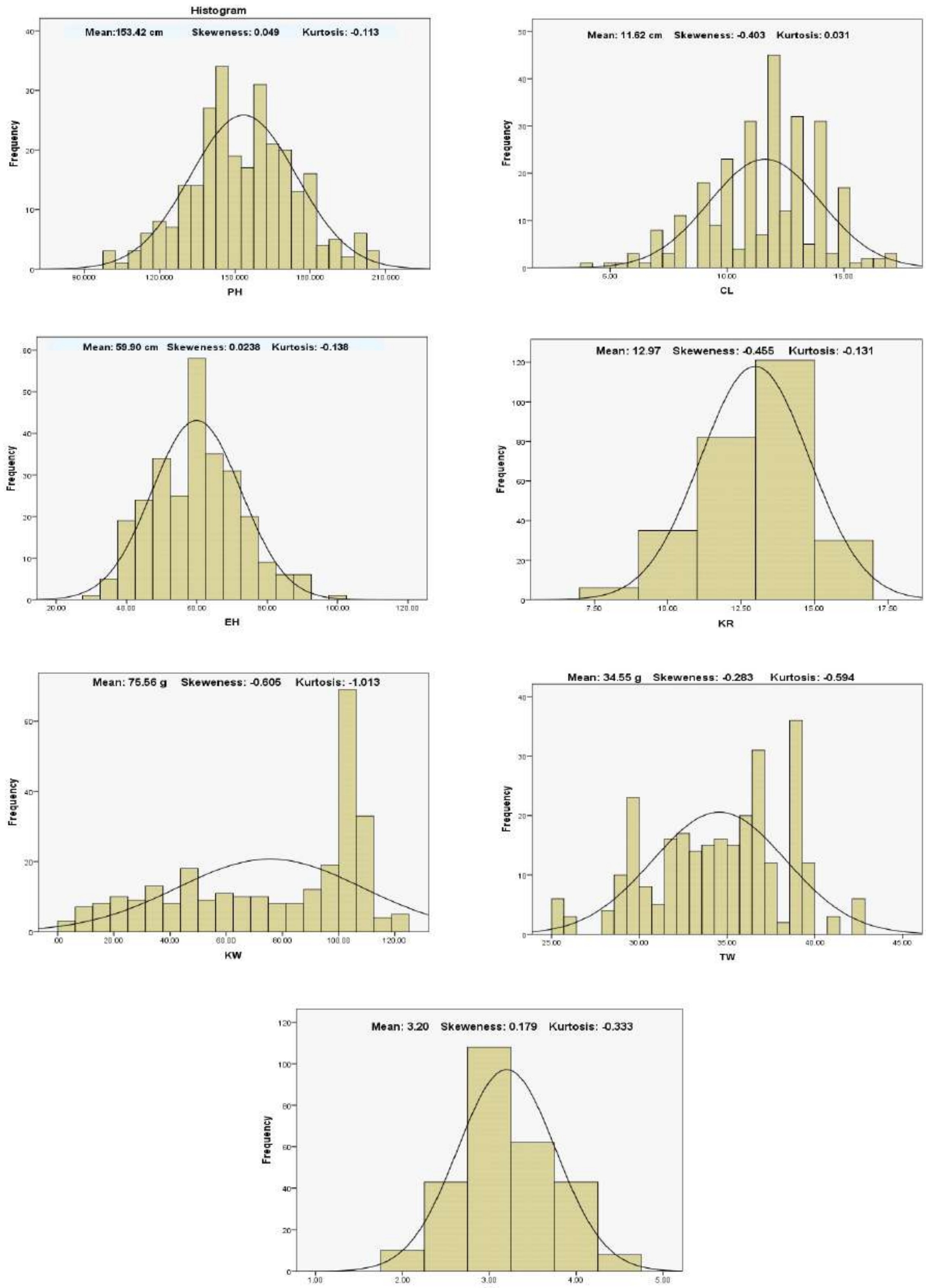


Fig.2: Frequency distribution of seven quantitative traits in maize doubled haploid lines

yield components *viz*., plant height; ear height, cob girth, cob length, number of kernel rows per cob, kernel weight per cob and test weight were computed for doubled haploid population and the results are presented in Fig. 3 & 4. Kernel weight per cob had a significant positive correlation with cob length, cob girth, kernel rows per cob ($p<0.001$) followed by plant height ($p<0.01$), and ear height ($p<0.05$). It indicated that kernel weight per cob can be increased through improvement in characters that showed positive and significant association. Similar results were reported earlier in maize by several workers on different characters *viz*., for the association of kernel yield with plant height (Raghu *et al*., 2011 and Zarei *et al*., 2012), ear height (Raghu *et al*., 2011 and Munawar *et al*., 2013), number of kernel rows per cob (Sofi and Rather, 2007) and 100 grain weight (Raghu *et al*., 2011, Nataraj *et al*., 2014 and Zarei *et al*., 2012).

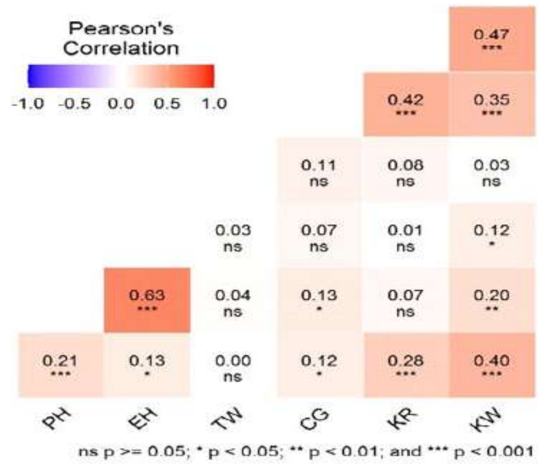


Fig. 3: Pearson correlations among seven morphological traits in doubled haploid population in maize (*Zea mays* L.)

Principal Component Analysis (PCA)

PCA was performed on the data recorded on seven quantitative characters in 275 maize DH lines. Out of seven principal components (PCs) three exhibited more than 1.00 eigen value and showed about 67.22 per cent cumulative variability among the traits studied. Eigen values of three principal component axes and percentage of variation obtained from the principal component analysis are presented in Table 3. The PC1 exhibited 30.87 per cent while, PC2 and PC3 exhibited 21.25 per cent and 15.10 per cent variability, respectively among the doubled haploids for the traits under study.

Individual Trait Contribution to Total Germplasm Variability

Starting with the first PC, the plot sloped steeply downward initially and then became approximately horizontal line. The point at which the curve first began to straighten out was considered to indicate the maximum number of components indicated in Fig.5. (Kumawat *et al*., 2021)

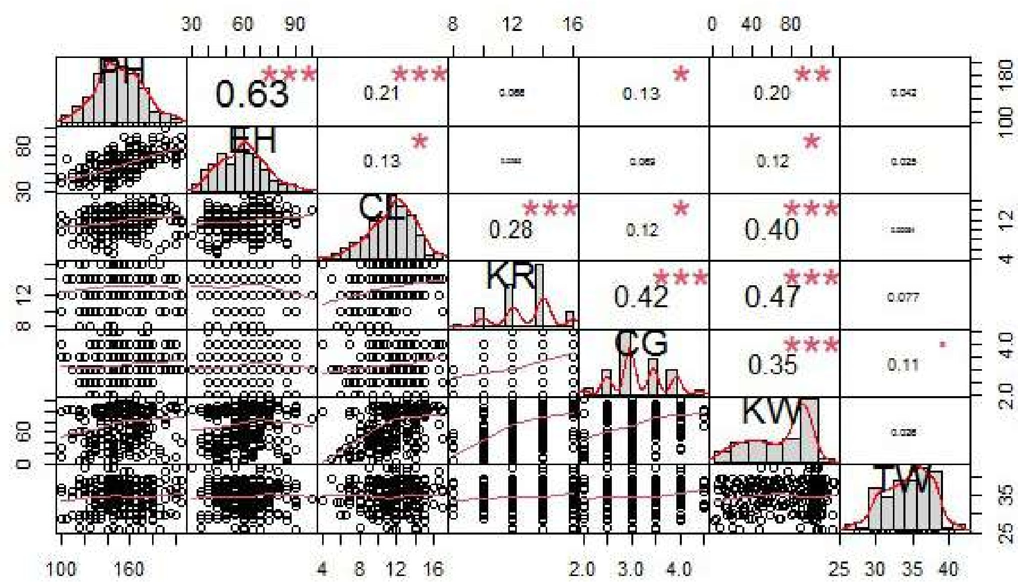


Fig. 4: Scatter plot with correlation values of seven quantitative traits in doubled haploid population in maize (*Zea mays* L.)

TABLE 3

Per cent variability explained by the seven eigen vectors

Parameters	PC1	PC2	PC3
Eigen values	2.16	1.487	1.057
% Variance explained	30.86	21.24	15.10
cumulative % variance	30.86	52.11	67.22
Plant height	15.22	32.05	0.09
Ear height	10.06	39.32	0.22
Cob length	15.78	0.34	9.51
Cob girth	15.60	7.00	9.24
Kernel rows per cob	20.13	15.53	0.45
Kernel weight per cob	22.67	5.69	5.91
Test weight	0.49	0.03	4.55

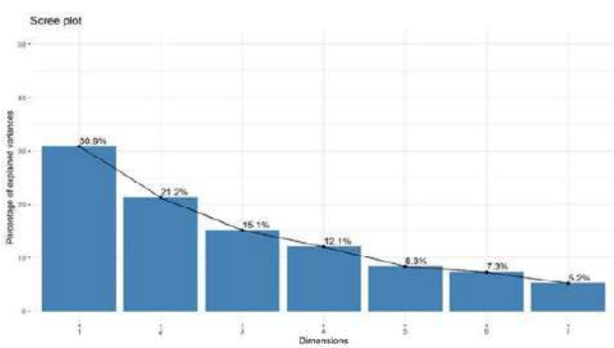


Fig. 5: Scree plot illustrating eigen values corresponding to seven extracted principal components

It could be seen from the first vector that the characters plant height (15.22), ear height (10.07), cob length (15.78), cob girth (15.61), kernel rows per cob (22.67), kernel weight per cob (22.67) and test weight (0.49) displayed positive contribution towards genetic divergence. The characters that contributed to the second component include plant height (32.05), ear height (39.32), cob length (0.35), cob girth (7.00), kernel rows per cob (15.53), kernel weight per cob (5.69) and test weight (0.03). PC III accounted 15.14 per cent of the total variability. The traits plant height (0.09), ear height (0.22), cob length (9.51), cob girth (9.24), kernel rows per cob (0.45), kernel weight per cob (5.91) and test weight (4.55) displayed positive contribution towards genetic diversity. Maji & Shaibu (2012) used PCA to categorize traits of maize (*Zea mays* L.) that contributed for most of the variance in the data.

The biplot diagram between PC 1 and PC 2 explained the distribution and the nature of diversity for both variables and the genotypes (Fig. 6). The genotypes which are close to the origin contributed less to the total genetic variance, whereas those genotypes away from the origin contributed more to the total variance.

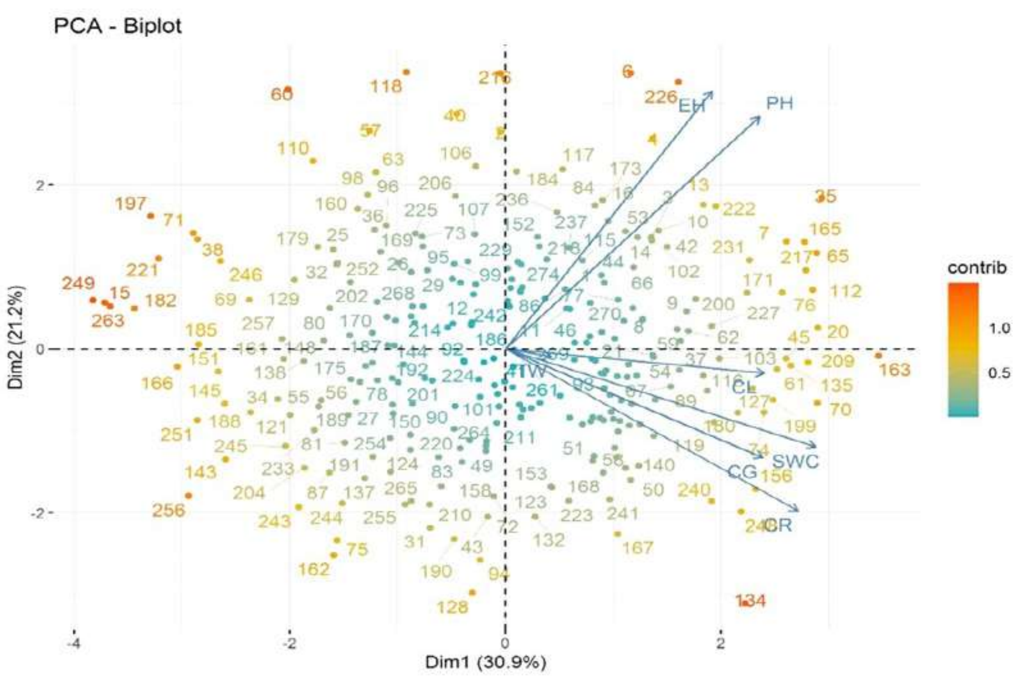


Fig. 6 : A genotype by trait bi-plot representing 275 doubled haploid maize lines distribution

Similar kind of observation was made by Swapnil *et al*. (2021). The traits plant height and ear height were found to be positively associated (an acute angle) and they were independent of cob length, cob girth, number of kernel rows per cob, kernel weight per cob and test weight. The bi-plot diagram exhibited high variability among the genotypes and between the parameters. (Yugandhar *et al*., 2018).

The K-mean clustering grouped the 275 DH lines in to three clusters (Table 4, Fig. 7). Cluster-C comprised of 32 doubled haploid inbred lines which showed maximum plant height (175.65), ear height (73.59), cob girth (3.51), cob length (12.53), kernel weight per cob (92.37) and test weight (35.64). Cluster-B consisted of 118 inbred lines with similar performance for morphological trait *i.e.* number of kernel rows per cob (13.77). Cluster-A had 110 genotypes characterized by the features such as the lowest plant height (145.64), ear height (56.06), cob girth (2.92), cob length (10.43), kernel weight per cob (59.65) and test weight (33.95). Since cluster C consisted of lines superior for kernel weight and other major productivity traits, these DH lines can be used in the development of superior hybrids.

TABLE 4

Cluster Mean of doubled haploid inbred lines included in three different K-clusters

Traits	Cluster A	Cluster B	Cluster C
PH (cm)	145.64	153.19	175.65
EH (cm)	56.06	59.27	73.59
CG (cm)	2.92	3.4	3.51
CL (cm)	10.43	12.36	12.53
KR	11.96	13.77	13.31
KW (g)	59.65	83.64	92.37
TW (g)	33.95	34.5	35.64

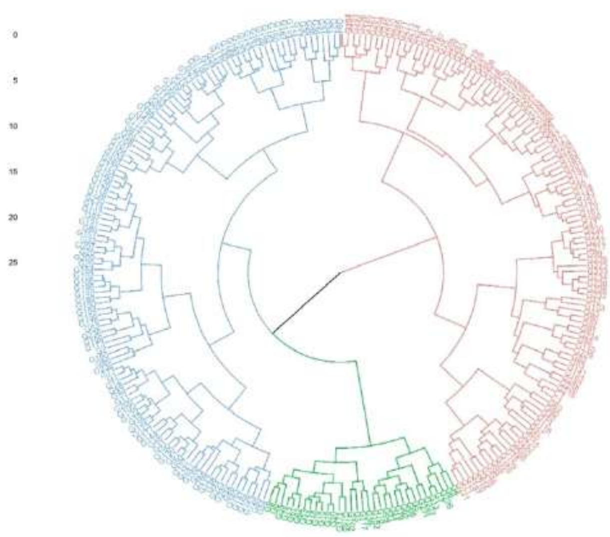


Fig. 7: K- means clustering of 275 doubled haploid lines

All the quantitative traits exhibited platykurtic distribution (< 3.0). It indicated the involvement of many genes, with the majority of them displaying complementary epistasis with increasing effects. The present investigation of PCA analysis revealed that the genotypes which are close to the origin in biplot, contributed less to the total genetic variance whereas those genotypes away from the origin contributed more to the total variance and also recorded better *per se* performance for the plant height, EH, CL, CG, KR, KW and TW(expand the terms). So, these genotypes could be used to develop heterotic hybrids in future maize breeding programme. Kernel weight per cob had a significant positive correlation with cob length, cob girth, kernel rows per cob followed by plant height and ear height. It indicated that kernel weight per cob can be increased through improvement in characters that showed positive and significant association. By K-means clustering its concluded that cluster C consisted of lines superior for kernel weight and other major productivity traits, these DH lines can be used in the development of superior hybrids.

Acknowledgement : The authors acknowledge financial assistance from Prime Minister's Fellowship for Doctoral Research, SERB- CII and industry partner Bayer Cropscience Pvt. Ltd.

REFERENCES

BROWN-GUEDIRA, G. L., 2000, Evaluation of genetic diversity of soybean introductions and North American ancestors using RAPD and SSR markers. *Crop Sci*., **40** : 815 - 823.

COUTO, E. G. D. O., CURY, M. N., BANDEIRA, E. SOUZA, M., GRANATO, I. S. C. AND VIDOTTI, M. S., 2019, Effect of

F_1 and F_2 generations on genetic variability and working steps of doubled haploid production in maize. *PLoS ONE*., **14** (11) : e0224631.

FASOULAS, A. C., 1981, Principles and methods of plant breeding. *Arist. Univ. Thessaloniki*, pp. : 147.

GREVENIOTIS, V., SIOKI, E. AND IPSILANDIS, C. G., 2017, Frequency distribution analysis of a maize population. *Cereal. Res. Commun*., **45** (4) : 687 - 698.

KUMAR, R., MISHRA, T. K. AND PRADHAN, B., 2019, Studies on frequency distribution, skewness and kurtosis in F_1 M_1 mutant populations of sesame. *Int. J. Curr. Microbiol. App. Sci*., **8** (4) : 1755 - 1760.

KUMAWAT, G., SHAHI, J. P., CHANDRA, K., CHOUDHARY, M. K., SINGAMSETTI, A. AND KOLI, G. K., 2021, Multivariate analysis of maize genotypes grown under water logging stress. *J. Crop Weed*, **17** (2) : 129 - 136.

MAJI, A. T. AND SHAIBU, A. A., 2012, Application of principal component analysis for rice germplasm characterization and evaluation. *J. Plant Breed. Crop Sci*., **4** : 87 - 93.

MUNAWAR, M., SHAHBAZ, M., HAMMAD, G. AND YASIR, M., 2013, Correlation and path analysis of grain yield components in exotic maize (*Zea mays* L.) Hybrids. *Int. J. Sci. Basic Appl. Res*., **12** (1) : 22 - 27.

NATARAJ, V., SHAHI, J. P. AND AGARWAL, V., 2014, Correlation and path analysis in certain Inbred genotypes of maize (*Zea Mays* L.) at Varanasi. *Int. J. Innov. Res*., **3** (1) : 14 - 17.

PAULINE, V., 2021, Perform factorial analysis from 'FactoMineR' with a shiny application. http://factominer.free.fr/graphs/factoshiny.htmlPauline Vaissie.

RAGHU, B., SURESH, J., KUMAR, S. S. AND SAIDAIAH, P., 2011, Character association and path analysis in maize (*Zea mays* L.). *Madras Agric. J*., **98** : 7 - 9.

SWAPNIL, JAISHREEPRIYANKA, R., SINGH, D. AND MANDAL, S. S., 2021, Principal component analysis in maize (*Zea mays* L.) under normal sown condition of Bihar. *J. Pharm. Innov*., **10** (10) : 641 - 644.

SNAPE, J. W. AND RIGGS, T. J., 1975, Genetical consequences of single seed descent in the breeding self-pollinated crops. *Heredity.,* **35** : 211 - 219.

SOFI, P. AND RATHER, A. G., 2007, Studies on genetic variability, correlation and path analysis in maize (*Zea mays* L.). *Maize Genetic Cooperation Newsletter*, **81** : 26 - 27.

SUMATHI, K., NATESAN, S. AND GANESAN, K. N., 2018, Studies on skewness and kurtosis of sorghum downy mildew resistant BC3F3 progenies in maize. *Int. J. Curr. Microbiol App. Sci*., **7** (6) : 3834 - 3838.

TUKEY, J. W., 1977, Exploratory data analysis. Addison-Wesley Pub. Co., **26** : 163 - 182.

YUGANDHAR, P. R., KOTA, S., KIRAN, B. AND SRIDHAR, M., 2018, Principal component analysis for agro morphological and quality characters in germplasm of rice (*Oryza sativa* L.). *Int. J. Adv. Biol. Res*., **8** (2) : 268 - 273.

ZAREI, B., KAHRIZI, D., ABOUGHADARESH, A. P. AND SADEGHI, F., 2012, Correlation and path coefficient analysis for determining interrelation ships among grain yield and related characters in corn hybrids. *Int. J. Agric. Crop Sci*., **4** (20) : 1519 - 1524.

Mysore J. Agric. Sci., 57 (1) : 220-228 (2023)

Resistance Response of Local Landraces and Advanced Rice Genotypes to Paddy Caseworm, *Nymphula depunctalis* (Guenee) under Field Condition

PANDIT[1], L. VIJAYKUMAR[2], M. THIPPAIAH[3], B. SHIVANNA[4], C. N. LAKSHMINARAYANA REDDY[5] AND R. KRISHANAMURTHY[6]

[1,3&4]Department of Agricultural Entomology; [5]Department of Plant Pathology, [6]Department of Soil Science, College of Agriculture, UAS, GKVK, Bengaluru - 560 065

[2]Department of Agricultural Entomology, College of Agriculture, V.C. Farm, Mandya

e-Mail : jatagondapandit@gmail.com

AUTHORS CONTRIBUTION

PANDIT : Conceptualization, investigation, draft preparation and analysis;

L. VIJAYKUMAR: Conceptualization, framing research proposal and data curation ;

M. THIPPAIAH & B. SHIVANNA: Data curation and draft correction;

C. N. LAKSHMINARAYANA REDDY & R. KRISHANAMURTHY : Supervision and draft correction

Corresponding Author :

PANDIT

Dept. of Agril. Entomology, College of Agriculture, UAS, GKVK, Bengaluru

Received : August 2022

Accepted : October 2022

ABSTRACT

Field screening was carried out on fifty landraces and 38 AVT (advanced varietal trail) rice genotypes compared with resistant and susceptible check, against paddy caseworm, *Nymphula depunctalis* (Guenee) at the Agriculture College V. C. Farm Mandya, in two seasons, during late *kharif* 2020 and *summer* 2021. The mean per cent leaf damage by paddy caseworm on different genotypes was evaluated at 30 and 50 days after transplanting (DAT) in two seasons and the genotypes were categorized into resistant or susceptible based on the standard evaluation system for rice (SES-IRRI). Out of 50 land races, 20 land races were reacted as resistant by recording up-to 1 per cent of leaf damage, 9 genotypes showed moderately resistant reaction by recording 1-10 per cent leaf damage, 13 genotypes reacted as moderately susceptible (11-25 % leaf damage) and 8 genotypes have shown susceptible reaction with 26-50 per cent leaf damage. Likewise, among AVT genotypes, 12 genotypes found resistant with less than 1 per cent leaf damage, 14 genotypes reacted as a moderately resistant by recording up-to 10 per cent leaf damage and only 11 genotype was found moderately susceptible (11-25 % leaf damage). None of the landraces and AVT rice genotypes found highly resistant or highly susceptible against paddy caseworm.

Keywords : Screening, Local landraces and AVT genotypes, Paddy caseworm

RICE (*Oryza sativa* Linn.) is the staple food of more than half of the world's population (Kulagod *et al.,* 2011). Rice belongs to the genus Oryza, family 'Poaceae' (Gramineae), it contributes about 40 per cent of the total food grain production. More than 92 per cent of the world's rice is produced and consumed in Asia. Rice covers about one-fourth of the total cropped area and provides food for more than half of the Indian population. United Nations designated the year 2004 as the 'International Year of Rice' because of its importance. Asia's rice production mainly depends on irrigated rice fields, which produce 75 per cent of all rice harvested, and it provides bout 700 calories day^{-1} person^{-1} for about 3000 million people living mostly in developing countries (Sangeetha and Baskar, 2015).

In India, rice is being grown in an area of 43.66 m ha with an annual production of 118.87 mt and productivity of 2722 kg ha^{-1}, and it is the second-largest producer and consumer of rice after China in the world. In Karnataka Rice is being cultivated in an area of 1.18 m ha with a production of 3.63 mt and productivity of 3.07 t ha^{-1} (Anonymous., 2020). India ranks first in area and production, and is majorly cultivated in West Bengal, Andhra Pradesh, Tamil Nadu, Orissa, Chhattisgarh, Punjab, Uttaranchal, Bihar, Uttar Pradesh, Haryana and Assam.

In modern agriculture, high-yielding rice varieties are extensively grown with the use of fertilizers and manures. Such a cultivation pattern of rice accidentally or inadvertently offers infestation of a large number of insect pests, which results in severe loss in crop yields. (Neeta *et al.,* 2013). The rice crop is subjected to the persistent pressure of more than 100 different insect species (Khan & Pathak, 1987) and 20 of them are of major economic significance (Pathak & Khan, 1994).

Rice is attacked by several insect pests from nursery to harvest, which cause severe yield loss across the countries. In India, the major constraints of rice production is the occurrence of insect pests at various stages of crop growth. Among the insect pests, the most important and widely distributed pest species are stem borer (Scirpophaga incertulas Walker), planthoppers, (BPH, WBPH and GLH) and defoliators like, leaf folder (Cnaphalocrocis medinalis Guenée), paddy caseworm (Nymphula depunctalis Guenee) and rice horned caterpillar (Melanitis leda ismene Cramer) (Salim, 2002). The average yield loss in rice due to various insects pest estimated to be 31.5 per cent in Asia (Pathak & Khan, 1994).

Caseworm (Nymphula depunctalis Guenee) is a sporadic pest of rice and found in water stagnant condition. The first sign of caseworm is the characteristic cut leaves; the leaf blades are cut as if it is cut by scissors. Cut leaf sections are used by the larvae to make their protective tubular cases. Cut leaf blades naturally roll up into a tube, which the larvae attach with silk (Shepherd *et al.,* 1995). During the outbreak of leaf folder and caseworm, a yield reduction of 30 per cent was reported from severely damaged fields. So far, chemical control is the only practical method available for the farmer for its management and as the damage caused by insect pests is highly visible to farmers, it triggers them to go for toxic insecticide application.

Growing resistant variety plays a major role in the management of insects, especially in low input farming situations of India. It is also highly compatible with all other methods of pest management. Keeping this in view, the present study was undertaken to screen the genotypes for resistance to paddy caseworm under field conditions.

Material and Methods

The studies on field evaluation of local landraces and AVT (advance varietal trials) rice genotypes, for resistance against paddy caseworm in rice was carried out by comparing with BR-6255 and TN-1 as a standard resistant and susceptible check, at 'A' bock, College of Agriculture, V.C. Farm, Mandya, UAS, GKVK, Karnataka during *kharif* 2020 and summer 2021.

Sources of Materials : A total of 50 local landraces of rice (Table 2) along with advanced rice genotypes (AVT), (Table 3) were collected from Zonal Agricultural Research Station, V.C. Farm Mandya and sown separately, for evaluation. The seedlings of landraces and AVT genotypes with 25 days old have been transplanted in 2 rows of 25 hills with the spacing 20 × 15 cm between rows and plants, respectively. Each entry was raised as per package of practice, except the plant protection measures (Anonymous, 2016). To enhance the incidence, a steady water level of 5 inches was maintained and 30 per cent excess urea was applied in the experimental field (Kulagod *et al.,* 2011).

The observation on a number of damaged leaves (white horizontal scrapping) was recorded from randomlly10 hills in each test entry, on 30 and 50 days after transplanting (DAT) following the method developed by International rice research institute, Los Banos, Philippines (Anonymous, 2013). The mean per cent leaf damage of two season, was calculated in each entry and it was converted to 0-8 scale using the standard evaluation system (SES) for rice (Anonymous, 2013). Based on the level of infestation, rice genotypes were grouped into different resistance categories for interpretation (Table 1).

Statistical Analysis : The data set on per cent leaf damage by paddy caseworm was subjected to Microsoft excel for tabulation of data and calculation of simple mean and standard deviation.

TABLE 1

The standard evaluation system for paddy caseworm in rice (IRRI, 2013)

Scale	Damaging rate	Resistance category
0	No Scrapping	Highly Resistant
1	Less than 1%	Resistant
3	1-10 %	Moderately Resistant
5	11-25 %	Moderately susceptible
7	26-50 %	Susceptible
9	51-100 %	Highly Susceptible

RESULTS AND DISCUSSION

In the present investigation, on a resistance-susceptibility test, a total of 50 local landraces and 38 AVT of rice were screened for per cent leaf damage by paddy caseworm during *kharif* 2020 and Summer 2021 and were grouped into different resistance categories based on 0-8 scale using by standard evaluation system (SES) for rice.

In *Kharif* 2020

Results revealed that, among 50 local landraces studied, the per cent leaf damage of paddy caseworm was recorded varied from 0.20 ± 0.09 to 47.10 ± 10.12 per cent, similarly the per cent leaf damage recorded among 38 AVT genotypes, varied from *i.e.,* minimum to maximum mean per cent of leaf damage were noticed 0.12 ± 0.11 to 31.10 ± 15.07 (Table 2 & 3) respectively.

Among local landraces screened, none of varieties were found Highly Resistant (HR) with score '0' *viz.*, no per cent leaf damage. The Minimum per cent leaf damage was recorded Kari kagga (0.20) with score 1 and Resistance category, whereas resistant check *i.e.,* BR-6255 recorded 0.37 per cent leaf damage, among local landraces, 20 varieties showed resistance, 9 were moderately resistant, 13 moderately susceptible and 8 susceptible and highest per cent leaf damage was found in Navara (47.10) as compared with susceptible check *viz.,* TN-1 (42.07%) (Table 2 and fig. 1) respectively.

Among the AVT genotypes evaluated, here also, none of the genotypes showed highly resistant reaction but in AVT- 11 (0.12) recorded least per cent leaf damage & it is less than standard resistant check (BR-6255). Overall, 12 genotypes showed resistance with leaf damage ranging from 0.12 to 0.56 per cent. Further 14 genotypes showed moderately resistant reaction with 3.52 to 10.49 per cent damage. The moderately susceptible reaction was ranged from 11.92 to 16.14 per cent leaf damage. Whereas, one of the AVT genotypes *i.e.,* AVT-IM-6 reacted as susceptible with 31.10 per cent leaf damage which less than the susceptible check and none of AVT genotypes reacted as highly susceptible (Table 3 and Fig. 2).

In Summer 2021

During summer 2021, the leaf damage among the local landraces screened varied from 0.40 ± 0.99 to 59.73 ± 0.77 per cent in Karikagga and Kundipullana respectively. And where in 38 AVT rice genotypes screened, the per cent leaf damage varied between 0.45 ± 0.30 and 35.21 ± 13.56 per cent in AVT-IM-4and AVT-IM-6, wherein resistant and susceptible check *i.e.,* BR-6255 and TN-1, the per cent leaf damage was recorded from 0.72 ± 0.55 and 53.65 ± 5.23 and some of these evaluated genotype *i.e.,* Karikagga, Nagaland paddy, AVT-IM-4 and AVT-IM-7, *etc.,* which shown under resistant category less than resistant check variety respectively, (Table 2 & 3).

Out of 50 landraces screened, during summer 2021, none of them were found highly resistant. Whereas some landraces showed resistant reaction with range of 0.40 to 0.98 per cent leaf damage and majority of landraces were found to be moderately resistant with leaf damage ranging from 3.97 to 9.51 per cent in Rajbhoga and Talasiva. 13 landraces showed moderately susceptible reaction with ranged from 14.82 to 22.79 per cent leaf damage in Mapilai samba 1 and Neermullare. The landraces *viz.,* Jig madike, Chinaponna -2, Kalaieera, Aishwarya and Kana kunja recorded 28.75, 28.85, 35.05, 36.22 and 39.91 per cent damage respectively and were categorized as susceptible. Navara, Krishnaleela and Kundipullan of variety was recorded as Highly susceptible with greater than 50 per cent leaf damage respectively (Table 2 and Fig. 3).

TABLE 2

Screening of different local landraces of rice to paddy caseworm (*N. depunctalis*) under field condition, *kharif* 2020 and summer 2021

Genotypes	Per cent of leaf damage			Score	Resistance Category
	Kharif 2020 (Mean ± SD)	Summer 2021 (Mean ± SD)	Mean		
Kavekantak	0.38 ± 0.92	0.57 ± 1.99	0.47	1	R
GK-5	16.72 ± 2.27	18.09 ± 7.55	17.41	5	MS
Gangadale	0.42 ± 0.13	0.59 ± 1.47	0.50	1	R
Talasiya	5.41 ± 2.66	9.51 ± 2.2	7.46	3	MR
Neermulka	0.49 ± 0.88	0.87 ± 0.93	0.71	1	R
Karimundaga	0.23 ± 0.87	0.73 ± 1.73	0.48	1	R
Manjula sona	17.24 ± 0.91	19.53 ± 0.74	18.38	5	MS
Naweli	0.33 ± 0.66	0.81 ± 0.89	0.57	1	R
Jig madike	27.02 ± 0.77	28.75 ± 0.9	27.88	7	S
Game	22.37 ± 0.73	21.95 ± 0.5	22.16	5	MS
Khushiadhikshan	0.53 ± 0.89	0.66 ± 0.83	0.86	1	R
Kalajeera	28.74 ± 0.67	35.05 ± 0.68	31.89	7	S
Rahodaya	5.72 ± 0.73	7.35 ± 0.82	6.54	3	MR
Chinaponna 2	24.4 ± 0.99	28.85 ± 0.76	26.62	7	S
Neermullare	16.39 ± 0.82	22.79 ± 0.73	19.59	5	MS
Aishwarya	32.21 ± 0.95	36.22 ± 0.79	34.21	7	S
Marabattu-2	0.30 ± 0.92	1.04 ± 0.70	0.67	1	R
Krishnaleela	43.81 ± 0.28	53.78 ± 0.84	48.79	7	S
Tagarli	7.89 ± 0.65	8.56 ± 0.53	8.22	3	MR
Malgudi sanna 2	0.47 ± 0.72	1.17 ± 0.75	0.82	1	R
Kaggali keerana	21.67 ± 0.68	21.58 ± 0.74	21.62	5	MS
Bangara gandu	16.62 ± 0.69	18.66 ± 0.77	17.64	5	MS
Kana kunja	34.31 ± 0.87	39.91 ± 0.94	37.11	7	S
Kundipullan	36.52 ± 1.88	59.73 ± 0.77	48.12	7	S
PSB 87	19.63 ± 0.71	22.04 ± 0.77	20.83	5	MS
Nirga samba	0.57 ± 0.39	1.19 ± 0.54	0.88	1	R
Bangara kale	20.03 ± 0.75	21.85 ± 0.63	20.94	5	MS
Jenugudu	0.52 ± 1.27	0.98 ± 1.79	0.75	1	R
Kalakoli	0.76 ± 1.25	0.45 ± 0.71	0.60	1	R
Black sticky	15.74 ± 0.82	22.76 ± 0.67	19.25	5	MS
Chinaponni	9.05 ± 0.6	7.41 ± 0.84	8.23	3	MR
Volbogsugandha	9.61 ± 0.63	8.56 ± 0.79	9.08	3	MR
Punkattkodi-1	8.25 ± 1.04	6.79 ± 0.52	7.52	3	MR
Punkattkodi-2	0.24 ± 1.04	1.51 ± 2.11	0.85	1	R
Murkanna sanna	0.48 ± 1.07	0.96 ± 1.73	0.72	1	R
Dunda	9.11 ± 1.51	8.69 ± 0.97	8.9	3	MR

Genotypes	Per cent of leaf damage			Score	Resistance Category
	Kharif 2020 (Mean ± SD)	Summer 2021 (Mean ± SD)	Mean		
Mapilai samba 1	14.81 ± 1.28	14.82 ± 2.37	14.82	5	MS
GK-1	0.25 ± 0.99	0.64 ± 1.08	0.44	1	R
Mapilai samba 2	0.4 ± 0.70	0.49 ± 1.35	0.46	1	R
Puttabatta 2	0.31 ± 0.53	0.58 ± 0.15	0.60	1	R
Nagaland paddy	0.36 ± 0.21	0.52 ± 1.55	0.44	1	R
Narali	0.41 ± 1.04	0.67 ± 1.29	0.54	1	R
Raj bhoga	7.49 ± 2.38	3.97 ± 2.05	5.73	3	MR
Nalibatta	14.2 ± 3.92	18.28 ± 5.89	16.24	5	MS
Sanbag	15.38 ± 4.24	17.89 ± 6.3	16.64	5	MS
That jasmine	9.05 ± 2.81	10.58 ± 8.36	9.81	3	MR
Navara	47.10 ± 10.12	52.68 ± 8.4	49.89	7	S
Kyasare 1	0.35 ± 1.12	0.60 ± 1.55	0.47	1	R
Adribatta	15.16 ± 8.33	20.71 ± 10.03	17.93	5	MS
Kari kagga	0.20 ± 0.09	0.40 ± 0.99	0.30	1	R
BR-2655(Resistant check)	0.37 ± 0.23	0.72 ± 0.55	0.54	1	R
TN-1 (Susceptible)	42.07 ± 3.23	53.65 ± 5.23	47.86	7	S

DAT - Days after transplanting; Score= 0- Highly resistant (HR) (0 % leaf damage); 1- Resistant (R) (Less than 1 % Leaf damage); 3- Moderately resistant (MR) (1-10 % leaf damage); 5- Moderately susceptible (MS) (11-25 % leaf damage); 7-Susceptible (S) (26-50 % leaf damage); 8- Highly susceptible(HS) (51-100 % leaf damage) (IRRI, 2013)

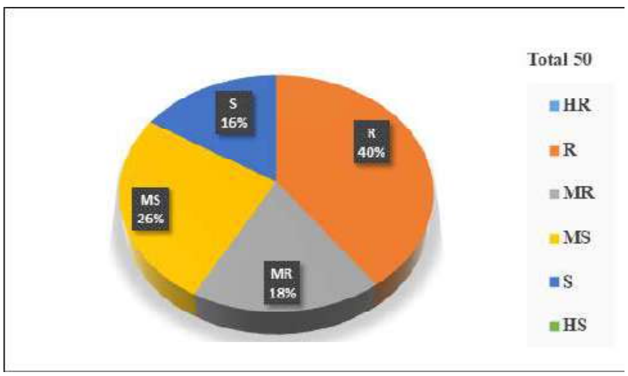


Fig. 1 : Per cent of genotypes under different resistance category (local landraces)

Among AVT genotypes, none of them showed a highly resistant reaction, 7 genotypes showed resistance reaction with 0.45 to 0.85 per cent damage, 10 genotypes were found moderately resistant against caseworm damage (7.18 to 10.21%). 10 genotypes were found to show moderately susceptible reactions with range from 14.46 to 22.09 per cent leaf damage, respectively. Further, only one genotype (Nattijaddu) showed a susceptible reaction (31.13 %) and none of them were found highly susceptible (Table 3 and Fig. 4)

Among the evaluated local landraces and AVT genotypes, the majority of the genotypes categorized into resistant, moderately resistant and few genotypes showed moderately susceptible in *kharif* 2020 and summer 2021, which was compared with resistant and susceptible check.

The overall mean of per cent leaf damage of both seasons were recorder and categorized into resistant to susceptible category, the majority of the genotypes *viz.,* 20 local landraces and 12 AVT were found Resistant, 9 and 14 local and AVT genotype under moderately resistant, whereas moderately susceptible *i.e.,* 13 and 11 local landraces and AVT genotypes were recorded, none of varieties were found Highly Resistant and Highly Susceptible and these compared with by using resistant and susceptible check *i.e.,* BR-6255 and TN-1, these varieties used as resistant and susceptible check for screening against leaf folder

TABLE 3

Screening of AVT rice genotypes to paddy caseworm (*N. depunctalis*) under field condition, *kharif* 2020 and summer 2021

Genotypes	Per cent of leaf damage			Score	Resistance Category
	Kharif 2020 (Mean ± SD)	Summer 2021 (Mean ± SD)	Mean		
AVT-IM-2	4.3 ± 3.71	7.56 ± 3.79	5.19	3	MR
AVT-IM-16	16.14 ± 5.54	16.24 ± 8.49	12.64	5	MS
AVT-IM-11	0.12 ± 1.63	1.31 ± 1.13	0.71	1	R
AVT-IM-15	5.2 ± 3.15	8.02 ± 4.45	5.46	3	MR
AVT-IM-24	10.49 ± 4.72	14.11 ± 5.57	9.77	3	MR
AVT-IM-19	3.8 ± 4.37	10.81 ± 6.81	6.32	3	MR
AVT-IM-3	10.34 ± 4.91	13.09 ± 8.21	9.45	3	MR
AVT-IM-6	31.1 ± 15.07	35.21 ± 13.56	27.13	7	S
AVT-IM-22	14.77 ± 6.98	22.09 ± 6.58	14.61	5	MS
AVT-IM-5	0.31 ± 1.31	0.70 ± 0.56	0.50	1	R
AVT-IM-20	0.32 ± 0.99	0.85 ± 1.15	0.58	1	R
AVT-IM-4	0.28 ± 1.75	0.45 ± 0.3	0.36	1	R
AVT-IM-17	0.36 ± 0.67	0.55 ± 1.11	0.45	1	R
AVT-IM-18	3.52 ± 3.34	7.84 ± 4.63	4.9	3	MR
AVT-IM-7	0.22 ± 0.36	0.49 ± 1.55	0.35	1	R
AVT-IM-9	13.19 ± 8.36	14.24 ± 8.07	11.93	5	MS
AVT-IM-10	0.24 ± 0.17	1.08 ± 1.33	0.66	1	R
AVT-IM-28	12.49 ± 8.53	15.14 ± 8.34	12.05	5	MS
AVT-1 IM-2	11.92 ± 7.91	15.08 ± 10.85	11.63	5	MS
AVT-30	14.01 ± 10.25	15.66 ± 10.53	13.3	5	MS
AVT-8	5.68 ± 4.06	7.68 ± 6.51	5.81	3	MR
AVT-14	5.32 ± 3.38	10.59 ± 4.85	6.43	3	MR
AVT-25	0.25 ± 0.11	1.25 ± 1.58	0.75	1	R
AVT-27	4.2 ± 2.8	8.5 ± 6.97	5.17	3	MR
AVT-12	5.44 ± 4.51	9.01 ± 5.5	6.32	3	MR
AVT-13	13.75 ± 8.12	16.63 ± 7.68	12.83	5	MS
Nattijaddu	28.57 ± 14.46	31.13 ± 8.9	24.72	5	MS
Hanasu	3.98 ± 2.98	7.18 ± 5.74	4.71	3	MR
BPT-5204	13.77 ± 8.67	14.46 ± 8.96	12.3	5	MS
Ative	8.15 ± 4.37	10.21 ± 5.18	7.58	3	MR
GMS-1	0.38 ± 0.22	0.50 ± 1.64	0.44	1	R
Halaga	15.29 ± 8.48	16.14 ± 8.52	13.3	5	MS
Masali	5.59 ± 3.7	8.77 ± 8.58	6.02	3	MR
Kavame	15.74 ± 3.19	20.52 ± 9.88	13.15	5	MS
Kaje jaya	7.62 ± 1.76	9.51 ± 6.77	6.29	3	MR
Bili halaga	0.56 ± 1.69	1.23 ± 1.24	0.89	1	R
MO-21 (Prathiksha)	0.51 ± 1.45	1.14 ± 1.59	0.82	1	R
MO-4	0.56 ± 0.91	0.81 ± 1.52	0.68	1	R

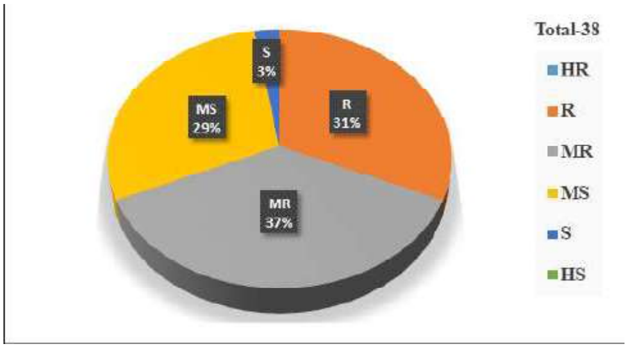


Fig. 2 : Per cent of genotypes under different resistance category (AVT genotypes)

by early authors, in this case also used and which shown same reaction.

These variations might be due to differences in the host plant resistance mechanisms among the genotypes, selective pressure on insects due to feeding and also influence local weather parameters *viz.,* Rainfall, RH and Temperature respectively.

There are no reports about this genotypes against paddy caseworm, however, early some authors reported for leaf folder, in present study evaluated for paddy caseworm, these some of genotypes also shown resistant to caseworm, which indicates that, these evaluated genotypes have multiple resistant.These results are in close agreement with the early reports of Sandeepkumar *et al.* (2021), Monika (2021), Girish *et al.* (2015) and Thorat *et al.* (2020) where, the authors have categorized most of the evaluated genotypes under resistant and moderately resistant categories and few genotypes were found to show moderately susceptible, susceptible and highly susceptible reactions whereas, none of the genotypes were completely free from leaf damage by leaf folder.

Subsequently, many rice researchers screened different germplasm lines in the field under natural populations by using SES and identified a few cultivars with resistance to paddy caseworm, like, Tripathi and Saxena (2013) who carried out for evaluation of local, improved and hybrid varieties of rice for insect pest complex which include paddy caseworm in rewa region during 2006-08 and Regmi *et al.* (2017) the findings revealed that the lowest population of leaf folder, caseworm and grasshopper was recorded in Radha-4 variety followed by Ramdhan and Sabitri variety even had a higher preference of insect pest but yield loss was minimum, among evaluated varieties. The varietal susceptibility was evaluated by Rao and Padhi (1984) with up to 21 cultivars in wet seasons 1979 and 1980 under out break levels of insect infestation in the field at Central Rice Research Institute, Cuttack, among evaluated cultivars, C. 62-10 was resistant while 15 others were moderately.

Likewise, in another study by Singh *et al.* (2015) the leaf damage reported from 1.98 to 26.37 per cent. Out of 60 genotypes evaluated, 18 genotypes were found resistant and 24 moderately resistant & none of them were susceptible and highly susceptible. Similarly, Raju *et al.* (2018) tested 21 rice genotypes and reported 10 major resistant rice genotypes and 11 reacted as moderately resistant against leaf folder. Where, the results of Pandey *et al.* (2018) revealed that, out of 97 genotypes evaluated 6 genotypes were no infestation *i.e.,* Highly resistant, 88 genotypes recorded Resistant with 1-10 per cent damage, whereas only one genotype reported as Moderately resistant with 11-30 per cent damage, respectively.

This variation in the per cent of leaf damage range, which was reported by earlier authors might be due to differences in the resistance mechanisms among the varieties, selective pressure on insects due to feeding and local climatic conditions.

Growing resistant variety is an important tactic accepted by the farmers for the effective management of insect pests. In the present study, a precise method was followed for the assessment of resistance to caseworm, N. depunctalis, was investigated by using SES method. These present findings showed that most of genotypes are under resistant and moderately resistant category. The genotypes like, Kari kagga, Karimundaga, Kavekantak, AVT-IM-7 and AVT-IM-4, *etc.,* which show resistant and are less than the resistant check, in present studies. The mechanism of resistant should be found out & it can be used as donor parent and further can be that utilized in breeding programmer for transfering the resistant gene to commercial & high yielding varieties in order to develop resistantance against insect pests.

Acknowledgement : The authors are thankful to Science and Engineering Research Board (SERB), Department of Science and Technology, Ministry of Science and Technology, Government of India under the Grant No. EEQ/2017/000484/26/3/2018 for providing funding and laboratory facilities. The authors are also thankful to University of Agricultural Science, GKVK, Bengaluru and PG students of Agricultural College, V.C. Farm, Mandya for their help.

REFERENCES

ANONYMOUS, 2013, Standard evaluation system for rice. International rice research institute, Los Bonas, Philippines.

ANONYMOUS, 2016, Package of practices for higher yield, University of Agricultural Sciences, Bangalore, Karnataka, India, pp. : 423.

ANONYMOUS, 2020, http://www.agricoop.nic.in

GIRISH, V. P., HEGDE, M. AND BALIKAI, R. A., 2015, Screening of rice genotypes against leaf folder, *Cnaphalocrosis medinalis* (Guenee). *Int. J. Agric. Stat. Sci.,* **11** (1) : 255 - 257.

KHAN, Z. R. AND PATHAK, M. D., 1987, Prospects of host plant resistance in rice against major insect pests and diseases. In: International Plant Protection: Focus on the Developing World. Vol. I. E. D. Magallona (ed.) Proceedings of the 11th International Congress of Plant Protection, Manila, Philippines, pp. : 510 - 519.

KULAGOD, S. D., HEGDE, M. G., NAYAK, G. V., VASTRAD, A. S. AND HUGAR, P. S., 2011, Influence of fertilizer on the incidence of insect pests in paddy. *Karnataka J. Agric. Sci.,* **24** (2) : 241 - 243.

MONIKA, B. K., 2021, Studies on species complex, mechanism of resistance and management of leaf folders in rice. *M.Sc. Thesis* (Unpub), Univ. Agric. Sci., Bangalore.

NEETA, M., GEETA, C., DINSEH, P. AND AMITABH, M., 2013, Army worm - A serious sporadic insect pest of rice in rewa region of Madhya Pradesh. *Ind. J. Appl. Res.,* **3** (9) : 489 - 490.

PANDEY, V. K., KAR, S. AND GUPTA, A. K., 2018, Screening of indigenous rice (*Oryza sativa* L.) against gall midge, stem borer, leaf folder, insect pest and leaf blast brown spot disease in bastar region. *Bioscan,* **13** (2) : 569 - 573.

PATHAK, M. D. AND KHAN, Z. R., 1994, Insect pests of rice. *International Rice Research Institute,* UPLB, Philippines.

RAJU, K. A., KRISHNAYYA, P. V., KUMAR, S. R. AND KUMAR, V. M., 2018a, Screening of the recent rice varieties against leaf folder, *Cnaphalocrocis medinalis* Guenee (Pyralidae : Lepidoptera). *J. Entomol. Zool. Stud.,* **6** (3) : 817 - 820.

RAO, P. S. P. AND PADHI, G., 1984, Varietal susceptibility to rice case worm Nymphula depunctalis Guenee and its behaviour. *Oryza,* **21** (3) : 157 - 162.

REGMI, R., KARKI, D., PUDASAINI, K., DHUNGANA, I., OJHA, M. S., POKHREL, B., POKHAREL, P. AND ARYAL, A., 2017, Varietal screening of rice against leaf folder (*Cnaplocrosis medinalis* guenee), caseworm (Nymphula depunctalis guenee) and grasshopper (Hieroglyphus banian fabricius) damage under field condition in chitwan, Nepal. *Journal of Agriculture and Forestry University,* **1** : 79 - 87.

SADDAMHUSEN ALASE, NAGARAJA, A., PRAMESH, D. AND PRASANNAKUMAR, M. K., 2021, Influence of weather parameters on false smut disease development in rice. *Mysore J. Agric. Sci.,* **55** (4) : 320 - 325.

SALIM, M., 2002, Final technical DFID project report. Tillage by nutrient interaction in rice-wheat system, NARC, Islamabad. pp. : 13 - 25.

SANDEEPKUMAR, YADAV, D., SHARMA, K., YADAV, S., VIJAYKUMAR, L. AND DEEKSHA, M. G., 2021, Screening of rice landraces and their morpho-biochemical basis of resistance against Cnaphalocrocis medinalis, *Ind. J. Agri. Sci.,* **91** (3) : 50 - 55.

SANGEETHA, C. AND BASKAR, P., 2015, Influence of different crop establishment methods on productivity of rice. *Agri. Review,* **36** (2) : 113 - 124.

SHEPARD, B. M., BARRION, A. T. AND LITSINGER, J. A., 1995, Rice-feeding insects of tropical asia. International Rice Research Institute, Manila, Philippines. pp. : 228.

SHIVUKUMARA, VIJAYKUMAR, L., KITTURMATH, M. S. AND SHIVANNA, B., 2022, Mechanism of host plant resistance in rice genotypes against brown planthopper. *Mysore J. Agric. Sci.,* **56** (2) : 345 - 352.

SINGH, V. K., GUPTA, P., SINGH, R. AND SINGH, 2015, Field evaluation of rice germplasm against leaf folder, Cnapalocrocis medinalis guenee under irrigated condition. *Ann. Plant Soil Res.,* **17** : 565 - 567.

THORAT, S. S., GANGWAR, R. K., PARMAR, M. B., PRAJAPATI, D. B., KACHA, D. J. AND PAMPANIYA, A. G., 2020, Field screening of different genotypes against yellow stem borer and leaf folder in rice. *Extended Summaries,* pp. : 685 - 687.

TRIPATHI, K. AND SAXENA, A., 2013, Evaluation of local, improved and hybrid rice varieties against insect pests in district Rewa (M. P.), India, *Int. J. Sci. and Res. Pub.,* **11** (3) : 2250 - 225.

Mysore J. Agric. Sci., 57 (1) : 229-244 (2023)

Impact of Different Land - Use Systems on Soil Physico-chemical Properties

PRADEEP AND R. KRISHNA MURTHY
Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : chikkanaragund3108@gmail.com

AUTHORS CONTRIBUTION

PRADEEP :
Carried out the experiment and participated in the sequence alignment and drafted the manuscript;
R. KRISHNA MURTHY :
Conceived the study, designing, coordination and drafting the manuscript

Corresponding Author :
PRADEEP
Department of Soil Science and Agricultural Chemistry, College of Agriculturre, UAS, GKVK, Bengaluru

Received : August 2022
Accepted : November 2022

ABSTRACT

Changes in land use and improper soil management have led to severe land degradation around the globe through the modification in soil physico-chemical and biological processes. The study aimed to assess the soil properties of different land use system types. In this regard soil samples (0-30 cm, 30-60 cm and 60-90 cm depth) were collected from different land uses; Natural forest, teak plantation, horticulture (mango and guava) land use system, agriculture (Finger millet cropping system), agri-horti land use system (custard and amla) and agroforestry (melia dubia). Soil collected from different land use systems was analyzed for both physical and chemical properties. The present investigation revealed that the soil texture was sandy clay loam. The mean bulk density of the soils ranged from 1.28 and 1.38 g cm^{-3} and the mean total porosity ranged from 35.54 - 42.71 per cent. The soil pH was acidic in agriculture (Finger millet cropping system-chemical fertilizer) land use and neutral in other land use systems and the mean electrical conductivity value ranged from 0.06-0.11 dSm^{-1}. The highest mean value (1.11%) of organic carbon was recorded in natural forest and the lowest mean value (0.25%) was recorded in agriculture (Finger millet cropping system-chemical fertilizer) land use. However, the mean values of available N ranged from 141.32 kg ha^{-1} to 260.02 kg ha^{-1}. Higher mean available P_2O_5 (88.76 kg ha^{-1}) and K_2O (207.59 kg ha^{-1}) were recorded in agriculture land use (Finger millet cropping system-integrated nutrient management). The concentration of secondary and micronutrients were higher in natural forest and tree plantations. The study revealed that conversion of natural forest to different land use systems had adverse effects on soil physical and chemical properties. Therefore, land use systems in the region must adopt a suitable management practice to enhance soil fertility and productivity.

Keywords : Soil properties, Soil depth, Natural forest, Teak plantation, Horticulture land use system, Agriculture, Agri-horti land use system and agroforestry

CHANGING land use from forest to croplands leads to a change in the chemical, physical and biological properties of the soil. Deforestation increases soil erosion which leads to floods, drought and natural ecosystem degradation. Land use change to cropland have changed significantly from the twentieth century, it is estimated that 25 per cent of the Earth's surface will be occupied by cropland, shifting cultivation and livestock production in the twenty first century. Globally the decreasing rate of forest was about 10 million hectares per year between 2015 and 2020 (UN FAO forestry data 2020). In the Indian context, about 275 million people, comprising nearly 27 per cent of the country's population, depend on forests for their subsistence or livelihoods (CSE 2020). The increasing demand for forest resources from global markets have contributed to the increased rates of conversion of forests to plantation crops.

Soil is an important component of terrestrial ecosystems, which directly or indirectly influences the life on earth. Soil health is one of the important deciding factors in the success of human civilization. In the recent past, with population explosion and urbanization, the forest land is permanently converted to various other land use systems *viz.,* agriculture, horticulture, plantations, agroforestry apart from various other uses. The intention of conversion of land is primarily to increase the production of food, fodder and wood to meet the increasing needs of burgeoning population. In the race to meet the production goals farming community has resorted to, inappropriate land use and soil management practices in terms of monoculture, intensive cropping patterns with heavy mechanization and injudicious usage of agri-chemicals (Chandel *et al*., 2018), rendering soil health and its sustainability completely out of context. In this context a study was conducted to know the Impact of different land - use systems on soil physico-chemical properties'

Material and Methods

Study Area

The study was conducted in different land use systems at University of Agricultural Sciences, GKVK, Bengaluru, Karnataka. It is located in the Northern part of Bengaluru between Latitude: 13º 05' North and Longitude: 77º 34' East and Altitude: 924 m (above mean sea level). GKVK has a tropical climate with distinct wet and dry seasons. The maximum and minimum temperature recorded was 29.6 and 18.2º C respectively. The annual rainfall for the period 1986 to 2021 ranged from 461 mm to 1115.8 mm, with a mean of 712 mm. The average relative humidity at 7:00 a.m. and 2:00 p.m. ranged from 89 - 47 per cent, respectively. The average wind speed recorded was 6.4 kmph. The annual mean sunshine was 6.7 hours.

The study area comprised of different predominant land use systems such as agriculture (Finger millet), horticulture (Mango and Guava), agri-horti system (Custard apple and Amla) and plantation (Teak and Melia dubia.) which have widely replaced the natural forest of GKVK. Hence to assess the impact of different land use systems on soil physico-chemical properties among different land uses. Different-land uses were identified such as;

1) Natural Forest: An undisturbed forest area and it was classified as dry deciduous forest. The forest area mainly comprised of *Acacia ferruginea, Ailanthus triphysa, Albizia amara, Albizia lebbeck, Albizia odoratissima, Azadirachta indica, Cassia siamea, Eucalyptus sp., Gliricidia sepium, Hardwickia binnata, Leucaena leucocephala, Pongamia pinnata, Santalum album, Swietenia macrophylla and Tamarindus indica* etc. 2) Teak plantations: The plantation was established in the year of 1986, with a spacing of 2 m x 2 m spacing. 3) Mango land use system: The mango plantation was established over an area of 10 hectares between 1974 - 77 with a spacing of 10 m x 10 m. 4) Guava land use system: The guava plantation was established in 1994 with a spacing of 6 m x 3 m. 5) Custard apple land use system: The custard apple saplings were planted during 2009 with a spacing of 5 m X 5m and finger millet, field bean, cowpea, niger, foxtail millet and fodder maize were grown continuously as inter crops from 2012. 6) Amla land use system: The amla saplings were planted during 2009 with a spacing of 6 m x 6 m and finger millet, field bean, cowpea, niger, foxtail millet and fodder maize were grown continuously as inter crops from 2012.) 7) Finger millet cropping system-chemical fertilizer: The finger millet crop is being continuously fertilized 50:50:25 N:P:K kg/ha/year since 1978.8) Finger millet cropping system-organic manure: The finger millet crop is being continuously manured with FYM 10 t/ha/year since 1978.9) Finger millet cropping system-integrated nutrient management: The finger millet crop is being continuously manured with FYM 10 t/ha/year and 50:50:25 N:P:K kg/ha/year since 1978 and 10) Melia dubia land use system: Melia dubia plantation was established during 2012 with a spacing of 8 m x 5 m spacing.

Soil Sampling and Analysis

In each land use system, five quadrats measuring 20 m x 20 m were randomly laid down in such a way that it represents the land use studied. Within each quadrat, soils were collected from ten points (5 in the corners and 5 in the center) at three depth classes *i.e.* 0-30, 30-60 and 60-90 cm. The five sub-samples at each location and depth class were pooled to get one composite sample for each depth class per plot. The soils were mixed thoroughly and large plant debris, roots and stones were removed manually by hand. Equal number of soil samples from the same depths were collected from undisturbed plots separately for bulk density by using soil core of known volume. In the laboratory, the soil samples were homogenized, air-dried, grounded and passed through 2 mm sieve for further physical and chemical analysis.

Physico-Chemical Analysis of the Soils

Air-dried soil samples were used for analysis of texture, bulk density, pH, electrical conductivity (EC), organic C, available N, P_2O_5, K_2O, exchangeable cations *i.e.* Ca and Mg, available S and micronutrients. Soil texture was estimated using an International pipette method as described by Black (1965). Bulk density was determined by the core (Grossman and Reinsch 2002). Soil pH and electrical conductivity in soil samples were measured in 1:2 soil: water extract as outlined by Jackson (1973). Organic C was estimated by Walkley and Black (1934) rapid titration method. The alkaline potassium permanganate method was adopted to analyse the available nitrogen content in soils (Subbaiah and Asija, 1956). The available phosphorus in the soil samples was determined by Bray's No.1 reagent (0.03 NH_4F + 0.025 N HCl) (Jackson, 1973). The available sulphur was determined as described by Black (1965). Available potassium was extracted with 1 M ammonium acetate at pH 7 and measured using a flame photometer (Page *et al*., 1982). Exchangeable calcium and magnesium were estimated by titrating suitable aliquot of ammonium acetate extract of soil against standard EDTA solution as described by Piper (1966) and The micro nutrients such as Zn, Cu, Mn and Fe were extracted by using DTPA (Diethylene tri amine penta acetic acid) and measured by using AAS (Lindsay and Norwell 1978).

Statistical Analyses

Analysis of variance (ANOVA) at 95 per cent confidence level was analyzed taking sampling sites as replicates (random effects) and land use types as treatments (fixed effects) using MS EXCEL and using SPSS for windows (IBM SPSS ver. 17.0).

Results and Discussion

Effect of different Land-use Systems on Physical Properties of Soil

Particle Size Distribution

The soils of different land use systems were sandy clay loam in texture. Among different land use systems, the highest mean value of sand content (67.49%) was recorded in finger millet cropping system-organic manure and the lowest mean value (54.67%) was recorded in amla land use system. The highest mean value of silt content (12.55%) was recorded in natural forest and the lowest mean value (5.91%) was recorded in finger millet cropping system-chemical fertilizer. The highest mean value of clay content (34.43%) was recorded in amla land use and the lowest mean value (23.94%) was recorded in finger millet cropping system-chemical fertilizer (Table 1). This could probably due to soils which were derived from coarse grained parent materials. The soils were dominant in sand content but the accumulation of clay and silt were observed in the subsurface layer with decrease in sand content. Similar results have been reported. According to the results of analysis of variance (ANOVA) revealed that there was a significant difference of the sand and clay particle under different land use systems at different soil depths. The highest (73.18%) and the lowest (47.26%) value of sand was recorded on the surface (0-30 cm) soil layer of finger millet cropping system-chemical fertilizer and subsurface layer (60-90 cm) of teak plantation, respectively (Table 1). Whereas the highest (39.38%) and lowest (19.76%) values of clay content were recorded in the subsurface (60-90 cm) soil layer of the amla land use system and surface layer of guava land use, respectively (Table 1).

Under different soil depth, the higher sand content was obtained at the surface (0-30 cm) soil layer, whereas the higher silt and clay content was recorded in the subsurface (60-90 cm) soil layer (Table 1).

TABLE 1

Physical properties of soils under different land use systems

Land use systems	Depth (cm)	Particle size (%)			Textural class	BD ($g\ cm^{-3}$)	Total Porosity (%)	MWHC (%)
		Sand	Silt	Clay				
Natural Forest	0-30	62.02	9.27	28.71	SCL	1.21	45.98	41.15
	30-60	58.78	11.92	31.3	SCL	1.29	42.41	35.24
	60-90	52.89	16.45	30.66	SCL	1.35	39.73	32.67
	Range	52.89-62.02	9.27-16.45	28.71-31.30		1.21-1.35	39.73-45.98	32.67-41.15
	mean	57.9	12.55	30.22		1.28	42.71	36.35
Teak	0-30	68.12	7.23	24.65	SCL	1.28	41.53	37.32
	30-60	57.15	10.18	32.67	SCL	1.33	39.41	33.96
	60-90	47.26	15.43	37.31	SCL	1.41	38.56	30.87
	Range	47.26-68.12	7.23-15.43	24.65-37.31		1.28-1.41	38.56-41.53	30.87-37.32
	mean	57.51	10.95	31.54		1.34	39.83	34.05
Mango	0-30	70.21	7.23	23.56	SCL	1.3	41.74	36.01
	30-60	68.45	8.28	23.27	SCL	1.36	39.78	31.23
	60-90	59.76	9.73	30.51	SCL	1.4	37.17	21.56
	Range	59.76-70.21	7.23-9.73	23.27-30.51		1.30-1.40	37.17-41.74	21.56-36.01
	mean	66.14	8.41	25.78		1.35	39.56	29.6
Guava	0-30	71.41	8.83	19.76	SCL	1.31	43.19	33.05
	30-60	65.76	11.28	22.96	SCL	1.35	38.72	28.01
	60-90	54.68	13.53	31.79	SCL	1.41	32.35	22.34
	Range	54.68-71.41	8.83-13.53	19.76-31.79		1.31-1.41	32.35-43.19	22.34-33.05
	mean	63.95	11.21	24.84		1.35	38.08	27.8
Finger Millet-chemical fertilizer	0-30	73.18	5.87	21.22	SCL	1.32	43.1	30.15
	30-60	69.12	4.98	23.45	SCL	1.38	35.12	22.43
	60-90	57.87	6.87	27.16	SCL	1.43	28.42	19.56
	Range	57.87-73.18	4.98-6.87	21.22-27.16		1.32-1.43	28.42-43.10	19.56-30.15
	mean	66.72	5.91	23.94		1.38	35.54	24.04

Table 1 contd......

continued from Table 1

Land use systems	Depth (cm)	Particle size (%)			Textural class	BD (g cm^{-3})	Total Porosity (%)	MWHC (%)
		Sand	Silt	Clay				
Finger Millet-organic manure	0-30	72.13	6.15	21.79	SCL	1.27	44.98	38.56
	30-60	69.32	6.01	24.18	SCL	1.33	38.34	22.26
	60-90	61.01	9.12	29.34	SCL	1.38	33.92	19.34
	Range	61.01-72.13	6.01-9.12	21.79-29.34		1.27-1.38	33.92-44.98	19.34-38.56
	mean	67.49	7.09	25.1		1.33	39.08	26.72
Finger Millet-integrated nutrient management	0-30	72.2	5.69	20.96	SCL	1.28	43.05	31.78
	30-60	65.13	6.23	22.87	SCL	1.35	37.52	25.12
	60-90	57.27	10.12	28.65	SCL	1.4	30.65	19.89
	Range	57.27-72.20	5.69-10.12	20.96-28.65		1.28-1.40	30.65-43.05	19.89-31.78
	mean	64.87	7.35	24.16		1.34	37.07	25.59
Custard apple	0-30	60.37	13.31	26.32	SCL	1.32	41.25	33.34
	30-60	55.37	8.87	35.76	SCL	1.34	38.35	29.57
	60-90	48.85	12.89	38.26	SCL	1.4	36.83	28.21
	Range	48.85-60.37	8.87-13.31	26.32-38.26		1.32-1.40	36.83-41.25	28.21-33.34
	mean	54.86	11.69	33.45		1.35	38.81	30.37
Amla	0-30	61.46	12.11	27.22	SCL	1.33	41.87	32.14
	30-60	54.75	9.87	36.69	SCL	1.36	38.73	29.23
	60-90	47.79	13.78	39.38	SCL	1.41	34.21	26.76
	Range	47.79-61.46	9.87-13.78	27.22-39.38		1.33-1.41	34.21-41.48	26.76-32.14
	mean	54.67	11.92	34.43		1.36	38.27	29.38
Melia dubia	0-30	65.21	8.23	26.56	SCL	1.31	43.05	36.34
	30-60	59.45	11.28	29.27	SCL	1.34	41.91	30.56
	60-90	50.26	15.43	34.31	SCL	1.38	40.25	29.89
	Range	50.26-65.21	8.23-15.43	26.56-34.31		1.31-1.38	40.25-43.05	29.89-36.34
	mean	58.31	11.65	30.05		1.34	41.74	32.26
	CD (P=0.05)	1.61	1.74	0.67		0.165	0.23	0.28
	SEm±	0.43	0.51	0.18		0.0068	0.07	0.1
	CV (%)	57.6	38.16	28.21		0.48	18.13	23.38

Generally, the clay content was higher in the subsurface layer of different land use systems due to the translocation of finer particles from the surface horizons and subsequent illuviation in subsurface horizons. Similar observations were reported by Dasog and Patil (2011).

Bulk Density

The soil bulk density was significantly affected by land use and soil depth at $P \leq 0.01$ (Table 1). Considering the land use types, the highest mean value of bulk density (1.38 g cm^{-3}) was recorded in finger millet cropping system-chemical fertilizer and the lowest mean value (1.28 g cm^{-3}) of bulk density was recorded in natural forest (Table 1). Bulk density is an indicator of soil compaction and soil health. It affects infiltration, rooting, water holding capacity, soil porosity, plant nutrient availability and soil microorganism's activity all of which are key to soil processes and productivity. Bulk density is found to decrease under natural forest and trees due addition of organic matter (litterfall, fine root recycling, twigs *etc*.) at regular intervals. The addition of litter increased the organic matter in soil and inverse relationship of bulk density and per cent OC is established by several workers (Gupta and Sharma, 2008 and Oyedele *et al*., 2009)).

Total Porosity

The results of the analysis of variance (ANOVA) showed that the total porosity of soil was significantly affected by land use types and soil depth (Table 1). Considering the land use types with soil depth, the highest values of total porosity (45.98%) was recorded on the surface soil layer of natural forest while lowest values of total porosity (28.72%) was recorded in subsurface layer (60-90 cm) of the finger millet cropping system-chemical fertilizer (Table 1). The higher value of soil total porosity in natural forest was implied due to low bulk density of forest plantation. The mean total porosity of teak plantation, mango land use system, guava land use system, custard apple land use system, amla land use system, finger millet cropping system-organic manure and finger millet cropping system-integrated nutrient management were 39.83, 39.56, 38.08, 38.81, 38.27, 39.08 and 37.07 per cent respectively (Table 1). At different soil depths, the higher value of total porosity was recorded in the surface soil layer. The total porosity varies across the different land use types was implies to the bulk density values of that respective soil.

Maximum Water Holding Capacity

The soil moisture holding capacity is significantly influenced by varying land use systems (Table 1). Highest soil moisture content (36.35%) was recorded in natural forest followed by teak plantation (34.05%), agroforestry (32.26%), custard land use system (30.37%), mango (29.60%), amla land use system (29.38%) and least soil moisture was recorded in agriculture (finger millet cropping system-chemical fertilizer) (24.04%). Moisture holding capacity corroborates with other characteristics of land use systems. Soil bulk density was lowest in natural forest and tree plantations compared to agriculture and horticulture systems. Soil porosity and maximum water holding capacity were also recorded higher under natural forest and tree plantations. In tree plantations and natural forest higher amount of litter and organic matter were added, which has increased the soil organic carbon and thereby increased the soil moisture holding capacity of the soils, whereas in agriculture system there was no continuous addition of litter or organic matter. However, horticulture and agroforestry were also a tree based systems, but the tree spacing was larger in horticulture (10 m x 10 m) and agroforestry (8 m x 5 m) leading to less organic matter input and thereby less soil moisture holding capacity (Bhavya *et al*., 2018).

Chemical Properties of Soils under different Land use Systems

Soil pH

The soil pH was significantly influenced by different land use systems and soil depths (Table 2). The highest soil pH (6.80) was recorded in natural forest, which was followed by finger millet cropping system-organic manure and finger millet cropping system-integrated nutrient management having soil

TABLE 2

Chemical properties of soils under different land use systems

Land use systems	Depth (cm)	pH	EC (dSm^{-1})	OC (%)
Natural Forest	0-30	6.67	0.099	1.57
	30-60	6.78	0.115	0.98
	60-90	6.96	0.125	0.77
	Range	6.67-6.96	0.099-0.125	0.77-1.57
	mean	6.8	0.11	1.11
Teak	0-30	5.48	0.063	0.99
	30-60	5.66	0.079	0.86
	60-90	5.83	0.093	0.59
	Range	5.48-5.83	0.063-0.093	0.59-0.99
	mean	5.66	0.08	0.81
Mango	0-30	5.59	0.061	0.81
	30-60	5.72	0.069	0.62
	60-90	5.98	0.078	0.49
	Range	5.59-5.98	0.061-0.078	0.49-0.81
	mean	5.76	0.07	0.64
Guava	0-30	5.78	0.064	0.69
	30-60	5.93	0.078	0.47
	60-90	6.03	0.083	0.39
	Range	5.78-6.03	0.064-0.083	0.39-0.69
	mean	5.91	0.08	0.51
Finger Millet-chemical fertilizer	0-30	4.09	0.059	0.43
	30-60	4.21	0.065	0.21
	60-90	4.35	0.07	0.11
	Range	4.09-4.35	0.059-0.070	0.11-0.43
	mean	4.22	0.06	0.25
Finger Millet- organic manure	0-30	6.01	0.077	0.53
	30-60	6.17	0.087	0.41
	60-90	6.32	0.09	0.32
	Range	6.01-6.32	0.077-0.090	0.32-0.53
	mean	6.17	0.08	0.42
Finger Millet- integrated nutrient management	0-30	5.98	0.052	0.63
	30-60	6.12	0.074	0.5
	60-90	6.22	0.086	0.38
	Range	5.98-6.22	0.052-0.086	0.38-0.63
	mean	6.11	0.07	0.50

Table 2 contd......

Land use systems	Depth (cm)	pH	EC (dSm^{-1})	OC (%)
Custard	0-30	5.54	0.041	0.65
	30-60	5.78	0.058	0.53
	60-90	5.88	0.067	0.45
	Range	5.54-5.88	0.041-0.067	0.45-0.65
	mean	5.73	0.06	0.54
Amla	0-30	5.61	0.057	0.57
	30-60	5.72	0.068	0.41
	60-90	5.85	0.071	0.36
	Range	5.61-5.85	0.057-0.071	0.36-0.57
	mean	5.73	0.07	0.45
Melia dubia	0-30	4.78	0.069	0.86
	30-60	4.87	0.072	0.71
	60-90	5.05	0.081	0.58
	Range	4.78-5.05	0.069-0.081	0.58-0.71
	mean	4.9	0.07	0.72
	CD (P=0.05)	0.33	0.023	0.142
	SEm±	0.10	0.004	0.035
	CV (%)	1.84	0.01	0.12

pH of 6.17 and 6.11 respectively. The low pH was recorded in finger millet cropping system-chemical fertilizer (4.22). Soil pH or reaction indicates two important chemical properties (*i.e.* soil acidity and alkalinity) of soil, which are having profound influence on soil physical and biological properties and hence the plant nutrient availability. Soil pH regulates soil biogeochemical processes and has cascading effects on terrestrial ecosystem structure and functions.

The mean pH values of natural forest and tree based systems found to be neutral. This could be due to addition of litter in tree based land use systems. It can also be observed that, with the increase in the age of the tree based land use system, the soil pH is becoming more neutral. Verma *et al.* (2001) also found that soil pH increased under tree plantations. Whereas in melia dubia land use system recorded was slightly acidic, this might be due to the continuous addition of litter and subsequent release of organic acids, which tend to decrease the soil pH. These results are supported by Ananthkumar (2011). While in finger millet-chemical fertilizer, applied acid forming fertilizers (Ammonical fertilizers) release of H^+ ions after mineralization and lack of addition of organic manures to soil, hence crop takes up secondary and micronutrient from soil results in soil acidity (Gajanana *et al.*, 2005).

Considering the interaction of land use types with soil depth, soil pH increased consistently with increased in soil depth in all land use systems due to leaching of basic cations due to high rainfall. These results are supported by Rudramurthy *et al.* (2007).

Electrical Conductivity

The electrical conductivity (EC) values of soils were significantly affected by land use types and soil depths (Table 2). Highest EC was recorded in natural forest (0.11 dSm^{-1}), whereas lowest (0.06 dSm^{-1}) was recorded in custard land use systems and finger millet cropping system-chemical fertilizer. Soil EC under natural forest was higher compared to other land use systems. This could be due to enrichment of soil mineral by basic salts due to weathering and decomposition of litter. Verma *et al*. (2001) reported that soil EC increased in tree plantations. The lowest mean value of EC was found at 0 to 30 cm depths in different land use systems this might be mainly due to variation in soluble salts in soils and variation in the degree of leaching loss of salts from soils due to the intensity of rainfall and restricted drainage. These results are in line with the findings of Nagaraj *et al*. (2002).

Soil Organic Carbon

The analysis of variance revealed that the SOC (Soil Organic Carbon) content was significantly affected by land use types and soil depth (Table 2). Natural forest shows the highest mean value of organic carbon (1.11%). Similar result was observed by Govind *et al.* (2022). Followed by teak plantation (0.84%) and the lowest mean value observed in finger millet cropping system-chemical fertilizer (0.25%). In all the land use systems the organic carbon content decreases with increasing soil depth. The highest value of SOC content was (1.57%) recorded at the depth of 0-30 cm (surface) in natural forest land and the least value of SOC (0.11%) was recorded at depth of 60-90 cm (subsurface) in finger millet cropping system-chemical fertilizer (Table 2). However, the highest value of SOC on the surface layer of forest land use systems was attributed to the excessive amount of plant residues and biomass on surface land. The present research finding is in agreement with findings of Chibsa and Taa (2009), Iqbal *et al.* (2012) and Takele *et al.* (2014) in which they reported that the SOC decreases with increasing soil depth, with more accumulation on the upper surface soil layer. Singh and Sharma, 2012. Amanuel *et al.* (2018) also reported that overall mean soil organic carbon stock was higher under natural and mixed forest compared with other land use types and at all depths. The closer spacing of the plantation rendered thick and denser canopy and more is the litter biomass added. While the least mean soil organic carbon content was recorded in agriculture based land use systems compared to tree based land use because of continuous disturbance of soil through tillage activities and less input of litter and plant residues in the agriculture systems. These results are in line with the findings of Shivakumar *et al.* (2020).

Available Primary Nutrients in Soil under different Land Use Systems

The available nitrogen (N), phosphorous (P) and potassium (K) content of soils were significantly affected by land use types and soil depth (Tables 3). The highest mean value of available nitrogen (260.02 kg ha^{-1}) was recorded in finger millet cropping system-integrated nutrient management followed by mango (248.53 kg ha^{-1}), finger millet cropping system-organic manure (246.33 kg ha^{-1}), agroforestry (melia dubia) with 241.58 kg ha^{-1}, natural forest (227.12 kg ha^{-1}) and lowest mean (141.32 kg ha^{-1}) was noticed in amla land use system. Highest available nitrogen was recorded in agriculture system due to application of chemical nitrogenous fertilizers and organic source. The combined application of organic and inorganic fertilizer in soil has led to increase in organic matter content in the soil which has direct relation with the availability of nitrogen content in the soil and this result was found to be in accordance with Hemalatha and Chellamuthu (2013). Among tree-based land use system, the higher soil available nitrogen was recorded in mango land use system, this might be due to higher litter fall (6243.15 kg/ha/ year) and also due to higher nitrogen concentration (1.34%) in leaf litter. Similar results were reported by Sushanta kumar *et al.* (2018). The Available nitrogen in soil decreased significantly with increasing soil depth. This can be attributed to more turn-over of organic residues in the top layer compared to deeper layers. The available phosphorus and potassium in soil were significantly differed among different land use systems. The highest mean value (88.76 kg ha^{-1}) of available phosphorus was recorded in finger millet cropping system-integrated nutrient management followed by finger millet cropping system-organic manure (78.32 kg ha^{-1}), agroforestry (melia dubia) with 73.11 kg ha^{-1}, mango (55.12 kg ha^{-1}), natural forest (48.28 kg ha^{-1}) and least

TABLE 3

Available primary nutrient status of soil under different land use systems

Land use systems	Depth (cm)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
Natural Forest	0-30	245.65	70.72	173.15
	30-60	225.67	46.07	155.25
	60-90	210.05	28.05	131.47
	Range	210.05-245.65	28.05-70.72	131.47-173.15
	mean	227.12	48.28	153.29
Teak	0-30	178.34	54.15	141.14
	30-60	157.34	43.55	122.28
	60-90	131.45	29.14	110.15
	Range	131.45-178.34	29.14-54.15	110.15-141.14
	mean	155.71	42.48	124.52
Mango	0-30	276.25	76.44	166.45
	30-60	265.56	55.17	148.35
	60-90	203.78	33.75	122.49
	Range	203.78-276.25	33.75-76.44	122.49-166.45
	mean	248.53	55.12	145.76
Guava	0-30	171.24	65.46	155.38
	30-60	155.47	55.43	135.26
	60-90	142.47	23.47	119.67
	Range	142.47-171.24	23.47-65.46	119.67-155.38
	mean	156.39	48.12	136.77
Finger Millet-chemical fertilizer	0-30	234.57	59.16	135.25
	30-60	228.24	47.45	129.13
	60-90	178.11	30.56	114.76
	Range	178.11-234.57	30.56-59.16	114.76-135.25
	mean	213.64	45.72	126.38
Finger Millet-organic manure	0-30	289.26	86.35	145.53
	30-60	251.89	78.48	131.27
	60-90	199.35	70.13	119.28
	Range	199.35-289.26	70.13-86.35	119.28-145.53
	mean	246.33	78.32	132.03
Finger Millet-integrated nutrient management	0-30	285.48	105.5	230.04
	30-60	268.35	92.65	201.36
	60-90	226.24	68.13	191.38
	Range	226.24-285.48	68.13-105.5	191.38-230.04
	mean	260.02	88.76	207.59

Table 3 contd......

Land use systems	Depth (cm)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
Custard apple	0-30	187.65	55.35	155.24
	30-60	142.87	46.25	138.12
	60-90	101.45	40.67	126.39
	Range	101.45-187.65	40.67-55.35	126.39-155.24
	mean	143.99	47.42	139.92
Amla	0-30	177.24	60.57	219.37
	30-60	137.67	47.85	178.25
	60-90	109.05	31.05	145.16
	Range	109.05-177.24	31.05-60.57	145.16-219.37
	mean	141.32	46.49	180.92
Melia dubia	0-30	277.79	93.01	205.18
	30-60	237.49	74.54	186.35
	60-90	209.48	51.79	175.39
	Range	209.48-277.79	51.79-93.01	175.39-205.18
	Mean	241.58	73.11	188.97
	CD (P=0.05)	10.27	5.15	12.65
	SEm±	2.678	1.66	3.65
	CV (%)	142.77	121.32	148.26

available phosphorus (45.72 kg ha^{-1}) was recorded in finger millet cropping system-chemical fertilizer. The available phosphorous and potassium were higher in the surface soil layer than in the subsurface soil layer. Generally, variations in available phosphorous content in soils could be related to the intensity of soil weathering or soil disturbance under different land use systems. The buildup of available phosphorus in integrated treatments that is organic plus inorganic fertilizer treatment was mainly due to the increase in dissolution of native P compounds by the decomposition of FYM and the available P content in the soil and it was also contributed by the application of phosphorus through fertilizer and it was also due to increased phosphatase activity in the soil has led to increase in available phosphorus content in the soil. Similar results were reported by Hemalatha and Chellamuthu (2013).

The highest mean available potassium was recorded in finger millet cropping system-integrated nutrient management (207.59 kg ha^{-1}) followed by agroforestry (melia dubia) with 188.97 kg ha^{-1}, amla land use system with 180.92 kg ha^{-1}, natural forest (153.29 kg ha^{-1}) and mango (145.76 kg ha^{-1}). The trends noticed in these land use systems may be due to regular and continuous application of inorganic fertilizers. Among tree based land use systems, in melia dubia higher soil available potassium was recorded due higher litter fall (1750.37 kg/ha/year) and in and this result was found to be in accordance with Ishwarya laxmi *et al.* (2021). The available K in soil decreased significantly with increase in soil depth. A decreasing trend was observed with successive increase in soil depth as a consequence of higher litter fall and fine root turnover at surface layer. Similar decrease with soil depths has also been reported by Bhardwaj *et al.* (2001), Swamy *et al.* (2006) and Mishra and Swamy (2007).

Secondary Nutrients in Soil under different Land Use Systems

According to the analysis of variance results indicated that the exchangeable calcium (Ca),

TABLE 4

Secondary nutrient status of soil under different land use systems

Land use systems	Depth (cm)	Ca (cmol (p+) kg^{-1})	Mg (cmol (p+) kg^{-1})	S (cmol (p+) kg^{-1})
Natural Forest	0-30	6.65	1.89	6.15
	30-60	4.95	1.75	4.75
	60-90	3.46	0.58	4.12
	Range	3.46-6.65	0.58-1.89	4.12-6.15
	mean	5.02	1.4	5.01
Teak	0-30	5.87	0.61	5.87
	30-60	3.51	0.39	4.23
	60-90	2.42	0.31	3.36
	Range	2.42-5.87	0.31-0.61	3.36-5.87
	mean	3.93	0.44	4.49
Mango	0-30	6.55	1.41	6.55
	30-60	5.31	0.97	4.89
	60-90	2.78	0.29	4.34
	Range	2.78-6.55	0.29-1.41	4.34-6.55
	mean	4.88	0.89	5.26
Guava	0-30	6.47	0.49	4.23
	30-60	4.29	0.38	3.78
	60-90	2.88	0.21	3.54
	Range	2.88-6.47	0.21-0.49	3.54-4.23
	mean	4.54	0.36	3.85
Finger Millet-chemical fertilizer	0-30	1.46	0.48	2.24
	30-60	1.22	0.15	1.67
	60-90	1.08	0.09	0.47
	Range	1.08-1.46	0.09-0.48	0.47-2.24
	mean	1.25	0.24	1.46
Finger Millet-organic manure	0-30	2.68	0.57	4.43
	30-60	2.56	0.26	2.68
	60-90	2.23	0.11	1.16
	Range	2.23-2.68	0.11-0.57	1.16-4.43
	mean	2.49	0.31	2.75
Finger Millet- integrated nutrient management	0-30	3.41	0.54	4.68
	30-60	3.01	0.32	3.74
	60-90	2.78	0.17	1.39
	Range	2.78-3.41	0.17-0.54	1.39-4.68
	mean	3.06	0.34	3.27

Table 4 contd......

Land use systems	Depth (cm)	Ca (cmol (p+) kg^{-1})	Mg (cmol (p+) kg^{-1})	S (cmol (p+) kg^{-1})
Custard apple	0-30	4.15	1.25	6.12
	30-60	3.79	1.03	5.26
	60-90	2.54	0.89	1.33
	Range	2.54-4.15	0.89-1.25	1.33-6.12
	mean	3.49	1.05	4.23
Amla	0-30	4.19	0.68	5.95
	30-60	2.86	0.37	4.68
	60-90	2.45	0.01	1.06
	Range	2.45-4.19	0.01-0.68	1.06-5.95
	mean	3.16	0.35	3.89
Melia dubia	0-30	5.87	0.81	7.98
	30-60	4.53	0.59	5.62
	60-90	2.36	0.43	4.44
	Range	2.36-5.87	0.43-0.81	4.44-7.98
	mean	4.25	0.61	6.01
	CD (P=0.05)	0.812	0.094	0.921
	SEm±	0.173	0.031	0.258
	CV (%)	2.11	0.114	1.899

magnesium (Mg) and sulphur (S) of the study area was significantly affected by land use types and soil depth (Tables 4). The highest mean value (5.02 cmol (p+) kg^{-1}) of available calcium was recorded in natural forest soil followed by mango (4.88 cmol (p+) kg^{-1}), guava (4.54 cmol (p+) kg^{-1}), agroforestry (melia dubia) with 4.25 cmol (p+) kg^{-1} and lowest mean value (1.25 cmol (p+) kg^{-1}) was recorded in finger millet cropping system-chemical fertilizer. The highest mean value (1.40 cmol (p+) kg^{-1}) of available magnesium was recorded in natural forest soils followed by custard land use (1.05 cmol (p+) kg^{-1}), mango (0.89 cmol (p+) kg^{-1}), agroforestry (melia dubia) with 0.61 cmol (p+) kg^{-1}, teak plantation (0.44 cmol (p+) kg^{-1}) and lowest mean (0.31 cmol (p+) kg^{-1}) was noticed in finger millet cropping system-chemical fertilizer. Muche *et al*. (2015) found that, significantly higher exchangeable bases (Ca and Mg) were found in soil of the natural forest compared to the other land use types. This higher litter fall in natural forest (5182.79 kg/ha/year) and higher leaf litter calcium and magnesium concentration (2.67% and 0.44%) respectively, result in soil enriched with calcium and magnesium upon decomposition of litter. This variation in exchangeable bases (Ca and Mg) might be attributed to leaching losses, low content in the parent rock and the proportion of clay minerals as well as the conversion of forest land into the other land use types. Aweto and Dikinya (2003) reported that calcium and magnesium were higher in soil under the tree canopies and it was mainly due to the accumulation of litter.

The exchangeable calcium and magnesium recorded in soil were found to decrease with increasing soil depth. Maximum calcium (6.65 cmol (p+) kg^{-1}) and magnesium (1.89 cmol (p+) kg^{-1}) were recorded at depth of 0-30 cm and least calcium (1.08 cmol (p+) kg^{-1}) and magnesium (0.01 cmol (p+) kg^{-1}) were recorded at of 60-90 cm soil depth. The exchangeable calcium and magnesium decreased with increase in soil depth. This might be attributed to continuous addition of litter for several years and these soils remained undisturbed for many years.

The highest mean value (6.01 cmol (p+) kg^{-1}) of available sulphur was recorded in agroforestry (melia dubia) followed by mango (5.26 cmol (p+) kg^{-1}), natural forest soils (5.01 cmol (p+) kg^{-1}), teak plantation (4.41 cmol (p+) kg^{-1}) and lowest mean value was noticed in finger millet cropping system-chemical fertilizer (1.46 cmol (p+) kg^{-1}). The maximum available sulphur content of 7.98 cmol (p+) kg^{-1} was recorded in the surface soil layer of melia dubia and a minimum available sulphur content of 0.47 cmol (p+) kg^{-1} was recorded in the subsurface (60-90 cm) layer of finger millet cropping system). When compared to agriculture (finger millet) system, the available sulphur level in soils under agroforestry (melia dubia) was much higher followed by mango, natural forest (Table 4). The reason for this could be due to increasing soil organic carbon content which reduces sulphate ion leaching. Acid soils in Manipur have an inorganic sulphur level ranging from 10 to 70 ppm, according to Herojith Singh *et al*. (2007), with the higher available sulphur content ascribed to higher organic matter content.

Micronutrients in Soil under different Land Use Systems

The DTPA extractable iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) content of soils were significantly affected by land use types and soil depth (Tables 5). The highest mean value (18.88 mg kg^{-1}) of DTPA extractable iron (Fe) was recorded in natural forest soils followed by teak plantation (15.25 mg kg^{-1}), agroforestry (melia dubia) with 14.17 mg kg^{-1}, mango (14.07 mg kg^{-1}) and lowest mean value (8.19 mg kg^{-1}) was recorded in finger millet cropping system-chemical fertilizer. The highest mean value (32.74 mg kg^{-1}) of DTPA extractable manganese (Mn) was recorded in natural forest soils followed by teak plantation (25.79 mg kg^{-1}), mango (18.67 mg kg^{-1}), agroforestry (melia dubia) with 18.07 mg kg^{-1} and lowest mean value (7.78 mg kg^{-1}) was recorded in finger millet cropping system-chemical fertilizer. The highest mean value (1.53 mg kg^{-1}) of DTPA extractable zinc (Zn) was recorded in natural forest soil followed by teak plantation (1.31 mg kg^{-1}), agroforestry (melia dubia) with 1.22 mg kg^{-1}, mango (1.16 mg kg^{-1}) and lowest mean value (0.38 mg kg^{-1}) was recorded in finger millet cropping system-chemical fertilizer. The highest mean value (1.62 mg kg^{-1}) of DTPA extractable copper (Cu) was recorded in mango followed by natural forest soils (1.49 mg kg^{-1}), teak plantation (1.02 mg kg^{-1}), agroforestry (melia dubia) with 0.86 mg kg^{-1} and lowest mean value (0.41 mg kg^{-1}) was recorded in finger millet-chemical fertilizer.

Iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) availability depends on soil pH, organic matter content, adsorptive surfaces, other physical, chemical and biological conditions in the soil rhizosphere (Kaur *et al*., 2020). The difference in various micronutrients status under different tree species could be attributed to variation in concentration and rate of decomposition of micronutrients in the litter as well as the quantity of litter added. The DTPA extractable iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) content in soil was decreased with increasing soil depth.

The results showed a distinct change in soil properties of the different land use systems. The study area has low bulk density, which is indicating the higher soil OM. The soil pH was acidic in agriculture (finger millet) land use and it is neutral in natural forest. The soil electrical conductivity was normal in all the land use systems. The higher SOC was recorded in natural forest and higher available N was recorded in the cultivated (finger millet). The higher SOC and available N were observed in the surface soil layers and they found decreasing with increasing soil depth. The available P_2O_5 and K_2O contents were higher in agriculture (finger millet) compared to other land use systems. Even higher concentration of secondary and micronutrients were recorded in natural forest, agroforestry, mango and teak plantation. These results demonstrate that conversion of natural forest into different land use systems adversely affect the soil properties, but land restoration in the region by promoting specific management practice like application of organic residue and sustainable land management practice in land use systems will improve and maintain soil physical and chemical properties.

References

Amanuel, W., Yimer, F. and Karltun, E., 2018, Soil organic carbon variation in relation to land use changes: the case of Birr watershed, upper Blue Nile River Basin, Ethiopia, *J. Ecol. Environ.,* **42** : 16.

Ananthkumar, M. A., 2011, Soil properties and dynamics of major nutrients in soils as influenced by shade trees, rainfall pattern and nutrient management in coffee growing areas of Karnataka. *Mysore J. Agric. Sci.,* **45** (3) : 45 - 58.

Aweto, A. O. and Dikinya, O., 2003, The beneficial effects of two tree species on soil properties in a semi-arid savanna rangeland in Botswana. *Land Cont. Rec.,* **11** (3) : 339 - 344.

Bhardwaj, S. D., Panwar. and Gautam, S., 2001, Biomass production potential and nutrient dynamics of *Populus del-toides* under high density plantations. *Indian For.,* **127** : 144 - 153.

Bhavya, V. P., Anil Kumar, S., Ashok Alur, Shivanna, M., and Shivakumar, K. M., 2018, Changes in soil physical properties as a result of different land use systems with Depth, *Int. J. Curr. Microbiol. Appl. Sci*., **7** (01) : 323 - 327.

Black, C. A., 1965, Methods of Soil Analysis Part-I. Physical and mineralogical properties. Agronomy Monograph No. 9. *Am. Soc. Agron. Inc*. Madison, Wisconsin, USA, 18 - 25.

Center for Science and Environment (CSE) annual data. 2020.

Chandel, S., Hadda, M. S. and Mahal, A. K., 2018. Soil quality assessment through minimum data set under different land uses of submontane, Punjab, *Communications in Soil Sci., Plant Ana.*, **49** (6) : 658 - 674, DOI: 10.1080/00103624.2018.1425424.

Chibsa, T. and Taa, A., 2009, Assessment of soil organic matter under four land use systems in bale highlands, Southeast Ethiopia A. Soil organic matter contents in four land use systems: forestland, grassland, fallow land and cultivated land. *World Appl. Sci. J.,* **6** (9) : 1231 - 1246.

Dasog, G. S. and Patil, P. L., 2011, Genesis and classification of black, red and lateritic soils of north Karnataka. In: Special publ. on Soil Science Research in north Karnataka, *76th Annual Convention of ISSS, Dharwad chapter of ISSS (Eds.)* C. V. Patil, S. C. Kotur, G. S. Dasog and H. T. Channal, pp. : 1 - 10.

Food and Agriculture Organization of the United Nations annual data. 2020.

Gajanana, G. N., Ganapathi and Shankar, M. A., 2005, Relevance of organic matter for sustainable crop production in dryland - A success story for 25 years. *Tech. Bulletin*, AICRP for dryland Agriculture, GKVK, UAS, Bangalore, pp. : 66.

Govind. K. and Krishnamurthy, R., 2022, Impact of different land-use systems on selected soil physicochemical properties in Biligirirangana Hills, Chamarajanagara district. *Mysore J. Agric. Sci.,* **56** (2) : 135 - 143.

Grossman, R. B. and Reinsch, T. G., 2002, Bulk density and linear extensibility. *Methods of soil analysis: Part 4 physical methods*, **5** : 201 - 228.

Gupta, M. K. and Sharma, S. D., 2008, Effect of tree plantation on soil properties, profile morphology and productivity index in Uttarakhand. *Annl. For.,* **16** (2) : 209 - 224.

Hemalatha, S. and Chellamuthu, S., 2013, Impacts of long term fertilization on soil nutritional quality under finger millet: maize cropping sequence. *J. Environ. Res.,* **7** (4A) : 1571 - 1576.

Herojit Singh Athokpam, R. K., Kumarjit Singh, L. N., Singh, N., Gopimohan Singh., Nandini Chongtham and Kumar Singh, A. K., 2007, Sulphur status and forms in acid soils of Manipur. *Indian J. Agric. Res*., **41 (3)** : 205 - 209.

Iqbal, M., Khan, A. G., Hassan, A. U. and Amjad, M., 2012, Soil physical health indices, soil organic carbon, nitrate contents and wheat growth as influenced by irrigation and nitrogen rates. *Int. J. Agric. Biol*., **14** : 20 - 28.

Ishwarya Laxmi, V., Krishna, A., Madhavi Lata, A., Madhavi, A. and Parameswari, Y. S., 2021, Evaluation of Melia Dubia for its biomass production, Carbon Stock, Carbon Sequestration and Economic Returns in Agroforestry System. *Int. J. Curr. Microbiol. Appl. Sci*., **33** (11) : 46 - 54.

Jackson, M. L., 1973, Soil chemical analysis. Prentice Hall of India (Pvt.) Ltd., New Delhi.

Kaur, R., Singh, B., Dhaliwal, S. S. and Dynamics, 2020, of Soil cationic micronutrients in a chronosequence of poplar (*Populus deltoides* Bartr.), Based agroforestry system in India. *J. Soil Sci. Plant Nutr*. https://doi.org/10.1007/s42729-020-00272-4

Lindsay, W. L. and Norwell, W. A., 1978, Development of a DTPA soil test for Zn, Fe, Mn and Cu. *Soil Sci. Soc. Am. J*., **42** : 421 - 428.

Mishra, A. and Swamy, S. L., 2007, Eco-physiology, productivity and nutrient uptake of soybean under *Populus deltoides* based agri-silviculture system. *J. Soils & Crops,* **17** (2) : 217 - 214.

Muche, M., Kokeb, A. and Molla, E., 2015, Assessing the physicochemical properties of soil under different land use types. *J. Environ. & Anal. Toxicol,* **5** : 309.

Nagaraj, J. S., Aseef, K. M., Violet D'souza, M. and Jayarama, 2002, Soil nutrient status of Chikmagalur district in Karnataka cropped to arabica coffee and their relationship with coffee yield. Proc.*15th Plantation Crops Symposium PLACROSYM*, **15** : 282 - 286.

Oyedele, D. J., Awotoyem, O. O. and Popoola, S. E., 2009, Soil physical and chemical properties under continuous maize cultivation as influenced by hedgerow trees species on an alfisol in South Western Nigeria. *Afr. J. Agric. Res.,* **4** (7) : 736 - 739.

Page, A. L., Miller, R. H. and Keeney, D. R., 1982, Methods of soil and plant analysis, Part-2*, Soil Sci. Soc. Am. J., Inc. Publis., Madison, Wisconsin, USA,* pp. : 367.

Piper, C. S., 1966, *Soil and Plant Analysis*. Hans Publishers, Bombay.

Rudramurthy, H. V., Puttaiah, E. T. and Vageesh, T. S., 2007, Chemical properties of soils under different land use systems in Shimoga district of Karnataka. *J. Indian Soc. Soil Sci.,* **55** : 259 - 264.

Subbaiah, B. V. and Asija, G. L., 1956, A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci*., **25** : 259 - 260.

Sushanta Kumar, N., Sudarshan, M., Arun Kumar, S. and Bhagwati, P. B., 2018, Rates of decomposition and nutrient mineralization of leaf litter from different orchards under hot and dry sub-humid climate. *Arch. Agron. Soil Sci.,* **37** : 340 - 365.

Shivakumar, K. M., Prakash, S. S., Nagaraja, M. S., Vijay Kumar, C. and Prabhudev, D., 2020, Effect of Different land use systems on major nutrient statusmin soils of Westernghat-Chikamagalur, Karnataka, India. *Int. J. Curr. Microbiol. Appl. Sci*., **9** (11) : 3502 - 3510.

Singh, B. and Sharma, K. N., 2012, Depth wise distribution of soil organic carbon and nutrients under some tree species after seventeen years of plantation, *J. Indian Soc. Soil Sci*., **60** (3) : 198 - 203.

Swamy, S. L., Mishra, A. and Puri, S., 2006, Comparison of growth, biomass and nutrient distribution in five promising clones of *Populus deltoides* under an agrisilviculture system. *Biore. Techn.,* **97** : 57 - 68.

Takele, L., Chimdi, A. and Abebaw, A., 2014, Dynamics of soil fertility as influenced by different land use systems and soil depth in west Showa Zone, Gindeberet district, Ethiopia. *Agric. For. Fish*, **3** (6) : 489 - 494.

Verma, R. K., Shadangi, D. K. and Totey, N. G., 2001, Analysis of biodiversity and improvement in soil quality under plantations on degraded land. *Indian J. For.,* **24** (1) : 21 - 28.

Walkley, A. and Black, I. A., 1934, An examination of the digestion method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci*., **37** : 29 - 38.

Mysore J. Agric. Sci., 57 (1) : 245-250 (2023)

Effect of Nano NPK Fertilizers on Growth, Yield and Fruit Quality of Sapota [*Manilkara achrus* (Mill.). Fosberg] Cv. Kalipatti

Priyanka Mirji, G. K. Mukunda and K. N. Srinivasappa
Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : mirjipriyanka123@gmail.com

Authors Contribution

Priyanka Mirji : Data collection and data analysis;
G. K. Mukunda : Execution of field experiment, data collection and analysis;
K. N. Srinivasappa : Experimental materials and designing of the experiment

Corresponding Author :
Priyanka Mirji
Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru

Received : September 2022
Accepted : December 2022

Abstract

The study was conducted in the Department of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru during the year 2020-2022 to investigate the 'Effect of nano NPK fertilizers on growth and quality of sapota [*Manilkara achrus* (Mill.). Fosberg] Cv. Kalipatti'. The experiment was planned with randomized complete block design (RCBD) consisting of 12 treatments and 3 replications. The maximum plant height (3.78 m) was noticed in the treatment T_{10} (50% RDF + 0.3% Nano NPK fertilizer foliar spray), maximum chlorophyll content (2.30 mg/ g) was noticed in the treatment T_9 (50% RDF + 0.2% Nano NPK fertilizer foliar spray) and maximum fruit length (6.53 mm), fruit width (5.43 mm), pulp weight (26.67g), TSS (22.33 °Brix), reducing sugar (9.31%) and total sugars (22.18%) were noticed in treatment T_9 (50 per cent of RDF and foliar application of 0.2% of nano NPK fertilizer). Among all the different treatments T_9 (50 per cent of RDF and foliar application of 0.2% of nano NPK fertilizer) and T_8 (50 per cent of RDF and foliar application of 0.1 per cent of nano NPK fertilizer) were proved significant improvement for plant growth, yield and quality of sapota fruits.

Keywords : Nano NPK, RDF, Sapota, Kalipatti, Foliar spray

Sapota [*Manilkara achras* (Mill.) Fosberg] native of Mexico belongs to the botanical family Sapotaceae. It is mainly introduced for its delicious fruits. Many fruit growers were attracted to the cultivation of sapota on account of its better adaptation to diverse soil and climatic conditions. It is getting popular in countries *viz*., India, Sri Lanka, Jamaica, Burma, Philippines, Central Asia and Southern Florida (USA).

It is gaining more importance in the tropical, sub-tropical and semiarid climate. It can also sustain in waste land and marginal lands, but fruit set, yield and the economy were inferior due to improper nutrition. This crop also suffers from a malady called mummification or stone fruit, is very severe in old orchards in certain areas of hill zones. The severity leads to a loss of crop to the tune of more than 70 per cent (Satish, 2003).

The successful commercial cultivation of this crop depends on many factors such as climate, soil, irrigation, fertilizer, spacing and season of growing *etc.* Among the different management practices, nutrient management plays an important role in growth, yield and economy of fruit crop. To perform sustainable yield and economy, it needs high amount of nutrients (Mishra, 2014).

The intensive and exploitative agriculture with high inputs and high yielding varieties and improved technologies, have helped for better fruit production. But, competition for water and nutrients and the major nutrients usually supplied through straight fertilizers in large quantities for improving fruit set, productivity and to meet nutritional requirement of the fruit trees. But, application of straight fertilizers leads to evaporation, leaching and run off of nutrients. Hence, the experiments have been conducted to reduce the nutrient losses and increase the nutrient use efficiency of fertilizers through use of nano-fertilizers. These nano-fertilizers shown significantly improved yield in different fruit crops. Therefore, based on the possible benefits of soil and foliar application of nano-fertilizers (NFs) seems to be benificial.

Nano-fertilizers (NFs) are widely used in fruit crop nutrition as soil based and spray based applications (Pruthviraj *et al.,* 2022) that provide nutrients with high efficiency and low waste due to their faster and higher translocation to different parts of plants. After penetrating the leaf or root cuticle tissue, NFs move through different pathways (apoplastic, symplastic, lipophilic and hydrophilic), which influence their effectiveness, final fate and may also change their properties and reactivity, delivery and translocation inside plant tissues, which may result in various responses of different plant parts to the same NP (Nano Particle).

NFs are much smaller than conventional materials and due to a greater surface area to weight ratio, different shapes and higher penetrability, they may have more significant effects on growth and developmental processes and can directly enter leaf tissues through stomata. The concentration and consumption time of NFs can influence their effects on plants and different plant processes (Rame Gowda *et al.,* 2022). Due to their tiny scale, NPs have high penetrability into plant tissues and high concentrations of NFs may negatively affect growth and development. To prevent these negative effects, they are generally applied in very low concentrations at the mg L^{-1} level. Therefore, to achieve higher yield and lower damage applied in lower concentration to reach required nutrients by the plants, also reduce the use of large amount of inorganic fertilizers (50%) in conventional method and reduce the cost of about 10 per cent compared to conventional fertilizers.

Material and Methods

A field study on ‘Effect of nano NPK fertilizers on plant growth and quality of sapota fruits Cv. Kalipatti’ was initiated during 2020-2022. The experiment was conducted in the Department of Horticulture, UAS, GKVK, Bengaluru. The experiment site is situated in Eastern dry zone (Zone-5) of Karnataka State at 13^{o} 05" North latitude and 77^{o} 34" East longitude with an elevation of about 924 meters above mean sea level. The major rainfall received from South-West monsoon between June to September months and North-East monsoon between October to December months. The soil type of experimental site is red sandy to lateritic with clay content. The available nitrogen, phosphorous and potassium in soil were 94.08, 333.45 and 135.74 kg ha^{-1} respectively, which indicate that the soil is medium in available P while deficient in available N and K content.

The experiment was laid out in Complete Randomized Block Design (RCBD) with twelve treatments and three replications consisting of different concentrations of nano fertilizers and RDF application for sapota trees. Sapota trees were planted at distance of 10 x 10m (Standing crop) 30 years old trees. The treatments were T_1- Control (RDF 400: 160: 150 g/plant), T_2- Water soluble normal NPK fertilizers foliar spray (NPK fertilizer), T_3- 25 per cent RDF (100: 40: 37 g/plant) + 0.1 per cent Nano NPK fertilizer foliar spray, T_4- 25 per cent RDF + 0.2 per cent Nano NPK fertilizer foliar spray, T_5- 25 per cent RDF + 0.3 per cent Nano NPK fertilizer foliar spray, T_6- 25 per cent RDF + 0.4 per cent Nano NPK fertilizer foliar spray, T_7- 25 per cent RDF + 0.5 per cent Nano NPK fertilizer foliar spray, T_8- 50 per cent RDF (200: 80: 75 g/plant) + 0.1 per cent Nano NPK fertilizer foliar spray, T_9- 50 per cent RDF + 0.2 per cent Nano NPK fertilizer foliar spray, T_{10}- 50 per cent RDF + 0.3 per cent Nano NPK fertilizer foliar spray, T_{11}- 50 per cent RDF + 0.4 per cent Nano NPK fertilizer foliar spray, T_{12}- 50 per cent RDF + 0.5 per cent Nano NPK fertilizer foliar spray.

The treatments were imposed to sapota trees in split application and first imposition was done through foliar application of nano NPK fertilizers for three times-first at the end of last season harvest, second spray at one month after the first spray and third spray when fruit lets were at pea size and soil application of RDF was at a once. Other cultural operations were attended to keep the plot clean and plant protection measures were carried out at regular intervals.

Selected tree for each treatment with three replications were tagged for recording observations on various parameters of plant growth, yield and quality. The mean value of the data was taken to represent a particular treatment with respect to character. Fruits were randomly selected from tagged shoots in each treatment to study the quality and postharvest parameters.

Results and Discussion

Tree Height

Tree height of sapota, influenced by different treatments consisting of different concentrations of RDF and nano NPK fertilizers was recorded and the values for plant height were significantly higher in treatment T_{10} (3.78m), however it was on par with T_9(3.73m), T_7 (3.67m) and T_8 (3.62m). The treatment T_1 (2.93m) recorded significantly lower values for plant height (Table 1). This might be due to the fact that nano fertilizer has unique properties due to its more surface area with high absorption, which causes an increase in photosynthesis and increased leaf area hence, increased the plant height (Sekhon, 2014). The results are in conformity with the findings of Sabir *et al*. (2014) in blueberries and Mohasedat *et al.* (2018) in apple.

Chlorophyll Content

Chlorophyll content of sapota leaves significantly differed among the treatments and was recorded highest chlorophyll content of leaf in treatment T_9 (2.30 mg/ g) depicted in Table 1. which was on par with the treatment T_8 (2.20 mg/ g) and T_{10} (2.10 mg/g). This might be due to foliar spray of nano formulations enhanced the availability of nutrients by easy penetration through stomata of leaves *via* gas exchange. Nitrogen fertilizer activates the enzymes associated with chlorophyll formation hence it increases the chlorophyll content in the leaves. The same observations were made by Roshdy and Refai (2016) in date palm and Abdelaziz *et al*. (2019) in mango.

Table 1

Effect of nano NPK fertilizers on plant height and chlorophyll content of sapota

Treatments	Tree Tree height (m)	Chlorophyll content (mg/g)
T_1	2.93	1.98
T_2	3.00	1.98
T_3	3.10	1.93
T_4	3.53	1.97
T_5	3.60	2.05
T_6	3.67	2.03
T_7	3.55	2.03
T_8	3.62	2.20
T_9	3.73	2.30
T_{10}	3.78	2.10
T_{11}	3.53	1.98
T_{12}	3.30	1.82
Mean	3.45	2.03
F test	*	*
SEm±	0.05	0.06
CD @ 5%	0.17	0.20
CV	2.85	5.95

Yield and Quality Parameters

Fruit length, width and number of seeds per fruit : The results revealed that there was a significant difference among the treatments. Maximum length and width of fruit was observed in the treatment T_9 (6.53 mm and 5.43 mm respectively), however which was on par with treatment T_8 (6.43mm and 5.27mm respectively) and lowest fruit length and width was observed in T_1 (5.30mm and 4.23mm respectively) depicted in Table 2. This may be due to nano fertilizers which are unique in behaviour and characteristic delivery the nutrients throughout the plant growth period and especially potassium has a positive effect on the process of dividing and expanding the cells by stimulating the expansion of cell wall, thus increased fruit length and width. The

TABLE 2

Effect of nano NPK fertilizers on fruit length and width and number of seeds per fruit of sapota

Treat-ments	Length of fruit (cm)	Width of fruit (cm)	Number of seeds per fruit	Fruit pulp weight (g)	Rind weight (g)
T_1	5.30	4.23	1.00	16.67	16.67
T_2	5.47	4.83	1.67	18.33	15.67
T_3	5.50	5.13	1.00	22.67	15.00
T_4	5.93	5.10	1.67	25.00	13.00
T_5	5.60	5.13	2.00	25.33	14.00
T_6	5.50	5.13	1.33	25.33	13.67
T_7	5.43	4.70	1.33	25.67	13.67
T_8	6.43	5.27	1.67	25.67	13.00
T_9	6.53	5.43	1.33	26.67	12.33
T_{10}	5.73	4.50	1.67	26.00	14.33
T_{11}	5.33	4.37	1.67	22.67	13.00
T_{12}	5.53	4.33	1.67	23.33	14.00
Mean	5.69	4.85	1.50	23.61	14.03
F test	*	*	NS	*	NS
SEm±	0.15	0.084	-	1.19	-
CD@5%	0.45	0.25	-	3.50	-
CV	4.72	2.095	-	8.75	-

similar results are in conformity with the findings of Sabir *et al.* (2014) in blue berries, Kamiab and Zamanibahramabadi (2016) in almond and Mohamad Gad *et al.* (2021) in mango. The values for number of seeds per fruit among all the treatments were non-significant.

Fruit Pulp Weight and Rind Weight

The results revealed that values for fruit pulp weight differed significantly among the treatments. The highest fruit pulp weight was recorded in the treatment T_9 (26.67 g) followed by T_8 (25.67 g) and lowest fruit pulp weight was recorded in T_1 (16.67 g). The value for rind weight was non-significant among all the treatments (Table 2.). There was increase in pulp weight may be due to highest fruit size, Except TSS content of Table 3, other contents have to be merged in Table 2 along with fruit weight. TSS content is to be depicted in Table 3 for understanding of fruit and biochemical contents.

TSS of Fruit

The results revealed that values for TSS of fruit differed significantly among the treatments (Table 3.). The highest TSS of fruit recorded in the treatment T_9 (22.33 °Brix) followed by T_8 (21.67 °Brix) and TSS of fruit was recorded in T_1 (17.33 °Brix respectively). There was increased TSS of fruit pulp may be due to nano-fertilizers application confirms the importance of nanoparticles as unique in behavior and characteristics, such as the small size, delivery of nutrients and highly active area, which increased the rapidity of fruit chemical reactions. These results are in consistent with Roshdy and Refaai (2016) in date palm and Mohamad Gad *et al.* (2021).

Sugar Content

Reducing, Non-reducing and Total sugars content in fruit pulp was estimated and it was found statistically

TABLE 3

Effect of nano NPK fertilizers on TSS of sapota fruits

Treatments	TSS °Brix
T_1	17.33
T_2	17.67
T_3	19.00
T_4	19.67
T_5	21.67
T_6	19.67
T_7	19.33
T_8	21.67
T_9	22.33
T_{10}	19.67
T_{11}	18.67
T_{12}	20.33
Mean	19.75
F test	*
SEm±	0.65
CD @ 5%	1.92
CV	5.75

significant among the treatments. The highest value for reducing sugar was observed in T_9 (9.31%) which was on par with T_8 (9.28%). Similarly, the value for total sugars was observed highest in T_9 (22.18) however which was on par with T_8 (22.16%) and T_{10} (21.19%). The lowest values for both reducing sugar and total sugars were observed in T_1 (7.40% and 17.37% respectively). Non- significant results were obtained for non-reducing among the treatments (Table 4). This might be due to the fact that important regulatory effect of nano fertilizers in activating metabolic enzymes, biosynthesis and translocation of sugars, water absorption and nutrient transport which might have increased the sugar level in the fruit. These results are in consistent with Abdelaziz *et al.* (2019) in almond, Wassel *et al*. (2017) in grape and Mosa *et al.* (2021) in peach.

On the basis of present investigation it may be concluded that 50 per cent of RDF with foliar application of 0.2 per cent nano NPK fertilizer and 50 per cent of RDF with foliar application of 0.1 per cent of nano NPK fertilizer were proved significant for improved tree tree growth, yield and quality of sapota fruit when compared with other treatments especially with respect to obtaining maximum tree tree height, chlorophyll content and quality attributes (Fruit length, width, number of seeds per fruit, fruit pulp weight, rind weight, TSS of fruit, reducing, non-reducing and total sugars).

TABLE 4

Effect of nano NPK fertilizers on reducing sugar, non reducing sugar and total sugars in sapota pulp

Treat-ments	Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)
T_1	7.40	16.67	17.37
T_2	8.20	15.67	18.40
T_3	8.02	13.33	19.30
T_4	8.22	13.00	19.60
T_5	9.07	15.00	18.92
T_6	6.06	13.67	16.93
T_7	9.20	13.67	19.15
T_8	9.28	14.00	22.16
T_9	9.31	12.33	22.18
T_{10}	8.40	14.33	21.19
T_{11}	7.82	13.00	17.67
T_{12}	8.13	14.00	18.34
Mean	8.26	14.06	19.27
F test	*	NS	*
SEm±	0.14	-	0.53
CD @ 5%	0.42	-	1.56
CV	3.05	-	4.79

REFERENCES

ABDELAZIZ, F. H., AMMA, A. K. L., MOHAMED, A. Z. AND ZAKIER, M. A., 2019, Response of Keitte mango trees to spray boron prepared by nanotechnology technique. *NY Sci. J.*, **12** : 48 - 55.

KAMIAB, F. AND ZAMANIBAHRAMABADI, E., 2016, The effect of foliar application of nano-chelate super plus ZFM on fruit set and some quantitative and qualitative traits of almond commercial cultivars. *J. Nuts.,* **7** (1) : 9 - 20.

MISHRA, D., 2014, Nutrient removal studies in guava under high density orchard system. *J. Agri. Crop Sci.,* **1** : 36 - 38.

MOHAMED GAD, ABDEL-MOHSEN, M. AND ZAGZOG, O., 2021, Improving the yield and fruiting characteristics of Ewais mango cultivar by spraying with nano-chitosan and nano-potassium silicate. *Scientific J. Agri. Sci.* **3** (2) : 68 - 77.

MOHASEDAT, Z., DEHESTANI-ARDAKANI, M., KAMALI, K. AND ESLAMI, F., 2018, The effects of nano-bio fertilizer on vegetative growth and nutrient uptake in seedlings of three apple cultivars. *Adv. In Biores*, **9** (2) : 1 - 5.

MOSA, W. F., EL-SHEHAWI AM, MACKLED, M. I., SALEM, M. Z., GHAREEB, R. Y., HAFEZ, E. E. AND ABDELSALAM, N. R., 2021, Productivity performance of peach trees, insecticidal and antibacterial bioactivities of leaf extracts as affected by nano fertilizers foliar application. *Scientific Reports*, **11** (1) : 1 - 19.

Pruthviraj, N., Geetha, K. N., Prakash, S. S., Jayadeva, H. M., Pushpa, K. and Shankar, A. G., 2022, Impact of different methods of nano fertilizers application on soil chemical properties and fertility status in sunflower growing soils. *Mysore J. Agric. Sci.,* **56** (1) : 275 - 284.

Rame Gowda, Uma Rani, K. and Roopashree, B., 2022, Application of nanotechnology in improving seed quality and crop productivity : prospects and developments - A review. *Mysore J. Agric. Sci.,* **56** (4) : 10 - 20.

Roshdy, K. H. A. and Refaai, M. M., 2016, Effect of nanotechnology fertilization on growth and fruiting of zaghloul date palms. *J. Plant Production*, Man Soura Univ., **7** (1) : 93 - 98.

Sabir, A., Yazar, K., Sabir, F., Kara, Z., Yazici, M. A. and Goksu, N., 2014, Vine growth, yield, berry quality attributes and leaf nutrient content of grapevines as influenced by seaweed extract (*Ascophyllum nodosum*) and nanosize fertilizer pulverizations. *Sci. Hortic*. **175** : 1 - 8.

Satish, K. B., 2003, Nutrient status of mummified and non mummifiedsapota cv. Kalipatti. *M.Sc. (Hort.) Thesis,* University of Agricultural Sciences, Bangalore, pp. : 1 - 3.

Sekhon, B. S., 2014, Nanotechnology in agri-food production an overview. *Nanotechnology, Science and Applications*, **7** : 31 - 53.

Wassel, A. E. H., El-Wasfy, M. and Mohamed, M., 2017, Response of flame seedless grapevines to foliar application of nano fertilizers. *J. Product Dev*., **22** (3) : 469 - 485.

Mysore J. Agric. Sci., 57 (1) : 251-262 (2023)

Effect of Application of Blended Granite Rock Dust with Solid and Liquid Organic Manures on Yield of Maize (*Zea mays* L.)

S. P. Pooja and A. Sathish
Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : poojaspjapu@gmail.com

Authors Contribution

S. P. Pooja :
Carried out the experiment, drafted the manuscript and performed the statistical analysis
A. Sathish :
Conceived the study and corrected the manuscript

Corresponding Author :
S. P. Pooja
Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru

Received : August 2022
Accepted : February 2023

Abstract

A field experiment was conducted to evaluate the effect of blended granite rock dust along with solid and liquid organic manures on yield of maize at Ramagiri, Holalkere Taluk, Chitradurga district, Karnataka, India. The characterization of granite rock dust, panchagavya, jeevamrutha and bio-enriched pressmud compost indicate that, the pH of panchagavya was 5.48, bio-enriched pressmud compost -7.10 and jeevumrutha recorded pH 8.01. Highest organic carbon, N, P, K, Ca, Mg and S contents were recorded in bio-enriched pressmud compost (41.58, 1.37, 2.41, 2.30, 3.83, 2.56 and 2.01 %, respectively) followed by panchagavya (0.92, 0.22, 0.88, 1.15, 0.51, 0.11 and 1.02 %, respectively) and jeevamrutha (0.08, 0.08, 0.53, 0.13, 0.51 and 1.24 %, respectively). Micronutrients *viz*., Fe, Mn and Zn were also higher in bio-enriched pressmud compost than panchagavya and jeevamrutha. Whereras, highest Cu content was recorded in panchagavya followed by bio-enriched pressmud compost and jeevamrutha. Similarly, highest bacteria, actinomycetes and fungi load were observed in case of bio-enriched pressmud compost (21×10^5, 15×10^4 and 17×10^3, respectively) followed by panchagavya and jeevamrutha. At the end significantly, higher kernel yield (87.63 q ha^{-1}) of maize was recorded in the treatment T_{11} which received 75 per cent K + Bio-enriched pressmud compost treated Rock dust @ 6 t ha^{-1} and followed by T_9 treatment (79.59 q ha^{-1}) than compared to the rest of the treatments and this shows the efficiency of bio-enriched pressmud compost and panchagavya in enhancing the nutrient release rate from granite rock dust than jeevamrutha, FYM and rock dust alone applications.

Keywords : Granite rock dust, Bio-enriched pressmud compost, Panchagavya, Jeevamrutha, FYM, Maize production

Rock dust is a pulverized stone, often produced as a by-product of the mining and crushing industries. It has the same mineralogical and elemental composition as that of parent rock. The commonly occurring nutrient elements are Ca, Mg, K, Fe *etc*. in large proportion and minor amounts of P, S, Zn, Cu *etc*. which are not in available form. The elements that are contained in the rock dust become available upon weathering. There are few but consistent reports on the use of multi-nutrient rock and mineral fertilizers in the organic and conventional production systems (Fyfe *et al.,* 2006).

Organic waste, such as pressmud or filter cake, is generated as a by-product of sugarcane industries and characterized as a soft, spongy, amorphous and dark brown to brownish material (Ghulam *et al.,* 2012). Pressmud supplies a good amount of organic manure (Bokhtiar *et al*., 2001), used as an alternate source of plant nutrient, as a soil amelio rates (Razzaq, 2001) and also as one of the substrates in bio-composting (Chand *et al*., 2011). It contains significant amounts of iron, manganese, calcium, magnesium, silicon and phosphorus and enhanced the suitability of SPM as a source of nutrient (Yadav and Solomon, 2006).

Panchagavya is one of the widely used traditional organic formulations, which is mostly prepared by farmers themselves. Panchagavya is a fermented product made from five ingredients obtained from cow, such as milk, urine, dung, curd and clarified butter (Amalraj *et al*., 2013). Panchagavya is a traditional formulation derived from gavya used in India to safeguard plants and soil microorganisms. Panchagavya has been shown to increase plant production and also has been shown to have beneficial effects on a variety of crops (Natarajan, 2002). Recently, higher number of cultivable bacterial genera was obtained from the organic formulation prepared using fermented cow manure (Giannattasio *et al*., 2013). In addition, few novel and plant growth-promoting bacteria such as *Larkinella bovis* and *Microbacterium suwonense* were isolated from traditional organic formulations and tested for their plant growth promotion (Anandham *et al*., 2011a).

Jeevamrutha is a plant growth-promoting substance containing beneficial microorganisms that provides the necessary nutritional requirement for growth and yield of a crop. The microorganisms that supply nitrogen like *Azotobacter, Acetobacter, Azospirillum* and phosphorus-solubilizing bacteria like *Pseudomonas* and potash-solubilizing bacteria like *Bacillus silicus* are present in dung that is used to prepare jeevamrutha. Microbial activities will be activated upon the addition of jeevamrutha which further maintains soil productivity (Vanaja *et al.,* 2009).

Now-a-days solid and liquid organic manures like, panchagavya, jeevamrutha and bio-enriched press mud composts are becoming popular to combat the adverse effect of chemical fertilizers. These can supply essential nutrients to the crop plant and also provide several growth promoters and bio-control agents to prevent disease and pest infestation. As such these organic manures can be prepared by using several farm inputs and daily household materials. The cost incurred in preparing these solid and liquid organic manures are very less comparing with the chemical fertilizers and pesticides. In view of the above, the current study focused on evaluating the effect of blended application of granite rock dust along with solid and liquid manures on yield of maize.

Material and Methods

Characterization of Rock Dust

Rock dust was collected from the nearby M-Sand industry and was characterized for particle size distribution, bulk density, particle density, maximum water holding capacity, pH, electrical conductivity, total phosphorus, potassium, calcium, magnesium, sulphur and micro nutrients (Fe, Mn, Zn and Cu) as per the standard protocols as given in Table 1.

The sample used in the experiment was granite rock dust obtained from local M-Sand manufacturing industry (Mavinahole Village, Channagiri Taluk, Davanagere District, Karnataka). Particle size class was determined by sieve method. A known weight (100 g) of dried rock dust sample was passed through sieves of different BSS mesh number (3, 8, 12, 16, 36, 72, 100 and 200) and the material retained on each sieve was collected, weighed and expressed in per cent. For nutrient analysis, finely ground 0.1g of rock dust was oven dried at 100 ^{0}C for 2 hours. Then digested by treating rock dust with perchloric acid and hydrofluoric acid in 1:10 ratio in silica crucibles till the acids get evaporated to dryness and diluted with 5ml of 6N HCl and made up to 2/3rd volume of silica crucible with deionized water. The crucibles were kept on hotplate till residues completely dissolved. The volume of the digested sample was made up to 100 ml with distilled water and used for total elemental analysis.

Preparation of Panchagavya, Jeevamrutha and Bio-Enriched Pressmud Compost

Preparation of Panchagavya

Ingredients : The cow by-products *viz*., cow dung (7kg), cow urine (3 liters), cow milk (2 liters), cow curd (2 liters) and cow ghee (1kg) were collected from Gir cow and jaggery (250g), banana (12

TABLE 1

Methods Followed for Analysis of Physico-Chemical and biological Properties of Rock dust Panchagavya, Jeevamrutha and Bio-Enriched Pressmud Compost

Parameters	Methods	Reference
Physical properties		
Colour	Visual evaluation	-
Odour	Sensory evaluation	-
Bulk density (g/cc)	Keen Raczkowski Cup	Piper, 1966
Particle density (g/cc)	Keen Raczkowski Cup	Piper, 1966
MWHC (%)	Keen Raczkowski Cup	Piper, 1966
Chemical properties		
pH (1:2.5)	pH meter method	Jackson (1973)
EC (dS m^{-1}) (1:2.5)	Conductivity meter method	Jackson (1973)
Organic carbon	Walkley and Black wet digetion	Walkley and Black (1934)
Total Nitrogen	Kjeldhal digestion and distillation method	Piper (1996)
Total Phosphorous	Vanado-molybdo phosphoric yellow colour method	Piper (1996)
Total Potassium	Flame photometry	Piper (1996)
Total Calcium	Complexometry using versenate solution	Piper (1996)
Total Magnesium	Complexometry using versenate solution	Piper (1996)
Total sulphur	Turbidometry	Bardsley and Lancaster (1965)
Total Micronutrients Fe, Mn, Zn, Cu	Atomic Absorption Spectrophotometry	Lindsay and Norwell (1978)
Biological properties		
Bacteria	Nutrient Agar medium andSerial dilution technique	Waksman (1927)
Actinomycetes	Ken knight s Agar medium and Serial dilution technique	Waksman (1927)
Fungi	Martin s rose Bengal Agar and Serial dilution technique	Waksman (1927)

numbers), tender coconut (2 liters), yeast (100g) and water (10 liters) were used in the study.

Procedure : Firstly, cow dung and cow ghee were taken into a clean plastic container, mixed properly until the smell of cow dung decreases, due to the masking effect of ghee used and the mixture was kept undisturbed for 2 days by covering with the wet muslin cloth. Then cow urine and water were added and left the mixture for 15 days in a well-ventilated, clean and shady place covered with wet muslin cloth for proper aeration and also to avoid the interaction of external agents like mosquitoes or any other insects and animals. Then after 15 days, the remaining ingredients like, jaggery, milk, curd, coconut water, yeast and banana were added and the mixture was covered with wet muslin cloth for 21 days for maturation with proper stirring twice a day with the help of wooden stirrer in both the directions. After 21 days, the solution was ready for further usage (Chakraborty and Sarkar, 2019).

Preparation of Jeevamrutha

Ingredients : In this experiment all the by-products of cow were collected from gir cow. Water (200 litres), cow dung (10 kg), cow urine (10 litres), Jaggery (2 kg), pulse flour (2 kg) and soil collected from the experimental plot (500g).

Procedure : The cow by-products were mixed in a proper container and kept in a clean, well ventilated and under the shade by covering it with a wet muslin cloth. The mixture was stirred twice a day. After 21 days of maturation the product was ready for usage (Shankaran, 2009).

Enrichment Technique for Generation of Bio Enriched Pressmud

Sugarcane pressmud is the solid waste left over after the filtration of sugarcane juice and distillery spentwash is the liquid waste. Compost is obtained by composting pressmud and spentwash in the ratio 1:2.5 by wind-row method.

In the present experiment the pressmud compost (collected from Shri Chamundeswari Sugars *Ltd*., Bharathi Nagar, Maddur taluk, Mandya District, Karnataka) was enriched by mixing 2g of microbial culture from each pack containing *Bacillus megaterium, Pseudomonas fluorescens* and *Azotobacter chroococcum* were collected and mixed with kg of pressmud compost. The compost was mixed thoroughly and conditioned by sprinkling water twice a week to maintain the moisture content in the compost to 60-70 per cent. The compost was placed under shade, allowed for proliferation of microbial population for 10 days and then used for further experimental works.

Characterization of Panchagavya, Jeevamrutha and Bio-Enriched Pressmud Compost

The physical, chemical and biological properties of panchagavya, jeevamrutha and bio-enriched pressmud compost were analysed to estimate their constituents using standard procedures. The standard procedures followed for estimation of various properties of these solutions are given in Table 1.

Field Experiment to Study the Effect of Bio-Treated Granite Rock Dust on Yield of Maize

Field experiment was conducted at Ramagiri, Holalkere Thaluk, Chitradurga District, Karnataka, India during 2020 and 2021 with twelve treatments following randomized complete block design replicated thrice to assess the agricultural use efficiency of bio-treated rock dust using maize as a test crop. The granite rock dust collected from M-stand industry was treated with panchagavya or jeevamurtha, bio-enriched pressmud compost or farm yard manure in the ratio of 10:1:2, respectively (*i.e.*, the treatments with liquid organic manure, for every 10 parts of rock dust, 1 part of panchagavya or jeevamrutha along with 2 parts of farm yard manure as a carbon source was added and for the treatments with solid organic manure, for every 10 parts of rock dust, 2 parts of bio-enriched pressmud compost was added). The bio-treated granite rock dust was cured for fifteen days and used for the experimental plots as per the treatments along with recommended dose of FYM which was applied fifteen days prior to sowing of maize. The recommended dose of fertilizers [150:75:40 (N, P_2O_5, K_2O kg ha^{-1}) + 10 kg $ZnSO_4$ ha^{-1} for irrigated condition] was applied at the time of sowing. Sowing of maize seeds (MAH-14-5) was done by dibbling method with a spacing of 60 cm between the rows and 30 cm between the plants. Finally, at the end after harvest kernel yield from each treatment was recorded.

Treatment details

Treatments	*Details*
T_1	Absolute control
T_2	100% RDK
T_3	75% RDK +Rock dust @ 6 t ha^{-1}
T_4	75% K + Rock dust @ 3 t ha^{-1}
T_5	50% K + Rock dust @ 6 t ha^{-1}
T_6	50% K + Rock dust @ 3 t ha^{-1}
T_7	75% K + Jeevamrutha treated Rock dust @ 6 t ha^{-1}
T_8	50% K + Jeevamrutha treated Rock dust @ 3 t ha^{-1}
T_9	75% K + Panchagavya treated Rock dust @ 6 t ha^{-1}
T_{10}	50% K + Panchagavya treated Rock dust @ 3 t ha^{-1}
T_{11}	75% K + Bio-enriched pressmud compost treated Rock dust @ 6 t ha^{-1}
T_{12}	50% K + Bio-enriched pressmud compost treated Rock dust @ 3 t ha^{-1}

Note : 100% RD-N, P and Zn is common for all the treatment except T_1,

- RD-FYM is used for all the treatments except T_1, T_{11} & T_{12}
- FYM- Farm Yard Manure, POP- Package of Practice.
- RDF- Recommended dose of fertilizers (150:75:40 (N, P_2O_5, K_2O kg ha^{-1}) + 10 kg $ZnSO_4$ ha^{-1} for irrigated condition) and FYM- 10 t ha^{-1}.

RESULTS AND DISCUSSION

Rock dust used in the present investigation, a waste product generated in M-Sand producing industry. It is composed of many elements including nutrient elements that are naturally found in the rocks. The application of rock dust in crop production thus may improve the physical and chemical properties of soil. The elements contained in the rock dust are become available upon weathering. Use of this waste in agriculture not only supplies the nutrients but also solves the problem of its accumulation and causing damage to environment. In this regard, in order to evaluate the efficacy of rock dust in crop production, a field experiment was carried out to study the effect of application of blended granite rock dust with solid and liquid organic manures along with the recommended dose of fertilizers and farm yard manure on yield of maize. The results obtained and discussions in these results are presented in this chapter under following headings.

Characterization of Rock Dust

Particle size of the rock dust indicated that particles of > 2 mm size were 7.32 per cent and that of < 2 mm are 92.68 per cent. Out of 92.68 per cent of fine earth material, the highest particles were in the size range of 0.44 to 0.22 mm and particles which were passed through 0.08 mm were 17.86 per cent (Table 2). The size of the particle may varied from source to source.

TABLE 2

Particle size analysis of rock dust

BSS Mesh Number	Sieve size (mm)	Particles retained on sieve (%)
3	4.75	1.50
8	2.00	5.82
12	1.33	6.14
16	1.00	12.15
36	0.44	10.11
72	0.22	30.18
100	0.16	10.82
200	0.08	5.42
Per cent particles passed finally through last sieve		17.86

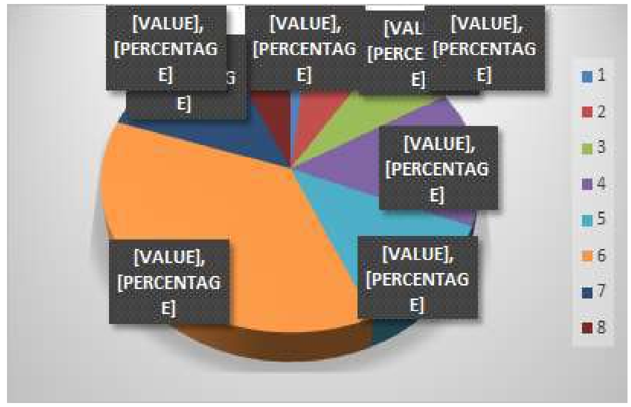


Fig. 1: Particle size classes of rock dust
Note: 1 to 8 which indicates BSS mesh number as presented in the Table 2

For instance, the particles which are obtained from mining sites are coarser in size, if it wass from polishing and M-Sand industries are finer in size (Hassan *et al*., 2013). The particle density of dust (2.09 g/cc) indicates that it is composed of light minerals. The bulk density of 1.52 g/cc indicates that it gets compacted upon settling. The MWHC and per cent porosity were 17.70 per cent and 27.1 per cent, respectively. The lower value of MWHC and porosity suggests that it is fine powder of rock fragments.

The results of the chemical analysis revealed that rock dust was neutral (7.20) in reaction with an electrical conductivity 0.41 dS m^{-1}. The total macronutrients *viz*., P, K, Ca, Mg and S contents were 1.01, 5.74, 8.40, 4.32 and 1.60 per cent, respectively and total micronutrients like Fe, Mn, Zn and Cu contents were 1365, 23, 25 and 67 mg kg^{-1}, respectively. Weerasuriya *et al*. (1993) reported that acidulated mica was a promising multi nutrient fertilizer due to its higher nutrient contents. Whereas, Hinsinger *et al*. (1996) reported similar elemental composition for granite and diorite rock powders which was collected from quarry units in Herne Hill, near Perth (Western Australia).

Characterization of Solid and Liquid Organic Manures

The physical and chemical properties of Panchagavya, Jeevumrutha and bio-enriched pressmud compost are presented in Table 4.

TABLE 3
Physical and chemical properties of rock dust

Parameters	Value
Physical properties	
MWHC (%)	17.70
P.D (g/cc)	2.09
B.D (g/cc)	1.52
Particle size < 0.08mm in (%)	17.86
Chemical properties	
pH (1:2.5)	7.20
EC (dS m^{-1}) (1:2.5)	0.41
Total phosphorous (%)	1.01
Total potassium (%)	5.74
Total Calcium (%)	8.40
Total Magnesium (%)	4.32
Total Sulphur (%)	1.60
Total Fe (ppm)	1365
Total Mn (ppm)	23
Total Zn (ppm)	25
Total Cu (ppm)	67

The colour of freshly prepared panchagavya was light brown and as the storage period increased the colour turned to darker. It might be due to series of non-enzymatic Maillard's reactions (the reaction between reducing sugars and proteins by the impact of heat), started with the binding of aldehyde group of lactose with ε-amino group of the lysyl - residues (amino-acid radical or residue of amino-acid lysine) from different milk proteins during storage. These reactions will occur due to the formation of pigments responsible for brown-colour, such as pyralysins and melanoidins, polymers such as lacto-lysine of fructose-lysine, as well as due to low-molecular weight organic acids (LMWOAs). The use of cow dung and cow urine enhanced the rate of decomposition with the increment in heat and for that dark brown colour was developed (Kneifel *et al*., 1992; Singh *et al*., 1992).

Freshly prepared Panchagavya possessed a fruity smell. Foul odour was observed after 20 days and progressed up to the end of storage. The reason behind this might be the light sensitiveness of riboflavin which absorbed visible and ultra violet light, converting that energy into highly reactive forms of oxygen. That induced a whole series of oxidative reactions, caused oxidation of fat (Min & Biswas, 2002 and Borle *et al.,* 2001).

The colour of freshly prepared jeevamrutha was moderate green and it turned to darker 20 days after maturation and this is mainly due to the presence of jaggery. Presence of jaggery along with water promoted the growth of microbes and that enhanced the decomposition of applied cow dung in it. Due to that dark green colour and mild foul odour was produced (Ravindra *et al.,* 2016).

In case of solid organic manures like, FYM, Pressmud compost and bio enriched pressmud compost physical parameters like bulk density (BD) and maximum water holding capacity (MWHC) were analysed. The BD values of FYM, pressmud compost and bio enriched pressmud compost was 0.70, 1.04 and 1.08 Mg m^{-3}, respectively. Lower values of BD can be attributed due to porous nature of the manure and greater organic matter content which decreases BD (Rose, 1991; Tompe and More, 1996). The MWHC values of FYM, pressmud compost and bio-enriched pressmud compost was 39.01, 60.21 and 63.35 per cent, respectively. The reason for greater MWHC can be correlated to the smaller surface area of the particles and greater number of micropores which could retain more water on the surface (Rose, 1991; Tompe and More, 1996).

Among the organic manures, the highest pH was recorded by Jeevumrutha (8.01) compared to Panchagavya (5.48). Whereas, the highest EC (10.14 dS/m) and organic carbon (0.921%) contents were recorded in Panchagavya compared to jeevamrutha (1.22 dS/m and 0.082%, respectively) (Table, 4). Pathak and Ram (2013) also found low pH in Panchagavya due to production of several organic acids in it during fermentation. Alcohol (methanol, propanol, butanol and ethanol) production in Jeevumrutha as a by-product of fermentation made it alkaline in nature (Natarajan, 2008).

The highest content of N, P and K (0.22, 0.88 and 1.15%, respectively) were recorded in Panchagavya compared to jeevamrutha (0.084, 0.532 and 0.133%, respectively). There were no differences in calcium content in both panchagavya (0.512%) and jeevamrutha (0.512%), but magnesium and sulphur contents were recorded higher in jeevamrutha (0.153 and 1.022%, respectively) than panchagavya (0.115 and 1.242%, respectively). The micronutrient like, iron, manganese, zinc and copper content were higher in panchagavya (205.80, 7.80, 47.00 and 18.40 ppm, respectively) than jeevamrutha (85.2, 4.6, 4.6 and 14.2 ppm, respectively) (Table, 4). Dhanoji *et al.,* (2018) and Parvathi and Ushakumari (2017) also recorded higher macro and micro nutrient contents in Panchagavya.

All the solid organic manures like, FYM, pressmud compost and bio-enriched pressmud compost were neutral in reaction and recorded pH 7.40, 7.10 and 7.10, respectively, electrical conductivity recorded was 2.40, 2.80 and 2.52 dS m^{-1} and total OC content registered was 17.83, 35.08 and 41.58 per cent, respectively. Similarly, lower organic carbon content in FYM (16.39 ± 1.12) was reported by Zubair *et al.* (2012) and higher organic carbon content (44.07 %) was recorded in pressmud biocompost, made of pressmud and spentwash blending (Prabhavathi and Parama, 2019). The nitrogen content in FYM, pressmud compost and bio-enriched pressmud compost were recorded 0.60, 1.26 and 1.37 per cent, respectively (Table, 4). Similar results were also obtained by Gaur and Singh (1993) wherein 27 per cent increase in nitrogen content, when mechanized compost inoculated with *Azotobacter* and rock phosphate. It was also evident from the experiments of Kapoor *et al*. (1983) that *Azotobacter* inoculation helps in increasing the N content of compost.

The total phosphorus content of FYM, pressmud compost and bio-enriched pressmud compost was 0.56, 1.92 and 2.41 per cent, respectively. The results are evident from Gaur and Singh (1993) who reported that the available P_2O_5 content of city compost was increased by 60-114 per cent where rock phosphate was applied and inoculated with *Aspergillus awamori*. Total potassium values recorded 0.64, 2.00 and 2.30 per cent, respectively. Bio-enrichment of pressmud compost with plant growth promoting rhizobacteria increased the available P and K contents and could act as an efficient biofertilizer (Patil *et al.,* 2013).

Secondary nutrients *i.e.* calcium, magnesium and sulphur content in FYM, pressmud compost and bio enriched pressmud compost) were 1.07, 3.66 and 3.83 per cent, 0.52, 1.60 and 2.56 per cent and 0.08, 1.93 and 2.00 per cent, respectively. The enriched compost (Meena and Biswas, 2015) prepared by using rock phosphate mixed with rice straw and *Aspergillus awamori*, showed the similar increment with respect to secondary nutrients content (0.610 per cent S, 2.830 per cent Ca, 1.990 per cent Mg).

The total iron (Fe) content in FYM, pressmud compost and bio-enriched pressmud compost was 930.00, 1150.20 and 1258.00 mg kg^{-1}, respectively and manganese (Mn) content recorded 89.80, 137.20 and 171.00 mg kg^{-1}, respectively. The total zinc (Zn) in FYM, pressmud compost and bio- enriched pressmud compost recorded was 20.20, 22.80 and 29.00 mg kg^{-1}, respectively. While total copper (Cu) content recorded was 22.60, 24.80 and 32.20 mg kg^{-1}, respectively (Table, 4). There was an increase in trend in nutrient content with bio-enriched pressmud compost and similar results were also recorded by Korai *et al.* (2014).

The microbial population of panchagavya, jeevumrutha and bio-enriched pressmud compost are given in Table 5. Higher bacterial count was noticed in bio-enriched pressmud compost (21 x 10^5) followed by panchagavya (18 x 10^5) and jeevamrutha (10 x 10^5). Highest fungi count was also recorded in bio-enriched pressmud compost (15 x 10^4) followed by panchagavya (11 x 10^4) and jeevamrutha (3 X 10^4). Similarly highest value of actinomycetes was found in bio-enriched pressmud compost (17 x 10^3) followed by panchagavya (15 x 10^3) and jeevamrutha (8 x 10^3). This confirmed that, there is increase in microbial load in compost with bio-enrichment and the results can be evident from Zayed and Motaal (2005) used together the *Aspergillus niger* and *Trichoderma*

TABLE 5
Biological properties of panchagavya, jeevamrutha and bio-enriched pressmud compost

Parameters	Panchagavya	Jeevamrutha	FYM	Pressmud compost	Bio-enriched pressmud compost
Bacteria (CFU x 10^5 ml^{-1} of sample)	18 x 10^5	10 x 10^5	8 x 10^5	12 x 10^5	21 x 10^5
Actinomycetes (CFU x 10^4 ml^{-1} of sample)	11 x 10^4	3 x 10^4	3 x 10^4	5 x 10^4	15 x 10^4
Fungi (CFU x 10^3 ml^{-1} of sample)	15 x 10^3	8 x 10^3	6 x 10^3	11 x 10^3	17 x 10^3

viride strains as a fungal activator in the presence or absence of FYM for composting of bagasse enriched with rock phosphate. Kapoor *et al.* (1983) were also noticed that there was a 3 to 6 fold increase in the *Azotobacter* population in 3 weeks after inoculation of normal compost and also indicated that the inoculation of *Azotobacter* can be done only after composting process because, it does not have the ability to survive in the high temperature prevailing during composting. At the end of 49 days after composting, the matured biocompost (Rahman *et al*., 2012) was deep black in color with pH of 6.47, increase in bacterial count (242.0 x 10^6 cfu g^{-1}), moisture content (22.16 per cent), total carbon (25.00 per cent) which confirms the efficiency and value addition by bio-enrichment of compost. Similar results of increase in microbial load by using panchagava and jeevamrutha were also observed by Devakumar *et al*. (2018) and Kambar *et al*. (2016).

Kernel Yield

Data on the kernel yield of maize is presented in Table 6. The variability in kernel yield was observed in the first season (2020-2021), second season (2021-2022) and in pooled data.

In the first season, significantly higher kernel yield of 86.77 q ha^{-1} was recorded in the treatment with the application of 75 per cent RDK + Bio-enriched pressmud compost treated Rock dust @ 6 t ha^{-1} (T_{11}) compared to the other treatments and second highest kernel yield (78.81 q ha^{-1}) was recorded in the treatment T_9 (75% K + Panchagavya treated Rock dust @ 6 t ha^{-1}). However, it was on par with the treatment T_{12} (76.55 q ha^{-1}) and T_{10} (73.13 q ha^{-1}). Treatment which received jeevamrutha treated rock dust (T_7) recorded kernel yield of 67.06 q ha^{-1} which was on par with the treatment T_8 (64.85 q ha^{-1}), T_2 (64.85 q ha^{-1}), T_3 (64.07 q ha^{-1}) and T_5 (62.34 q ha^{-1}), but in the treatments with rock dust application @ 3 t ha^{-1} along with FYM (T_4 and T_6) recorded significantly higher values of kernel yield (57.09 and 54.83 q ha^{-1}, respectively) compared to the control treatment T_1 (46.79 q ha^{-1}).

Significantly higher yield (88.49 q ha^{-1}) was recorded in the treatment with the application of 75 per cent RDK + Bio-enriched pressmud compost treated Rock dust @ 6 t ha^{-1} (T_{11}) than compared to the other treatments and second highest kernel yield (80.37 q ha^{-1}) was recorded in the treatment T_9 (75% K + Panchagavya treated Rock dust @ 6 t ha^{-1}) and was on par with the treatment T_{12} (78.09 q ha^{-1}) and T_{10} (76.21 q ha^{-1}). In case of jeevamrutha treated rock dust treatment (T_7) recorded kernel yield of 70.72 q ha^{-1} and was on par with the treatment T_8 (67.63 q ha^{-1}), T_2 (66.56 q ha^{-1}), T_3 (66.72 q ha^{-1}) and T_5 (65.00 q ha^{-1}). Treatments with rock dust application @ 3 t ha^{-1} along with FYM (T_4 and T_6) recorded significantly higher values of kernel yield (57.92 and 53.94 q ha^{-1}, respectively) than compared to the absolute control T_1 (44.76 q ha^{-1}).

The significant increase in kernel yield of maize with the application of 75 per cnt RDK + Bio-enriched pressmud compost treated Rock dust @

TABLE 6

Effect of blended granite rock dust along with liquid and solid organic manures on kernel yield of maize

Treatments	Kernel yield (q ha^{-1})		
	2020-2021	2021-2022	Pooled mean
T_1	46.79	44.76	45.78
T_2	64.58	66.56	65.57
T_3	64.07	66.72	65.39
T_4	57.09	57.92	57.51
T_5	62.34	65.00	63.67
T_6	54.83	53.94	54.39
T_7	67.06	70.72	68.89
T_8	64.85	67.63	66.24
T_9	78.81	80.37	79.59
T_{10}	73.13	76.21	74.67
T_{11}	86.77	88.49	87.63
T_{12}	76.75	78.09	77.08
SEm±	2.16	2.22	2.08
CD @ 5%	6.35	6.51	6.10

Treatments Details

T_1 - Absolute control	T_7 - 75% K + Jeevamrutha treated Rock dust @ 6 t ha^{-1}
T_2 - 100% RDK	T_8 - 50% K + Jeevamrutha treated Rock dust @ 3 t ha^{-1}
T_3 - 75% RDK +Rock dust @ 6 t ha^{-1}	T_9 - 75% K + Panchagavya treated Rock dust @ 6 t ha^{-1}
T_4 - 75% K + Rock dust @ 3 t ha^{-1}	T_{10} - 50% K + Panchagavya treated Rock dust @ 3 t ha^{-1}
T_5 - 50% K + Rock dust @ 6 t ha^{-1}	T_{11} - 75% K + Bio-enriched pressmud compost treated Rock dust @ 6 t ha^{-1}
T_6 - 50% K + Rock dust @ 3 t ha^{-1}	T_{12} - 50% K + Bio-enriched pressmud compost treated Rock dust @ 3 t ha^{-1}

Note: 100% RD-N, P and Zn is common for all the treatment except T_1.

* RD-FYM is used for all the treatments except T_1, T_{11} and T_{12} *FYM- Farm Yard Manure, POP- Package of Practice.

* RDF- Recommended dose of fertilizers (150:75:40 (N, P_2O_5, K_2O kg ha^{-1}) + 10 kg $ZnSO_4$ ha^{-1} for irrigated condition) and FYM- 10 t ha^{-1}.

6 t ha^{-1} may be attributed to improvement in availability of nutrients as consequence of release of nutrients from the added granite rock dust might have influenced the growth and yield of maize. The nutrient element contained in the rock dust is made available slowly upon dissolution of minerals as it is applied with organic manures besides the organic acids that are released by roots caused the dissolution (Barker *et al*., 1998) and thus releasing the nutrients in slow and sustained manner that has helped in getting higher yield in maize. The increase in yield of maize might also be attributed to the supply of readily soluble form of nutrients supplied through urea, SSP and MOP and slow releasing source, rock dust. These findings are in line with those reported by Chathurika *et al*. (2015).

Application of granite rock dust blended with solid and liquid organic manures enhances the mineral dissolution rate through their specialized mechanisms *viz*., production of organic acids, lowering soil pH, acidolysis, chelation, metal complexing ligands and bio-film formation. The study indicated that effective blending of granite rock dust with locally available and prepared organic amendments like bio-enriched pressmud compost, panchagavya and jeevamrutha could be a potential source of available nutrients for plant growth and development for achieving a better yield and the study also confirmed that granite rock dust, a waste product generated at M-sand manufacturing industries can be effectively used in agriculture with eco-friendly manner.

References

Amalraj, E. L. D., Kumar, P. K. G., Ahmed, M. H. S. K., Abdul, R. and Kishore, N., 2013, Microbiological analysis of panchagavya, vermicompost and FYM and their effect on plant growth promotion of pigeon pea (*Cajanus cajan* L.) in India. *Org. Agric*., **3** : 23 - 29.

Anandham, R., Kwon, S. W., Weon, H. Y., Kim, S. J., Kim, Y. S., Gandhi, P. I., Kim, Y. K. and Jee, H. J., 2011a, *Larkinella bovis* sp. *nov*., isolated from fermented bovine products and emended descriptions of the genus Larkinella and of *Larkinella insperata* Vancanneyt *et al*., 2006. *Int. J. Syst. Evol. Microbiol*., **61** : 30 - 34.

Barker, W. W., Welch, S. A., Chu, S. and Banfield, J. F., 1998, Experimental observations of the effects of bacteria on aluminosilicate weathering. *Am. Minerol.,* **83** : 1551 - 1563.

Bokhtiar, S. M., Paul, G. C., Rashid, M. A. and Rahman, A. B. M., 2001, Effect of press mud and organic nitrogen on soil fertility and yield of sugarcane grown in high Ganges river flood plain soils of Bangladesh. *Indian Sugar,* **L1** : 235 - 240.

Borle, F., Sieber, R. and Bosset, J. O., 2001, Photo-oxidation and photoprotection of foods with particular reference to dairy products. An update of review article (1993-2000). *Sci. Aliments*., **21** : 571 - 590.

Bradsley, C. E. and Lancaster, J. D., 1965, Sulphur. In: Methods of soil analysis, Part 2. Eds. *Am. Soc. Agron.,* pp. : 1102 - 1116.

Chakraborty, B. and Sarkar, I., 2019, Quality analysis and characterization of panchagavya, jeevamrutha and sasyamrutha. *Int. J. Curr. Microbiol. App. Sci.,* **8** (5) : 2018 - 2026.

Chand, K., Shahi, N. C., Lohani, U. C. and Garg, S. K., 2011, Effect of storage conditions on keeping qualities of jiggery. *Sugar Tech.,* **13** (1) : 81 - 85.

Chathurika, J. A. S., Indraratne, S. P., Dandeniya, W. S. and Kumaragamage, D., 2015, Beneficial management practices on growth and yield parameters of maize (*Zea mays*) and soil fertility improvement. *Tropical Agric. Res.,* **27** (1) : 59 - 74.

Devakumar, N., Lavanya, G. and Rao, G. G. E., 2018, Influence of jeevamrutha and panchagavya on beneficial soil microbial population and yield of organic fieldbean (*Dolichos lablab* L.). *Mysore J. Agric. Sci.,* **52** (4) : 790 - 795.

Dhanoji, M. M., Meena, M. K. and Naik, M. C., 2018, Manure and plant extracts for foliar nutrition in organic farming : A review. *Int. J. Chem. Studies,* **6** (6) : 1447 - 1454.

Gaur, A. C. and Singh, G., 1993, Role of IPNS in sustainable and environmentally sound agricultural development in India. *PAO/RAPA Bull.*, pp. : 199-313.

Gaur, A. C. and Singh, G., 1993. Influence of azotobacter and rock phosphate on enriching mechanized compost. In: Recycling of crop, Animal and Industrial waste in agriculture. Tandon HLS (Ed.), pp. : 12.

Ghulam, S., Khan, M. J., Usman, K. and Shakeebullah, 2012, Effect of different rates of press mud on plant growth and yield of lentil in calcareous soil. *Sarhad J. Agric.,* **28** (2) : 249 - 252.

Giannattasio, M., Vendramin, E., Fornasier, F., Alberghini, S., Zanardo, M., Stellin, F., Concheri, G., Stevanato, P., Ertani, A., Nardi, S., Rizzi, V., Piffanelli, P., Spaccini, R., Mazzei, P., Piccolo, A. and Squartini, A., 2013, Microbiological features and bioactivity of a fermented manure product (preparation 500) used in biodynamic agriculture. *J. Microbiol. Biotechnol.,* **23** : 644 - 651.

Hassan, M., Mohamed, E. T. and Kamail, M., 2013, Evaluation of silicate-based rocks as soil conditioners. *Int. Conf. Food Agric. Sci*., **55** (2) : 6-11.

Hinsinger, E., Bolland, M. D. A. and Gilkes, 1996, Silicate rock powder : effect on selected chemical properties of a range of soils from Western Australia and on plant growth as assessed in a glasshouse experiment. *Fertil. Res*., **45** : 69 - 79.

Fyfe, W. S., Leonardos, O. H. and Theodoro, S. H., 2006, Sustainable farming with native rocks : The transition without revolution. *An. Acad. Bras. Cienc.,* **78** (4) : 715 - 720.

Jackson, M. L., 1973, Soil chemical analysis. Prentice Hall India Pvt. Ltd., New Delhi.

Kambar, B., Devakumar, N. and Sheshadri, T., 2016, Influence of farm yard manure, jeevamrutha and panchagavya on growth and yield of French bean (*Phaseolus vulgaris* L.). *Mysore J. Agric. Sci.,* **50** (2) : 279 - 283.

Kapoor, K. K., Yadav, K. S., Singh, D. P., Mishra, M. M. and Tauro, P., 1983, Enrichment of compost by Azotobacter and phosphate solubilising micro organisms. *Agric. Wastes,* **5** : 125 - 133.

Kneifel, W., Ulberth, F. and Schaffer, E., 1992, Tristymulus colour reflectance measurement of milk and dairy products. *Lait.,* **72** : 383 - 391.

Korai, P. K., Memon, K. S., Pan, G., Rajper, A. A., Jamro, G. M., Korai, S. K. and Jarwar, A. D., 2014, Effect of sugarcane pressmud biocompost on dry matter yield and nutrient uptake in maize. *J. Biol. Agric. Healthcare.,* **4** (23) : 142 - 146.

Lindsay, W. L. and Norvell, W. A., 1978, Development of DTPA soil test for ascertaining available iron, copper, manganese and zinc. *Soil Sci. Soc. American J.,* **42** : 421 - 428.

Meena, M. D. and Biswas, D. R., 2015, Effect of rock phosphate enriched compost and chemical fertilizers on microbial biomass phosphorus and phosphorus fractions. *African J. Microbiol. Res.,* **9** : 1519 - 1526.

Min, D. B. and Boff, J. M., 2002, Chemistry and reaction of singlet oxygen in foods. *Compr. Rev. Food. Sci. Food Safety.* **1** : 58 - 72.

Natarajan, K., 2002, Panchagavya - A manual. Other Indian, Mapusa Goa, pp. : 33.

Natarajan, K., 2008, Panchagavya: A manual (2nd Ed.). Organic farming association of India (OFAI), Mapusa, Goa, pp. : 56.

Parvathi, S. U. and Ushakumari, K., 2017, Preparation and characterization of on-farm liquid organic manures. *Trends in Biosciences*, **10** (32) : 6880 - 6885.

Pathak, R. K. and Ram, R. A., 2013, Bio-enhancers : A potential tool to improve soil fertility, plant health in organic production of horticultural crops. *Progress. Hortic.,* **45** (2) : 237 - 254.

Patil, N. N., Jadhav, S., Ghorpade, S. S. and Sharma, A. B., 2013, Isolation and enrichment of sugar press mud (SPM) adapted microorganism for production of biofertilizer by using sugar press mud. *Intl. J. Adv. Biotech. Res.,* **14** (1) : 96 - 104.

Piper, C. S., 1966, Soil and plant analysis. Hans's publishers, Bombay.

Prabhavathi, N. and Parama, R. V. R., 2019, Effect of sugar industry solid waste pressmud and bio compost on soil physical and chemical properties at different intervals during finger millet crop. *J. Pharmacogn. Phytochem.,* **8** (3) : 3038 - 3042.

Rahman, M. A., Rahman, M. M., Begum, M. F. and Alam, M. F., 2012, Effect of bio compost, cow dung compost and NPK fertilizers on growth, yield and yield components of chili. *Int. J. Bio. Sci.,* **2** (1) : 51 - 55.

Ravindra, U., Nayaka, M. K. and Revanna, M. L., 2016, Microbial quality evaluation of liquid jaggery. *Int. J. Appl. Pure Sci. Agric.,* **2** (6) : 114 - 117.

Razzaq, A., 2001, Assessing sugarcane filtercake as crop nutrients and soil health ameliorant. *Pak. Sugar. J.,* **21** (3) : 15 - 18.

Rose, D. A., 1991, The effect of long continual organic manuring on some physical properties of soil. *R. Soc. Chem.,* pp. : 197 - 205.

Shankaran, D., 2009, Zero budget natural agriculture. Keerthi Prakasana, Siddalinga Nagar, Gadang, pp. : 9 - 12.

Singh, H. and Creamer, L. K., 1992, Heat stability of milk. In: Fox P. F., editor. Advanced Dairy Chemistry

Proteins, Elsevier Science Publishers Ltd. Cambrige, pp. : 621 - 656.

Tompe, S. V. and More, S. D., 1996, Influence of press mud cake on soil characteristics of a vertisol. *J. Maharashtra Agri. Univ.,* **21** (1) : 6 - 8.

Vanaja, R., Srikanthamurthy, H. S., Ningappa, K., Shivakumar, Nagaraju, B, Ningaraju, 2009, Sustainable agricultural practices, Green Foundation, Bangalore, pp. : 52.

Waksman, S. A., 1927, Principles of soil microbiology. Bailliere, Tindall and Cox, London. pp. : 122.

Walkley, A. J. and Black, C. A., 1934, An examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.,* **37** : 29 - 38.

Weerasuriya, T. J., Pushpakumara, S. and Cooray, P. I., 1993, Acidulated pegmatitic mica : A promising new multi-nutrient mineral fertilizer. *Fertilizer Res*., **34** : 67 - 77.

Yadav, R. L. and Solomon, S., 2006, Potential of developing sugarcane byproduct based industries in India. *Sugar Tech.,* **8** (2 & 3) : 104 - 111.

Zayed, G. and Abdel-Motaal, H., 2005, Bio-production of compost with low pH and high soluble phosphorus from sugar cane bagasse enriched with rock phosphate. *World J. Microbiol. Biotechnol.,* **21** : 747 - 752.

Zubair, M., Anwar, F., Ashraf, M., Ashraf, A. and Chatha, S. A. S., 2012, Effect of green and farm yard manure on carbohydrates dynamics of salt-affected soil. *J. Plant Nutr. Soil Sci.,* **12** (3) : 497-510.

Mysore J. Agric. Sci., 57 (1) : 263-269 (2023)

Genetic Variability Studies for Yield and Yield Components in Cowpea [*Vigna unguiculata* (L.) Walp]

R. Poornima, S. Shymalamma, T. V. Krishna and D. C. Hanumanthappa
Department of Plant Biotechnology, College of Agriculturre, UAS, GKVK, Bengaluru - 560 065
e-Mail : poornima.r.naik@gmail.com

Authors Contribution

R. Poornima : Conceptualization, investigation, original drafts preparation and analysis;
S. Shymalamma : Conception, draft correction and supervision;
T. V. Krishna & D. C. Hanumanthappa : Draft correction and supervision

Corresponding Author :
R. Poornima
Department of Plant Biotechnology, College of Agriculturre, UAS, GKVK, Bengaluru

Received : August 2022
Accepted : January 2023

Abstract

Experimental studies were conducted to evaluate 54 genotypes of cowpea for genetic variability, heritability and genetic advance among varieties for 17 characters under study. The estimates of phenotypic coefficient of variation for all parameters were higher than that of the genotypic coefficient of variation suggest that there was an environmental influence on the performance of the genotypes. A high heritability value coupled with high genetic advance as per cent has been noticed in the parameters like number of nodes per plant, seed yield, biomass per plant, haulm yield, number of branches per plant, number of seed per pod, peduncle length, pod length, plant height, 100 seed weight, NDVI, Cu, Mn, Zn and Fe, content indicate the presence of a weak or slight environmental influence and prevalence of additive gene action in gene expression. Characters namely days to 50 per cent flowering and SPAD recorded a high heritability with low and moderate genetic advance, respectively suggesting the prevalence of non additive gene action. The information on genetic variability among the cowpea genotypes studied showed that there is sufficient genetic variation for all the traits and considerable progress in cowpea breeding could be achieved by exploiting these traits.

Keywords : Cowpea, Variability, Heritability, Genetic advance

Cowpea [*Vigna unguiculata* (L.) Walp], an autogamous leguminous crop belongs to the leguminosae family (Mackie and Smith, 1935) with a chromosomal number of 2n = 2x = 22 (Darlington and Wylie, 1955). It is known as Lobia, Southern pea, Blackeye pea, Chawalie and Mulatto-Gelato in different parts of the world. This pulse crop is rich in protein, vitamins and minerals and is primarily used for grain, vegetable, animal feed as well as green manure crop. The nutritive value of 100 g, Dietary Fiber (10.6 g), Folates (633 g), Niacin (2.075 mg), Pantothenic acid (1.496 mg), Pyridoxine (0.357 mg), Riboflavin (0.226 mg, Thiamin (0.853 mg) and Vitamin-C (1.5 mg) (USDA National Nutrient data base). Fresh seeds of cowpea are consumed as a vegetable and dried seeds used to make dal, flour, biscuits, and a variety of other foods. For animals, it's an excellent source of protein and other essential minerals. Further, cowpea is one of the most adaptable, drought-tolerant, and versatile pulse crop. The worlds total pulse production area is 78 million hectares, with a yield of 70 million tonnes and a productivity of 908 kg per hectare (Anonymous, 2012). This crop is most commonly grown in semi-arid and arid regions worldwide. Though cowpea is one of the vigorously growing drought tolerant pulse, its low productivity is one of the basic constraints. Cowpea exhibits considerable amount of morphological diversity. However, the growth circumstances and grower preferences for each variety differ from region to region (Padulosil, 1997). Availability of heterogeneity in the breeding material would increase the probability of evolving desired genotypes. The higher the genetic variability, the more likely it is that superior genotypes will be selected. The genetic parameters such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) provide an indication of the level of variability existing in a genetic population. Estimates of genetic characteristics, such as heritability and genetic advance, aid the plant breeder in selecting elite genotypes from various genetic populations. Genetic divergence across parents is essential for selection, as the segregating generations have greater variation that can be utilized in selecting superior genotypes (Nimbalkar *et al.,* 2017). With these considerations the present investigation was conducted to assess the genetic variability, heritability and genetic advance of cowpea genotypes.

Material and Methods

The experimental material, comprised of 54 genotypes of cowpea including 4 checks, were grown during *rabi* 2021 in a Randomized Complete Block Design with three replications at L block, GKVK, UAS, Bangalore. Data were recorded on five randomly selected plants for days to 50 per cent flowering, plant height, number of branches per plant, biomass per plant, number nodes per plant, pod length, peduncle length, number of seeds per pod, 100 seed weight (g), Seed Yeild (Kg/ha), haulm yield per plant, micronutrients (Cu, Zn, Fe, Mn), Soil Plant Analysis Development (SPAD) and Normalized Difference Vegetation Index (NDVI). The genetic and PCV were calculated according to Burton and Devane (1953), Heritability according to Hanson *et al.* (1956) GA as per Robinson *et al.* (1949).

Results and Discussion

Genetic Parameters

The major genetic parameters, such as analyses of variance, phenotypic coefficients of variation (PCV), genotypic coefficients of variation (GCV), heritability and genetic progress, were recorded and calculated across 54 genotypes (Fig. 1) for 17 different characters. This research demonstrated that was slightly larger than the indicating the apparent relationship between two traits not just attributable to genetics but partly to the environment favorable influence (Fig: 3).

Analysis of Variance

The analyses of variance revealed that genotype-based mean of squares for all characters were significant (Table 1). It demonstrated that there is a high degree of genetic heterogeneity among the genotypes studied. Quantifying the genetic diversity

Fig. 1 : Field evaluation of cowpea genotypes

Fig. 2 : Comparison of cowpea genotypes with checks

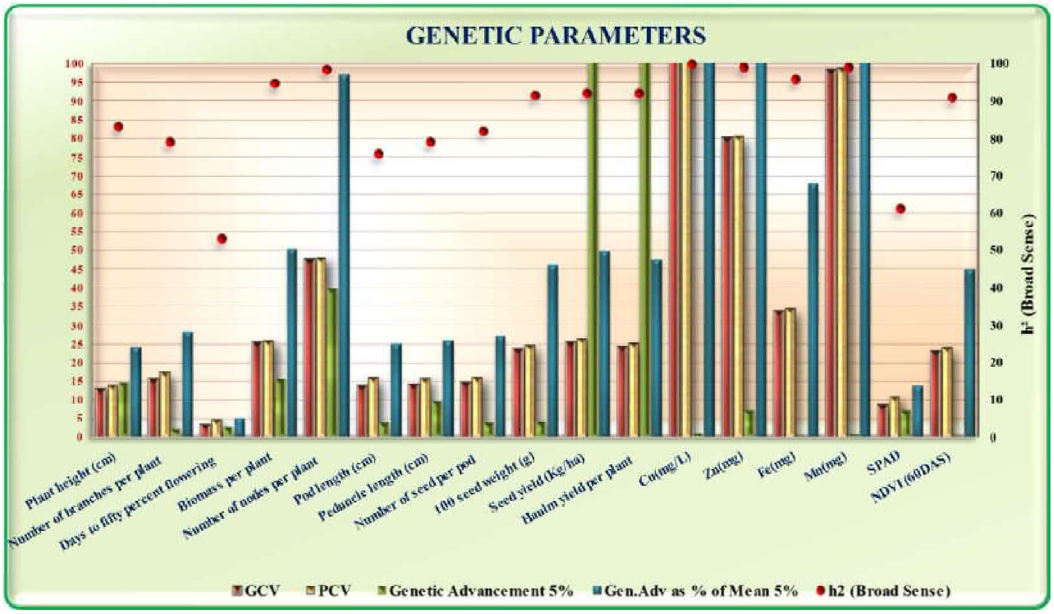


Fig. 3 : Genetic variability parameters for yield and yield component character

TABLE 1

Analysis of variance of various characters

Source Degrees of freedom	Replication 2	Treatment 54	Error 108
Plant height (cm)	10.1080	188.344 **	11.89
Number of branches per plant	0.1260	3.734 **	0.302
Days to fifty percent flowering	10.497 *	11.407 **	2.602
Biomass per plant	3.9790	181.379 **	3.44
Number of nodes per plant	8.0550	1138.902 **	6.775
Pod length (cm)	0.5640	15.123 **	1.456
Peduncle length (cm)	13.650	87.293 **	7.115
Number of seed per pod	1.4690	13.057 **	0.892
100 seed weight (g)	0.0980	13.7 **	0.419
Seed yield (Kg/ha)	15044.1150	585606.527 **	16709.542
Haulm yield per plant	7764.410	1320145.382 **	37490.64
Cu(mg/L)	0.0010	0.497 **	0
Zn(mg)	0.649 **	35.523 **	0.122
Fe(mg)	00	0.068 **	0.001
Mn(mg)	00	0.3 **	0.001
SPAD	1.2340	68.834 **	12.085
NDVI (60DAS)	00	0.056 **	0.002

Where,*and** significant level of 5% and 1%, respectively of a population is crucial for breeding programmes as it reveals the genetic composition of the population.

Genotypic and phenotypic coefficients of variation are beneficial in detecting the amount of variability present in the available genotypes for different characters. In general, if the phenotypic coefficient of variation for all the characters is higher than that of genotypic coefficient of variation, it indicates the influence of various environmental parameters in the expression of genes or characters.

Genotypic Coefficient of Variation (GCV)

Genotypic coefficient of variation (GCV) ranged from 3.354 to 154.63 (Table 2). Highest GCV was recorded for Cu (154.63) followed by Mn (98.37), Zn (80.12), number of nodes per plant (47.56), Fe (33.64), seed yield (Kg/ha) (25.23), biomass per plant (25.11), haulm yield per plant (24.02), 100 seed weight (23.40) and NDVI (22.80), indicating the availability of rich genetic variability for these attributes in the present experimental material. Number of branches per plant (15.385), number of seed per pod (14.49), peduncle length (14.00), pod length (13.79), plant height (12.78) and SPAD (8.47) exhibited moderate GCV. Whereas, SPAD (8.47) and days to fifty percent flowering (3.35), exhibited low magnitude of GCV.

Phenotypic Coefficient of Variation

The phenotypic coefficient of variation (PCV) ranged from 11.67 (crop duration) to 52.12 (pod weight). Highest PCV was recorded for pod weight (52.12) followed by seed yield per plant (31.72), number of pod clusters per plant (31.36), number of pods per plant (27.21), number of primary branches per plant (26.92), 100 seed weight (24.13), pod length (23.81) and number of pods cluster (21.32). Length of main stem (18.94), pod girth (18.85), days to 50 per cent flowering (16.44), number of seeds per pod (12.84) and crop duration (11.67) exhibited moderate PCV. Further, none of the characters exhibited low PCV in the present study.

GCV and PCV values are in close agreement with the findings for 100-seed weight and grain yield (Manggoel *et al.,*2012); for pod length and 100-seed weight (Ajayi *et al.,* 2014); for seed yield per plant , pod length and 100 grain weight (Selvakumar *et al.,* 2015); for pod length (Khandait *et al.,* 2016); for number of pod per plant and pod length (Rajput, 2016); and for number of seeds per pod (Srinivas *et al.,* 2017). Selection will be successful for characters with small differences in GCV and PCV estimates since these characters have little environmental influence.

Heritability and Genetic Advance

Crop improvement in any species depends on the quantum of available genetic variability, which reflects the heritable portion of variability in the species. The high heritability of any character will give greater genetic advance under selection and accordingly a breeder will make breeding strategies. Genetic advance gives the magnitude of improvement per generation in the base population by selection. Heritability and genetic advance would help in determining the influence of various environmental factors in the expression of characters and the extent to which improvement is possible after artificial selection. The estimates of genetic variation and heritability would provide a better idea about the efficiency of artificial selection (Burton, 1953).

In the present study, a high estimate of broad sense heritability was observed for all the characters. The broad sense heritability ranged from 53 per cent (days to 50% percent flowering) to 99.85 per cent (Cu) (Fig.3).

Heritability estimates alone cannot provide any reliable information regarding the amount of genetic progress that would result from the artificial selection. Therefore, heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone (Singh and Chaudhary, 1985).

Genetic advance is a measure of predetermined progress under artificial selection program and genetic advance as per cent of mean (GAM) ranged between 5.03 per cent (days to 50% flowering) to 318.29 per cent (Cu). The high broad sense heritability coupled

TABLE 2

Estimates of genetic variability parameters for yield and yield component character

Characters	Var Environmental	ECV	Var Genotypical	GCV(%)	Var Phenotypical	PCV (%)	h2 (Broad Sense)	Genetic Advancement	Genetic Advancement as % of Mean (GAM)
Plant height (cm)	11.89	5.75	58.818	12.788	70.708	14.021	83.185	14.409	24.027
Number of branches per plant	0.302	7.909	1.144	15.385	1.446	17.299	79.096	1.959	28.186
Days to fifty percent flowering	2.602	3.158	2.935	3.354	5.537	4.607	53.008	2.569	5.03
Biomass per plant	3.44	6.048	59.313	25.112	62.753	25.829	94.518	15.424	50.292
Number of nodes per plant	6.775	6.374	377.376	47.568	384.151	47.993	98.236	39.663	97.123
Pod length (cm)	1.456	7.799	4.556	13.795	6.012	15.847	75.779	3.828	24.738
Peduncle length (cm)	7.115	7.224	26.726	14	33.841	15.753	78.974	9.464	25.629
Number of seed per pod	0.892	6.795	4.055	14.49	4.947	16.004	81.971	3.756	27.024
100 seed weight (g)	0.419	7.204	4.427	23.404	4.846	24.488	91.344	4.142	46.079
Seed yield (Kg/ha)	16709.542	7.49	189632.33	25.233	206341.87	26.321	91.902	859.975	49.83
Haulm yield per plant	37490.64	7.115	427551.58	24.028	465042.22	25.059	91.938	1291.545	47.46
Cu(mg/L)	0	5.999	0.165	154.63	0.166	154.746	99.85	0.837	318.298
Zn(mg)	0.122	8.155	11.8	80.129	11.923	80.543	98.975	7.04	164.217
Fe(mg)	0.001	7.1	0.022	33.642	0.023	34.383	95.736	0.302	67.81
Mn(mg)	0.001	9.912	0.1	98.372	0.101	98.87	98.995	0.647	201.625
SPAD	12.085	6.775	18.917	8.477	31.001	10.852	61.019	6.999	13.641
NDVI (60DAS)	0.002	7.225	0.018	22.807	0.02	23.924	90.879	0.264	44.79

with high GAM recorded for all traits except for days to 50 per cent flowering and SPAD reading. Similar trend of heritability and GAM for pod length, number of seeds per pod, days till 50 per cent flowering and total seed weight per pod were reported by Manggoel *et al.* (2012) and comparable results for pod length, 100 seed weight, and seeds per pod by Adewale *et al.* (2010).

The high broad sense heritability coupled with high GAM indicated the role of additive gene effects for plant height, number of branches per plant, biomass per plant, number of nodes per plant, pod length, peduncle length, number of seed per pod, 100 seed weight, seed yield, haulm yield per plant, Cu, Zn, Fe, Mn and NDVI and reveals the presence of minor environmental influence and pervasiveness of additive gene action in gene expression of these characters. A high heritability combined with high genetic advance is an indication of additive gene action and selection based on these parameters would be more rewarding (Johnson *et al,* 1955). This suggests the importance of these characters through selection. Corroborative findings were reported by (Suganthi and Murugan, 2008) for seed yield per plant.

All the characters exhibited high genetic advance (as% of mean) except SPAD (13.64%) that exhibited moderate genetic advance; and days to 50 per cent flowering that exhibited low genetic advance (5.03%). improvement in these characters can be achieved by hybridization.

A significant variation for all the 17 characters studied in the experiment indicates the presence of variability in the genotypes and suggests scope for improvement. High estimates of GCV, heritability coupled with genetic advance for components traits of yield *viz.*, biomass per plant, number of nodes per plant, 100 seed weight, seed yield, haulm yield per plant, Cu, Zn and Mn content indicate the pervasiveness of additive gene action and clearly paves the way for cowpea improvement in terms of quantity and quality by artificial selection. Further, high heritability and a low genetic advance recorded for the days to 50 per cent flowering and moderate genetic advance recorded for SPAD suggests the prevalence non additive gene action. Further improvement in these characters can be achieved by hybridization.

Acknowledgements : Special thanks to AICRP on arid legumes GKVK campus, UAS-B for sharing the germplasm and AICRP on Agroforestry GKVK campus, UAS-B for Micronutrient analysis facility.

REFERENCES

ADEWALE, B. D., OKONJI, C., OYEKANMI, A. A., AKINTOBI, D. A. C. AND AREMU, C. O., 2010, Genotypic variability and stability of some grain yield components of cowpea. *Afr. J. Agric. Res.,* **5 (9)** : 874 - 880.

AJAYI, A. T., ADEKOLA, M. O., TAIWO, B. H. AND AZUH, V. O., 2014, Character expression and differences in yield potential of ten genotypes of cowpea (*Vigna unguiculata* L. Walp*). Int. J.Plant Res.,* **4 (3)** : 63 - 71.

ANONYMOUS, 2012, FAO, FAOSTAT, Food and Agriculture Organization of the United Nations, Rome, Italy.

ALLARD, R. W., 1960, Principles of plant breeding, *John Willey and Sons*, New York. pp. : 20 - 24 and 88 - 89.

BURTON, G. M., 1952, Quantitative inheritance in grasses. Sixth International Grassland Congress, **1** : 277 - 285.

Burton, G. W., Devane, E. W., 1953, Estimating heritability in tall fescue (*Festuca arundiraceae*) from replicated clonal material. *Agron. J.*, **45** : 478 - 481.

DARLINGTON, C. D. AND WYLIE, A. P., 1955, Chromosome atlas of flowering plants. George Allen and Unwin Ltd., London.

HANSON, C. H., ROBINSON, H. F. AND COMSTOCK, R. E., 1956, Biometrical studies on yield in segregating population of Korean lespedesa. *Agron. J.,* **48** : 268 - 272.

JOHNSON, H. W., ROBINSON, H. D., AND COMSTOCK, R. E., 1955, Estimates of genetical and environmental variability in soyabeans. *Agron. J.*, **47** : 314 - 318.

KHANDAIT, R., JAIN, P. K., SINGH, Y., PRAJAPATI, S. AND SOLANKI, S., 2016, Genetic variability in diverse genotypes of cowpea (*Vigna unguiculata* L.). TECHNOFAME- *A J. Multidisciplinary Advance Res.,* **5** (2) : 120 - 126.

LUSH, J. L., 1940, Intrasire correlations and regression of offspring on dams as a methods of Estimating heritability of characters. *Proc. American Soc. of Animal Prod*., **33** : 293 - 301.

MACKIE, W. W. AND SMITH, F. L, 1935, Evidence of field hybridization in beans. *J. American Soc. Agron*., **27** : 903 - 908.

MANGGOEL, W., UGURU, M. I., NDAM, O. N. AND DASBAK, M. A., 2012, Genetic variability, correlation and path coefficient analysis of some yield components of ten cowpea [*Vigna unguiculata* (L.)Walp] accessions. *J. Plant Breed. Crop Sci.,* **4** (5) : 80 - 86.

NIMBALKAR, R. D., KATRE, Y. Y. AND PHAD, D. S., 2017, Genetic diversity in Chickpea (*Cicer arietinum* L.). BIOINFOLET, **14** (1) : 60 - 63.

PADULOSI, S. AND NG, N. Q., 1997, Origin, taxonomy and morphology of [*Vigna unguiculata* (L.) Walp.] In : Advances in cowpea research (eds B. B.Singh, R. D. R. Mohan., K. E. Dashiell and L. E. N. Jackai), Ibadan, Nigeria, pp. : 1-12.

ROBINSON, H. F., CORNSTOCK, R. E. AND HARVEY, P. M., 1949, Estimates of heritability and degree of dominance in corn. *Agron. J.,* **41** : 353 - 359.

SELVAKUMAR, G. AND KUMARI, R. U., 2015, Variability analysis in inter subspecies crosses of cowpea (*Vigna unguiculata* (L.) Walp) and (*Vigna unguiculata* (L.) Walp. spp. sesquipedalis). *J. Plant Sci. Res*., **31** (1) : 109 - 113.

SRINIVAS, J., KALE, V. S., NAGRE, P. K. AND SORATUR, R. S., 2017, Study of genetic variability, heritability and genetic advance in cowpea [*Vigna unguiculata* (L.) Walp]. *Int. J. Current Microbiol. Appl. Sci.,* **6** (6) : 3314 - 3318.

SINGH, R. K. AND CHAUDHARY, B. D., 1985, Biometrical Methods in Quantitative Genetics Analysis, Kalyani Publishers, pp. : 318

SUGANTHI, S. AND MURUGAN, S., 2008, Association analysis in cowpea [*Vigna unguiculata* L. Walp.]. *Legume Res.* **31** (2) : 130 - 132.

USDA National Nutrient Database for Standard Reference .https://data.nal.usda.gov.

Mysore J. Agric. Sci., 57 (1) : 270-279 (2023)

Studies on Effect of Age and Management Practices on Flowering Behaviour and Fruit Set in Mango (*Mangifera indica* L.) Cv. Alphonso

B. R. Premalatha, H. S. Shivaramu, M. N. Thimmegowda, S. V. Patil, A. P. Mallikarjuna Gowda, M. Murali Mohan and M. K. Prasanna Kumar

Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru - 560 065

e-Mail : premalathabr@gmail.com

Authors Contribution

B. R. Premalatha : Investigation, orginal draft preparation, analysis;
H. S. Shivaramu : Conceptualization;
M. N. Thimmegowda & S. V. Patil : Data curation and draft correction;
A. P. Mallikarjuna Gowda, M. Murali Mohan & M. K. Prasanna Kumar : Conceptualization and suggestions.

Corresponding Author **:**
B. R. Premalatha
Department of Agronomy,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : July 2022
Accepted : December 2022

Abstract

Alphonso is one of the most important commercial mango variety in India known for its typical sugar acid blend, pleasant flavour, good taste, soft, firm, fibreless, bearing habit long keeping quality and early bearing habit. In mango, the proportion of male and hermaphrodite flowers vary greatly but it is one of the factor which decides the fruit set and development. Hence, the present study was undertaken to study the effect of age and management practices on flowering behaviour and fruit set in Mango (*Mangifera indica* L.) Cv. Alphonso at Regional Horticultural Research and Extension Centre, UHS Campus, GKVK, Bengaluru and at Dryland Agriculture, UAS, GKVK, Bengaluru during 2018-19 and 2019-20 with two age groups (10 and 25 years old plantation) and two management practices (control and PPC spray). The results indicated that, there was significant difference among different age groups, trees sprayed with plant protection chemicals and also direction of the tree. Young aged trees of 10 years recorded significantly lower male flowers per tree (1776.01), higher hermaphrodite flowers (196.12), lower sex ratio (9.06) and higher fruit set percentage (4.64 %). Among the management practices, the trees sprayed with plant protection chemicals recorded significantly lower male flowers (1694.06), higher hermaphrodite flowers (196.30), lower sex ratio (8.63) and higher fruit set percentage (4.63 %). North side of the tree bears minimum number of male flowers (1707.22) and maximum number of hermaphrodite flowers (206.33) while, higher fruit set percentage (4.89 %) was recorded in east direction.

Keywords : Flowering behaviour, Fruit set, Direction, Mango

Mango (*Mangifera indica* L.) is the most popular tropical fruit, on account of its nutritive value, taste, attractive fragrance and health promoting qualities it is also known as the 'king of fruits' (Dutta *et al.,* 2013) and also known as 'Ambassador Fruit of India'. It's cultivation and usage are deep-rooted in Indian culture and tradition. It has been grown in Indian sub - continent for 4000 years (De Candolle, 1904) or more. Indian subcontinent has rich diversity of mango having about thousands of varieties and hence, India is considered to be the centre of origin of mango (Ravishankar *et al.,* 1979). India is the largest producer of mango contributing to 55 per cent of the world's total production. In India, it is cultivated in an area of 2.26 m ha, with a production of 21.8 mt (Anonymous, 2018b). The leading mango producing states in India are Uttar Pradesh producing 45.52 lakh MT from an area of 2.66 lakh hectares followed by Andhra Pradesh producing 43.74 lakh MT from an area of 3.63 lakh hectares (Anonymous, 2018). Though, India is the largest producer of mango, the average national productivity is around 9.7 t/ha, which is much lower compared to Brazil (15.83 t/ha), Pakistan (10.62 t/ha) and Indonesia (9.78 t/ha).

India has about thousands of mango varieties, among them about 30 are grown commercially and most of them have eco-geographical requirements for optimum growth and yield. 'Alphonso' is one of the leading commercial cultivar mainly grown in Karnataka, Maharastra, Tamilnadu, Gujarat and Andra Pradesh. The fruits of this variety are medium in size, ovate oblique in shape and orange yellow in colour. The pulp is yellow to orange in colour. Due to its typical sugar acid blend, it has pleasant flavour, good taste, soft, firm, fibreless and has got longer keeping quality. However, the variety suffers from serious drawbacks like irregular and shy bearing habit and eventually lower fruit set and poor yield. The average productivity of 'Alphonso' mango is around 4.5 t/ha which is very low compared to other commercial cultivars. Flowers, fruit set, fruit drop and fruit development are important factors that finally decides the yield of tree. It is particularly important in mango where proportion of male and hermaphrodite flowers varies greatly. Time and peak period of flowering, sex ratio, flowering behaviour, insect pests, diseases and weather parameters like temperature and relative humidity influences flowering and fruit set in Alphonso mango (Vidya *et* al., 2014, Sudha and Narendrappa, 2015 and Anonmous., 2017). Hence, the present investigation was carried out with the objective to study the effect of different age groups and use of plant protection chemicals on flowering behaviour in Alphonso mango.

Material and Methods

The experiment was carried out in two plantations of different age group with two management levels comprising plant protection spray at UHS campus and Dryland Agriculture Project, GKVK, Bengaluru with a sample size of 9 trees in each location during 2018-19 and 2019-20. The experimental design adopted was factorial RBD (FRBD) comprising of 2 age group (10 years at UHS campus and 25 years at Dryland Agriculture Project) and two management practices (Control and PPC spray) with 9 replications using Alphonso variety planted at a spacing of 10 m X 10 m.

Daily meteorological data recorded at the observatory at AICRP on Agrometeorology unit, Zonal Agricultural Research Station (ZARS), University of Agricultural Sciences, GKVK, Bengaluru during the crop growth period of 2018-19 and 2019-20 was collected. The normal and actual realized weather parameters *viz.,* rainfall, mean temperature (maximum and minimum), relative humidity, bright sunshine hours and wind speed were collected. The plantations were cleaned in the beginning of the mango season to avoid contamination from the host plants in and around the orchard trees and basins were made for each tree to conserve rainwater. To control the major diseases and pests like powdery mildew, anthracnose, fruit fly and mango hoppers, two sprays comprising Hexaconazole 5 per cent SC @ 1 ml/litre, Lambda-cyhalothrin 5 per cent EC @ 0.5 ml/litre and Wettable Sulphur 80 per cent WP @ 2 gm/litre were given at the time of flower bud initiation and fruiting stage for PPC spray treatment and the control treatment was maintained without any spray.

Nine trees were selected in each treatment and in each tree, five flowering panicles were selected from four directions totalling to 20 panicles for observations on flowering and fruiting behaviour. Panicle initiation data was noted with the emergence of first panicle on the tree. Male and hermaphrodite flowers was counted on panicles tagged during the flowering season. Number of total flowers was counted on the selected panicles. Number of male and hermaphrodite flowers was counted and their percentage to total number of flowers was worked out.

$$\text{\% of male flowers} = \frac{\text{No. of male flowers}}{\text{Total no. of flowers}} \times 100$$

Male flowers percent : The percentage of male flowers was calculated by employing the following formula and expressed in percentage.

$$\text{\% of hermaphrodite flowers} = \frac{\text{No. of hermaphrodite flowers}}{\text{Total no. of flowers}} \times 100$$

Hermaphrodite flowers per cent : The percentage of hermaphrodite flowers was calculated by employing the following formula and expressed in percentage

$$\text{Sex ratio} = \frac{\text{No. of male flowers per panicle}}{\text{No. of hermaphrodite flowers per panicle}}$$

Sex ratio (Perfect to male flowers) : The ratio of male flowers to hermaphrodite flowers was calculated as follows

$$\text{\% of Fruit set} = \frac{\text{Mean no. of fruits at pea stage}}{\text{Mean no. of hermaphrodite flowers}} \times 100$$

The collected data on different parameters was analysed by using analysis of variance (ANOVA) based on Factorial randomized block design (FRBD) concept.

RESULTS AND DISCUSSION

The nature of flower production in mango is a very complex one related to the mechanism of controlling the balance between vegetative and reproductive development and of course, the climatic condition which play vital role in the condition growth and flowering. Phenomena of flowering in mango trees is especially challenging for physiologists, breeders and growers (Rani, 2018). The inflorescence of mango bears mainly two types of flowers male and hermaphrodite. It is only perfect or hermaphrodite flowers, which after proper pollination and fertilization, sets fruits.

Number of male flowers : Statistical analysis of individual years and the pooled data showed that the trees of different age groups, management levels and direction varied significantly ($P > 0.05$) among each other with respect to the number of male flowers (Table 1). Among the different age group of trees, the trees of older age showed significantly higher number of male flowers (1885.58, 1768.96 and 1827.27) during 2018-19, 2019-20 and pooled data, respectively. Among the management levels, the control treatment without PPC spray showed significantly higher number of male flowers (2046.63, 1771.80 and 1909.22) during 2018-19, 2019-20 and pooled data, respectively. Direction also plays a key role in flowering behaviour. It was observed that the East side bears significantly maximum number of male flowers (2026.58,

TABLE 1

Number of male flowers as influenced by different ages, management practices and directions of Alphonso mango

2018-19	A_1 – 10 years of age		A_2 – 25 years of age		D - Mean
Treatments	M_1 - Control	M_2- With PPC	M_1 - Control	M_2- With PPC	
D_1 - North	1926.16	1556.67	1875.36	1614.27	1743.11
D_2 - South	2089.09	1676.24	2089.62	1745.69	1900.16
D_3 - East	2187.58	1801.88	2277.84	1839.03	2026.58
D_4- West	1949.20	1585.76	1978.22	1664.62	1794.45
A - Mean	A_1	1846.57	A_2	1885.58	
M - Mean	M_1	2046.63	M_2	1685.52	

	A	M	D
F - test	*	*	*
S.Em.±	13.14	13.14	18.59
CD at 5%	36.80	36.80	52.05

continued…

	AM	AD	MD	AMD
F - test	NS	NS	NS	NS
S.Em.±	18.59	26.29	26.29	37.18
CD at 5%	NS	NS	NS	NS

2018-19	A_1 – 10 years of age		A_2 – 25 years of age		D - Mean
Treatments	M_1 - Control	M_2- With PPC	M_1 - Control	M_2- With PPC	
D1 - North	1669.16	1629.30	1721.70	1665.20	1671.34
D2 - South	1796.56	1700.30	1828.10	1789.09	1778.51
D3 - East	1808.78	1750.71	1888.10	1826.47	1818.51
D4- West	1705.11	1583.63	1756.90	1676.16	1680.45
A - Mean	A1	1705.44	A2	1768.96	
M - Mean	M1	1771.80	M2	1702.61	

	A	M	D
F - test	*	*	*
S.Em.+	11.12	11.12	15.73
CD at 5%	31.14	31.14	44.04

	AM	AD	MD	AMD
F - test	NS	NS	NS	NS
S.Em.+	15.73	22.24	22.24	31.46
CD at 5%	NS	NS	NS	NS

Pooled	A_1 – 10 years of age		A_2 – 25 years of age		D - Mean
Treatments	M_1 - Control	M_2- With PPC	M_1 - Control	M_2- With PPC	
D_1 - North	1797.66	1592.98	1798.53	1639.73	1707.22
D_2 - South	1942.82	1688.27	1958.86	1767.39	1839.34
D_3 - East	1998.18	1776.29	2082.97	1832.75	1922.55
D_4 - West	1827.16	1584.69	1867.56	1670.39	1737.45
A - Mean	A1	1776.01	A2	1827.27	
M - Mean	M1	1909.22	M2	1694.06	

	A	M	D
F - test	*	*	*
S.Em.+	8.79	8.79	12.43
CD at 5%	24.60	24.60	34.79

	AM	AD	MD	AMD
F - test	NS	NS	NS	NS
S.Em.+	12.43	17.57	17.57	24.85
CD at 5%	NS	NS	NS	NS

Note : * Significant at 5 % level, NS : Non significant, PPC : Plant protection chemicals

1818.51and 1922.55 in 2018-19, 2019-20 and pooled data, respectively) compared to other directions and lowest number of male flowers was recorded in North direction during both the years. This might be due to profuse light and higher temperatures on Eastern side. However, non-significant differences were observed among the interactions.

Number of hermaphrodite flowers : The hermaphrodite flowers have an important criterion in determining the yield as these flowers after pollination and fertilization sets the fruit. Highly significant difference among the different ages, management levels and direction were observed for hermaphrodite flowers (Table 2). Among the different age groups, the trees of younger age showed significantly higher number of hermaphrodite flowers (196.71, 195.54 and 196.12) during 2018-19, 2019-20 and pooled data, respectively. Among the management levels, the trees with plant protection chemicals spray recorded significantly higher number of hermaphrodite flowers (196.14, 196.45 and 196.30) during 2018-19, 2019-20 and pooled, respectively. On the other hand, hermaphrodite flower number was significantly higher on the panicles of North side (205.08, 207.57 and 206.33 in 2018-19, 2019-20 and pooled data, respectively) followed by south direction. The findings are in confirmation with the findings of Majumdar and Mukherjee (1961), Desai *et al*. (1985), Asif *et al*. (2002), Anonmous., 2018a and Manjarekar *et al*., (2018) who also observed highest percentage of perfect flowers on the north and lowest on the eastern side.

Percentage of male and hermaphrodite flowers and sex ratio : The data indicated that, the percentage of male flowers and sex ratio was significantly higher in older aged trees (90.63 and 9.78, 90.16 and 9.23 and 90.43 and 9.51 during 2018-19, 2019-20 and pooled data of two years, respectively). While, the percentage of hermaphrodite flowers was significantly higher in young aged orchard (9.74, 10.33 and 10.01 during 2018-19, 2019-20 and pooled data of two years, respectively). This is due to higher panicle length and breadth in younger trees and also the younger trees are more vigorous compared to older ones.

Among the management levels, significantly higher percentage of hermaphrodite flowers (10.45, 10.38 and 10.40 per cent during 2018-19, 2019-20 and pooled data of two years respectively) and lower

TABLE 2

Number of hermaphrodite flowers as influenced by different ages, management practices and directions of Alphonso mango

2018-19	A_1 - 10 years of age		A_2 - 25 years of age		D - Mean
Treatments	M_1 - Control	M_2 - With PPC	M_1 - Control	M_2 - With PPC	
D_1 - North	205.29	207.93	202.13	204.98	205.08
D_2 - South	202.13	205.98	194.47	200.33	200.73
D_3 - East	190.22	193.22	188.22	186.20	189.47
D_4 - West	183.62	185.24	181.62	185.24	183.93
A - Mean	A1	196.71	A2	192.90	
M - Mean	M1	193.46	M2	196.14	

	A	M	D
F - test	*	*	*
S.Em.±	0.57	0.57	0.81
CD at 5 %	1.60	1.60	2.27

continued…

	AM	AD	MD	AMD
F - test	NS	NS	NS	NS
S.Em.±	0.81	1.15	1.15	1.62
CD at 5 %	NS	NS	NS	NS

2019-20	A_1 - 10 years of age		A_2 - 25 years of age		D - Mean
Treatments	M_1 - Control	M_2 - With PPC	M_1 - Control	M_2 - With PPC	
D_1 - North	209.47	212.27	200.27	208.29	207.57
D_2 - South	197.09	204.10	193.53	199.33	198.51
D_3 - East	186.13	191.30	182.47	190.40	187.58
D_4 - West	181.64	182.31	178.02	183.59	181.39
A - Mean	A1	195.54	A2	191.99	
M - Mean	M1	191.08	M2	196.45	

	A	M	D
F - test	*	*	*
S.Em.±	0.86	0.86	1.22
CD at 5 %	2.42	2.42	3.42

	AM	AD	MD	AMD
F - test	NS	NS	NS	NS
S.Em.±	1.22	1.73	1.73	2.44
CD at 5 %	NS	NS	NS	NS

Pooled	A_1 – 10 years of age		A_2 – 25 years of age		D - Mean
Treatments	M_1 - Control	M_2- With PPC	M_1 - Control	M_2- With PPC	
D_1 - North	207.38	210.10	201.20	206.63	206.33
D_2 - South	199.61	205.04	194.00	199.83	199.62
D_3 - East	188.18	192.26	185.34	188.30	188.52
D_4- West	182.63	183.78	179.82	184.42	182.66
A - Mean	A1	196.12	A2	192.44	
M - Mean	M1	192.27	M2	196.30	

	A	M	D
F - test	*	*	*
S.Em.±	0.51	0.51	0.73
CD at 5 %	1.44	1.44	2.03

	AM	AD	MD	AMD
F - test	NS	NS	NS	NS
S.Em.±	0.73	1.03	1.03	1.45
CD at 5%	NS	NS	NS	NS

Note: * Significant at 5 % level, NS : Non significant PPC : Plant protection chemicals

TABLE 3

Percentage of male and hermaphrodite flowers in flowering panicle and sex ratio as influenced by different ages and management practices of Alphonso mango

Parameters / Treatments	2018-19			2019-20			Pooled		
	Percentage of flowers		Sex ratio	Percentage of flowers		Sex ratio	Percentage of flowers		Sex ratio
	Male	Hermaphrodite	Male: Hermaphrodite	Male	Hermaphrodite	Male: Hermaphrodite	Male	Hermaphrodite	Male: Hermaphrodite
Age (A)									
A_1 - 10 years	90.26	9.74	9.40	89.67	10.33	8.73	89.99	10.01	9.06
A_2 - 25 years	90.63	9.37	9.78	90.16	9.84	9.23	90.43	9.57	9.51
F - test	*	*	NS	*	*	*	*	*	*
S.Em.±	0.12	0.12	0.14	0.12	0.12	0.11	0.09	0.09	0.09
CD at 5 %	0.36	0.36	NS	0.34	0.34	0.32	0.26	0.26	0.27
Management (M)									
M_1 - Control	91.33	8.67	10.59	90.22	9.78	9.28	90.82	9.18	9.94
M_2 With PPC	89.55	10.45	8.60	89.62	10.38	8.67	89.60	10.40	8.63
F - test	*	*	*	*	*	*	*	*	*
S.Em.±	0.12	0.12	0.14	0.12	0.12	0.11	0.09	0.09	0.09
CD at 5 %	0.36	0.36	0.41	0.34	0.34	0.32	0.26	0.26	0.27
Age x Management									
A_1M_1	91.23	8.77	10.44	89.97	10.03	9.02	90.65	9.35	9.73
A_1M_2	89.29	10.71	8.36	89.37	10.63	8.44	89.34	10.66	8.40
A_2M_1	91.44	8.56	10.73	90.47	9.53	9.55	91.00	9.00	10.14
A_2M_2	89.82	10.18	8.84	89.86	10.14	8.90	89.86	10.14	8.87
F - test	NS	NS	NS	NS	NS	NS	NS	NS	NS
S.Em.±	0.18	0.18	0.20	0.16	0.16	0.16	0.13	0.13	0.13
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: * Significant at 5 % level, NS : Non significant PPC : Plant protection chemicals

TABLE 4

Fruit set percentage as influenced by different ages, management practices and directions of Alphonso mango

2018-19	A_1 – 10 years of age		A_2 – 25 years of age		D - Mean
Treatments	M_1 - Control	M_2 - With PPC	M_1 - Control	M_2 - With PPC	
D_1 - North	4.20	4.39	3.68	4.16	4.11
D_2 - South	4.19	4.61	3.90	4.44	4.29
D_3 - East	4.99	5.85	4.43	5.03	5.07
D_4 - West	4.96	5.46	4.46	5.03	4.98
A - Mean	A1	4.83	A2	4.39	
M - Mean	M1	4.35	M2	4.87	

	A	M	D
F - test	*	*	*
S.Em.±	0.06	0.06	0.09
CD at 5%	0.17	0.17	0.24

	AM	AD	MD	AMD
F - test	NS	NS	NS	NS
S.Em.±	0.09	0.12	0.12	0.17
CD at 5%	NS	NS	NS	NS

2019-20	A_1 - 10 years of age		A_2 - 25 years of age		D - Mean
Treatments	M_1 - Control	M_2 - With PPC	M_1 - Control	M_2 - With PPC	
D_1 - North	3.39	3.99	2.77	3.37	3.38
D_2 - South	3.90	4.45	3.36	3.75	3.87
D_3 - East	4.81	5.42	4.12	4.50	4.71
D_4- West	4.34	5.30	3.93	4.40	4.49
A - Mean	A1	4.45	A2	3.78	
M - Mean	M1	3.83	M2	4.40	

	A	M	D
F - test	*	*	*
S.Em.±	0.05	0.05	0.07
CD at 5%	0.15	0.15	0.21

	AM	AD	MD	AMD
F - test	NS	NS	NS	NS
S.Em.±	0.07	0.11	0.11	0.15
CD at 5%	NS	NS	NS	NS

continued…

Pooled Treatments	A_1 – 10 years of age		A_2 – 25 years of age		D - Mean
	M_1 - Control	M_2- With PPC	M_1 - Control	M_2- With PPC	
D_1 - North	3.79	4.19	3.23	3.77	3.75
D_2 - South	4.04	4.53	3.63	4.10	4.08
D_3 - East	4.90	5.63	4.27	4.77	4.89
D_4 - West	4.65	5.38	4.19	4.71	4.73
A - Mean	A1	4.64	A2	4.08	
M - Mean	M1	4.09	M2	4.63	

	A	M	D
F - test	*	*	*
S.Em.+	0.04	0.04	0.06
CD at 5 %	0.11	0.11	0.16

	AM	AD	MD	AMD
F - test	NS	NS	NS	NS
S.Em.+	0.06	0.08	0.08	0.11
CD at 5 %	NS	NS	NS	NS

Note: * Significant at 5 % level, NS : Non significant PPC : Plant protection chemicals

sex ratio (8.60, 8.67 and 8.63) was observed in plant protection chemicals sprayed trees compared to the control during 2018-19, 2019-20 and average of both the years, respectively (Table 3).

Fruit set percentage : The data indicated that, the fruit set percentage varied significantly with respect to different age groups, management practices and direction. However, the interactions were non-significant. Significantly higher fruit set percentage was noticed in younger trees (4.83, 4.45 and 4.64 %) compared to older trees during both the years of study period. Among the management levels, PPC sprayed trees recorded significantly higher fruit set percentage (4.87, 4.40 and 4.63 per cent during 2018-19, 2019-20 and pooled data, respectively). East side of the tree recorded significantly higher fruit set percentage (5.07, 4.71 and 4.89% during 2018-19, 2019-20 and pooled data, respectively) compared to other directions (Table 4) followed by West direction. However, bees and other pollinators play an important role in orchards in providing this stimulus for fruit set.

The study revealed there was distinct variations in production of hermaphrodite flowers and fruit set percentage with respect to age, management practices and direction. The young trees of 10 years age, plant protection chemicals sprayed trees and north side of the tree produced significantly higher hermaphrodite flowers, while higher fruit set percentage was found on east side.

References

Anonymous, 2017, *Annual Report*, 2016-17, AICRP on Agro-meteorology, UAS, GKVK, Bengaluru.

Anonymous, 2018a, *Annual Report*, 2017-18, AICRP on Agro-meteorology, UAS, GKVK, Bengaluru.

Anonymous, 2018b, Horticultural Statistics at a Glance, horticulture statistics division department of agriculture, cooperation & farmers welfare ministry of agriculture & farmers welfare Government of India.

Asif, M., Usman, M., Jaskani, M. J. and Khan, M. M., 2002, Comparative study of flower sex ratio in different cultivars of mango (*Mangifera indica* L.), *Int. J. Agri. Biol.,* **4** (2) : 220 - 222.

De Condolle, A., 1904, Origin of cultivated plants. Kegan Paul, Trench, London.

DESAI, A. G., LIMAYE, V. P. AND GUNJATE, R. T., 1985, Floral biology of alphonso, goamankur and kesar varieties of mango. *J. Maharashtra Agri. Univ.,* **10** (2) : 193 - 195.

DUTTA, S. K., SHRIVASTAV, M., CHAUDHARY, R., LAL, K., PATIL, P., SINGH, S. K. AND SINGH, A. K., 2013, Low temperature storage of mango (*Mangifera indica* L.) pollen. *Scientia Hort.,* **161**: 193-197.

MAJUMDAR, P. K. AND MUKHERJEE, S. K., 1961, Studies on the variability of sex expression in mango (*Mangifera indica* L.). *Indian J. Hort.*, **18** : 12 - 19.

MANJAREKAR, R. G., KHANVILKAR, M. H., SHIRKE, G. D., KARLE, S. S. AND AHIRE, P. G., 2018, Effect of fertilizer levels on flowering behaviour and yield of fruits in mango Cv. Alphonso. *Int. J. Curr. Microbiol. App. Sci.,* Special Issue - **6** : 508 - 514.

RANI, 2018, Advances in crop regulation in mango (*Mangifera indica* L.). *Int. J. Curr. Microbiol. App. Sci*., **7** (9) : 35-42.

RAVISHANKAR, H., RAO, M. M. AND BOJAPPA, K. M., 1979, Fruit-bud differentiation in mango 'Alphonso' and 'Totapuri' under mild tropical rainy conditions. *Sci. Hort.,* **10** : 95 - 99.

SUDHA, S. AND NARENDRAPPA, T., 2015, *In-vitro* efficacy of bioagents against *Colletotrichum gloeos porioides* causing anthracnose of mango. *Mysore J. Agric. Sci*., **49** (2) : 355 - 358.

VIDYA, A., SWAMY, G. S. K., PRAKASH, N. B., JAGADEESH, R. C., JAGADESH, S. L., GANGADHARAPPA, P. M. AND MUKESH, L. C., 2014, Effect of pre-harvest sprays of nutrients on the physico-chemical characters in mango (*Mangifera indica*) cv. Mallika. *Mysore J. Agric. Sci*., **48** (4) : 529 - 533.

Mysore J. Agric. Sci., 57 (1) : 280-286 (2023)

Scale Development to Measure Attitude of Farmers towards Kisan Call Centre Advisory Services

R. PUNEETH RAJA[1] AND K. VENKATARANGA NAIKA[2]
[1]Department of Agricultural Extension, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
[2]Professor of Agril. Extension (Rtd.) & Former University Librarian, UAS, GKVK, Bengaluru - 560 065
e-Mail : puneeethraj@gmail.com

AUTHORS CONTRIBUTION

R. PUNEETH RAJA : Conceptualization, design, data collection and analysis of data;
K. VENKATARANGA NAIKA : Conceptualization, draft editing and supervision

Corresponding Author :
R. PUNEETH RAJA
Department of Agricultural Extension,
College of Agriculturre,
UAS, GKVK, Bengaluru

Received : September 2022
Accepted : November 2022

ABSTRACT

Kisan Call Centre (KCC) was launched on 21st January, 2004 to provide free agricultural advisory services to every citizen engaged in agriculture through a toll-free number 1800-180-1551 and provide the solution to the quarries made by the farmers in the regional languages. In this study an attempt is made to develop and standardize scale to measure the attitude of the farmers towards Kisan Call Centre (KCC) advisory services. To develop a scale five dimensions, a tentative list of 65 items pertaining to the attitude of the farmers distributed under identified five dimensions were made, for which relevancy and item analysis was calculated. The finally developed attitude scale was found to be highly reliable (0.616) and valid (0.7723). The attitude scale consisted of 22 statements classified under five dimensions namely, Services, Feedback, Crop management marketing and weather. The developed scale was administered to 32 KCC beneficiaries in the Bengaluru rural district 2021-22. It was found that nearly half (43.75 %) of farmers had favourable attitude towards Kisan Call Centre advisory services followed by 31.25 per cent of the farmers had least favourable and one-fourth (25.00 %) of the respondents had most favourable attitude towards Kisan Call Centre advisories.

Keywords : Advisery services, Attitude, Scale, Kisan call centre

THE Department of Agriculture & Cooperation (DAC), Ministry of Agriculture, Govt. of India has launched Kisan Call Centres (KCC) on 21st January, 2004 across the country to deliver advisory services to the farming community in 22 languages. The purpose of establishing these call centres is to respond to issues raised by farmers, instantly in local language. There are call centres for every state, which are expected to handle traffic from any part of the country and cater to needs of agriculture and allied sector farmers in the local language over a telephonic conversation. A farmer from any part of the State can contact the KCC by dialling the toll-free number 1551 or 1800-180-1551. The operator at the KCC will attend the call to answer queries of the farmers immediately. In case the operator at the call centre is not able to address the farmer's query immediately, the call will be forwarded to agricultural specialists. At the most the call centre will take 48 hours to provide with the suitable solution. Information and Communications Technology (ICT) can be broadly interpreted as technologies that facilitate communication, processing and transmission of information by electronic means. It has revolutionised the whole communication process (Dishant Jojit James, 2017), still there is a problem with the internet connectivity at farmers field and little or no awareness of usage of internet, KCC is one of the best ICT solutions to access the required information but the sophisticated scale to measure attitude was lacking, therefore an attempt is made to develop a scale comprising of five dimensions and 22 Statements were developed with the following objectives

1. To develop and standardize a scale to measure the attitude of the farmers towards Kisan Call Centre advisory services
2. To measure the attitude of the farmers towards Kisan Call Centre advisory services

METHODOLOGY

The present study was carried out during 2021-22 to develop and standardize a scale to measure the attitude of the farmers towards Kisan Call Centre advisories. The data was collected from the beneficiaries of KCC services in Bangalore rural District of Karnataka. A total of 32 KCC beneficiaries were selected randomly and interviewed personally.

Ex-post facto research design was adopted, as the researcher had no direct control over independent variables, because their manifestation has already occurred or because they are inherently not amenable to manipulation and inferences about relationship among variables are made without direct intervention, from associated influence of independent variables on dependent variables (Kerlinger, 1966). The collected data was analysed based on the cumulated score, the respondents were categorized as least favourable, favourable and most favourable attitude by considering mean and half standard deviation as a measure of check.

RESULTS AND DISCUSSION

Development of Scale to Measure the Attitude of the Farmers towards KCC Advisories

Attitude towards Kisan Call Centre is operationally defined as the positive or negative feelings / thoughts that the farmers have developed towards the performance and services of KCC. The method of summated rating scale suggested by Likert, 1932 and Edwards, 1969 was followed in the development of the scale following six stages *viz.,* identification of components, collection of items / statements, relevancy test, item analysis, reliability and validity.

Identification of Dimensions

Services, feedback, crop protection, marketing and weather were the five major dimensions identified related to the Attitude of the Farmers towards KCC advisories based on a review of literature and in discussion with experts in the field of agricultural extension.

Collection and Editing of Items

A tentative list of 65 items pertaining to the attitude of the farmers were distributed under identified five dimensions. The items developed were edited as per the 14 criteria enunciated by Edwards (1969) and Thurstone and Chave (1929). As a consequence, 09 statements were eliminated and the remaining 56 statements were included for obtaining the judge's opinion.

Relevancy Analysis

The proforma containing 56 items under the five dimensions were sent to 110 judges by means of google forms and handed over personally in the field of Agricultural Extension and Economics to critically evaluate the relevancy of each item on five-point continuum *viz.* Most Relevant (MR), Relevant (R), Somewhat Relevant (SWR), Less Relevant (LR) and Not Relevant (NR) and the responses were assigned the score of 5,4,3,2,1, respectively. The judges were also requested to make necessary modifications and additions or deletion of statements if they desire to do so. Out of 110, 52 judges returned the questionnaire duly completed and were considered for further processing. From the data gathered, 'Relevancy Percentage' 'Relevancy Weightage' and 'Mean Relevancy Score' were worked out for all the 56 statements. Using the said criteria, individual statements were screened for relevancy using the following formulae.

$$\text{Relevancy Weightage of } i^{th} \text{ indicator } (RW_i) = \frac{(MRx5)+(Rx4)+(SWRx3)+(LRx2)+(NRx1)}{\text{Maximum possible score}}$$

$$\text{Relevancy Percentage of } i^{th} \text{ indicator } (RP_i) = \frac{(MRx5)+(Rx4)+(SWRx3)+(LRx2)+(NRx1)}{\text{Maximum possible score}} \times 100$$

$$\text{Mean Relevancy Score of } i^{th} \text{ indicator } (MRS_i) = \frac{(MRx5)+(Rx4)+(SWRx3)+(LRx2)+(NRx1)}{\text{Number of judges respondent}}$$

Individual items were screened based on these three calculated values. Accordingly, items having relevancy weightage of more than 0.80 *i.e.* relevancy percentage of more than 80 per cent and mean relevancy score with more than or equal to 4 (Table 1) were included for further analysis, from 56 statements a total of 26 were retained and considered for item analysis.

Item Analysis

For item analysis, thirty-two farmers were selected from the non-sample area *i.e.,* Bangalore rural District and the respondents were asked to indicate their response in each of the items in their respective scoring pattern. Based on the total scores obtained, the respondents were arranged in descending order. The top 25 per cent of the respondents with their total scores were considered as high group and the bottom 25 per cent as low group. These two groups provide criterion groups in terms of evaluating the individual statements suggested by Edwards (1969). 't' value was calculated for each of the statement using the following formula given below :

$$t = \frac{\bar{X}_H - \bar{X}_L}{\sqrt{\dfrac{\sum X_H^2 - \dfrac{(\sum X_H)^2}{n} \times \sum X_L^2 - \dfrac{(\sum X_L)^2}{n}}{n(n-1)}}}$$

Where,

X_H = The mean score on given statement of the high group

X_L = The mean score on given statement of the low group

ΣX^2_H = Sum of squares of the individual score on a given statement for high group

ΣX^2_L = Sum of squares of the individual score on a given statement for low group

n = Number of respondents in each group

Σ = Summation

t = The extent to which a given statement differentiates between the high and low groups.

After computing the 't' value for all the 26 statements, and only those with 't' value equal and greater than 1.69 (Table 2) were finally selected for inclusion in the final scale. Wherein, out of 26 statements 22 items were significant at 5 per cent.

Standardization of the Scale

Reliability of the Scale

The split-half method was employed to test the reliability of the scale. The value of correlation coefficient was 0.5518 and this was further corrected by using Spearman Brown formula (1910) to obtain the reliability coefficient of the whole set. The 'r' value of the scale was 0.616, which was found significant at one per cent level indicating the high reliability of the scale. It was concluded that, the scale constructed was reliable.

a) Half test reliability formula

$$r_{1/2} = \frac{N(\Sigma XY) - (\Sigma X)(\Sigma Y)}{\sqrt{(N\Sigma X^2 - (\Sigma X)^2)(N\Sigma Y^2 - \Sigma Y)^2)}}$$

Where,

ΣX = Sum of the scores of the odd number items

ΣY = Sum of the scores of the even number items

ΣX^2 = Sum of the squares of the odd number items

ΣY^2 = Sum of the squares of the even number items

b) Whole test reliability formula

$$r_{11} = \frac{2 \times r1/2}{1 + r1/2}$$

Where, $r_{1/2}$ = Half test reliability

Validity

The data was subjected to statistical validity, which was found to be 0.7723 for scale which is greater

TABLE 1

Selected statements based on the relevancy percentage, relevancy weightage and mean relevancy

(n- 52)

Statements	RP	RW	MRS
Services			
KCC provides advisories on various aspects of agricultural and allied sectors	88.846	0.888	4.442
Awareness programmes on KCC organized to encourage farmers to avail the services	87.308	0.873	4.365
KCC does not create awareness of schemes in relation to the Agriculture and allied sectors (-ve)	83.846	0.838	4.192
Farmers get their queries solved faster through KCC	83.846	0.838	4.192
KCC has helped farmers in improving their economic conditions by its advisory services	85.000	0.850	4.250
Feedback			
Farmers need not to be educated to avail the benefits of KCC advisories	82.02	0.82	4.201
The queries made by farmers are responded by KCC officials are friendly and cordial	82.256	0.822	4.2827
Farmers feedback is fast in KCC than other conventional methods	80.385	0.804	4.019
KCC has impacted significantly on the economic conditions of the farmers	80.769	0.808	4.038
Awareness among the farmers need to be created to avail the benefits of Agro-advisory services of KCC	86.538	0.865	4.827
KCC does not provides up-to-date and suitable information for the queries (-ve)	82.692	0.827	4.635
Crop management			
The advises given by KCC are practical and motivate farmers to adopt them in the farm situation	86.538	0.865	4.327
KCC advisories have helped farmers to take proper plant protection measures	85.385	0.854	4.269
Faces difficulties in connecting to KCC and in explaining the symptoms of diseases over phone call	84.615	0.846	4.231
KCC provides a solution without analysing the symptoms thoroughly (-ve)	83.462	0.835	4.173
KCC is a boon to the farmers in improving the yield of the crops	80.385	0.804	4.019
Marketing			
KCC provides market information at the right time	81.154	0.812	4.058
KCC advisories help to know the daily market prices for various commodities	81.154	0.812	4.058
Market information given by KCC are based on the proper analysis of supply and demand	80.385	0.804	4.019
KCCs are helping farmers in connecting to the regulated markets	80.000	0.800	4.000
The farmers can rely on KCC for marketing related information	84.231	0.842	4.212
Weather			
KCC does not predicts and forecasts the weather conditions well in advance (-ve)	84.538	0.842	4.27
KCC offers the solutions based on the weather conditions	80.000	0.800	4.000
KCC weather advisories saved my crops and yield despite the adverse conditions	80.769	0.808	4.038
Contingency crops advised by KCC have helped to get income despite of failure of main crop due to adverse climatic conditions	81.154	0.812	4.558
The advice given by KCC on weather are not based on the scientific analysis	88.846	0.888	4.442

TABLE 2

Selection of statements based on the 't' value for the final scale

(n- 32)

Statements	Mean	T value
Services		
KCC provides advisories on various aspects of agricultural and allied sectors	4.625	5.163
Awareness programmes on KCC organized to encourage farmers to avail the services	3.851	0.917*
KCC does not create awareness of schemes in relation to the Agriculture and allied sectors (-ve)	4.500	2.558
Farmers get their queries solved faster through KCC	4.375	1.714
KCC has helped farmers in improving their economic conditions by its advisory services	4.125	1.906
Feedback		
Farmers need not to be educated to avail the benefits of KCC advisories	4.224	2.468
The queries made by farmers are responded by KCC officials are friendly and cordial	4.412	3.125
Farmers feedback is fast in KCC than other conventional methods	4.375	2.887
KCC has impacted significantly on the economic conditions of the farmers	4.015	1.562*
Awareness among the farmers need to be created to avail the benefits of Agro-advisory services of KCC	4.625	3.661
KCC does not provides up-to-date and suitable information for the queries (-ve)	4.375	3.098
Crop management		
The advisories given by KCC are practical and motivate farmers to adopt them in the farm situation	4.251	3.023
KCC advisories have helped farmers to take proper plant protection measures	4.262	3.026
Faces difficulties in connecting to KCC and in explaining the symptoms of diseases over phone call	4.871	3.512
KCC provides a solution without analyzing the symptoms thoroughly (-ve)	4.375	3.556
KCC is a boon to the farmers in improving the yield of the crops	4.625	3.336
Marketing		
KCC provides market information at the right time	3.912	0.642*
KCC advisories help to know the daily market prices for various commodities	4.750	3.244
Market information given by KCC are based on the proper analysis of supply and demand	4.625	3.336
KCCs are helping farmers in connecting to the regulated markets	4.875	5.035
The farmers can rely on KCC for marketing related information	4.375	2.562
Weather		
KCC does not predicts and forecasts the weather conditions well in advance (-ve)	4.375	2.873
KCC offers the solutions based on the weather conditions	4.421	3.032
KCC weather advisories saved my crops and yield despite the adverse conditions	4.125	1.835
Contingency crops advised by KCC have helped to get income despite of failure of main crop due to adverse climatic conditions	4.500	3.335
The advice given by KCC on weather are not based on the scientific analysis	3.912	1.254*

*Statements which is having a 't' value less than 1.69 were eliminated

TABLE 3

New scale to measure the attitude of the farmers towards kisan call centre advisory services

Statements	SA	A	UD	DA	SDA
Services					
Farmers get their queries solved faster through KCC					
KCC does not creates awareness on schemes about the Agriculture and allied sectors *					
KCC provides advisories on various aspects of agriculture and allied sector.					
KCC has helped farmers in improving their economic conditions by its advisory services					
Feedback					
Farmers feedback is fast in KCC than other conventional methods					
The queries made by farmers are responded to by KCC officials are friendly and cordial					
Farmers need not be educated to avail the benefits of KCC advisories					
Awareness among the farmers need to be created to avail the benefits of agro-advisory services of KCC					
KCC does not provide up-to-date and suitable information for the queries *					
Crop management					
The advisories given by KCC are practical and motivate farmers to adopt them in the farm situation					
KCC advisories have helped to take proper plant protection measures					
Face difficulties in connecting the call to KCC and in explaining the symptoms of diseases over phone call					
KCC provides a solution without analyzing the symptoms thoroughly *					
KCC is a boon to the farmers in improving the yield of the crops					
Marketing					
KCC advisories help to know the daily prices for commodities in various markets.					
Market information given by KCC is not based on the proper analysis of supply and demand *					
KCCs are helping farmers in connecting to the regulated markets					
The farmers cannot rely on KCC for marketing related information *					
Weather					
KCC weather advisories have helped my crops and yield despite the adverse conditions					
KCC does not predicts and forecasts the weather conditions well in advance *					
KCC offers the solutions based on the weather conditions					
Contingency crops advised by KCC have helped to get income despite of failure of the main crop due to adverse climatic conditions					

*- Negative statements; SA-Strongly Agree, A-Agree, UD-Undecided, DA- Disagree, SDA- Strongly Disagree

than the standard requirement of 0.70. Hence, the validity coefficient was also found to be appropriate and suitable for the tool developed. Thus, the scale was developed to analyse the Attitude of farmers on Kisan Call Centre advisory services.

$$\text{Validity} = \sqrt{r_{11}}$$

Administration of the Scale

The final scale (Table 3) consists of 22 (16 positive and Six negative) statements for determining the attitude of farmers on Kisan Call Centre advisory services. The response was collected on a five-point continuum, *viz.,* Strongly Agree, Agree, Undecided, Disagree and Strongly Disagree with an assigned score of 5,4,3,2 and 1 for positive statements and reverse scoring for negative statements respectively.

Attitude of Farmers towards KCC Advisories

The attitude scale developed was administered to 32 farmers (users of KCC services) in Bengaluru Rural District during 2021-22. The Table 4 revealed that, nearly half (43.75) of farmers had favourable attitude towards KCC advisory services followed by 31.25 per cent of the farmers had least favourable and one fourth (25.00%) of the respondents had most favourable attitude towards KCC advisories. This implies considerable number of users of KCC have favourable attitude and KCC is serving the farming community. These findings are in the line with the findings of Parmar *et al.* (2015) Koshy & Kumar (2016), Srikanth (2016) and Suresh & Shivamurthy (2017)

The attitude scale developed is found to be reliable and valid. Hence, it can be used in the future by the researchers conducting research on KCC to analyse the attitude of farmers towards Kisan Call Centre advisories. The results of the study revealed that less than half (43.75 %) of farmers had favourable attitude towards KCC advisory services. Thus, it can be concluded that, the scale developed could be useful to analyse the attitude of the farmers towards KCC advisory services overtly.

TABLE 4

Overall attitude of the farmers about KCC advisories

(n-32)

Category	Frequency	Per cent
Least favorable	10	31.25
Favorable	14	43.75
Most favorable	8	25.00

REFERENCES

JAMES, D. J. AND LAKSHMINARAYAN, M. T., 2017, Attitude of agricultural extension functionaries towards information and communication technology tools. *Mysore J. Agric. Sci.*, **51** (4) : 872 - 876.

EDWARDS, A. L., 1969, Techniques of attitude scale construction. VIkils, Feger and Simons Pvt. Ltd., 9, Sport Road, Ballard Estate, Bombay.

KERLINGER, F. N., 1986, Foundation of behavioural research. *S. S. Chandra publishers,* Delhi, 151 - 153.

KOSHY, S. M. AND KUMAR, N. K., 2016, Attitude of farmers towards Kisan Call Centres. *Journal of Extension Education*, **28** (4) : 5753 - 5759.

LIKERT, R. A., 1932, A technique for the analysement of attitudes. *Archives of Psychology,* New York, pp. : 140.

PARMAR, V. S., SHARMA, O. P., BHUVA, R. M. AND PATEL, A. I., 2015, Relationship between personal and socio-economic characteristics of farmers and their attitude towards the use of Kisan Call Centre. *Trends in Biosciences,* **8** (3) : 693 - 694.

SURESH, D. K. AND SHIVAMURTHY, M., 2017, Development of a scale to measure the attitude of farmers towards carbon sequestration technologies and its application in rice and sugarcane based farming system. *Part I-research Papers*, **51** (2) : 315 - 320.

SRIKANTH CHOWADRY, L. V., 2016, Impact of kisan call centre (KCC) Services in Kolar district. *M.Sc. (Agri.), Thesis*, (Unpub.), University of Agricultural Sciences, Bangalore.

Mysore J. Agric. Sci., 57 (1) : 287-291 (2023)

Effect of Foliar Application of Nutrients to Enhance Productivity through Combating the Dry Spell Effect in Cowpea

K. Pushpa[1], N. Pruthviraj[2], P. Rudraswamy[3] and Vinay M. Gangana Gowdra[4]
[1&4]Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru
[2]AICRP on Weed Management, [3]AICRP on Arid legumes, UAS, GKVK, Bengaluru
e-Mail : pruthvikannahatti@gmail.com

Authors Contribution

K. Pushpa :
Prepared objectives, recorded the observations;
N. Pruthviraj &
P. Rudraswamy :
Statistical analysis of the experiment;
Vinay M. Gangana Gowdra :
Preparation of manuscript

Corresponding Author :
N. Pruthviraj
AICRP on Weed Management, UAS, GKVK, Bengaluru

Received : October 2022
Accepted : February 2023

Abstract

Field experiment was conducted at UAS, Bangalore during 2019 with 8 treatments to evaluate the effect of foliar application of nutrients to enhance productivity through combating the dry spell effect in cowpea. The results showed that among different treatments, foliar spray of soluble NPK (19:19:19) @ 1 per cent concentration at flower initiation and pod formation stage recorded higher growth parameters *viz.,* plant height (33.9 cm) and number of branches (8.2), yield and yield related parameters *viz.,* number of pods (21.3), number of seeds (17.1), pod length (15.9 cm) and seed yield (1738 kg ha^{-1}) and the same treatment also recorded higher gross returns (52140 Rs ha^{-1}), net returns (26143 Rs ha^{-1}) and B:C ratio (2.0) but it was on par with the treatment foliar spray of soluble NPK (19:19:19) @ 1 per cent concentration at pod formation stage.

Keywords : Anther culture, Arka Meghana, Callogenesis, Embryogenesis, Incubation conditions

Cowpea [*Vigna unguiculata* (L.) Walp] is an annual legume of tropical and subtropical area, commonly known as *lobia*. It is a drought tolerant and warm-weather crop, which is well adapted to the drier regions of the tropics. In India, cowpea is grown in an area of 3.9 million hectares, particularly in western, central and peninsular regions.

The crop is known for initial fast growth, extensive root development and early establishment of the crop in wake of drought like situation. It has the ability to fix atmospheric nitrogen through its root nodules and it grow well in poor soils with more than 85 per cent sand and with less than 0.2 per cent organic matter and low levels of phosphorus. It also has the excellent ability against soil erosion from rain water and being denoted as a prominent cover crop.

For any crop, fertilizer is the most critical input for utilizing the yield potential of improved high yielding crop varieties. However, in recent days *i.e.,* post green revolution era, due to indiscriminate nutrient mining, soil fertility is depleting at an alarming rate and to provide food for growing human population, there is a need to add fertilizers to augment the sustainable crop production. However, root is common to be first part of plant that absorbs nutrients from soils, but nutrients availability might be restricted; then affects fertilizer efficiency. So, it is better to recommend foliar application of KNO_3 that provides nutrients for plant (Altindisl *et al*., 1998).

In fact, foliar fertilization is applied in small droplets on the leaves and stems of the plant; then nutrients are absorbed through these parts of plants which can supply the nutrients for plants rapidly to obtain high performance guarantee. (Kuepper, G. 2003). From an ecological perspective, foliar fertilization is more acceptable, because the small amounts of nutrients is used for rapid use by plants (Stampar *et al*., 1998).

Cowpea an important component of traditional intercropping system, especially in the complex and elegant subsistence farming systems of dry regions. Research on foliar application of nutrients for cowpea during dry spell was meagre hence the present investigation was carried out to evaluate the effect of foliar application of nutrients to enhance productivity through combating the dry spell effect in cowpea.

Material and Methods

A Field experiment was conducted at Zonal Agricultural Research Station, GKVK, Bengaluru during 2019. The experiment was laid out in Randomized Complete Block Design with eight treatments (T_1: Absolute control; T_2: Water spray; T_3: Foliar spray of soluble NPK (19:19:19) @ 1 per cent at flower initiation stage; T_4: Foliar spray of soluble NPK (19:19:19) @ 1 per cent at pod formation stage; T_5: Foliar spray of soluble NPK (19:19:19) @ 1 per cent at flower initiation & pod formation stage; T_6: Foliar spray of soluble KNO_3 @ 0.5 per cent at flower initiation stage; T_7: Foliar spray of soluble KNO_3 @ 0.5 per cent at pod formation stage; T_8: Foliar spray of soluble KNO_3 @ 0.5 per cent at flower initiation & pod formation stage) treatments replicated thrice.

The cowpea was sown in a plot size of 4.5 m × 4 m (25.2 m^2) for each treatment. one seed per hill were sowed to a depth of 5 cm on distance between row to row (45 cm) and plant to plant (10 cm). Plant protection measures, weed management practices and irrigation practices were common for all treatments.

Results and Discussion

Growth and Yield Parameters

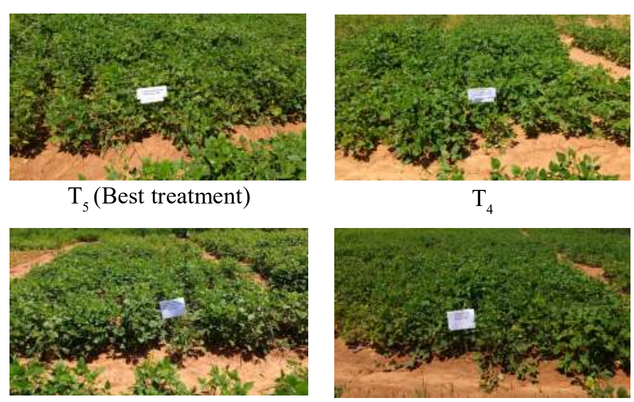
The results of the field experiment conducted to evaluate the effect of foliar application of nutrients to enhance productivity through combating the dry spell effect in cowpea were presented in Tables 1 & 2 and Fig 1 & 2. The experimental results revealed that foliar spray of soluble NPK (19:19:19) @ 1 per cent concentration at flower initiation and pod formation stage recorded higher plant height (33.9 cm), number of branches (8.2), leaf area (9 49 plant^{-1}), total dry

Table 1

Chemical and nutrient status of the experimental site

Parameter	Status
pH	5.69 - 5.89
EC (dSm^{-1})	0.08 - 0.09
Organic carbon (%)	0.43 - 0.50
Available N (kg ha^{-1})	125.8 - 151.1
Available P_2O_5 (kg ha^{-1})	16.6 - 19.2
Available K_2O (kg ha^{-1})	93 - 124.6
Exchangeable Ca. (me/100g)	2.3 - 2.7
Exchangeable Mg. (me/100 g)	0.7 - 0.9
Available S. (ppm)	3.47 - 4.21
Available Fe (ppm)	13.19 - 24.00
Available Zn (ppm)	1.40 - 2.43
Available Cu (ppm)	0.79 - 1.99
Available Mn (ppm)	24.19 - 36.14

Fig. 1: General view of the experimental site



T_5 (Best treatment) T_4

T_3 T_6

Fig. 2: Cowpea as influenced by foliar application of nutrients

TABLE 2

Growth parameters as influenced by foliar application of nutrients to enhance productivity through combating the dry spell effect in cowpea

Treatments	Plant height (cm)	No. of Branches	Leaf area (cm^2 $plant^{-1}$)	Total dry matter (g $plant^{-1}$)
T_1: Absolute control	26.4	4.2	589	8.87
T_2: Water spray	27.9	5.3	611	9.24
T_3: Foliar spray of soluble NPK (19:19:19) @ 1% at flower initiation stage	31.6	7.2	811	10.88
T_4: Foliar spray of soluble NPK (19:19:19) @ 1% at pod formation stage	32.7	7.6	845	11.22
T_5: Foliar spray of soluble NPK (19:19:19) @ 1% at flower initiation & pod formation stage	33.9	8.2	949	13.78
T_6: Foliar spray of soluble KNO_3 @ 0.5% at flower initiation stage	30.3	5.9	658	9.68
T_7: Foliar spray of soluble KNO_3@ 0.5% at pod formation stage	30.7	6.4	712	10.21
T_8: Foliar spray of soluble KNO_3 @ 0.5% at flower initiation & pod formation stage	31.4	7.0	784	10.58
S.Em. ±	0.92	0.2	36	0.85
CD (p=0.05)	2.83	0.6	110	2.55

matter production (13.78 g $plant^{-1}$) number of pods (21.3), number of seeds (17.1), pod length (15.9 cm) and seed yield (1738 kg ha^{-1}) which was on par with the foliar spray of soluble NPK (19:19:19) @ 1 per cent concentration at pod formation stage and recorded plant height (32.7 cm), leaf area (845 $plant^{-1}$), total dry matter production (11.22 g $plant^{-1}$) number of branches (7.6), number of pods (20.5), number of seeds (16.6), pod length (14.8 cm) and seed yield (1684 kg ha^{-1}). Reflection of increase in vegetative growth, yield and its components as shown in Table 1 and 2 were might be due to foliar spray of NPK compared to control which provides balanced supply of nutrients and rapid absorption by the plants.

TABLE 3

Yield and yield related parameters as influenced by foliar application of nutrients to enhance productivity through combating the dry spell effect in cowpea

Treatments	No. of Pods	No. of seeds	Pod length (cm)	Seed yield (kg ha^{-1})
T_1: Absolute control	13.6	14.0	10.9	1023
T_2: Water spray	14.2	14.3	12.1	1212
T_3: Foliar spray of soluble NPK (19:19:19) @ 1% at flower initiation stage	18.2	16.0	14.4	1611
T_4: Foliar spray of soluble NPK (19:19:19) @ 1% at pod formation stage	20.5	16.6	14.8	1684
T_5: Foliar spray of soluble NPK (19:19:19) @ 1% at flower initiation & pod formation stage	21.3	17.1	15.9	1738
T_6: Foliar spray of soluble KNO_3 @ 0.5% at flower initiation stage	15.6	15.3	13.6	1436
T_7: Foliar spray of soluble KNO_3@ 0.5% at pod formation stage	16.4	15.5	14.0	1519
T_8: Foliar spray of soluble KNO_3 @ 0.5% at flower initiation & pod formation stage	17.3	16.2	14.3	1575
S.Em. ±	0.4	0.2	0.3	38
CD (p=0.05)	1.2	0.6	0.9	116

The importance of foliar fertilization be accounted by its essential role in respiration, their metabolism activation of the enzyme, photosynthesis, chloroplast formation, chlorophyll synthesis and natural hormone biosynthesis (Dhakal *et al*., 2016). Application of 19:19:19 fertilizers recorded faster growth and inturn enhanced the yield of cowpea in red sandy soils by Kuntoji and Subbarayappa (2021) Increased dry matter accumulation in pulse crop through Urea, KCl & Zinc was also observed by Chatterjee and Bhattacharya (1986) & Chandrasekhar and Bangarusamy (2003). Fatokun (2002) reported that the application of 19:19:19 NPK @ 3 per cent recorded the highest uptake of nitrogen, phosphorous and potassium by cowpea grain, stover as well as total uptake compared to rest of the treatments. The increased uptake of these nutrients by cowpea was due to increase in grain and stover yield and N, P and K content of grain and stover under the different organic sources (Giller 2007). On the other hand foliar application of NPK at pod formation stage recorded on par results, this signifies that foliar application of nutrients at one stage is sufficient to record higher growth and yield parameters.

Economics of cowpea cultivation was presented in Table 4 Foliar spray of soluble KNO_3 @ 0.5 per cent concentration at flower initiation and pod formation stage recorded higher cost of cultivation (26050 Rs. ha^{-1}) but higher gross returns (52140 Rs. ha^{-1}), net returns (26143 Rs. ha^{-1}) and B:C ratio (2.0) was recorded in the treatment, foliar spray of soluble NPK (19:19:19) @ 1 per cent concentration at flower initiation and pod formation stage which was on par with the treatment foliar spray of soluble NPK (19:19:19) @ 1 per cent concentration at pod formation stage and recorded gross returns (50520 Rs. ha^{-1}), net returns (25223 Rs. ha^{-1}) and B:C ratio (1.99). Similar results were recorded by Kuepper (2003) : Sinchana and Subbarayappa (2021) and reported that foliar application NPK for cowpea improved the net income similar observations were recorded in maize by Kuntoji and subbarayappa (2021). Stampar *et al.,* 1998 reported that foliar application of NPK at 2 per cent spray during pod filling stage enhanced the income and net returns to the tune of 12 per cent higher compared to the control treatment.

TABLE 4

Economics of cowpea as influenced by foliar application of nutrients to enhance productivity through combating the dry spell effect in cowpea

Treatments	Cost of cultivation (Rs ha^{-1})	Gross Returns (Rs ha^{-1})	Net Returns (Rs ha^{-1})	B:C Ratio
T_1: Absolute control	24592	30690	6098	1.24
T_2: Water spray	24842	36360	11518	1.46
T_3: Foliar spray of soluble NPK (19:19:19) @ 1% at flower initiation stage	25297	48330	23033	1.91
T_4: Foliar spray of soluble NPK (19:19:19) @ 1% at pod formation stage	25297	50520	25223	1.99
T_5: Foliar spray of soluble NPK (19:19:19) @ 1% at flower initiation & pod formation stage	25997	52140	26143	2.00
T_6: Foliar spray of soluble KNO_3 @ 0.5% at flower initiation stage	25350	43080	17730	1.69
T_7: Foliar spray of soluble KNO_3@ 0.5% at pod formation stage	25350	45570	20220	1.79
T_8: Foliar spray of soluble KNO_3 @ 0.5% at flower initiation & pod formation stage	26050	47250	21200	1.81
S.Em. ±	-	1011	521	0.01
CD (p=0.05)	-	3056	1612	0.04

Foliar spray of soluble NPK (19:19:19) @ 1 per cent concentration during flower initiation and pod formation stage recorded higher growth, yield and yield related parameters and the same treatment recorded higher economics in cowpea production but the treatment foliar spray of soluble NPK (19:19:19) @ 1 per cent concentration during pod formation stage recorded on par results hence from the economic point of view foliar application of NPK (19:19:19) @ 1 per cent at pod formation stage is recommended for farmers.

Reference

ALTINDIŞLI, A., IRGET, M. E., KALKAN, H., KARA, S. AND OKTAY, M., 1998, Effect of foliar applied KNO_3 on yield, quality and leaf nutrients of Carignane and Colombard wine grapes, improved crop quality by nutrient management, *Agron. J.,* pp : 103 - 106.

CHANDRASEKHAR, C. N. AND BANGARUSAMY, U., 2003, Maximizing the yield of mung bean by foliar application of growth regulating chemicals and nutrients. *Madras Agricul. J.,* **90** (1 - 3) : 142 - 145.

CHATTERJEE, B. N. AND BHATTACHARYA, K. K., 1986, Principle and practices of grain legume production. *Oxford and IBH publishing Co. Ltd.,* New Delhi, pp : 12 - 64.

DHAKAL, Y., MEENA, R. S. AND KUMAR, S., 2016, Effect of INM on nodulation, yield, quality and available nutrient status in soil after harvest of green gram. *Legum Res.,* **39** (4) : 590 - 594.

FATOKUN, A. C., 2002, Breeding cowpea for resistance to insect pest; attempted crosses between cowpea and *Vigna vexillata*. *In*: challenges and opportunities for enhancing sustainable cowpea production, International Institute for Tropical Agriculture (IITA) Ibadan, Nigeria, pp : 52 - 61

GILLER, K. E., 2007, Nitrogen fixation in tropical cropping systems. 2nd ed. Wallingford, UK: CAB International, pp : 152 - 163.

KUEPPER, G., 2003, Foliar fertilization, The national sustainable agriculture information service. *J. Agric. Sci.,* **12** (4) : 123 - 156.

KUNTOJI, A. AND SUBBARAYAPPA, C. T., 2021, Effect of different levels of nitrogen and zinc on quality and nutrient content of maize in rural and peri-urban southern transact of Bengaluru, *Mysore J. Agric. Sci.*, **55** (3) : 12 - 18.

SINCHANA, S. AND SUBBARAYAPPA, C. T., 2021, Soil and foliar application of zinc for different approaches of nutrients on soil properties, nutrient uptake, growth and yield of maize, *Mysore J. Agric. Sci.*, **55** (3) : 266 - 267.

STAMPAR, F., HUDINA, M., DOLENC, K. AND USENIK, V., 1998, Influence of foliar fertilization on yield quantity and quality of apple (*Malus domestica* borkh), Improved crop quality by nutrient management, *J. Agric. Sci.,* **5** (1) : 13 - 16.

Mysore J. Agric. Sci., 57 (1) : 292-301 (2023)

Effect of Types of Irrigation and Organic Mulches on Growth of Mulberry

V. S. Ramya[1], S. Chandrashekhar[2] and C. Seenappa[3]
[1&2] Dept. of Sericulture, [3]Dept.Agronomy, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : ramya123vs@gmail.com

Authors Contribution

V. S. Ramya : Conceptualization of research, designing of the experiments & investigation;
S. Chandrashekhar : Contribution of experimental materials;
C. Seenappa : Execution of field / lab experiment

Corresponding Author :
V. S. Ramya
Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru

Received : August 2022
Accepted : February 2023

Abstract

A field experiment was carried out to study the effect of types of irrigation and organic mulches on growth of mulberry at Department of Sericulture, University of Agricultural Sciences, Bangalore during *Kharif* 2021. The experiment was laid out in Factorial Randomized Complete Block Design (FRCBD) with fourteen treatment combinations and three replications. Main plots include two different types of irrigation *viz.,* Surface drip irrigation- I_1 and Subsurface drip irrigation- I_1 at 15-20 cm depth both at 0.75 Cumulative Pan Evaporation (CPE) and Organic mulches (M_1-Mulching with glyricidia leaves, M_2- Mulching with pongamia leaves, M_3- Mulching with neem leaves, M_4-Live mulch with cowpea, M_5- Live mulch with horsegram and M_6- Live mulch with *dhaincha* and M_7-control without mulch, observations were recorded at 30, 45 and 60 Days After Pruning (DAP). The results of the experiment revealed that the subsurface drip irrigation at 0.75 CPE recorded highest shoot length (79.14, 111.38 and 143.33cm, respectively), number of shoots plant^{-1} (15.32, 19.69 and 27.43 no. respectively), number of leaves plant^{-1} (141.72, 252.02 and 350.96 no. respectively) and leaf area (115.45, 165.31 and 115.45 cm^2 respectively). Among mulches live mulch with cowpea showed highest shoot height (90.53, 118.78 and 149.82 cm respectively), number of shoots plant^{-1} (16.10, 21.20 and 25.30 no. respectively), number of leaves plant^{-1} (146.05, 259.81 and 360.96 no. respectively) and leaf area about 119.25, 170.09 and 246.54 cm^2 respectively. However, effect of irrigation methods and different mulches differed non-significantly.

Keywords : V1 Mulberry, Irrigation methods, Organic mulches and Growth parameters

Mulberry is a hardy, deep rooted and perennial plant with short proliferation period, fast growth rate and plant adapts itself to varied climatic conditions like tropical, subtropical and temperate regions. Quality of mulberry leaves was determined based on fertility status of soil and moisture content of mulberry leaf. Mulberry leaf is the major economic component in sericulture where production of quality leaf per unit area has a direct effect on cocoon quality. Quality of mulberry leaf is influenced by variety, spacing, irrigation levels, nitrogen levels and season (Basanna *et al.,* 1979). The role of leaf moisture in determining productivity of mulberry production is generally recognized and appreciated. Judicious use of water plays an important role for obtaining higher leaf quality and quantity. Moisture content and nutrients in mulberry leaves is considered as one of the most important criteria in assessing the leaf quality (Paul *et al*., 1992). Higher moisture content of mulberry leaf is one of the important criteria which has a direct effect on growth and development of silkworms. It improves ingestion, digestion and also helps in conversion of nutrients in silkworm body.

Mulberry requires about 1.2 - 1.5 ha cm of water per irrigation at an interval of 3 days depending upon the type of soil and season. About 20 irrigations are required per crop of 65 - 70 days' duration to achieve the maximum leaf yield. Thus, the total water requirement for per crop is 24-30 ha cm and annual requirement for five crops is about 120-150 ha cm of water (Rajaram and Qadri, 2014).

Water is the major source for crop production and is the most limiting factor in Indian Agriculture. Though India has the largest irrigation area, irrigation efficiency has not been achieved more than 40 per cent. Per capita water availability in the country has dropped from 6008 m^3 in 1947 to 1250 m^3 and now is expected to dwindle down to 760 m^3 (Singh, 2006). Among all other inputs, irrigation water has highest impact on mulberry leaf quality and yield. The need of the hour is to maximize the production per unit of water. Hence, further improvement in quality and yield of crop may need to adopt new irrigation systems such as subsurface drip irrigation. Subsurface drip irrigation which supplies water and nutrients directly to the crop root zone. Crops can be 'spoon-fed' with water and nutrients. The spoon feeding characteristic of the subsurface drip irrigation system has a great potential to minimize the water losses. Organic mulches help in soil moisture conservation, slowly decompose and release of nutrients into soil while improving the soil structure. Higher leaf production and productivity is achieved by improved methods of irrigation system along with moisture conservation practices like organic mulching. With this background, current study was undertaken with the objectives to find out best method of irrigation and organic mulching for increased quality and yield of mulberry.

Material and Methods

The experiment was conducted during *kharif* 2021 in well-established V-1 mulberry garden at Department of Sericulture, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bangalore. The field is located at a latitude of 12°582 N and longitude of 77°352 East and at an altitude of 930 m above mean sea level in the Eastern Dry Zone (Zone-5) of Karnataka. The experiment with fourteen treatment combinations *viz.,* methods of irrigation (I_1 - Surface drip irrigation @ 0.75 CPE and I_2 - Subsurface drip irrigation (15-20 cm depth) @ 0.75 CPE), six mulches (M_1-Mulching with glyricidia leaves, M_2- Mulching with pongamia leaves, M_3- Mulching with neem leaves, M_4-Live mulch with cowpea, M_5- Live mulch with horsegram and M_6- Live mulch with *dhaincha*) with M_7- control were laid out in Factorial RCBD design with three replications.

The data on growth parameters at 30, 45 and 60 DAP of crop were recorded in each treatment on randomly selected five plants from each net plot and mean value was worked out. The experimental data collected on growth components of plant were subjected to Fisher's method of Analysis of Variance (ANOVA) as outlined by Panse and Panse, V. G. and Sukhatme (1967). Wherever, F test was significant for comparison among the treatment means, Critical Difference (CD) was worked out. If F test found non-significant, again CD values NS (non-significant) was indicated.

Results and Discussion

The results and discussion on effect of different irrigation methods and organic mulches on growth of mulberry are revealed in the following sub headings.

Shoot Length

The data on shoot length varied significantly due to different treatments at 30, 45 and 60 DAP (Table 1). Significant difference in shoot length was observed among different irrigation methods. Subsurface drip irrigation at 0.75 CPE has recorded highest shoot length (79.14, 111.38 and 143.33cm respectively) over surface drip irrigation at 0.75 CPE (72.84, 107.64 and 137.42 cm respectively). The significant difference in shoot length may be due to supply of water at root zone and minimized weed growth. Similarly, Kombali *et al.,* 2016 reported that subsurface drip irrigation at 100 per cent pan evaporation recorded significantly higher cane length (226.6 cm) and cane girth (.91 cm). Similar studies were reported by Sudhakar *et al.,* 2018 increase in depth of subsurface drip irrigation from ½ ft. to 1½ ft. significantly increased plant height

TABLE 1

Shoot length of mulberry as influenced by different methods of irrigation and organic mulching

Treatments	Shoot length of plant (cm)		
	30 DAP	45 DAP	60 DAP
	Different types of Irrigation (I)		
I_1 - Surface drip irrigation (I_1) @ 0.75 CPE	72.84	107.64	137.42
I_2 - Subsurface drip irrigation (I_2) @ 0.75 CPE	79.14	111.38	143.33
F-test	*	*	*
S.Em. ±	0.71	0.85	0.89
CD at 5 %	2.06	2.47	2.59
	Different types of mulches (M)		
M_1 - Glyricidia leaves	78.93	111.11	142.89
M_2 - Pongamia leaves	75.17	107.98	138.99
M_3 - Neem leaves	68.43	104.30	135.70
M_4 - Live mulch with cowpea	90.53	118.78	149.82
M_5 - Live mulch with Horsegram	80.12	113.92	143.46
M_6 - Live mulch with *Dhaincha*	72.41	108.36	138.51
M_7 - Control (without mulch)	66.35	102.18	133.26
F-test	*	*	*
S.Em. ±	1.32	1.59	1.66
CD at 5 %	5.46	6.54	6.85
	Interaction (I×M)		
T_1 - I_1 M_1	75.43	109.48	140.21
T_2 - I_1 M_2	71.85	105.62	136.66
T_3 - I_1 M_3	66.67	98.92	134.29
T_4 - I_1 M_4	88.90	117.29	147.82
T_5 - I_1 M_5	76.59	112.69	139.43
T_6 - I_1 M_6	69.27	107.96	134.81
T_7 - I_1 M_7	61.17	101.56	128.72
T_8 - I_2 M_1	82.43	112.73	145.57
T_9 - I_2 M_2	78.49	110.33	141.32
T_{10} - I_2 M_3	70.20	109.68	137.11
T_{11} - I_2 M_4	92.16	120.26	151.83
T_{12} - I_2 M_5	83.65	115.14	147.49
T_{13} - I_2 M_6	75.55	108.76	142.20
T_{14} - I_2 M_7	71.53	102.80	137.81
F- test	NS	NS	NS
S. Em±	1.88	2.25	2.35
CD at 5 %	NS	NS	NS

DAP- Days After Pruning; *- Significant; NS- Non significant

from 160.20 to 163.60 cm compared to surface drip irrigation of 157.80 cm.

Shoot length was significantly influenced by different mulches. Live mulch with cowpea has recorded highest shoot length (90.53, 118.78 and 149.82 cm respectively), among mulches lowest shoot length was recorded in neem leaves mulched plot (68.43, 104.30 and 135.70 cm). Similar results were reported by Mas-Ud *et al.,* 2021 who found that among different varieties of cowpea live mulch types, the Padituya live mulch produced the tallest (96 cm) maize plants at vegetative growth and this was significantly higher than the other two living mulch types, with the control producing the shortest plants of 87 cm. The difference in height could be as a result of enhanced soil nutrients (e.g., nitrogen), which is associated with legume plants like cowpea. Interaction on types of irrigation and organic mulches found non-significant with respect to shoot length of mulberry crop. However, T_{11} - $I_2 M_4$ recorded highest shoot length 92.16, 120.26 and 151.83 cm respectively, which is followed by T_4- I_1M_4, which recorded 88.90, 117.29 and 147.82 cm respectively. The least shoot length of 61.17, 101.56 and 128.72 cm respectively was recorded by T_7- I_1M_7.

Number of Shoots Plant^{-1}

The significant difference in number of shoots plant^{-1} were observed among types of irrigation and organic mulches at 30, 45 and 60 DAP (Table 2). Subsurface drip irrigation at 0.75 CPE has recorded a greater number of shoots plant^{-1} (15.32, 19.69 and 27.43 no. respectively) over surface drip irrigation at 0.75 CPE (14.18, 17.95 and 21.51 no. respectively). The significant difference in number of shoots may be due effective utilization of water by crop which is supplied directly to root zone. The results are in confirmation with findings of Seenappa, 2015, reported that number of shoots plant^{-1} increased in subsurface drip irrigation with higher level at 1.0 CPE about 26.42 during harvest. Evaporation loss from surface drip irrigation is 10 per cent of applied water could be saved when drip laterals were placed at 15-30 cm below the soil surface there by crops growth will be enhanced (Evett *et al.,*1995). It has been found that subsurface drip irrigation reduced evaporation from the soil and increased the wetted soil volume and surface area more than surface systems allowing a deep rooting pattern (Phene, 1995).

Subsurface drip irrigation is most advanced method of irrigation for getting more crop growth which enables the application of small amounts of water to the soil through drippers placed below the soil surface with discharge rates generally in same range of surface drip irrigation (ASAE Std., 1999).

Live mulch with cowpea has recorded more number of shoots (16.10, 21.20 and 25.30 no. respectively), among mulches lowest number of shoots was recorded in neem leaves mulched plot (13.90, 18.73 and 24.10 no. respectively).

Similar results were also observed by Boateng *et al.,* 2019, reported that living mulch with Canavalia-grown tomato plants (60 days) had early number of days to 50 per cent flowering when compared to control (65 days). This could be due to higher atmospheric nitrogen fixed to enrich the soil by *Canavalia ensiformis* than the other treatments. Interaction on types of irrigation and organic mulches found non-significant with respect to number of shoots of mulberry crop. However, T11 - I_2M_4 recorded highest number of shoots of 16.73, 22.66 and 28.20 respectively, which is followed by T_4 - I_1M_4, which recorded 15.46, 19.73 and 22.40 respectively. The least number of shoots of 12.60, 16.20 and 20.60 respectively was recorded by T_7- I_1M_7.

Number of Leaves Plant^{-1}

The results on number of leaves plant^{-1} were significantly influenced by types of irrigation and organic mulches at 30, 45 and 60 DAP (Table 3). The data on number of leaves plant^{-1} varied significantly due to different treatments of mulberry crop. Number of leaves plant^{-1} (141.72, 252.02 and 350.96 no. respectively) varied significantly by subsurface drip irrigation at 0.75 CPE over surface drip irrigation at 0.75 CPE (134.26, 244.73 and 339.77 no. respectively). The

TABLE 2

Number of shoots plant^{-1} of mulberry influenced by different methods of irrigation and organic mulching

Treatments	Number of shoots palnt^{-1} 30 DAP	45 DAP	60 DAP
	Different types of Irrigation (I)		
I_1 - Surface drip irrigation (I_1) @ 0.75 CPE	14.18	17.95	21.51
I_2 - Subsurface drip irrigation (I_2) @ 0.75 CPE	15.32	19.69	27.43
F - test	*	*	*
S.Em. ±	0.29	0.29	0.31
CD at 5 %	0.85	0.84	0.90
	Different types of mulches (M)		
M_1 - Glyricidia leaves	15.26	19.43	25.60
M_2 - Pongamia leaves	14.23	17.70	23.60
M_3 - Neem leaves	13.90	18.73	24.10
M_4 - Live mulch with cowpea	16.10	21.20	25.30
M_5 - Live mulch with Horsegram	15.333	19.33	25.36
M_6 - Live mulch with *dhaincha*	14.73	17.93	24.23
M_7 - Control (without mulch)	13.7	17.43	23.13
F- test	*	*	*
S.Em. ±	0.54	0.54	0.58
CD at 5 %	2.25	2.23	2.39
	Interaction (I×M)		
T_1 - I_1 M_1	14.80	18.86	23.66
T_2 - I_1 M_2	13.93	17.20	20.53
T_3 - I_1 M_3	13.40	17.33	22.53
T_4 - I_1 M_4	15.46	19.73	22.40
T_5 - I_1 M_5	14.73	18.66	19.66
T_6 - I_1 M_6	14.33	17.66	21.20
T_7 - I_1 M_7	12.60	16.20	20.60
T_8 - I_2 M_1	15.73	20	27.53
T_9 - I_2 M_2	14.53	18.2	26.66
T_{10} - I_2 M_3	14.40	20.13	25.66
T_{11} - I_2 M_4	16.73	22.66	28.20
T_{12} - I_2 M_5	15.93	20.00	31.06
T_{13} - I_2 M_6	15.13	18.20	27.26
T_{14} - I_2 M_7	14.80	18.66	25.66
F - test	NS	NS	NS
S. Em ±	0.77	0.77	0.82
CD at 5 %	NS	NS	NS

DAP- Days After Pruning *- Significant; NS- Non significant

TABLE 3

Number of leaves plant^{-1} of mulberry influenced by different methods of irrigation and organic mulching

Treatments	Number of leaves plant^{-1}		
	30 DAP	45 DAP	60 DAP
	Different types of Irrigation (I)		
I_1 - Surface drip irrigation (I_1) @0.75 CPE	134.26	244.73	339.77
I_2 - Subsurface drip irrigation (I_2) @0.75 CPE	141.72	252.02	350.96
F- test	*	*	*
S.Em. ±	1.38	2.42	2.564
CD at 5 %	4.035	7.051	7.45
	Different types of mulches (M)		
M_1 - Glyricidia leaves	139.45	251.96	355.10
M_2 - Pongamia leaves	134.26	244.07	341.88
M_3 - Neem leaves	131.70	235.30	335.77
M_4 - Live mulch with cowpea	146.05	259.81	360.96
M_5 - Live mulch with Horsegram	142.55	253.59	347.62
M_6 - Live mulch with *Dhaincha*	140	251.26	345.02
M_7 - Control (without mulch)	131.92	242.65	331.21
F-test	*	*	*
S.Em. ±	2.59	4.538	4.79
CD at 5 %	10.67	18.65	19.72
	Interaction (I×M)		
T_1 - I_1 M_1	133.54	247.93	351.13
T_2 - I_1 M_2	128.87	239.26	336.57
T_3 - I_1 M_3	125.62	231.8	327.61
T_4 - I_1 M_4	145.33	256.8	357.26
T_5 - I_1 M_5	140.63	250.92	343.2
T_6 - I_1 M_6	136.02	248.53	340.66
T_7 - I_1 M_7	129.82	237.91	321.95
T_8 - I_2 M_1	145.37	256	359.08
T_9 - I_2 M_2	139.66	248.87	347.186
T_{10} - I_2 M_3	137.79	238.80	343.93
T_{11} - I_2 M_4	146.78	262.83	364.67
T_{12} - I_2 M_5	144.47	256.27	352.05
T_{13} - I_2 M_6	143.98	253.99	349.38
T_{14} - I_2 M_7	134.02	247.38	340.47
F - test	NS	NS	NS
S. Em±	3.67	6.41	6.78
CD at 5 %	NS	NS	NS

DAP- Days After Pruning; *- Significant; NS- Non significant

significant difference in number of leaves may be due to water in close association with rhizosphere zones of mulberry and making use of water efficiently. The results are in line with Gopinath (1994) noticed that in mulberry, higher growth was obtained under irrigated condition and additional mulberry cultivation area coverage under irrigation by using the water saved in drip irrigation was also noticed by the author. Anantha krishna *et al.* (1995) reported that 48 per cent of increased mulberry leaf growth and yield along with 67 per cent of water savings with drip irrigation which equals to irrigation at 40 per cent CPE from open class pan evaporimeter. However, irrigation at 80 per cent CPE value with 33 per cent water saving under drip method of irrigation was found to be ideal for mulberry compared to conventional furrow method of irrigation. The results are in line with Seenappa and Devakumar, 2015 reported that subsurface drip irrigation at higher levels at 1.0 CPE increased number of leaves from 215.11 at 30 DAP to 402.67 at harvest.

Sudhakar *et al.,* 2018, reported that number of leaves of mulberry plant has been increased with increase in depth of subsurface drip irrigation, where number of leaves increased from 274.4 at a depth of ½ ft. to 290.5 at a depth of 1½ ft. The reasons may be the advantages involved in the sub-surface drip irrigation methods. It is noticed that the water infiltration was down word instead of upward due to gravitational forces of the soil. Inline drips laid in varied depths have an advantage over other methods because the moisture regimes are exactly remaining near to the rhizosphere zone leading to constant availability of water thereby increasing growth parameters of mulberry.

Live mulch with cowpea has recorded more number of leaves (146.05, 259.81 and 360.96 no. respectively) where, lowest number of leaves was recorded in neem leaves mulched plot (131.70, 235.30 and 335.77 no. respectively). Similar results were also observed by Boateng *et al.,* 2019, reported that living mulch with Canavalia-grown tomato plants had more number of fruits per tomato plant and second highest was found in cowpea plot where lowest number of fruits found in Mucuna plots. Mulches used as cover crops and intercropping (as live crop grown in between the rows of main crop) provide different benefits in agro-ecologies through competition and allelopathy such as nitrogen fixation, erosion control, improving organic matter, nutrient recycling, pest and weed control and improving soil organism (Khan *et al.,* 2019). Interaction on types of irrigation and organic mulches found non-significant with respect to number of leaves of mulberry crop. However, T_{11} - I_2M_4 recorded highest number of leaves of 146.78, 262.83 and 364.67 respectively, which is followed by T_4- I_1M_4, which recorded 145.33, 256.8 and 357.26respectively. The least number of leaves of 129.82, 237.91 and 321.95 respectively was recorded by T_7- I_1M_7.

Leaf Area (cm²)

The findings on leaf area (cm²) were significantly influenced by types of irrigation and organic mulches at 30, 45 and 60 DAP and leaf area varied significantly due to different treatments of mulberry crop. Subsurface drip irrigation @ 0.75 CPE increased leaf area (115.45, 165.31 and 241.73 cm² respectively) varied significantly over surface drip irrigation @ 0.75 CPE (108.03, 149.29 and 223.52 cm² respectively). The above results were in conformity with the findings of Sudhakar *et al.,* 2018. Leaf area of mulberry plant has been increased with increase in depth of subsurface drip irrigation where leaf area increased from 190.2 at ½ ft. to 198.9 cm² at 1½ ft. This might be due to increased levels of water infiltration in the form of vertical, horizontal water percolation and water holding capacity was noticed in all the sub-surface drip irrigations compared to the traditional methods of irrigations (flood & surface drip irrigations) and drip irrigation method will not only save the irrigation water, reduce the frequency of irrigation and seepage accompanied with plant nutrients but they are also effective because of their close association with rhizosphere zones of mulberry and making use of water efficiently. Subsurface drip has also proven to be an efficient irrigation method with potential advantages of high water use efficiency,

TABLE 4

Leaf area of mulberry as influenced by different methods of irrigation and organic mulching

Treatments	Leaf area (cm^2)		
	30 DAP	45 DAP	60 DAP
	Different types of Irrigation (I)		
I_1 - Surface drip irrigation (I_1) @0.75 CPE	108.03	149.29	223.52
I_2 - Subsurface drip irrigation (I_2) @0.75 CPE	115.45	165.31	241.73
F- test	*	*	*
S.Em. ±	1.31	2.74	1.31
CD at 5 %	3.83	7.98	3.83
	Different types of mulches (M)		
M_1 - Glyricidia leaves	112.37	153.49	232.08
M_2 - Pongamia leaves	103.98	150.34	228.50
M_3 - Neem leaves	99.85	143.76	223.07
M_4 - Live mulch with cowpea	119.25	170.09	246.54
M_5 - Live mulch with Horsegram	117.27	165.06	236.91
M_6 - Live mulch with *Dhaincha*	114.67	161.98	232.38
M_7 - Control (without mulch)	114.78	156.41	228.88
F-test	*	*	*
S.Em±	2.46	5.14	4.59
CD at 5 %	10.13	21.13	18.87
	Interaction (I×M)		
T_1 - I_1 M_1	110.50	150.55	220.50
T_2 - I_1 M_2	100.75	146.62	217.56
T_3 - I_1 M_3	95.88	138.80	213.81
T_4 - I_1 M_4	115.54	156.90	239.46
T_5 - I_1 M_5	112.69	153.57	226.76
T_6 - I_1 M_6	110.55	151.08	224.23
T_7 - I_1 M_7	110.33	147.55	222.33
T_8 - I_2 M_1	114.25	156.43	243.66
T_9 - I_2 M_2	107.22	154.06	239.44
T_{10} - I_2 M_3	103.82	148.72	232.33
T_{11} - I_2 M_4	122.96	183.28	253.63
T_{12} - I_2 M_5	121.85	176.55	247.06
T_{13} - I_2 M_6	118.80	172.89	240.54
T_{14} - I_2 M_7	119.24	165.27	235.44
F- test	NS	NS	NS
S. Em±	3.48	7.26	6.49
CD at 5 %	NS	NS	NS

DAP- Days After Pruning; *- Significant; NS- Non significant

fewer weed and disease problems, less soil erosion, efficient fertilizer application, maintenance of dry areas for tractor movement at any time flexibility in design and lower labour costs compared to conventional drip irrigation.

Live mulch with cowpea has recorded higher leaf area (119.25, 170.09 and 246.54 cm^2 respectively) over neem leaves mulched plot (99.85, 143.76 and 223.07 cm^2 respectively). Similar results reported by Boateng *et al.,* 2019, fruit weight per plant was highest in Canavalia-grown tomato plants (535 g) and lowest in Mucuna-grown tomato plants (302 g) and there were significant differences between treatment.

Legumes have been found to enhance soil fertility and increase crop yield. In a similar work, (Chaudary *et al.,* 1991) found that legumes could have multiple uses including use as cover crops, live mulch or food crops. The legumes can generate considerable quantity of organic matter (up to 80 q ha^{-1}) possessing about 40 kg of nitrogen ha^{-1} of which about is 2/3 being fixed from atmosphere by bacteria. Interaction on types of irrigation and organic mulches found non-significant with respect to leaf area of mulberry crop. However, T_{11} - I_2M_4 recorded highest number of leaves of 122.96, 183.28 and 253.63 respectively, which is followed by T_4- I_1M_4, which recorded 115.54, 156.90 and 239.46 respectively. The least number of leaves of 110.33, 147.55 and 222.33 respectively was recorded by T_7- I_1M_7.

Irrigation is an important tool among all other agricultural inputs. However, method of irrigation plays an important role in determining the growth and yield of mulberry, thus subsurface drip irrigation showed better results over surface drip irrigation because it is placed below soil surface and near to rootzone of mulberry which helps in absorption of nutrients and reduction in evaporation loss directly from soil surface. Organic mulches played an important role by covering soil surface, conserving soil moisture, by fixing nitrogen from atmosphere, improving the organic matter in soil intern helps to get successful mulberry crop production.

Acknowledgement : The authors are thankful to the Department of Sericulture, UAS, GKVK, Bengaluru. Also acknowledge gratitude for SFS, ZARS, UAS, Bangalore for providing mulching materials and AICRP on Agrometeorology, UAS, Bangalore, for providing weather data during the research period.

REFERENCES

ANANTHAKRISHNA, K. H., ARUN SARPESHKAR, M. AND MURALIDHARA, H. R., 1995, Drip irrigation for mulberry cultivation. *Indian Silk*, **34** (3) : 17 - 19.

ASAE STD., 1999, Soil and water terminology. S., 526.1. ASAE standards. *American Soc. Agric. Eng.,* St. Joseph, MI

BASANNA, H. M., KODANDARAM, M. S. AND SRINIVASAN, F. B., 1979, Studies on the chemical composition of new mulberry cultivars in different agronomical treatments. Annual Report, Central Sericulture Research and Training Institute (CSR&TI), Mysore, pp. : 4042.

BOATENG, S. K., MENSAH1, A. O. AND ALLOTEY, D., 2019, The effect of leguminous cover crops on growth and yield of tomato. *Int. J. Horti. Agri. Foodsci.,* **3** (5) : 2456 - 8635.

CHOUDHURY, P. C., DAS, P. K., GHOSH, A. AND MATHUR, V. B., 1991, Green manuring cum dry weed mulching for improvement of soil fertility and soil moisture conservation. *Ann. Rep.,* Central Sericulture Research and Training Institute (CSR&TI), Mysore, pp. : 13.

EVETT, S. R., HOWELL, T. A. AND SCHNEIDER, A. D., 1995, April. Energy and water balances for surface and subsurface drip irrigation: a comparison point and area sources. *Irrig. Sci.,* **22** : 171 - 176.

GOPINATH, G. R., 1994, Drip irrigation for mulberry gardens. *Indian silk,* **33** (2) : 27 - 31.

KHAN, I. A., REHMAN, O. U., KHAN, S. A., SAMADY, H. A. AND ALZAHRANI, Y., 2019, Effect of Different Herbicides, Plant extracts and mulches on yield and yield components of maize. *Planta Daninha*, **38** : 112 - 118.

Kombali, G., Sheshadri, T., Nagaraju, Thimmegowda, M. N., Basavaraja, P. K. and Mallikarjuna, G. B., 2016, Performance of sugarcane under varied levels of irrigation and nutrients through subsurface drip fertigation. *Mysore. J. Agri. Sci.,* **50** (2) : 290 - 293.

Mas-Ud, M., Dokurugu, F. and Kaba, J. S., 2021, Effectiveness of cowpea (*Vigna unguiculata* L.) living mulch on weed suppression and yield of maize (*Zea mays* L.). *Open Agriculture*, **6** : 489 - 497.

Panse, V. G. and Sukhatme, P. V., 1967, Statistical methods for agricultural workers. *Indian Council of Agricultural Research*, New Delhi.

Paul, D. C., Rao, G. S. and Deb, D. C., 1992, Impact of dietary moisture on nutritional indices and growth of *Bombyx mori* and concomitant larval duration. *J. insect Physiol.,* **38** (3) : 229 - 235.

Phene, C. J., 1995, The sustainability and potential of subsurface drip irrigation. In: Micro irrigation for a change World, Eds F. R. Lamn. Orlando, Florida, USA. pp. : 359 - 367.

Rajaram, S. and Qadri, S. M., 2014, Computation of irrigation water requirements, its managements and calendaring in mulberry crop for sustainable sericulture under Tamil Nadu conditions. *Int. J. Engg. And Sci.,* **4** (1) : 1 - 19.

Seenappa, C. and Devakumar, N., 2015, Effect of different methods and levels of irrigation and mulching on growth and yield of mulberry in eastern dry zone of Karnataka. *Mysore. J. Agri. Sci*, **49** (2) : 206 - 210.

Seenappa, C., 2015, Enhancing water productivity in mulberry and cocoon production in eastern dry zone of Karnataka*. Uni. Agri. Sci. Bang., Thesis.,* pp. : 76 - 87.

Singh, D. K. and Rajput, T. B. S., 2006, Response of lateral placement depths of subsurface drip irrigation on okra (*Abelmoschus esculentus*). *Int. J. Plant Prod.* **1** (1) : 73 - 84.

Sudhakar, P., Hanumantharayappa, S. K., Swamy Gowda, M. R., Jalaja S., Kumar and Sivaprasad, V., 2018, Impact of micro irrigation methods on Mulberry (*Morus alba* L.) leaf quality and production*, Int. J. Pure App. Biosci*. **6** (3) : 332 - 339.

Mysore J. Agric. Sci., 57 (1) : 302-310 (2023)

Effect of Plant Growth Habit and other Fruit Quality Traits on TSS and Average Fruit Weight in Advanced Breeding Lines of Muskmelon (*Cucumis melo* L.)

G. V. Ranjitha, A. Mohan Rao, H. M. Nateshan, S. Ramesh and H. C. Lohithaswa
Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
Namdhari Seeds, Pvt. Ltd., Bidadi, Bengaluru
e-Mail : ranjgcv96@gmail.com

Authors Contribution

G. V. Ranjitha : Data collection, field experiment and manuscript writing;
A. Mohan Rao : Conceptualization and supervision;
H. M. Nateshan & S. Ramesh : Conceptualization and design;
H. C. Lohithaswa : Editing

Corresponding Author :
G. V. Ranjitha
Department of Genetics and Plant Breeding,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : July 2022
Accepted : January 2023

Abstract

Muskmelon (*Cucumis melo* L.) is one of the most diversified (including growth habit trait) species among the members of the Cucurbitaceae family. The fruit is valued for attractive shape, size, flavour, flesh colour and sweetness. For increased acceptability by farmers and consumers, high yielding cultivars with consumer preferred fruit quality traits are desirable. An investigation was carried out to study the influence of plant growth habit and other end user preferred quality traits *viz.,* fruit shape, flesh colour and fruit cavity size on commercially important traits *viz.,* Total Soluble Solids (TSS) and average fruit weight in muskmelon during 2021 rainy season at experimental plots of Namdhari Seeds Pvt. Ltd., Itakudibbanahalli, Karnataka, India. Seventy-two advanced breeding lines (ABLs) were grouped into different classes based on different plant growth habit (3), fruit shape (4), flesh colour (4) and fruit cavity size (3). Trait means of different classes of ABLs were statistically compared for TSS and average fruit weight. Non-significance of means of plant growth habit and fruit cavity size classes for TSS and average fruit weight indicated lack of influence of these traits on TSS and average fruit weight. On the contrary, significant mean differences of four different classes of fruit shape and flesh colour for TSS and average fruit weight suggested prevailing influence of these quality traits on TSS and average fruit weight.

Keywords : Muskmelon, ABLs, Fruit shape, Flesh colour, Fruit cavity size

Muskmelon (*Cucumis melo* L.; 2n = 2x = 24) is one of the most economically important species of the Cucurbitaceae family. It is the most diversified species of the genus *Cucumis* and this variability is reflected at morphological (including growth habit), physiological and biochemical (including TSS) traits (Whitaker and Davis, 1962; Kirkbride, 1993 and Burger *et al*., 2003) and at molecular level (Stepansky *et al*., 1999; Mliki *et al*., 2001; Akashi *et al*., 2002 and Monforte *et al*., 2003). Muskmelon is believed to be originated in East Africa and subsequently diversified into Asia from Mediterranean Sea to Eastern Asia. India is regarded as secondary centre of origin of muskmelon. In India, muskmelon is considered as commercially important cucurbit, widely grown in Uttar Pradesh, Rajasthan, Punjab, Bihar and some parts of Andhra Pradesh, Tamil Nadu and Karnataka mainly for dessert purpose. In a tropical country like India, muskmelon is considered as best thirst quencher during hot summer. Melon fruit is one of the most valued summer fruits because of its high nutritive and medicinal value. It is a good source of vitamin A, vitamin C, carbohydrates and energy (Chakrabarti *et al*. 2001). In addition to this, it has many health promoting benefits. Fruit juice has cooling effect and also acts as a demulcent and diuretic drink. It is also good for eye and skin health, also is a natural remedy for dyspepsia since it is having more of water and fibre content.

There are several types or botanical groups of melon and the recent classification has been proposed by Pitrat *et al.* (2000). Accordingly, the sweet melons belong to the Cantalupensis (Cantaloupe), Reticulatus (Muskmelon), Inodorous (Casaba) and Makuwa groups and the non-sweet, generally long-fruited melons belong to the Chate, Flexuosus and Conomon groups. *Cucumis melo* shows extreme genetic variation for fruit traits such as shape, size, presence of netting, sutures and grooves, flesh colour, sweetness, fruit cavity size, consistency, acidity, aroma and sugar composition. Muskmelon being a dessert fruit, quality parameters like TSS, flesh colour, fruit shape and flesh texture are important ones. However, a common driving point across different market segments of muskmelon is high sugar content and pleasant flavour. Growth habit is a plant architectural trait and muskmelon exhibits different plant growth habits. Variability provides an intriguing subject for investigations into the genetic, biochemical and molecular bases of fruit appearance and quality. Considering high diversity of melon, breeding programs should focus on more than one melon type. A good genotype irrespective of the growth habit must have high yield, market-standard size, small internal cavity and high soluble solids content (Nunes *et al*., 2005).

We hypothesize that TSS and average fruit weight are not affected by plant growth habit whereas other important fruit quality traits *viz.,* fruit shape, flesh colour and fruit cavity size have influence on TSS and average fruit weight.

Material and Methods

The experimental material consisted of 72 ABLs that have been previously derived from crosses involving genotypes procured from different countries of the world (Fig. 1). Variation exhibited by ABLs with respect to distinct growth habit, fruit shape, flesh colour and fruit cavity size is detailed in Table 1.

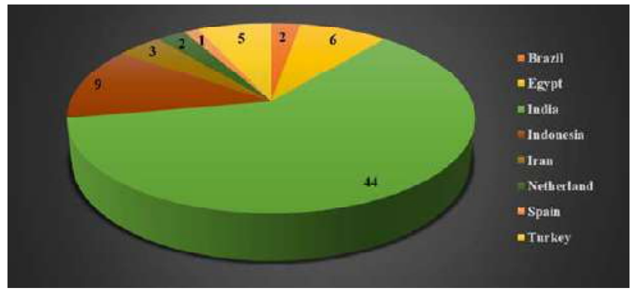


Fig. 1: ABLs classified based on country of collection of parental lines and involved in deriving them

ABLs were evaluated during 2021 rainy season in alpha lattice experimental design with two replications at the experimental plots of Namdhari Seeds, Pvt. Ltd., at Itakudibbanahalli, Tumkur. The experimental site is located at 13.8162° N, 77.3166° E and 787m above mean sea level. Initially, seedlings of 72 ABLs were raised in nursery with all plant protection measures. Fifteen days old seedlings were transplanted to experimental field with a spacing of 1.5m between rows and 0.5m between plants. All recommended package of practices were followed to raise a healthy crop.

Data Recording and Statistical Analysis

Out of twelve plants maintained in each genotype and in each replication, randomly selected six plants were

Table 1

List of morphological traits and their corresponding distinct classes exhibited by 72 ABLs in muskmelon

Trait	Class			
	1	2	3	4
Growth habit	Compact	Bushy	Open	-
Fruit shape	Round	Oval	Elongated globe	Obovate
Flesh colour	Green	Light green	White	Salmon
Fruit cavity size	Small	Medium	Large	-

tagged, excluding plants at borders. Data were recorded on plant growth habit at vegetative stage (40 DAS). While observations on three qualitative traits *viz.,* fruit shape, flesh colour and fruit cavity size and two quantitative traits *viz.,* TSS (%) and average fruit weight (kg fruit^{-1}) was recorded at fruit maturity stage (110 DAS) (Table 2). Average fruit weight and TSS of ABLs belonging to three growth habit classes, four fruit shape classes, four flesh colour classes and three fruit cavity size classes were computed.

Statistical significance of differences among trait means of average fruit weight and TSS among three growth habit classes *viz.,* (1) Compact, (2) Bushy and (3) Open type, four fruit shape classes (1) Round, (2) Oval, (3) Elongated globe and (4) Obovate, four flesh colour classes (1) Green, (2) Light green, (3) White and (4) Salmon and three fruit cavity size classes, (1) Small, (2) Medium and (3) Large (https://plantauthority.gov.in/crop-dus-guidelines), was examined using F-test (Fisher, 1950). Non significance and otherwise of F tests indicate lack of influence and significant influence of average fruit weight and TSS respectively.

Results and Discussion

In the present investigation, we were able to classify advanced breeding lines into different classes of plant growth habit, fruit shape classes, flesh colour classes and fruit cavity size classes. Thirty-eight of the 72 ABLs exhibited compact type growth habit, 14 of bushy type and 22 showed open type growth habit at their vegetative phase (Fig. 2A). With respect to fruit shape out of 72 lines 39 ABLs were produced round shape fruits, 24 produced oval, five ABLs produced elongated globe shape fruits and four ABLs produced obovate shape fruits (Fig. 2B) Flesh colour exhibited by advanced breeding lines were Green (12), Light green (37), White (7) and Salmon (16), (Bokashi, 1992; Malik, 2014), (Fig. 2C). More than half of the ABLs *i.e.,* 56 lines showed medium fruit cavity size, 14 showed smaller cavity size and very few that is only two lines recorded larger fruit cavity size (Fig. 2D).

The results of ANOVA indicated prevalence of significant variability ($p<0.001$) among advanced breeding lines for TSS and average fruit weight. This result, by and large suggested existence of substantial

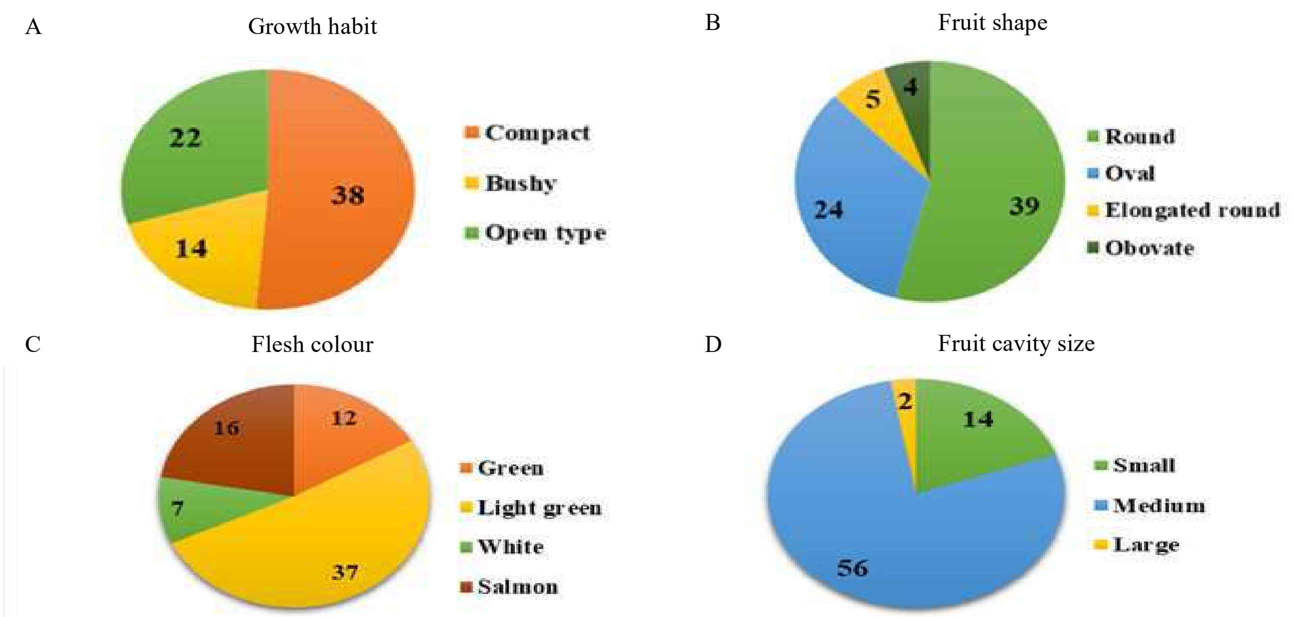


Fig. 2 : Distribution of 72 ABLs grouped under different classes of (A) plant growth habit (B) fruit shape (C) flesh colour (D) fruit cavity size

TABLE 2

Description of fruit traits of muskmelon lines used in the study

Trait	Description	Method of Observation	References
Growth Habit	Growth habit is a plant architectural trait in muskmelon exhibiting different kinds.	Recorded growth habitat at vegetative phase (40 DAS) on visual basis	-
Fruit shape	Fruit shape is one of the most important physical properties and consumer preference parameter. Consumers prefer fruits of equal weight and uniform shape. Classification of ABLs based on fruit shape is vital in meeting quality standards and increasing market value. It is also helpful in planning packaging, transportation and marketing operations and also may provide an optimum packaging configuration	Shape of the fruit in longitudinal section was observed visually	Bokashi, 1992; Kandasamy, 2004; Shivapriya and Sudhakar, 2014
Flesh colour	The development of flesh colour is an ethylene dependent trait. Flesh colour is an important trait from the consumer point of view. Expression of colour in the fruit flesh is conditioned by its carotenoid type and concentration which in turn is influenced by genetic and environmental factors.	Flesh colour of the fruit was observed visually at Fruit maturity stage (110 DAS)	Bokashi, 1992; Malik, 2014
Fruit cavity size	Small seed cavity is a desirable character in muskmelon as it decides fruit flesh quantity.	Cavity size was measured using a centimetre scale after making a transverse cut across the melon fruit.	Ahmed, 2009
Total soluble solids (TSS)	TSS content is a reliable indicator of quality. TSS can be measured quickly by squeezing juice from the melon fruit flesh on a refractometer. Breeders routinely use this method to screen large quantities of fruits for sweetness. Expected TSS of melon fruit flesh is at least 9% to be considered as acceptable. Large genetic variability observed among melon germplasm for TSS and sugar concentration is accounted mainly for differences in the levels of sucrose.	Flesh of five fruits in each ABL was crushed separately and a drop of juice was placed on Hand Refractometer (0-32%) and the reading was noted and expressed in percentage.	Hubbard *et al.*, 1989; Stepansky *et al.*, 1999b; Burger, 2000; Rodriguez, 2002
Average fruit weight (kg)	Average fruit weight is of economic importance as it is directly proportional to fruit yield vine^{-1}	Weight of randomly chosen 3 individual fruits harvested at maturity from each ABL was recorded. Mean fruit weight was calculated and expressed in kilograms fruit^{-1}.	Ibrahim, 2014

TABLE 3

Analysis of Variance among advanced breeding lines for TSS (%) and average fruit weight (kg) *

Source of variation	Degrees of freedom	TSS (%)	P value	Average fruit weight (kg)	P value
Replication	1	1.0000		0.22158	
Genotype	71	20.0266 ***	2×10^{-16}	0.76928 ***	2×10^{-16}
Block	16	2.1011		0.05893	
Residuals	55	1.2070		0.06356	

Significant @ P=0.05, ** Significant @ P=0.01, *** Significant @ P=0.001

variability among ABLs for commercially important traits such as TSS and average fruit weight in muskmelon (Table 3). These results are in agreement with those of Prasad (2004) and Sushmitha *et al*. (2017).

TSS and average fruit weight among ABLs were comparable among plants bearing different plant growth habit classes (compact, bushy and open type) which supports our hypothesis (Table 4). Similarly, there were no significant differences among ABLs bearing different fruit cavity sizes (Small, Medium and Large) for TSS and average fruit weight which is contrary to the hypothesis we made (Table 5) as indicated by 'F' test. These results suggest lack of either desirable / undesirable effects in favour of any plant growth habit and fruit cavity size concerning TSS and average fruit weight.

On the contrary ABLs differing for four different fruit shape classes (Round, Oval, Elongated globe and Obovate) exhibited significant influence on TSS and average fruit weight (Table 6) and the results are in agreement with those of Potekar, 2014. TSS was higher in case of round shape fruits. While, elongated round shaped fruits expressed higher average fruit weight (Table 6). Similarly, there were significant differences among ABLs with different fruit flesh colour for TSS and average fruit weight. Plants having salmon flesh colour showed higher TSS and that of white flesh registered low TSS (Table 7), (Fageria and Luthra, 2005).

Implications in Breeding Muskmelon

Muskmelon being a dessert fruit, quality parameters like flesh colour, fruit shape and total soluble solids are important. It is possible to develop new muskmelon cultivars with desired combination of both farmer and end user preferred traits. We believe that round fruits with salmon colour flesh are likely to be preferred by consumers, as round and salmon

TABLE 4

Relationship of plant growth habit with TSS (%) and average fruit weight (kg) among advanced breeding lines of muskmelon

Growth habit	Mean		Source of variation	Degrees of freedom	Mean sum of squares		P value
	TSS (%)	Average fruit weight (kg)			Total soluble solids (TSS) (%)	Average fruit weight (kg)	
Compact	10.98	1.35	Between Groups	2	8.8482	0.4121	TSS (%) 0.4191
Bushy	9.71	1.52	Within Groups	69	10.0470	0.3931	Average fruit weight (kg) 0.3560
Open type	10.93	1.58					

TABLE 5

Relationship of fruit cavity size with TSS (%) and average fruit weight (Kg) among advanced breeding lines of muskmelon

Fruit cavity size	Mean		Source of variation	Degrees of freedom	Mean sum of squares		P value
	TSS (%)	Average fruit weight (kg)			Total soluble solids (TSS) (%)	Average fruit weight (kg)	
Small	9.03	1.61	Between Groups	2	30.7311	0.2170	TSS (%) 0.0830
Medium	11.12	1.43					
Large	11.25	1.3	Within Groups	69	9.5866	0.3894	Average fruit weight (kg) 0.5753

TABLE 6

Relationship of fruit shape with TSS (%) and average fruit weight (kg) among advanced breeding lines of muskmelon

Fruit shape	Mean		Source of variation	Degrees of freedom	Mean sum of squares		P value
	TSS (%)	Average fruit weight (kg)			Total soluble solids (TSS) (%)	Average fruit weight (kg)	
Round	11.72	1.41	Between Groups	3	33.5115 **	1.2009 *	TSS (%) 0.01
Oval	9.12	1.55					
Elongated globe	10.9	1.62	Within Groups	68	8.9766	0.3927	Average fruit weight (kg) 0.04
Obovte	10.37	1.24					

* Significant @ P=0.05, ** Significant @ P=0.01

TABLE 7

Relationship of flesh colour with TSS (%) and average fruit weight (Kg) among advanced breeding lines of muskmelon

Flesh colour	Mean		Source of variation	Degrees of freedom	Mean sum of squares		P value
	TSS (%)	Average fruit weight (kg)			Total soluble solids (TSS) (%)	Average fruit weight (kg)	
Green	9.79	1.55	Between Groups	3	80.9436 **	1.4231 *	TSS (%) 2.7×10^{-6}
Light green	9.76	1.64					
White	9.57	1.34	Within Groups	68	6.8840	0.3388	Average fruit weight (kg) 0.008
Salmon	14.15	1.04					

* Significant @ P=0.05, ** Significant @ P=0.01, *** Significant @ P=0.001

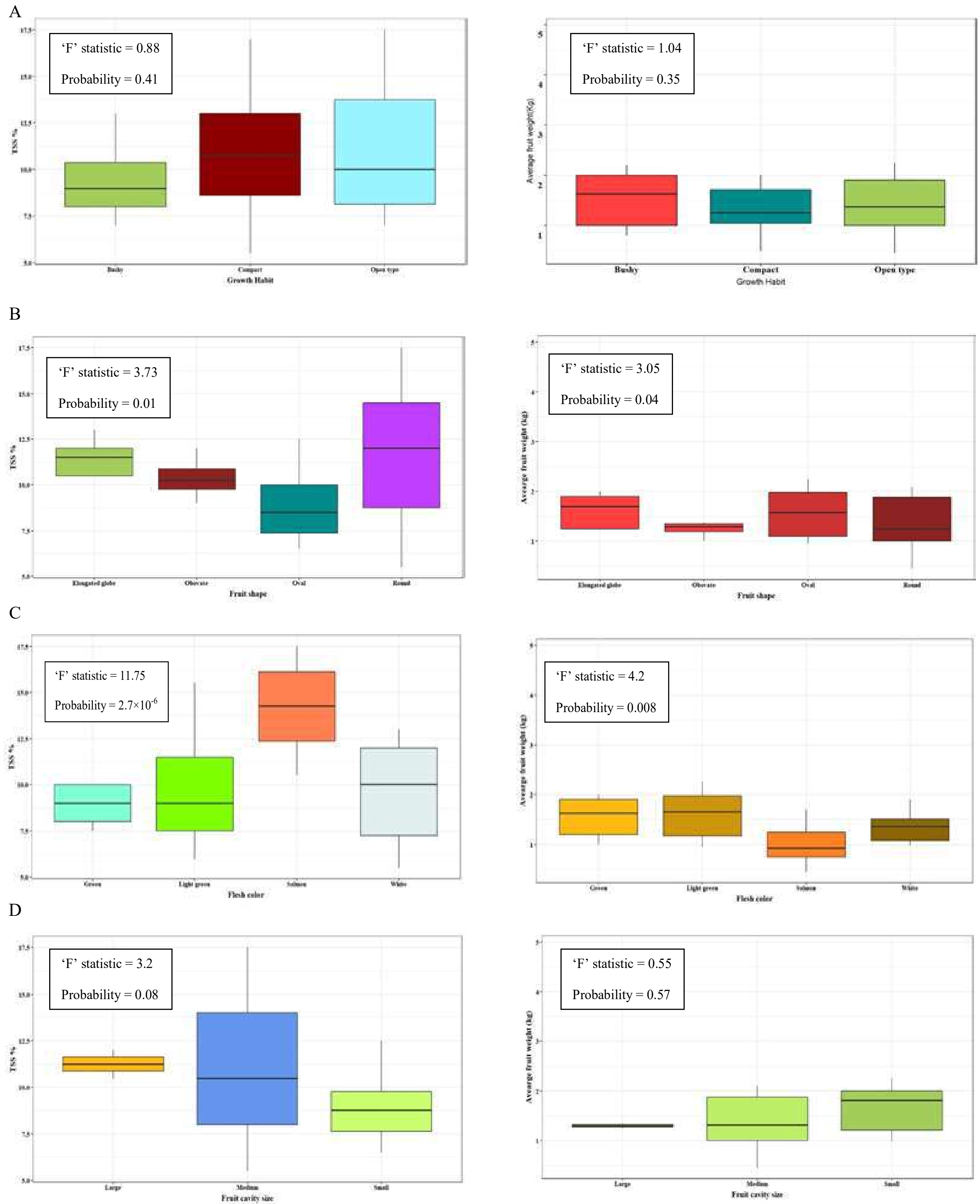


Fig. 3 : Box-Whisker plots depicting the effect of (A) growth habit (B) fruit shape (C) flesh colour (D) fruit cavity size on TSS and average fruit weight in 72 Advanced Breeding Lines (ABLs) of muskmelon

colour fleshed fruits have higher TSS and have market standard size. Understanding the variability for commercially important traits among ABLs with different fruit shape and fruit flesh colour classes is expected to enable and enhance the pace and efficiency of developing high yielding muskmelon cultivars with desired combinations of quality traits.

Our study suggested that fruit quality traits such as fruit shape and fruit flesh colour are consumer preferred traits have significant effect on TSS and average fruit weight. On the contrary, plant growth habit and fruit cavity size has no influence on TSS and average fruit weight in muskmelon. As of Indian market is concerned, melon fruit with round shape and salmon flesh colour is more preferrable in comparison to other flesh colour and fruit shape (Commercial melon breeder, Namdhari seeds, Pvt. Ltd., Bidadi, Bangalore). Hence from the study lines with preferred traits can be utilized in breeding program to affect the crosses to develop particular hybrids for Indian market. In middle east and European countries green fleshed fruits are of consumer preference (Karchi *et al*., 2000) and long melons are preferred in India and Pakisthan as their tender fruits are eaten raw. Hence, according to the needs breeder's objectives specificity we can utilize them in developing cultivars with desired combination of fruit traits.

Acknowledgement : The senior author gratefully acknowledges Namdhari Seeds Pvt. Ltd., Bidadi, Bangalore, for extending research facilities and for providing financial support in the form of student-fellowship dated: 17/03/2021 for conducting thesis research for partial fulfilment for the award of Ph.D. degree by University of Agricultural Sciences, Bangalore, India.

References

Ahmed, O. K., 2009, Evaluation of objective maturity indices for muskmelon (*Cucumis melo* L.) cv. Galia. *Journal of King Abdulaziz University*. DOI:10.4197/Sci.21-2.9

Akashi, Y., Fukunda, N., Wako, T., Masuda, M. and Kato, K., 2002, Genetic variation and phylogenetic relationships in East and South Asian melons, *Cucumis melo* L., based on the analysis of five isozymes. *Euphytica*. **125** : 385 - 396.

Bokashi, A. I., Mondal, S. N. and Monowar, H., 1992, Studies on the performance of muskmelon hybrid, *Indian. J. Hort.,* **49** (4) : 354 - 357.

Burger, Y., Saar, U., Distelfeld, A., Katzir, N., Yeselson, Y., Shen, S. and Schaffer, A. A., 2003, Developing of sweet melon (*Cucumis melo*) genotypes combining high sucrose and organic acid content. *J. Am. Soc. Hort. Sci*., **128** : 537 - 540.

Chakrabarti, A. K., 2001, Importance of vegetables. In Textbook of vegetables, tuber crops and spices. Eds. *Indian Council of Agric. Res.,* New Delhi, pp. : 4

Fageria, M. S. and Luthra, J. P., 2005, Genetic variability in muskmelon (*Cucumis melo* L.) In: National seminar on Cucurbits, 22 - 23, Sept. GBPUAT, Pantnagar, pp. : 142.

Fisher, R. A., 1950, Statistical methods for research workers, 11th Edition, Oliver and Boyd, London, UK, pp. : 362.

Hubbard, N. L., Huber, S. C. and Pharr, D. M., 1989, Sucrose phosphate synthase and acid invertase as determinants of sucrose concentration in developing muskmelon (*Cucumis melo* L.) fruits. *Plant Physiol*., **91** : 1527 - 1534.

Ibrahim, E. M., 2012, Variability, heritability and genetic advance in Egyptian sweet melon (*Cucumis melo* var. *aezyptiacus* L.) under water stress condition. *Int. J. Pl. Breed. Genet.,* **6** (4) : 236 - 244.

Kandasamy, M. R., 2004, Morphological, biochemical and molecular characterization in landraces of melon (*Cucumis melo* L.), *Ph.D (Hort.), Thesis*, *Kerala Agric. Univ.,* Thrissur.

Karchi, Z., 2000, Development of melon culture and breeding in Israel. *Acta Horticulturae*, **510** : 13 - 17.

Kirkbride, J. H., 1993, Biosystematic monograph of the genus *Cucumis* (Cucurbitaceae). *Parkway Publ, Boone*. North Carolina, USA, pp. : 159.

MALIK, A. A., VASHISHT, V. K., KULDEEP, S., ABHISHEK, S., SINGH, D. K., HIRA, S., M. MONFORTE, A. J., JAMES, D. AND NARINDER, P. S. D., 2014, Diversity among melon (*Cucumis melo* L.), landraces from Indo-Gangetic plains of India and their genetic relationship with USA melon cultivars. *Genet. Resour. Crop. Evol.*, **61** : 1189 - 1208.

MLIKI, A., STAUB, J. E., ZHANGYONG, S. AND GHORBEL, A., 2001, Genetic diversity in melon (*Cucumis melo* L.): An evaluation of African germplasm. *Genet. Resour. Crop. Evol.,* **48** : 587 - 597.

MONFORTE, A. J., GARCIA MAS, J. AND ARUS, P., 2003, Genetic variability in melon based on microsatellite variation. *Plant Breed*., **122**: 153–157.

NUNES, G. H. S., SANTOS JÚNIOR, J. J., ANDRADE, F. V., BEZERRA, NETO, F., MENEZES, J. B. AND PEREIRA, E. W. L., 2005, Desempenho de híbridos do grupo inodorus em Mossoro. *Horticultura Brasileira*, **23** : 90 - 94.

PITRAT, M., HANELT, P. AND HAMMER, K., 2000, Some comments on intraspecific classification on cultivars of melon. Proceedings of Cucurbitaceae 2000, 7th Eucarpia Meeting on Cucurbit Genetics and Breeding. *Acta Hort.*, **510** : 29–36.

POTEKAR, S. V., NAGRE, P. K. AND SAWANT, S. N., 2014, Genetic variability study in muskmelon (*Cucumis melo* L.). *Int. J. Trop. Agric.,* **32** (3/4) : 349 - 351.

PRASAD, V. S. R., PITCHAIMUTHU, M. AND DUTTA, O. P., 2004, Variation diversity pattern and choice of parental selection in musk melon (*Cucumis melo* L.). *J. Hort. Sci.,* **61** : 319 - 322.

RODRIGUEZ, J. C., SHAW, N. AND CANTLIFFE, D., 2002, High tunnel cantaloupe and specialty melon cultivar evaluation, production of galia type muskmelon using a passive ventilated greenhouse and soilless culture. Cucurbitaceae, pp. : 365 - 372.

SHIVAPRIYA, M. AND SUDHAKAR, T., 2014, Characterization of muskmelon local types of Karnataka for yield attributing traits, National seminar-cum-workshop on strategies for improvement, enhancing productivity and utilization of cucurbits., Aug 8-10, 2014. Sovienir and book abstracts, pp. : 130.

STEPANSKY, A., KOVALSKI, I. AND PERL-TREVES, R., 1999, Intraspecific classification of melons (*Cucumis melo* L.) in view of their phenotypic and molecular variation. *Plant Syst. Evol.,* **217** : 313 - 332.

SUSHMITHA, P., SRINIVASULU, B., PARATPARA RAO, M., DEVI PRIYA, A. AND NARAYANA REDDY, M.L., 2017, Quality assessment of different muskmelon varieties by chemical and sensory analysis. *Agric. Update.,* **12**(3): 667-670

WHITAKER, T. W. AND DAVIS, G. N., 1962, Cucurbit, Botany, Cultivation and Utilization. *Interscience Publ.,* New York, USA, pp. : 249 p.

Mysore J. Agric. Sci., 57 (1) : 311-317 (2023)

Identification of Potential Genotypes for Bean Common Mosaic Virus Resistance in Field Bean

S. B. Sangeeta[1], H. K. Ramappa[2], T. V. Krishna[3] and H. A. Prameela[4]
[1,2&4]Department of Plant Pathology, [3]Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : ssb7311bjpr@gmail.com

Authors Contribution
S. B. Sangeeta : Conceptualization, draft preparation & data analysis;
H. K. Ramappa & H. A. Prameela : Conceptualization and draft correction;
T. V. Krishna : Supervision and provided genotypes for screening

Corresponding Author :
S. B. Sangeeta
Department of Plant Pathology, College of Agriculture, UAS, GKVK, Bengaluru

Received : August 2022
Accepted : February 2023

Abstract

Evaluation of 50 genotypes was taken up under glasshouse conditions through mechanical sap inoculation method against bean common mosaic virus (BCMV). Among 50 genotypes screened none of the them were found immune to BCMV disease. Genotype (GLP-67-1) showed resistant (R) reaction, 26 genotypes showed moderately resistant (MR), 15 genotypes showed moderately susceptible (MS), five genotypes showed susceptible (S) and three genotypes showed highly susceptible (HS) reaction to BCMV. The genotypes were further screened through double antibody sandwich enzyme linked immune sorbent assay (DAS-ELISA) and the results revealed that genotypes which had exhibited bean common mosaic disease associated symptoms in glasshouse condition showed strong positive reaction to specific antibody of BCMV by producing bright yellow color.

Keywords : Bean common mosaic virus, Resistant, Screening, Susceptible, DAS-ELISA

Field bean (*Lablab purpureus* L.), also known as faba beans or lablab beans, is one of the most ancient legume crops known for its food and fodder values (Shivakumar *et al.,* 2016). It is the third most important leguminous crop after soybean (*Glycine max* L.) and peas (*Pisum sativum* L.) (Singh *et al.,* 2013 and Paunina *et al.,* 2018). It is a multiutility and multi-beneficial leguminous crop, extensively grown for vegetable, pulse, fodder, green manure, cover crop, medicine and ornamental purpose. Despite of its importance as a multi-purpose crop, it can withstand drought better than cowpea (Ramesh and Byregowda, 2016). Karnataka contributes about 90 per cent of both area and production of field bean in India (Praneetha *et al.,* 2022).

Field bean has been exposed to variety of diseases caused by fungi, bacteria, viruses and nematodes with losses estimating millions of rupees annually. Among the viral diseases, dolichos yellow mosaic, dolichos enation, leaf roll, bean common mosaic and bean common mosaic necrosis (Mwaipopo *et al.* 2017) diseases have been reported in India (Capoor and Verma, 1950).

In Karnataka, BCMV infecting field bean was first reported by Udayashankar *et al.* (2011). This virus is the type member of the genus *Potyvirus* belongs to family *Potyviridae*. This disease causes significant yield losses (50 to 100 %) in different host crop plants (Drijfhout, 1991). The plants infected with BCMV is characterized by mosaic, mottling, vein banding twisting of leaf, uneven leaf lamina, vein clearing and puckering symptoms (Mangeni *et al.,* 2014). Management of viruses is generally a difficult task since the viruses are systemic and contagious in nature. Hence, identification of resistant genotypes has been considered as the most efficient approach against plant viruses (Tewari and Ramanujam, 1994). Keeping these aspects in view, an attempt has been made to identify the resistant genotypes against BCMV.

Material and Methods

The screening was conducted under glasshouse conditions at the Department of Plant Pathology, UAS, GKVK, Bengaluru by using completely randomized design (CRD) with three replications and five plants in each replication. Fifty field bean genotypes were screened for resistance against BCMV. The genotypes were collected from All India National Project (AINP) on Arid legumes, Zonal Agricultural Research Station, (ZARS), GKVK, Bengaluru.

Maintenance of BCMV culture : The field bean plants showing characteristic symptoms of BCMV *viz.,* mosaic, mottling, vein banding, vein netting, vein clearing and puckering (Fig. 1) were collected from the naturally infected field at the ZARS, GKVK, Bengaluru.

The infected leaf sample was crushed using phosphate buffer (0.1 M, p^H 7.0) and mechanically inoculated to two leaf stage old healthy susceptible genotype of field bean *i.e.,* GL-161. The inoculated plants were kept in insect proof cage for symptom expression under glasshouse conditions. These plants were used as stock culture and maintained continuously by inoculating to healthy field bean plants at regular intervals. The maintained stock culture was used as a source of inoculum for screening. Fifteen seeds of each genotypes were sown in pro-trays which contained coco-peat with nutrient mixture and maintained upto two leaf stage. Then the seedlings were transplanted to pots containing sterilized soil for inoculation studies. After transplanting, the seedlings were inoculated with the BCMV.

Mechanical inoculation of BCMV : The field bean plants at two leaf stage just above the cotyledon leaves were sap inoculated mechanically as described by Ashfaq *et al.* (2010). After inoculation, plants were jet sprayed with water to remove excess inoculum and abrasive (Carborandum). Field bean genotype GL-161 was used as a susceptible check throughout the screening studies.

Assessment of disease severity : Thirty days after inoculation, disease severity scores were noted according to the scale given by Diwakar and Mali, 1976 (Table 1). However, little little modification in the scale was made based on the different symptoms exhibited by the genotypes. The per cent disease index (PDI) was calculated using the formula given by Wheeler (1969). Based on the PDI values obtained, the genotypes were classified into five categories (Table 1).

$$\text{Per cent disease index (PDI)} = \frac{\text{Sum of all disease ratings}}{\text{Total number of ratings} \times \text{maximum disease grade}} \times 100$$

Serological Assay

DAS-ELISA was employed for investigation of virus infected field bean leaves after four weeks of inoculation. Polysterene plates were coated with anti-BCMV antibodies (LOEWE, Germany), diluted

A : Mosaic and Vein netting B : Mottling and puckering C. Vein banding and vein clearing

Fig. 1: Naturally infected field bean plants showing peculiar symptoms of BCMV

Table 1

Disease reaction scale (0-5) (Diwakar and Mali, 1976)

Scale	Description	Type of symptoms	Category
0	No disease symptoms	No symptoms	Immune
1	1-5 per cent of plants showing symptoms	Only mild mosaic	Resistant
2	5-15 per cent of plants showing symptoms	Mild mosaic or Mosaic or Mottling	Moderately resistant
3	15-25 per cent of plants showing symptoms	Mild mosaic or Mosaic and Mottling	Moderately susceptible
4	25-50 per cent of plants showing symptoms	Mild mosaic or Mosaic, Mottling or Puckering and vein netting	Susceptible
5	>50 per cent of plants showing symptoms	Mild mosaic, Mosaic, Mottling, Vein clearing, Vein banding, Puckering and Vein netting	Highly susceptible

1:200 in coating buffer and incubated for four hours at 37 °C. Sap was extracted by grinding leaves in the extraction buffer in pestle and mortar and then centrifuged at 8000 rpm for 5 min. Exactly 200 µL of the extracted sap of sample was then added to the coated polysterene plate and incubated overnight at 4 °C. Alkaline phosphatase (ALP) conjugated anti-BCMV antibody was added in 1:200 dilutions and incubated for four hours at 37 °C followed by incubation with p-nitrophenyl phosphate (AGDIA, India) at room temperature for 1 hr. The change in color at the end of test confirms the presence of BCMV and the absorbance values were measured on ELISA plate reader at 405 nm (Basavaraj, 2014).

Results and Discussion

A total of 50 genotypes of field bean were screened for resistance against BCMV in glasshouse conditions. A perusal of the data in Table 2 and Fig. 3 revealed that different type of reactions were reflected by different genotypes in the form of severity of disease expressed as per cent. The results indicated that highest PDI (88.89) was recorded in susceptible check (GL-161) and lowest PDI was noticed in GLP-67-1 (2.42). Out of 50 genotypes screened, none of them showed immune reaction, only one genotype *i.e.,* GLP-67-1 exhibited resistant (2 PDI) reaction and 26 genotypes *viz.,* GLP-15, GLP-77, GLP-75, GLP-10-1, GL-145, GL-58, GL-46, GL-109, GL-266, GL-251, GL-569, GL-157, GL-65, GL-83, GL-7, GL-140, GL-110, GLB-25, GLB-22, GLB-18, GLB-11, GLB-12, GLB-17, GLB-14, GLB-8 and GLB-7 showed moderately resistant (52 PDI) reaction. Fifteen genotypes *viz.,* GLP-9, GL-156, GLP-14, GL-139, GL-119, GL-529, GL-131, GLB-24, GLB-19, GLB-15, GLB-16, GLB-6, GLB-9, GLB-13 and GLB-3 showed moderately susceptible (30 PDI) reaction, five genotypes *viz.,* GLB-1, GLB-4, HA-3, GLB-23 and GL-13 showed susceptible reaction (10 PDI) and three genotypes *viz.,* GLB-2, GLB-5 and GL-161 exhibited highly susceptible (6 PDI) reaction (Fig. 3).

Screened genotypes showed different kinds of characteristic symptoms *viz.,* mild mosaic, mosaic, mottling, vein clearing, vein banding, vein netting and puckering upon mechanical inoculation (Fig. 2 and Fig. 4). For further confirmation, all genotypes were screened through DAS-ELISA with aid of anti-BCMV specific antibody.

The results of DAS-ELISA revealed that the absorbance value of resistant genotype was 0.42, whereas, moderately resistant and moderately susceptible genotypes absorbance value ranged from 0.44-0.63 and 0.73-1.15, respectively. The absorbance value for susceptible and highly susceptible genotypes were ranged from 1.13-1.58 and 1.6-1.89, respectively.

These genotypes were further categorized into different groups *viz.,* immune (0), resistant (1), moderately resistant (2), moderately susceptible (3), susceptible (4) and highly susceptible (5) based on

TABLE 2

Reaction of field bean genotypes to BCMV infection under glasshouse conditions

Geno-types	10 DPI	15 DPI	30 DPI	45 DPI	Disease score	Disease reaction	Severity	OD value @ 405nm
GLB-1	MM	MM, Mo	MM, Mo,VN	MM, Mo,VN	4	S	44.44	1.58
GLB-2	MM	MM,M,Mo	MM,M,Mo,VB	MM,M,Mo,VB, VC	5	HS	83.28	1.79
GLB-3	MM	Mo, MM	Mo, MM	Mo, MM	3	MS	18.28	1.09
GLB-4	M	M,P	M, P,VN	M, P,VN	4	S	41.26	1.49
GLB-5	MM	MM,M, Mo Mo,VN	MM, M, Mo,VN,VB	MM,M, Mo,VN, VB	5	HS	78.63	1.62
GLB-6	MM	MM,M	MM,M	MM,M	3	MS	17.23	0.96
GLB-7	MM	MM,Mo	MM,Mo	MM,Mo	2	MR	10.21	0.52
GLB-8	M	M	M	M	2	MR	8.38	0.46
GLB-9	M	M,Mo	M,Mo	M,Mo	3	MS	19.85	0.11
GLB-11	MM	MM,Mo	MM,Mo	MM,Mo	2	MR	9.36	0.47
GLB-12	MM	MM, M, Mo	MM, M, Mo	MM, M, Mo	2	MR	13.69	0.63
GLB-13	MM	MM, Mo	MM, Mo	MM, Mo	3	MS	19.12	1.00
GLB-14	NS	MM,M	MM,M	MM,M	2	MR	10.57	0.54
GLB-15	NS	M	M, Mo	M, Mo	3	MS	20.67	1.12
GLB-16	NS	MM, M	MM, M	MM, M	3	MS	17.83	0.98
GLB-17	NS	MM, Mo	MM, Mo	MM, Mo	2	MR	9.57	0.51
GLB-18	NS	MM, Mo	MM, Mo	MM, Mo	2	MR	10.13	0.59
GLB-19	NS	M, MM	M, MM	M, MM	3	MS	18.32	0.99
HA-3	MM	Mo, MM	Mo, MM	Mo, MM	4	S	36.96	1.38
GLB-22	NS	MM,M	MM,M	MM,M	2	MR	9.54	0.52
GLB-23	NS	M, Mo	M, Mo, VN	M, Mo, VN	4	S	39.12	1.86
GLB-24	NS	M, Mo	M, Mo	M, Mo	3	MS	20.61	1.08
GLB-25	NS	MM,M	MM, M	MM, M	2	MR	8.57	0.49
GL-136	NS	MM,M	MM,M	MM,M	4	S	35.33	1.13
GL-131	NS	MM, Mo	MM, Mo	MM, Mo	3	MS	18.36	0.93
GL-83	MM	MM, Mo	MM, Mo	MM, Mo	2	MR	11.24	0.60
GL-7	MM	MM, M	MM, M	MM, M	2	MR	10.21	0.53
GL-140	NS	MM,Mo	MM, Mo	MM, Mo	2	MR	12.63	0.61
GL-110	MM	MM, M	MM, M	MM, M	2	MR	9.56	0.53
GL-119	MM	MM,M	MM, M	MM, M	3	MS	19.96	0.98
GL-529	NS	MM,M	MM,M	MM,M	3	MS	19.45	0.96
GL-109	NS	M	M	M	2	MR	7.36	0.46
GL-266	MM	MM, Mo	MM, Mo	MM, Mo	2	MR	9.65	0.49
GL-251	M	M, Mo	M, Mo	M, Mo	2	MR	12.96	0.63

Continued........

Geno-types	10 DPI	15 DPI	30 DPI	45 DPI	Disease score	Disease reaction	Severity	OD value @ 405nm
GL-145	M	M	M	M	2	MR	7.36	0.44
GL-58	NS	MM,M	MM,M	MM,M	2	MR	9.65	0.48
GL-46	NS	M, Mo	M, Mo	M, Mo	2	MR	10.21	0.51
GL-139	NS	MM	MM	MM	3	MS	17.24	0.54
GL-161	NS	MM,M, Mo, VB, VC	MM, M, Mo, VB,VC, P	MM,M, Mo, VB,VC, P	5	HS	88.89	1.89
GL-156	NS	M	M,Mo	M,Mo	3	MS	21.96	1.13
GLP-10-1	NS	M,MM	M,MM	M,MM	2	MR	9.24	0.48
GLP-67-1	NS	MM	MM	MM	1	R	2.42	0.42
GLP-9	M	M,MM	M,MM	M,MM	3	MS	15.64	0.93
GLP-14	M	M, Mo	M, Mo	M, Mo	3	MS	21.21	1.10
GLP-15	MM	MM, M	MM, M	MM, M	2	MR	10.21	0.52
GLP-77	NS	M	M	M	2	MR	8.11	0.48
GLP-75	MM	MM,M	MM,M	MM,M	2	MR	9.56	0.53

MM- Mild Mosaic, M- Mosaic, Mo- Mottling, P- Puckering, VC- Vein Clearing, VB- Vein Banding, VN- Vein Netting, DPI- Days Post Inoculation, R- Resistant, MR- Moderately Resistant, MS- Moderately Susceptible, S- Susceptible, HS- Highly Susceptible

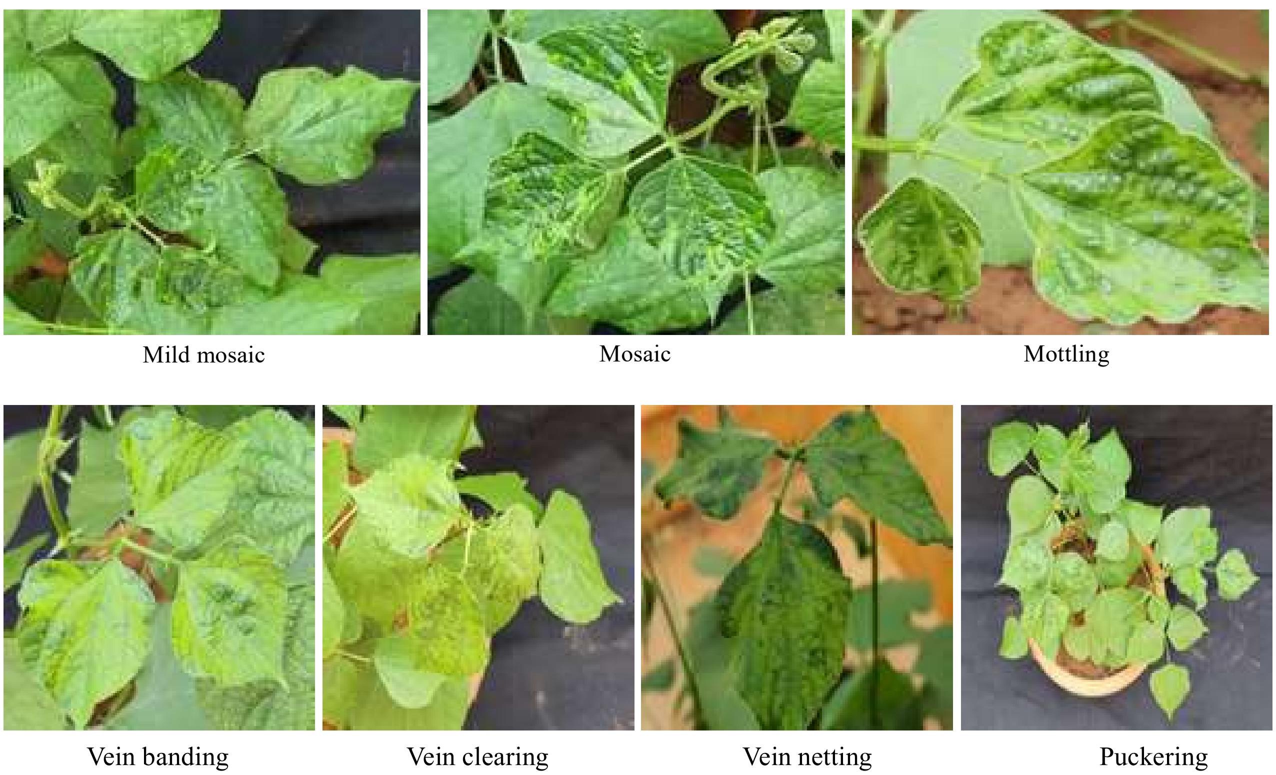


Fig. 2: Field bean leaves showing different kinds of BCMV symptoms upon mechanical inoculation

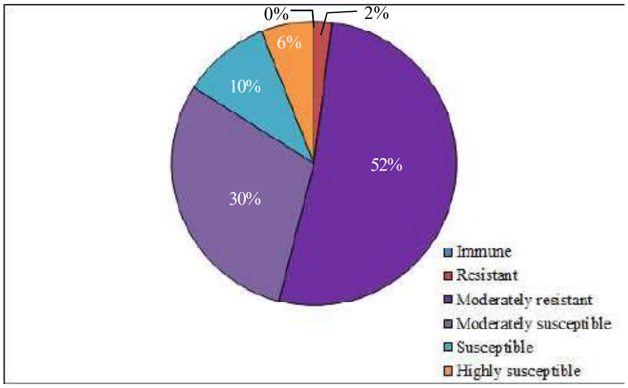


Fig. 3: Grouping of field bean genotypes based on BCMV disease reaction under glasshouse

Fig. 4: Field bean genotypes exhibiting different kind of symptoms upon artificial inoculation

the PDI value obtained by respective genotypes (Table 3).

The results are in agreement with that of screening experiment conducted by Renuka (2014), in which 75 field bean genotypes were screened against BCMV under glasshouse conditions at UAS, GKVK, Bengaluru. Among 75 field bean genotypes were screened, only one genotype (Kadale avare) showed moderately resistant (MR) reaction, 22 genotypes showed susceptible (S) reaction and remaining 52 genotypes showed highly susceptible (HS) reaction. The results obtained are also in conformity with Manjunatha *et al.* (2021), where 350 common bean genotypes were screened under natural conditions and artificial inoculation method during 2016-2017, 2017-2018 and 2018-2019. Eleven genotypes *viz.,* EC400445, EC400414, ET400414, ET4515B, EC540173, IC360831, BD9116291, EC31084, EC541703, ET8409, IC340947 and IC356024 were found resistant.

Use of resistant genotype is regarded as a durable method for controlling plant diseases mainly the viral diseases. By this background, screening of 50 genotypes against BCMV at GKVK, Bengaluru was undertaken. From this study it can be revealed that field bean genotypes showing resistant, moderately resistant reaction to BCMV could serve as potential donor of resistance in breeding programme. The major drawback in evaluation of genotypes is that some genotypes which had shown resistant in one location could turn out to be susceptible in location because of environmental impact on genotype and environmental-genotype interaction need to studied for durable resistance in future.

TABLE 3

Grouping of field bean genotypes based on reaction to BCMV disease under glasshouse conditions

Scale	Category	Genotypes
0	Immune	Nil
1	Resistant	GLP-67-1
2	Moderately resistant	GLP-15, GLP-77, GLP-75, GLP-10-1, GL-145, GL-58, GL-46, GL-109, GL-266, GL-251, GL-569, GL-157, GL-65, GL-83, GL-7, GL-140, GL 110, GLB-25, GLB-22, GLB-18, GLB-11, GLB-12, GLB-17, GLB-14, GLB-8, GLB-7
3	Moderately susceptible	GLP-9, GL-156, GLP-14, GL-139, GL-119, GL-529, GL-131, GLB-24, GLB-19, GLB-15, GLB-16, GLB-6, GLB-9, GLB-13, GLB-3
4	Susceptible	GLB-1, GLB-4, HA-3, GLB-23, GL-13
5	Highly susceptible	GLB-2, GLB-5, GL-161

References

Ashfaq, M., Khan, M. A., Javed, N., Mughal, S. M., Shahid, M. and Sahi, S. T., 2010, Effect of urdbean leaf crinkle virus infection on total soluble protein and antioxidant enzymes. *Pak. J. Bot.*, **42** (1) : 447 - 454.

Basavaraj, S., 2014, Survey, molecular detection and partial characterization of cucumber mosaic virus (CMV) and banana bract mosaic virus (BBRMV) isolates infecting banana in Karnataka. *Ph. D. Thesis,* Univ. Agric. Sci., Bangalore, India, pp. : 36.

Capoor, S. P. and Varma, P. M., 1950, A new virus disease of *Dolichos lablab*. *Curr. Sci.,* **19** (8) : 228 - 305.

Diwakar, M. P. and Mali, V. R., 1976, Cowpea mosaic virus-a new record for Marathwada. *J. Maharashtra Agril. univ.,* **1** : 274 - 277.

Drijfhout, E., 1991, Bean common mosaic In: Hall R., editor. Compendium of bean diseases. MN: *APS Press*, *Am. Phytopathol. Soc.*, 37 - 39

Mangeni, B., Abang, M. M., Omuse, C. N., Leitich, A. W. and Mukoye, B., 2014, Distribution and Pathogenic Characterization of bean common mosaic virus (BCMV) and bean common mosaic necrosis virus (BCMNV) in western Kenya. *J. Agri. food and Appl. Sci.,* **2** (10) : 308 - 316.

Manjunatha, L., Basavaraja, T., Manjunatha, N., Srinivasa, N., Kumar, V., Chandora, R. and Singh, N. P., 2021, Identification of stable resistant donors against necrosis inducing strain of bean common mosaic virus in common bean (*Phaseolus vulgaris* L.). *Arch. Phytopathol. Plant Prot.*, **54** (15-16) : 1033 - 1046.

Mwaipopo, B., Nchimbi-msolla, S., Njau, P., Tairo, F., William, M., Binagwa, P. and Mbanzibwa, D., 2017, Viruses infecting common bean (*Phaseolus vulgaris* L.) in Tanzania: A review on molecular characterization, detection and disease management options. *Afr. J. Agric. Res.,* **12** (18) : 1 - 9.

Paunina, I., Gaile, Z., Bankina, B. and Balodis, R., 2018, Field Bean (*Vicia faba* L.) Yield and quality depending on some agrotechnical aspects, *Agron. Res.,* **16** (1) : 212 - 220.

Praneetha, S., Srivastava, J. N., Muthuselvi, R. and Malathi, S., 2022, Important diseases of Indian bean (*Dolichos lablab* L.) and their Management. In *Diseases of Horticultural Crops*, *Apple Academic Press*, 205 - 224.

Ramesh, S. and Byregowda, M., 2016, Dolichos bean (*Lablab purpureus* L. Sweet var. Lignosus) genetics and breeding-present status and future prospects. *Mysore J. Agric. Sci.,* **50** (3) : 481 - 500.

Renuka, H. M., 2014, Studies on dolichos mosaic virus disease on field bean, (*Lablab purpureus* L. Sweet.) *M.Sc. (Agri). Thesis,* Univ. Agric. Sci., Bangalore, 32 - 36.

Shivakumar, M. S., Ramesh, S., Byregowda, M., Rao, A. M. and Gangappa, E., 2016, Genetics of quantitative traits in dolichos bean (*Lablab purpureus* L. Sweet) var. lignosus. *Mysore J. Agric. Sci.,* **50** (3) : 555 - 568.

Singh, A. K., Bharati, R. C., Manibhushan, N. C. and Pedpati, A., 2013, An assessement of faba bean (*Vicia faba* L.) current status and future prospect. *Afr. J. Agric. Res.,* **8** (55) : 6634 - 6641.

Tewari, V. P. and Ramanujam, S., 1994, Grow *Pusa Jwala*, a disease resistant high yielding chilli. *Ind. Farm.*, **24** : 20 - 21.

Udayashankar, A. C., Chandra Nayaka, S., Niranjana, S. R., Lund, O. S. and Prakash, H. S., 2011, First report of bean common mosaic virus infecting *Lablab purpureus* in India. *Plant dis.,* **95** (7) : 881 - 889.

Wheeler, B. E. J., 1969, An introduction to plant disease, *Jhon Whiley and Sons Ltd*. London, pp. : 342.

Mysore J. Agric. Sci., 57 (1) : 318-334 (2023)

Optimum Portfolio and Capital Asset Pricing Model for Equity Market

Shaik Mohammad Irfan[1], C. P. Gracy[2], M. S. Ganapathy[3], Siddayya[4], G. M. Gaddi[5] and Mahin Sharif[6]
[1,2,3&4]Institute of Agri Business Management, [5&6]Department of Agricultural Economics
College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : irfan48.ag@gmail.com

Authors Contribution

Shaik Mohammad Irfan : Conceptualization, investigation, original draft preparation & data analysis;
C. P. Gracy : Conceptualization, data curation & draft correction;
M. S. Ganapathy & Siddayya : Data curation, data analysis and draft correction;
G. M. Gaddi & Mahin Sharif : Supervision and draft correction

Corresponding Author :
Shaik Mohammad Irfan
Institute of Agri Business Management, College of Agriculture, UAS, GKVK, Bengaluru

Received : October 2022
Accepted : February 2023

Abstract

Risk and return play an important role in making any investment decision. Risk is the chance that an investment's actual return will be less than its expected return. This risk of loss is linked to the expected variability in the investment's return (Neeraj and Anurag, 2014). The study aims at making strategic decisions for the opportunity that is available for investors as per as returns are concerned and the investment of risk thereof while investing in the equity of firms listed in National Stock Exchange (NSE). Diversification of investment helps to spread risk over many securities. Portfolio construction is a widely used concept on how investors can construct investment portfolios to maximise returns and minimise risk. The study comprised of fifteen Nifty FMCG stocks along with Nifty FMCG index and Nifty Fifty index for the period January, 2011 through December, 2021. The optimum portfolio for the sample study investment is P & G Hygiene and Health Care Limited (25.02 per cent), Dabur India Limited (15.20 per cent), Marico Limited (13.72 per cent), Nifty FMCG Index (10.47 per cent), Colgate-Palmolive India Limited (9.16 per cent), ITC Limited (7.58 per cent), Hindustan Unilever Limited (6.74 per cent), Nifty Fifty Index (6.09 per cent), Nestle India Limited (3.04 per cent), Radico Khaitan Limited (2.98 per cent), which has a portfolio mean return of 1.37 per cent per month and with a portfolio beta (β_p) of 0.43 and with a portfolio Treynor ratio of −1.75, with a portfolio Sharpe ratio −22.80 and with a portfolio standard deviation (σ_p) of 3.32 and portfolio variance (σ^2_P) of 0.11. The study has captured Security Market Line (SML) and Security Characteristic Line (SCL) for portfolio allocation decisions.

Keywords : Risk, Return, Optimum portfolio, Nifty FMCG stocks, Nifty FMCG index, Nifty fifty index, Capital asset pricing model (CAPM), Security market line (SML), Security characteristic line (SCL)

Risk is a mixture of 'danger' and 'opportunity' similar to the two faces of a coin. Unexpected portion of an event *i.e.,* what actually happens may (and often does) differ from what is expected can also be termed as risk. Generally, people are extra sensitive to underperformance compared to expectations. Risk is neither good nor bad, but just a fact of life. The question that entities have to address is therefore not how to avoid risk but how best to incorporate it into the decision making (Aswath Damodaran, 2012).

Total risk associated with return can be divided into expected and un-expected portions. Actual return (R) comprises of expected portion E (R) and unexpected portion (U). The unexpected portion is constituted by systematic (M) and unsystematic (E) portions. In any given period, the unexpected portion of a return would be positive or negative; through time, the average value of unexpected portion of a return (U) would be zero.

Systematic risk is the market-wide risk which can not be eradicated, but the degree of its impact may vary across securities. Unsystematic risk is firm-specific risk which can be reduced by holding a diversified portfolio. Interest rate risk, Market risk and Purchasing power or Inflationary risk generally causes market-wide or systematic risk. Business or liquidity risk, financial or credit or default risk, operational risk in general causes firm-specific or un-systematic risk. Country risk, foreign-exchange risk, political risk, environmental risk, speculative risk and absolute risk are some of the other kinds of risk (David *et al.,* 2021).

Objectives of the Study

1. To study the association of log returns of stock prices of selected nifty stocks using correlation, variance and covariance
2. To find most optimal portfolio for allocating investment funds in different nifty stocks by considering risk-return criteria
3. To construct Security Market Line (SML) and Security Characteristic Line (SCL) for drawing investment decisions

Methodology

Sample and Data Collection

The study considers ten year monthly stock prices from January, 2011 to December, 2021 of all the fifteen Nifty FMCG stocks *i.e.,* Britannia Industries Limited, Colgate-Palmolive India Limited, Dabur India Limited, Emami Limited, Godrej Consumer Products Limited, Hindustan Unilever Limited, ITC Limited, Jubilant Foodworks Limited, Marico Limited, Nestle India Limited, P & G Hygiene and Health Care Limited, Radico Khaitan Limited, Tata Consumer Products Limited, United Breweries Limited, United Spirits Limited along with Nifty FMCG Index and Nifty Fifty Index which is considered as market index representing the market condition. Monthly log returns of the stock prices was calculated. Ninety day Treasury bill rate issued by the Reserve Bank of India (RBI) from December, 2012 to December, 2021 is collected and mean monthly Treasury bill rate is computed for considering it as a risk-free rate (*i.e.,* r_f = 2.13 per month). Microsoft Excel software was used for analysis.

Analytical Tools and Techniques Employed

Capital Asset Pricing Model (CAPM) was employed by calculating logarithmic return of the stocks. The logarithmic return is the natural log of the ratio of the current stock price to the end-of-the-period stock price.

$$\text{Logarithmic return} = \ln \left[\frac{\text{current period stock price}}{\text{previous period stock price}}\right] \times 100$$

Systematic Risk is measured by Beta (β), which is obtained by dividing co-variance of stock 'i' and market index 'm' with variance of the market index 'm'.

$$\beta_i = \frac{\sigma_{i,m}}{\sigma_m^2} \text{ (or) } \frac{\sigma_i}{\sigma_m} r_{i,m}$$

where,

β_i = beta of stock 'i'

$\sigma_{i,m}$ = co-variance of stock 'i' and the market index 'm'

σ_i = standard deviation of stock 'i'

σ_m = standard deviation of the market index 'm'

$r_{i,m}$ = correlation co-efficient between stock 'i' and market index 'm'

Variability or volatility of expected returns associated with a given investment is the measure of risk. The Capital Asset Pricing Model (CAPM) relates the risk measured by beta to the level of the expected rate of return on a security. The model, also called the Security Market Line (SML), is given as follows:

$$E(r_i) = r_f + \beta_i\,(E(r_m) - r_f)...........(1)$$

where,

$E(r_i)$ = the expected return on security 'i'

r_f = the risk-free rate

$E(r_m)$ = the expected return on the market index 'm'

β_i = beta, an index of non-diversifiable (non-controllable, systematic) risk

$\beta_i*(r_m - r_f)$ = risk premium, the additional return required to compensate investors for assuming a given level of risk.

Thus, CAPM (or SML) equation (Eq.1) shows that the expected rate of return on a given security E (r_i) is equal to the return required for securities that have no risk (r_f) plus a risk premium [β_i *(E(r_m) – r_f)] required by investors for assuming a given level of risk.

The key component in the CAPM, beta (β), is a measure of the security's volatility relative to that of a benchmark index or an average security *i.e.,* if β = 0.5, it means the security is only half as volatile, or risky, as a benchmark index or an average security. That is, beta measures the sensitivity of the stock's return to the changes in the market conditions. The higher the degree of systematic risk, the higher the return on a given security. The figure (Fig. 1) below graphically illustrates the CAPM as the Security Market Line (SML).

Security Market Line (SML)

The Security Market Line (SML) graphs the systematic (or market) risk versus the return of the whole market at a certain time and shows under priced and overpriced securities. Securities which are fairly priced plot exactly on the SML. Underpriced securities plot above the SML, whereas overpriced securities plot below the SML (Prasanna Chandra, 2017). If the security's risk versus actual return is plotted above the SML, it is undepriced because the investor can expect a greater return for the inherent risk (the suggested strategy is BUY). A security plotted below the SML is overpriced because the investor would be accepting less return for the amount of risk (the suggested strategy is SELL). The farther the returns from the y-axis, the more riskier

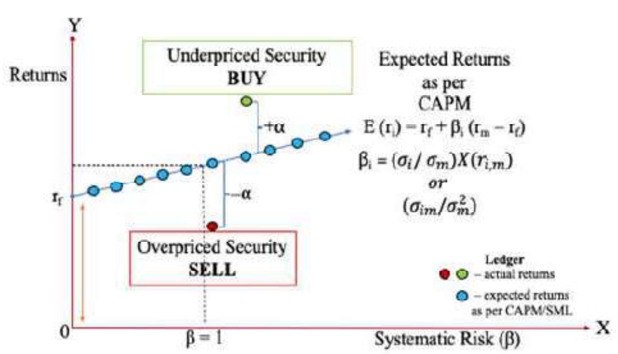


Fig.1: Security market line

the stock is. Therefore, an investor can find a disequilibrium in security price to make a profit by buying the underpriced securities and selling the overpriced securities and based on the risk appetite can choose the securities closer or farther from the y-axis.

Jensen's Alpha (α)

Jensen's Alpha (α) is calculated as the difference between the investment's actual return and its expected return (as per CAPM). Investors would prefer an investment with a high positive alpha.

- α < 0: the investment has earned too little for its risk (or, was too risky for the return),
- α = 0: the investment has earned a return adequate for the risk taken,
- α > 0: the investment has a return in excess of the reward for the assumed risk.

Security Characteristic Line (SCL)

Security Characteristic Line (SCL) is a regression line, plotting the performance of a particular security or portfolio against that of the market index at every point in time for a given period of time. The SCL is plotted on a graph where X-axis is the excess return of the market index 'm' over the risk-free return (r_f) and the Y-axis is the excess return on a security 'i' over the risk-free return (r_f).

The slope of the characteristic line represents the security's Beta (β_i) and the intercept represents its Alpha (α_i).

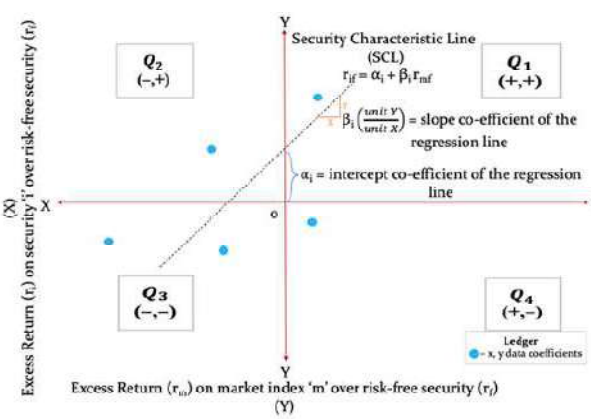


Fig. 2 : Security characteristic line

$$r_{i,f} = \alpha_i + \beta_i \, r_{m,f}$$

where,

$r_{i,f}$ = excess return on a security 'i' over risk-free security (r_f)

α_i = intercept co-efficient of the SCL's regression line

β_i = slope co-efficient of the SCL's regression line

$r_{m,f}$ = excess return (r_m) on market index 'm' over risk-free security (r_f)

Thus, SCL represents the relationship between the returns of two securities or a security and the market return, over a period of time.

Efficient Frontier Curve (EFC) and Capital Allocation Line (CAL)

EFC graphs all possible combinations of securities portfolios, with all possible weights. Every point on the graph represents highest returns for the risk level and lowest risk for a given return. In other words, given a risk profile, there is no combination of securities that performs better than the efficient frontier.

Capital Allocation Line (CAL) is a line tangent to the Efficient Frontier Curve (EFC) from the risk-free rate (r_f) (Fig.3). The efficient frontier contains all efficient risky portfolios and tangential line from the risk-free rate (r_f) meets it at a point which is the theoretical market portfolio (represented by point M). The market portfolio consists of all efficient securities which cannot be dominated. There is a level of risk for the portfolio in respect of which it gets what is termed as the market return. The market portfolio is well diversified and is the benchmark for

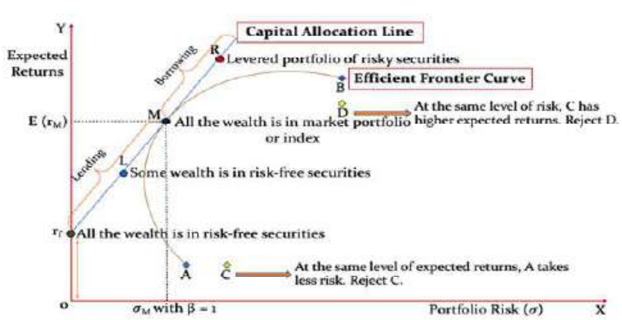


Fig. 3 : Efficient frontier curve and Capital allocation line

other securities. As per the Capital Allocation Line (CAL), an investor has the following choices:

1 – Invest fully in risk-free securities (r_f).

2 – Invest partly in risk-free securities (r_f) and partly in the market portfolio (L) – more risk averse state of investors, between these two points, investor can lend some money to government by buying treasury bills, government bonds and other money in buying risky securities.

3 – Invest fully in the market portfolio (M).

4 – Invest fully in the market portfolio and additionally borrow funds at risk-free rates and invest beyond the point 'M', (R) - less risk averse state of investors where investors borrow funds on risk-free rate for buying risky securities (R).

The return that the investor can expect then is represented as follows:

$$\mathbf{E(r_p) = r_f + \sigma_p \frac{r_m - r_f}{\sigma_m}}$$

where,

$E(r_p)$= expected return on portfolio

r_f = risk-free rate of return

r_m = rate of return on the market portfolio 'm'

σ_p = standard deviation of a portfolio

σ_m = standard deviation of market index

One of the most significant and discussed concepts in the field of modern finance is protfolio theory, which is based on the principle that investors can reduce the variability of portfolio returns by holding assests with low or negative return correlations (Eduard and Stefan, 2014). Correlation and variance-covariance matrices are often used in portfolio optimization (Imre and Andras, 2019).

Correlation measures the extent and direction (positive or negative) of the relationship between any two variables (Sowmya *et al.,* 2018 and Aravinda and Umesh, 2020). The correlation between two securities may be negative (correlation, $-1 \leq r < 0$), positive (correlation, $0 < r \leq 1$), no correlation ($r = 0$). There is a perfect positive/negative correlation, if correlation coefficient of 1 or -1 respectively. Whenever there exists a perfectly positive correlation between two

TABLE 1
Correlation coefficients between log returns of nifty stocks

Nifty Stocks	Britannia Industries Ltd	Colgate-Palmolive India Ltd	Dabur India Ltd	Emami Ltd	Godrej Consumer Products Ltd	Hindustan Unilever Ltd	ITC Ltd	Jubilant Foodworks Ltd	Marico Ltd	Nestle India Ltd	P & G Hygiene and Health Care Ltd	Radico Khaitan Ltd	Tata Consumer Products Ltd	United Breweries Ltd	United Spirits Ltd	Nifty FMCG Index	Nifty Fifty Index
Britannia Industries Ltd	1.00	0.31	0.37	0.51	0.36	0.30	0.26	0.32	0.33	0.37	0.27	0.23	0.27	0.38	0.20	0.47	0.37
Colgate-Palmolive India Ltd	0.31	1.00	0.22	0.20	0.31	0.33	0.24	0.24	0.25	0.38	0.33	0.09	0.22	0.21	0.19	0.43	0.28
Dabur India Ltd	0.37	0.22	1.00	0.26	0.33	0.43	0.28	0.39	0.21	0.44	0.14	0.16	0.21	0.37	0.24	0.51	0.37
Emami Ltd	0.51	0.20	0.26	1.00	0.32	0.10	0.31	0.31	0.37	0.22	0.23	0.22	0.34	0.41	0.32	0.40	0.49
Godrej Consumer Products Ltd	0.36	0.31	0.33	0.32	1.00	0.31	0.38	0.41	0.41	0.38	0.19	0.17	0.22	0.27	0.31	0.55	0.40
Hindustan Unilever Ltd	0.30	0.33	0.43	0.10	0.31	1.00	0.24	0.17	0.23	0.40	0.21	0.00	0.20	0.28	0.19	0.60	0.21
ITC Ltd	0.26	0.24	0.28	0.31	0.38	0.24	1.00	0.24	0.33	0.31	0.09	0.12	0.25	0.34	0.35	0.85	0.54
Jubilant Food works Ltd	0.32	0.24	0.39	0.31	0.41	0.17	0.24	1.00	0.22	0.33	0.26	0.33	0.41	0.23	0.15	0.37	0.46
Marico Ltd	0.33	0.25	0.21	0.37	0.41	0.23	0.33	0.22	1.00	0.27	0.14	0.17	0.25	0.34	0.33	0.45	0.38
Nestle India Ltd	0.37	0.38	0.44	0.22	0.38	0.40	0.31	0.33	0.27	1.00	0.27	0.20	0.37	0.24	0.27	0.53	0.33
P & G Hygiene and Health Care Ltd	0.27	0.33	0.14	0.23	0.19	0.21	0.09	0.26	0.14	0.27	1.00	0.01	0.11	0.14	0.02	0.21	0.27
Radico Khaitan Ltd	0.23	0.09	0.16	0.22	0.17	0.00	0.12	0.33	0.17	0.20	0.01	1.00	0.33	0.38	0.33	0.20	0.37
Tata Consumer Products Ltd	0.27	0.22	0.21	0.34	0.22	0.20	0.25	0.41	0.25	0.37	0.11	0.33	1.00	0.33	0.34	0.43	0.59
United Breweries Ltd	0.38	0.21	0.37	0.41	0.27	0.28	0.34	0.23	0.34	0.24	0.14	0.38	0.33	1.00	0.44	0.48	0.46
United Spirits Ltd	0.20	0.19	0.24	0.32	0.31	0.19	0.35	0.15	0.33	0.27	0.02	0.33	0.34	0.44	1.00	0.50	0.46
Nifty FMCG Index	0.47	0.43	0.51	0.40	0.55	0.60	0.85	0.37	0.45	0.53	0.21	0.20	0.43	0.48	0.50	1.00	0.62
Nifty Fifty Index	0.37	0.28	0.37	0.49	0.40	0.21	0.54	0.46	0.38	0.33	0.27	0.37	0.59	0.46	0.46	0.62	1.00

Note: Lesser the correlation co-efficient between the two stocks, greater the benefit of diversification

TABLE 2

Variance and co-variance coefficients between log returns of nifty stocks (in per cent per month)

Nifty Stocks	Britannia Industries Ltd	Colgate-Palmolive India Ltd	Dabur India Ltd	Emami Ltd	Godrej Consumer Products Ltd	Hindustan Unilever Ltd	ITC Ltd	Jubilant Foodworks Ltd	Marico Ltd	Nestle India Ltd	P & G Hygiene and Health Care Ltd	Radico Khaitan Ltd	Tata Consumer Products Ltd	United Breweries Ltd	United Spirits Ltd	Nifty FMCG Index	Nifty Fifty Index
Britannia Industries Ltd	0.51	0.13	0.14	0.35	0.18	0.13	0.11	0.25	0.13	0.15	0.10	0.19	0.18	0.25	0.17	0.14	0.13
Colgate-Palmolive India Ltd	0.13	0.32	0.07	0.11	0.13	0.11	0.08	0.15	0.08	0.12	0.10	0.06	0.11	0.11	0.13	0.10	0.08
Dabur India Ltd	0.14	0.07	0.29	0.13	0.13	0.14	0.09	0.22	0.06	0.13	0.04	0.10	0.10	0.19	0.16	0.11	0.10
Emami Ltd	0.35	0.11	0.13	0.90	0.22	0.06	0.17	0.31	0.20	0.11	0.11	0.24	0.29	0.36	0.37	0.16	0.23
Godrej Consumer Products Ltd	0.18	0.13	0.13	0.22	0.52	0.13	0.16	0.32	0.17	0.15	0.07	0.15	0.14	0.18	0.27	0.16	0.14
Hindustan Unilever Ltd	0.13	0.11	0.14	0.06	0.13	0.34	0.08	0.11	0.08	0.13	0.07	0.00	0.11	0.16	0.13	0.15	0.06
ITC Ltd	0.11	0.08	0.09	0.17	0.16	0.08	0.34	0.15	0.11	0.10	0.03	0.08	0.13	0.18	0.25	0.20	0.16
Jubilant Foodworks Ltd	0.25	0.15	0.22	0.31	0.32	0.11	0.15	1.16	0.14	0.20	0.15	0.41	0.40	0.23	0.20	0.17	0.25
Marico Ltd	0.13	0.08	0.06	0.20	0.17	0.08	0.11	0.14	0.32	0.09	0.04	0.11	0.13	0.18	0.23	0.11	0.11
Nestle India Ltd	0.15	0.12	0.13	0.11	0.15	0.13	0.10	0.20	0.09	0.31	0.08	0.13	0.18	0.12	0.18	0.12	0.09
P & G Hygiene and Health Care Ltd	0.10	0.10	0.04	0.11	0.07	0.07	0.03	0.15	0.04	0.08	0.28	0.01	0.05	0.07	0.01	0.05	0.07
Radico Khaitan Ltd	0.19	0.06	0.10	0.24	0.15	0.00	0.08	0.41	0.11	0.13	0.01	1.33	0.35	0.41	0.46	0.09	0.21
Tata Consumer Products Ltd	0.18	0.11	0.10	0.29	0.14	0.11	0.13	0.40	0.13	0.18	0.05	0.35	0.83	0.28	0.37	0.16	0.27
United Breweries Ltd	0.25	0.11	0.19	0.36	0.18	0.16	0.18	0.23	0.18	0.12	0.07	0.41	0.28	0.87	0.50	0.18	0.21
United Spirits Ltd	0.17	0.13	0.16	0.37	0.27	0.13	0.25	0.20	0.23	0.18	0.01	0.46	0.37	0.50	1.47	0.25	0.28
Nifty FMCG Index	0.14	0.10	0.11	0.16	0.16	0.15	0.20	0.17	0.11	0.12	0.05	0.09	0.16	0.18	0.25	0.17	0.13
Nifty Fifty Index	0.13	0.08	0.10	0.23	0.14	0.06	0.16	0.25	0.11	0.09	0.07	0.21	0.27	0.21	0.28	0.13	0.25

TABLE 3

Portfolio for only minimising risk of nifty stocks

(in per cent per month)

Nifty Stocks	Weights (W)	Average returns (r_i)	Beta (β_i) [σ_i/σ_m] $x[r_{i,m}]$	Individual Risk: Individual Standard Deviation (σ)	Individual Risk: Individual Variance (σ^2)	Co-efficient of Variance	Individual Treynor Ratio [$(r_i - r_f)/\beta_i$]	Individual Sharpe Ratio [$(r_i - r_f)/\sigma_i$]
Britannia Industries Ltd	0.00	2.25	0.52	7.14	0.51	317.33	0.23	1.68
Colgate-Palmolive India Ltd	9.15	0.98	0.32	5.70	0.32	581.63	–3.64	– 20.24
Dabur India Ltd	15.19	1.40	0.39	5.42	0.29	387.14	–1.86	– 13.43
Emami Ltd	0.00	1.01	0.92	9.50	0.90	940.59	–1.21	– 11.75
Godrej Consumer Products Ltd	0.00	1.57	0.57	7.21	0.52	459.23	–0.98	– 7.74
Hindustan Unilever Ltd	6.76	1.66	0.25	5.88	0.35	354.21	–1.93	–8.08
ITC Ltd	7.59	0.54	0.63	5.82	0.34	1077.77	–2.55	–27.38
Jubilant Foodworks Ltd	0.00	1.97	0.99	10.80	1.17	548.22	–0.17	–1.51
Marico Ltd	13.68	1.62	0.43	5.72	0.33	353.08	–1.18	–8.92
Nestle India Ltd	3.02	1.37	0.36	5.56	0.31	405.84	–2.13	–13.68
P & G Hygiene and Health Care Ltd	25.05	1.73	0.28	5.32	0.28	307.51	–1.40	–7.44
Radico Khaitan Ltd	2.98	1.69	0.84	11.60	1.35	686.39	–0.52	–3.77
Tata Consumer Products Ltd	0.00	1.54	1.06	9.12	0.83	592.21	–0.56	–6.52
United Breweries Ltd	0.00	0.92	0.85	9.37	0.88	1018.47	–1.43	–12.89
United Spirits Ltd	0.00	0.98	1.11	12.17	1.48	1241.84	–1.03	–9.44
Nifty FMCG Index	10.48	1.13	0.51	4.14	0.17	366.37	–1.97	–24.22
Nifty Fifty Index	6.09	0.88	1.00	5.06	0.26	575.00	–1.25	–24.78
Total Weight	100							

Note : Risk-free rate (r_f) : 2.13 per cent per month is mean monthly t-bill rate from Dec, 2012 to Dec, 2021 securities, there is no need to diversify because it does not reduce the unsystematic risk whereas a perfectly negative correlation (a correlation coefficient of -1) between securities implies that a certain combination of these securities can reduce the unsystematic risk to zero. A compounded portfolio with an overall low correlation is crucial for investors who aim to diversify in order to eliminate unsystematic risk (Logubayom and Victor, 2019). From the previous studies of (Touran, 1993 and Dmitriy *et al.,* 2015 and Hongli, 2021), the strength of correlation can be sorted in the categories of zero correlation (0.00-0.13), weak correlation (0.13-0.30), moderate correlation (0.30-0.70) and strong correlation (0.70-1.00). The lower the correlation between the selected Nifty stocks, the greater the benefit of diversification. The correlation co-efficient between the log returns of stock prices is presented in the Table 1. Among the stocks P & G Hygiene and Health Care Limited has the lowest correlation with all other stocks. Among all the pairs, Radico Khaitan Limited and Hindustan Unilever Limited has shown zero correlation reflecting their independence.

Variance and Co-variance Coefficients between Log Returns of Nifty Stocks

It is evident from Table 2 that United Spirits Limited (1.47), Radico Khaitan Limited (1.33) and Jubilant Foodworks Limited (1.16) has the highest variances whereas P & G Hygiene and Health Care Limited (0.28), Nifty Fifty Index (0.25) and Nifty FMCG Index (0.17) has the lowest variance. United Spirits Limited and Radico Khaitan Limited has the highest co-variance of 0.50 while all the other pairs had smaller covariance values.

Optimum Portfolio for Nifty Stocks

A rational investor's optimum portfolio (proportion of each security in the portfolio) is that portfolio which minimises risk, given the return (*i.e.,* minimise portfolio Standard Deviation) or maximise return, given the risk (*i.e.,* maximise portfolio Treynor Ratio). Technically, it is the tangent point of Capital Allocation Line (CAL) with Efficient Frontier Curve (EFC).

TABLE 4
Portfolio characteristics for only minimising risk of nifty stocks

(in per cent per month)

Portfolio characteristics	Values
Portfolio Mean Returns	1.37
Portfolio Risk :	
Portfolio Variance (σ_p^2)	0.11
Portfolio Standard Deviation (σ_p)	3.32
Portfolio Beta (β_p)	0.43
Portfolio Treynor Ratio $[(r_p - r_f)/\beta_p]$	–1.75
Portfolio Sharpe Ratio $[(r_p - r_f)/\sigma_p]$	–22.80

Portfolio for Only Minimising Risk (*i.e.,* Minimise Portfolio Standard Deviation) of Nifty Stocks

The portfolio of stocks for only minimising risk is presented in Table 3. If the investor's objective is only to minimise the risk, then the ideal portfolio choice is to invest 25.05 per cent on P & G Hygiene and Health Care Limited, 15.19 per cent on Dabur India Limited, 13.68 per cent on Marico Limited, 10.48 per cent on Nifty FMCG Index, 9.15 per cent on Colgate-Palmolive India Limited, 7.59 per cent on ITC Limited, 6.76 per cent on Hindustan Unilever Limited, 6.09 per cent on Nifty Fifty Index, 3.02 per cent on Nestle India Limited, 2.98 per cent on Radico Khaitan Limited.

The portfolio characteristics for only minimising risk shows a portfolio Standard Deviation (σ_p) of 3.32, which is lower than all of the individual stocks (Table 3). Portfolio Mean Return 1.37, which is same as Nestle India Limited (1.37) and higher than Colgate-Palmolive India Limited (0.98), Nifty Fifty Index (0.88) *etc*., However it is much lower than Britannia Industries Limited (2.25), Hindustan Unilever Limited (1.66), Jubilant Foodworks Limited (1.97), P & G Hygiene and Health Care Limited (1.73), Radico Khaitan Limited (1.69) *etc*.

Portfolio Beta of 0.43, which is same as Marico Limited (0.43) and higher than Colgate-Palmolive India Limited (0.32), Dabur India Limited (0.39),

TABLE 5

Portfolio for only maximising returns of nifty stocks

(in per cent per month)

Nifty Stocks	Weights (W)	Average returns (r_i)	Beta (β_i) [σ_i/σ_m] $x[r_{i,m}]$	Individual Risk: Individual Standard Deviation (σ)	Individual Risk: Individual Variance (σ^2)	Co-efficient of Variance	Individual Treynor Ratio [$(r_i - r_f)/\beta_i$]	Individual Sharpe Ratio [$(r_i - r_f)/\sigma_i$]
Britannia Industries Ltd	100	2.25	0.52	7.14	0.51	317.33	0.23	1.68
Colgate-Palmolive India Ltd	0	0.98	0.32	5.70	0.32	581.63	–3.64	–20.24
Dabur India Ltd	0	1.40	0.39	5.42	0.29	387.14	–1.86	–13.43
Emami Ltd	0	1.01	0.92	9.50	0.90	940.59	–1.21	–11.75
Godrej Consumer Products Ltd	0	1.57	0.57	7.21	0.52	459.23	–0.98	–7.74
Hindustan Unilever Ltd	0	1.66	0.25	5.88	0.35	354.21	–1.93	–8.08
ITC Ltd	0	0.54	0.63	5.82	0.34	1077.77	–2.55	–27.38
Jubilant Foodworks Ltd	0	1.97	0.99	10.80	1.17	548.22	–0.17	–1.51
Marico Ltd	0	1.62	0.43	5.72	0.33	353.08	–1.18	–8.92
Nestle India Ltd	0	1.37	0.36	5.56	0.31	405.84	–2.13	–13.68
P & G Hygiene and Health Care Ltd	0	1.73	0.28	5.32	0.28	307.51	–1.40	–7.44
Radico Khaitan Ltd	0	1.69	0.84	11.60	1.35	686.39	–0.52	–3.77
Tata Consumer Products Ltd	0	1.54	1.06	9.12	0.83	592.21	–0.56	–6.52
United Breweries Ltd	0	0.92	0.85	9.37	0.88	1018.47	–1.43	–12.89
United Spirits Ltd	0	0.98	1.11	12.17	1.48	1241.84	–1.03	–9.44
Nifty FMCG Index	0	1.13	0.51	4.14	0.17	366.37	–1.97	–24.22
Nifty Fifty Index	0	0.88	1.00	5.06	0.26	575.00	–1.25	–24.78
Total Weights	100							

Note: Risk-free rate (r_f) : 2.13 per cent per month is mean monthly t-bill rate from Dec, 2012 to Dec, 2021

Hindustan Unilever Limited (0.25), Nestle India Limited (0.36), P & G Hygiene and Health Care Limited (0.28) *etc.* and lower than Britannia Industries Limited (0.52), Emami Limited (0.92), Jubilant Foodworks Limited (0.99), Tata Consumer Products Limited (1.06), United Spirits Limited (1.11) *etc.*

Treynor ratio which reflects excess return of a security 'i' or portfolio 'p' over the risk-free security (r_f) per security's systematic risk (β_i) or portfolio's systematic risk (β_p) respectively was computed. The Portfolio Treynor ratio (–1.75) is higher than Colgate-Palmolive India Limited (–3.64), ITC Limited (–2.55), Nestle India Limited (–2.13) *etc.* and lower than Britannia Industries Limited (0.23), Jubilant Foodworks Limited (–0.17), Radico Khaitan Limited (–0.52), Tata Consumer Products Limited (–0.56), etc.

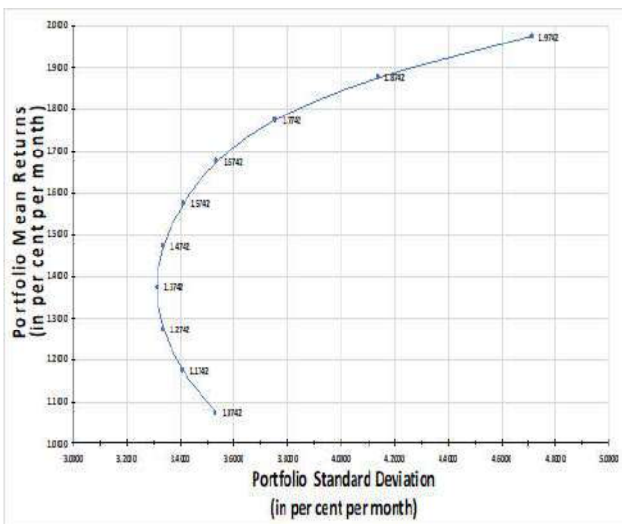


Fig. 4 : Efficient frontier curve of nifty stocks

Sharpe ratio which reflects excess return of a security 'i' or portfolio 'p' over the risk-free security (r_f) per security's total risk (σ_i) or portfolio's total risk (σ_p) respectively was computed. The portfolio Sharpe ratio (–22.80) is higher than ITC Limited (–27.38), Nifty FMCG Index (–24.22) and Nifty Fifty Index (–24.78) and lower than Colgate Palmolive India Limited (–20.24), Nestle India Limited (–13.68), Dabur India Limited (–13.43), United Breweries Limited (–12.89), Emami Limited (–11.75) *etc.*

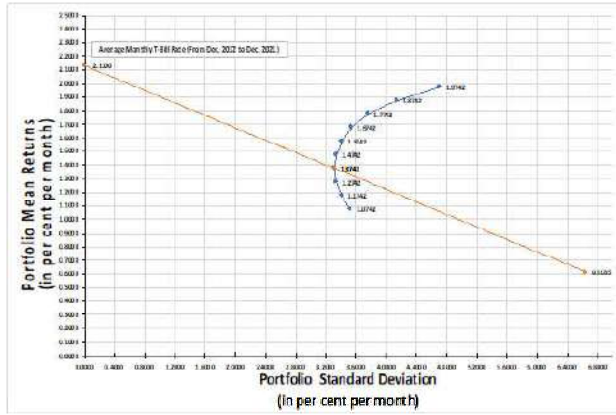


Fig. 5 : Optimum portfolio of nifty stocks

Portfolio for Only Maximising Return (*i.e.*, Maximise Portfolio Treynor Ratio) of Nifty Stocks

The portfolio of stocks for only maximising returns is provided in Table 5.

The results shows that if the objective is only to maximise the returns, invest 100 per cent on Britannia Industries Limited individual nifty stock. Results shows that portfolio characteristics are almost as same as Britannia Industries Limited individual nifty stock.

Portfolios of Nifty Stocks to Construct Efficient Frontier Curve

The optimum portfolio for estimating efficient frontier curve was computed by parametrising portfolio mean returns.

TABLE 6
Portfolio characteristics for only maximising returns of nifty stocks
(in per cent per month)

Portfolio characteristics	Values
Portfolio Mean Returns	2.25
Portfolio Risk :	
Portfolio Variance (σ^2_p)	0.51
Portfolio Standard Deviation (σ_p)	7.11
Portfolio Beta (β_p)	0.52
Portfolio Treynor Ratio $[(r_p - r_f)/\beta_p]$	0.23
Portfolio Sharpe Ratio $[(r_p - r_f)/\sigma_p]$	1.69

TABLE 7

Nifty stock weights and characteristics of different portfolios

(in per cent per month)

Nifty Stocks	1	2	3	Optimum Portfolio (4)	5	6	7	8	9	10
Britannia Industries Ltd	0.00	0.00	0.00	0.00	0.00	3.49	7.85	19.04	32.68	48.66
Colgate-Palmolive India Ltd	19.23	15.93	12.66	9.16	5.51	1.93	0.00	0.00	0.00	0.00
Dabur India Ltd	13.56	14.40	15.16	15.20	15.19	15.17	15.07	6.39	0.00	0.00
Emami Ltd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Godrej Consumer Products Ltd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hindustan Unilever Ltd	2.14	4.56	7.05	6.74	6.62	10.73	15.10	16.96	15.57	9.98
ITC Ltd	24.03	19.91	15.86	7.58	0.00	0.00	0.00	0.00	0.00	0.00
Jubilant Food works Ltd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	2.31
Marico Ltd	4.52	7.89	11.23	13.72	16.26	18.63	20.69	18.69	14.06	6.75
Nestle India Ltd	3.36	3.52	3.62	3.04	2.38	2.42	1.93	0.00	0.00	0.00
P & G Hygiene and Health Care Ltd	14.21	17.93	21.64	25.02	28.59	31.19	33.02	33.89	33.00	30.45
Radico Khaitan Ltd	0.00	1.02	2.14	2.98	3.90	4.54	4.92	5.01	4.02	1.86
Tata Consumer Products Ltd	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00
United Breweries Ltd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Spirits Ltd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nifty FMCG Index	0.00	0.00	0.00	10.47	20.55	11.90	0.69	0.00	0.00	0.00
Nifty Fifty Index	18.95	14.83	10.66	6.09	0.99	0.00	0.00	0.00	0.00	0.00
Total Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Portfolio Variance	0.12	0.12	0.11	0.11	0.11	0.12	0.13	0.14	0.17	0.22
Portfolio Standard Deviation	3.53	3.41	3.34	3.32	3.34	3.41	3.54	3.76	4.14	4.71
Portfolio Mean Returns	1.07	1.17	1.27	1.37	1.47	1.57	1.67	1.77	1.87	1.97
Portfolio Beta (β_p)	0.53	0.50	0.46	0.43	0.40	0.39	0.38	0.38	0.40	0.43
Portfolio Treynor Ratio $[(r_p - r_f)/\beta_p]$	–1.99	–1.92	–1.85	–1.75	–1.64	–1.44	–1.20	–0.93	–0.64	–0.36
Portfolio Sharpe Ratio $[(r_p - r_f)/\sigma_p]$	–29.89	–28.02	–25.64	–22.80	–19.65	–16.28	–12.88	–9.47	–6.18	–3.30

TABLE 8

Capital allocation line

(in per cent per month)

Weights (W)	Mean Return	Standard Deviation
0.00	2.1300 (t-bill)	0.0000
1.00	1.3742	3.3153
2.00	0.6185	6.6305

Efficient Frontier Curve of Nifty Stocks

The efficient frontier was obtained by plotting portfolio mean return against respective portfolio standard deviations (Fig. 4).

Capital Allocation Line (CAL)

Monthly mean return and standard deviations were derived for capital allocation line with portfolio weights of 0, 1 and 2, respectively.

Optimum Portfolio of Nifty Stocks

The capital allocation line was plotted along with the efficient frontier curve to obtain most efficient optimum portfolio (Fig. 5).

The most efficient optimum portfolio is at the tangency point of Capital Allocation Line (CAL) with Efficient Frontier Curve (EFC).

TABLE 9

Security market line for nifty stocks

(in per cent per month)

T-bill and Nifty Stocks	Beta (β_i)	Expected Return as per CAPM [$E(r_i) = r_f + \beta_i(r_m - r_f)$]	Actual Return (r_i)	Jensen's Alpha (α)
Risk-free Rate (r_f)	0	2.13	2.13	0.00
Britannia Industries Ltd	0.52	1.48	2.25	0.77
Colgate-Palmolive India Ltd	0.32	1.73	0.98	–0.75
Dabur India Ltd	0.39	1.64	1.40	–0.24
Emami Ltd	0.92	0.98	1.01	0.04
Godrej Consumer Products Ltd	0.57	1.41	1.57	0.16
Hindustan Unilever Ltd	0.25	1.82	1.66	–0.16
ITC Ltd	0.63	1.35	0.54	–0.81
Jubilant Foodworks Ltd	0.99	0.89	1.97	1.08
Marico Ltd	0.43	1.59	1.62	0.03
Nestle India Ltd	0.36	1.68	1.37	–0.31
P & G Hygiene and Health Care Ltd	0.28	1.78	1.73	–0.04
Radico Khaitan Ltd	0.84	1.08	1.69	0.61
Tata Consumer Products Ltd	1.06	0.80	1.54	0.73
United Breweries Ltd	0.85	1.07	0.92	–0.15
United Spirits Ltd	1.11	0.73	0.98	0.25
Nifty FMCG Index	0.51	1.49	1.13	–0.36
Nifty Fifty Index (r_m)	1.00	0.88	0.88	0.00

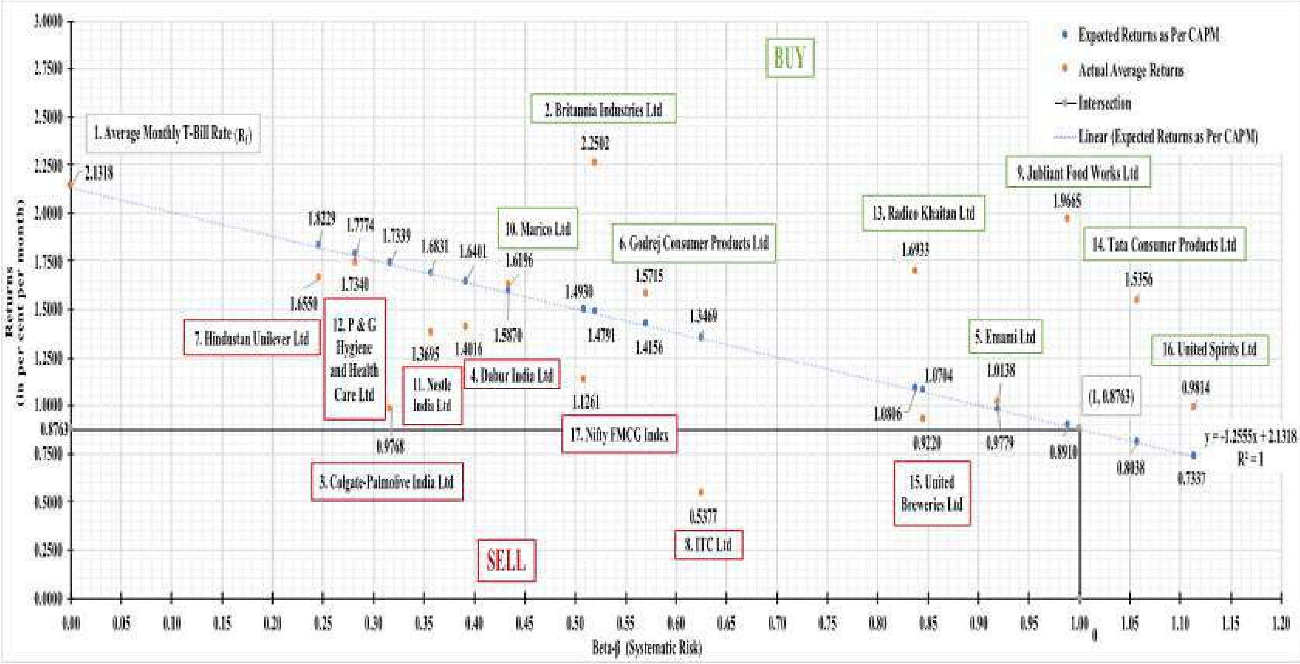


Fig. 6 : Security market line of nifty stocks

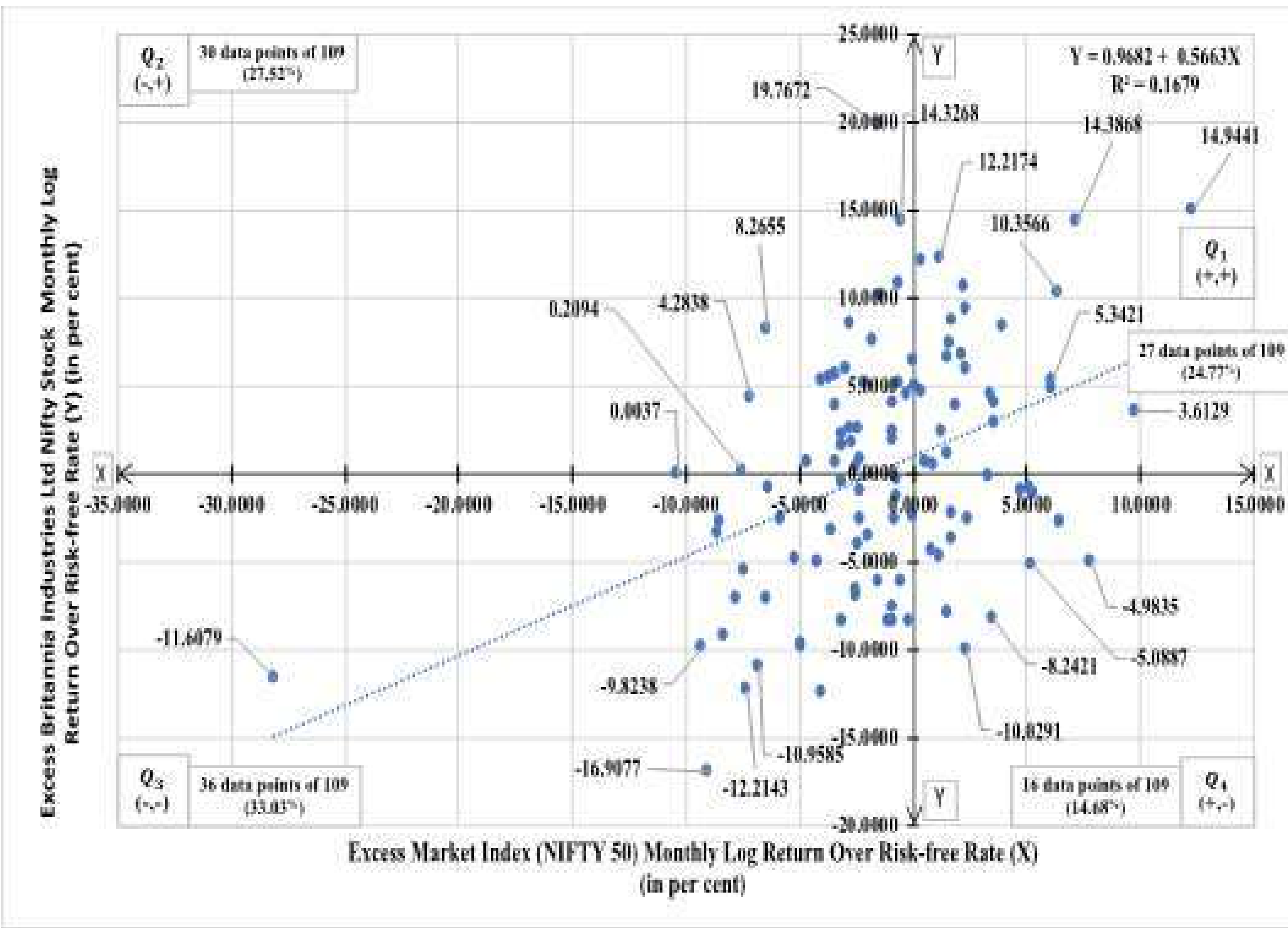


Fig.7: Security characteristic line for britannia industries limited nifty stock with nifty fifty index

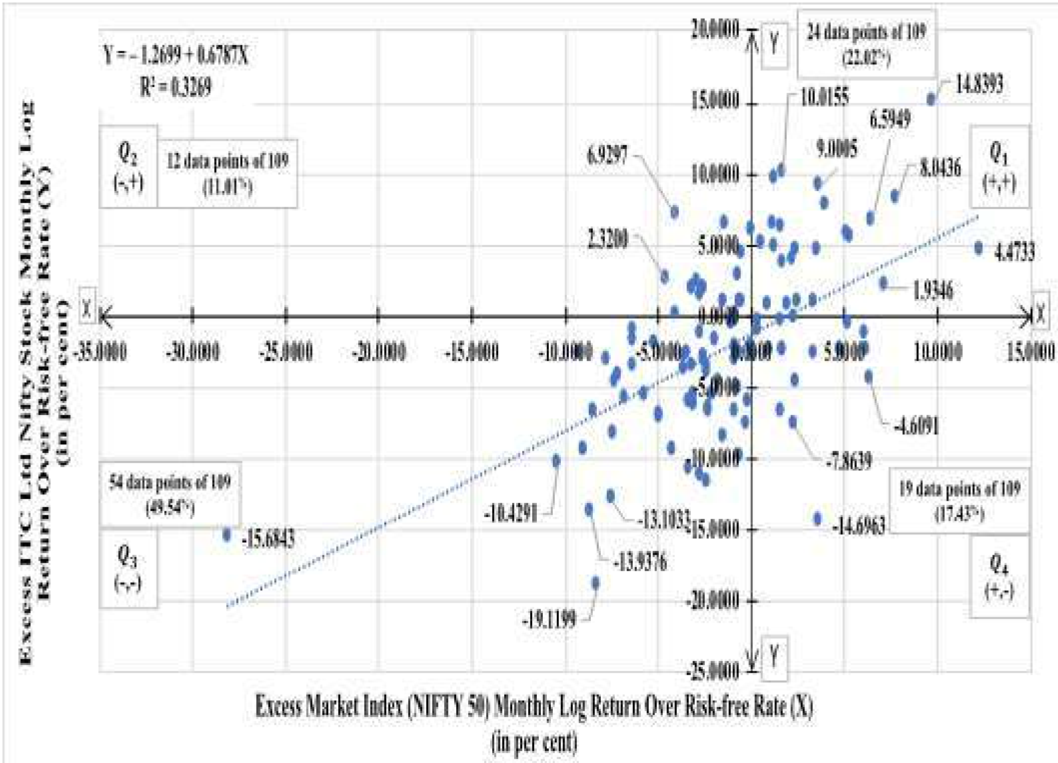


Fig. 8 : Security characteristic line for ITC limited nifty stock with nifty fifty index

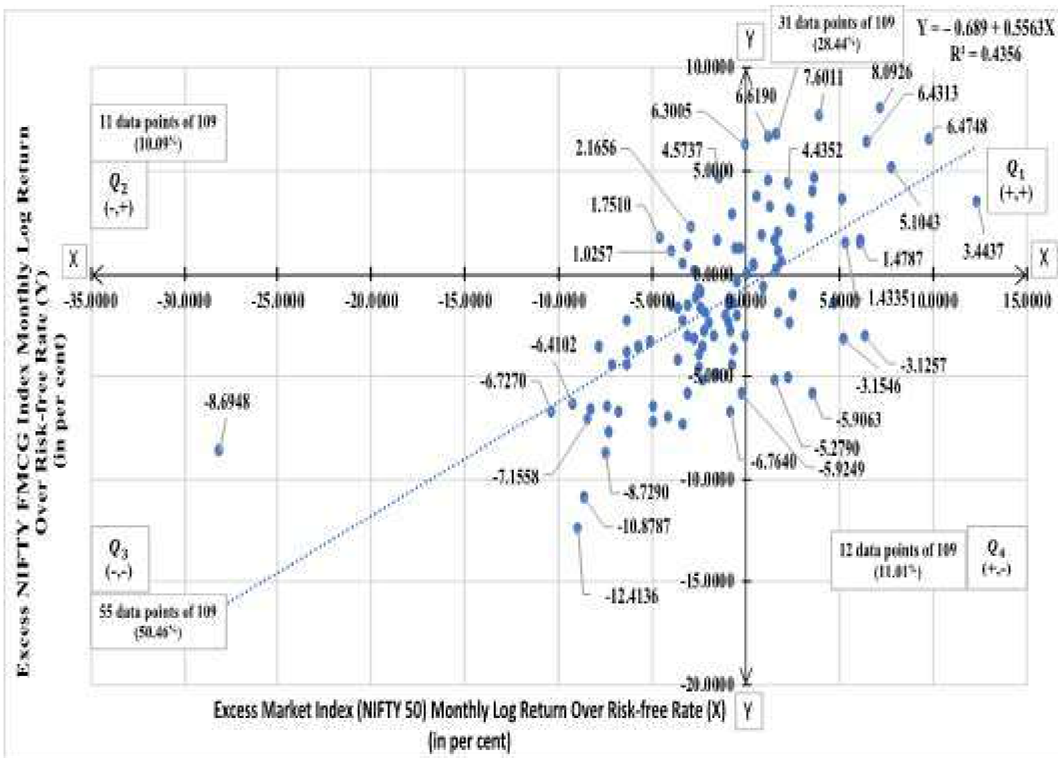


Fig. 9 : Security characteristic line for nifty FMCG index with nifty fifty index

The results shows that the optimum portfolio is to invest 25.02 per cent on P & G Hygiene and Health Care Limited, 15.20 per cent on Dabur India Limited, 13.72 per cent on Marico Limited, 10.47 per cent on Nifty FMCG Index, 9.16 per cent on Colgate-Palmolive India Limited, 7.58 per cent on ITC Limited, 6.74 per cent on Hindustan Unilever Limited, 6.09 per cent on Nifty Fifty Index, 3.04 per cent on Nestle India Limited, 2.98 per cent on Radico Khaitan Limited, which has a portfolio mean return of 1.37 per cent per month and with a portfolio Beta (β_p) of 0.43 and with a portfolio Treynor ratio of –1.75 and with a portfolio Sharpe ratio of –22.80 and with a portfolio standard deviation of 3.32 and portfolio variance of 0.11.

It may be noted here that the optimum portfolio had the portfolio characteristics similar to that of the only minimise risk portfolio (Table 4).

Security Market Line (SML) for Nifty Stocks

Security Market Line (SML) was obtained by using expected return from CAPM equation for all the Nifty FMCG Stocks by considering Nifty Fifty Index as an indicator for market conditions. The SML helps in stock investment decisions by identifying and buying underpriced or under valued stocks.

Results of the Security Market Line (SML) from Table 9 and Fig. 6, shows that Marico Limited (α = 0.03), Britannia Industries Limited (α = 0.77), Godrej Consumer Products Limited (α = 0.16), Radico Khaitan Limited (α = 0.61), Emami Limited (α = 0.04), Jubliant Foodworks Limited (α = 1.08), Tata Consumer Products Limited (α = 0.73) and United Spirits Limited (α = 0.25) are underpriced since their expected returns as per CAPM are lesser than actual returns and can be bought since the investment in these securities has a return in excess of the reward for the inherent risk. Whereas, Hindustan Unilever Limited (α = –0.16), P & G Hygiene and Health Care Limited (α = –0.04), Colgate - Palmolive India Limited (α = –0.75), Nestle India Limited (α = –0.31), Dabur India Limited (α = – 0.24), Nifty FMCG Index (α = – 0.36), ITC Limited (α = –0.81), United Breweries Limited (α = –0.15) are over priced since their expected returns as per CAPM are greater than actual returns and can be sold since the investment in these securities has earned too little for their risk. The greater the difference in Jensen's alpha (α), the greater the overvalued or undervalued, the stock is. The former stocks are more defensive (*i.e.,* less volatile) compared to the latter stocks since their Beta (β_i) values are relatively less. A similar study by Krunal *et al.,* 2017 has also categorised the FMCG stocks into defensive and aggressive ones based on the calculated Beta (β_i) values relative to CAPM Beta (β_i) values.

It can be observed from the results that it is better to buy t-bill since it gives a mean monthly return of 2.13 per cent, which is higher than mean monthly optimum portfolio for the sample (1.37) and of every individual Nifty FMCG Stocks of the sample, Nifty FMCG Index (1.13) and Nifty Fifty Index (0.88), but it is less than Britannia Industries Limited stock which has been giving a mean monthly return of 2.25 per cent.

Security Characteristic Line (SCL) for Britannia Industries Limited, ITC Limited and Nifty FMCG Index with Nifty Fifty Index

Security Characteristic Line (SCL) for Britannia Industries Limited, ITC Limited and Nifty FMCG Index with Nifty Fifty Index is presented in Fig. 7-9.

Security Characteristic Line (SCL) data points in Quadrant (Q_1) shows the returns during which both index (x-coefficient) and stock (y-coefficient) has performed well; Quadrant (Q_2) shows the returns during which Nifty Fifty Index (x-coefficient) has performed badly while the Britannia Industries Limited, ITC Limited and Nifty FMCG stocks (y-coefficient) has done well; Quadrant (Q_3) shows the returns during which both the index (x-coefficient) and stock (y-coefficient) has performed badly; Quadrant (Q_4) shows the returns during which the Nifty Fifty Index (x-coefficient) has performed well while Britannia Industries

Limited, ITC Limited and Nifty FMCG stocks (y-coefficient) has done badly (Fig. 7-9).

Every investment return comes with a risk. So, the question that entities have to address is therefore not whether to avoid risk but how best to incorpo rate it into the decision making. Diversification only reduces firm-specific risk, but not systematic (or market-level) risk.

In general, a typical investor tries to maintain a diversified portfolio. So, efficient markets reward for only systematic risk (β_p) which effects the whole market but the degree of its impact would vary across the securities.

A rational investor's optimum portfolio (proportion of each security in the portfolio) is that portfolio which minimises risk, given the return (*i.e.,* mini mise portfolio standard deviation) or maximises return, given the risk (*i.e.,* maximise portfolio Treynor ratio). Technically, it is the tangent point of Capital Allocation Line (CAL) with Efficient Frontier Curve (EFC).

For the sample with individual NIFTY FMCG stocks and NIFTY FMCG Index and NIFTY Fifty Index, optimum portfolio is at a proportional weights of 25.02 per cent on P&G Hygiene and Health Care Limited, 15.20 per cent on Dabur India Limited, 13.72 per cent on Marico Limited, 10.47 per cent on NIFTY FMCG Index, 9.16 per cent on Colgate-Palmolive India Limited, 7.58 per cent on ITC Limited, 6.74 per cent on Hindustan Unilever Limited, 6.09 per cent on NIFTY Fifty Index, 3.04 per cent on Nestle India Limited, 2.98 per cent on Radico Khaitan Limited, with a portfolio mean return of 1.37 per cent at a portfolio standard deviation of 3.32 and a portfolio beta (β_p) of 0.43 and with a portfolio Treynor ratio of –1.75 and a portfolio Sharpe ratio of –22.80.

Security Characteristic Line (SCL) helps investors track, identify and study the underlying reasons of a security's behavior relative to that of a given market index or a security at every point in time for a given period of time.

References

Aravinda, K. M. K. and Umesh, K. B., 2020, Extent and determinants of likelihood diverisification in north and south Bengaluru : an interspatial analysis. *Mysore J. of Agri. Sci.,* **54** (1) : 89 - 96.

Aswath Damodaran, 2012, Investment valuation - Tools and techniques for determining the value of any asset, third edition. *John Wiley and Sons*, Hoboken, New Jersey, pp. : 73.

David, H., Stephen, R., Randolph, W. and Bradford, J., 2021, Fundamentals of corporate finance, fourth european edition. *McGraw Hill*, London, pp. : 289.

Dmitriy, O. A., Elena, A. F. and Viktor, U. P., 2015, Fine structure of the price-demand relationship in the electricity market: multi-scale correlation analysis. *Energy Economics.,* **51** : 215 - 226.

Eduard, B. and Stefan, L., 2014, Volatility and dynamic conditional correlations of worldwide emerging and frontier markets. *Economic Modelling.,* **38** (3) : 175 - 183.

Hongli, N., 2021, Correlations between crude oil and stocks prices of renewable energy and technology companies: a multiscale time-dependent analysis. *Energy.,* **221** : 1 - 19.

https://corporatefinanceinstitute.com/resources/knowledge/finance/systematic-risk/ (Assessed on Jan, 2022).

https://rbi.org.in/Scripts/BS_NSDPDisplay.aspx?param=4 (Assessed on Jan, 2022).

https://www.investing.com/indices/cnx-fmcg (Assessed on Jan, 2022).

Imre, G. And Andras, L., 2019, Portfolio selection based on a configuration model and hierarchical clustering for asset graphs. Conference paper: Middle-European conference on applied theoretical computer sciences at Koper, Slovenia.

Krunal, K. B., Yesha B. M. and Payal, B. B., 2017, Validity of capital asset pricing model and stability of systematic risk (beta) of FMCG - A study on Indian stock market. *Journal of Management Research and Analysis*., **4** (2) : 69 - 73.

LOGUBAYOM, A. I. AND VICTOR, T. A., 2019, Portfolio optimization of some stocks on the Ghana stock exchange using the Markowitz mean-variance approach. *Journal of Financial Risk Management.,* **8** : 29 - 41.

MAYUR, S. AND URAVI, R., 2018, Comparative risk return analysis of Bombay stock market with selected banking stocks in India. *International Journal of Scientific Research in Science and Technology.,* **4** (5) : 908 - 916.

NAVYA, N., JERUSH, J. J., JOEL, C. R., AMALA, S. AND STEPHY, M. S., 2018, Assessment of capital asset pricing model in Indian stock market. *International Journal of Research and Analytical Reviews.,* **5** (4) : 993 - 100.

NEERAJ, G. AND ANURAG, S. G., 2014, A study of systematic risk with reference of selected companies. *Indian Journal of Applied Research.*, **4** (6) : 278 - 282.

PANKAJ, C., 2016, Test of CAPM: A study of India and US. *International Journal of Financial Management.,* **6** (2) : 51 - 58.

PANKAJ, C., 2016, Testing of CAPM in Indian Context. *Business Analyst.,* **37** (1) : 1 - 18.

PARASURAMAN, N. R., 2019, Financial management: A step-by-step approach, second edition. *Cengage*, India, pp. : 562 - 565 and 672 - 673.

PETRA, G. AND ELENA, G., 2013, CAPM and optimal portfolio. The VII international days of statistics and economics, Prague, September 19 - 21, pp. : 428 - 437.

PRASANNA CHANDRA., 2017, Investment analysis and portfolio management, fifth edition. *McGraw Hill*, India, pp. : 8.5.

SIMRANJEET, K. S., NEETIKA, J. AND RUCHI, K., 2018, Optimal portfolio construction: A case study of NSE. *Journal of Emerging Technologies and Innovative Research.*, **5** (8) : 512 - 521.

SOUMYA, S. D., MALLIKARJUNA, G. B., KRISHNAMURTHY, K. N. AND NAGARAJU., 2018, Character identification for tree species selection using path analysis in agro-forestry systems. *Mysore J. of Agri. Sci.,* **52** (1) : 6 - 11.

TOURAN, A., 1993, Probabilistic cost estimating with subjective correlations. *Journal of Construction Engineering and Management.,* **119** : 58 -71.

YASEER, K. M. AND SHAJI, K. P., 2018, Validity of CAPM by using portfolios: Evidence from Indian capital market. *Indian Journal of Finance and Banking.,* **2** (2) : 15 - 25.

Mysore J. Agric. Sci., 57 (1) : 335-343 (2023)

Impact of Village Adoption Programme (VAP) on Production and Income of the Beneficiary Farmers

M. Shivashankar, C. V. Sanketh, Rajegowda and N. Pallavi
ICAR-Krishi Vigyan Kendra, Kandali, Hassan - 573 217
e-Mail : shivubrunda@gmail.com

Authors Contribution

M. Shivashankar : Conceptualization and data collection;
C. V. Sanketh : Documentation and tabulation ;
Rajegowda : Planning & execution and report preparation ;
N. Pallavi : Data analysis

Corresponding Author :
M. Shivashnakar
ICAR-Krishi Vigyan Kendra, Kandali, Hassan

Received : January 2023
Accepted : March 2023

Abstract

Krishi Vigyan Kendra, Hassan made an attempt to assess the influence of technological interventions initiated through 'Village Adoption Program (VAP)'. VAP aims at boosting agricultural production, encouraging farmers to practice more scientific farming, making them to understand the technological options thereby uplifting the socio-economic status of farmers. In light of this, a study was conducted by selecting Rampura village of Hassan district under VAP for three years (2019-2022). Initially, majority of the farmers were lacking knowledge on scientific cultivation practices, improved varieties and different scientific production technologies. After KVK intervention and supply of critical inputs,farmers knowledge and adoption in advanced technologies available in agriculture improved. Farmers expressed that, KVK intervention reduced the drudgery in field operations, increased the knowledge on the animals husbandry and scientific management of crop stand by organizing various training programs, capacity development programs, demonstrations and educative extension materials. Simultaneously, their knowledge on backyard nutritional kitchen gardening increased. Conclusively, a noticeable change in farmer's awareness, farmers empowerment and capacity building through demonstrations and training programmes with respect to new technologies and utilization of the existing resources effectively were obseved. Crop diversification through improved varieties integrated with animal component resulted in obtaining maximum productivity and profitability of small and marginal farmers.

Keywords : Village adoption programme, Technological interventions, Awareness, Yield gap and impact

If the village perishes, India will perish too - Mahatma Gandhi. 'Village is defined as the settlement usually found in rural setting. It is generally larger than a hamlet and smaller than a town. Some geographers specifically defined, village as, an area which is having between 500 and 2,500 inhabitants'.

According to University Grants Commission (UGC), every University should have an extension dimension to make advantageous to the non university people. In this connection, State Agricultural University (SAUs), KVKs, ICAR institutes are adopting villages to extend the benefits to them through teaching, research and extension are the three dimensions of Agricultural University.

Village Adoption Scheme will equip and familiarize the people about the socio- economic dimensions of the rural communities, status of sustainable use of natural resources, changing perceptions and aspirations, priorities and innovative effort of the rural communities for sustainable development and inspire the community for self-help to roll out strategies, methodologies, processes to develop sustainably and create cohesive communities where every individual gets equal opportunity to realize his/her potential.

Through this process, people learn, document the ups and downs which can help them in revising strategies for better training and come up with new models of rural development for replication elsewhere by all stakeholders.

Hassan district has predominant agrarian population whose economic status mostly depends on agriculture and the population lives in its villages. Further, it was a mandatory activity of each KVK under the jurisdiction of UAS, Bangalore to adopt a village for every three years. Therefore, in order to effectuate this, KVK, Hassan district has adopted Rampura village, Channarayapatna taluk, Hassan District for three years from 2019-20 to 2021-22 with a financial support aided by the University of Agricultural Sciences, Bangalore.

The village Rampura, which was untouched by many technological interventions is situated nearly 71 Km away from the KVK. The total population of Rampura is 543 out of which 298 males and 245 females are living in 83 Houses. It is having total geographical area of 208 hectares, out of which the cultivable area is 171 ha and the cropping pattern comprising of cereals, pulses, oilseeds, coconut and Banana. Majority of the farmers were small (56.34%) and marginal (32.60%) farmers whose primary source of irrigation is through bore wells.

The farmers are mainly growing field crops *viz.,* finger millet, maize; pulses such as redgram, greengram, blackgram, field bean, chickpea. The farmers are also growing potato, banana and coconut. The village also possessed nearly 315 milching cows, 25 Buffalos, local goat, sheep and poultry birds. Transport of the agriculture produce was mainly through tractors and tata ace.

Nearly 70 per cent of the population was literates, consisting of graduates, higher, middle and primary educates. This village avails facilities like anganawadi, Govt. Higher Primary School, subsidiary ration shop and Temple. The village is also provided with one water tank which is used for drinking purpose and also provided with dairy. Hence, there is a need to study the impact of VAP on farmer's knowledge and adoption with respect to crop production to know the importance of this programme.

Methodology

An ex-post facto research design was employed for the study to assess the impact of VAP on farmer's knowledge and adoption with respect to crop production and allied enterprises in Rampura village, (2019-20 to 2021-22) of Channarayapattana of Hassan district. The data was collected from the 90 respondents who were continuously benefitted from village adoption programme during 2019-20 to 2021-22. Pre-post method of data collection was carried out. Initial data collection was done before the village adoption programme initiation as a base line survey and second data collection was carried out after the completion of village adoption programme. A personal interview method was used with the help of the constructed interview schedule. The data collected was analysed based on the mean score and frequency.

Results and Discussion

Socio-Economic Characteristics of Selected Farmers in Adopted Village

It is clear from the Table 1 that more than one third (38.89%) of the farmers were aged farmers (above 50 years) followed by 36.67 per cent of them were middle aged (between 36 to 50 years) and nearly one fourth (24.44%) of the farmers were young farmers. Generally, farmers of young and middle aged group are enthusiastic and will have inclination towards new ideas and zeal to earn more income.

It is evident from the Table 1 that 32.22 per cent of the farmers had primary school education. This may be due to the negligence of parents towards imparting education in their early ages due to their unawareness about the importance of education. Moreover, the family size of the farmer may have direct influence on education of children. More than one fourth of the farmers (31.11%) were having high school level of education, 20 per cent of the farmers were educated upto college PUC level followed by 10.00 per cent of

TABLE 1

Socio-economic profile of the selected famers in adopted village

(n=90)

Characters	No.	Per cent
Age (years)		
< 30	22	24.44
31 to 50	33	36.67
> 51	35	38.89
Education		
Degree	09	10.00
PUC	18	20.00
High school	28	31.11
Primary	29	32.22
Illiterate	06	6.67
Type of Family		
Nuclear	63	70.00
Joint	27	30.00
Size of the Family (members)		
1-3	28	31.11
4-6	49	54.44
> 7	13	14.45
Annual Income (Rs.)		
<11,000-24,999	7	7.78
25,000-75,000	51	56.67
>75,000	32	35.55

the farmers were educated upto degree level and 6.67 per cent farmers were belongs to illiterate category. Other contributing reason could be that the rural social environment in which they lived might not have encouraged parents to give formal education to their children.

Further, it is found that, nearly three fourth of the farmers (70.00%) were having nuclear family followed by joint family. Joint family system is the representative family type in rural India since centuries. This is because people in rural India believe in cooperative living and sharing the responsibilities. Agriculture, as livelihood requires large number of hands to cultivate crops. So, the above factor might have given way to the formation of joint families. With respect to family size, more than half of the respondents (54.44%) were having 4 to 6 family members followed by 31.11 per cent farmers having less than 3 members in a family and 14.45 per cent famers had more than 7 family members.

Even though the majority of the farmers perceived agriculture as their main occupation, more than half of farmer's (56.67%) annual income of the family ranges from Rs.25,000/- to 75,000/- category. Followed by 35.55 per cent and 7.78 per cent of farmers belong to more than Rs.75,000/- and Rs.11,000/- to 24,999/- annual income category, respectively. Due to the small sized and uneconomical land holdings, farmers might have less income. Moreover, prevailing drought situation in the area for the past couple of years and the higher dependency on rainfall might have been the reasons for such low income. The family income also includes the monthly income earned through different farm enterprises and the results are in concurrent with the Vivek and Sahana (2021).

Possession of Land, Livestock and House hold Materials

It is seen from the Table 2 that, more than half of the farmers (54.44%) were having a land area less than 2.5 acres followed by 21.11 per cent of farmers were having land area 2.5 acres to 5 acres. Further, 14.45 and 10.00 per cent of the farmers having 5 to 10 acres and more than 10 acres of land respectively.

More than three forth of the respondents possessed cows followed by poultry birds. Dairy enterprise (Cows and buffalos rearing) followed by backyard poultry activities found to be economical subsidiary enterprises generating constant revenue to their family income.

With respect to house hold material possessions, it was found that majority of them were having TV (95.55%) and mobile (83.33%) sets followed by Gas cylinder (78.88%), motor cycle (73.33 %) and pressure cookers (67.77%). Exactly half of the respondents having bicycle. Further, their income level was found to be correlated with their house hold material possession and as such it is impossible for them to

TABLE 2

Possession of land, livestock and house hold materials

(n=90)

Characters	No.	Per cent
Land holding		
Marginal farmers (<2.5 acre)	49	54.44
Small farmers (2.5 – 5 acre)	19	21.11
Medium farmers (5 – 10 acre)	13	14.45
Large farmers (> 10 acre)	9	10.00
*Livestock possession**		
Buffalo	12	13.33
Cow	73	81.11
Poultry	51	56.66
Sheep &Goat	21	23.33
*House hold material possession**		
Television	86	95.55
Bicycle	45	50.00
Motor cycle	66	73.33
Mobile	75	83.33
Gas	71	78.88
Pressure cooker	61	67.77
Housing condition		
Katchha (Straw) house	3	3.33
Tiled house	59	65.56
Pucca (RCC) house	28	31.11

* Multiple responses were obtained

possess much of other materials. Since majority of the farm women belongs to small land holdings, they might not have more house hold materials. Nearly two third of the respondents (65.56%) were found to have tiled houses followed by RCC houses (31.11%). This is primarily due to economic condition of the farm families which in turn determine their standard of living and the results are in line with the Kowsalya (2017).

Distribution of Respondents According to their Knowledge Level

The result presented in Table 3, shows that majority of the respondents (54.44%) in Rampura village belongs to low Knowledge level category followed by 27.78 and 17.78 per cent of the respondent farmers belongs to medium and high knowledge level categories, respectively before the village adoption programme by the KVK. Whereas, after the village adoption programme taken up by the KVK nearly two third (65.56%) of the respondents in the Rampura village belonged to high Knowledge level category followed by 25.56 and 8.88 per cent of the respondent farmers belonging to medium and low knowledge level categories, respectively. This might be due to the reason that before village adoption programme farmers were not aware about the improved varieties, technologies, breeds, mechanization, *etc.,* since village was interior, small and remained untouched by the developmental departments. So, after three years of adoption, there was increase in their knowledge about modern technologies, improved varieties, breeds and other improved aspects in health, education, agriculture and allied sectors. The results were in line with the Hema Sarat Chandra *et. al.,* (2017) and Jeyaseelan (2010).

TABLE 3

Distribution of respondents according to their knowledge level

(n=90)

Category	Before Adoption of village		After adoption of village	
	Percentage	Frequency	Percentage	Frequency
Low	49	54.44	8	8.88
Medium	25	27.78	23	25.56
High	16	17.78	59	65.56
	Mean= 62.13 SD=5.23		Mean= 79.80 SD=7.19	

Distribution of Respondents According to Their Adoption Level

The data in the Table 4 representing that exactly 60.00 per cent of the respondents in Rampura village belongs to low adoption category followed by 28.89 and 11.11 per cent of the respondents belongs to medium and high adoption category categories, respectively before the village adoption programme by the KVK.

TABLE 4
Distribution of respondents according to their adoption level (n=90)

Category	Before Adoption of village		After adoption of village	
	Percentage	Frequency	Percentage	Frequency
Low	54	60.00	16	17.78
Medium	26	28.89	31	34.44
High	10	11.11	43	47.78
	Mean= 59.08 SD=5.01		Mean= 76.51 SD=5.93	

Whereas, after the village adoption programme taken up by the KVK nearly half (47.78%) of the respondents in the Rampura village belongs to high adoption category followed by 34.44 and 17.78 per cent of the respondent belongs to medium and low adoption categories, respectively. Before village adoption programme, farmers were having less knowledge (as per the results in Table 1), that resulted in more number of the respondents belonging to the low adoption category. After the village adoption programme for three years, in the village has helped the farmers to increase their knowledge inturn it gave the confidence to the farmers about modern technologies, improved varieties, breeds and other improved aspects in health, education, agriculture and allied sectors which resulted in the more number of respondents falls to the high adoption category. The results were coincides with the Nagendra babu *et. al,* (2020) and Vijayalakshmi *et. al*. (2017). Policy incentives were found to correlate positively with adoption of decision-making. The availability of funding programs (Zhai and Williams, 2012) and government support and policies (Luthra *et al.,* 2016) were important in tackling barriers and driving adoption of technologies. Similar results were found by Montes De Oca Munguia *et al.,* 2021.

Yield Gap, Constraints Identified and Interventions Planned in Adopted Village

An effort was made to analyze the extent of yield gaps in major and important crops observing constraints and factors contributing to yield gaps. Based on the problems of identification and causes for the constraints, appropriate interventions were planned to reduce the yield gap. According to the data presented in Table 5, there was 25 per cent yield gap in tomato due to leaf curl virus, spotted wilt virus and *Helicoverpa armigera* infestations. The main reason for the yield gap could be because of poor knowledge on availability of resistant varieties. Hence suitable training programmes and demonstrations were planned and executed as a KVK intervention. Ragi was the main crop that was extensively grown by the farmers even though they were not obtaining the desired yield & income due to neck blast and drudgery in field operations for which 36 per cent yield gap was noticed. KVK intervention was to introduce improved varieties of ragi *viz*., MR-6, ML- 365 and GPU-28, to farmers for three years. Redgram was the second major crop wherein farmers rely on this crop for major income and after KVK intervention introduced new varieties (BRG-1 & BRG-2). However, a 32 percent yield gap was noticed which is due to pests and diseases attack as indicated in the Table. 3. In order to minimize the yield gap suitable capacity development programs, method demonstrations, introduction of improved varieties, demonstration of IPDM practices and educative literature were the interventions planned by KVK. However, 21 per cent of yield gap (low milk yield) noticed in dairy animals was mainly due to non-availability of suitable fodder varieties throughout the year. For which introduction of new improved varieties of fodder namely COFS- 31, CO-4, & COFS-29 were planned and implemented. Similar findings were reported by Srivastava *et. al.* (2014) and Chandan and Padaria (2022) on improved fodder scrops *viz*., CO-3 & CO-4 to 1509 farmers resulting in 6.6 per cent increase in milk yield. Similarly, constraints responsible for the yield gap that exists in sericulture and livestock enterprises were also identified and suitable interventions were planned and instigated.

TABLE 5

Yield gap, constraints identified and interventions planned in adopted village

Crop / Enterprise	Problem / Constraints	Causes	Yield gap (%)	Interventions Planned
Tomato	Severity of spotted wilt virus, leaf curl virus &*Helicoverpa*	Lack of knowledge about resistant varieties and climatic conditions	25	Training & Demonstrations
Ragi	Neck blast and drudgery in field operations	Non- availability of resistant varieties and climatic conditions and lack of improved tools & equipment's	36	Introduction of improved varieties, and demonstrations
Red gram	Fusarium wilt, *Helicoverpa* and *Maruca*	Predominance of wilt in the region, Poor management practices against *Helicoverpa*and *Maruca*	32	Introduction of new and improved varieties
Banana	Panama wilt and Pseudostem weevil	Poor management practices against Pseudostem weevil	23	Front line demonstration
Mango	Leaf hoppers, Powdery Mildew, Fruit Fly and intercultivation operations	Improper application of chemicals	09	Demonstrationof IPDM practices and extension literatures to create awareness
Dairy	Low milk yield	Non availability of improved fodder crops& poor nutrition	21	Introduction of new and improved high-yielding fodder varieties
Sericulture	Drudgery & Low yield	Non adoption of mechanization Low yield due to diseases	13	Method Demonstrations and Frontline demonstrations
Livestock	Low productivity in livestock keeping	Chicks suited for backyard poultry are not readily available Due to poor nutrition during rearing, fail to put on weight Non-availability of improved new breeds in sheep and goat	18	Introduction of improved breeds

Extension Activities Conducted to Create Awareness and Up-Scale the Technologies in Adopted Village

Situation analysis for extension activities was conducted to create awareness and upscale the technologies in the adopted village. The results revealed that a great majority of the stakeholders were lacking knowledge about improved varieties, IPDM practices and production technologies. In order to uplift their, socio-economic status and to create awareness on different practices followed in crop improvement programs. Later, KVK, Hassan has come up with new initiatives, to begin with and to understand the mindset of stakeholders, conducted group discussions to create awareness and the importance of Agriculture, involving 86 farmers during the year 2019-2020 and encouragingly the stakeholder participation number increased to 162 in the year 2021-2022, cumulative details are presented in the Table 6. Similarly, KVK conducted four capacity-building training programs involving 343 stakeholders in last three years. The main focus of agricultural research and extension was technology generation and dissemination. The number of technologies developed and introduced into the supply chain is important. At best, impact is assessed by the total numbers of adopters and increase in yield and income (Laura German *et al*., 2006 and Desai *et al.* 2014), obtained by the farmers. Method of demonstration on soil sampling technique and a series of lectures on the importance of soil sampling had increased the interests of farmers thereby increasing the participation (103) and programs (02). Comparably, majority of the farmers had marginal and small land holdings, had led them to practice animal husbandry (Dairy) as a profitable subsidiary occupation. Hence, along with the main involvements, animal health camps were organized involving the veterinary department and around 407 animal health checkup was carried out as an KVK intervention. Apart from this, exposure visits were also organized to advance stakeholders knowledge on integrated farming system and other important agricultural components which in turn promoted self-help groups to generate their own income and employment opportunities. Additionally, efforts were made to enhance various stakeholder enterprises *viz.*, by investing in different critical inputs that would gain additional income to farmers through increase in productivity. Due to all the above activities conducted under the adopted village programme, the knowledge and adoption of the farmers in the adopted village increased significantly.

TABLE 6

Extension activities conducted to create awareness and up-scale the technologies in adopted village

Activity	2019-20		2020-21		2021-22		Total	
	No of Programs	No. of farmers	No of Programs	No. of farmers	No of Programs	No. of farmers	No of Programs	No. of farmers
Group Discussions	107	07	122	06	178	11	407	24
Capacity Building (Training programs / Demonstrations)	212	31	285	33	312	41	809	105
Soil Sampling Demo	62	01	74	01	103	02	239	04
Animal Health Camps	86 (Animals)	01	95 (Animals)	01	162 (Animals)	02	343 (Animals)	04
Exposure visits	49	01	82	02	53	01	184	04
Follow-up visits	203	31	216	39	317	41	736	111
Total	719	72	874	82	1125	98	2718	252

Impact of Village Adoption Activities on Crop Production and Income Generation

In order to know the impact of the village adoption programme area under improved varieties, yield and income generation parameters were taken into consideration during data collection and analysis.

It is evident from the Table 7 that before the village adoption porgramme, the farmers were growing old finger millet varieties like Indaf-7 and GPU-28 in an area of 62.50 ha with the average yield of 20.50 q/ha, whereas after the VAP Programme, farmers are now cultivating improved finger millet varieties like ML-365, KMR-301 and KMR-630 in an area of 84.00 ha with the enhanced yield of 23.75 q/ha and With the total cash inflow of Rs.39,90,000/- to the village after the VAP as compared to Rs.25,62,500/- before VAP.

In the same pattern, before the VAP, farmers were growing old varieties of Redgram (BRG-1), fodder (Co-1), local varieties in Horse gram, Field bean, Cowpea, Niger and castor. Also farmers were practicing monoculture fish and local bird's cultivation before the VAP, this resulted in lesser area coverage, lesser yield and less total cash inflow to the village. Whereas, after the VAP, the KVK has introduced the improved varieties like BRG-2 & BRG-4 in Redgram, PHG-9 in Horse gram, HA-4 in Field bean, KBC-9 in Cowpea, KBN-1 in Niger and ICH-66 in castor, composite fish cultivation (Rohu, Catla and Common carp in the ratio 4:1:1), improved fodder variety COFS-31 and Giriraja breed in poultry. This has resulted in increased area coverage in all crops, increased yield to an average of 31.90 per cent as a whole and increased total cash inflow of Rs.85,05,851/- as compared to before VAP (Rs.52,88,368/-) to the village. The results are on par with the Manjunath *et. al.* (2019) and Sadvi *et. al.* (2020).

Village adoption is one of the most effective ways of showcasing the benefit of advanced technologies through effective transfer of technology within the stipulated period of adoption. It is a key to demonstrate the benefits of agro - ecological technologies as a model for adoption for upliftment of rural economy. In this regard, ICAR-KVK, Hassan has adopted Rampura village of Channarayapatna taluk.

Crop demonstration, input distribution, technology assessment, integrated rural development programmes, transfer of technology through meetings,

TABLE 7

Impact of village adoption activities on crop production and income generation

(n=90)

Crops	Area (ha)		Yield (Q/ha)		Total Production (Q)		Total income (Rs.)	
	Before	After	Before	After	Before	After	Before	After
Finger Millet	62.50	84.00	20.50	23.75	1281.25	1995.00	2562500	3990000
Redgram	07.00	08.50	11.25	14.30	78.75	121.55	393750	607750
Horse gram	09.50	12.80	06.50	08.75	61.75	112.00	216125	392000
Field Bean	08.00	10.40	06.80	08.20	54.40	85.28	228480	358176
Cowpea	10.20	12.90	07.25	09.20	73.95	118.68	295800	474720
Niger	01.50	02.00	03.20	04.25	04.80	08.50	38400	68000
Castor	01.75	02.25	08.75	10.50	15.31	23.62	88812.5	137025
Fodder crops	03.75	04.50	128.20 ton	148.30 ton	480.75	667.35	1346100	1868580
Fish	02.00	07.50	07.40	10.16	14.80	76.20	118400	609600
Poultry Birds	85.00	255.00	01.70 kg/bird	03.20 kg/bird	144.50	816.00	50575	97920
Total cash inflow							5288368	8505851

Integrated farming system, integrated pest and disease management, capacity building programmes, health campaign, seed production programmes, method demonstration, integrated nutrient management and diagnostic field visits were undertaken to fulfil the objectives of village adoption. This led to farmer's upliftment due to increase in awareness on crop productivity and income which ultimately resulted in the improvement of their socio-economic status. Such efforts need to be scaled up to bring up more villages under the ambit of improved farm technologies. With the concerted efforts of farmers, scientists of KrishiVigyan Kendra and line department's, Rampura village has become a model village in terms of adoption of new technology, knowledge on improved practices, processing, marketing and better income generation by the farmers.

References

Chandan, G. H. and Padaria, R. N., 2022, Adoption decision making behavior of farmers about contingency plans in Datia and Parbhani districts. *Mysore J. Agric. Sci.,* **56** (4) : 142 - 147.

Desai, B. K., Rao Satyanarayana, Biradar, S. A., Prahlad, U., Shashikumar, M., Santhosh and Jagannath, U. N., 2013, Development of profitable integrated farming systems for small and marginal farmers of Hyderabad Karnataka region under irrigated condition. *Int. J. Agri. Envi. & Biotech.,* **6** (4) : 617 - 622.

Hema Sarat Chandra N., Vishwatej Rudroju and Mishra, O. P., 2017, Model villages and village adoption approaches in the developmental arena of rural India: view and review. *Int. J. Pure App. Biosci.,* **5** (6) : 551 - 557.

Jeyaseelan, P., 2010, Awareness and utilization levels of farmers on various facilities and activities offered under a village adoption programme. *Int. Res. J. Manag. Sci.&Tec.,* **1** (1) : 96 - 103.

Kowsalya, K. S., 2017, Impact of Integrated Farming System Demonstration (IFSD) programme on livelihood and nutritional security of farmers of Mandya district. *Ph.D. thesis, Univ. Agri. Sci.,* Bangalore.

Laura German, Jeremias Mowo and Margaret Kingamkono, 2006, A methodology for tracking the fate of technological interventions in agriculture. *Agriculture and human values*, **23** : 353 - 369.

Luthra, S., Mangla, S. K., Xu, L. and Diabat, A., 2016, Using AHP to evaluate barriers in adopting sustainable consumption and production initiatives in a supply chain, *Int. J. Prod. Econ,* **181** : 342 - 349.

Manjunatha, A. V., Parmod Kumar and D. T., Preethika, 2019, Impact of National Food Security Mission on Input Use, Yield and Income. *Ind. J. Agri. Econ.,* **74** (4) : 562 - 575.

Montes De Oca Munguia, O., Pannell, D. J. and Llewellyn, R., 2021, Understanding the adoption of innovations in agriculture: A review of selected conceptual models. *Agronomy,* **11** (1) : 139.

Nagendra Babu, N., G., Sivanarayana, T., Gopikrishna and K., Umadevi, 2020, Impact of village adoption programme (VAP) on farmer's knowledge and adoption with respect to crop production. *Green farming,* **11** (2-3) : 217 - 220.

Sadvi, P., Rajini Devi, D. A. and Uma Reddy, R., 2020, A case study on village adopted by RARS, Polasa, Jagtial. *Agri. Update,* **15** (1&2) : 28 - 30.

Srivastava, A. P., Manisha N. Ashar and Ashok, V. Minj, 2014, Livelihood improvement through integrated farming system. *Indian farming*, **64** (2) : 32 - 35.

Vijaya Lakshmi, D., Vijay Kumar, P. and C. Padma Veni, 2017, Impact of cluster frontline demonstrations to transfer of technologies in pulse production under NFSM. *Bull. Env. Pharmacol. Life Sci.,* **6** (1) : 418 - 421.

Vivek, M. C. and S., Sahana, 2021, Socio-economic characteristics of the farmers following E-tendering system of Arecanut in Karnataka. *Ind. Res. J. Extn. Edu.,* **21** (2&3) : 117 - 125.

Zhai, P. and Williams, E. D., 2012, Analyzing consumer acceptance of photovoltaics (PV) using fuzzy logic model. *Renew. Energy,* **41** : 350 - 357.

Mysore J. Agric. Sci., 57 (1) : 344-350 (2023)

Genetic Variability Studies in Potato (*Solanum tuberosum* L.) Genotypes for Growth, Yield and Processing Quality Traits

SOUMYA SHETTY[1], B. T. KRISHNAPRASAD[2], H. AMARANANJUNDESWARA[3] AND S. SHYAMALAMMA[4]
[1&4]Department of Plant Biotechnology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
[2]Department of Agriculture Biotechnology, College of Agriculture, Hassan
[3]Horticulture Research and Extension Centre, Hassan
e-Mail : soumyashettyuas@gmail.com

AUTHORS CONTRIBUTION

SOUMYA SHETTY : Research work, draft preparation, writing and analysis;
B. T. KRISHNAPRASAD : Supervision, conceptualisation, methodology and editing ;
H. AMARANANJUNDESWARA : Field supervision and resources;
S. SHYAMALAMMA : Methodology and supervision

Corresponding Author :
SOUMYA SHETTY
Department of Plant Biotechnology,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : September 2022
Accepted : February 2023

ABSTRACT

The study was conducted to assess the extent and nature of genetic variability, heritability and genetic advance among the different thirty five potato genotypes for growth, yield and processing quality attributes over two seasons during *kharif* and *rabi*-2021. Results of analysis of variance revealed significant differences among the potato genotypes for different parameters. For all the characteristics evaluated, phenotypic coefficients of variation were higher than genotypic coefficients of variation. The phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) were found high for weight of tubers per plant (g), tuber shape, number of branches and marketable tuber yield. Range of variability for most of the traits was found high, which indicated ample scope for selection and improvement in these traits. Further, high heritability estimates coupled with genetic advance were recorded for parameters such as plant width, plant height, weight of tubers per plant and marketable tuber yield which revealed the presence of additive gene action in expression for these characters. Thus variability, heritability and genetic advance in combination provide a clear picture regarding the effectiveness of selection for improving the characters. Hence, this information in identified genotypes and traits could be used for future potato breeding programs.

Keywords : Potato, Phenotypic coefficients of variation (PCV), Genotypic coefficients of variation (GCV), Heritability, Genetic advance

POTATO (*Solanum tuberosum* L.) is the fourth most important crop in the world after wheat, maize and rice and its contribution towards securing the food, nutrition, avoiding the poverty and hunger, especially in developing world, where food is perpetually on demand to feed the increasing populations. Potatoes are considered as a non-fattening, nutritious and wholesome food, which supply important nutrients to the human diet. Potato protein is superior to that of cereals and rich in essential amino acid lysine and vitamin C (Chethan, *et. al.,* 2020). It can supplement the food needs of the country in a substantial way. Besides its significance to human food security, potato is also a crop with fascinating genetic traits and cultural history. The potato genome contains 12 chromosomes and 860 million base pairs, making it a medium-sized plant genome The present day cultivated potatoes (tetraploid; 2n=4x=48) in most of the world represent *Solanum tuberosum* subsp. *tuberosum* and *S. tuberosum* subsp. *andigena*.

In India, about 68 per cent of tubers are utilized for table purpose, 7.5 per cent for processing; 8.5 per cent for seed and remaining 16 per cent produce go as waste due to pre and post-harvest handling. Moreover, cold stores can accommodate only about 65 per cent of produce, which leads to huge wastage of potatoes.

The crop is mainly grown during winters in Indo-Gangestic plains and accounts to nearly 90 per cent production of the country. The major potato producing states are Uttar Pradesh, West Bengal, Bihar, Gujarat, Punjab, Madhya Pradesh, Assam and Haryana. There is a great scope for cultivation of potato suitable for processing and it has opened a new dimension for development of agro-based industries in the country. However, certain morphological, bio-chemical and physico-chemical attributes are necessary in potato varieties to meet the requirement for processing.

Breeding of potato is a cumbersome task due to inherent genetic and biological factors. However, the genetic advance helps to assess the extent of advancement that could be made through selection (Annigeri *et al*., 2022). Genetic variability estimates in conjunction with heritability and genetic advance gives a clear idea of scope of improvement through selection. Genetic analysis reveals the genetic nature of the inheritance of tuber yield and yield components which is required to design effective potato crop improvement. Therefore, the study was conducted with the objective to assess the extent and nature of genetic variability, heritability and genetic advance among the different potato genotypes for growth, yield and quality traits.

Material and Methods

Field experiment was conducted to evaluate different thirty five potato genotypes suitable for processing quality traits with economic yield for two seasons during both *kharif*-2021 and *rabi*-2021 at Horticulture Research and Extension Centre, Hassan, Karnataka (Plate 1). An experiment was laid out in Randomized Complete Block Design with two replications. Thirty five genotypes *viz*., AICRP- P-60, AICRP- P-61, AICRP- P-57, AICRP- P-74, AICRP-P-77, AICRP- C-1, AICRP- C-8, AICRP- C-10, AICRP- PH-3, AICRP- C-11, AICRP-C-23, AICRP-P-24, AICRP-P-43, AICRP-P-79, AICRP-P-53, AICRP-P-56, AICRP-C-29, AICRP-RH-2, AICRP-P-72, AICRP-C-13, AICRP-C-20(check), AICRP-C-24 (check), AICRP-C-17, AICRP-P-73, AICRP-P-81, AICRP-P-14, AICRP-P-1, CYT-1, CYT-2, Patna-1, Patna-2, FC-1, FC-3, FC-5 and FL were evaluated in the study. The land was prepared for the research well before planting by deep summer ploughing and incorporating FYM @ 25 t/ha into the soil followed by rotovator to break the soil clods. The tuber planting was taken up during both seasons by adopting scientific spacing of 60 cm x 20cm with 3 m X 3 m plot size. The recommended dosage of NPK @ 75:75:100 kg/ha was incorporated. From the recommended quantity of nitrogen, 50 per cent of nitrogen applied at the time of planting and remaining 50 per cent of nitrogen after 30 days after planting at earthing-up operation. The recommended package of practices was followed during different stages of crop growth to till harvesting. The observations related to vegetative growth, yield and quality attributes were recorded as follows.

Vegetative Growth Parameters

Germination (%), plant height (cm), number of leaves, number of branches per plant and the plant spread in North to South and East to West were

Plate 1: Field view and plot view of experiment conducted during *kharif* 2021

recorded. The number of days taken from the date of sowing to till harvest of each variety was counted and was considered as time taken for physiological maturity.

Yield Parameters

The number of tubers per plant and weight of tubers per plant were documented. Out of total tubers obtained in a plant, the tubers were sorted out into marketable tuber yield (>25 g) and unmarketable tuber yield (0-25 g). Total tuber yield was computed by adding marketable tuber yield and unmarketable tuber yield.

Processing Quality Traits

Shape and Size of the Tuber

Size of the tuber length and width were noted (Plate 2). The tuber sample was scored for shape as per the scale by Wooster and Farooq, 1995.

Plate 2 : Evaluation for tuber quality traits

Dry Matter Content (%)

The dry matter content was determined by hot air oven method.

Tuber Firmness (kg/cm^2)

The firmness of the tubers was determined by using digital penetrometer

Reducing Sugars (%)

Sugars present in the samples were estimated by following the method outlined by Lane and Eynon described by Ranganna (1977)

Extraction and Determination of Starch Content

The residue after extraction for sugar was washed several times with distilled water to ensure that there was no more soluble sugar in the residue. After that, following the procedure of Kang *et al*. (2009) starch content was estimated (Plate 3).

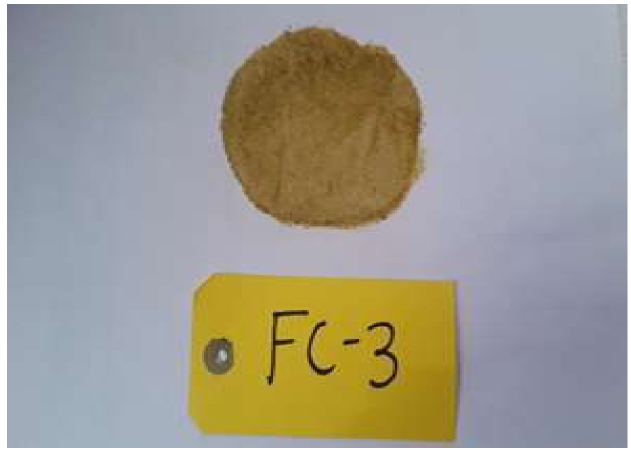


Plate 3 : Extraction of Starch

Statistical Analysis

Analysis of variance, the genotypic (GCV) and phenotypic (PCV) coefficient of variations, heritability and genetic advance (GA) and genetic advance mean (GAM) were computed using SAS software.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) showed highly significant differences among the genotypes for growth, yield and tuber quality parameters evaluated (Table 1). High variability among the various traits was observed in the genetic variability study. The estimates of PCV for all the characteristics was greater than the estimates of GCV (Table 2). The highest estimates of coefficients of variations was recorded for weight of tubers per plant (g) (GCV=42.38%; PCV=42.65%), followed by tuber shape (GCV=38.74%; PCV=39.74%), number of branches (GCV=25.17%; PCV=34.16%), marketable tuber yield (GCV=24.84%; PCV=27.42%) and total tuber yield (GCV=19.79%; PCV=22.96%). Lowest estimates of coefficients of variations were observed for reducing sugars (per cent), plant emergence (per cent) and maturity parameters.

TABLE 1

Analysis of variance for growth, yield and quality traits in potato genotypes

Characters	Mean sum of squares		
	Replication (df=3)	Genotypes (df=34)	Error (df=102)
Plant Emergence (%)	151.69	96.63 **	10.60
Plant height (cm)	31.91	491.90 **	7.12
Plant width EW (cm)	84.27	451.62 **	4.32
Plant width NS (cm)	28.86	450.98 **	5.20
No. of branches	0.54	1.46 **	0.25
No. of leaves	2.71	170.29 **	4.25
Maturity (No. of days)	14.00	284.91 **	22.05
No. of tubers per plant	0.48	9.71 **	2.75
Weight of tubers per plant (g)	149.48	37234.08 **	118.72
Total yield (t/ha)	15.39	45.13 **	3.62
Marketable yield (t/ha)	5.04	52.95 **	2.74
Tuber length	0.26	4.83 **	0.43
Tuber width	0.36	1.44 **	0.11
Tuber shape (1-9 scale)	0.26	9.66 **	0.12
Tuber firmness (kg/cm^2)	5.88	114.21 **	2.03
Dry matter (%)	0.62	20.72 **	1.62
Reducing sugar (%)	6.65	6.81	6.73
Starch (g)	1.25	182.39 **	0.34

*Significant at 5% level; **Significant at 1% level

The observed higher estimates of phenotypic and genotypic coefficients of variation for above characters, indicates the existence of adequate variability among the different potato genotypes for these traits. However, presence of narrow difference between phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) in some of the traits indicated lower environmental influence (Mariyappan *et al.,* 2022). Thus, simple selection could be helpful for bringing further improvement. Similar results were recorded for number of tubers per plant (Sattar *et al.,* 2007) marketable yield (Gunjan, 2008), total tuber yield and weight of tubers (Asefa *et al.,* 2016) in potato genotypes.

Heritability

The estimates of heritability (broad sense) varied for various parameters (Table 3). The maximum heritability for weight of tubers per plant (98.74 %) followed by plant width EW (96.28%), Plant width NS (95.54%), tuber shape (95.03%), plant height (94.45%) tuber firmness (93.24%) and marketable tuber yield (82.06%). Moderate heritability was observed for number of branches (54.30%) followed by number of tubers per plant (38.80%) parameters, while, low estimates of heritability was present for reducing sugars (9.10%). The observed high heritability values are in consonance with the earlier workers for the characters *viz.,* for tuber yield, plant height and weight of tubers per plant (Luthra *et al.,* 2001).

Genetic Advance (GA) and Genetic Advance Mean (GAM)

The highest genetic advance was recorded for plant height (22.04), plant width EW (21.37), plant width NS (21.26) and weight of tubers per plant (19.70). Marketable tuber yield recorded (6.61) and total tuber yield (5.71) GA values. The lowest genetic advance value was observed for number of branches (0.83).

TABLE 2

Mean, coefficient of variation, for various characters of potato genotypes

Characters	Mean	Range		Variance		Coefficient of Variation	
		Min	Max	GV	PV	GCV	PCV
A1	83.79	67.80	96.00	21.51	32.11	5.53	6.76
A2	71.58	40.00	94.00	121.19	128.31	15.38	15.82
A3	52.72	35.00	79.00	111.82	116.15	20.06	20.44
A4	50.70	28.20	77.00	111.44	116.65	20.82	21.30
A5	2.18	1.00	3.75	0.30	0.56	25.17	34.16
A6	39.96	24.00	55.00	41.51	45.76	16.12	16.93
A7	92.03	72.00	120.00	65.71	87.76	8.81	10.18
A8	7.40	2.00	12.00	1.74	4.49	17.83	28.62
A9	227.27	65.00	388.00	9278.84	9397.56	42.38	42.65
A10	16.28	7.30	25.00	10.38	14.00	19.79	22.99
A11	14.26	5.00	22.00	12.55	15.30	24.85	27.43
A12	6.35	3.90	11.00	1.10	1.53	16.52	19.47
A13	4.89	3.00	6.30	0.33	0.44	11.75	13.63
A14	3.99	1.00	8.00	2.38	2.51	38.74	39.74
A15	48.10	36.00	63.80	28.05	30.08	11.01	11.40
A16	20.63	16.00	27.00	4.77	6.40	10.59	12.26
A17	0.50	0.17	31.00	0.02	6.75	3.54	4.56
A18	17.20	58.00	82.50	45.51	45.85	9.45	9.48

Note: A1- Plant Emergence (%), A2- Plant height (cm), A3- Plant width EW (cm), A4- Plant width NS (cm), A5-No. of branches, A5-No. of branches , A6-No. of leaves, A7-Maturity (No. of days) A8- No. of tubers per plant,A9- Weight of tubers per plant (g), A10-Total yield (t/ha), A11-Marketable yield (t/ha) A12-Tuber length, A13-Tuber width, A14- Tuber shape (1-9 scale) A15-Tuber firmness (kg/cm^2), A16-Dry matter (%), A17- Reducing sugar (%) and A18- Starch (%)

These observed results on high genetic advance are in line with previous researchers for the characters like plant height (Sidhu and Pandita, 1979), tuber weight per plant (Ambrish, 2007) and weight of tubers per plant and leaf area (Rahman, 2015) in potato.

Maximum genetic advance mean was observed for plant height (30.86), plant width EW (29.93), plant Width NS (29.76) weight of tubers per plant (27.60) and maturity (20.23). However, moderate GAM values were recorded for marketable tuber yield (19.26), total tuber yield (18.00) and number of leaves (17.70). Lowest GAM mean value was documented for number of branches (1.17). These results are in line with works of Luthra *et al*. (2001) for height of the plant, number of leaves average tuber weight and total tuber yield.

Over all, high heritability estimates coupled with genetic advance were registered for the characters like plant width EW, plant width NS, plant height, weight of tubers per plant and marketable tuber yield per hectare. It reveals the presence of additive action in the expression of these traits which are found more crucial for potential selection.

It can be concluded from the results of the present study that the phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) were high for weight of tubers per plant, tuber shape, number of branches, marketable tuber yield and total tuber yield. Further, high heritability estimates coupled with genetic advance were recorded for parameterssuch as plant width, plant height, weight of tubers per plant and marketable tuber yield which

TABLE 3

Heritability, genetic advance and genetic advance as percent of mean for various characters of potato genotypes

Characters	Heritability (%)	GA	GAM
Plant Emergence (%)	66.99	7.82	10.95
Plant height (cm)	94.45	22.04	30.86
Plant width EW (cm)	96.28	21.37	29.93
Plant width NS (cm)	95.54	21.26	29.76
No. of branches	54.30	0.83	1.17
No. of leaves	90.71	12.64	17.70
Maturity (No. of days)	74.88	14.45	20.23
No. of tubers per plant	38.80	1.69	2.37
Weight of tubers per plant (g)	98.74	19.70	27.60
Total yield (t/ha)	74.12	15.71	18.00
Marketable yield (t/ha)	82.06	16.61	19.26
Tuber length	72.05	11.84	12.57
Tuber width	74.31	11.02	11.43
Tuber shape (1-9 scale)	95.03	3.10	4.34
Tuber firmness (kg/cm2)	93.24	10.53	14.75
Dry matter (%)	74.64	3.89	5.44
Reducing sugars (%)	9.10	2.02	3.06
Starch (g)	10.25	13.85	19.38

Note: GA- Genetic Advance, GAM-Genetic Advance mean

revealed the presence of additive gene action in expression of these characters. This information in identified genotypes and traits could be used for future potato breeding programs. Thus, variability, heritability and genetic advance in combination provide a clear picture regarding the effectiveness of selection for improving the characters.

REFERENCES

AMBRISH, C., 2007, Genetic analysis of clonal hybrids for tuber yield and its components in potato (*Solanum tuberosum* L.). *M.Sc. (Ag.) Thesis*, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh).

ANNIGERI, S. V. AND HIREMATH, S. M., 2022, Genetic variability studies in potato (*Solanum tuberosum* L.) genotypes under northern transitional zone of Karnataka, *The Pharma Innovation Journal*, **11** (2) : 1764 - 1767.

ASEFA, W, MOHAMMED, W. AND ABEBE, T., 2016, Genetic variability studies in potato (*Solanum tuberosum* L.) genotypes in Bale highlands, South Eastern Ethiopia. *J. Bio. Agri. Healthcare*, **6** (30) : 117 - 119.

CHETHAN, H., BHAIRAPPANAVAR, S. T., KOLER P. AND JAYARAMAIAH., 2020, Influence of organic nutrient sources on growth and yield of Potato (Solanum tuberosum) in southern transitional zone of Karnataka, *Mysore J. Agric. Sci.,* **54** (4) : 52 - 61

GUNJAN, S., 2008, Studies on genetic variability, association and divergence in potato (*Solanum tuberosum*L.). *M.Sc. (Ag.) Thesis*, Indira Gandhi Krishi Vishwavidyalaya, Raipur.

KANG, Y. Y., GUO, S. R., LI J.ANDDUAN. J. J., 2009, Effect of root applied 24 epibrassinolide on carbohydrate status and fermentative enzyme activities in cucumber (*Cucumis sativus* L.) seedlings under hypoxia, *Plant Growth Regul*., **57** : 259 - 269.

LUTHRA, S. K., 2001, Heritability, genetic advance and character association in potato. *J. Indian Potato Assoc*., **28** (1) : 1 - 3.

MARIYAPPAN, S. B. AND NANDINI, R., 2022, Genetic variability for yield and yield related traits in mung bean genotypes and its response to Mung bean yellow mosaic virus (MYMV) resistance under natural conditions, *Mysore J. Agric. Sci,*. **56** (2) : 200 - 210.

RAHMAN, M. D. H., 2015, Character association and generic diversity of potato (*Solanum tuberosum* L.), *M.Sc. (Ag.). Thesis*, Sher-e-Bangla Agric. Univ. Dhaka, Bangladesh.

RANGANNA, G. R. S., 1977, Evaluation of Indian and exotic potato cultivars for processing into French fries. *J. Indian Potato Assoc*., **25** (1-2) : 61 - 65.

SATTAR, M. A, SULTANA, N., HOSSAIN, M. M, RASHID, M. H., ISLAM, A., 2007, Genetic variability, correlation and path analysis in potato (*Solanum tuberosum* L.). *Bangladesh J. Plant Breed. Genet*, **20** (1) : 33 - 38.

SIDHU, A. S. AND PANDITA, M. L., 1979, Genetic variability and correlation studies in potato (*Solanum tuberosum* L.). *J. Indian Potato Assoc,* **6** (2) : 103 - 108.

WOOSTER, P. AND FAROOQ, K., 1995, National program of germplasm screening, general instructions for trial and guide to data collection. *Pak Swiss Potato Development Project, PARC,* Islamabad, Pakistan. pp. : 24.

Mysore J. Agric. Sci., 57 (1) : 351-359 (2023)

Chromobacterium violaceum Based Screening of Quorum Quenching Bacteria for the Biocontrol of Quorum Sensing Phytopathogens

K. Sowmiya, K. Tamilvendan and Mohan Chavan
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : sowmiyakaruna2@gmail.com

Authors Contribution

K. Sowmiya :
Data collection, analysis and interpretation;
K. Tamilvendan :
Conceptualization, editing and final approval;
Mohan Chavan :
Editing and suggestions

Corresponding Author :
K. Sowmiya
Department of Agricultural Microbiology,
College of Agriculturre
UAS, GKVK, Bengaluru

Received : September 2022
Accepted : November 2022

Abstract

Bacterial phytopathogens attack host by a series of mechanisms like virulence factor synthesis which is a consequence of quorum sensing (QS) mechanism as a group behavior in unison. Acyl homoserine lactones (AHLs) are major signaling auto inducer molecules of most of the QS systems. Hindering the AHLs to reach threshold concentration by quenching the signal can upset the QS. Soil bacterial community possesses quorum quenching (QQ) population which devitalize the quorum system by interfering with AHL signals using an array of QQ enzymes. Eight samples were collected from different experimental sites of University of Agricultural Sciences, GKVK, Bengaluru. A total of thirty-nine AHL degrading (QQ) bacterial isolates were obtained by *in vitro* enrichment culture technique in which N-hexaonyl-L-homoserine lactone (C_6-HSL) served as a sole carbon source. Preliminary screening studies were conducted using bioindicator *Chromobacterium violaceum* MCC 4212 where the inoculum level and incubation period were standardized as 0.1 per cent and 24-36 h, respectively. In violacein quantification assay, per cent (%) inhibition of violacein exhibited by the bacterial isolates varied from 53.58 to 80.89 per cent followed by soft agar overlay assay wherein 31 isolates showed violacein inhibion and eight isolates exhibited both growth and pigment inhibition. Fifteen efficient isolates were screened out of 39 for further QQ assays against the soft rot pathogen *Pectobacterium carotovorum* subsp. *carotovorum*.

Keywords : Acyl homoserine lactones, Bioindicator strain, Quorum quenching, Quorum sensing, Violacein

In the current farming trend, major food crops suffer from a lack of genetic diversity allowing pathogens and pests to rapidly spread throughout fields and devastate crops, causing yield losses up to 32 per cent worldwide (Rooney *et al*., 2020). Gram negative phytopathogens *viz., Pectobacterium carotovorum, Pseudomonas syringae, Ralstonia solanaearum* tops the list in causing serious crop damage leading to severe yield loss (Mansfield *et al*., 2012). These bacterial pathogens recruit their pathogenicity as a population dependent behavior called quorum sensing, wherein diffusible signaling molecules, majorly N- acyl homoserine lactones (autoinducers), play an important role as a language for communication. Concentration of these molecules regulates various pathogenicity traits *viz*., biofilm formation, production of plant cell wall degrading enzymes (Chandrashekar and Prasannakumar, 2021), phytotoxin and also regulation of secretion systems (Baltenneck *et al*., 2021). Hence, quorum sensing has turned out as a notable target for plant disease control recently.

The activity of disturbing the quorum sensing by disruption of signaling molecules is termed 'quorum quenching' (Fan *et al.,* 2020). Such anti-quorum sensing systems are found to be conserved in many prokaryotic and eukaryotic systems. QQ bacteria accounts for about 10 per cent of the total culturable bacteria recovered from several soils and rhizospheres (Dessaux *et al*., 2011). Attenuating virulence by quorum quenching is preeminent rather than bactericidal and bacteriostatic drugs since it is less likely to incite the evolution of resistance in bacteria. Quorum quenching, in addition to plant disease biocontrol, extend its application in the field of bioremediation by controlling biofouling in bioreactors, in aquaculture and so on (Malik *et al*., 2021).

Chromobacterium violaceum, a Gram negative proteobacterium, is known to be a well-established biosensor organism (Poli *et al*., 2018). It produces violacein, a purple pigment as an outcome of quorum sensing mechanism and can be used as a tool for measuring the impact of various quenching substances on quorum sensing (Kothari *et al*., 2017). It is also reported that *C. violaceum* can be employed as an indicator organism capable of detecting a range of AHLs to validate if quorum sensing inhibition is due to AHL interference (McLean *et al*., 2004).

Based on the above observations experiments were conducted to isolate quorum quenching bacteria by enrichment culture technique using C_6 HSL as substrate, followed by the screening for efficient QQ bacterial isolates using the bioindicator strain *Chromobacterium violaceum* MCC 4212.

Material and Methods

Collection of Soil Samples

A total of eight samples were collected from the experimental sites of University of Agricultural Sciences, GKVK, Bengaluru and represented with GIS coordinates (Table 1). Different experimental sites were targeted for sampling such as farmyard manure (FYM), vermicompost and rhizosphere soil. The samples were collected at a depth of 10 - 15 cm from the surface, transferred into the polypropylene bags and transported immediately to the laboratory. Sampling was carried out in the year 2020. The samples were stored at 4°C for further use.

Isolation of AHL Degrading Quorum Quenching Bacteria

The QQ bacteria were isolated by enrichment culture technique as given by Ye *et al*. (2019). In the present study N-Hexanoyl-L-homoserine lactone (C_6-HSL; e' 96% (HPLC)) (Product No. 56395, Sigma Aldrich, USA) was used as a substrate for isolation of QQ bacteria. The stock solution of concentration one mM L^{-1} was prepared using methanol and stored at -20°C for further use. Working solution was made by diluting the stock solutions with culture medium and filtering them through a 0.2 μM nylon membrane syringe filter. The working solution of concentration 20 μM L^{-1} was prepared by diluting 0.4 mL of stock solution in 1.96 mL of minimal salt medium (MSM) (Fan *et al*., 2020).

Suspension was prepared by mixing samples (50 mg) with 2 mL of the MSM without a carbon source and the mixture was vigorously vortexed. The suspension was then centrifuged using centrifuge model 5420 (Eppendorf India Pvt Ltd.) at 3000 rpm for 5 mins, the supernatant was inoculated (5% v/v) with 0.2 mL of the MSM containing 20 μM of C_6-HSL and the mixture was incubated at 30 °C for three days. After three days, the suspension was transferred to fresh MSM containing C_6-HSL (100 μM L^{-1}) at 5 per cent inoculum and cultivated under the same conditions. This step was repeated until the C_6-HSL supplementation was increased in three enrichment cycles (100, 200 and 400 μM L^{-1}). The final suspension was serially diluted (10^{-1} to 10^{-8}) and 0.1 mL of 10^{-6}, 10^{-7} and 10^{-8} dilutions was spread on Luria Bertani (LB) agar plates in triplicates, incubated for 24h at 30°C. The bacterial colonies that showed distinct morphology were picked for isolation. After several passages on LB agar, pure cultures were obtained and maintained on LB agar slants for further studies.

Standardization of inoculum level of *Chromobacterium violaceum*

The primary screening for AHL degrading bacteria was carried out by co-inoculation of isolated bacterial cultures with a quorum sensing induced chromogenic bioindicator strain. Accordingly, the standard strain *Chromobacterium violaceum* MCC 4212 was chosen as the bioindicator. The standard culture of *C. violaceum* MCC 4212 was procured as freeze-dried ampoule from National Centre for Culture Supply (NCCS), National Centre for Microbial Resources (NCMR), Pune, Mumbai, India. The culture was revived by the standard protocol as given in NCMR guidelines using LB broth. The fresh culture was stored in agar slant and glycerol stock at 4°C and -20°C, respectively, for further use.

The screening of bacterial isolates for QQ involved *Chromobacterium violaceum,* hence, standardization of inoculum level and respective violacein production was required. For standardization, the culture of overnight grown *C. violaceum* was adjusted to the OD_{600} = 0.1 using phosphate buffer (pH 7.2). A set of conical flasks containing 10 mL of LB broth were inoculated with 0.1, 0.2, 0.5, 1 and 2 per cent of *C. violaceum*, respectively and medium without inoculum served as control. All the flasks were incubated at 30°C with proper shaking (150 rpm). The samples were drawn at different time intervals (0, 3, 6, 9, 12, 24 and 36 h respectively) for the analysis of growth and violacein production (Kusari *et al*., 2014) that were assessed using UV visible spectrophotometer (Thermo scientific, Biomate 3s, China) at 600 and 585 nm respectively. One mL of *C. violaceum* culture collected from each flask were centrifuged using Eppendorf® Minispin® personal microcentrifuge (Eppendorf India Pvt. Ltd.) at 13000 rpm for 10 min for the analysis of violacein production. One mL of dimethyl sulfoxide (DMSO) was added to the cell pellet and vortexed thoroughly to extract the violacein in to the solvent. The cell debris was removed by centrifugation (13000 rpm, 10 min). The supernatant was then quantified spectrophotometrically at OD_{585}. Each setup was prepared in triplicates.

Screening of Quorum Quenching Bacteria

Violacein Inhibition Assay

A total of thirty-nine isolates were tested for their QQ ability quantitatively using violacein inhibition assay. Overnight grown *C. violaceum* and bacterial isolates were adjusted to OD_{600} = 0.1, using phosphate buffer. Each bacterial isolate was co-inculated with *Chromobacterium violaceum* both at 0.1 per cent. The bioindicator strain *C. violaceum* alone at 0.1 per cent without bacterial isolate served as negative control. All samples were incubated at 30°C on a rotary shaker (150 rpm) for 24-36h. Violacein unit was estimated spectrophoto metrically (OD_{585}) using the method as explained earlier. Inhibition of violacein production was calculated based on the following formula :

$$\text{Violacein inhibition percentage (\%)} = \frac{OD_{585}\text{ control} - OD_{585}\text{ sample}}{OD_{585}\text{ control}} \times 100$$

Soft Agar Overlay Method

The QQ ability of the isolates was qualitatively assessed using soft agar overlay assay as given by McLean *et al.* (2004). Three µL of test organisms were spot inoculated onto the center of the full-strength LB agar plate (2%) and grown overnight at 30 °C. Following overnight growth, the organisms were then overlaid with 5 mL LB soft agar (full strength LB broth containing 0.7% agar) at 45 °C, seeded with 0.1 per cent of overnight cultured *C. violaceum* (OD_{600} = 0.1) in 10 mL of LB broth and mixed thoroughly. The seeded media was poured over the surface of solidified LB plate containing overnight bacterial growth, to form the overlay and incubated at 30 °C for 24 - 36 h. The QQ activity was assessed by measuring the diameter of turbid halos created due to inhibition of violacein pigment.

Statistical Analysis

Statistical significance of variance for data collected was determined using ANOVA. The inhibition of violacein production and zone of pigment inhibition were analyzed by one-way ANOVA. Analysis was performed using Graphpad Prism 8.0.1 software.

Results and Discussion

Isolation of QQ Bacteria from different Samples

Occurrence of QQ and QS bacteria in soil microbial diversity entertains the balance in the natural

Sample	Site	Crop	GIS co-ordinates	Bacterial isolates
FYM	Agroforestry, GKVK	-	13.08670°N 77.57432°E	HSL 11 HSL 12 HSL 13 HSL 14
Vermicompost		-		HSL 21 HSL 22 HSL 23 HSL 24
Rhizosphere soil	CPH research plot, GKVK	Tomato (*Solanum lycopersicum* L.)	13.08290°N 77.57211°E	HSL 31 HSL 32 HSL 33 HSL 34 HSL 35 HSL 36 HSL 37 HSL 38
Rhizosphere soil	Horticultural field, GKVK	Dolichos bean (*Lablab purpureus*)	13.08104°N 77.56773°E	HSL 41 HSL 42 HSL 43 HSL 44 HSL 45
Rhizosphere soil	Horticultural field, GKVK	Cabbage (*Brassica oleracea*)	13.08113°N 77.56799°E	HSL 51 HSL52 HSL 53 HSL 54 HSL 55
Rhizosphere soil	Krishimela site, GKVK	Chilli (*Capsicum annuum* L.)	13.08429°N 77.57308°E	HSL 61 HSL 62 HSL 63 HSL 64
Rhizosphere soil	Agronomy field unit, E block, GKVK	Radish (*Raphanus sativus*)	13.07796°N 77.56986°E	HSL 71 HSL 72 HSL 73 HSL 74
Rhizosphere soil		Ragi (*Eleusine coracana*)	13.07833°N 77.57089°E	HSL 81 HSL 82 HSL 83 HSL 84 HSL 85

ecosystem (Zapata *et al.,* 2017). QS systems use short chain AHLs as cue for most of the bacterial phytopathogenicity (Morohoshi *et al*., 2019). These AHLs act not only as language but also as a competitive advantage as it results in formation of tetrameric compound which will be toxic for most of the co-existing bacterial population. Such competitive advantage of QS can be countered by a variety of bacteria in the environment due to their heterogeneity. Enzymatic degradation of those competent signaling molecules *i.e.,* quorum quenching by bacteria has evolved as one such competing strategies. In the present study enrichment of minimal salt medium supplemented with C_6-HSL as a sole carbon source was used to boost the growth of AHL degrading bacteria and three enrichment cycles were carried out. After enrichment, the cell suspensions of different dilutions were spread on the LB agar plates. The dilutions of 10^{-8} and 10^{-7} yielded colonies that were too less to count, hence, colonies from 10^{-6} dilution were also taken for isolation. A total of thirty-nine isolates showing distinct colony morphology, were obtained from FYM, vermicompost and six different rhizosphere soils collected from experimental sites of UAS, GKVK, Bengaluru (Table 1). AHL signal molecules can be utilized by QQ bacteria *via* synthesis of AHL degrading/ modifying enzymes and the resulting products can be exploited as energy and nitrogen source (Chong *et al*., 2012). The culturable QQ bacterial population was reported to be 10 per cent in the soil and rhizospheres (Dessaux *et al*., 2011). Christaen *et al*. (2011) isolated 59 isolates that were able to use AHL signal as a carbon and nitrogen source, from sixteen different environmental sample. The highest number of isolates (8) were obtained from rhizosphere of Tomato. Amin *et al*. (2016) isolated 45 bacterial isolates from rhizosphere soil of tomato and rice in Malaysia and screened six isolates with QQ activity, all belonged to *Bacillus* spp. A study conducted by Saranya *et al*. (2021) revealed that 25 per cent of the bacterial isolates possessed QQ ability among 96 rhizobacteria isolates. This study is in consistence with previous studies regarding the existence of QQ activity in bacteria from the soil (Li-Xing *et al*., 2012; Magdalena *et al*., 2021 and Lohith kumar and Krishna Naik, 2021).

Standardisation of Inoculum Level and Violacein Production by *Chromobacterium violaceum*.

Bioindicator strain based screening of QQ bacterial isolates is the most prevalent approach for studying their efficiency in QS inhibition. Gram-negative biosensor strain, C*hromobacterium violaceum* is known to produce violacein, a purple pigment, as a result of quorum sensing utilizing the CviI/CviR synthase-receptor signaling (McClean *et al.,* 1997). Loss of this pigment is an index of quorum quenching behavior. Therefore, standardization of *C. violaceum* was done for inoculum size and their respective violacein production. The growth of *C. violaceum* and its violacein production at different intervals where inoculation level varied from 0.1 to 2 per cent was estimated spectrophotometrically at 600 nm and 585 nm, respectively. The results are presented in the Fig. 1.

In all the inoculum levels, *C. violaceum* showed lag phase of growth till 6 h, later it entered log phase which lasted upto 24 h of incubation. After 24 h, it entered early stationary phase. With regards to violacein production, which is a population dependent QS attribute, it was at basal level till mid log phase, later there was an inflation at all the

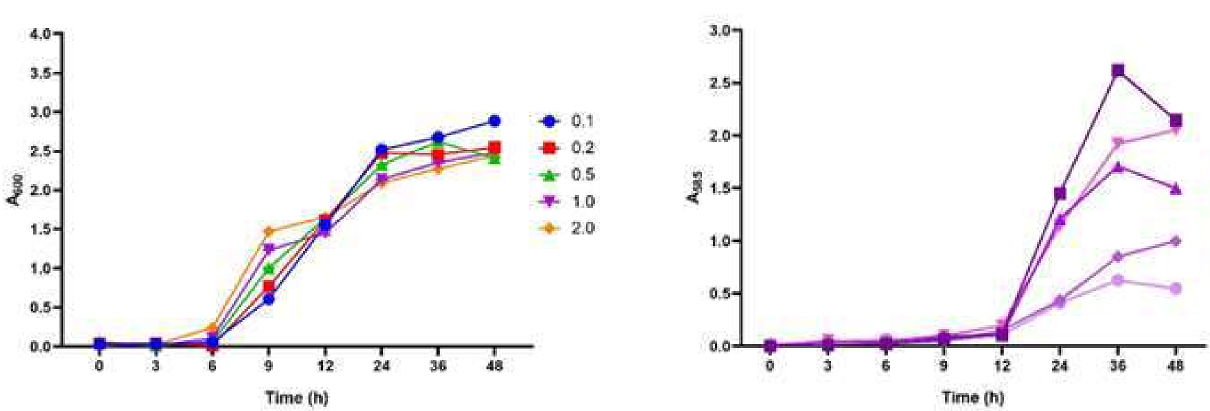


Fig. 1 : Growth and production of violacein by *Chromobacterium violaceum* at different inoculum levels. (a) at OD_{600} and (b) at OD_{585}

inoculum levels. The threshold population density for the quorum concentration was estimated as OD_{600}> 1.25 and it was observed that the bacterial culture could produce pigment. Results of growth studies of *C. violaceum* were similar to the observations of Kanekar and Devasya (2022). With increase in inoculum size, the violacein escalation fold size was reduced and it was also found to be less than 0.1 per cent inoculum size. This increase in decreasing trend with step up in inoculum level may be due to competence within population for nutrient and also due to the fact that higher concentration of AHL counters the quorum sensing system by negative feedback mechanism, since AHL synthesis is a costly step. Further a detailed study needs to be carried out to elucidate the reason behind this reduced level of violacein production with increase in bacterial inoculum. *Chromo bacterium violaceum* at 0.1 per cent (OD_{600}=0.1) showed steady growth with distinct growth phases over a period of time and increased violacein production with growth. Violacein production was found to be higher during 24-36 h of growth. Accordingly, inoculum size of 0.1 per cent and incubation period of 24-36 h for *C. violaceum* were used for further screening studies.

Screening of Quorum Quenching Bacteria using *Chromobacterium violaceum* MCC 4212

The QQ efficacy of the test isolates were determined by quantification of violacein extracted using dimethyl sulfoxide (DMSO). The violacein unit was measured spectrophotometrically and inhibition percentage of violacein production by the 39 bacterial isolates were calculated. Test isolates inhibited violacein pigment when co-inoculated with the biosensor organism.

Chromobacterium violaceum is known to produce hydrogen cyanide and violacein that pose toxicity towards interfering prokaryotes and eukaryotes. Bacteria with quorum quenching activity drastically reduce such toxicity by unleashing enzymes (Mion *et al*., 2021). Violacein synthesis in *C. violaceum* was tested in presence and absence of test isolates and was found to be reduced in coculture conditions. The results of violacein inhibition rendered by the bacterial isolates is presented in Fig. 2. The percentage inhibition of violacein pigment by the quorum quenching isolates ranged between 53.57 and 80.87 per cent. Significantly higher percentage of violacein inhibiton was exhibited by the isolate HSL 52 (80.87±1.07mm) followed by HSL 61 (80.24±0.64 mm). The lowest was recorded by the isolate HSL 84 (53.57±1.4 mm). The results are in agreement with the findings of Rajesh and Rai (2014) and Venkatramanan *et al.* (2020) who reported that the endophytic bacteria of *Pterocarpus santalinus* and ethyl acetate extract of *Passiflora edulis* inhibited violacein production up to 80 and 88 per cent, respectively.

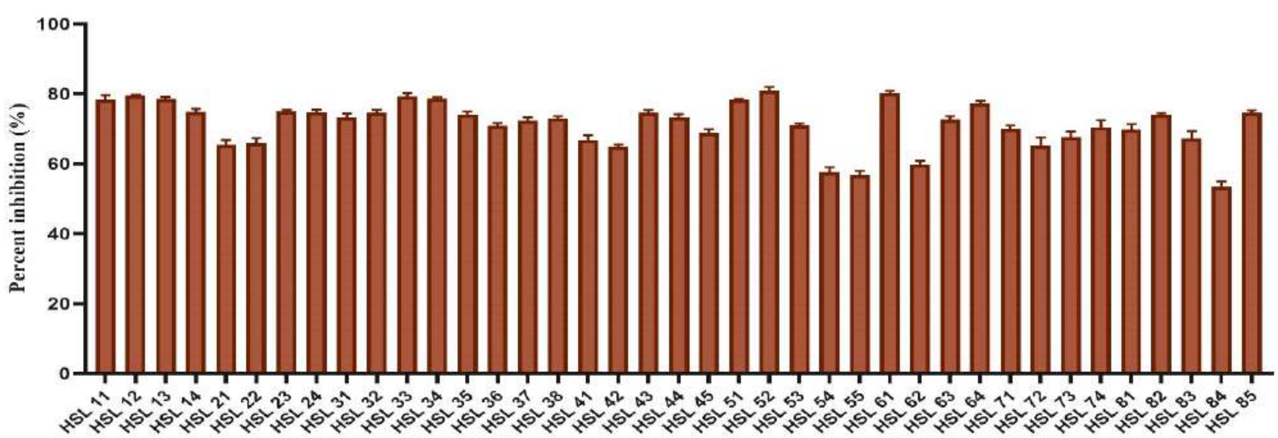


Fig. 2 : Inhibition of violacein production (%) by QQ bacterial isolates

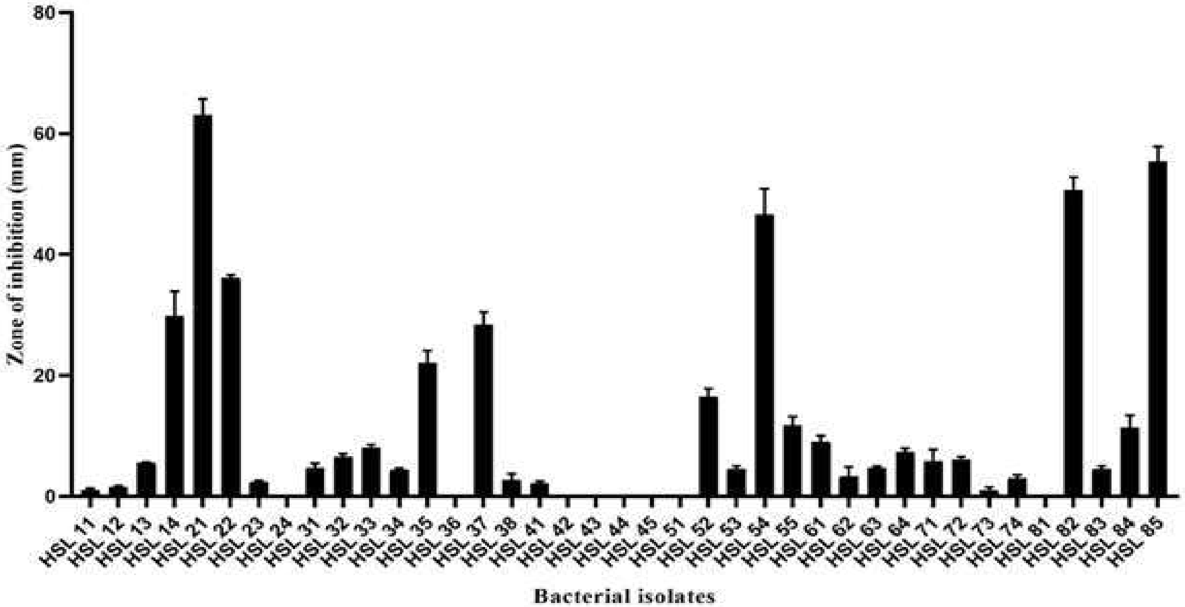


Fig. 3: Zone of pigment inhibition exhibited by bacterial isolates in soft agar overlay technique

The bacterial isolates were further assayed qualitatively by soft agar overlay technique. This was done to confirm whether the violacein inhibition is due to attenuation of quorum sensing and not due to growth inhibition. QQ mechanism mainly aims for antivirulence strategy rather than antibacterial activity. *Chromobacteriun violaceum* as a model for screening of QQ isolates was reported previously on screening of QQ bacteria from antlion (Christianto, 2011) and bacteria from soil (Chong *et al*., 2012). Out of thirty-nine bacterial isolates, thirty-one bacterial isolates showed only pigment inhibition and eight isolates (HSL 24, HSL 36, HSL 42, HSL 43, HSL 44, HSL 45, HSL 71 and HSL 81) have shown clear halo and turbid halo depicting both growth and pigment inhibtion (Plate 1). Thus, inhibition of violacein by these bacterial isolates (around 65% - 75%) was not merely due to quorum sensing inhibition but by killing of the bioindicator, exemplifying the fact given by Abudoleh and Mahasneh (2017). The ability of bacterial isolates to inhibit violacein production was indicated by varying zone of pigment inhibition. The zone of pigment inhibition of bacterial isolates is depicted in Fig. 3. Khoiri *et al*. (2016) could show that efficient strains showed inhibition zone diameter equal or more than 4mm, with the highest quorum quenching activity recorded by the isolates GG3 (10.17 mm) and B37 (10 mm). In the present preliminary screening studies, 15 efficient bacterial isolates performed consistently in both quantitative and qualitative assay with better pigment inhibition, and hence were chosen for further biocontrol studies.

a **b** **c**

Plate 1 : Soft agar overlay method : a. Control; b. Pigment inhibition only and c. Growth and pigment inhibition

Due to bacterial resistance development there is need for safe and efficient alternative in biocontrol and quorum quenching is arising as a pinch-hit in the field of bacteria pathogen biocontrol. In this study, thirty-nine soil bacteria were isolated from different environment samples by enrichment with AHL as sole carbon source. Primary screening studies using the bioindicator strain, *C. violaceum* yielded fifteen efficient QQ bacterial isolates. Our further studies will focus on the biocontrol potential of these QQ isolates against *Pectobacterium carotovorum* subsp. *carotovorum* (Pcc) and their mechanism of action in attenuating the virulence of pathogens.

Acknowledgement : The project was supported by Indian council of Agricultural research-Senior research fellowship (ICAR-SRF), New Delhi, India.

References

ABUDOLEH, S. M. AND MAHASNEH, A. M., 2017, Anti-quorum sensing activity of substances isolated from wild berry associated bacteria. *Avicenna J. Med. Biotechnol.*, **9** (1) : 23 - 30.

AMIN, N. M., RAHIM, M. Y. N., REDZUAN, R. A., TAMIZI, A. A. AND BUNAWAN, H., 2016, Quorum quenching bacteria isolated from rice and tomato rhizosphere soil in Malaysia. *J. Appl. Biol. Sci.*, **10** (1) : 61 - 63.

BALTENNECK, J., REVERCHON, S. AND HOMMAIS, F., 2021, Quorum sensing regulation in phytopathogenic bacteria. *Microorganisms*, **9** (2) : 239.

CHANDRASHEKAR, B. S. AND PRASANNA KUMAR, M. K., 2021, Characterization of *Acenitobactor radioresistance*: A new bacterial soft rot associated pathogen of tomato in India. *Mysore J. Agric. Sci.,* **55** (4) : 83 - 90.

CHONG, T. M., KOH, C. L., SAM, C. K., CHOO, Y. M., YIN, W. F. AND CHAN, K. G., 2012, Characterization of quorum sensing and quorum quenching soil bacteria isolated from Malaysian tropical montane forest. *Sensors*, **12** (4) : 4846 - 4859.

CHRISTIAEN, S. E., BRACKMAN, G., NELIS, H. J. AND COENYE, T., 2011. Isolation and identification of quorum quenching bacteria from environmental samples. *J. Microbiol. Methods*, **87** (2) : 213 - 219.

CHRISTIANTO, B., 2011, Screening of quorum quenching activity of bacteria isolated from ant lion. *Microbiol. Indones.*, **5** (1) : 8 - 8.

DESSAUX, Y., CHAPELLE, E. AND FAURE, D., 2011, Quorum sensing and quorum quenching in soil ecosystems. In: *Biocommunication in soil microorganisms.* [(Eds.) Witzany, G.], SSBM (London), pp. : 367.

FAN, X., YE, T., LI, Q., BHATT, P., ZHANG, L. AND CHEN, S., 2020, Potential of a quorum quenching bacteria isolate *Ochrobactrum intermedium* D-2 against soft rot pathogen *Pectobacterium carotovorum* subsp. *carotovorum*. *Front. Microbiol.*, **11** : 898.

KANEKAR, S. AND DEVASYA, R. P., 2022, Growth-phase specific regulation of cviI/R based quorum sensing associated virulence factors in *Chromobacterium violaceum* by linalool, a monoterpenoid. *World J. Microbiol. Biotechnol.*, **38** (2) : 1 - 11.

KHOIRI, S., DAMAYANTI, T. A. AND GIYANTO, G., 2016, Identification of quorum quenching bacteria and its biocontrol potential against soft rot disease bacteria, *Dickeya dadantii*. *AGRIVITA*, **39** (1) : 45 - 55.

KOTHARI, V., SHARMA, S. AND PADIA, D., 2017, Recent research advances on *Chromobacterium violaceum*. *Asian Pac. J. Trop. Med.,* **10** (8) : 744 - 752.

KUSARI, P., KUSARI, S., LAMSHÖFT, M., SEZGIN, S., SPITELLER, M. AND KAYSER, O., 2014, Quorum quenching is an antivirulence strategy employed by endophytic bacteria. *Appl. Microbiol. Biotechnol.,* **98** (16) : 7173 - 7183.

LI-XING, W., YU-QIAN, Z., HAN, M., YU-XIANG, Y., ZHE-XUE, Q., YUAN-YUAN, Z. AND LIAN-HUI, W., 2012, Screening and isolating quorum sensing inhibitor from bacteria. *Afr. J. Microbiol. Res.,* **6** (**5**) : 927 - 936.

LOHITH KUMAR, N. AND KRISHNA NAIK, L., 2021, Isolation and Characterization of Saline Tolerant Rhizo bacteria from Saline Tracts of Karnataka. *Mysore J. Agric. Sci.,* **55** (4) : 175 - 180.

MAGDALENA, S., JOHANNA, I. AND YOGIARA, Y., 2021, Detection of Quorum Quenching-Producing Bacteria from Rhizosphere Soil as a Biocontrol Agents. *Teknosains: Media Informasi Sains dan Teknologi*, **15** (1) : 18 - 24.

MALIK, S., PRASAD, S., KUMARI, T., GHOSHAL, S., AGRAWAL, A., SHEKHAR, S. AND SAMAL, B., 2021, Quorum Quenching for Sustainable Environment. In: *Handbook of Research on Microbial Remediation and Microbial Biotechnology for Sustainable Soil*, IGI Global, pp. : 542 - 568.

Mansfield, J., Genin, S., Magori, S., Citovsky, V., Sriariyanum, M., Ronald, P. and Dow, M., 2012, Top 10 plant pathogenic bacteria in molecular plant pathology. *Mol. Plant Pathol.,* **13** : 614 - 629.

McClean, K. H., Winson, M. K., Fish, L., Taylor, A., Chhabra, S. R., Camara, M., Daykin, M., Lamb, J. H., Swift, S., Bycroft, B. W. and Stewart, G. S., 1997, Quorum sensing and *Chromobacterium violaceum*: exploitation of violacein production and inhibition for the detection of N - acylhomoserine lactones. *Microbiology*, **143** (12) : 3703 - 3711.

Mclean, R. J., Pierson iii, L. S. and Fuqua, C., 2004, A simple screening protocol for the identification of quorum signal antagonists. *J. Microbiol. Methods,* **58** (3) : 351 - 360.

Mion, S., Carriot, N., Lopez, J., Plener, L., Ortalo-Magne, A., Chabriere, E., Culioli, G. and Daude, D., 2021, Disrupting quorum sensing alters social interactions in *Chromobacterium violaceum*. *npj Biofilms and Microbiomes*, **7 (**1) : 1 - 16.

Morohoshi, T., Ogasawara, Y., Xie, X., Hamamoto, H. and Someya, N., 2019, Genetic and biochemical diversity for N-acylhomoserine lactone biosynthesis in the plant pathogen *Pectobacterium carotovorum* subsp. *carotovorum*. *Microbes Environ.,* **34** (4) : 429 - 435.

Poli, J. P., Guinoiseau, E., De Rocca Serra, D., Sutour, S., Paoli, M., Tomi, F., Quilichini, Y., Berti, L. and Lorenzi, V., 2018, Anti-Quorum Sensing Activity of 12 Essential Oils on *Chromobacterium violaceum* and Specific Action of cis-cis-p-Menthenolide from Corsican *Mentha suaveolens* ssp. *Insularis*. *Molecules*, **23** (9) : 2125.

Rajesh, P. S. and Rai, V. R., 2014, Quorum quenching activity in cell-free lysate of endophytic bacteria isolated from *Pterocarpus santalinus* Linn., and its effect on quorum sensing regulated biofilm in *Pseudomonas aeruginosa* PAO1. *Microbiol. Res.,* **169** (7-8) : 561 - 569.

Rooney, W. M., Chai, R., Milner, J. J. and Walker, D., 2020, Bacteriocins targeting Gram-negative phytopathogenic bacteria: Plantibiotics of the future. *Front. Microbiol*., **11** : 575981.

Saranya, P. J., Tamilvendan, K., Earanna, N. and Mallesha, B., 2021, Isolation and screening of quorum quenching rhizobacterial isolates from the experimental farms of Gandhi Krishi Vigyana Kendra, Bengaluru, Karnataka, India. *Curr. Appl. Sci. Technol*., **40** (37) : 1 - 11.

Venkatramanan, M., Sankar Ganesh, P., Senthil, R., Akshay, J., Veera Ravi, A., Langeswaran, K., Vadivelu, J., Nagarajan, S., Rajendran, K. and Shankar, E. M., 2020, Inhibition of quorum sensing and biofilm formation in *Chromobacterium violaceum* by fruit extracts of *Passiflora edulis*. *ACS omega*, **5** (40) : 25605 - 25616.

Ye, T., Zhou, T., Li, Q., Xu, X., Fan, X., Zhang, L. and Chen, S., 2019, *Cupriavidus* sp. HN-2, a novel quorum quenching bacterial isolate, is a potent biocontrol agent against *Xanthomonas campestris* pv. *campestris*. *Microorganisms*, **8** (1) : 45.

Zapata, L. S., Tabarez, M. R., Alvarez, J. C. and Escobar, V. V., 2017. Reviewing microbial behaviors in ecosystems leading to a natural quorum quenching occurrence. *Brazilian Braz. Arch. Biol. Technol.*, **60**.

Mysore J. Agric. Sci., 57 (1) : 360-366 (2023)

Isolation and Screening of Bacterial Endophytes Against *Alternaria solani* - Causing Early Blight Disease in Potato (*Solanum tuberosum* L.)

G. S. Srikanth, K. Nagaraju and R. Muthuraju
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : srikanthgs07@gmail.com

Authors Contribution
G. S. Srikanth :
Data analysis, data collection and drafting the article;
K. Nagaraju:
Conceptualization & critical revision;
R. Muthuraju :
Critical revision of the draft

Corresponding Author :
G. S. Srikanth
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru

Received : August 2022
Accepted : February 2023

Abstract

The use of endophytes as biocontrol agents has been gaining importance towards the sustainable agriculture and eco friendly farming. The present study is designed to isolate and screen the bacterial endophytes that inhibit the fungal pathogen *Alternaria solani* that causes early blight disease in the potato and in most of the solanaceous crops. The bacterial endophytes (62) were isolated from different parts of potato plant *viz.,* leaf, stem, roots and tubers. Among them, ten isolates were taken as efficient isolates which significantly inhibited the growth of fungal pathogen in dual culture method. The highest inhibition percentage against the pathogen was recorded in the isolate PEL-4 (71.46%) followed by PES-5 (69.38%). All the ten efficient isolates were found to be Gram positive. Six isolates tested positive for starch hydrolysis. Eight isolates tested catalase positive. Only three isolates were tested positive for HCN production.

Keywords : Endophytes, Pathogen, Biocontrol, *Alternaria solani,* Solanaecous crops

The extensive use of chemicals for the cultivation of crops has been causing many adverse effects on the human health and also on the environment in the recent times. In this regard, bio-control strategies are gaining importance as a remedy or as an alternate towards sustainable agriculture and organic farming. Off-late, endophytes have been gaining importance to combat the various biotic and abiotic stresses that cause damage to the crops by various means. The term 'Endophyte' is derived from the Greek words 'Endon' (within) and 'Phyte' (plant). Endophytes are the microorganisms (bacteria or fungi), present in the plants for the whole or a part of their lifecycle, residing inter and intra-cellular healthy tissues of the host plant, without causing any noticeable disease symptoms.

Biological control by microbial endophytes is the best way to control pathogens as they are inherently safe, cost-effective and environmental friendly (Rabiey *et al.,* 2019). These endophytes colonize the plant tissues and fight against other microbial pathogens on the same ecological habitats. Therefore, the plant-endophyte association promotes plant health *via* several mechanisms and potentially contributes to the host plant resistance against pathogens (Malhadas *et al.,* 2017). These endophytes not only act as biocontrol agents but also possess various plant growth promotion traits, or helping the host plant to tolerate stress (Ullah *et al.,* 2019) and help in the overall growth and development of the crop plants. Endophytic bacteria have been isolated from roots, leaves, stems, a few from flowers, fruits and seeds (Imran *et al.,* 2019).

Potato (*Solanum tuberosum* L.) is the third most important food crop after rice and wheat interims of its usage as a stable food around the globe. India is the second largest producer of potato in the world behind China. The world wide consumption of potato was 241 million tonnes, third after rice and wheat (FAOSTAT, 2020). Potato occupies premier place in the list of vegetable crops in the world including India. It is a member of Solanaceae family (chromosome number 2n = 48). Potatoes are an important source of carbohydrate, protein, vitamins and minerals. It is used as a staple food in many countries of the world.

Even though, there are many reports available against the early blight disease, only a few have been reported in potato, especially the reports with respect to the beneficial effect of endophytes isolated from various parts of potato plant are scarce. The present study highlights the potential of bacterial endophytes isolated from potato for the control of early blight disease causing *Alternaria solani*. Potato plants are susceptible to a wide range of diseases *viz.,* late blight, early blight, wilt, scab, *etc.* Among them, *Alternaria solani* is a kind of fungal pathogen that causes early blight disease of tomato, potato and many other vegetable crops and lead to huge losses in agricultural production. Early blight disease in potato can cause up to 80 per cent of annual yield losses in some regions of the world (Peters *et al.,* 2008). In the present study, the bacterial endophytes were isolated from the potato plants collected from various places and were screened *in-vitro* against the pathogen *Alternaria solani*.

Material and Methods

The present study was carried out in the Department of Agricultural Microbiology, University of Agricultural Sciences, Gandhi Krishi Vigana Kendra (GKVK), Bengaluru.

Sample Collection

The plant and tuber samples of potato were collected from different regions of Bengaluru Rural, Bengaluru Urban, Chickaballapura and Kolar districts (Table 1).

Isolation of Endophytic Bacteria from Leaf / Stem / Roots / Tubers of Potato

The isolation of endophytes was carried out as per the standard procedures given by Bacon *et al*. (2002). The randomly selected plants were uprooted manually and washed in running tap water to remove the attached portion of soil. Shoot / root / leaf / tuber sections of 2 cm length were excised using flame sterilized scalpel. The surface sterilization of the shoot / root/leaf / tuber pieces was carried out with the following immersion sequence: 70 per cent ethanol and three per cent sodium hypochlorite. They were then rinsed four times with sterile water and dried in laminar flow. The cut ends of surface sterilised segments were removed with flame sterilized scalpel and were placed in the plates with nutrient agar medium with the cut surface touching the agar. The plates were incubated for 24 h at 27 ˚C.

Table 1

Geographical information of the regions where plants were collected for endophytes isolation

Place (District)	Location	Lattitude (N)	Longitude (E)	Number of bacterial isolates
Bengaluru Urban	Samandur	12° 73' 792''	77° 74' 967''	6
	Halehalli	12° 74' 964''	77° 74' 964''	5
	Harohalli	12° 75' 335''	77° 75' 438''	8
	Arehali	12° 92' 023''	77° 49' 346''	7
Kolar	Malur	13° 06' 025''	76° 50' 045''	6
	Vatrakunte	13° 07' 753''	78° 12' 968''	4
Chickaballapura	Shidlaghatta	13° 25' 104''	77° 58' 062''	5
	Hunasenahalli	13° 34' 395''	77° 82' 368''	5
Bengaluru Rural	Vijayapura	13° 30' 377''	77° 80' 231''	6
	Bhatrenahalli	13° 31' 920''	77° 81' 813''	8
	Total			62

For sterility check, 0.1 ml aliquot from the final wash was inoculated to the nutrient agar plate (Gyaneshwar *et al.,* 2001). Samples were discarded if any growth was detected in the sterility check.

Screening of the Endophytic Isolates *in-vitro* Against *Alternaria Solani*

The isolated bacterial endophytes were tested against the pathogen in dual culture method to check the inhibition of the pathogen by the endophytes. The pathogen, *Alternaria solani* was procured from the Department of Plant Pathology, University of Agricultural Sciences, GKVK, Bengaluru.

Dual Culture Method

Dual culture technique was followed for *in-vitro* screening of bacterial endophytes against *Alternaria solani*. The endophytes were streaked in the same plate parallel to the inoculated pathogen and kept for incubation. The zone of inhibition was measured and the percent inhibition of the growth of pathogen was calculated using the formula.

$$I = \frac{(C-T)}{C} \times 100$$

Where,

I = Per cent inhibition

C = Growth of fungal pathogen in control (mm)

T = Growth of fungal pathogen in dual culture plate (mm)

The best isolates showing high inhibition of the pathogen were selected for further study following the method given by Gravel (2005).

Characterization of the Endophytic Isolates

The efficient isolates that inhibited the higher per cent growth of pathogen in the dual culture method were selected for further characterization.

Morphological Tests for Bacterial Endophytes

The following morphological tests *viz*., cell shape, Gram reaction were carried out to characterize the tentatively identified endophytes.

Cell Shape

The purified cultures, at log phase were observed microscopically for the cell morphological characteristics.

Gram Staining

Gram staining was carried out using the procedure given by Harrigan and McCance (2014). The slides were viewed with the light microscope under oil-immersion. Gram-positive bacteria appear violet and gram-negative bacteria appear pinkish red.

Biochemical Characterization of Efficient Endophytic Isolates

The ability of the isolates to hydrolyze starch was examined in the petriplates containing starch agar which were inoculated with test cultures and incubated at 30 °C for three days. After incubation the plates were flooded with Lugol's iodine solution and allowed to stand for 15-20 minutes. The clear zone around the colony was considered as positive for the test.

The nutrient agar slants were inoculated with test organisms and were incubated at 30 °C for 24 hours. After incubation the slides were flooded with one mL of three per cent hydrogen peroxide and observed for production of effervescence. The occurrence of effervescence was scored positive for catalase activity (Yunting *et al*., 2013).

Hydrogen cyanide production was detected as described by Bakker and Schippers (1987). Petri plates containing 10 per cent Trypticase soya agar supplemented with 4.4 g of glycine per litre were inoculated with the bacterial endophytes and inverted with a lid containing filter paper, impregnated with 0.5 per cent picric acid and two per cent sodium carbonate, over each petri plate. The plates were incubated at 28 °C for three to five days. A change in colour of the filter paper from yellow to orange-brown on the filter paper indicated cyanide production.

Statistical Analysis

The data was statistically analysed using WASP: 2.0 (Web Agri Stat Package 2) statistical tool (www.icargoa.res.in/wasp2/index.php) and the means were separated by Duncan's Multiple Range Test (DMRT).

Results and Discussion

Isolation of Endophytic Bacteria from Leaf / Stem / Roots / Tubers of Potato

A total of sixty two endophytic bacterial isolates were obtained from different parts of the potato plant collected from different regions. They varied among themselves in colony morphology, color and other characters and were further evaluated for screening and biochemical characterisation. In the same way, Shuang *et al.* (2022) isolated and characterised an endophyte *Bacillus* sp. K-9, from the tubers of potato and studied its biocontrol potential against potato scab disease.

Screening of the Endophytic Isolates *in vitro* against *Alternaria solani*

The sixty two isolates obtained were tested for their antagonistic activity against the pathogen *Altenaria solani* by dual culture method *in vitro.* The pathogen and the bacterial endophyte were inoculated in the same plate and the zone diameter was measured both in the control plate inoculated with pathogen only and in the plate with pathogen and endophyte. Later, the inhibition percentage was calculated and ten isolates *viz.,* PEL-4, PEL-5, PEL-6, PEL-8, PES-5, PER-6, PER-10, PEL-13, PEL-20 and PEL-22 were found to be significantly superior among the sixty two

Table 2

Screening of the endophytic isolates *in vitro* against *Alternaria solani* by dual culture

Sl. No.	Bacterial Isolate	Per cent Inhibition	Sl. No.	Bacterial Isolate	Per cent Inhibition	Sl. No.	Bacterial Isolate	Per cent Inhibition
1	PEL-1	32.26 ^{A}	22	PEL-11	40.14 ^{s}	43	PEL-14	35.41 ^{w}
2	PEL-2	42.3 ^{pq}	23	PES-8	33.32 ^{xy}	44	PEL-15	29.1 ^{D}
3	PEL-3	33.19 ^{xyz}	24	PES-9	35.2 ^{w}	45	PEL-16	52.48 ^{i}
4	PEL-4	71.46 ^{a}	25	PES-10	43.55 ^{mn}	46	PER-11	36.43 ^{v}
5	PES-1	44.27 ^{lm}	26	PET-1	31.93 ^{AB}	47	PER-12	42.46 ^{op}
6	PEL-5	62.07 ^{f}	27	PET-2	16.42 ^{J}	48	PER-13	32.47 ^{zA}
7	PEL-6	64.13 ^{e}	28	PET-3	33.52 ^{x}	49	PES-15	49.08 ^{j}
8	PEL-7	46.9 ^{k}	29	PES-11	32.42 ^{zA}	50	PES-16	43.28 ^{n}
9	PEL-8	65.67 ^{d}	30	PES-12	41.04 ^{r}	51	PEL-17	23.55 ^{F}
10	PES-2	43.17 ^{no}	31	PEL-12	52.25 ^{i}	52	PEL-18	25.22 ^{E}
11	PER-1	15.25 ^{K}	32	PER-5	31.35 ^{B}	53	PET-6	31.89 ^{AB}
12	PES-3	44.38 ^{l}	33	PER-6	68.26 ^{c}	54	PEL-19	52.66 ^{i}
13	PES-4	38.66 ^{t}	34	PER-7	37.12 ^{uv}	55	PEL-20	58.39 ^{g}
14	PES-5	70.08 ^{b}	35	PER-8	45.06 ^{l}	56	PET-7	22.52 ^{G}
15	PER-2	37.48 ^{u}	36	PER-9	28.65 ^{D}	57	PET-8	41.64 ^{pqr}
16	PEL-9	52.09 ^{i}	37	PER-10	62.29 ^{f}	58	PER-14	24.89 ^{E}
17	PEL-10	40.26 ^{s}	38	PET-4	30.21 ^{C}	59	PER-15	32.63 ^{yzA}
18	PES-6	20.21 ^{I}	39	PET-5	42.18 ^{pq}	60	PET-8	41.55 ^{qr}
19	PES-7	38.96 ^{t}	40	PES-13	56.43 ^{h}	61	PEL-21	21.45 ^{H}
20	PER-3	62.07 ^{f}	41	PES-14	52.41 ^{i}	62	PEL-22	69.36 ^{b}
21	PER-4	42.2 ^{pq}	42	PEL-13	69.38 ^{b}			

Note: P- Plant, E- Endophyte, L- Leaf, R- Root, S- Stem

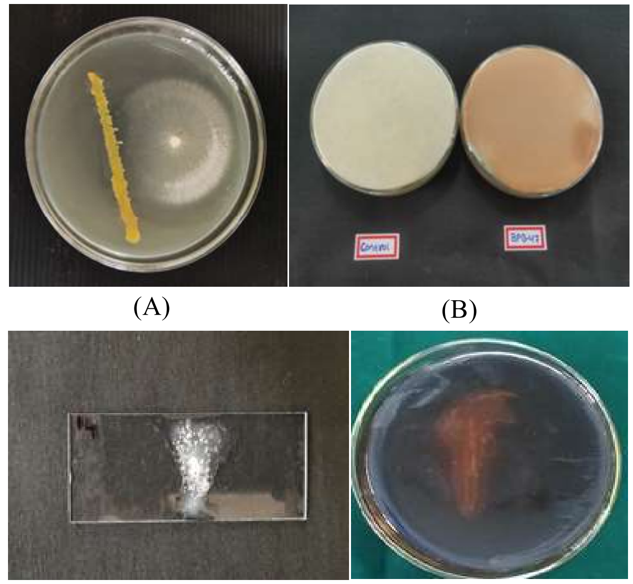
Means with same letter, in a column do not differ significantly at P= <0.05 as per Duncan Multiple Range Test (DMRT) isolates with the values ranging from 15.25 per cent to 71.46 per cent. The highest inhibition percentage was found with the isolate PEL-4 (71.46%) and the lowest percentage was observed with the isolate PER-1 (15.25%) (Table 2) (Fig. 1A). This might be due to the production of secondary metabolites and volatile organic compounds by the bacterial endohytes that suppressed the fungal pathogen. These results obtained are in line with the study made by Sahu and Brahmaprakash (2018), where the inhibition percentage of the fungal pathogens by the various endophytic bacterial isolates varied from 51 per cent to 78.02 per cent against *Scelrotium rolfsii* and nine per cent to 70.81 per cent against *Rhizoctonia solani*. Also, similar results were reported by Maruti and Sriram (2021), while working with both bacterial and fungal endophytes against the wilt pathogen of pomegranate.

Characterization of Endophytic Isolates

The morphological characters of the endophytic isolates are mentioned in the Table 2. Among the 10 efficient isolates, eight were Gram negative and two were Gram positive (PER-10 and PEL-20) (Table 3).

Biochemical Characterization of Efficient Bacterial Endophytic Isolates

The primarily screened 10 isolates were subjected to various biochemical tests such as starch hydrolysis,



(A) (B) (C) (D)

Fig. 1: (A) Dual culure method; (B) HCN Production; (C) Catalase Test; (D) Starch Hydrolysis

Note : P - Plant, E - Endophyte, L - Leaf, Pathogen - *Alternaria solani*

catalase test and HCN production to tentatively characterise and identify the bacteria (Fig. 1). Among the 10 isolates, six tested positive for starch hydrolysis (PEL-4, PES-5, PER-10, PEL-13, PEL-20 and PEL-22) and four were found negative (PEL-5, PEL-6, PEL-8 and PER-6).

Among the 10 bacterial isolates, nine were found positive for catalase activity, where as only one isolate (PER-10) tested negative (Table 4) (Fig. 1C).

TABLE 3

Morphological characteristics of the endophytic bacteria isolated from various parts of potato plant

Isolates	Colony colour	Colony shape	Colony surface	Cell shape
PEL-4	White	Round	Smooth glistening	Rods
PEL-5	Creamish white	Irregular	Smooth glistening	Rods
PEL-6	Yellow	Round	Glistening	Rods
PEL-8	Creamish white	Round	Smooth glistening	Rods
PES-5	Creamish white	Round	Smooth glistening	Rods
PER-6	Yellow	Round	Smooth	Rods
PER-10	Bright white	Round	Smooth shiny	Coccii
PEL-13	White	Irregular	Dull	Rods
PEL-20	White	Round	Smooth glistening	Rods
PEL-22	Creamish white	Round	Smooth	Rods

Note: P- Plant, E- Endophyte, L- Leaf, R- Root, S- Stem

TABLE 4

Biochemical characteristics of endophytic bacteria *in vitro*

Isolate code	Gram reaction	Catalase Test	Starch Hydrolysis	HCN Production
PEL-4	-	+	+	+
PEL-5	-	+	-	-
PEL-6	-	+	-	-
PEL-8	-	+	-	-
PES-5	-	+	+	+
PER-6	-	+	-	-
PER-10	+	-	+	-
PEL-13	-	-	+	-
PEL-20	+	+	+	-
PEL-22	-	+	+	+

Note: P- Plant, E- Endophyte, L- Leaf, R- Root, S- Stem

Later, when the isolates were subjected to HCN production, the filter papers turned to brown in only three isolates (PEL-4, PES-5 and PEL-22) and were taken as positive and the other seven isolates were recorded as negative due to the absence of colour change which indicated that there was no HCN production (Table 4) (Fig. 1B). From these results we can conclude that the isolated bacterial endophytes showed positive results to various biochemical tests separately. These results are in confirmation with the results of Sahu and Brahmaprakash (2018). The isolates possessing various biochemical characteristics have a wider application and usage and are used for further studies. In the present study, the bacterial endophytes inhibit the growth of the pathogen. The efficient isolates which showed highest inhibition per cent of the pathogen in dual culture technique are used for future studies and molecular characterization of the isolates were carried out.

The endophytes are present in each and every plant. They possess various plant growth promoting traits and confer innate resistance to the plants against disease causing pathogens and also against various abiotic stresses. They aid in the growth and development of plants in a positive way and confer numerous beneficial characteristics that are needed to be harnessed commercially. These endophytes are widespread and inhabitate in almost every part of the plants and are acting as natural soldiers to the plants. The biocontrol and growth promotion properties of the endophytes prove to be very useful and improve the plants resistance to the diseases and confer ability to withstand varying environmental conditions.

REFERENCES

BACON, C. W., GLENN, A. E. AND HINTON, D. M., 2002, Isolation, *in planta* detection and culture of endophytic bacteria and fungi. *J. Food Sci. Technol.,* **17** : 136 - 138.

BAKKER, A. W. AND SCHIPPERS, B., 1987, Interactions of deleterious and beneficial rhizosphere micro organisms and the effect of cropping practices. *Annu. Rev. Phytopathol.,* **25** : 339 - 358.

UN Food and Agriculture Organization, Statistics Division (FAOSTAT). 2022.

GRAVEL, V., MARTINEZ, C., ANTOUN, H. AND TWEDDELL, R. J., 2005, Antagonist microorganisms with the ability to control *Pythium* damping-off of tomato seeds in rockwool. *BioControl.*, **50** : 771 - 786.

GYANESHWAR, P., JAMES, E. K., NATARAJAN, M., REDDY, P. M., REINHOLD-HUREK, B. AND LADHA, J. K., 2001, Endophytic colonization of rice by a diazotrophic strain of *Serratia marcescens. J. Bacteriol.,* **183** : 2634 - 2645.

HARRIGAN, W. F. AND MCCANCE, E. M., 2014 , Laboratory Methods in Microbiology. Academic Press, London and New York. pp. : 14 - 16.

IMRAN, A., ZABTA, K., SHINWARI, S. AND SIKANDAR, S., 2019, Plant beneficial endophytic bacteria: Mechanisms, diversity, host range and genetic determinants. *Microbiol. Res.,* **221** : 36 - 49.

MALHADAS, C., MALHEIRO, R., PEREIRA, J. A., DE PINHO, P. G. AND BAPTISTA, P., 2017, Antimicrobial activity of endophytic fungi from olive tree leaves. *World J. Microbiol. Biotechnol.*, 33 : 46.

MARUTI, B. AND SRIRAM, S., 2021, Isolation and *in vitro* screening of endophytes against wilt pathogen in pomegranate and guava. *Mysore J. Agric. Sci.,* **55** (4) : 181 - 188.

PETERS, R., DRAKE, K., GUDMESTAD, N., PASCHE, J. AND SHINNERS-CARNELLEY, T., 2008, First report of reduced sensitivity to a QoI fungicide in isolates of *Alternaria solani* causing early blight of potato in Canada. *Plant Dis.,* **92** : 1707 - 1707.

RABIEY, M., HAILEY, E. L., ROY, R. S., GRENZ, K., MAHIRA, A. S., AL-ZADJALI, A. S. M., BARRETT, A. G. AND JACKSON, W. R., 2019, Endophytes vs tree pathogens and pests: can they be used as biological control agents to improve tree health? *Eur. J. Plant Pathol.,* **155** : 711 - 729.

SAHU, P. K. AND BRAHMAPRAKASH, G. P., 2018, Modified liquid dual culture methodology for screening bacterial endophytes against fungal pathogens, *Mysore J. Agric. Sci.,* **52** (2) : 234 - 240.

SHUANG, M., SUN, J. AND TENG, W., 2022, Identification and growth-promoting effect of endophytic bacteria in potato. *Ann. Microbiol.*, **72** (1) : 1 - 11.

ULLAH, A., NISAR, M., ALI, H., HAZRAT, A., HAYAT, K., KEERIO, A., IHSAN, M., LAIQ, M., ULLAH, S., FAHAD, S., KHAN, A., AKBAR, A. AND YANG X., 2019, Drought tolerance improvement in plants: An endophytic bacterial approach. *Appl. Microbiol. Biotechnol.,* **103** (18) : 7385 - 7397.

YUNTING, Z., TENGFEI, F., WENSUO, J., WEN, Z., QIZHI, L., BINGBING, L. AND LUSHENG, 2013, Identification and characterization of a *Bacillus subtilis* strain TS06 as bio-control agent of strawberry replant disease (*Fusarium* and *Verticillium* wilts). *Afric. J. Biotecnol.,* **11** (3) : 570 - 580.

Mysore J. Agric. Sci., 57 (1) : 367-373 (2023)

Consumer Preference for Broiler Meat in Urban and Rural Transects of Bengaluru South - A Conjoint Analysis Approach

A. Sree Lakshmi, M. R. Girish and Mamatha Girish
Institute of Agribusiness Management, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : sreelakshmi.abm@gmail.com

Authors Contribution

A. Sree Lakshmi : Conceptualization, investigation, data collection, data analysis and manuscript preparation;
M. R. Girish & Mamatha Girish : Conceptualization, data curation and editing of draft research paper

Corresponding Author :
A. Sree Lakshmi
Institute of Agribusiness Management, College of Agriculture, UAS, GKVK, Bengaluru

Received : September 2022
Accepted : January 2023

Abstract

The present study attempts to analyse the consumer preference for broiler meat in urban and rural transects of Bengaluru South. For the study, 90 consumers were randomly selected by taking 45 each from urban and rural transects. To analyse the consumer preference, conjoint analysis was used which is a statistical technique where respondents ranked preferences for different offers decomposed to determine the person's inferred utility function for each attribute and the relative importance of each attribute. The attributes taken for the study were the type of meat, price of meat, place of purchase, form in which the meat was purchased and frequency of purchase. The results revealed that the type of meat (broiler meat) was the most important factor considered by consumers in both urban and rural transects. The second important factor which influenced the preference was place of purchase for urban consumers while it was price of the meat for rural consumers. The third, fourth and fifth factors were price, frequency, and form for urban consumers while the corresponding factors were frequency of purchase, place of purchase and form for rural consumers. The study revealed that consumers preferred broiler meat over country chicken and layer meat in both urban and rural transects, which highlights the importance of the broiler industry. The findings of the study may be helpful to stakeholders in broiler poultry industry to reorient their strategies for better market positioning in consonance with the attribute-based preferences of consumers.

Keywords : Conjoint analysis, Consumer preference, Broiler, Urban transect, Rural transect

Poultry is one of the fastest-growing sectors in India with an estimated CAGR of 15.20 per cent for the period - 2021 to 2026. It plays a very important role in the economic development of the country. According to the 20th Livestock Census (2019), the total poultry population in the country was 851.81 million, out of this, commercial poultry accounted for 63 per cent while the remaining (37%) was backyard poultry.

The Indian broiler industry is experiencing rapid growth mainly driven by an increase in per capita consumption. The impressive growth in the poultry sector in general and the broiler industry, in particular, is the result of technological breakthroughs in breeding, feeding and health and sizeable investments from the private sector. The broiler industry is growing with the backward integration system providing opportunities for the rural masses with all the technical inputs and assured remunerations. However, these efforts have concentrated on productivity and production by neglecting several front-end activities such as wholesaling, processing, retailing and equitable inclusive development (www.icfa.org.in).

The growth in broiler segment is expected to remain strong due to consumer preference for poultry, increasing income levels and changing food habits. Over the years, poultry meat has found broad consumer acceptance, in part due to its low relative price (Mohan Kumar and Bhat, 2012). The present study analyses the factors influencing consumer preference for broiler meat in urban and rural transects of Bengaluru South.

Methodology

Study Area

The study was conducted in urban and rural transects of Bengaluru South. For the study, Southern Bengaluru was purposively selected. The distinction between urban and rural transects of Bengaluru was made based on the survey stratification index (Ellen *et al.*, 2017) developed by considering the percentage of built-up area and its linear distance from the city centre. Vidhana Soudha, the building of the State legislature, was used as the reference point to measure the distance (Pooja and Umesh, 2021). Up to about 20 to 25 km away from the city centre, building density was strongly correlated to distance (the closer to the city, the higher the percentage of built-up area). Beyond that, however, the two parameters were negatively correlated (Udaykumar and Umesh, 2019). Accordingly, the urban and rural transects were formed.

Sampling Framework

The study was based on primary data collected from sample respondents using a pre-tested structured schedule through personal survey method. For the study, 45 consumers from urban transect and 45 consumers from rural transect, were drawn randomly, resulting in a total sample size of 90 consumers. The data was collected during the year 2021-22.

Analytical Tool Used

Conjoint Analysis

Conjoint Analysis is a versatile marketing research technique that can provide valuable information for new product development and forecasting, market segmentation and pricing decisions, advertising and distribution, competitive analysis and repositioning. It is a technique used in assessing consumers value judgments. Hence, for the present study, the tool was used to analyse the consumer's preference for broiler meat.

The attributes included in a conjoint analysis experiment correspond to important consumption characteristics or characteristics hypothesized to influence purchase behaviour. The attributes are further divided into levels. The levels are sample classes for each of the selected attributes and should span the realistic range of each attribute (Bellundagi *et al.*, 2016) The conjoint experiment employs a full-profile approach, in which the level of each attribute of the consumption to be rated is specified.

Conjoint analysis helps to identify the factors that matter most to different categories of consumers that are included in the study by estimating the relative importance that each attaches to a given factor in making a purchase decision. Since, the demand functions for various attributes of consumers differ, with households being driven by utility and restaurants by profit, it is expected that the relative importance that each class attached to the attributes will differ. However, despite these differences, conjoint analysis can also provide overall relative importance that all the different categories of consumers attach to a given factor in making a purchasing decision (Kwadzo *et al.*, 2013).

The following seven steps were taken for conducting conjoint analysis.

a) Establishing the attributes
b) Assigning levels for each attribute
c) Selecting the conjoint methodology
d) Deciding which profile to present to the respondents
e) Establishing preferences for each attribute
f) Choosing the presentation method
g) Selecting a method for part-worth estimation

Based on the goodness of fit, the additive conjoint model was used in this study. The model has been formulated as:

$$Y = \sum_{i=1}^{n} \sum_{j=1}^{m} V_{ij} X_{ij}$$

where,

Y = Consumers overall evaluation of broiler meat.

V_{ij} = Part-worth contribution or utility associated with the j^{th} level (j, j=1, 2, ….., m) of the i^{th} attribute (i, i=1, 2, …, n)

X_{ij} = Dummy variable representing the preference for the j^{th} level of the i^{th} attribute (one, if the j^{th} level of the i^{th} attribute is present, otherwise zero)

n = Number of attributes

m = Number of levels of attribute 'i'

For the present study, a profile describing alternatives was constructed by combining the levels of five attributes. The attributes and their levels (Tables 1 and 2) were identified through discussions with consumers during preliminary survey and also in consultation with subject matter specialists and accordingly, 16 cards were generated separately for urban and rural consumers with different combinations and the same were used for collection of information pertaining to consumer preferences in the study area. The consumers were requested to rank each card based on their preferences.

TABLE 1

Attributes and their relative levels for Bengaluru urban transect

Attributes	Levels
Type	Broiler
	Country chicken
Price	Up to Rs.150 per kg
	Rs.151 per kg – Rs.200 per kg
	More than Rs. 200 per kg
Purchase	Shop
	Online
Frequency	Weekly
	Fortnightly
	Monthly
Form	Whole bird (dressed)
	Specific parts

TABLE 2

Attributes and their relative levels for Bengaluru rural transect

Attributes	Levels
Type	Broiler
	Country chicken
	Layer
Price	Up to Rs. 150 per kg
	Rs. 151 per kg – Rs. 200 per kg
	More than Rs. 200 per kg
Purchase	Shop
	Directly from farm
Frequency	Weekly
	Fortnightly
	Monthly
Form	Whole bird (dressed)
	Specific parts

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Sample Consumers in Urban Transect of Bengaluru South

As mentioned earlier, the sample in urban transect for the study comprised of 45 consumers who consumed meat. The socio-economic characteristics of sample consumers in urban transect are presented in Table 3. It can be observed from the table that majority (62.23%) of the consumers belonged to the age group of 31 to 50 years followed by the age group of 20 to 30 years (24.44%) and the age group of above 50 years (13.33%). Sixty per cent of the respondents were males while the remaining (40%) were females. All the sample consumers were literate with majority (64.44%) of them being graduates followed by those (26.67%) who had studied up to PUC level and those (8.89%) up to high school. With regard to the occupation, it was found that majority (42.23%) of the consumers were employed in the private sector followed by those (24.44%) in Government sector, self-employed (20%) and homemakers (13.33%). With respect to income, it was found that majority (48.89%) of the consumers had monthly income ranging from Rs.20,001 to Rs.50,000 followed by those (40%) who had income of more than Rs.50,000 and those (11.11%) with up to Rs.20,000. It was found that Majority (75.55%) of the sample consumers consumed meat on a weekly basis followed by those who consumed it on a fortnightly basis (17.78%) and monthly basis (6.67%).

Socio-Economic Characteristics of Sample Consumers in Rural Transect of Bengaluru South

As mentioned, the sample in rural transect for the study also comprised of 45 consumers who consumed

TABLE 3

Socio-economic characteristics of sample consumers in urban transect of Bengaluru south

(n_1=45)

Particulars	Number	Per cent
Age (years)		
a. 20 to 30	11	24.44
b. 31 to 50	28	62.23
c. Above 50	6	13.33
Total	45	100.00
Gender		
a. Male	27	60.00
b. Female	18	40.00
Total	45	100.00
Literacy Level		
a. Illiterate	0	0
b. Primary School	0	0
c. High School	4	8.89
d. PUC	12	26.67
e. Degree and above	29	64.44
Total	45	100
Occupation		
a. Private employee	19	42.23
b. Government employee	11	24.44
c. Self-employed	9	20.00
d. Homemaker	6	13.33
Total	45	100
Income Level		
a. Up to Rs. 20,000 per month	5	11.11
b. Rs.20,001 to Rs.50,000 per month	22	48.89
c. More than Rs. 50,000 per month	18	40.00
Total	45	100.00
Frequency of meat consumption		
a. Weekly	34	75.55
b. Fortnightly	8	17.78
c. Monthly	3	6.67
Total	45	100.00

meat. The socio-economic characteristics of consumers in rural transect are presented in Table 4. It can be observed from the table that majority (51.11%) of the consumers belonged to the age group of 31 to 50 years followed by the age group of 20 to 30 years (35.56%) and the age group of above 50 years (13.33%). Majority (55.56%) of the respondents were males while the remaining (44.44%) were females. All the sample consumers were literate with majority (40%) of them having studied up to high school level followed by those (26.67%) who had studied up to PUC level, degree and above (22.22%) and up to primary school level (11.11%). In the case of occupation of sample consumers, it was found that about 29 per cent of them were farmers and around 29 per cent of them were homemakers followed by those (20%) who were self-employed, private employees (17.78%) and Government employees (4%). With respect to income, it was found that majority (75.56%) of the consumers had monthly income up to Rs.20,000 followed by those (20%) who had income ranging from Rs.20,001 to Rs.50,000 and those (4.44%) with more than Rs.50,000. Majority (66.67%) of the sample consumers consumed meat on a weekly basis followed by those who consumed it on a fortnightly basis (17.77%) and monthly basis (15.56%).

The important attributes considered for analysing the consumer preference in urban and rural transects of Bengaluru were the type of meat, place of purchase, form in which they purchased the meat, frequency of purchase and price. For each respondent, the part-worth utilities were estimated using OLS regression analysis.

The additive model was found to be a relatively better fit. In the case of urban transect, Pearson's rank correlation yielded a value of 0.950 significant at five per cent level and Kendall's correlation yielded a value of 0.809 significant at 5 per cent level. In the case of rural transect, Pearson's rank correlation yielded a value of 0.912 significant at 5 per cent level and Kendall's correlation yielded a value of 0.880 significant at five per cent level (Table 5). This ensures strong confidence in the suitability of the additive model.

TABLE 4

Socio-economic characteristics of sample consumers in rural transect of Bengaluru south

(n_2=45)

Particulars	Number	Per cent
Age (years)		
a. 20 to 30	16	35.56
b. 31 to 50	23	51.11
c. Above 50	6	13.33
Total	45	100.00
Gender		
a. Male	25	55.56
b. Female	20	44.44
Total	45	100.00
Literacy Level		
Illiterate	0	0
Primary School	5	11.11
High school	18	40.00
PUC	12	26.67
Degree and above	10	22.22
Total	45	100.00
Occupation		
a. Private employee	8	17.78
b. Government employee	2	4.44
c. Self-employed	9	20.00
d. Farming	13	28.89
e. Homemaker	13	28.89
Total	45	100
Income Level		
a. Up to Rs. 20,000 per month	34	75.56
b. Rs.20,001 to Rs.50,000 per month	9	20.00
c. More than Rs.50,000 per month	2	4.44
Total	45	100.00
Frequency of meat consumption		
a. Weekly	30	66.67
b. Fortnightly	8	17.77
c. Monthly	7	15.56
Total	45	100.00

The relative importance of the part-worth functions was compared across different attributes within segments to arrive at the relative importance of each attribute. The average part-worth and the relative importance of the attributes for urban and rural transects of Bengaluru South are presented in Tables 6 and 7.

TABLE 5

Correlation among attributes of consumer preference for broiler meat in Bengaluru

Correlation	Value	
	Urban consumers	Rural consumers
Pearson's R	0.950*	0.912*
Kendall's tau	0.809*	0.880*

Note: * significant at five per cent level

The results of the conjoint analysis of preference for broiler meat by urban consumers of Bengaluru South is presented in Table 6. The type of meat with a relative importance of 62.512 per cent was the

TABLE 6

Conjoint analysis of preference for broiler meat by urban consumers of Bengaluru south

Attribute	Level	Utility level	Relative importance
Type	Broiler	0.453	62.512
	Country chicken	-0.453	
Price	Up to Rs. 150 per kg	1.214	13.878
	Rs. 151 per kg –	2.428	
	Rs. 200 per kg	-3.642	
	More than Rs.200 per kg		
Purchase	Shop	1.188	17.200
	Online	-1.188	
Frequency	Weekly	0.389	4.534
	Fortnightly	0.063	
	Monthly	-0.452	
Form	Whole bird (dressed)	0.038	1.876
	Specific parts	-0.038	
	Total		100

TABLE 7

Conjoint analysis of preference for broiler meat by rural consumers of Bengaluru south

Attribute	Level	Utility level	Relative importance
Type	Broiler	2.020	
	Country chicken	1.791	47.749
	Layer	-3.821	
Price	Up to than Rs. 150 per kg	1.903	
	Rs.151 per kg – Rs. 200 per kg	3.806	33.169
	More than Rs.200 per kg	-5.709	
Purchase	Shop	0.423	7.289
	Directly from farm	-0.423	
Frequency	Weekly	0.481	
	Fortnightly	0.004	10.119
	Monthly	-0.485	
Form	Whole bird (dressed)	0.970	1.674
	Specific parts	-0.970	
	Total		100

most important attribute considered by consumers in urban transect while making purchasing decisions pertaining to meat. Most urban consumers preferred broiler meat (utility level of 0.453) while few preferred country chicken. Though country chicken is free from steroids, antibiotics & hormones and hence a better option from the health point of view, most of the urban consumers preferred broiler meat due to relatively lesser price, tenderness of the meat and availability. The place of purchase of meat with a relative importance of 17.200 per cent was the second important factor. Majority of the consumers preferred to buy meat from shops (utility level of 1.188) while few preferred to buy online. Most consumers prefer to buy broiler meat dressed at shops in their presence. Now-a-days, meat is also ordered through online platforms such as Fresh to Home, Licious, fipola *etc.* are available. Moreover, consumers can check comparative prices online and often get various discounts and offers. Due to these reasons, consumers are finding it convenient to get it ordered online and delivered home. The relative importance of price was 13.878 per cent which revealed that price was the third important factor considered by consumers in urban transect.

Majority preferred a price ranging from Rs.151 per kg to Rs.200 per kg (utility level of 2.428). A research study by Aral *et al.* (2013) in Turkey indicated that consumers top consideration while buying broiler meat was its price. The relative importance for frequency of purchase was 4.534 per cent. In the Indian context, majority of the households cook and consume meat on weekends, *i.e.,* Sundays as they don't cook on most of the weekdays due to cultural reasons. Moreover, the entire family is generally available on Sundays which makes it more conducive for having non-vegetarian food. The relative importance of the form in which the meat is purchased was 1.876 per cent. Urban consumers preferred whole birds (dressed) as well as specific parts of chicken meat depending upon the dishes to be prepared.

The results of the conjoint analysis of preference for broiler meat by rural consumers of Bengaluru South is presented in Table 7. Even in the case of rural consumers, the type of meat (relative importance of 47.749 per cent) was the most important attribute considered while purchasing meat. Majority of consumers preferred broiler meat (utility level of 2.020) while the remaining consumers preferred consuming country chicken and layer meat.

A research study by Salawu *et al*. (2014) in Ghana also found that broiler meat was largely preferred by consumers compared to other types of poultry meat (cockerel, layer and turkey). The price of meat was ranked as the second most important factor by rural consumers, with a relative importance of 33.169 per cent. Majority of the consumers preferred a price ranging from Rs.151 to Rs.200 per kg (utility level of 3.806). The consumers willingness to pay was substantially influenced by their income level, tastes and preferences. The frequency of purchase with a relative importance of 10.119 per cent was the third factor which influenced the purchase decision of rural consumers. Majority of the rural consumers also preferred consuming meat on a weekly basis (utility level of 0.481) mainly due to cultural reasons. The relative importance of the place of purchase and form were 7.289 per cent and 1.674 per cent respectively. The rural consumers purchased broiler meat from a meat shop or a nearby farm and invariably bought whole birds (dressed) and hardly bought specific parts of chicken.

The study found that among the various attributes considered, the type of meat was the most important factor that influenced the preference of consumers in both urban and rural transects. Broiler meat was preferred by consumers in both urban and rural transects. The consumption of country chicken by the sample consumers was relatively more in rural transect as compared to that in urban transect. The consumers in rural transect prioritised price more than consumers in urban areas while making purchases. The urban consumers ranked place of purchase (meat shops or online platforms) as the second most preferred factor whereas the rural consumers have ranked it as the third factor. The frequency of purchase and the form in which the meat is purchased were the factors which influenced the consumers the least while making purchase decisions. Based on the findings of the study, the stakeholders in the broiler poultry industry may reorient their strategies for better market positioning in consonance with the attribute-based preferences of consumers. Given the robust growth of the broiler sector mainly driven by increase in consumer demand, the Government may act accordingly to sustain the atmosphere required for the same and thereby safeguard the interests of all stakeholders in the industry.

Acknowledgement : The article is a part of the sub-project entitled 'Effects of Urbanization on Value Chains and Livelihoods of Farmers and other Stakeholders (Poultry and Sheep / Goat Value Chains)' under the Indo-German Collaborative Research Project entitled 'The Rural-Urban Interface of Bangalore: A Space of Transitions in Agriculture, Economics and Society'. The Department of Biotechnology (DBT), GoI, New Delhi, India (Sanction order: BT/IN/German/DFG/14/BVCR/2019-Phase-II dated 19-03-2021) is duly acknowledged for the financial support provided to this project.

References

George, T. M. Kwadzo, Fidelis Dadzie, Yaw, B. Osei-Asare and John, K. M. Kuwornu, 2013, Consumer preference for broiler meat in Ghana: A conjoint analysis approach. International Journal of Marketing Studies, **5** (2) : 66 - 73.

Ellen, M. H., Monish, J., Nils, N. and Thomas, M., 2017, Construction and use of a simple index of urbanization in the rural-urban interface of Bangalore, India. *Sustainability*, **9** (11) : 1 - 21.

Mohan Kumar, H. T. and Jayarama Bhat, B., 2012, Technical efficiency of contract broiler farming in Karnataka. *Mysore Journal of Agricultural Sciences*, **46** (4) : 842 - 845.

Pooja and Umesh, K.B., 2021, Why do farm households migrate? Evidence from rural-urban interface of Bengaluru. *Mysore Journal of Agricultural Sciences*, **55** (3) : 132 - 141.

Salawu, M. B., Ibrahim, A. G., Lamidi, L. O. and Sodeeq, A. E., 2014, Consumption and consumer preference for poultry meat types in Ibadan Metropolis. *Journal of Economics and Sustainable Development*, **5** (28) : 20 - 25.

Udaykumar, M. S. and Umesh, K. B., 2020, Investment and crop diversity: empirical evidence from rural-urban interface of Bengaluru. *Current Journal of Applied Science and Technology.* **39** (30) : 1 - 10.

Veerabhadrappa Bellundagi, Umesh, K. B., Roopa, H. S. and Ravi, S. C., 2016, Application of conjoint analysis for consumer preference evaluation in ragi in Karnataka. *Indian Journal of Economics and Development*: **4** (10) : 1 - 6.

Yilmaz Aral, Erol Aydin, Pinar Demir, Ahmet Cumhur Akin, Yavuz Cevger, Çağla Yüksel Kaya Kuyululu and Mehmet Saltuk Arikan, 2013, Consumer preferences and consumption situation of chicken meat in Ankara Province, Turkey. *Turkish Journal of Veterinary and Animal Sciences*, **37** (1) : 582 - 587.

Mysore J. Agric. Sci., 57 (1) : 374-387 (2023)

Spatio-Temporal Dynamics of Growth, Instability and Crop Diversification in Karnataka

J. Thejaswi Kumar[1] and T. M. Gajanana[2]
[1]Department of Agricultural Economics, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
[2]Division of Social Science and Training, ICAR-IIHR, Bengaluru - 560 089
e-Mail : thejaswi3596@gmail.com

Authors Contribution

J. Thejaswi Kumar : Conceptualization, investigation, original draft preparation and data analysis;
T. M. Gajanana : Conceptualization, data curation and draft correction

Corresponding Author :
J. Thejaswi Kumar
Department of Agricultural Economics, College of Agriculture UAS, GKVK, Bengaluru

Received : August 2022
Accepted : December 2022

Abstract

Crop diversification is considered as a pathway to promote agricultural development. The present paper examines the subtleties of crop diversification in Karnataka through spatial and temporal trends across the districts. The analysis carried out from 2000-01 to 2018-19 indicated steady improvement in crop diversification in the State. The Compounded Annual Growth Rate (CAGR) in cereal crops was negative whereas, it was positive in horticulture and plantation crops and commercial crops. However, higher instability was found in other crop groups compared to cereal crops. The districts falling in the southern part of the state tend to be more diversified than other districts. The spectral changes have revealed improvement in spatial diversity over the years in the state. Transitional probability matrix revealed that the shift in area was towards horticulture and plantation crops, commercial crops and condiments and spice crops in the State. However, the major retention in area was found in cereal crops since the share in total gross cropped area is more compared to other crop groups.

Keywords : Growth, Instability index, Composite entropy, Transitional probability matrix, Diversification

Crop diversification is a process of reallocation of resources across crops based on their comparative advantage. It is generally viewed as a shift from traditional lower-value to higher-value crops and is an important pathway for agricultural development. It also enhances farmer's adaptability to biotic and abiotic stresses and promotes self-reliance and sustainability in agriculture. Diversification serves as a sole source of combating risk against climate and weather vagaries in both rain fed and erratic rainfall ecosystems. The significance of crop diversification becomes more pronounced in the WTO-led globalized regime that restricts the scope for prices as an incentive to increase production. Farmers will remain in a disadvantageous position unless they adapt to market signals.

Several studies have highlighted the importance of crop diversification as a means of agricultural sustainable development. Joshi *et al.* (2006) and Birthal *et al.* (2014) decomposed agricultural growth into area effect, yield effect, price effect and diversification effect and found diversification to be an important source of growth. The shift from lower-value to higher-value crops is identified as an important factor in poverty reduction (Birthal *et al.* 2015;). Aheibam *et al.* (2017) observed that crop diversification is an important step towards poverty reduction and transition from subsistence to commercial agriculture. As regards farm sustainability, diversified farming systems incorporate functional biodiversity at multiple temporal and spatial scales to enhance ecosystem services critical to agricultural production. Diversification helps in minimizing the adverse effects of the current system of crop specialization and monoculture through nutrient recycling.

Crop Instability is one of the important decision making parameters in the context of agricultural production. Wide fluctuations in crop output not only affect prices but also result in wide variations in the disposable income of the farmers. High growth in production accompanied by low level of instability for any crop is desired for sustainable development of agriculture (Tripathi and Prasad, 2009). The specific objectives of the article is to analyze the growth, instability and extent of crop diversification comprehensively for all the districts in Karnataka State considering the various crop groups.

METHODOLOGY

The present study is carried out in Karnataka state of India and secondary data was used for analyzing crop growth, instability and diversification. Secondary data used for the study was collected from published sources of Directorate of Economics and Statistics (DES), Bengaluru, Karnataka. Time series data from 2000 to 2019 pertaining to area, production, productivity of different crops were collected for each district and compiled accordingly for the analysis. Due to accounting and compiling ambiguities, the data of newly formed districts was combined with original district and analysis has been carried out considering the 27 districts as of 2007.

The crops were classified into seven major crop groups as a standard grouping followed by Directorate of Economics and Statistics (DES), Karnataka. The major crop groups were Cereal crops, millet crops, oilseed crops, pulse crops, horticulture and plantation crops, commercial crops and last one is condiments and spice crops. The cereal crops includes paddy, jowar, bajra, maize, ragi and wheat. Millet crops considered were navane, save, haraka, baragu and minor millets. Pulse crops included redgram, blackgram, horsegram, greengram, bengalgram and other pulses. The oilseed crops were groundnut, castor, sesamum, linseed, soybean, niger, mustard, sunflower and safflower. Commercial crops were cotton, sugarcane, tobacco, mesta and sunhemp. Horticulture and plantation crops considered were potato, onion, tomato, beans, brinjal, banana, sweet potato, tapioca, grapes, mango, papaya, cashewnut (raw), guava, sapota, cashewnut (processed), lemon and coconut. Condiments and spice crops were dry chillies, turmeric, dry ginger, black pepper, cardamom, garlic, areca nut (raw), coriander and arecanut (processed).

Compounded Annual Growth Rate

For analyzing the growth in area, production and productivity in different crop groups across the districts of Karnataka from 2000-2019 Compounded Annual Growth Rate (CAGR) was used. The methodology followed by Nadkarni and Deshpande (1982) was used to calculate the CAGR. It was calculated using the formula;

$$Y = ab^t e... \qquad (1)$$

Where

Y = Dependent variable for which the growth rate is estimated (area, production, productivity of maize).

a = Intercept

b = Regression co-efficient

t = Time variable

e = Error term

The compound growth rate was obtained from the logarithmic form of the equation (1) as below :

$$\ln Y = \ln a + t \ln b$$

The per cent compound growth rate was derived using the relationship

$$\text{CAGR} = (\text{Anti ln of b} - 1) \times 100$$

Instability Analysis

The co-efficient of variation was used as a measure to study the variability in area, production, productivity. The Coefficient of Variation (CV) was computed using the following formula given by Kent (1924),

$$CV = \frac{Standard\ Deviation\ (SD)}{Mean} \times 100$$

Whenever the trend of series was found to be significant, the variation around the trend rather than the variation around mean was used as an index of instability. The formula suggested by Cuddy and Della (1978), was used to compute the degree of variation around the trend.

$$Instability\ Index = CV * \sqrt{1 - R^2}$$

Where, R^2 = Coefficient of determination from a time-trend regression adjusted by the number of degrees of freedom.

Composite Entropy Index

The extent of crop diversification was captured using Composite Entropy Index (CEI). The CEI has two components *viz.* distribution and number of crops or diversity. The value of CEI increases with the decrease in concentration and rises with the number of crops. The value of C.E.I. ranges from zero to one. The index possesses all desirable properties of Modified Entropy Index and is used to compare diversification across situations having different and large number of crops since it gives due weightage to the number of crops (Pandey and Sharma, 1996; Chand, 1996). The formula of C.E.I. is given by,

$$CEI = -\left(\sum_{i=1}^{N} P_i * log_N P_i\right) * \left\{1 - \left(\frac{1}{N}\right)\right\}$$

Where,

N= is the number of crop groups

P= is the proportion of area of a given crop group to the total gross cropped area

Markov Chain Model

Markov chain analysis is used to study the changes occurred in the cropping pattern of crop groups. The estimation of the probability matrix (P) is central to this analysis and was done by LINGO software package. The elements P_{ij} of the matrix indicated the probability that area would switch from the i^{th} crop group to j^{th} crop over a period of time and the diagonal elements P_{ii} indicated the probability that the area share of a crop would be retained in successive time periods. Each row of the matrix sums to 1.00. The average area under a particular crop is considered to be a random variable which depended only on its past area of cultivation to that crop and which is denoted algebraically by:

$$A_{jt} = \sum_{i=1}^{n} A_{it-1} * P_{ij} + e_{jt} \ (i = 1,2,\ldots..n)$$

Where,

A_{jt} = Area under j_{th} crop group during period t

A_{it-1}= Area under i^{th} crop group during t-1

P_{ij} = Probability of shifting area from i^{th} crop group to j^{th} crop group

e_{jt} = The error term which is statistically independent of e_{it-1} and

n = Number of crop groups

The transitional probabilities P_{ij}, which can be arranged in a (c x n) matrix, have the following properties,

$$\sum_{i=1}^{n} P_{ij} = 1 \quad \text{And}$$
$$0 \le P_{ij} \le 1$$

Thus, the expected shift in area under cultivation of each crop group during period 't' is obtained by multiplying the area under cultivation of crop group in the previous period (t-1) with the transitional probability matrix.

Results and Discussion

Changes in Area Share of Crops

A preliminary insight into crop diversification can be gained from the changes in area share of crops. The decadal changes in shares of different crops show that agriculture in Karnataka has remained dominated by cereal crops Table 1. Pulse crops are the next important crops, followed by commercial crops and

TABLE 1

Per cent cropped area of major crop groups of Karnataka (% GCA)

Crop group	Years		
	2000-01	2010-11	2018-19
Cereal crops	46.32	41.92*	33.64*
Millet crops	0.58	0.19*	0.14*
Oilseed crops	15.43	12.54	7.44*
Pulse crops	16.67	21.58	26.63*
Horticulture and Plantation crops	6.15	8.59*	10.31
Commercial crops	10.99	10.20	11.94*
Condiments and spice crops	3.86	4.99	9.89*
Gross Cropped Area (GCA)	100.00	100.00	100.00

Note: '*' denotes significance at 5 per cent level.

horticulture and plantation crops. However, area shares of cereal crops have declined from 46 per cent to 34 per over the period and found to be statistically significant. The same trend was observed in oilseed crops where area share to the total gross cropped area decreased from 15 per cent to seven per cent and found to be statistically significant. Also, this trend was surprisingly observed in millet crops where the area share declined significantly. However, the area share of pulse crops, commercial crops and condiments and spice crops have shown increasing trend over the period and was statistically significant. The proportional increase was high in case of pulse crops and condiments and spices crop group, where the pulse crop area share has increased from 17 per cent to 27 per cent and four per cent to 10 per cent in case of condiment and spice crops. The major factors which had influenced increase in pulse area were Technology Mission on Oilseeds and Pulses (TMoP) and significant effects of Accelerated Pulse Production Program (APPP) in the state started post 2000's. The findings of the study conducted by Mohan *et al.* (2020) and Shivagangavva and Reddy (2016) revealed significant increase in area and production of pulses in the state and the authors concluded that above factors were the reason for the same.

Compounded Annual Growth Rate of different Crop Groups in Karnataka (2000-2019)

The Compounded Annual Growth Rate (CAGR) in area, production and productivity of different crop groups is presented in Table 2. The spatial and temporal variation in growth rates helps in understanding the complex cropping pattern and the dynamics of crop diversity shifts in the State comprehensively. The results indicated that the total cereal area in the State was decreasing at a rate of 0.98 per cent annually and found to be significant. Among the districts high declining growth was observed in Bengaluru Urban, Bidar and Dakshina Kannada. The similar declining trend was observed in production pattern of these districts. In case of millets declining growth of -6.51 per cent was observed in the State over the years. The major reduction in growth of millet crops area was found in Raichur with a CAGR of -49.27 per cent and Mysore had shown high positive CAGR of 38.78 per cent along with similar values of production over the years. The growth of oilseed crops in the State was found to be negative and significantly decreasing over the years at a rate of -4.26 per cent. The declining rate was most profoundly observed in Dakshina Kannada, Bengaluru Urban, Shivamogga, Hassan and Vijayapura districts. The highest positive and significant rate was observed in Bidar with a CAGR of 8.64 per cent over the years. The CAGR of area (2.73 %) and production (5.64 %) in case of pulse crops were found to be positive and statistically significant and Vijayapura (11.11 %) had the highest positive growth rate in area whereas highest negative growth was found in Kodagu (-24.13 %) over the years. In the case of horticulture and plantation crops, the CAGR of area (2.32%) and production (6.61%) were found to be positive and statistically significant, with Koppal (10.53%) having the highest positive growth rate and Bengaluru Urban (-3.04%) having the highest negative growth rate in area over the years. The CAGR of area (2.67%) and production (4.20%) in commercial crops were found to be positive and statistically significant, with Gulbarga (14.54%)

TABLE 2

Compounded annual growth rate of area, production and productivity in different crop groups in Karnataka (2000-2019)

Districts	Cereal crops			Millet crops			Oilseed crops			Pulse crops		
	A	P	Y	A	P	Y	A	P	Y	A		
Bagalkote	-1.09*	2.19	3.32*	-23.80*	-26.19*	-28.86*	-4.01*	-1.92*	2.18*	8.83*	9.70*	0.80
Bengaluru - Rural	-1.94*	-2.24	-0.68	24.33	19.69	38.18*	-9.33*	-10.08*	-1.21	-2.67*	1.00	3.38
Bengaluru - Urban	-6.32*	-6.43*	-0.12	-18.00	-18.51	-18.87	-13.18*	-12.97*	-0.34	-7.48*	-4.45*	3.28*
Belagavi	-0.98*	3.30*	4.32*	-12.17*	-11.80*	0.43	-1.99*	0.03	2.07	3.45*	8.02*	4.43*
Bellary	1.08*	2.74*	1.64*	-8.36*	-8.34*	0.02	-5.50*	-2.04*	3.66*	1.57	3.67*	2.02*
Bidar	-6.04*	-6.47*	-0.46	-23.81*	-25.74*	-13.70	8.64*	11.53*	2.66*	-1.56*	-0.35	3.78*
Vijayapura	-2.89*	1.20	4.21*	-33.22*	-30.17*	-31.71*	-10.29*	-8.29*	2.23	11.11*	12.66*	1.40
Chamarajanagar	-1.44*	1.88	3.37*	-19.67	-20.13*	-29.58*	-1.53	-3.67*	-2.17	-0.07	2.17*	2.24
Chikmagalur	-0.98*	-0.04	0.94	6.28*	6.88*	0.57	-3.68*	-2.10	1.64	0.88	5.54*	4.62*
Chitradurga	-0.03	1.93	1.96	-2.37*	-1.39	1.00	-4.50*	-7.15*	-2.77	2.14*	2.29	0.14
Dakshina Kannada	-4.64*	-3.29*	1.42*	0.00*	0.00*	0.00	-17.11*	-14.79	-14.35	-7.57*	-5.03	2.78*
Davanagere	-0.22	1.21	1.43	-10.76*	-13.00*	-2.51*	-5.76*	-4.29*	1.56	-2.93*	-0.05	2.96*
Dharwad	-0.63*	2.95	3.61	-16.23*	-15.22*	1.20	1.56	3.66*	2.06	2.57*	5.72*	3.07
Gadag	-0.17	2.83	3.00	-14.53*	-17.11*	-3.02*	-4.44*	-2.18	2.36*	5.05*	6.47*	1.33
Gulbarga	-2.04*	1.44	3.13*	-15.62*	-18.19*	-3.44*	-5.48*	-3.58*	1.60	1.17*	5.11*	3.48*
Hassan	0.11	2.39*	2.27*	-1.79	-5.03	-7.15	-10.60*	-10.48*	0.13	-2.59*	-0.68	1.96*
Haveri	0.68*	3.56*	2.86*	-16.63*	-14.50*	2.56*	-2.02*	0.98	3.06*	-8.09*	-5.44*	2.88*
Kodagu	-2.02*	-0.52	1.53	11.52	10.31	18.72	6.66	6.19	-4.40	-24.13*	-22.29*	2.44*
Kolar	1.54*	1.93	0.01	-4.48	-6.68*	-2.67*	-3.73*	-3.91*	-0.56	1.63*	7.06*	4.95*
Koppal	0.69	2.15	1.46	-4.43*	-3.84	0.62	-3.95*	-2.44*	1.57	5.23*	6.89*	2.42
Mandya	-1.31	-1.11	0.20	24.48	34.18*	35.18	-5.13*	-6.62*	-1.57	-0.10	0.25	0.35
Mysore	-1.62*	-0.55	1.09*	38.78*	34.99*	48.94*	-6.22*	-5.89*	0.36	-0.39	0.44	0.84
Raichur	-1.64*	1.73*	3.43*	-49.27*	-46.38*	-45.89*	-8.88*	-5.69*	3.50*	9.00*	14.01*	4.60*
Shivamogga	-0.46	2.12*	2.59*	-20.43	-20.11*	-31.71*	-12.47*	-10.09*	2.71*	-9.43*	-7.80*	1.79*
Tumkur	-1.64*	-2.37	-0.74	-4.39*	-5.76*	-1.42	-5.66*	-7.29*	-1.73	-2.60*	-3.81*	-1.25
Udupi	-2.58*	-1.06*	1.56*	0.00	0.00	0.00	-2.12*	0.02	2.18*	-7.15*	-5.95*	1.30
Uttara Kannada	-1.36*	1.30*	2.70*	9.92	8.73	18.72	-5.41*	-3.48*	2.05*	-3.96*	-2.88*	1.13
State Total	-0.98*	1.33	2.34*	-6.51*	-6.94*	-0.46	-4.26*	-2.42*	1.93*	2.73*	5.64*	2.84*

Note: '*' indicates significance at 5 % LoS, A- Area (hectare), P-Production (tonnes), Y-Producitivty (Kg/hectare) except in Commercial crops (tonnes/hectare)

Table 2 cont…

Districts	Horticulture and Plantation crops			Commercial crops			Condiments and Spice crops		
	A	P	Y	A	P	Y	A	P	Y
Bagalkote	8.56*	12.22*	3.37*	5.37*	5.47	0.09	15.01*	19.32*	3.74*
Bengaluru - Rural	2.94*	3.42*	0.47	-7.71*	-8.06*	-0.38	5.19*	11.39*	5.89*
Bengaluru - Urban	-3.04*	-1.42	1.67*	-10.63*	-11.15*	-0.58	1.70	7.56*	5.77*
Belagavi	4.64*	8.58*	3.77*	3.19*	5.29*	2.03	1.60	7.79*	6.10*
Bellary	5.15*	8.65*	3.32*	3.82*	4.27*	0.43	5.25*	11.77*	6.20*
Bidar	3.33*	6.31*	2.88*	-1.76*	-1.82	-0.06	-3.73*	4.52	8.57*
Vijayapura	4.74*	9.09*	4.16*	9.43*	10.59*	1.06	1.16	7.73*	6.49*
Chamarajanagar	4.91*	13.84*	8.51*	-0.78	-4.51*	-3.76*	5.09*	7.26*	2.07*
Chikmagalur	2.94*	8.88*	5.77*	-0.56	-2.53	-1.98*	5.27*	6.43*	1.10
Chitradurga	2.81*	8.32*	5.36*	0.67	-17.91*	-18.45*	4.44*	10.51*	5.81*
Dakshina Kannada	0.30	4.46*	4.15*	-21.44*	-26.21*	-0.02	3.42*	5.84*	2.34*
Davanagere	1.53*	5.45*	3.87*	-2.42	-5.73*	-3.39*	5.16*	11.86*	6.37*
Dharwad	-1.35	2.23	3.63	-1.46	8.79*	10.41*	-4.55*	-8.66*	-4.31*
Gadag	1.73	3.09	1.34	-0.61	24.53*	25.29*	-1.34*	1.18	2.55
Gulbarga	2.31*	6.20*	3.80*	14.54*	14.59*	0.04	-2.54*	-2.96	-0.44
Hassan	-0.06	1.57*	1.62	0.60	-6.05*	-6.61*	5.10*	10.83*	5.45*
Haveri	2.32*	6.35*	3.94*	2.56*	12.05*	9.25*	-3.83*	7.39*	11.66*
Kodagu	0.97	5.42*	4.41*	-21.81*	-20.29*	1.63	5.18*	10.79*	5.33*
Kolar	2.61*	4.74*	2.08*	-7.62*	-11.62*	-4.33*	1.33	5.52*	4.14*
Koppal	10.53*	16.03*	4.97*	-1.89	18.87*	21.16*	7.21*	15.24*	7.49*
Mandya	3.78*	9.61*	5.62*	1.91	1.76	-0.15	0.07	3.26*	3.19*
Mysore	3.40*	9.75*	6.14*	0.60	-1.99	-2.57*	7.98*	14.90*	6.41*
Raichur	-0.32	3.41*	3.75*	6.39*	15.40*	8.46*	5.23*	12.00*	6.43*
Shivamogga	1.22*	3.73	2.48	-9.26*	-8.19*	1.18	5.94*	8.61*	2.52*
Tumkur	3.13*	6.56*	3.33*	0.82	-1.21	-2.01	6.93*	11.38*	4.16*
Udupi	0.42*	6.46*	6.02*	-8.96	-9.09	-0.15	5.20*	7.35*	2.05*
Uttara Kannada	3.94*	8.91*	4.79*	-0.43	13.06*	13.54*	4.23*	9.65*	5.20*
State Total	2.32*	6.61*	4.19*	2.67*	4.20*	1.49	3.51*	7.62*	3.98*

Note: ‘*’ indicates significance at 5 % LoS, A- Area (hectare), P-Production (tonnes), Y-Producitivty (Kg/hectare) except in Commercial crops (tonnes/hectare) having the highest positive growth rate and Kodagu (-21.81%) having the highest negative growth rate in area over the years. The similar trend was also found in condiments and spice crops where both area (3.51 %) and production (7.62 %) of State have positive and significant growth over the years. Among the districts, Bagalkote had high positive CAGR of 15.01 per cent and Dharwad had high negative growth rate of 4.55 per cent in area over the years.

The CAGR of area in various crop group over the years revealed that the growth rate was negative and statistically significant in case of cereals, millets and oilseed crops. Whereas, the CAGR was significantly positive in case of pulses, horticulture and plantations, commercial crops and condiment and spice crops. The trend clearly exhibits the shift in area from traditional conventional crop groups towards modern remunerative crop groups over the years. It was evident from the study conducted by Anjum and Madhulika (2018) that growth rate of cereals crops like paddy and wheat was found negative and whereas the case was opposite in commercial crops and horticultural crops. It was mainly attributed to shift in consumer preference towards high nutrient rich alternate diet and also income oriented production systems. Within the farm sector, diversification towards High Value Crops (HVCs), including vegetables, condiments, spices, fruits and plantations, is claimed to be an important means of securing agriculture-based livelihoods, accelerating growth and reducing rural poverty (Bigsten and Tengstam, 2011; Birthal *et al.,* 2015; Michler and Josephson, 2017). Sustained rise in per capita income, increasing urbanization and changing lifestyle, accompanied by liberalization of agri-food markets, have been triggering rapid changes in the food basket in favor of high value food commodities, including fruits, vegetables (Kumar and Joshi, 2017). These factors have been quite robust in the recent past and are unlikely to subside in the foreseeable future, implying a faster growth in the demand for high value food commodities (Kumar and Joshi, 2017). Besides, increasing globalization of agri-food markets is also crafting opportunities for exports of high value food commodities.

Instability Indices in different Crop Groups of Karnataka (2000-2019)

The results of instability examination in different crop groups of Karnataka are presented in Table 3. The indices help in understanding the stability in cropping pattern over time and space in State. Low level of instability accompanied by high growth in production for any crop is desired for sustainable development of agriculture (Tripathi and Prasad, 2009).

In the various crop groups, low instability index was observed in area of cereals (5 %) and horticulture and plantation crops (5 %) compared to other crop groups in the State. In production of millets (35 %) and condiment and spice crops (35 %) moderate instability was observed in the State. In case of cereals all the districts had low (0-20 %) to moderate (20-35%) instability indices in area, production and productivity over the years. However, in millet crops the instability was in the high range (>35 %) in all the districts for area, production and productivity. In oilseed crops, low instability was seen in area of Haveri (14 %) and Gadag (15 %). In area under pulse crops, the lowest instability was observed in Bidar (9 %) but the instability in production was on the extreme side with 125 per cent. The indices in case of horticulture and plantation crops showed better stability with low to moderate instability (0-35 %). In commercial crops, the instability was lowest in Mysore (11 %) with moderate instability in production and productivity. In the case of condiment and spice crops, Shivamogga had good stability in area with instability value of nine per cent followed by Tumkur (10 %) along with low instability values in production and productivity. Instability in agricultural production, for any reason, results in unpredictable behavior and decision making from the population engaged in primary sector which is passed on to the economy as a whole (Krishnan and Chanchal, 2014). With the passage of time adoption of green revolution technology spread to much larger area and a large number of improvements in various aspects of technology

TABLE 3

Instability indices of area, production and productivity in different crop groups of Karnataka (2000-19)

Districts	Cereal crops			Millet crops			Oilseed crops			Pulse crops		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y
Bagalkote	9	26	20	184	237	58	23	25	20	20	40	35
Bengaluru - Rural	14	33	25	183	178	49	27	31	21	14	31	29
Bengaluru - Urban	14	36	26	122	121	64	27	29	39	14	39	45
Belagavi	8	25	24	20	41	42	19	24	29	25	39	21
Bellary	13	16	8	46	85	34	23	23	36	32	35	18
Bidar	12	23	21	81	87	34	17	46	41	9	125	37
Vijayapura	13	30	24	163	196	110	34	34	31	20	38	31
Chamarajanagar	14	26	19	89	79	54	29	35	35	21	37	36
Chikmagalur	7	17	13	34	80	52	29	41	24	13	25	14
Chitradurga	8	31	31	23	42	37	15	37	38	15	35	25
Dakshina Kannada	19	20	7	0	0	0	30	39	36	27	41	23
Davanagere	10	25	19	45	45	25	18	22	22	24	22	17
Dharwad	7	38	36	37	55	41	20	29	27	16	34	38
Gadag	9	36	33	23	45	29	15	32	28	21	40	43
Gulbarga	8	21	18	65	81	37	24	31	34	10	32	27
Hassan	7	31	29	92	72	56	31	48	27	24	36	21
Haveri	7	28	31	16	32	35	14	27	28	21	45	26
Kodagu	9	11	5	394	387	402	104	111	38	50	64	28
Kolar	16	41	30	108	96	20	20	49	39	12	46	40
Koppal	12	28	21	51	112	75	18	27	32	13	35	37
Mandya	19	26	14	312	247	139	37	47	22	24	25	28
Mysore	12	20	10	264	263	201	31	43	25	14	24	20
Raichur	11	19	13	86	93	58	30	27	27	24	25	28
Shivamogga	7	17	13	194	189	166	28	39	18	25	29	15
Tumkur	13	33	25	18	36	35	19	57	48	11	36	30
Udupi	6	8	6	0	0	0	37	33	22	30	29	20
Uttara Kannada	3	15	13	384	367	402	24	21	32	21	40	20
State Total	5	18	14	23	35	20	18	20	24	9	21	19

Table 3 contd......

Districts	Horticulture and Plantation crops			Commercial crops			Condiments and Spice crops		
	A	P	Y	A	P	Y	A	P	Y
Bagalkote	25	27	18	21	28	17	31	36	32
Bengaluru - Rural	14	24	24	33	38	15	17	27	22
Bengaluru - urban	47	36	17	87	90	19	40	26	23
Belagavi	14	20	18	18	33	24	25	62	34
Bellary	21	36	23	35	37	42	50	102	54
Bidar	30	33	17	16	29	23	22	113	62
Vijayapura	21	29	25	33	35	22	26	49	32
Chamarajanagar	18	36	27	28	38	31	28	37	18
Chikmagalur	6	11	10	26	44	25	22	46	22
Chitradurga	6	16	17	44	115	87	20	22	25
Dakshina Kannada	9	19	22	123	134	95	29	37	15
Davanagere	11	19	11	44	46	25	14	27	28
Dharwad	22	44	42	20	31	35	33	41	38
Gadag	29	39	30	32	60	49	36	47	54
Gulbarga	23	45	26	29	41	39	33	55	32
Hassan	18	18	22	20	37	24	27	36	15
Haveri	15	17	15	19	59	56	33	32	22
Kodagu	23	40	31	40	45	52	25	18	18
Kolar	9	19	14	72	66	29	22	37	23
Koppal	26	40	38	56	70	73	41	39	42
Mandya	17	20	18	30	31	10	22	40	15
Mysore	12	21	15	11	30	34	22	29	18
Raichur	28	32	17	50	49	35	40	31	26
Shivamogga	10	49	44	16	27	24	9	17	15
Tumkur	4	19	19	33	53	30	10	16	13
Udupi	3	23	23	180	181	21	28	32	28
Uttara Kannada	7	32	32	30	40	27	11	25	23
State Total	5	12	12	19	28	21	23	35	19

have taken place. As the benefit of these advancements got translated at farm, the variability in yield of food grains had declined and that led to decline in variability of food grains production as well. Other factors which might have contributed to the decline in variability in food grains yield and production seems to be (i) policy of minimum support prices (ii) expansion of irrigation and (iii) improvement in availability of other inputs and institutional credit (Chand and Raju, 2008).

Composite Entropy Indices for Crop Diversification in Karnataka

To have a closer look at the changes in crop diversification across districts three different time points of almost decadal interval *viz.* 2000-01, 2010-11 and 2018-19 were considered. Table 4 shows Composite Entropy Index (CEI) indicating extent of diversification in various districts of the State.

TABLE 4

Composite entropy indices of districts in Karnataka for different time periods.

Rank	Districts	2000-01	Districts	2010-11	Districts	2018-19
1	Dharwad	0.76	Dharwa	0.75	Chitradurga	0.74
2	Gadag	0.70	Gadag	0.72	Dharwad	0.74
3	Haveri	0.68	Chamarajanagar	0.68	Chamarajanagar	0.72
4	Chitradurga	0.66	Chitradurga	0.68	Bagalkote	0.68
5	Tumkur	0.63	Tumkur	0.68	Tumkur	0.66
6	Chikmagalur	0.63	Hassan	0.66	Belagavi	0.64
7	Chamarajanagar	0.61	Chikmagalur	0.65	Mysore	0.63
8	Belagavi	0.60	Bagalkote	0.63	Mandya	0.63
9	Bellary	0.60	Mysore	0.63	Gadag	0.62
10	Hassan	0.58	Belagavi	0.61	Chikmagalur	0.61
11	Mysore	0.58	Bellary	0.60	Bellary	0.57
12	Bagalkote	0.57	Vijayapura	0.59	Hassan	0.57
13	Kolar	0.56	Mandya	0.57	Uttara Kannada	0.56
14	Koppal	0.55	Haveri	0.57	Kolar	0.56
15	Mandya	0.55	Kolar	0.57	Koppal	0.56
16	Udupi	0.54	Bidar	0.56	Haveri	0.55
17	Uttara Kannada	0.53	Koppal	0.56	Raichur	0.55
18	Dakshina Kannada	0.52	Bengaluru - Rural	0.54	Udupi	0.53
19	Bidar	0.52	Uttara Kannada	0.51	Bidar	0.53
20	Vijayapura	0.51	Dakshina Kannada	0.51	Gulbarga	0.49
21	Bengaluru - Rural	0.50	Udupi	0.51	Bengaluru - Urban	0.49
22	Davanagere	0.50	Raichur	0.51	Bengaluru - Rural	0.47
23	Shivamogga	0.48	Davanagere	0.49	Vijayapura	0.47
24	Raichur	0.48	Gulbarga	0.48	Davanagere	0.46
25	Gulbarga	0.48	Kodagu	0.45	Shivamogga	0.41
26	Kodagu	0.41	Shivamogga	0.44	Dakshina Kannada	0.32
27	Bengaluru - Urban	0.41	Bengaluru - Urban	0.44	Kodagu	0.27
	State Total	0.67	State Total	0.69	State Total	0.72
	CV (%)	14.40	CV (%)	14.64	CV (%)	19.96

TABLE 5

Results of paired t-test

Pair	CV (%)	Mean	SD	t-value	p-value
CEI 2000-01 - CEI 2010-11	14.40	0.0165	0.0236	2.0555	0.0000
CEI 2010-11 - CEI 2018-19	14.64	0.0202	0.0735	3.2305	0.0127
CEI 2000-01 - CEI 2018-19	19.96	0.0037	0.0773	2.0565	0.6343

There was a wide variation in diversification index and changes therein across the districts. Some districts in the northern region (e.g., Bagalkote and Belagavi), central region (e.g., Chitradurga) and southern region (e.g., Chamarajanagar and Mysore) have shown an improvement in crop diversification. On the other hand, districts like Gadag and Bellary (northern), Haveri and Chikmagakur (central), Dakshina Kannada (coastal) have shown an increase in crop concentration. For remaining districts, there is no discernible trend in crop diversification. Interestingly, agriculture in Chitradurga, the lowest rainfall receiving district, has remained more diversified than others, while coastal and hilly districts like Dakshina Kannada and Kodagu are at the bottom of crop diversification index. However, the State diversification was steadily improving over the years and this trend was also observed in study conducted by Saraswati *et al.* (2011) where the results showed that diversification was high among horticultural and commercial crops and it was attributed to shift in area towards high value crops and improved livelihood income from alternate crops.

In order to understand the trend in diversification, Coefficient of Variation (CV) in CEI was calculated across districts over the years. The CV had remained nearly constant till 2010, but has increased afterwards. Further, test of significance for the change in CEI was carried out and the results are presented in Table 5. From 2000-01 to 2018-19, there was increase in CEI and it was found to be statistically significant.

However, ranking of the districts had not changed much during 2000-01 to 2010-11. This is explained with the help of correlation matrix of CEI - 2000 - 01, CEI - 2010 - 11 and CEI - 2018 - 19 (Table 6). The correlation coefficients were significant at 1 per cent level between CEI - 2000 - 01 and CEI - 2010 - 11 indicating that neither CEI values nor ranking of districts has changed significantly over time. Similar pattern was observed during CEI - 2010 - 11 and CEI - 2018 - 19 at 5 per cent level of significance. However, the correlation coefficients during CEI - 2000 - 01 and CEI - 2018 - 19 were found to be statistically insignificant indicating CEI values and ranking of districts have changed significantly over time and space (Fig. 1). The similar pattern was reported by Nayak and Kumar (2019) where the crop diversification indices in different periods were highly correlated and found statistically significant.

TABLE 6

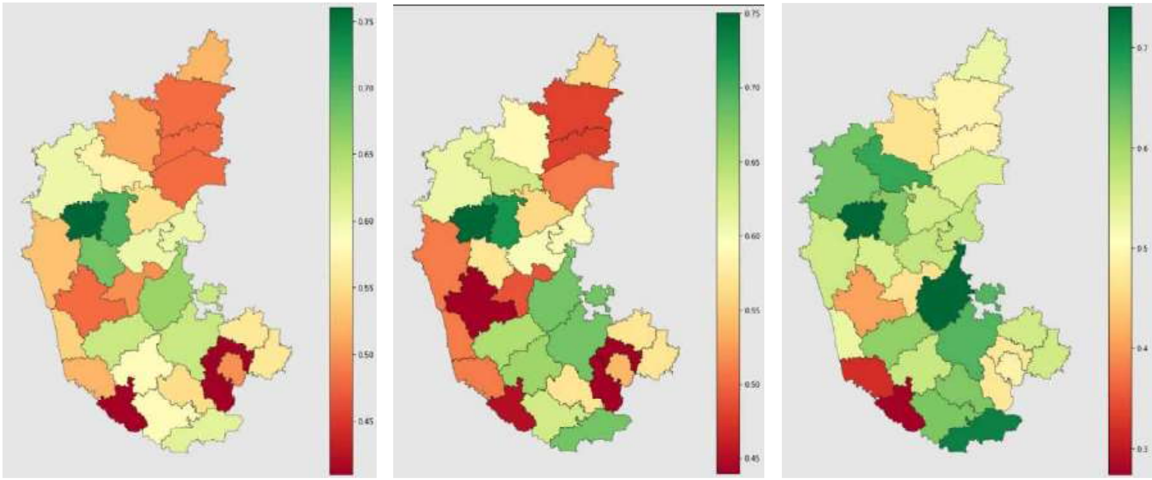
Correlation coefficients

	CEI 2000-01	CEI 2010-11	CEI 2018-19
CEI 2000-01	1	0.982***	0.964
CEI 2010-11	0.982***	1	0.958**
CEI 2018-19	0.964	0.958**	1

Note: '***'- significant at 1 % level, '**'-significant at 5 % level (2-tailed for both)

Shift in Area of Major Crop Groups of Karnataka

The results of transitional probability matrix for Karnataka Table 7, revealed that cereals crops had the highest retention (97.86 %) of area under cultivation followed by pulse crops (95.03 %), oilseed crops (55.91 %) and commercial crops (49.44 %). From the table it was evident that the area lost by cereal crops was majorly shifted to horticulture and plantation crops and commercial crops. Also, the area shift from different crop groups was seen towards horticulture and plantation crops, commercial crops and condiments and



CEI_2000-01 CEI_2010-11 CEI_2018-19

Fig. 1: Spectral changes in crop diversification over time and space in Karnataka

spice crops in the State. Sathishkumar and Umesh (2017) also observed similar trend in shift of area from various crops towards high value crops in the southern dry zone of Karnataka. Hence, the results of the transitional probability matrix are in line with the above study.

There has been a steady rise in crop diversification across the districts in Karnataka. The improvement in crop diversification index for the entire span of 2000 to 2019 was significant. However, a regional divide in crop diversification was observable between the districts (mostly the coastal and hilly region) vis-a-vis other districts. High value crop groups had positive growth over the years indicating good improvement in area and production which eventually enable farm livelihood with better income and food security. But, the instability in these crops was found to be on the higher side compared to cereals crops. Hence, for sustainable agricultural development in the State, integration of horizontal and vertical supply chains, market integration, symmetric price discovery and enhanced processing linkages has to be improved in order to reduce the instability. However, the macro level analysis provide broader picture and status of diversification of the State which may be contradictory to the micro ecosystems depending on regional factors which influence the diversification. However, some insights were provided in study

TABLE 7

Transitional probability matrix

	Cereal crops	Millet crops	Oilseed crops	Pulse crops	Horticulture and Plantation crops	Commercial crops	Condiments & Spices
Cereal crops	0.9786	0.0013	0.0037	0.0000	0.0098	0.0065	0.0000
Millet crops	0.0000	0.3211	0.6789	0.0000	0.0000	0.0000	0.0000
Oilseed crops	0.0000	0.0069	0.9503	0.0000	0.0428	0.0000	0.0000
Pulse crops	0.0164	0.0000	0.0000	0.5163	0.1641	0.0891	0.2142
Horticulture and Plantation crops	0.0000	0.0000	0.0000	0.6832	0.3168	0.0000	0.0000
Commercial crops	0.0000	0.0000	0.0000	0.2246	0.1857	0.4944	0.0953
Condiments & Spices	0.0000	0.0000	0.0000	0.3853	0.0000	0.6037	0.0110

conducted by Basavraj *et al.* (2016) where the micro level evidences on crop diversification were found to be in favor of high value crops in Gadag district of Karnataka. Although the results of the present paper need further scrutiny at micro level, the following broad suggestions are made. As the extent of crop diversification varies across regions, there is a need to go for an agro-climatic regional planning (ACRP) by explicitly recognizing the local resource endowments and constraints of the agro-climatically homogeneous regions.

References

Aheibam, M., Singh, R., Feroze, S. M., Singh, N. U., Singh, R. J. and Singh, A. K., 2017, Identifying the determinants and extent of crop diversification at household level: An evidence from Ukhrul district, Manipur. *Economic Affairs*, **62** (1) : 89 - 95.

Anjum, S. and Madhulika, 2018, Growth and instability analysis in Indian agriculture. *International Journal of Multidisciplinary Research and Development*, **5** (11) : 119 - 125

Basavaraj, N. D., Gajanana, T. M. and Satishkumara, M., 2016, Crop Diversification in Gadag District of Karnataka. *Agricultural Economics Research Review,* **29** (1) : 151 - 158

Bigsten, A. and Tengstam, S., 2011, Smallholder diversification and income growth in Zambia. *J. Afr. Econ.,* **20** (5) : 781 - 822.

Birthal, P. S., Negi, D. S., Jha, A. K. and Singh, D., 2014, Income sources of farm households in India: Determinants, distributional consequences and policy implications. *Agricultural Economics Research Review*, **27** (1) : 37 - 48.

Birthal, P. S., Roy, D. and Negi, D. S., 2015, Assessing the impact of crop diversification on farm poverty in India. *World Development*, **72** : 70 - 92.

Birthal, P. S., Roy, D. and Negi, D.S., 2015, Assessing the impact of crop diversification on farm poverty in India. World Dev., **72** : 70 - 92.

Chand, R. and Raju, S. S., 2008, Instability in Indian agriculture during different phases of technology and policy. National Centre for Agricultural Economics and Policy Research, Discussion Paper: NPP 01/2008.

Chand, R., 1996, Diversification through high-value crops in Western Himalayan region: Evidence from Himachal Pradesh. *Indian Journal of Agricultural Economics,* **41** (4) : 652 - 63.

Cuddy, J. D. A. and Della, V. P. A., 1978, Measuring the instability of time series data. *Oxford Bulletin of Economics and Statistics*, **40** (1) : 79 - 85.

Joshi, P. K., Birthal, P. S. and Minot, N., 2006, Sources of agricultural growth in India: Role of diversification towards high value crops. Discussion Paper 98, Markets, Trade and Institutions Division, International Food Policy Research Institute, Washington, DC.

Kent, F. C., 1924, Elements of Statistics. New York; McGraw - Hill Book Co., Inc., pp. : 87.

Krishan, B. and Chanchal, A., 2014, Agricultural growth and instability in Western Himalayan Region: An analysis of Himachal Pradesh, India. *Journal of Agriculture and Life Sciences*, **1** (1) : 21 - 27.

Kumar, P. and Joshi, P. K., 2017, Food demand and supply projections to 2030: India. Brouwer, F. and Joshi, P. K. (Eds.), International Trade and Food Security: The Future of Indian Agriculture. CABI, Wallingford.

Nadkarni, M. V. and Deshpande, R. S., 1982, Agricultural Growth, Instability in Productivity and Rainfall: Case of Karnataka. *Economic and Political Weekly,* **17** (52) : 127 - 134.

Michler, J. D. and Josephson, A. L., 2017, To specialize or diversify: agricultural diversity and poverty dynamics in Ethiopia. World Dev., **89** : 214 - 226.

Mohan, K. B., Reddy, B. S., Goudappa, S. B., Patil, S. S. and Hiremath, G. M., 2020, Growth performance of pulses in Karnataka, India. *Int. J. Cur. Microbiol. App. Sci.* **9** (02) : 2272 - 2280.

Nayak, C. and Kumar, C. R., 2019, Crop diversification in Odisha: An analysis based on panel data. *Agricultural Economics Research Review,* **32** (1) : 67 - 80

Pandey, V. K., Sharma, K. C., 1996, Crop diversification and self-sufficiency in food grains. *Indian J. Agric. Econ,* **51** (4) : 644 - 651.

Saraswati, P. A., Basavaraja, H., Kunnal, L. B., Mahajanashetti, S. B. and Bhat, A. R. S., 2011, Crop diversification in Karnataka: An economic analysis. Agricultural Economics Research Review, **24** : 351 - 357.

Satishkumar, M. and Umesh, K. B., 2017, Dynamics of cropping pattern and crop diversification in southern dry zone of Karnataka - An econometric analysis. *Mysore J. Agric. Sci.,* **51** (2) : 233 - 239

Shivagangavva, P. D. and Reddy, B. S., 2016, Growth in demand and supply of pulses in India - A normative approach. *J. of Applied and Natural Science,* **8** (4) : 1756 - 1761.

Tripathi, A. and Prasad, A. R., 2009, Agricultural development in India since Independence: A study on progress, performance and determinants. Journal of Emerging Knowledge on Emerging Markets, **1** (1) : 63 - 92.

Mysore J. Agric. Sci., 57 (1) : 388-398 (2023)

Morphometric Evaluation of Selected Jackfruit (*Artocarpus heterophyllus* Lam.) Genotypes / Varieties for the Fruit and Flake Quality Traits

M. D. Valeeta, S. Syamalamma, B. Kalpana and S. N. Nagesha
Department of Plant Biotechnology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : valeeta.marina22@gmail.com

Authors Contribution

M. D. Valeeta : Conceptualization, investigation and original draft preparation;
S. Syamalamma : Conceptualization, draft correction and supervision;
B. Kalpana & S. N. Nagesha : Draft correction and supervision

Corresponding Author :
M. D. Valeeta
Department of Plant Biotechnology,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : August 2022
Accepted : November 2022

Abstract

The current study involved morphometric evaluation of flake and fruit quality traits in nineteen Jackfruit genotypes/varieties. Greater variability was observed in fruit traits *viz*., fruit length (31.5-68.5 cm), fruit diameter (45.5-75.9 cm), fruit weight (2.739-11.185cm) fruit shape (oblong, ellipsoid, spheroid, irregular), fruit rind weight per kg fruit (330-524gm), fruit rind-thickness (0.60-2.90 cm), core-thickness (1.40-8.85cm) and latex exudation (low, medium, high).Variability was also observed in flake quality traits *viz*., flake length (4.34-7.3 cm), flake width (2.95-5.88 cm), flake thickness (0.35-1.66 cm), individual flake weight (13.33-70.50), weight of flakes/kg of fruit (450-709 gm), no. of flakes/kg of fruit(13-29.50), and flake colors (cream, yellow, orange and coppery red). Maximum variation was observed for the flake thickness (52.95%) followed by fruit rind thickness (33.51 cm) and minimum variation was observed for core thickness (2.41cm). Among nineteen genotypes a higher fruit length, fruit diameter, and fruit weight was observed in G1 (68.5 cm), G4 (75.9cm) and G10 (11.185 kg), respectively. Similarly, a higher fruit rind weight per kg fruit was recorded in G8 (524 gm), fruit rind thickness in G19 (2.9 cm) and core thickness in G13 (8.85 cm). ANOVA revealed a significant mean sum of squares for all fruit and flake quality traits except for fruit rind weight/kg of fruit and number of flakes/kg of fruit. Genetic variability, heritability and genetic advance for the 12 characters were analysed. A trend of higher magnitude of PCV than GCV was observed. The estimates of PCV ranged from 15.22- 44.46 per cent and a higher per cent of PCV was recorded for fruit rind thickness (44.46%). The estimates of GCV ranged from 9.23-32.95 per cent, heritability ranged from 26.97 to 99.49 per cent and GAM ranged from 9.87-69.40 per cent.

Keywords : Morphometric evaluation, Jackfruit, Fruit traits, Flake traits, ANOVA PCV, GCV

Jackfruit (*Artocarpus heterophyllus* Lam.) is an important tropical fruit crop in the Moraceae family, native to rain forest of Western Ghats of India. It is a major dry land horticulture crop gaining lot of importance, due to its multiple uses and easy cultivation practices. It is widely cultivated in South Asian countries such as India, Malaysia, Thailand, Vietnam, China as well as in Brazil and Queensland. It is widely distributed across several Southern, Eastern as well as North-Eastern states of India (APAARI, 2012). The area and production of Jackfruit in most of these states is very scanty. However, the recent estimates indicate that, the crop is grown in 18.8 M ha with the production of 1893 MT in India. In Karnataka it is grown in 2.40 M ha with a production of 92.2MT (http://nhb.gov.in/).

Jackfruit is an evergreen, latex producing, monoecious tree producing largest tree borne fruit. The tree grows to a height of 8-25 m by the age of 10-25 years and with a canopy diameter of 3.5-7.0 m. Fruits are usually larger in size (0.5 to 80 kg) and botanically it is called as sorosis, which is formed from the modification of the pistillate flowers. It consists of edible (pulp and seed) and non-edible (rind and rachis) portions (Naik, 1949). Jackfruit is one of the hardy fruit crop and serves as a food for millions of poor people in the countryside during the pre- monsoon and monsoon season, when there is a scarcity of food. Hence it is referred as 'The poor man's food' (Rahman *et al.,* 1995).

Tender green fruit is used as vegetable and the ripe fruit is eaten fresh as dessert. Seeds are also consumed by boiling or by baking. Leaves are used as the source of fodder and wood is extensively used for furniture making. Owing to its multipurpose uses right from fruits to seeds as well as from leaves to wood, every part can be utilized, hence it can be aptly called as second 'Kalpa Vriksha' among trees species (Rahman *et al.,* 1995).

Innumerable types or forms with different fruit characters of Jackfruit *viz.,* (i) Soft fleshed (ii) firm fleshed exists due to cross pollination and they are mainly grouped into two textural forms. One with soft flesh, pulpy perianth with high fibre and less shelf life and the other one is firm fleshed with thick and firm carpels which are used for table purpose and value addition (Rahman *et al.,* 1999). Based on flake colour they are grouped mainly into four types owing to its carotenoid compositions such as cream, yellow, orange and coppery red types (Kavya *et al*., 2019).

Similarly, Jagadeesh *et al*. (2007) analyzed the bio-chemical composition of the flakes from the firm type jackfruit clones and reported total carotenoid contents ranging from 0.363mg to 0.879mg/100g of fresh weight. These clones were further classified as yellow, light yellow, cream, lemon yellow, deep yellow, saffron, orange and deep saffron types.

Variations also exist in fruit weight, number of flakes per fruit, flake thickness, sensory quality, flesh type, sweetness, flavor and taste. Such variations will be helpful for development of new varieties or selections in crop improvement (Phaomei *et al.,* 2017). One such variations was reported by Rana *et al.* (2018) with a varying fruit shape having a length of 30 to 100 cm and a diameter of 15 to 50 cm and with individual fruit weight of 10 - 25 kg or more.

Uikey *et al*. (2020), recorded a longer fruit length of about 42.67 cm in GDJF-9 genotype followed by 36.00 cm in GDJF-13 genotype and a lower length of 20.80 cm was recorded in GDJF-7.

Kavya *et al.* (2019), studied twenty jackfruit genotypes across the various districts of Karnataka with the superior traits and reported the highest fruit weight of about 23.20 kg with an average fruit length and diameter of about 38.15 cm and 22.58 cm respectively.

A study was under taken by Shyamalamma *et al*. (2008) in jackfruit and assessed carotenoids content in five different pulp colors of Jackfruit. Results revealed that, the red and orange color pulp contained significantly higher concentrations of β-Cryptoxanthine (45.44mg/100g) followed by β-Carotene (43.14 mg / 100 g), α-Carotene (39.40 mg / 100 g) and Lycopene (30.20mg/100g) respectively.

The ripe Jackfruit flakes have a high nutritional value and are rich source of carbohydrates (16-25. 40 g), protein (1.20-1.90 g), fat (0.10-0.40 g), fiber (1.0-1.5 g) per 100g edible portion. Jackfruit also contains minerals such as calcium (20.0-37.0 mg), potassium (191-407 mg), iron (0.50-1.10 mg), sodium (2.0-41.0 mg), phosphorus (38.0-41.0 mg), magnesium (27.0-54.0 mg) and vitamins such as vitamin A (38.0-41.0IU), thiamine (0.03-0.09 mg) and riboflavin(0.05-0.4 mg) per 100g edible portion (Mukprasirt and Sajjaanantakul, 2004).

Fruit extract exhibited antimicrobial activities (Ragas *et al*., 2004) and it is also rich in anti oxidants, phenols and flavonoids contents (Shanmugapriya *et al.,* 2011). Because of its higher nutritive value, it is gaining popularity in western countries, thus the ethnic and mainstream marketing opportunities are plenty. In this regard fruit quality and flake quality parameters were studied in order to obtain the best suitable genotypes / variety for the table purpose, processing purpose as well as for the crop improvement programme, So that the farmers can take up Jackfruit farming as an alternative along with the other commercial fruit crops.

Material and Methods

Experimental Material

The present study consisted of 19 genotypes / varieties of Jackfruit collected from different places of Karnataka. These are selected based on varied flake colours such as cream, yellow, orange and coppery red. The genotypes/ varieties used in the study are listed in Table 1 and depicted in Plate 1.

Table 1

List of genotypes used in the present study

Treat-ment no.	Genotypes used	Location
G1	Siddu	Seegenahalli, Tumkur
G2	Janagere	Janagere, Magadi
G3	Kemparaju	Kodiyala, Tumkur
G4	Lakshminarayanrao	Hosakere, Tumkur
G5	Umashankar	Biligerepalya,Tiptur
G6	Subanna	Bomanahalli, Doddballapura
G7	Nelagudige	Nelagudige, Doddballapura
G8	Singapur Jack	GKVK ,Bengaluru
G9	Ramachandra	GKVK,Bengaluru
G10	Byrachandra	GKVK,Bengaluru
G11	Malaysia jack	GKVK,Bengaluru
G12	HV-1	GKVK,Bengaluru
G13	Gumless	GKVK,Bengaluru
G14	Swarna	GKVK,Bengaluru
G15	Thailand pink	GKVK,Bengaluru
G16	Malleshwaram red	GKVK,Bengaluru
G17	Lalbaug madhura	GKVK,Bengaluru
G18	Tubagere red	GKVK,Bengaluru
G19	KT-17	Kachahalli, Doddballapura

Methods

Three average sized fruits were collected from the above said genotypes / varieties during two seasons of the year 2020-21 and 2021-22, from various places in Karnataka as well as the Jackfruit Garden, Department of Plant Biotechnology, University of Agricultural Sciences (UAS), GKVK, Bengaluru. The observations were recorded as per the DUS Jackfruit descriptors on fruit quality and flake quality traits (PPV and FRA, 2020).

Statistical Analysis

The data recorded on the above mentioned fruit and flake quality traits were statistically analysed using Microsoft Excel and RStudio software.

ANOVA

Analysis of variance (ANOVA) was performed to detect significant differences among the jackfruit genotypes using Microsoft Excel and RStudio software.

Variability Parameters

To estimate the contribution made by each factor to variation, GCV (Genotypic coefficient of variation), PCV (Phenotypic coefficient of variation), broad sense heritability, GA (Genetic advance) and GAM (Genetic advance as *per cent* of mean) were estimated.

Results and Discussion

ANOVA

ANOVA is the diagnostic step to detect different sources of variation relevant to the results of field experiments such as those being reported in the present study. ANOVA revealed significant mean squares attributed to test genotypes for all the fruit quality traits except for fruit rind weight per kg of fruit (Table 2) and for all the flake quality except for weight of flakes / kg of fruit (Table 3). These results indicated substantial differences among the genotypes for fruit quality and flake quality traits such as fruit length, fruit diameter, fruit weight, rind thickness, core thickness, flake length, flake width, flake thickness, individual flake weight and number of flakes / kg of fruit and thus provide justification for their use in the present study. Further, there is no significant differences among the genotypes for fruit rind weight per kg of fruit and the weight of flakes per kg of fruit. This suggests that the above said traits are almost similar in all genotypes.

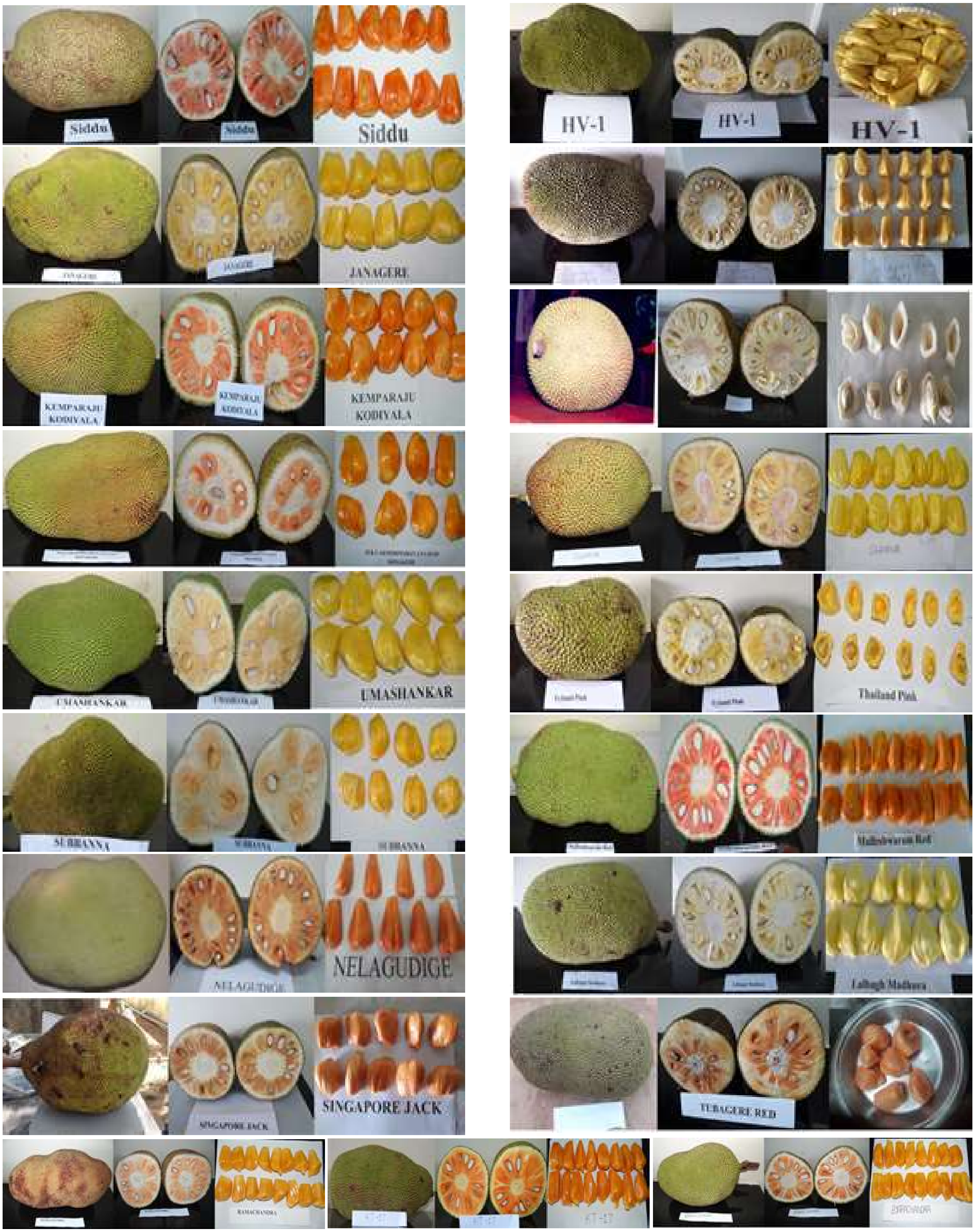


Plate 1 : Jackfruit genotypes /varieties used in the study

TABLE 2

ANOVA of Jackfruit genotypes for fruit quality

Source of variation	DF	MSS					
		Fruit length	Fruit diameter	Fruit weight	Rind weight /kg of fruit	Rind thickness	Core diameter
Replication	1	0.24	97.37	0.005	9904.79	0.014	0.37
Genotypes	18	174.9**	199.8*	13.82**	7013.83	0.65*	179.4**
Error	18	22.9	85.92	2.71	4034	0.25	0.018

*Significance at P=0.05, **Significance at P=0.01

TABLE 3

ANOVA of Jackfruit genotypes for flake quality

Source of variation	DF	MSS					
		Flake length	Flake width	Flake thickness	No of flakes/ kg of fruit	Wt of flakes/ kg of fruit	Individual flake wt
Replication	1	0.41	0.17	0.16	1.68	0.014	16.64
Genotypes	18	1.12*	0.95*	0.26**	78.19*	0.65	174.93**
Error	18	0.46	0.38	0.18	3.68	0.25	20.61

*Significance at P=0.05, **Significance at P=0.01

Morphological Evaluation of Selected Jackfruit Genotypes for Fruit Quality

A total of seven quantitative characters of the fruit were recorded and evaluated to know the genetic variability among the studied nineteen jackfruit genotypes / varieties. Wide range of variation was observed among the genotypes in terms of fruit length, fruit diameter, fruit weight, fruit shape, fruit rind weight per kg fruit, fruit rind thickness, core thickness and latex exudation (Table 4).

Fruit length (*cm*) : Fruit length plays a major role in determining the size, shape as well as edible portion of the fruit. Longer sized fruits are preferred for the export purposes whereas smaller sized fruits are preferred for house hold consumption. In the present findings, fruit length varied from 28 to 69 cm with a mean value of 48.33cm. Longer fruit length was recorded in G17 (68.5 cm) followed by G18 (63.5 cm) and smaller fruit length was (31.5 cm) in genotype G5. Similarly, a firm flesh type with the higher fruit length of about 68.5 cm was reported by Karunarathne *et al*. (2018) in Sri Lankan region.

Fruit diameter (*cm*) : Diameter of the fruits is directly proportional to flake size and to some extent to the number of flakes. The results on fruit diameter revealed significant variation in fruit diameter (Table 4). The higher (75.9 cm) fruit diameter was recorded in G4 genotype and the lower was in G18 (45.5 cm) genotype, with a mean of 62.51 cm. The coefficient of variation for fruit diameter was 14.82. Similar findings were reported by Dey and Baruah (2019) with fruit diameter varying from 74 cm to 49.67 cm.

Fruit weight (*kg*) : In a study carried out by Gayatri *et al*. (2020) reported a small Jackfruit genotype with a oblong fruits known as Rudrakshi, weighing an average of two to five kg. Similarly the higher and the lower fruit weight of about 17.50 kg and 1.69 kg respectively was reported by Krishnan *et al.* (2015) from the jackfruit collection of Kuttanad region. These results revealed a significant variation in fruit weight among the jackfruit genotypes with a fruit weight ranging from 2.73 kg to11.18 kg. Among the present genotypes, the higher fruit weight was recorded in G10 (11.18 kg) followed by G12 (11.02 kg) with a mean fruit weight of 7.33kg.

Fruit rind weight per kg fruit (*gm*) : Higher fruit rind weight is not a desirable quality for its use in

TABLE 4

Morphometric evaluation of selected jackfruit genotypes for fruit quality

Genotypes	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (kg)	Fruit rind weight per kg fruit (gm)	Fruit rind thickness (cm)	Core thickness (cm)	Latex exudation	Fruit shape
G1	53	67	9.922	330	1.45	5.05	M	E
G2	54.5	67.5	8.1245	392.5	0.80	6.10	L	E
G3	44.25	47.5	4.656	436	1.10	5.25	H	E
G4	49.65	75.9	9.391	522	2.40	6.03	L	E
G5	31.5	50.75	2.739	440.5	1.00	3.95	H	O
G6	42.5	66.25	6.04	441.5	1.35	5.00	H	E
G7	54	69.75	10.9625	430	2.05	6.45	H	E
G8	50	69.5	8.43	524	1.75	7.75	L	O
G9	48.5	66	8.322	413.5	1.25	5.10	H	O
G10	45.5	64.5	11.185	368.5	0.60	6.75	M	O
G11	37.5	55	3.33	413	1.40	5.40	M	E
G12	55.17	75.45	11.025	491.25	1.72	8.85	M	E
G13	53.5	61	6.1	430	0.95	8.65	L	O
G14	44	75.5	6.0835	389.5	1.70	6.70	H	S
G15	35.75	46.75	3.53	415	1.10	7.80	M	E
G16	37	65.25	6.33	335	1.60	1.40	H	I
G17	68.5	51.615	8.935	486.5	1.65	3.90	M	O
G18	63.5	45.5	6.12	342	2.10	3.05	M	O
G19	50	67	8.016	347.5	2.90	4.20	M	O
Mean	48.33	62.51	7.33	.418.33	1.52	5.65		
CV	9.90	14.829	22.48	15.18	33.51	2.413011		
SE	3.38	6.55	1.16	44.91	0.36	0.09643		
CD (5%)	10.054	19.47	3.46	133.43	1.069	0.28651		
Significance	S	S	S	NS	S	S		

*L-Low, **M-Medium, *** H-High; * E-Ellipsoid, **O-Oblong, ***S-Shperoid ****I-Irregular

value addition or for table purposes. Weight of rind is indirectly proportional to edible portion of fruit, and it ranged from 250 to 550 gm with a mean value of 418.33 gm. The higher fruit rind weight per kg of fruit was recorded in G8 (524 gm) and the lower fruit rind weight was recorded in G1 (330 gm). At the same time, thicker rind will help to protect fruits from post-harvest damages. Non-significant differences were observed in the fruit rind weight per kg of fruit among the genotypes studied.

Fruit rind thickness (*cm*) : Higher fruit rind thickness renders lower edible portion of the jackfruit. It varied significantly with a range of 0.6 to 2.9 cm among nineteen jackfruit genotypes. The higher fruit rind thickness of 2.9 cm was recorded in G19 and a lower thickness was recorded in G10 (0.6 cm). These results are in accordance with Akter and Rahman (2017), who reported a maximum rind thickness of about 2.5 cm.

Fruit shape : Fruit shapes such as ellipsoid, clavate, oblong, spheroid, irregular were recorded among the nineteen genotypes. Spheroid and oblong shaped fruits are more preferable for the market purposes as they are in perfect shapes and one can expect higher flake number. In present study, nine genotypes (G1, G2, G3, G4 G6, G7, G11, G12, G15) were ellipsoid in shape, eight genotypes (G5, G8, G9, G10, G13, G17, G18, 19) were oblong in shape and few genotypes such as G14 and G16 were spheroid and irregular in shape. Wann (2012) reported wide variations in fruit shape of jackfruit ranging from ellipsoid, oblong, spheroid and irregular shape. Variation in fruit shape may be due to the combined effect of genetic traits and the nature of pollination. Uniform pollination results in complete fruit set and provide a definite fruit shape whereas inadequate pollination gives irregular shaped fruits (Dey and Baruah, 2019).

Core thickness (*cm*) : Similar to the rind thickness, higher core thickness is also not preferred, as it reduces the edible portion of the fruit. Among the genotypes the core thickness was higher in G12 (8.85 cm) followed by in G13 (8.65 cm). Lower core thickness was recorded in G16 (1.4 cm). Wangchu *et al.* (2013), reported core diameter ranging from 0.29 cm to 2.16 cm with a general mean of 0.54 cm.

Latex exudation : The consumer preferences for Jackfruit in the market also depends on the latex exudation. Higher latex content also hampers with the Jackfruit cutting. Latex exudation was found to be high in 7 genotypes, medium in 9 genotypes and low in 3 genotypes. Nowadays there is a lot of scope for identification and improvement of gumless genotypes. The gumless type of Jackfruit with medium to low latex with a medium fruit size (6.4-9kg) was developed at Indian Institute of Horticultural Research, Bengaluru (APAARI, 2012).

Morphological Evaluation of Selected Jackfruit Genotypes for Flake Quality Traits

Flake Length

The mean flake length among the genotypes was 5.69 cm. Higher flake length was observed in G17 (7.3cm) followed by G9 (7cm) and a lower flake length of about 4.34cm was observed in G5 genotype. Similar results were found by Dey and Baruah (2019) with a higher flake length of 7.37 cm. The variation in flake length might be attributed to genetic character of the individual genotype.

Flake Width

The observations on flake width (Table 5) revealed that, there is significant variations in flake width among the genotypes. The broader flake width of 5.88 cm was recorded in G6 genotype and it was lower in G10 (2.95 cm) and the mean flake width recorded at 4.45 cm. A comparable results were obtained by the Paulpi and Daryono (2021), with a flake width ranging from 2.3-5.7 cm.

Flake Thickness

Flakes with higher thickness is favoured for canning purposes on the other hand flakes with lower thickness is preferred for chips making. The thickness of the flakes in the present study ranged from 0.35 cm to 0.95 cm with the mean flake thickness of 0.8cm. Higher thickness of flake was observed in G3 (1.66cm) followed by G17 (1.6cm) and a lower flake thickness was observed in G13 (0.35cm). Similar results were reported by Krishnan *et al.* (2015), with a higher flake thickness of about 0.63 cm in APJ-2 genotype, which was collected from Kuttanad regions of Kerala.

Individual Flake Weight (gm)

It plays a major role in determining the economic value of the fruit. Lower the flake weight higher the number of flakes per fruit and also to some extent proportionate to the fruit weight. Fruits with higher flake weight are considered more attractive than the smaller ones. Individual flake weight differed significantly with a maximum flake weight (70.50 gm) recorded in G17 followed by G06 (55.75 gm) and minimum was in G9 (13.33gm) genotypes. A higher individual flake weight of 42.5cm and a lower individual flake weight of about 15gm was reported by Rai *et al.* (2003).

Weight of Flakes / kg of Fruit

This parameter is economically important in terms of yield. The weight of the flakes per kg of fruit was higher in G4 (858 gm) followed by G 10 (709 gm). The lower weight was recorded in G8 (450gm). Dey and Baruah (2019) reported a higher weight of

TABLE 5

Morphometric evaluation of selected jackfruit genotypes for flake quality

Genotypes	Flake length	Flake width	Flake thickness	Individual flake wt	Wt of flakes/ kg of fruit	No of flakes/ kg of fruit	Flake color
G1	6.095	4.71	0.75	46.70	645	20.50	Coppery Red
G2	5.24	4.31	0.78	41.75	617.5	15.50	Yellow
G3	5.57	4.33	1.66	38.18	607	13.00	Coppery Red
G4	6.1775	5.17	1.24	37.20	858	13.00	Coppery Red
G5	4.34	4.06	0.66	29.60	485.5	19.50	Yellow
G6	6.33	5.88	1.17	55.75	576.5	11.00	Orange
G7	5.71	4.47	0.76	50.50	558	11.50	Orange
G8	5.175	4.43	0.645	16.33	450	15.50	Orange
G9	7	4.50	0.65	13.33	581	28.50	Orange
G10	5.35	2.95	0.625	13.50	709	31.00	Orange
G11	5.5	5.65	0.6	19.00	528	24.00	Yellow
G12	5.16	3.93	0.37	31.67	567.5	15.50	Cream
G13	4.65	3.95	0.35	55.63	540	29.50	Cream
G14	5.81	3.93	0.7	37.33	555	17.00	Yellow
G15	5.225	4.30	0.55	22.00	527.5	18.50	Yellow
G16	5.1375	4.02	0.61	35.50	667	25.00	Coppery Red
G17	7.3	5.25	1.6	70.50	603.5	13.50	Yellow
G18	6.19	3.90	0.865	41.00	505	13.50	Coppery Red
G19	6.3	4.87	0.78	34.33	541.5	16.50	Coppery Red
Mean	5.69	4.45	0.809	36.3	525.79	18.56	
CV	11.9	13.9	52.95	12.5	10.218	10.36	
SE	0.48	0.43	0.30	3.21	42.29	1.36	
CD(5%)	1.43	1.301	0.89	9.54	125.67	4.032	
Significance	S	S	S	S	NS	S	

flakes/ kg fruits in SON1 genotype (540gm) followed by KA3 (480gm) genotype, among 22 accessions collected from the Assam region.

Number of Flakes / kg of Fruit Weight

It is directly proportional to weight of the individual flakes and a lower flake number is preferred for the commercial purposes. The number of flakes varied significantly among the genotypes and it ranged from 11 to 29 with a mean value of 18.56. The higher number of flakes were found in G13 (29.5) followed by G9 (28.50) genotype and the lower number of flakes/ kg of fruit was found in G6 (11). Chandrashekar *et al.* (2018) reported varying no of flakes / kg fruit weight in HRS TKD AH-5 (24.19) and HRS TKD AH-14 (22.85) genotypes respectively, which were grown under coffee ecosystem of lower Pulney hills in Tamil Nadu.

Flakes Colour

Colour of the flakes often results from the carotenoid content. It differs from genotype to genotype based on the different agro climatic zones. Flake colour is also of economic importance since the consumer preference for coppery red colour is more followed by orange coloured flakes. In the present study, the genotypes with four flake colours were identified. Among them coppery red (31.57%), yellow (37.57%), orange (26.31%) and cream (10.52%) were observed. Akter and Rahman (2017), reported distinctly varied flake colours among the twenty-three jackfruit germplasms in Bangladesh region. The colours varied from yellow (73.91%), whitish yellow (17.39%) and cream colour (8.70%).

Genetic Variability, Heritability and Genetic Advance

The GCV and PCV values for the 12 characters studied are presented in Table 6. A trend of higher magnitude of PCV than that of GCV, indicates the influence of environmental factors on the expression of the traits evaluated in the present study (Table 6).

Phenotypic Co-efficient of Variation (PCV) and Genotypic Co-efficient of Variation (GCV)

As expected, the magnitude of PCV was higher than the corresponding GCV for all the traits. The estimates of PCV ranged from 15.22 to 44.46 per cent. Higher percentage of PCV (> 30%) was recorded for rind thickness (44.46%), fruit weight (39.24%), no of flakes per kg of fruit (34.54%) and core diameter (33.86%).

Moderate estimates (10 to 30%) were recorded for individual flake weight (27.24%), flake thickness (22.82%), fruit length (20.58%), fruit diameter (19.12%), flake width (18.40), rind weight per kg of fruit (17.77%), flake length (15.62%) and weight of flakes per kg of fruit (15.22%). GCV ranged from 9.23 to 32.95 per cent and the higher estimates of GCV (>30%) was recorded in core diameter (33.78%), number of flakes per kg of fruit (32.95%) and fruit weight (32.16%). Lower estimates (10 to 30%) were recorded for rind thickness (29.20%), flake thickness (27.03%) individual flake weight (24.19%), fruit length (18.04), fruit diameter (12.07%), flake width (12.03%), weight of flakes per kg of fruit (11.28%) and flake length (10.08). However rind weight per kg of fruit (9.23%) showed lesser estimate (<10%).

Similar observations were made by Chandrashekar *et al.* (2018), with a maximum GCV in yield (83.94%), followed by fruit productivity (75.58%), fruit stalk length (62.65%), number of fruit per cluster (62.08%), flake (flakes) / seed ratio (52.56%), fruit core weight (51.20%) and fruit weight (47.62%),

TABLE 6

Estimation of components of variance, coefficient of variance, heritability, genetic advance over mean in Jackfruit varieties/genotypes for fruit and flake traits

Traits	Mean	Range		Co-efficient of variability (%)		H^2	GAM
		Min	Max	GCV	PCV		
Fruit length	48.33	28.00	69.00	18.04	20.58	76.84	32.57
Fruit diameter	62.51	32.00	83.00	12.07	19.12	39.85	15.70
Fruit weight	7.32	2.00	11.85	32.16	39.24	67.17	54.29
Rind weight /kg of fruit	418.32	250.00	550.00	9.23	17.77	26.97	9.87
Rind thickness	1.52	0.50	4.30	29.20	44.46	43.15	39.52
Core diameter (cm)	5.65	1.40	8.85	33.78	33.86	99.49	69.40
Flake length	5.69	3.24	8.00	10.08	15.62	41.67	13.41
Flake width	4.45	2.90	6.30	12.03	18.40	42.78	16.22
Flake thickness	0.67	0.35	0.95	27.03	22.82	71.26	39.67
Individual flake weight	36.30	12.00	71.00	24.19	27.24	78.91	44.28
No of flakes/kg of fruit	18.52	10.00	32.00	32.95	34.54	91.00	64.74
Wt of flakes/kg of fruit	585.4	378.00	896.00	11.28	15.22	54.94	17.23

whereas minimum was observed in case of leaf blade length (13.79%).

Heritability (Broad sense) : Heritability provides information regarding the amount of transmissible genetic variation. It also determines response to selection. High heritability estimates are helpful in making selection of superior genotypes apparently from phenotypic performance. In the present study, heritability values ranged from 26.97 to 99.49 *per cent*. The estimates of heritability were high for core diameter (99.49%), number of flakes/ kg of fruit (91.00%) followed by individual flake weight (78.91%) and fruit length (76.84%). Chandrashekar *et al*. (2018), reported broad sense heritability of 83 per cent in fruit length , 92.16 per cent in fruit weight, 80.18 per cent in fruit diameter, 93.16 per cent in no of flakes per fruit, 76.02 per cent in flake length and 88 per cent in flake width.

Genetic Advance as per cent of Means (GAM)

The estimates of expected GAM ranged from 9.87 to 69.40 per cent. The expected GAM was least for fruit rind weight / kg of fruit (9.87%) followed by flake length (13.41%) and the estimates of expected GAM were high for core diameter (69.40%) followed by no of flakes per kg of fruit (64.74%) (Table 6).

Debnath and Deb (2022), reported very high genetic advance for fruit core weight (498.40%), 100 seed weight (301.20%), fruit stalk length (201.45%). The moderate genetic advance was observed for fruit productivity (133.70%) and weight of flakes per kg fruit (129.74%). Extremely low genetic advance was recorded for acidity percentage of ripe fruit (0.05%), flake / fruit ratio (0.12%), seed width (0.93%), seed length (1.21%), shelf life of fruit (1.30%) and flake width (1.79%). High heritability coupled with high expected GAM indicates effectiveness of selection for the fruit and flake quality traits among the Jackfruit genotypes. Thus, in the present study the following genotypes can be selected based on two years data recorded.

Trait	Table purpose	Value addition
Fruit weight	G5	G10
Indiviual flake weight	G17	G9
Weight of flakes/kg of fruit	G10	G8
No.of flakes/kg of fruit	G6	G9
Flake length	G17	G5
Flake thickness	G3	G13

References

AKTER, A. AND RAHMAN, H. 2017, Evaluation of jackfruit (*Artocarpus heterophyllus* Lam.) germplasm. *Research & Reviews: J. Bot*., **7 (1)** : 38 - 53.

APAARI, 2012, Jackfruit Improvement in the Asia-Pacific Region - A status report. Asia pacific association of Agricultural Research Institutions, Bangkok, Thailand. pp. : 182.

CHANDRASHEKAR, K. G., VIJAYAKUMAR, R. M., SUBRAMANIAN, S., KAVINO, M. AND JOHN, J.A., 2018, Morphological characterization of jackfruit (*Artocarpus heterophyllus* Lam.) Local genotypes under coffee ecosystem of lower pulney hills. *Int. J. Curr. Microbiol. App. Sci.,* **7 (3)** : 2210 - 2224.

DEBNATH, A. AND DEB, P., 2022, Study on genetic variability estimates of jackfruit (*Artocarpus heterophyllus* Lam.) Germplasm at northern regions of tripura state, India. *Curr. J. Appl. Sci.*, **41 (17)** : 1 - 8.

DEY, B. AND BARUAH, K. 2019, Morphological characterization of jackfruit (*Artocarpus heterophyllus* Lam.) of Assam. *Int. J. Curr. Microbiol. App. Sci.*, **8** (11) : 1005 - 1016

GAYATRI, KAVYA, K. AND SHYAMALAMMA, S., 2020, Characterization of selected jackfruit germplasm accessions for fruit shape through morphological and marker based assay. *Indian J. Agric Res.*, **54** (5) : 599 - 604.

JAGADEESH, S. L., REDDY, B. S., BASAVARAJ, N., SWAMY, G. S. K., GORBAL, K., HEGDE, L. AND KAJJIDONI S, T., 2007, Inter tree variability for fruit quality in jack fruit selections of western ghats of India. *Sci. Hort.*, **112** (4) : 382 - 387.

KARUNARATHNE, S. I., RANAWEERA, L. T., DAUNDASEKERA, D., ANANDA, G. K., KANNANGARA, S. K., RANATHUNGA, A. P., MADHUKALPANI, O., WEEBADDE, C. AND SOORIYAPATHIRANA, S. S., 2018, Assessment of the applicability of morphometric, organoleptic and phylogenetic analyses to differentiate soft and firm flesh bearing trees of jackfruit (*Artocarpus heterophyllus* Lam.) *in Sri Lanka. J. Agric. Sci.,* Sri Lanka., **13** (3) : 200 - 218.

KAVYA, K, SHYAMALAMMA, S. AND GAYATRI, 2019, Morphological and molecular genetic diversity analysis using SSR markers in jackfruit (*Artocarpus heterophyllus* Lam.) genotypes for pulp colour. *Indian J. Agric. Res.,* **53** (1) : 8 - 16.

KRISHNAN, G. G., JAYALEKSHMI, ELIZABETH, J. AND THUSHARA, S. S., 2015, Assessment of physic-chemical properties of jackfruit collections from kuttanand region of Kerala. *Asian J. Hort.*, **10** (2) : 262 - 266.

MUKPRASIRT, A. AND SAJJAANANTAKUL, K., 2004, Physico-chemical properties of flour and starch from jack fruit seed, *Int. J. Food Sci. Technol,* **39** (3) : 271 - 276.

NAIK, K. C., 1949, South Indian Fruits and Their Culture. P. Varadachery & Co, Madras, 300 - 302.

PHAOMEI, G., PEREIRA L.S. AND MATHEW, B., 2017, Diversity of jackfruit (*Artocarpus heterophyllus* Lam.) in rongram block of west garo hills, meghalaya. *Int. J. Sci. Environ. Technol.,* **6** (3) : 1940 - 1947.

RAGASA C. Y., JORVINA K. AND RIDEOUT J. A., 2004, Antimicrobial Compounds from *Artocarpus heterophyllus*. *Philipp J. Sci.,* **133** (2) : 97 - 101.

RAHMAN, A. K., HUQ, M. M., MIAN, E. AND CHESSON, A., 1995, Microscopic and chemical changes occurring during the ripening of two forms jackfruit (*Artocarpus heterophyllus* L). *Food Chem*., **52** : 405 - 410.

RAHMAN, M. A., NAHAR, N., MIAN, A. J. AND MOSIHUZZAMAN, M., 1999, Variation of carbohydrate composition of two forms of fruit from jack tree (*Artocarpus heterophyllus* L.) with maturity and climatic conditions, *Food Chem*., **65** : 91 - 97.

RAI, M., NATH, V., DAS, B., RAVI, A. AND KUMAR, M., 2003, Evaluation of Jackfruit genotypes for yield and quality attributes under Eastern Indian condition. *Orissa J. Hort.* **31** (1) : 1 - 6.

RANA, R. C., PRADHAN AND MISHRA, S., 2018, Variation in properties of tender jackfruit during different stages of maturity. *JFST*., **55** (6) : 2122 - 2129.

SHANMUGAPRIYA K., SARAVANA P. S., PAYAL, H., MOHAMMED S. P. AND BINNIE, W., 2011, Antioxidant activity, Total phenolic and flavonoid contents of *Artocarpus heterophyllus* and *Manilkara zapota* seeds and its reduction potential. *Int. J. Pharm. Sci.,* **3** (5) : 256 - 260.

SHYAMALAMMA, S., CHANDRA, S. B. C., HEGDE, M. AND NARYANSWAMY, P., 2008, Evaluation of genetic diversity in jackfruit (*Artocarpus heterophyllus* Lam.) based on amplified fragment length polymorphism markers. *Genet. Mol. Res.,***7** (3) : 645 - 656.

UIKEY, A., EKTA, P. N. AND POONAM, M., 2020, Evaluation of different jack fruit cultivars for their physical parameters fruit. *Int. J. Curr. Microbiol. App. Sci.,* **11** : 3022 - 3026.

WANGCHU, L., SINGH, D. AND MITRA, S. K., 2013, Studies on the diversity and selection of superior types in jackfruit (*Artocarpus heterophyllus* Lam). *Genet. Resour. Crop Evol.*, **60** : 1749 - 1762.

Mysore J. Agric. Sci., 57 (1) : 399-408 (2023)

Response of FYM and Bio Digester Liquid Manure (BDLM) on Productivity and Soil Properties of Finger Millet [*Eleusine coracana* (L.) Gaertn] under Dryland Condition

B. G. Vasanthi, Mudalagiriyappa, K. M. Puneetha, M. C. Harish and M. Madan Kumar
All India Co-ordinated Research Project for Dryland Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : mudal68@yahoo.com

Authors Contribution

B. G. Vasanthi : Investigation and drafting;
Mudalagiriyappa : Monitoring and reviewing;
K. M. Puneetha & M. Madan Kumar : Preparation of manuscript and review;
M. C. Harisha : Chemical analysis

Corresponding Author :
B. G. Vasanthi
All India Co-ordinated Research Project for Dryland Agriculture, UAS, GKVK, Bengaluru

Received : November 2022
Accepted : February 2023

Abstract

A field experiment was carried out at ARS, Balajigapade in reddish brown sandy loam soil during *kharif*-2019 to study the 'Response of FYM and Bio digester liquid manure (BDLM) on productivity and soil properties of finger millet (*Eleusine coracana* (L.) Gaertn) under dryland condition'. The experiment was laid out in Factorial Randomised Block Design consisted of two different factors of organic manures *viz.*, FYM and BDLM applied at three different levels, nine treatments were replicated thrice. The results showed that among different levels of FYM application, application of FYM 10 t ha^{-1} gives significantly higher grain (3148 kg ha^{-1}) and straw yield (4458 kg ha^{-1}) and was on par with FYM 7.5 t ha^{-1}, whereas application of different levels of BDLM alone did not have significant implication on yield of finger millet. however significant effect on higher soil available nutrients *viz*, N, P, K, Ca, Mg, Mn, Fe and Cu and soil enzymatic activities was also recorded with conjugate application of FYM 10 t ha^{-1} (M3) and BDLM @ 125 per cent N equivalent.

Keywords : : FYM, Bio-digester liquid manure, Finger millet

Finger millet (*Eleusine coracana* L.) is one among the foremost important millet grown for both grain and fodder purpose and ranks third in importance among millets in India after sorghum and pearl millet. Finger millet is not only a major food grain crop but also an excellent fodder for cattle. The recent energy crisis, hike in the prices of the inorganic fertilizers and declining soil health and productivity requires the use of organic manures compulsorily in agricultural crop production. Use of chemical fertilizers has not only increased the crop yields but has caused many environmental hazards like soil, air and water pollution finally human health hazards, thereby making the crop productivity unsustainable. The increasing costs of fertilizers prevent their use by resource poor farmers.

Organic farming is the most effective approach to address all these concerns and the consumers need. It is resource conserving and helps to maintain soil health and fertility. With increasing hazards by using the synthetic chemicals in agro ecosystems, organic farming provides an alternative option for both sustaining productivity and retaining soil health with chemical residue free food. Today, organic farming is a well-researched science that combines the knowledge of soil fertility, plant pathology, entomology and other biological and environmental sciences. It does not use the non-renewable external inputs and energy. Since, no chemical are used for crop production there are low chances of pesticide residues in food. The decrease in cattle population in recent years and utilization of agricultural wastes into valuable by-products has made the availability of organic manure in agriculture questionable both in time and quantity.

In this context depletion of soil health, which results in decline or stagnation in yield of many staple food crops, the use of organics plays a predominant role in sustaining the soil fertility, besides offering avenue for converting wastes into wealth by effective recycling. Addition of organics will provide dual benefit of improving tropical soil by adding nutrients and improving soil moisture retention overall enhancing soil physical and biochemical properties. Greater opportunities exist for increased crop production by increasing the rate, timing and by improving management of mineral fertilizers (Ramachandrappa *et. al.,* 2013).

Farmyard manure is the most commonly used organic manure in India. It consists of a mixture of cattle shed wastes containing dung, urine, bedding material and some left-over straw and feeding wastes. The nutrient content of FYM varies with the constituents or composition of different organic materials used for its production.

Non-availability of sufficient quantity of farmyard manures has drawn the attention of many researchers and cultivators to utilize the on-farm wastes, green biomass of *Glyricidia maculata, Pongamia pinnata etc.* and ubiquitous weeds *viz., Parthenium histirophorous*, *euphotorium*, lantana, calatropis, *etc*., for biodigested liquid manure production can substitute the farmyard manure and compost (Ananda and Sharanappa., 2017).

Bio digester Liquid Manure (BDLM) is the low cost on farm input, capable of supplying the nutrients for the growing crop. It is prepared by mixing organic residues like cattle wastes, weed biomass, crop residues *etc.,* in large quantity which is allowed to ferment in the bio digester tank for mineralization. Within 20-30 days this liquid manure can be used as nutrient source. It is not only a good source of macro and micro nutrients to crop but also adds enormous beneficial microbial load to soil (Reddy *et al.,* 2008).

Liquid bio-digester manure has been used for finger millet, paddy, maize, redgram, groundnut, soybean, field bean and other crops along with the compost. High crop productivity and improved soil health are noticed with the application of BDLM alone or conjugation with FYM. Hence an investigation was carried out to study the efficacy of bio digested liquid manures on the yield potential of finger millet and its effect on soil properties.

Material and Methods

A field experiment was under taken at ARS, Balajigapade, during *Kharif* 2019 to study the 'Response of farm yard manure (FYM) and Bio-digester liquid manure (BDLM) on productivity and soil properties of finger millet (*Eleusine coracana* (L.) Gaertn) under dryland condition'. The experiment was laid out in a Factorial Randomized Complete Block Design consisting of nine treatments *i.e.,* T_1: 5 t ha^{-1} FYM + BDLM @ 75% N equivalent, T_2: 5 t ha^{-1} FYM + BDLM @ 100% N equivalent, T_3: 5 t ha^{-1} FYM + BDLM @ 125% N equivalent, T_4: 7.5 t ha^{-1} FYM + BDLM @ 75% N equivalent, T_5: 7.5 t ha^{-1} FYM+ BDLM @ 100% N equivalent, T_6: 7.5 t ha^{-1} FYM + BDLM @ 125% N équivalent, T_7: 10 t ha^{-1} FYM + BDLM @ 75% N equivalent, T_8: 10 t $^{-1}$ FYM+ BDLM @ 100% N equivalent, T_9: 10 t ha^{-1} FYM + BDLM @ 125% N equivalent, replicated thrice.

The initial soil sample was analyzed for various physical and chemical parameters by adopting standard procedures. The soil pH was neutral (7.59) and the electrical conductivity was normal (0.12 dSm-1). The organic carbon content was low (0.24%). The soil was low in available nitrogen (148.17 kg ha^{-1}), high in phosphorus (80.34 kg ha^{-1}), medium in potassium (175.8 kg ha^{-1}) and available sulphur (21.56 kg ha^{-1}) status.

Bio-digested liquid manure and FYM were analyzed initially for its chemical composition by adopting standard procedures. BDLM and FYM were applied to the experimental plots as per the treatments. The required quantity of liquid manures based on Nitrogen equivalent was applied to the soil. Liquid manures were applied in two equal splits at 15 and 45 days after sowing. Thinning and gap filling was done 15 days after sowing, to ensure uniform plant population and to maintain single plant at 10 cm apart. Two hand weeding and two inter- cultivations were carried out in order to keep the plots free from weed competition and to form soil mulch.

The observations *viz,* grain yield, straw yield, soil nutrient status after harvest and enzymatic activities were carried out, surface soil samples (0-15 cm) depth and plant samples were collected from each replication and each treatment. The analysis and interpretation of the data was carried out using Fisher's method of analysis technique (Gomez and Gomez, 2010). For computing the economics, different variable cost items were considered. The cost includes expenditure on land preparation, seeds, manures, fertilizers and labour charges as per calculated at prevailing market prices at the time of their use. Labour requirement was worked out on the basis of number of labours engaged for conducting different field operations.

Results and Discussion

Grain and Straw Yield of Finger Millet as Influenced by Application of Farm Yard Manure (FYM) and Enriched Bio-Digester Liquid Manure (BDLM) at Three Different Levels

Data pertaining to grain and straw yield of finger millet as influenced by application of farmyard manure and enriched bio-digester liquid manure is furnished in Table 1, Fig. 1 and Fig. 2. Results revealed that

Table 1

Influence of FYM and bio-digester liquid manure on productivity and economics of finger millet

Treatment	Grain yield	Straw yield	COC	Net return	B:C
	kg ha^{-1}		Rs ha^{-1}		
Level of FYM					
M1 : 5 t ha^{-1} FYM	2311	3268	25526	51017	3.00
M2 : 7.5 t ha^{-1} FYM	2831	3735	29337	64027	3.18
M3 : 10 t ha^{-1} FYM	3148	4458	33126	71149	3.15
S. Em. ±	134.13	194.09			
CD (p=0.05)	402.12	581.89			
Levels of BDLM					
B1: BDLM @ 75% N equivalent	2607	3695	28270	58090	3.05
B2: BDLM @ 100% N equivalent	2810	3790	29348	63447	3.16
B3: BDLM @ 125% N equivalent	2873	3976	30370	64657	3.13
S. Em. ±	134.13	194.09			
CD (p=0.05)	NS	NS			
Interactions					
M_1B_1	2204	3186	24470	48633	2.99
M_1B_2	2322	3280	25537	51360	3.01
M_1B_3	2408	3339	26570	53096	3.00
M_2B_1	2542	3473	28270	55742	2.97
M_2B_2	2958	3595	29370	67731	3.31
M_2B_3	2992	4136	30370	68575	3.26
M_3B_1	3075	4426	32070	69883	3.18
M_3B_2	3150	4454	33137	71256	3.15
M_3B_3	3218	4495	34170	72280	3.12
S. Em. ±	232.32	336.18			
CD (p=0.05)	696.48	NS			

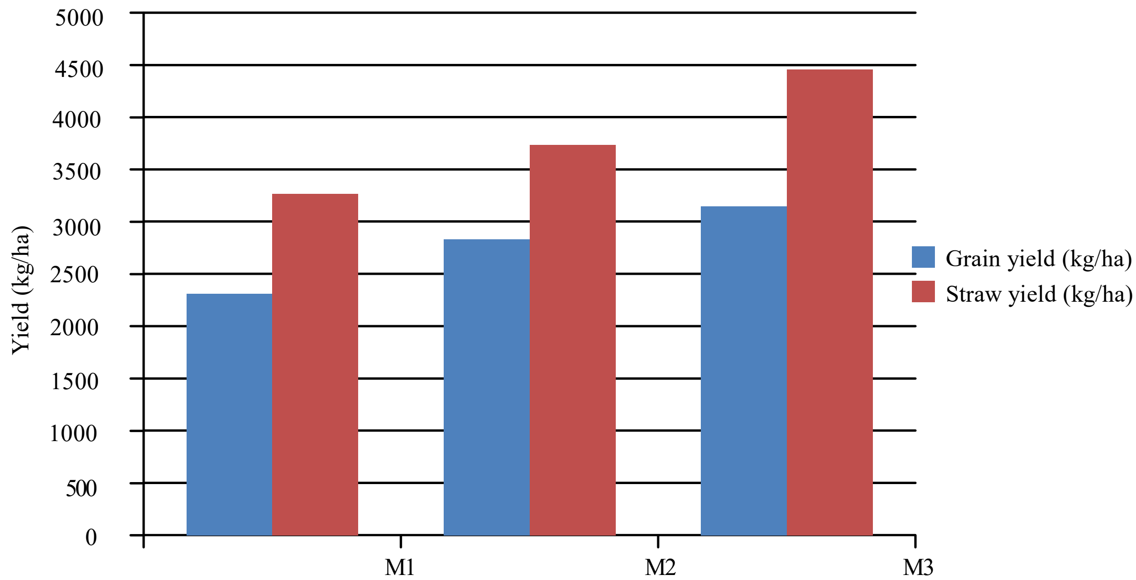


Fig. 1 : Influence of FYM on grain and straw yield of finger millet

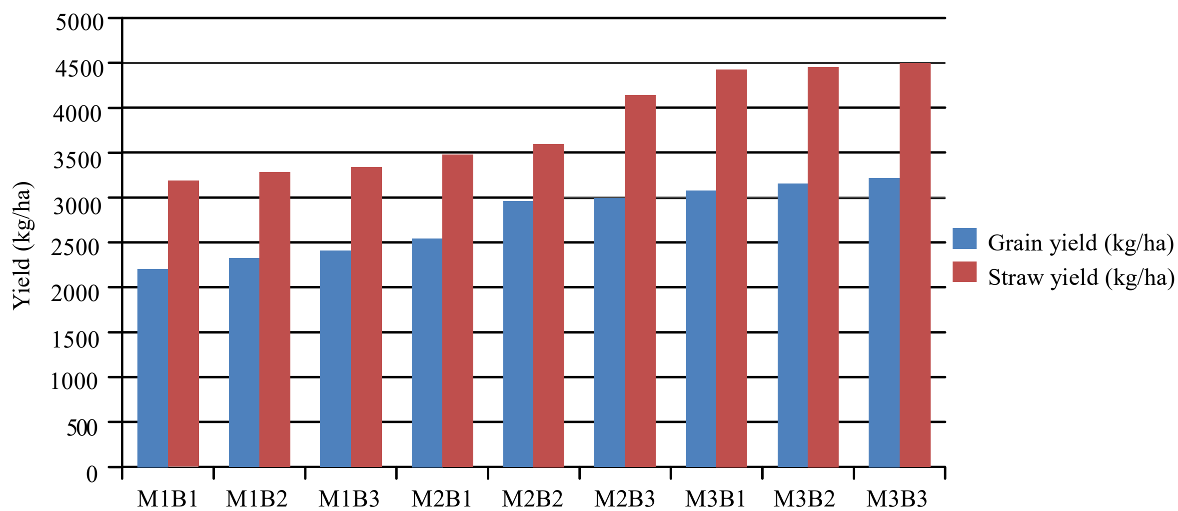


Fig. 2 : Influence of FYM and bio digester liquid manure on grain and straw yield of finger millet

among different levels of FYM application significantly higher grain yield (3148 kg ha^{-1}) was recorded with M_3 : 10 t ha^{-1} FYM over M_1 : 5 t ha^{-1} FYM and it was on par with M_2 : 7.5 t ha^{-1} FYM, while significantly higher straw yield (4458 kg ha^{-1}) was recorded in M_3 : 10 t ha^{-1} FYM. However there was no significant difference w.r.t grain and straw yield among different levels of BDLM application but relatively higher grain and straw yield (2873 kg ha^{-1} and 3976 kg ha^{-1} respectively) was recorded in B_3: BDLM @ 125 per cent N equivalent.

There was significant interaction between different levels of FYM and BDLM application. Significantly higher grain yield was recorded with application of 10 t ha^{-1} FYM and BDLM @ 125 per cent N equivalent (M_3B_3) and was on par with M_3B_2.

The increase in yield was attributed due to slow and steady rate of nutrient release into soil solution which matched with the absorption pattern by finger millet. Farm yard manure which supplies nitrogen, phosphorus and potassium in available forms to the plants through microbial decomposition, might have improved the plant growth parameters like plant height, number of tillers hill-1 and weight of the grains which eventually led to higher yield. This is in agreement with the findings of (Singh *et al*., 2019). Enriched bio-digester liquid manures supplies secondary and micro nutrients along with N, P and K and also acted as growth promoters which helped to enhance the yield (Ananda *et al*., 2017). This could also be attributed to the higher availability of NPK during crop growth period which might have improved the plant height, number of tillers and also due to higher enzymatic activity which helped in nutrient release and uptake by the crop eventually increases the straw yield (Monisha *et al*., 2019). The combined application of FYM and BDLM enhanced the microbial population in the rhizosphere and increased efficiency of crop production by nourishing and fortifying the host plant with required nutrients (Nuti and Giovannetti, 2015).

Economics of Finger Millet Influenced by Application of Farm Yard Manure (FYM) and Enriched Bio-Digester Liquid Manure (BDLM) at three different Levels

Data pertaining to economics of finger millet as influenced by different levels of farmyard manure and enriched bio-digester liquid manure is furnished in Table 1 among different levels of FYM application higher net returns (71149 Rs. ha^{-1}) was recorded in M_3: 10 t ha^{-1} FYM, while higher B:C ratio (3.18) was recorded with M_2 : 7.5 t ha-1 FYM. The higher B:C ratio and higher net returns might be due to lower cost of cultivation, higher benefit: cost ratio was the consequence of gross returns and cost of cultivation.

With respect to different levels of BDLM application higher net returns (64657 Rs. ha^{-1}) was recorded with B_3: BDLM @ 125 per cent N equivalent, while higher B:C ratio (3.16) was recorded with B_2:BDLM @ 100 per cent N equivalent.

Conjugate use of FYM and BDLM showed higher net returns (72280 Rs. ha^{-1}) was observed with application of 10 t ha^{-1} FYM and BDLM @ 125 per cent N equivalent (M_3B_3), while higher B : C ratio (3.31) was recorded with application of 7.5 t ha^{-1} FYM and BDLM @ 100 per cent N equivalent (M_2B_2) which was closely followed by (M_2B_3). Similar trend was observed w.r.t grain yield of finger millet where conjuctive use of both FYM and BDLM resulted in higher yield than application of only FYM or BDLM alone which is very well reflected in economics also.

Chemical Properties of Soil as Influenced by Application of Farm Yard Manure (FYM) and Enriched Bio-Digester Liquid Manure (BDLM) at Three Different Levels on Finger Millet

Data pertaining to soil nutrient status of finger millet as influenced by farmyard manure and enriched bio-digester liquid manures furnished in Table 2 and Table 3.

TABLE 2

Effect of FYM and bio digester liquid manure on soil primary nutrient status of finger millet

Treatment	pH 1:2.5	EC dSm^{-1}	OC %	Av. N	Av. P	Av. K
				kg ha^{-1}		
Level of FYM						
Initial	5.61	0.031	0.50	148.17	80.34	175.26
M1 : 5 t ha^{-1} FYM	5.65	0.043	0.53	153.93	89.17	182.92
M2 : 7.5 t ha^{-1} FYM	5.67	0.038	0.55	160.65	92.85	208.63
M3 : 10 t ha^{-1} FYM	5.66	0.041	0.58	173.87	96.43	219.49
S. Em. ±	0.07	0.001	0.01	2.22	1.11	1.11
CD (p=0.05)	NS	NS	NS	6.66	3.33	3.33

Treatment	pH 1:2.5	EC dSm^{-1}	OC %	Av. N	Av. P	Av. K
					kg ha^{-1}	
Levels of BDLM						
B1: BDLM @ 75% N equivalent	5.61	0.036	0.54	155.9	89.17	185.1
B2:: BDLM @ 100% N equivalent	5.65	0.043	0.55	163.7	92.85	201.6
B3: BDLM @ 125% N equivalent	5.73	0.043	0.57	168.8	96.43	224.3
S. Em. ±	0.07	0.002	0.01	2.22	1.11	1.11
CD (p=0.05)	NS	0.01	NS	6.66	3.33	3.33
Interactions						
M_1B_1	5.54	0.033	0.50	145.39	82.27	166.9
M_1B_2	5.69	0.047	0.54	154.90	89.81	175.5
M_1B_3	5.72	0.050	0.56	161.51	95.83	206.3
M_2B_1	5.78	0.040	0.54	156.67	91.63	191.3
M_2B_2	5.54	0.040	0.54	160.92	93.94	212.4
M_2B_3	5.69	0.033	0.56	164.35	95.90	222.2
M_3B_1	5.51	0.033	0.57	165.58	93.61	197.2
M_3B_2	5.71	0.043	0.58	175.36	94.79	216.8
M_3B_3	5.77	0.05	0.60	180.67	97.57	244.5
S. Em. ±	0.04	0.004	0.03	3.85	1.93	1.92
CD (p=0.05)	NS	NS	NS	11.53	5.77	5.77

TABLE 3

Effect of FYM and bio-digester liquid manure on soil secondary and micronutrient nutrient status

Treatments	Ca	Mg	Fe	Mn	Cu
	mg g^{-1}			ppm	
Level of FYM					
M1 : 5 t ha^{-1} FYM	2.42	1.32	16.54	28.70	1.97
M2 : 7.5 t ha^{-1} FYM	2.52	1.39	16.84	33.07	2.11
M3 : 10 t ha^{-1} FYM	2.51	1.48	17.35	35.19	2.30
S. Em. ±	0.10	0.05	0.29	1.06	0.14
CD (p=0.05)	NS	NS	NS	3.18	NS
Levels of BDML					
B1: BDLM @ 75% N equivalent	2.39	1.29	16.70	31.03	2.04
B2:: BDLM @ 100% N equivalent	2.49	1.40	16.89	32.50	2.14
B3: BDLM @ 125% N equivalent	2.58	1.50	17.13	33.44	2.20
S. Em. ±	0.10	0.05	0.29	1.06	0.14
CD (p=0.05)	NS	0.16	NS	NS	NS

Treatments	Ca	Mg	Fe	Mn	Cu
	mg g^{-1}		ppm		
Interactions					
M_1B_1	2.37	1.23	16.56	27.23	1.91
M_1B_2	2.40	1.33	16.69	28.84	1.96
M_1B_3	2.50	1.40	16.36	30.04	2.04
M_2B_1	2.40	1.27	16.56	31.49	1.99
M_2B_2	2.57	1.40	16.65	33.48	2.12
M_2B_3	2.60	1.50	17.30	34.24	2.22
M_3B_1	2.40	1.37	16.99	34.36	2.23
M_3B_2	2.50	1.47	17.34	35.17	2.33
M_3B_3	2.63	1.60	17.73	36.04	2.33
S. Em. ±	0.17	0.09	0.50	1.84	0.24
CD (p=0.05)	NS	0.28	NS	NS	NS

The results revealed that the conjunctive use of different levels of FYM and BDLM did not show significant effect on soil pH, electrical conductivity (EC) and organic carbon status of soils after the harvest of finger millet crop.

However, soil available nutrients after harvest of the crop w.r.t. different levels of FYM application showed significantly higher available nutrients, Nitrogen (173.87 kg ha-1), Phosphorous(96.43kg ha-1), Potassium (219.49 kg ha^{-1}) and manganese (35.19 ppm**)** content with application of FYM@ 10 t ha^{-1} (M3) but for secondary nutrients like Ca and Mg the result was found non-significant. Among different levels of BDLM application significantly higher available nitrogen (168.8kg ha^{-1}), phosphorous (96.43 kg ha^{-1}), potassium (224.30kg ha^{-1}) and calcium (1.50 mg kg^{-1}) were recorded with application of BDLM @ 125 per cent N equivalent (B_3) but magnesium content of soil did not show significant difference. Significantly higher available Nitrogen (180.67 kg ha^{-1}), Phosphorous (67.57 kg ha^{-1}) and Potassium (244.50 kg ha^{-1}) were recorded with application of 10 t ha^{-1} and BDLM @ 125 per cent N equivalent, while the secondary nutrients (Ca) and micronutrients (Fe, Mn and Cu) interaction was non- significant except for magnesium which was significantly higher in its availability (1.60 mg kg^{-1}) in M_3B_3. (10 t ha^{-1} FYM + BDLM @ 125 per cent N equivalent)

This may be attributed to the fact that nutrient status of post harvest soil sample is dependent on both supply of nutrients through various sources. The increase in available nutrients may be due to the effect of application of enriched of bio- digested liquid manure with microbial consortia that was more pronounced in increasing the post-harvest soil available nutrients. Application of organic manures at higher dose than the recommendation improved the N, P and K status of soil. It was mainly due to mineralization of nitrogen from organic manures through increased activity of soil microorganisms. Sudheendra Saunshi *et al*. (2014). This might also be due to slow and steady release of nutrients from FYM and enriched BDLM application. These results corroborate with the findings of Suresh Naik, 2011 and Manjunath, 2010. Higher nutrient availability due to enhanced microbial activity lead to mineralization and release of nutrients matching with crop demand and better uptake of nutrients by providing favourable environment.

Effect of Application of Farm Yard Manure (FYM) and Enriched Bio-Digester Liquid Manure (BDLM) On Soil Enzymatic Activities In Finger Millet Production

Data pertaining to soil enzymatic activity as influenced by application of farmyard manure and enriched bio-digester liquid manure is furnished in Table 4.

TABLE 4

Effect of FYM and bio-digester liquid manure on soil enzymatic activity under finger millet production in dryland condition

Treatments	Dehydrogenase (µg TPF/g per 24 hr)	Acid phosphatase µg PNP/g soil)	Alkaline phosphatase µg PNP/g soil)	Urease (µg NH4/ g soil/hr)
Level of FYM				
M1 : 5 t ha-1 FYM	50.00	30.88	15.07	21.60
M2 : 7.5 t ha-1 FYM	56.95	36.64	17.60	24.93
M3 : 10 t ha-1 FYM	58.91	38.98	19.16	26.86
S. Em. ±	1.21	0.09	0.06	0.43
CD (p=0.05)	3.63	0.27	0.19	1.29
Levels of BDLM				
B1: BDLM @ 75% N equivalent	50.17	32.14	16.01	22.06
B2:: BDLM @ 100% N equivalent	57.22	36.17	17.26	24.96
B3: BDLM @ 125% N equivalent	58.47	38.19	18.55	26.37
S. Em. ±	1.21	0.09	0.06	0.43
CD (p=0.05)	3.63	0.27	0.19	1.29
Interactions				
M1B1	45.94	27.81	14.27	18.48
M1B2	51.81	31.74	15.26	23.11
M1B3	52.25	33.09	15.66	23.22
M2B1	52.09	31.67	15.88	23.18
M2B2	59.16	37.97	17.34	25.02
M2B3	59.59	40.30	19.57	26.60
M3B1	52.48	36.93	17.87	24.53
M3B2	60.68	38.81	19.18	26.76
M3B3	63.59	41.19	20.42	29.30
S. Em. ±	2.10	0.16	0.11	0.75
CD (p=0.05)	NS	0.47	0.33	NS

10 t ha^{-1} FYM + BDLM @ 125% N equivalent

5 t ha^{-1} FYM + BDLM @ 75% N equivalent

General view of the experiment

Among different levels of FYM application, 10 t of FYM application per ha (M_3) resulted in significantly higher soil enzymatic activity *viz,* dehydrogenase, acid phosphatase, alkaline phosphatase and urease (58.91 µg TPF/g per 24 hr, 38.98 µg PNP/g soil, 19.16 µg PNP/g soil and 26.86 µg PNP/g soil respectively), among different levels of BDLM application significantly higher soil enzymatic activity of dehydrogenase (58.47 µg TPF/g per 24 hr), acid phosphatase (38.19 µg PNP/g soil), alkaline phosphatase (18.55 µg PNP/g soil) and urease (26.37 µg PNP/g soil was recorded with application of BDLM @ 125 per cent N equivalent.

Among interactions significantly higher soil enzymatic activity of acid phosphatase (49.19 µg PNP/g soil) and alkaline phosphatase (20.42 µg PNP/g soil) observed with M_3B_3 (10 t ha^{-1} FYM + BDLM @ 125 per cent N equivalent).

Enzymes play a key role in biochemical process of organic matter decomposition in soil. Enzymatic activity in soil is considered as an index of microbial activity, which is influenced by nature, age of crop and addition of fertilizers and manures. Soil quality refers to a soil's ability to sustain productivity in terms of agricultural production. The activities of soil hydrolytic enzymesis a common approach for estimating soil quality (Gil-Sotres *et al*., 2005). The dehydrogenase activity is proposed as the best indicator of microbiological redox system, which is considered as good and adequate parameter of microbial oxidative action in soil. The increase in soil organic matter content, resulting from the application of compost, in addition to the incorporation of stable enzymes contained in the compost (Díaz-Marcote and Polo 1995), favors the formation of complexes with free enzymes and therefore, the soil enzyme activities increase. Soil dehydrogenase activity reflects the total range ofoxidative activity of soil microflora and is consequently used as an indicator of microbial activity (Masciandaro *et al*. 1994 and Perucci 1992). The study by Smith and Powlson (2003) showed that the presence of added nitrogen source acts as readily available N pool stimulates the urease activity; there is a significant linear correlation between dehydrogenase and urease activities and soil organic matter contents.

In conclusion considering the above findings application of 10 t of FYM ha^{-1} (M_3) resulted in significantly higher grain yield (3148 kg ha^{-1}) and it was on par with M_2 : 7.5 t ha^{-1} FYM. Higher straw yield (4458 kg ha^{-1}) which fetched more profit was obtained with application of 7.5 t of FYM ha^{-1} to reduce the cost of cultivation. It might be due to improved plant growth characters like plant height, number of tillers hill-1, weight of the grains and also due to increased soil enzymatic activities which enhances the steady rate of nutrient release into soil solution to match the absorption pattern of finger millet which eventually led to higher yield.

References

Ananda, M. R., Sharanappa and Kalyana Murthy, K. N., 2017, Response of Finger Millet under Organic Nutrient Management in Groundnut (*Arachis hypogaea* L.) - Finger Millet (*Eleusine coracana* L.) Cropping System. *Int. J. Pure Appld. Sci.* **5** (5) : 200 - 206.

Ananda, M. R. and Sharanappa, 2017, Growth, yield and quality of groundnut as influenced by organic nutrient management in groundnut (*Arachis hypogaea* L.) - finger millet (*Eleusine coracana* L.) cropping system. *Mysore J. Agric. Sci.,* **51** (2) : 385 - 391

Diaz-Marcote, I. and Polo, A. M. S. W., 1995, Compost for the restoration of degraded soil. Proc. World Congress on Waste Management. 15th - 20th October,; ISWA, Vienna (CD Rom).

Gomez, K. A. and Gomez, A. A., 2010, Statistical procedures for agricultural research*, 2nd edn.* John Wiley and Sons, New York.

Gil-Sotres, F., Trasar-Cepeda, C., Leiros, M., C. and Seoane, S., 2005, different approaches to evaluating soil quality using biochemical properties. *Soil Biol. Biochem.*, **37** : 877 - 887.

Manjunatha, R., 2010, Effect of different combinations of organic nutrient sources on growth and yield of maize (*Zea mays* L.) under Cauvery command area. *M.Sc. (Agri.) Thesis*, Univ. of Agril. Sci., Bangalore.

MONISHA , V., RATHINASWAMY, A., MAHENDRAN, P. P. AND KUMUTHA, K., 2019, Influence of integrated nutrient management on growth attributes and yield of foxtail millet in red soil. *Int. J. Chem. stud.* **7** (3) : 3536 - 3539.

MASCIANDARO, G., CECCANTI, B. AND GARCIA, C., 1994, Anaerobic digestion of straw and piggery waste waters. II. Optimizationof the process, *Agrochim.*, **38** : 195 - 203.

NUTI, M. AND GIOVANNETTI, G., 2015, Borderline products between bio- fertilizers/bio-effectors and plant protectants: the role of microbial consortia. *J. Agric. Sci. Tech.* **5** : 305 - 315.

PERUCCI, P., 1992, Enzyme activity and microbial biomass in a field soil amended with municipal refuse. *Biol. Feril. Soils*. **14** : 54 - 60.

RAMACHANDRAPPA, B. K., SATHISH, A., DHANAPAL, G. N., GANAPATHI, BALAKRISHNA REDDY, P. C., SHANKAR, M. A. AND SRIKANTH BABU, P. N., 2013. Response of rainfed finger millet to levels and time of application of potassium in alfisols of Karnataka. *Mysore J. Agric. Sci.,* 47 (4) : 693 - 700.

REDDY, V. C. AND SHIVANANDAM, V. N., 2010, Developing organic package of practice for yield maximization of rainfed finger millet. Annual Progress Report, *Research Institute on Organic Farming,* Univ. Agric. Sci., Bangalore. pp. : 26 - 31

SINGH, C. K., SINGH, N. D. AND SHARMA, P. S., 2019, Effect of organic manures on yield attributes and grain yield of maize in Tawang District of Arunachal Pradesh. *J. Agri. Search,* **6** : 28 - 30.

SMITH, P. AND POWLSON, D. S., 2003, Sustainablity of soil management practices- a global perspective. In Abbott, LK; Murphy (eds) : *Soil Biological Fertility: A key to Sustainable Land Use in Agriculture. Springer Netherlands*, pp. : 241 - 254.

SUDHEENDRA, SAUNSHI, V. C. REDDY, RAJESH, RAWAL, BASAVARAJ KUMBAR AND ULLASA, M. Y, 2014, Enriched bio-digester liquid manures effect on nutrient uptake and economics of finger millet. *Trends in Biosciences* **7** (5) : 364.

SURESH NAIK, 2011, Effect of farmyard manure and bio digester liquid manure on growth and yield of rainfed maize (*Zea mays*). *M.Sc. (Agri.) Thesis*, Univ. Agril. Sci., Bangalore.

Mysore J. Agric. Sci., 57 (1) : 409-420 (2023)

Profile Characteristics and Economic Performance of Byadagi Chilli Growers in Haveri District of Karnataka

VEENA BUSHETTI[1] AND B. KRISHNAMURTHY[2]
[1]Department of Agricultural Extension, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
[2]Associate Director of Extension, University of Agricultural Extension, Bangalore - 560 065
e-Mail : bushettiveena@gmail.com

AUTHORS CONTRIBUTION

VEENA BUSHETTI : Conceptualization, investigation, data collection and original draft preparation;
B. KRISHNAMURTHY : Conceptualization, data curation, draft correction and data analysis

Corresponding Author :
VEENA BUSHETTI
Department of Agricultural Extension,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : August 2022
Accepted : February 2023

ABSTRACT

The study was conducted in Haveri district of Karnataka to study the profile characteristics and economic performance of Byadagi chilli growers during the year 2021-22. Byadagi chilli is a famous variety of chilli, it is named after the town of Byadagi which is located in the Haveri district of Karnataka. The *Ex-post-facto* research design has been adopted in the present study. Haveri, Hangal and Byadagi talukas were selected based on high, medium and low productivity of Byadagi chilli, respectively. From each taluka five villages and from each village 12 farmers were selected, thus total sample size encompassed to 180 farmers from 15 villages. It was observed that more than one-third (38.33%) of the growers belonged to medium overall economic performance category, the linear multiple regression analysis done to test the effect of independent variables on economic performance, showed that all the significant independent variables together explained to the extent of 79.99 per cent of variation in the economic performance. Less than half of the Byadagi chilli growers (47.22%) belonged to middle age category, 30.55 per cent of them were educated up to PUC, more than half (56.67%) of the Byadagi chilli growers belongs to joint family system. Equal number (40.00%) and more than one third (37.78%) of the Byadagi chilli growers belonged to medium category of extension participation, social participation and mass media exposure, respectively and only 34.44 per cent of the farmers have undergone training programmes.

Keywords : Byadagi chilli, Profile characteristics, Economic performance, Training received

AGRICULTURE is indisputably India's major source of income, particularly in the rural areas. It also makes a substantial contribution to the Gross Domestic Product (GDP). Friendly agriculture is critical for holistic rural development in terms of food security, rural employment and environmentally sustainable technologies such as soil conservation, sustainable natural resource management and biodiversity protection. Green revolution, white revolution, yellow revolution and blue revolution have all occurred in Indian agriculture and related activities. Agriculture in India provides a living for the bulk of the population and should never be overlooked. Despite the fact that its contribution to GDP has decreased to less than 20.00 per cent and that other sectors' contributions have expanded at a faster rate (Anonymous, 2011).

Byadagi chilli is a famous variety of chilli mainly grown in Karnataka. It is named after the town of Byadagi which is located in the Haveri district of Karnataka. The business pertaining to Byadagi chilli has the second largest turnover among all chilli varieties of India. An oil, oleoresin extracted from these chillies is used in the preparation of nail polish and lipsticks. Byadagi chilli is also known for its deep red colour, less spiciness and used in many food preparations of South India. Byadagi chilli has been accorded Geographical Indication (GI) in February 2011. Its GI tag is 129.

There are Two Types of Byadagi : *Chillies viz.,* dabbi and kaddi. Byadagi dabbi, which is small, plump and more popular for its colour, flavour and taste. Though it has more seeds, it is less spicy compared to the kaddi variety. This variety is best suited for masala preparation and oleoresin extraction. Many established food companies prefer this variety for their products. Among cosmetic products, it is mainly used in nail polish and lipstick. The kaddi type is gnarled, thin, long and has fewer seeds. Byadagi chilli is an important ingredient in spicy preparations like bisibele bath, sambar, chutney and other food items of South India and is widely used in the Udupi cuisine. It is also used in meat preparation because of the bright red colour that it imparts to the meat. 25 industries in and around Byadagi are involved in grinding these chillies into powder and selling them to masala manufacturers like MTR, ITC Food Products.

The extraction of oleoresin has also led to the creation of cold storage units in Byadagi since the chilli pods have to be maintained at a low temperature of 4 to 6 degree celsius to maintain the colour and purity. Storing in cold storage units also increases the amount of oleoresin extracted from chilli by about 30 - 40 per cent. About 50 litres of oleoresin can be extracted from about 1 tonne of Byadagi chillies. Companies have been set up in and around Byadagi that are involved in the extraction of oleoresin. This oleoresin is then sent to Kerala where it is further refined before being exported to countries like US, Japan and those in Europe (Anonymous, 2020).

Byadagi chillies are primarily sold at the Byadagi chilli market; annual sales are about Rs.3 billion ($75 million). This market attracts traders from all over Karnataka and from neighbouring Andhra Pradesh because of favourable conditions for the business like a fair price, immediate payment and accurate measurement of the chilli. The recent increase in sales of low-priced, more-pungent chilli varieties into the market has caused a decrease in the price of Byadagi chillies as well. Because of this, the farmers involved in its cultivation may not be able to make the required profits on their yield. The study was undertaken with the objective, to study the profile characteristics and economic performance of Byadagi chilli growers.

METHODOLOGY

The study was conducted in Haveri district of Karnataka during the year 2021-22. Haveri district has been purposively selected for the study, since it is the major export hub for Byadagi chilli. The *Ex-post-facto* research design was adopted for the study. Based on the statistical data of Byadagi chilli production and productivity in the year 2019-20, talukas having high, medium and low productivity of chilli were selected for the study. *i.e.* Haveri (high), Hangal medium) and Byadagi (low). Simple random sampling technique was employed for selection of the respondents. From each taluka five villages selected based on availability of a greater number of Byadagi chilli growers after discussion with the Department of Agriculture and Horticulture officers. So total number of villages selected was 15 and from each village 12 farmers were selected. Thus, the total sample size for the study was 180.

Economic performance of Byadagi chilli growers is operationalized as the ratio of value of output to the total expenditure incurred for Byadagi chilli production in a year expressed in index value. The procedure developed by Shankaraiah and Crouch (1977) was used in the present investigation. To assess the total expenditure incurred for Byadagi chilli production, the expenditure on total inputs (*i.e.* seed / seedlings, fertilizers, plant protection chemicals, manures, micro-nutrients, growth regulators, *etc.*), labour, electricity, repair, maintenance and miscellaneous were considered for a duration of one year. Further, to estimate the value of total output realized, the revenue gained from the marketing of Byadagi chilli for a period of one year was considered.

Economic Performance Index (EPI) value for Byadagi chilli growers was calculated by using the formula:

$$EPI = \frac{VTO}{TE} \times 100$$

Where,

EPI = Economic Performance Index

VTO = Value of Total Output for a period of one year,

TE = Total Expenditure incurred for a period of one year

Considering the value of Economic Performance Index (EPI), the Byadagi chilli growers were grouped into three classes with Mean and Standard Deviation as a measure of check.

For the present study relevant variables were selected after extensive review of the relevant literature and consultation with the experts considering the theoretical background and objectives of the study. Keeping the objective of the study in the mind, age, education, family type, size of land holding, farming experience, extent of chilli area, cropping pattern, annual income, livestock possession, farm implements, extension participation, mass media exposure, sources of information, social participation, deferred gratification, cosmopoliteness, training received and credit orientation were taken as profile characteristics of Byadagi chilli growers.

Results and Discussion

It can be seen from the Table 1. that personal characteristics of Byadagi chilli growers. Less than half of the Byadagi chilli growers (47.22 %) belonged to middle age category, followed by old (33.33 %) and young (19.45 %) age categories respectively. The interest and attitude shown by the middle-aged Byadagi chilli growers towards farming might be the

Table 1

Personal characteristics of Byadagi chilli growers (n=180)

Characteristics	Category	Byadagi chilli growers	
		Frequency	Per cent
Age (years)	Young (up to 35)	35	19.45
	Middle (36-50)	85	47.22
	Old (> 50)	60	33.33
Education	Illiterate	2	1.11
	Primary school	10	5.56
	Middle school	40	22.22
	High school	45	25.00
	PUC	55	30.55
	Graduation	27	15.00
	Post-graduation and above	1	0.56
Family type	Nuclear	78	43.33
	Joint	102	56.67

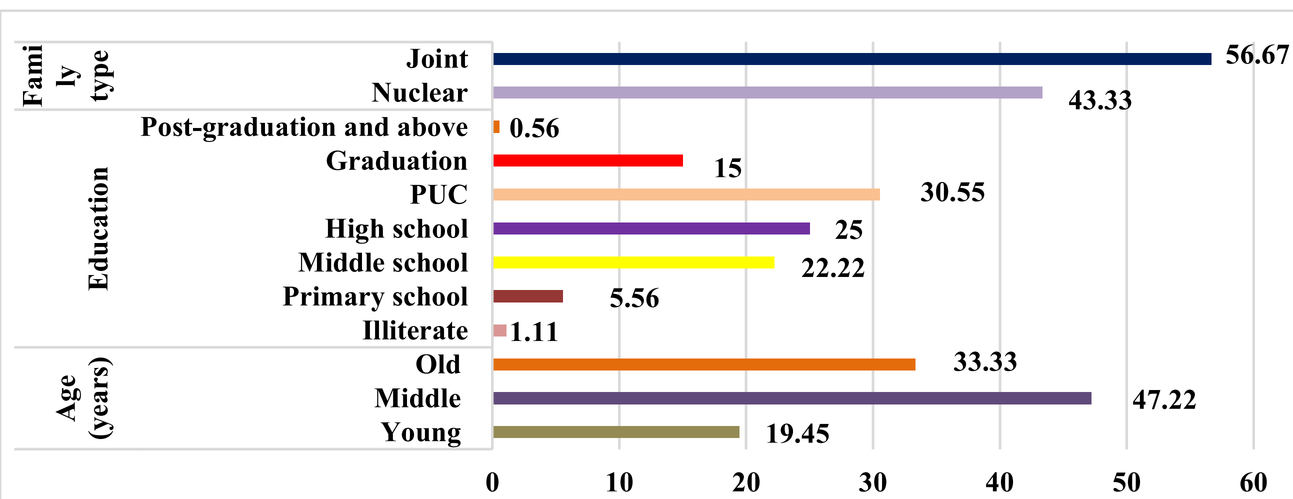


Fig. 1 : Personal characteristics of Byadagi chilli growers

apparent reason behind this trend. More than that, they were enthusiastic in nature and possess higher innovativeness towards profit gain. Middle aged Byadagi chilli growers hold more physical vigour and possess higher work efficiency. They can take independent decision in financial affairs to implement their ideas for farm progress. Education of the individual determines their knowledge level and the mental status of the individual. Results pertaining to the education level of Byadagi chilli growers depicted that 30.55 per cent of Byadagi chilli growers were educated up to PUC followed by 25.00, 22.22, 15.00, 05.56 and 1.11 per cent belonging to the category of high school, middle school, graduate, primary school level of education and illiterate, respectively. Only one respondent belonged to post-graduation and above (0.56%). The credible reason for nearly one-third number of Byadagi chilli growers to be educated up to PUC and one fourth (25.00%) up to high school level might be due to their medium income level, family conditions and lack of higher-level education facilities in their villages. They have to travel nearby towns to pursue their higher education. Data pertaining to the family type presented in the table indicates that more than half (56.67%) of the Byadagi chilli growers belongs to joint family system followed by 43.33 per cent nuclear family. The major reason Byadagi chilli growers belonging to joint family are probably due to the existence of ancestral customs like unity and togetherness in the villagers may help in solving the problems easily. The head of the family member encourages the younger generations to take up new innovations in farming activities. Comparable findings were ensued by Riza (2021).

It can be observed from the Table 2, that the socio-economic and psychological characteristics of Byadagi chilli growers were analysed based on size of land holding, farming experience, extent of chilli area, annual income, cosmopoliteness, deferred gratification, livestock possession, possession of farm implements and credit orientation.

Nearly half (49.44%) of the Byadagi chilli growers were marginal farmers, followed by small (28.34%) and big (22.22%) farmers. The possible reasons that could be attributed are that, fragmentation of land from generation to generation, so the size of land holding has been declined. Thus, majority of the respondents belonged to marginal and small farmers. Data pertaining to the farming experience presented in the table indicates that more than one-third (41.67%) of the Byadagi chilli growers belonged to medium farming experience followed by 37.22 and 21.11 per cent of them belonged to low and high farming experience respectively. One of the reasons for the present finding could be that they might be from joint family system initially assigned with non-farming responsibilities. This could have reduced their number of experience in farming.

It can be noticed from the Table 2, that 41.11 per cent of the Byadagi chilli growers were small farmers, followed by marginal (37.78%) and big (26.11%) farmers, respectively with respect to extent of chilli area. The probable reason for this might be majority of the farmers are marginal, so they are growing chilli in part of their land, not as a major monocrop. It can be observed that, more than one-third (36.11%) of Byadagi chilli growers belonged to medium level of annual income followed by low (32.78%) and high (31.11%). The probable reason for varied income categories of Byadagi chilli growers might be due to their farm holding size, cropping pattern, type of soil and practice of subsidiary occupations. It can be found out from the data that, 41.67 per cent of Byadagi chilli growers possessed medium level of cosmopoliteness, while 36.11 per cent had low and 22.22 per cent had high level of cosmopoliteness. The tendency exhibited by a farmer to seek farm information from outside his social circle is defined by his cosmopoliteness. Most of the respondents exhibit medium level of cosmopoliteness due to their involvement in several social activities, optimum economic status and contact with extension officials. Hence, leading to their vital participation in extension activities such as farm visit, exhibitions, krishimela, demonstrations *etc*.

It can be observed that, 40.00 per cent of the Byadagi chilli growers had medium level of deferred gratification followed by low (36.67%) and high

TABLE 2

Socio economic and psychological characteristics of Byadagi chilli growers

(n=180)

Characteristics	Category	Byadagi chilli growers	
		Frequency	Per cent
Size of land holdings	Marginal (< 2.5 acres)	89	49.44
	Small (2.51 – 5.0 acres)	51	28.34
	Big (>5.0 acres)	40	22.22
Farming experience (years)	Low (<10.54)	67	37.22
	Medium (10.54-13.66)	75	41.67
	High (>13.66)	38	21.11
	Mean=12.10	S.D=3.12	
Extent of chilli area	Marginal (< 2.5 acres)	68	37.78
	Small (2.51 – 5.0 acres)	83	41.11
	Big (>5.0 acres)	29	26.11
Annual income (Rs.)	Low (<3,66,753.2)	59	32.78
	Medium (3,66,753.2-473791.2)	74	36.11
	High (>4,73,791.2)	47	31.11
	Mean= 4,20,272.2	S.D=1,07,038.1	
Cosmopoliteness	Low (<10.20)	65	36.11
	Medium (10.20-13.38)	75	41.67
	High (>13.38)	40	22.22
	Mean=11.79	S.D=3.18	
Deferred gratification	Low (<36.67)	66	36.67
	Medium (36.67-42.65)	72	40.00
	High (>42.65)	42	23.33
	Mean= 39.66	S.D=5.98	
Livestock possession	Low (<1.67)	60	33.33
	Medium (1.67-2.88)	93	51.67
	High (>2.88)	27	15.00
	Mean=2.77	S.D=1.21	
Possession of farm implements	Low (<2.72)	43	23.88
	Medium (2.72-3.81)	91	50.56
	High (>3.81)	46	25.56
	Mean=3.26	S.D=1.09	
Credit orientation	Low (<11.01)	53	29.44
	Medium (11.01-12.48)	82	45.56
	High (>12.99)	45	25.00
	Mean= 12.00	S.D=1.98	

(23.33%) level. The apparent reason could be that, most of the Byadagi chilli growers are prepared for future uncertainties with their economic savings and they believe in their ability to foreseen and manage the uncertainties. Entrepreneurs are required to invest on farm facilities, inputs, *etc*. and needs to wait for the returns. This finding is expected by the Byadagi chilli growers, who normally save money by resorting to postponement of immediate needs and use the same for future investment. More than half (51.67%) of the Byadagi chilli growers belonged to medium livestock possession category followed by low (33.33%) and high (15.00%), respectively. The reason might be majority of the farmers having one or two cow/buffalo for milk purpose for their home consumption. They are not practicing dairy activity or selling milk to milk cooperatives/ KMF/ anywhere. If they have a greater number of livestock, they may face the problem of feed / fodder and it may add extra cost. It is evident that more than half (50.56%) of the Byadagi chilli growers possessed medium level of farm implements followed by high (25.56%) and low (23.88%) level of assets respectively. The results could be attributed to their family annual income, size of the land holding and requirement of farm implements. Capital is the life blood of any farming activity / enterprise and adoption of agricultural innovation in particular, substantial amount of investment is required. Considering this fact, 45.56 per cent of the Byadagi chilli growers belonged to medium category followed by low (29.44%) and high (25.00%) categories of credit orientation. Here many of the farmers taken crop loan from formal sources and also from non-formal sources. Because of the complications / procedure to avail loan from the banks and lack of information about it made them to have medium level of credit orientation. The findings are in proportion with Savitha (2007), Shirur (2015) and Sumana (2017).

Table 3 depicts the cropping pattern of Byadagi chilli growers. In the study area, multiple crops were cultivated by the respondents. In *kharif* season, main crops cultivated by the respondents were groundnut, maize, cotton, jowar, onion and vegetables *i.e.,* coriander, cucumber, tomato, *etc*. Nearly three-fourth

TABLE 3

Cropping pattern of Byadagi chilli growers

(n=180)

Crops cultivated	Byadagi chilli growers	
	Frequency	Per cent
Kharif crops		
Groundnut	48	26.67
Maize	96	53.33
Cotton	39	21.67
Jowar	53	29.44
Onion	116	64.44
Vegetables (Coriander, cucumber, tomato)	129	71.67
Rabi crops		
Jowar	74	41.11
Bengal gram	67	37.22
Cowpea	49	27.22
Urd	79	43.89
Wheat	31	17.22
Summer crops		
Groundnut	29	16.11
Maize	41	22.78

*Multiple responses are possible

(71.67%) of them growing vegetables in *kharif* season. Nearly two-third (64.44%) of the Byadagi chilli growers growing onion, followed by 53.33, 29.44, 26.67 and 21.67 per cent of farmers growing maize, jowar, groundnut and cotton respectively. In *rabi* season, main crops cultivated by the respondents were jowar, bengal gram, cowpea, urd and wheat. 43.89 per cent of them growing urd in *rabi* season. 41.11 per cent of the Byadagi chilli growers growing jowar, followed by 37.33, 27.22 and 17.22 per cent of farmers growing bengal gram, cowpea and wheat respectively. In summer only those who are having irrigation facility they grow crops. 22.78 per cent of them growing maize followed by 16.11 per cent growing groundnut. The probable reason might be these all crops are suitable to this region, since from their ancestors they are practicing / cultivating same crops.

Results depicted in Table 4 explains that extension characteristics of Byadagi chilli growers. It can be observed that more than one-third of the Byadagi chilli growers belonged to medium (37.78%) and low (35.56%) level of mass media exposure category followed by more than one-fourth (26.67%) of them belonged to high category. The reason for above trend might be due to the exposure of farmers towards mass media channels such as cell phone, television, radio, newspaper, farm magazine *etc*. Hence, the mental horizon of farmers gets widen and then later on, they tend to accept and trial various practices. Mass media acts as quickest source for dissemination of information to a large category of audience within a limited period. And also, they are highly useful for gaining information on market prices, weather and success stories. 40.00 per cent of Byadagi chilli growers had medium level of extension participation followed by low (37.22%) and high (22.78%) level. The reason for most of Byadagi chilli growers possessing medium level of extension participation might be due to their willingness and interest towards various extension activities such as training programme, demonstration, field days / field visit, extension group meeting, exhibitions, krishimela, conducted tour, campaign, FFS / FS and frequency of their visit to successful farmer fields to gather information on recent farm technologies and trial those in their farm.

It is clearly seen from the Table 4 that 40.00 per cent of the Byadagi chilli growers had medium level of

TABLE 4

Extension characteristics of Byadagi chilli growers

(n=180)

Characteristics	Category	Byadagi chilli growers	
		Frequency	Per cent
Mass media exposure	Low (<31.59)	64	35.56
	Medium (31.59-38.24)	68	37.78
	High (>38.24)	48	26.67
	Mean=34.91	S.D=6.65	
Extension participation	Low (<19.85)	67	37.22
	Medium (19.85-.21.37)	72	40.00
	High (>21.37)	41	22.78
	Mean=20.61	S.D=1.78	
Social participation	Low (<9.08)	65	36.11
	Medium (9.08-10.36)	72	40.00
	High (>10.36)	43	23.89
	Mean=9.72	S.D=1.29	
Sources of information	Low (<51.36)	51	28.33
	Medium (51.36-59.84)	84	46.67
	High (>59.84)	45	25.00
	Mean= 55.60	S.D=8.48	
Training received	Yes	62	34.44
	No	118	65.56

social participation followed by low (36.11%) and high (23.89%) level of social participation. The findings about social participation can be explained on the basis of the fact that majority of the respondents have participated in activities of social organizations as a member / office bearer, such as any Panchayat Raj Institutions, cooperatives, youth clubs, farmer associations and FPOs / FPCs. It can be visualized from Table 4 that, less than half (46.67%) of the Byadagi chilli growers had medium level of source of information, whereas, 28.33 per cent and 25.00 per cent of them fitted to low and high level source of information category, respectively. The farmer with formal educational qualification shows the tendency of sources of information. The reason behind medium level source of information behaviour is due to the frequency of using sources of information channels such as personal localite, personal cosmopolite and mass media sources by them. Hence, the information sources act as channel to promote various technology adoptions by the farmer society. Nearly two third (65.56%) of the Byadagi chilli growers have not undergone training on agriculture and allied agricultural activities and only 34.44 per cent have undergone training programmes.

From the Table 5, it can be observed that training received by Byadagi chilli growers on different aspects. Less than one third (29.03%) of the farmers received training related to crop production, besides

TABLE 5

Training received by Byadagi chilli growers on different aspects

(n=62)

Purpose of training	Frequency	Per cent
Livestock related	11	17.74
Disease and pest management	17	27.42
Marketing and export	13	20.97
Value addition and processing	3	4.84
Crop production	18	29.03

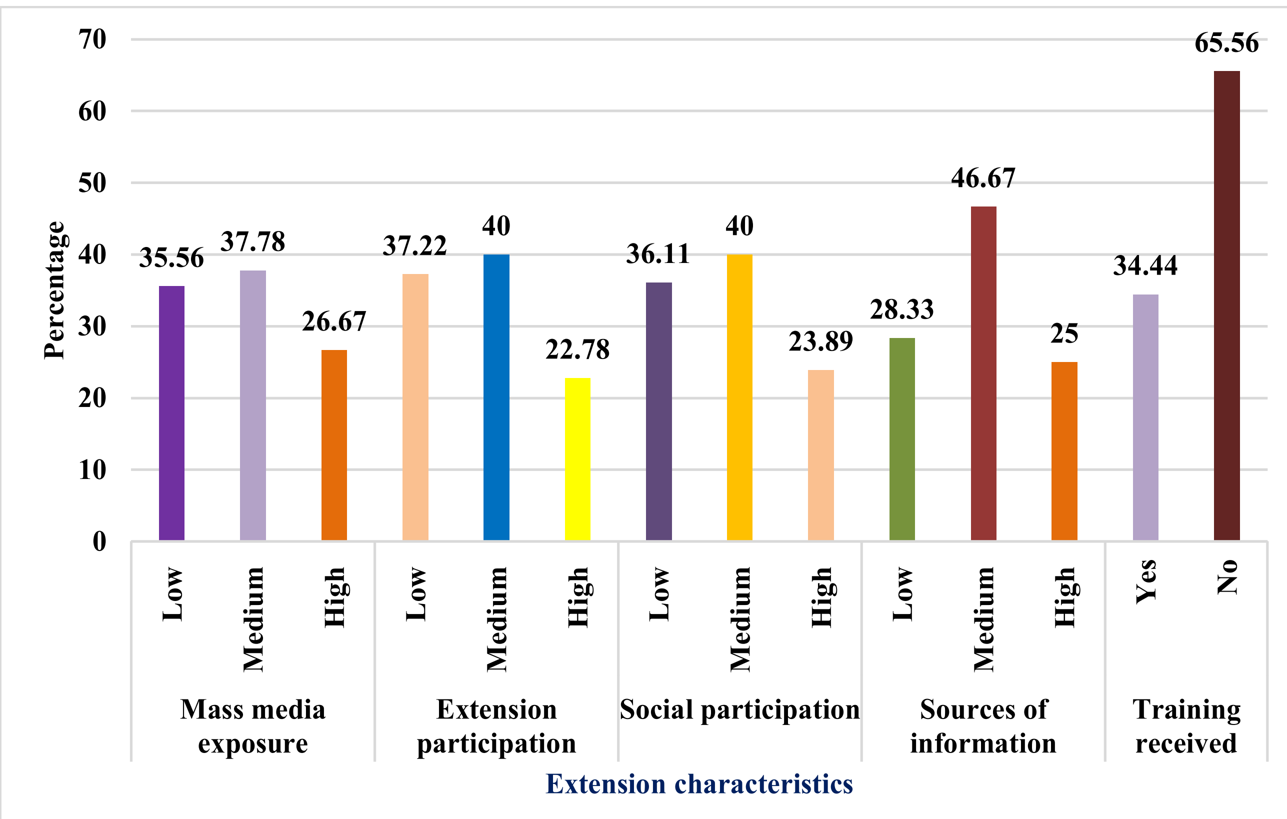


Fig. 2: Extension characteristics of Byadagi chilli growers

more than one fourth (27.42 %) of the farmers have received training on disease and pest management aspects. A notable per cent *i.e.* 20.97 and 17.74 per cent of the farmers undergone training on marketing & export and livestock related respectively, whereas only small per cent of farmers (4.84%) undergone on value addition and processing related training programme. Farmers mainly concentrate on the production aspects, therefore they undergone crop production related training programmes conducted by agricultural departments like Krishi Vigyana Kendra, agricultural university, *etc*. Increase in pest and disease incidence which reduces the yield and returns, might be the reason farmers for attending pest and disease management related training programs. Production and pest management are directly proportionate to the income of the farmers and hence farmers may be concentrating on these two important aspects. Only few interested, farmers having ambitious to improve their economic performance and influenced by other progressive farmers been attended such kind of training programs. These might be the main possible reasons for the above results.

Table 6 reveals that overall economic performance of the Byadagi chilli growers, more than one third (38.33%) of the growers had medium overall economic performance followed by low (32.78%) and high (28.89) category, respectively. This might be due to the reason that the cost of production and profit are in inverse proportion. These results are in conformity with Harish (2010) and Bindu (2018).

TABLE 6

Distribution of respondents according to overall economic performance of Byadagi chilli growers

(n=180)

Category	Byadagi chilli growers Frequency	Byadagi chilli growers Per cent	B.C Ratio
Low (<118.69)	59	32.78	
Medium (118.69-136.55)	69	38.33	1.48
High (>136.55)	52	28.89	
Mean= 127.62		S.D=17.86	

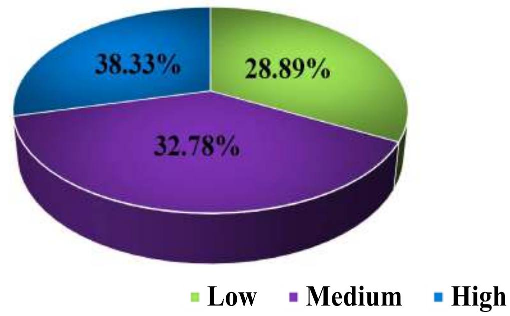


Fig. 3: Distribution of respondents according to overall economic performance of Byadagi chilli grower

Table 7 reveals the relationship of personal, socio-economic, psychological and communication characteristics of Byadagi chilli growers with their economic performance.

TABLE 7

Relationship between independent variables of Byadagi chilli growers with their economic performance

(n=180)

Independent variables	Correlation co-efficient (r)
Age	0.0960 NS
Education	0.1532 NS
Size of landholding	0.2111 *
Farming experience	0.1999 *
Family type	0.0898 NS
Cropping pattern	0.2345 *
Extent of chilli area	0.22196 *
Annual income	0.3816 **
Source of information	0.2996 **
Training received	0.4195 **
Farm implements	0.2981 **
Mass media exposure	0.3816 **
Extension participation	0.4166 **
Social participation	0.2165 *
Cosmopoliteness	0.3816 **
Deferred gratification	0.0981 NS
Livestock possession	0.2218 *
Credit orientation	0.2316 *

**- Significant at 1 per cent; *- Significant at 5 per cent
NS-Non-Significant

The variables such as size of land holding, farming experience, cropping pattern, extent of chilli area, social participation, livestock possession and credit orientation were found to have positive significant relationship with the economic performance of Byadagi chilli growers at five per cent level of significance. Whereas, annual income, source of information, training received, farm implements, mass media exposure, extension participation and cosmopoliteness were found to be positive significant at one per cent level of significance with economic performance of Byadagi chilli growers. The remaining variables such as age, education, family type and deferred gratification had non-significant relationship with economic performance of Byadagi chilli growers

With the large size of land holding, Byadagi chilli growers can get higher yield which leads to the higher returns. They will also be having higher resource mobilization and risk bearing ability. So, it can be concluded that, larger the size of land holding and extent of chilli area, more will be the economic performance of Byadagi chilli growers. It is imperative that the growers with more experience in cultivation or farming can easily and effectively perceive the things and they can accurately take up the adaptation measures. Cropping pattern refers to the proportion of land under cultivation of different crops at different points of time. Some scientific evidence proves a 10 to 25 per cent increase in crop yield in crop rotation rather than monoculture. It will add to get high returns which effects to economic performance. Those who possessed a greater number of dairy animals due to which they got more milk yield and higher income from dairy enterprise. It is directly proportionate to economic performance of Byadagi chilli growers.

Credit plays a vital role in economic performance of Byadagi chilli growers. Credit availability at cheaper rates of interest encourages the farmers to borrow more. Borrowing more money will facilitate the growth of farming activities or increase in production or productivity and economic performance. Byadagi chilli growers were involved in different crops cultivation, subsidiary occupations. So, the income from different sources also affects to their economic condition and entrepreneurial behaviour to taken up any activity. Hence, annual income was observed to have positive and significant relationship with the economic performance. If Byadagi chilli growers participate in extension activities to greater extent, they can get valuable advices to enhance their productivity and returns like advice to take up subsidiary enterprises like dairy, poultry, multiple cropping, adopting innovative and improved practices in Byadagi chilli cultivation. Therefore, extension participation had positive and significant relationship with economic performance.

Greater social participation encourages Byadagi chilli growers to develop contact with the support system that promotes the Byadagi chilli growers through reinforcing behaviour. The tendency of the Byadagi chilli grower to participate in various extension activities helps him to gather information from various sources. This helps to cooperate and acquire knowledge for growing better price yielding crops, share infrastructure like storage, negotiate for better crop prices with buyers, negotiate for better input prices with sellers, *etc.* which helps to better economic performance by getting high returns to Byadagi chilli growers.

Training enhances farmer's knowledge, skills and practices of Byadagi chilli cultivation as well as marketing aspects. It directly contributes to increase in productivity, increase in production of livestock, improvement in efficiency of input use (cost saving), increase in crop intensity, diversification towards high value crops and improved price realization by farmers. By this way farmer can get high returns, which will help to better economic performance. Farming tools, implements and equipment are critical to the success of a farmer. The benefits of possession of farm implements are timeliness of operation, precision of operation, enhancement of safety, reduction of drudgery of labour, reduction of loss of crops, increased productivity of land and increased economic return to farmers. It will reduce the cost and economically cost effective to the Byadagi chilli growers.

Higher cosmopoliteness ensures a hope for the exchange of information and facts with the outside society for enhancement of mental ability to coordinate the things properly and the Byadagi chilli grower who exposed highly towards mass media are well equipped with knowledge regarding market prices and are capable to stand firm with proper decisions suitable for marketing of their products. They will plan accordingly market prices, which helps to increase their economic performance.

The personal, socio-economic, psychological and communication characteristics of Byadagi chilli growers having significant to highly significant relationship with their economic performance. The results are supported by the findings of Latha (2003), Veena (2017), Bindu (2018).

The linear multiple regression analysis applied to test the effect of independent variables on economic performance (Table 8) showed that annual income, mass media exposure, cosmopoliteness and extension participation were showing significant contribution at one per cent level of significance. Whereas, size of land holding, farming experience, cropping pattern, extent of chilli area, source of information, farm implements, training received, livestock possession and credit orientation were showing significant contribution at five per cent level of significance. The remaining variables such as age, education, family type, social participation and deferred gratification were not showing any significant contribution to economic performance of Byadagi chilli growers. The R^2 of regression model suggested that, all the variables together explained to the extent of 79.99 per cent of variation in the economic performance. Thus, it may be inferred that all the above significant predictor variables at different level were found be important in explaining the economic performance of Byadagi chilli growers. These findings are in line of Darshan *et. al.* (2019) and Naresh (2019).

The study implies that, Byadagi chilli growers were found to have medium level of economic performance. This was arrived based on cost benefit analysis of

Table 8

Multiple regression of independent variables with economic performance of Byadagi chilli growers

(n=180)

Independent Variables	Regression co-efficient	S.E(b)	't'
Age	0.4374	0.3810	0.8712 NS
Education	0.2887	0.2680	0.9280 NS
Size of landholding	0.4701	0.9816	2.088 *
Farming experience	0.3719	0.8912	2.396 *
Family type	0.5682	0.7206	1.268 NS
Cropping pattern	0.3201	0.6678	2.086 *
Extent of chilli area	0.2080	0.4818	2.316 *
Annual income	0.2519	0.9618	3.818 **
Source of information	0.3820	0.8788	2.300 *
Training received	0.2806	0.6786	2.418 *
Farm implements	0.2446	0.5666	2.316 *
Mass media exposure	0.1097	0.4180	3.808 **
Extension participation	0.1372	0.3981	2.900 **
Social participation	0.1664	0.2810	1.688 NS
Cosmopoliteness	0.3681	0.9910	2.692 **
Deferred gratification	0.8218	0.8120	0.988 NS
Livestock possession	0.3034	0.6882	2.268 *
Credit orientation	0.2429	0.5612	2.310 *
	Coefficient of Determination (R^2 = 0.7999 F=17.01**)		

**: Significant at 1 per cent; *: Significant at 5 per cent; NS : Non-significant

Byadagi chilli production followed by growers. Over the years in the study area, crop is getting effected with severe diseases like Anthracnose, Murda *etc.* which greatly effects the yield level. To control these diseases require expensive pesticides as well as they have to enhance the number of sprays. Both adding to the cost of production. This necessitates frontline extension agencies to take up large scale demonstration in Byadagi chilli growing belts on precision farming technology in Byadagi chilli cultivation which considerably save the cost of cultivation. Besides integrated crop management also be encouraged among Byadagi chilli growers. Variables such as size of land holding, farming experience, cropping pattern, extent of chilli area, social participation, livestock possession and credit orientation, annual income, source of information, training received, farm implements, mass media exposure, extension participation and cosmopoliteness had a significant relationship with the economic performance of Byadagi chilli growers. Hence, it is judicious that government and extension agencies should make an effort to manipulate these variables for advancement in entrepreneurial behaviour and economic performance of Byadagi chilli growers.

References

Anonymous, 2011, Socio economic and caste census, Planning commission, GoI, New Delhi.

Anonymous, 2020, Haveri district at a glance, GoK, Directorate of Economics and Statistics, Bangalore

Bindu, N., 2018, Economic performance and entrepreneurial behaviour of flower growers in Tumkur district. *M. Sc. (Agri) Thesis* (Unpub.), Univ. Agric. Sci., Bangalore.

Darshan, M. E., 2019, Awareness of farmers on national food security mission programme. *Mysore J. Agric. Sci.,* **53** (3) : 81 - 86.

Harish, L., 2010, A Study on knowledge adoption and economic performance of crossandra growers in Chickballapura and Chitradurga districts of Karnataka state. *M.Sc. (Agri.) Thesis* (Unpub.), Univ. Agric. Sci., Bangalore.

Latha, K. B., 2003, A critical analysis of adoption level, economic performance and marketing channels of coconut growers in central dry zone of Karnataka. *M.Sc. (Agri.) Thesis (Unpub.),* Univ. Agric. Sci., Bangalore.

Naresh, N. T., 2019, A study on entrepreneurial behaviour of rural youth practicing integrated farming system in Chamarajanagara district. *Mysore J. Agric. Sci.,* **53** (4) : 109.

Riza, M., 2021, A study on entrepreneurial and marketing behaviour of cassava growers in Thiruvananthapuram district of Kerala state, *M.Sc. Thesis* (Unpub.), Univ. Agric. Sci., Bangalore.

Savitha, C. M., 2007, A critical analysis of entrepreneurial behaviour of rural and urban women entrepreneurs. *Ph.D Thesis (Unpub.),* Univ. Agric. Sci., Bangalore.

Shankaraiah, C. and Crouch, B. R., 1977, Patterns of adaptation of factors associated with economic success in the wool Industry. Department of Agriculture, Univ. of Queensland, Brisbane, Australia.

Shirur, M, 2015, A study on mushroom entrepreneurship and consumer behaviour in Karnataka. *Ph. D. Thesis (Unpub.),* Univ. Agric. Sci., Bangalore.

Sumana, N. A., 2017, Entrepreneurial behaviour and marketing practices of grape growers in Chikkaballapura district. *M.Sc. (Agri.) Thesis (Unpub.),* Univ. Agric. Sci., Bangalore.

Veena Bushetti, 2017, Impact of feed and fodder development programmes on livestock farmers of North Karnataka. *M.Sc. (Agri.) Thesis (Unpub.),* Univ. Agric. Sci., Dharwad.

Mysore J. Agric. Sci., 57 (1) : 421-427 (2023)

Influence of Weather Parameters on Groundnut (*Arachis hypogaea* L.) under Middle Gujarat Region

S. T. YADAV
Agricultural Technical School, Pune - 412 307, Maharashtra
e-Mail : styadav@gmail.com

AUTHORS CONTRIBUTION

S. T. YADAV :
Carried out experiment, supervision, data collection, and data analysis

Corresponding Author :
S. T. YADAV
Agricultural Technical School, Pune - 412 307, Maharashtra

Received : September 2022
Accepted : December 2022

ABSTRACT

Field experiment for the two-years were conducted to study the influence of weather parameters on groundnut (*Arachis hypogaea* L.) under middle Gujarat region at Agronomy farm, B.A. College of Agriculture, Anand, AAU, Anand during 2019 and 2020. The results revealed that onset of monsoon (first date of sowing) was significantly superior for yield character due to well distributed rainfall and favourable weather condition during crop growing period. Significantly higher pod yield (2176 kg ha^{-1} and 1862 kg ha^{-1}) was recorded during both years of the experiment under onset of monsoon sowing which was statistically on par with 10 days after onset of monsoon sowing (1937 kg ha^{-1} and 1592 kg ha^{-1}) and significantly higher than the 20 days after onset of monsoon sowing (1614 kg ha^{-1} and 1369 kg ha^{-1}). Among the varieties, GG 20 recorded significantly higher pod yield (2043 and 1701 kg ha^{-1}) over other varieties (GJG 34 and TAG 3A). Hence, variety GG 20 is promising under onset of monsoon (first date of sowing) in terms of pod yield in middle Gujarat region. The higher rainfall was recorded in onset of monsoon sowing date as compared to other dates of sowing during 2019 and 2020. Also, the values of beyond for mean maximum air temperature of 36.0 ^{0}C, evaporation rate of 3.6 mm and bright sunshine of 5.9 hours were found detrimental. The higher in each unit of maximum air temperature, evaporation rate and BSS hours had resulted in increase of pod yield. The overall performance of groundnut crop showed higher yield during 2019 as compared to 2020 due to favourable weather conditions.

Keywords : Groundnut, Middle Gujarat, Weather parameter, Yield.

GROUNDNUT (*Arachis hypogaea* L.) is an important oilseed crop of tropical and subtropical regions of the world. In India, it is one of the most important cash crop occupied an area of 5.5 m ha producing 9.6 m.t. with a productivity of 1750 kg ha^{-1} (Shwetha *et al.,* 2017). The importance of rainfall in crop production depends mainly on commencement of sowing rains and amount and distribution of rainfall as water deficit is a major constraint in groundnut production, especially during pod formation which affect the pegging (Chandrika *et al.,* 2008). The well-distributed rainfall of at least 500 mm during crop growth period and abundance bright sunshine hours with relatively warmer temperature favours the crop. Sowing, emergence, germination, flowering, vegetative and pod development of groundnut requires good rainfall distribution and soil moisture. Moisture stress affect flowering, pod setting and resulting in lower yield.

The principal groundnut growing states in the country are Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, Rajasthan, Madhya Pradesh, Orissa and Uttar Pradesh which accounts for more than 80 per cent of the Indian area and production. Variation and uneven distribution of monsoon is the main cause of fluctuations in groundnut yield in India (Basu and Ghosh, 1995). Gujarat stands first in area and production. It occupies 1.95 m. ha., 28.93 per cent of the total area of the country producing 3.39 m.t. (42.43%) with a productivity of 1777 kg ha^{-1}. In Gujarat, Anand district occupies area about 7000 ha, producing 1200 m.t. with averge yield of 1701 kg ha^{-1} (Anonymous., 2011).

Optimum sowing time of groundnut depends upon the type of variety and growing season due to variation in agro ecological conditions. Sowing date is most important factor influencing the growth and yield of groundnut. Late or delayed sowing results in declining crop yield. Also, the maximum and minimum temperature during different growth stages *viz.* emergence, branching, flowering, pod initiation and pod development, *etc.* are equally important. Kulkarni *et al.,* (1988) observed that water deficit reduced the pod yields of Spanish type groundnut (cv. JG-11 and GG-2) at all the stages (vegetative, flowering and pod development). Thus, weather parameters being one of the most precious inputs and balanced with due consideration to the growth, development and yield of groundnut (Lal *et al.,* (2013). Keeping the above in view, the present investigation was carried out to study the influence of weather parameters on groundnut (*Arachis hypogaea* L.) and to identify the suitable sowing date for rainfed situation in middle Gujarat region.

Material and Methods

The field experiment was carried out during *kharif* season 2019 and 2020 at Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India under rainfed condition. Anand is located at the latitude of 22° 35' N and longitude of 72° 55' E and at an altitude of 45.1 m above the mean sea level. The treatments consisted of three dates of sowing *viz;* onset of monsoon - first date of sowing, 10 days after onset of monsoon - second date of sowing and 20 days after onset of monsoon - third date of sowing with three varieties *viz;* GG 20, GJG 34 and TAG 37A. The experiment was laid out in randomized block design (factorial) and replicated with four times. The crop was sown at a spacing of 30 cm X 10 cm. The soil at the experiment site is sandy loam in texture with water table deeper than 10 m (Lakkad, 1993). The experimental field can be characterized as a gentle slope with good drainage as well as fair moisture retentive capacity. The recommended dose of fertilizers (12.5 N, 25 P_2O_5 kg ha^{-1}) were applied to the crop as basal. All the package of practices was followed as per recommendation of AAU, Anand. Supplemental irrigations were given as a life saving irrigations. The agrometeorological data of various weather parameters were collected from the agrometeor ological observatory which is adjacent to the experimental site. The data in respect of pod yield were collected from net plot and were worked out in kg ha^{-1} at the time of harvesting. The statistical analysis was computed by using 'Analysis of variance techniques'. The significance was tested by 'F' value at 5 per cent level of significance. The value of critical difference (C.D.) for examining treatment means for their significance was done at 5 per cent level.

Meteorological Observations

Daily weather data for maximum and minimum temperature (°C), morning and afternoon relative humidity (%), solar radiation (MJ /m^2 /day), wind speed (m/s) and rainfall (mm) during crop growing period for Anand were recorded from the agrometeorological observatory, Department of Agricultural Meteorology, B. A. College of Agriculture, Anand Agricultural University, Anand.

Results and Discussion

Air Temperature

The result revealed that crop experienced highest maximum temperature of 36.0 °C during the emergence to vegetative stage in 2019 while, it was 36.5 °C during 2020 in crop season (Fig.1). The average maximum temperature showed more or less similar trend upto flowering stage and after it decreases upto to physiological maturity and harvesting of crop during 2019. While, during 2020, it was higher upto physiological maturity and it decreased later at harvesting. It was observed that the maximum temperature was relatively lower than

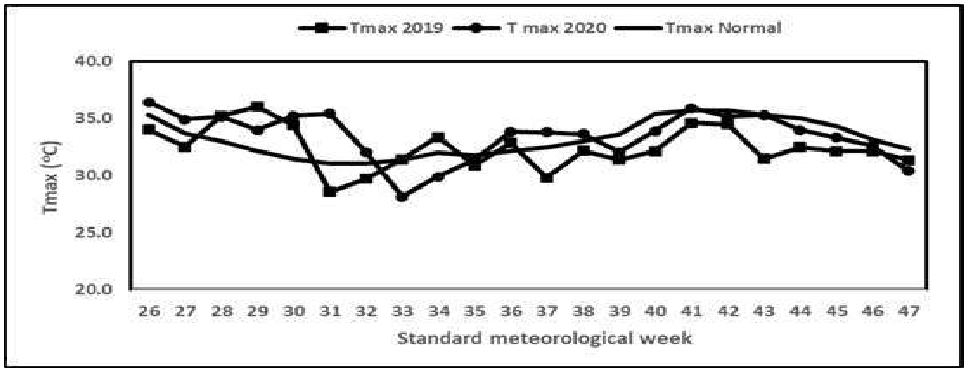


Fig. 1: Maximum temperature (°C) during crop growing season of 2019 and 2020

the normal from flowering to harvesting during 2019 and 2020.

The lowest minimum temperature of 17.8 °C and 15.20 °C recorded at physiological maturity to harvesting phase during 2019 and 2020, respectively (Fig.2). During establishment stage (26th to 27th SMW), minimum temperature was lower than normal in 2019 whlie, in 2020, it was higher than the normal. The minimum temperature showed increasing trends upto physiological maturity in both years. The minimum temperature was higher continuously upto pod development and it was lower at harvesting stage in 2020 as compared 2019. The variability in mean minimum temperature was lower during 2019 as compared to 2020. Minimum temperature was relatively higher than the normal from flowering to harvest during both the years.

Bright Sunshine Hours

The bright sunshine hours (BSS) during 2019 and 2020 crop growing season (Fig. 3). Analysis showed that weekly BSS during crop growth and development varied from 0.0 h to 10.5 h and 0.0 h to 10.1 h during 2019 and 2020, respectively. More bright sunshine hours were recorded during 2019 as compared to 2020, favored for crop growth and pod yield.

Higher weekly sunshine hours (9.5 h) was observed during 2020 compared to 2019 while, lowest value of sunshine hours was 0.1 h in 2019. The result showed that BSS was higher than the normal from sowing to flowering whereas, it was lower than the normal from flowering to harvesting.

Rainfall

The onset of monsoon took place on 29th June 2019 (26th SMW) and 25th June 2020 (26th SMW) with rainfall of 94.2 mm and 19.2 mm, respectively. Overall, total rainfall of 1289 mm and 894.8 mm were recorded during crop growth period of the year 2019 and 2020, respectively as compared to normal rainfall of 817.9 mm. The variability in weekly rainfall was more during 2019 crop season as

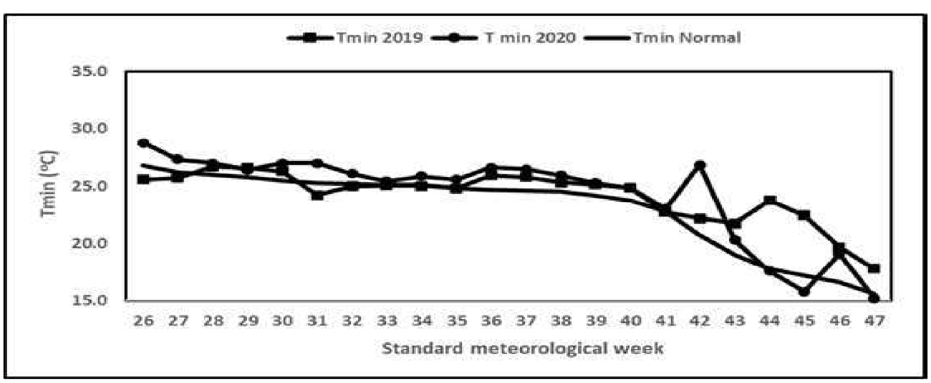


Fig. 2: Minimum temperature (oC) during crop growing season of 2019 and 2020

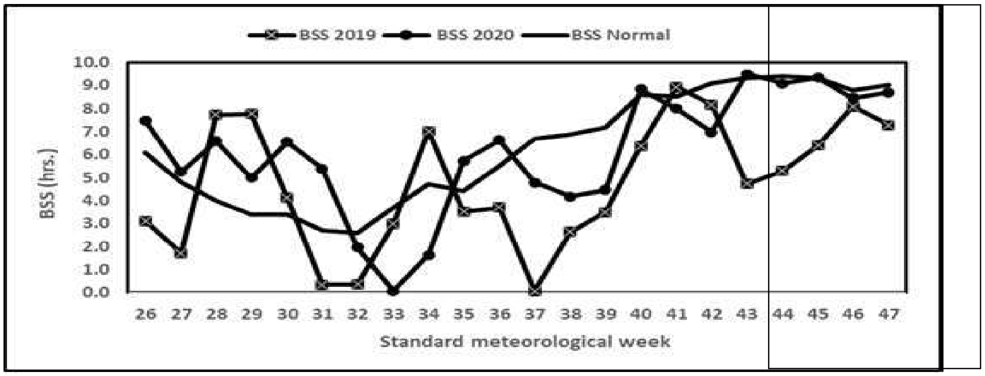


Fig. 3: Bright sunshine hours (h) during crop growing season of 2019 and 2020

compared to 2020. The higher rainfall was recorded from emergence to pod filling crop stage for all dates of sowing during 2019. During 2019, rainfall quantum and distribution were good, in turn resulted in better available soil moisture. While, during 2020, just after onset of monsoon, due to dry spell resulted in depletion in available soil moisture at time of sowing. Also, there was depletion soil moisture from peak leaf area stage to maturity had moisture stress condition due to low rainfall. The first date of sowing recorded higher groundnut yield due to higher rainfall and soil moisture. The result also showed that the final yield

TABLE 1

Evapotranspiration, rainfall and irrigation of groundnut for different crop growth stages by different dates of sowing and varieties during 2019

Crop stage	Evapotranspiration (mm)			Rainfall (mm)			Irrigation (mm)		
Varieties	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
Onset of monsoon (First date of sowing)									
Emergence	20.1	22.2	20.1	70.4	119.6	70.4	-	-	-
Flowering	39.8	42.2	41.9	208.2	213.0	250.2	-	-	-
Grain filling	104.8	100.3	100.6	686.6	632.6	644.6	-	-	-
Peak LAI	20.2	20.2	22.4	83.0	83.0	83.0	-	-	-
Maturity	59.3	59.3	59.3	140.0	140.0	140.0	-	-	-
10 days after onset of monsoon (Second date of sowing)									
Emergence	2.0	2.0	2.0	0.0	0.0	0.0	-	-	-
Flowering	52.1	52.1	50.1	573.8	573.8	409.4	40.0	40.0	40.0
Grain filling	100.4	100.4	99.0	362.4	362.4	519.2	-	-	-
Peak LAI	29.4	29.4	32.8	131.8	131.8	139.4	-	-	-
Maturity	35.4	35.4	35.4	64.0	64.0	64.0	-	-	-
20 days after onset of monsoon (Third date of sowing)									
Emergence	17.0	19.7	17.0	38.4	47.0	38.4	-	-	-
Flowering	53.4	51.1	53.4	563.6	555.0	563.6	-	-	-
Grain filling	63.1	67.0	63.1	266.6	326.6	266.6	-	-	-
Peak LAI	66.1	61.8	66.1	200.0	140.0	200.0	-	-	-
Maturity	21.3	21.3	21.3	63.4	63.4	63.4	-	-	-

*V_1=GG20, V_2=GJG34 & V_3=TAG 37A

of the groundnut crop was more during 2019 as compared to the 2020.

Daily observed and simulated soil moisture for the entire growing season during 2019 and 2020 are graphically presented in Fig. 2. It showed that during 2019, there was good amount of soil moisture from flowering initiation to physiological maturity stage of the first and second dates of sowing. Whereas, in the third date of sowing, higher moisture observed from sowing to peak leaf area index stage. During 2020, except first date of sowing there was decreasing trend noticed from sowing to harvest but soil moisture was sufficient during crop growing period. The result revealed that maximum soil moisture and higher pod yield was recorded in the first date of sowing during both the seasons.

Evapotranspiration (ET), Rainfall and Irrigation of Groundnut at Crop Growth Stages

The ET, rainfall and irrigation of groundnut as influenced by different dates of sowing and varieties during 2019 and 2020 are given in Table 1 to 2. Crop phenology was divided into five growth stages during both the seasons as a function of days after sowing (DAS). The maximum ET (mm) and rainfall (mm) were recorded in grain filling stage of the crop, whereas, it was minimum at harvesting stage during first date of sowing. The irrigation was applied 40.0 mm at flowering stage in second date of sowing during 2019 (Table 1). In 2020, ET (mm) and rainfall (mm) were higher in grain filling stage (first date of sowing) and flowering stage (second date of sowing), respectively. The irrigation was applied 60.0 mm immediately after each date of sowing during 2020 to facilitate better establishment (Table 2).

TABLE 2

Evapotranspiration, rainfall and irrigation of groundnut for different crop growth stages by different dates of sowing and varieties during 2020

Crop stage	Evapotranspiration (mm)			Rainfall (mm)			Irrigation (mm)		
Varieties	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
Onset of monsoon (First date of sowing)									
Emergence	14.0	14.0	14.0	15.4	15.4	15.4	60.0	60.0	60.0
Flowering	50.1	50.1	48.0	663.2	663.2	622.6	-	-	-
Grain filling	112.2	112.2	110.8	147.0	147.0	174.4	-	-	-
Peak LAI	19.5	19.5	23.0	0.0	0.0	13.2	-	-	-
Maturity	7.0	7.0	7.0	10.4	10.4	10.4	-	-	-
10 days after onset of monsoon (Second date of sowing)									
Emergence	5.6	5.6	7.9	7.0	7.0	9.8	60.0	60.0	60.0
Flowering	67.5	67.5	63.2	718.2	718.2	715.4	-	-	-
Grain filling	99.5	99.5	101.0	82.4	82.4	82.4	-	-	-
Peak LAI	3.6	3.6	4.1	10.4	10.4	10.4	-	-	-
Maturity	3.6	3.6	3.6	0.0	0.0	0.0	-	-	-
20 days after onset of monsoon (Third date of sowing)									
EEmergence	17.6	17.6	17.6	502.6	502.6	502.6	60.0	60.0	60.0
Flowering	43.1	43.1	42.6	212.4	212.4	212.4	-	-	-
Grain filling	77.7	78.3	77.6	90.8	90.8	90.8	-	-	-
Peak LAI	4.2	3.6	4.8	0.0	0.0	0.0	-	-	-
Maturity	0.7	0.7	0.7	0.0	0.0	0.0	-	-	-

*V1=GG20, V2=GJG34 & V3=TAG 37A

The total water, drainage and water entering soil were increased with delayed sowing during both the years. Higher rainfall, maximum temperature and ET were observed in both the year. Results showed that amount of rainfall, water entering soil and mean temperature were well distributed in the first date of sowing. Also, during flowering stage, the amount of rainfall and bright sunshine hours was higher. Hence, the pod yield of groundnut was higher in first sowing date as compared to other sowings. Less amount of rainfall, mean temperature as well as bright sunshine hours was recorded in pod formation during second and third dates of sowing.

Effect of Dates of Sowing and Varieties on Pod Yield

The individual as well as pooled statistical results of pod yield of groundnut as influenced by different dates of sowing and varieties are presented in Table 3.

TABLE 3

Pod yield of groundnut as influenced by sowing dates and varieties during 2019 and 2020

Treatments	Pod yield (kg ha^{-1})		
	2019	2020	Pooled
Onset of monsoon (First date of sowing)	2176	1862	2019
10 days after onset of monsoon (Second date of sowing)	1937	1592	1764
20 days after onset of monsoon (Third date of sowing)	1614	1369	1492
S.Em. ±	46.7	47.9	33.4
CD at 5%	135.3	138.7	95.1
Variety			
GG 20	2043	1701	1872
GJG 34	1915	1612	1763
TG 37A	1769	1511	1640
S.Em. ±	46.7	47.9	33.4
CD at 5%	135.3	138.7	95.1
CV (%)	8.5	10.3	9.3

Effect of Date of Sowing

Significantly higher pod yield (2176 kg ha^{-1} and 1862 kg ha^{-1}) was recorded during both years of the experiment under first date of sowing onset of monsoon which was statistically at par with second date of sowing (10 days after onset of monsoon) and significantly higher than the third date of sowing (20 days after onset of monsoon). The higher pod yield was recorded during 2019 compared to 2020. Similar trends were observed in pooled over years. The present study revealed that onset of monsoon is the better time for obtaining higher pod yield of groundnut during *kharif* season under middle Gujarat agroclimatic condition. In early sowing, there was a sufficient time to exploit the soil and environmental resources such as rainfall and availability of soil moisture for growth, development compared to delay sowing. Hence, result showed that the first date of sowing realizing higher pod yield than the other dates of sowing in middle Gujarat. Shah *et al.* (1999) was found similar results. Similar results were also reported by Sogut *et al*. (2016), Canavar and Kaynak (2008) and Munda and Patel (1998). Guled *et. al.,* (2013) recorded the higher yield (2244 kg ha^{-1}) I first date of sowing (onset of monsoon) as compared to other sowing dates.

Effect of Varieties

Effect of varieties on pod yield was found significant during both years and pooled results of field experiment. Significantly higher pod yield (2043 kg ha^{-1} and 1701 kg ha^{-1}) was observed with GG 20 over other varieties GJG 34 and TAG 37A. Hence, variety GG 20 is the promising one in terms of growth and yield in middle Gujarat agro climatic zone. Variety GG 20 was well respond to soil moisture at crop growth stages of groundnut crop. Guled *et. al.* (2013) was observed more yield (1969 kg ha^{-1}) in the variety M 335 than the other two varieties GG 20 and GG5.

It could be concluded from these results that the varieties and sowing dates had significant influence on yield of groundnut. Thus, to obtain higher pod yield of groundnut GG 20 variety should be sown earlier at onset of monsoon particularly in middle Gujarat agro climatic zone.

References

Anonymous, 2011. www.agricoop.nic.in/Agric. statistics.

Basu, M. S. and Ghosh, P. K., 1995, The status of technologies used to achieve high groundnut yields in India in achieving high groundnut yield. *ICRISAT, Patancheru*, India.

Canaver, O. and Kaynak, M. A., 2008, Effect of different planting dates on yield and yield components of Peanut (*Arachis hypogaea* L.). *Turkish J. Agri. and For.*, **32** : 521 - 528.

Chandrika, V., Parameswari, P. and Sreenivas, G., 2008, Effect of sowing time and rainfall distribution on yield of rainfed groundnut (*Arachis hypogaea* L.) in southern agroclimatic zone of Andhra Pradesh. *Legume Res.,* **31** (1) : 54 - 56.

Guled, P. M., 2013, Crop weather relationship studies in kharif groundnut (*Arachis hypogaea* L.) under middle Gujarat 'Agroclimatic condition'. *Ph. D. thesis,* Univ. Agric. Sci., Anand.

Kulkarni, J. H., Joshi, P. K. and Sojitra, K. K., 1988, Effect of photosynthetic source manipulation on nodulation and yield of peanut (*Archais hypogaea* L.) *Ann. of Plant Physio.,* **2** (1) : 74 - 81.

Lakkad, L. V., 1993, Study on the effect of irrigation and integrated nutrient management on growth, yield and quality of potato and their residual effects on succeeding summer groundnut crop. *Ph.D Thesis* Univ. Agric. Sci., Anand.

Lal, G, Saini, I. P., Mehta, R. S., Maheria, S. P. and Sharma, Y., 2013, Effect of irrigation and different seed treatment methods on growth and yield of fenugreek (*Trigonella foenum-graecum* L.). *Int J. Seed Spices,* **3** (2) : 29 - 33.

Munda, G. C. and Patel, C. S., 1998, Date of sowing, spacing and nutrition requirement of groundnut (*Arachis hypogaea* L.) under mid altitude of Meghalaya. *Indian J. Agric. Sci.*, **59** : 706 - 708.

Shah, S. M., Aslam, M., Shafiq, S. and Aslam, M. H., 1999, Effect of sowing dates and row spacing on soybean yield and yield components in autumn under rainfed conditions. *Pakistan J. Bot.,* **31** : 103 - 108.

Shwetha, Sreenivasa, A. G., Ashoka, J., Nadagoud, A. and Kuchnoor, P. H., 2017, Effect of Climate Change on Growth of Groundnut (*Arachis hypogaea* L.). *Int. J. Pure App. Biosci.,* **5** (6) : 985 - 989.

Sogut, T., Ozturk, F. and Kizil, S., 2016, *Effect of sowing time on peanut (Arachis hypogaea L.) cultivars: Fatty acid composition.* Proc. 'Agriculture for Life, Life for Agriculture' *Agri. and Agri. Sci. Proc.,* **10** : 76 - 82.

Disruption of Genome Integrity to Create Genetic Variability by Editing (Using CRISPR-CAS9) the Genes Associated with DNA Mismatch Repair and Characterization of their Relevance in Crop Improvement

V. Karthika and A. G. Shankar
Department of Crop Physiology, College of Agriculture, UAS, GKVK, Bengaluru

Genetic variation is crucial for crop improvement because of narrow variability in many species. A gene editing approach was adopted to create variations in the rice genome by targeting the mismatch repair genes (MMR), *Mut S Homolog 1* (*MSH1*), *Mut S Homolog 2* (*MSH2*) and *Mut L Homolog 1* (*MLH1*). The hypothesis is that any disruption in these genes leads to altered DNA mismatch repair that create indels and reprogrammed genome, resulting in altered phenotypes. The guide RNA with high specificity and least off targets were designed, cloned to a suitable binary vector *pRGEB 32*. Transgenic plants were developed by both *in vitro* agrobacterium tissue culture approach and modified *in planta* agrobacterium mediated direct embryonal axis transformation approach. Putative transformants were identified by selection against hygromycin. Sequencing analysis confirmed 4 edited plants in *MSH1* gene and 1 edited plant in *MSH2* and 3 edited lines in *MLH1* gene. These gene edited lines exhibited morphological variation with respect to plant height, tiller number, biomass etc. compared to the wild type plants. The flanking sequence analysis confirms that the observed phenotype is not due to the interference of transgene integration in the rice genome but due to the mutation in the MMR genes. The existing mutant plants have to be stabilized by crossing with its wild type counterpart and such stabilized lines could be a potential source to create more segregating population or act as donor lines in breeding programmes.

Influence of Leaf Thickness and Stomatal Characters on Water use Efficiency and Haplotype Mapping for Variability in Stomatal Characters in Rice

E. Soorya and M. S. Sheshshayee
Department of Crop Physiology, College of Agriculture, UAS, GKVK, Bengaluru

Rice is the major food crops which serve as staple food for majority of the world's population. Uneven rainfall and frequent droughts have brought the necessity to adopt aerobic cultivation. Water use efficiency (WUE) is an important physiological trait which determines the growth rates and has relevance under both resource sufficient as well as deficit conditions. WUE is a complex trait controlled by both photosynthesis and transpiration. Leaf thickness and stomatal frequency are two important traits that determine WUE through their influence on net assimilation rate (NAR) and mean transpiration rate (MTR), critical subcomponents of WUE. A study was conducted to evaluate 150 rice lines to screen for leaf thickness, stomatal frequency and leaf area. A sub-set of 32 lines were selected from 150 lines which were evaluated in phenomics facility under two water regimes *i.e.,* well-watered (100% FC) and water-limited (60% FC) conditions. Leaf thickness was measured as leaf mass area (LMA) and stomatal frequency was determined using the leaf imprint method. Leaf area and WUE were strongly related in the selected sub-set. NAR was key determinant of WUE under both well-watered and water-limited conditions. Leaf thickness played a major role in determining WUE under water-limited condition, whereas WUE was better explained by stomatal frequency under well-watered condition. The probable reduction in mesophyll conductance in thicker leaves might be compensated by having many stomata. Haplotype analyses indicated presence of 3 haplotypes for each gene but were not responsible for phenotypic variation.

Optimisation of Light Intensity for Better Water Use and Productivity in Vegetable Crops

LALTHANTLUANGA AND K. S. SHIVASHANKARA
Department of Crop Physiology, College of Agriculture, UAS, GKVK, Bengaluru

VEGETABLES grown under open field conditions are exposed to high light intensity and temperatures which effects crops growth, productivity and quality. Excess light can limit the yield and water use due to higher temperature under open field conditions. Therefore, it is necessary to optimize the light use for improving yield of vegetables. In the study 3 levels of light intensity namely 100, 70 and 50 per cent of full sun light was used. French bean, tomato and brinjal were used for the study. The low light regimes (70 and 50 %) of shade net showed overall better growth and productivity including improved shoot and root length, number of branches, total dry matter, fruit yield, leaf area, leaf chlorophyll fluorescence. Gas exchange parameters like photosynthetic rate and stomatal conductance showed higher value while the transpiration rate showed lower rate under the 50 and 70 per cent light intensities in all three crops. Light compensation point (LCP), light saturation point (LSP), maximum photosynthesis (A.max), carbondioxide compensation point (CCP) and carbondioxide saturation point (CSP) were higher under 100 per cent light intensity while carboxylation efficiency was better in 50 and 70 per cent light intensities. The water use efficiency was also better under low light regimes. Low light intensities improve the fruit weight, fat and water soluble vitamins, ascorbic acid (Vit-C), chlorophyll and carotenoids content in the fruits of brinjal and tomato than the control conditions with 100 per cent light intensity but the total phenols, antioxidants and total flavonoids accumulated were higher under control conditions in all three crops. Hence, the partially shaded low light intensity regimes improve water use and also productivity in the 3 vegetables studied.

Physiological and Molecular Characterization of Doubled Haploid Rice Lines Derived from Drought Adaptive Traits Pyramided F_1 Anthers

V. R. VENNELA AND B. MOHAN RAJU
Department of Crop Physiology, College of Agriculture, UAS, GKVK, Bengaluru

DOUBLED haploid (DH) rice lines developed previously through anther culture technique using anthers of F_1 plants derived from a cross between TIL-14 (Root & WUE) x AC35310 (EWC) which are in second generation were characterized under aerobic conditions for pyramided drought adaptive traits and productivity. Accordingly significant variability was observed among DH lines for the pyramided drought adaptive traits such as roots, WUE and EWC besides growth and productivity. Some of the DH lines had traits values similar and in some cases, more than the parents, F_1 hybrid and check varieties. Based on the variability, highly contrasting DH lines differing in root, WUE, EWC and grain yield were identified. When examined these contrasting lines under phenomics facility creating a moisture stress of 50 per cent at anthesis, high type DH lines continued to have higher trait value including grain yield compared to low type DH lines suggesting that the drought adaptive traits are relevant under stress condition. Further, gene expression studies revealed that the expression of a few wax biosynthetic genes was significantly more in high type compared to low type DH lines. Similarly, markers studies also confirm that the traits specific markers such as root and WUE are found only in high type rather than low type DH lines to suggest that these two traits have been passed onto a few DH lines from female parent (TIL14). Based on the traits value and grain yield, two best DH lines namely 30.1 and 33A were identified as potential lines for further crop improvement programmes.

Seed Size Optimization of Potato Mini-tuber and Influence of Plant Hormones on Tuberization in Potato

KAMALAKAR AND B. MOHAN RAJU
Department of Crop Physiology, College of Agriculture, UAS, GKVK, Bengaluru

ONE of the major constraints in potato cultivation has been unavailability of quality, disease-free planting material. Towards this, aeroponics technology emerged as a viable option where it facilitates mass multiplication and season independent production of disease-free planting material with an option to harvest mini-tubers multiple times. However, what size of mini-tubers to be harvested from aeroponic chambers is a big question and in absence this information, potato seed growers harvest mini-tubers of different sizes. In this scenario, it is highly relevant to determine the optimum mini-tubers size in potato keeping in view the seedlings vigour and yield. Accordingly, seedling vigour was determined in plants derived from different sized mini-tubers and found that, seedling vigour increased linearly up to 4 g of mini-tuber size and beyond which, it plateaued. Similarly, growth attributes and mini-tuber yield of plants derived from 4 g mini-tubers was no different from those derived from bigger sized tubers suggesting 4 g of mini-tuber size would be ideal to produce vigorous seedlings with higher productivity. Further, potato tubers have a dormancy period of 3 months during which period, tubers lose around 30 per cent moisture content (~1 g). Therefore, it is necessary to add this weight loss to the tubers while harvesting optimum sized mini-tubers from aeroponic chambers. Taken together, a fresh mini-tuber size of 5 g is considered as optimum size for harvesting from aeroponic chambers. Further, application of cytokinin was found to improve tuber yield in the present study suggesting cytokinin could be used to improve productivity in potato.

Biocontrol Potential of Quorum Quenching Rhizobacteria against Soft Rot Pathogen, *Pectobacterium carotovorum* subsp. *carotovorum*

J. SARANYA PACKIALAKSHMI AND K. TAMILVENDAN
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru

PECTOBACTERIUM CAROTOVORUM subsp.*carotovorum* (Pcc) is a brute force pathogen causing necrotic soft rot,virulence of which is induced by quorum sensing regulated production of plant cell wall degrading enzymes. Quorum quenching (QQ) by the disruption of the quorum sensing signals, the AHL molecules, is recently being proposed as the strategy for the biocontrol of plant pathogens. Employing QQ based suppression of plant pathogens with rhizobacteria, therefore, assumes a greater significance in the wake of development of multidrug resistance in plant pathogens. To harness the potential of QQ rhizobacteria in the biocontrol programme, ninety-six bacteria isolated from the rhizosphere of crops cultivated in farms of GKVK were screened for their QQ ability using the bioindicator *Chromobacterium violaceum* RU9. The *in vitro* screening yielded twenty-four isolates with variable QQ efficiency.Out of 24 isolates, the isolate BMR17 recorded significantly higher QQ efficiency of 93 per cent while BRR05, BBR58, BBR60, BAR70, BAR75, BAR78, BAR79 and BFR83 exhibited efficiency between 86 and 92 per cent. *In vitro* biocontrol assay of green gram seeds and *in vitro* maceration attenuation assay on Potato, Carrot, Radish and Cucumber evidenced that BRR05, BMR17, BMR22, RAR39, BBR57, BAR79 and BFR86 showed efficient QQ biocontrol potential. The isolates BRR05, BMR17 and BFR86 degraded different long chain and short chain AHL molecules as revealed by HPLC chromatogram and heat map. Principal Component Analysis of the plant growth and yield parameters of green gram as influenced by the inoculation of these three biocontrol isolates under greenhouse condition revealed that BFR86 (*Priestia megaterium)* is the potent QQ biocontrol agent against the pathogen Pcc f ollowed by BMR17 (*Staphylococcus hominis)* and BBR57 (*Priestia aryabhattai)*.

Influence of Marigold Flower Effluent and Plant Growth Promoting Microorganisms on Growth and Yield of Potato (*Solanum tuberosum* L.)

S. Tulja and N. Umashankar
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru

With reducing irrigation water resources and decreasing soil fertility, the present study, 'Influence of marigold flower effluent (MFE) and plant growth promoting microbes (PGPM) on growth and yield of potato' was taken-up. The experiment was conducted under greenhouse as well as field conditions with the application of MFE [Treated, untreated and untreated water (50:50)] along with PGPM consortia (*A. chrococcum* + *B. megaterium* + *P. fluorescens*) in different combinations, once before sowing. The irrigation water quality index was computed before application and found to be 10.508 and 46.262 of treated and untreated MFE, respectively with no ionic toxicity and phytotoxicity. The MFE was found to have antifungal activity against plant pathogens due to the presence of organic compounds as assessed by GC-MS. In pot experiment, the treatment RDF + 50:50 (Water: UMFE) + PGPM, reported higher potato yield with increased N fixers, P solubilizer and *P. fluorescens* in soil with a population of 22.91×10^5, 19.74×10^6 and 26.64×10^6cfu g^{-1}, respectively. In addition to this, soil enzymes *viz*., urease (15.19 µg NH_4^+-N g^{-1} h^{-1}), dehydrogenase (52.39 µg TPF g^{-1} h^{-1}), acid phosphatase (57.77 µg PNP g^{-1} h^{-1}) and alkaline phosphatase (36.28 µg PNP g^{-1} h^{-1}) activity was higher at flowering. The same treatment reported higher yields of 19.68 t ha^{-1} under field condition having more marketable tubers (9.44 t ha^{-1}) with a benefit cost ratio of 4.25 and net returns of Rs.270982 ha^{-1}. When compared to farmers practice the nutrient use efficiency was increased by 40.22, 42.21 and 38.17 per cent NPK, respectively. The tuber dry weight, crop growth ratio and phosphorus uptake were positively correlated to yield by 1.00** correlation. The study provides an evidence that UMFE on dilution (1:1), for one time application as organic amendment along with PGPM is beneficial for potato.

Microbial Processing of Horse Gram (*Macrotyloma uniflorum*) for Reduction of Antinutritional Factors

Sarvani Bharathula and Suvarna V. Chavannavar
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru

Horsegram is a protein rich legume crop that offers an alternate meat source to the vegans and poorer section people as well. However, it remains underutilized by reason of antinutritional factors such as tannins, phytates and oxalates etc. which hinders digestibility and thus nutritionally antagonistic. Hence, an attempt was made to investigate suitable processing methods to develop horse gram *dosa* with minimum antinutritional contents. The seeds were subjected to various processing methods like soaking, roasting, cooking and germination combined with /without fermentation and analyzed for antinutritional factors. A total of 13 lactic acid bacterial isolates (HLB-1, HLB-2, HLB-3, HLB-4, HLB-5, HLB-6, HLB-7, HLB-8, HLB-9, HLB-10, HLB-11, HLB-12 and HLB-13) were obtained from whole horse gram seeds and were characterized. Results showed that soaking in combination with fermentation was found to be effective in reducing antinutritional factors and was utilized further to develop horse gram *dosa*. The protocol was standardized as 2:1:0, 2:0:1, 2:0.5:0.5, 2:0.25:0.75 and 2:0.75:0.25 ratio of rice, black gram and horse gram dhal; inoculated with HLB-3, HLB-9, HLB-10, HLB-11, HLB-12 and HLB-13 isolates; at 6, 8 and 10 per cent inoculum; incubated and fermented at 25, 30 and 35^{0}C; for 8, 12 and 16 h using *Lactobacillus acidophilus* – NCIM 2903 as reference strain. The substrate ratio of rice, black gram and horse gram (2:0:1); inoculated with HLB-12 isolate; at 10 per cent inoculum; incubated at 35^{0}C; for 12 h duration was found to be the best processing method for effective reduction of tannins (72.25 %), phytates (59.50 %) and oxalates (62.05 %) with good sensory score (7.88 out of 9.00). The efficient isolate HLB-12 was subjected to molecular characterization and was identified as *Leuconostoc mesenteroides.*

A Comparative Study on the Effect of Desiccated Coconut Water and Dairy Whey on Beneficial Microflora, Growth and Yield of Soybean [*Glycine max* (L.) Merr.]

N. R. VIJAYALAKSHMI AND B. NARAYANASWAMY
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru

THE focus of this research was to see how desiccated coconut water and dairy whey from desiccated coconut industries and milk dairy, respectively, impacted beneficial microorganisms and soybean yield. The uncontrolled disposal agro-industrial wastewaters result in environmental problems like global warming, acidification, oxygen depletion, eutrophication, odour, etc. Standard assays were used to identify the microorganisms, minerals and growth hormones contained in desiccated coconut water and dairy whey. The effects of samples on the population and survivability of phyllosphere, rhizospheric beneficial microorganisms and soybean growth response were evaluated in two sets under glasshouse conditions, each with different concentrations of desiccated coconut water and dairy whey. On the Pot-I set, samples were foliar sprayed, while on the Pot-II set, samples were applied to the soil. In both sets of pot trials at varied intervals, the treatment of 10 per cent desiccated coconut water yielded better results. It's also statistically equivalent to a 10 per cent dairy whey treatment. The phyllosphere and rhizosphere microorganisms, as well as several plant growth and yield indices, were significantly greater in 10 per cent desiccated coconut water. The optimal treatment, as determined in the pot experiment, was next evaluated in the field on soybean growth and yield. At 90 days after sowing, there was a higher population of beneficial rhizosphere microflora such as *Azotobacter* sp (17.30 x 10^5 cfu g^{-1} of soil), *Rhizobium* sp (15.32 x 10^5 cfu g^{-1} of soil), phosphate solubilizing bacteria (9.04 x 10^5 cfu g^{-1} of soil) and *Pseudomonas* sp (15.60 x 10^5 cfu g^{-1} of soil). According to the study, desiccated coconut water and dairy whey discharged by desiccated coconut industries and milk dairy contain nutrients and plant growth-promoting substances. Desiccated coconut water and dairy whey, as a result, enhance the proliferation of plant-associated microorganisms, which promotes soybean growth and yield.

Isolation and Characterization of Saline Tolerant Rhizobacteria and their Evaluation for Plant Growth Promotion Potential in Tomato (*Solanum lycopersicum* L.)

N. LOHITH KUMAR AND L. KRISHNA NAIK
Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru

THE present study was carried out to isolate saline tolerant rhizobacteria and evaluate their performance for saline tolerance in tomato plants. Initially, eighty five bacterial isolates were isolated from saline soils of Gangavathi, Mandya and Bellary and screened at 10, 15, 20 and 23 per cent NaCl. Among the isolates, eight isolates were able to survive on trypticase soya agar amended with 23 per cent NaCl and were identified based on 16SrRNA sequence. Seven isolates were belong to *Staphylococcus* genera and one isolate belongs to *Bacillus*. Further, saline tolerance and plant growth promoting traits of isolates were examined. Among the eight strains, *Bacillus subtilis* GAN-4 and *Staphylococcus cohnii* MAN-3 recorded maximum ACC deaminase activity, biofilm formation, antioxidant activity, production of exopolysacchride, siderophore, proline, phenol and ammonia with solubilization of phosphorus and zinc. In addition, these two strains had higher surviving abilityon minimal media amended with Ca^+ and Mg^+ salts and also recorded significantly higher uptake of Na^+, K^+, Ca^+ and Mg^+. Thus, these two strains were chosen and treated to tomato plants to evaluate their plant growth potential at different saline concentration (2, 4, 6 and 8 dS m^{-1}) in a pot culture study. Under 2 dS m^{-1} salinity stress, plants inoculated with *Bacillus subtilis* GAN-4 recorded higher plant height, number of leaves, branches, flowers, plant biomass, fruit yield, chlorophyll content and phytohormones. Similarly, *Bacillus subtilis* GAN-4 treated plants recorded maximum osmolytes and antioxidants under 8 dS m^{-1}. *Bacillus subtilis* GAN-4 inoculated plants recorded maximum nitrogen and phosphorus contents of root, shoot and soil. *Bacillus subtilis* GAN-4 treated plants recorded highest K^+ content at 8 dSm^{-1}. Na^+, Ca^+ and Mg^+ contents recorded highest in the uninoculated plants at 8 ds m^{-1}. This study clearly points out to the utility of saline tolerant rhizobacterial isolates imparting the salinity stress in tomato.

Morphological Molecular and Physico Chemical Characterization of Tomato (*Solanum lycopersicum* L.) Varieties and Accessions for Growth Yield and Processing Traits

A. S. Ram Prasad and S. Shyamalamma
Department of Plant Biotechnology, College of Agriculture, UAS, GKVK, Bengaluru

Tomato is a popular vegetable grown worldwide for consumption either as fresh or processed form. It is rich in vitamins, minerals and antioxidants. Twenty tomato varieties and accessions were studied for growth, yield and processing traits. Among them thirteen exhibited indeterminate growth habit and seven were determinate types. Higher plant height (150.66 cm) and TSS content (4.42° Brix) were recorded in EC620456. The more number of primary branches (5.05), higher titratable acidity (0.60 %), vitamin C content (45.60 mg /100g FW), lycopene content (15.79 mg/100g FW) and less number of locules (2) were recorded in AS 07. Higher individual fruit weight (119.29 gm), maximum fruit length (10.69 cm) and diameter (6.89 cm) were observed in EC614997. Higher pulp to seed ratio (13.48) was recorded in Saahoo. Pericarp thickness (7.43 mm) and fruit firmness (6.21 Lb/kg) were maximum in ArkaVishesh and Jewel Esha. Total fruit weight per plant (5.88 kg) and yield per plot (35.65 kg) were higher in Sweakar 448. The biochemical parameters such as total phenols (58.67 mg/100g FW) and total carotenoids (17.84 mg/100g FW) were higher in Arka Apeksha and Roma VF, respectively. GCV, PCV and heritability values were high for total fruit weight per plant (28.81, 29.27 and 96.90 %) and vitamin-C content (31.43, 35.81 and 77.02 %). Higher PIC values were shown by lycopene specific primers HP 1 (0.27) and LEaat003 (0.22). The above mentioned genotypes can be utilized in crop improvement for higher yield and processing suitability.

Understanding the Relatedness among different *Eleusine* Species using SSR Markers Developed from *Eleusine indica* and *Eleusine coracana* Genome Sequences

G. M. Varsha and R. L. Ravikumar
Department of Plant Biotechnology, College of Agriculture, UAS, GKVK, Bengaluru

In the present investigation, an attempt was made to understand the morphological and molecular relationship between 12 genotypes belonging to seven *Eleusine* species. Studies on 14 qualitative and 10 quantitative traits revealed greater diversity among wild species compared to cultivated *Eleusine* species. The principal component analysis revealed that the plant height, number of fingers on main ear, finger length, flag leaf length, flag leaf width, days to 50 per cent flowering are the important traits that contribute most to the variation.The transfer potential of SSR markers showed 100 per cent transferability rate in all the species under study except for *E. multiflora* and *E. jaegeri*. The lowest transferability was observed for *E. multiflora i.e.,* 88 per cent for *E. indica* SSRs, 92 per cent for *E. coracana* SSRs and 86.7 per cent for EST SSRs.Out of 85 SSR markers studied, 61 markers (72%) exhibited polymorphism. The number of alleles produced per primer varied from 1 to 5, major allele frequency ranged from 0.33 to 1, gene diversity ranged from 0 to 0.77, polymorphic information content ranged from 0 to 0.68. Dendrogram based on UGPMA clustering using morphological and molecular data grouped the genotypes into two major clusters. Cluster I was a solitary cluster with GE7143 (*Eleusine multiflora*) genotype and other was with remaining wild and cultivated genotypes. The results indicated that *E. multiflora* was found distinct from other species while, *E. indica* and *E. coracana subsp africana* were found very close to *E. coracana* both morphologically and genetically which need to be exploited in interspecific hybridization.

Characterization and Validation of Lipase Gene Expressed in *E. coli* Isolated from *Pseudomonas fluorescence*

V. Sachin and T. M. Ningaraju
Department of Plant Biotechnology, College of Agriculture, UAS, GKVK, Bengaluru

Lipases (triacylglycerol acylhydrolase, EC 3.1.1.3) constitute one of the most important group of commercial biocatalysts. They can catalyze both the hydrolysis and synthesis of esters from glycerol and long-chain fatty acids. The laboratory-scale study on biodiesel production [a mixture of fatty acid alkyl esters (FAME)] of recombinant lipase (*rLP*) was evaluated in the present study as it is regarded as an attractive alternative for fossil fuel. To obtain a stable expression of *rLP* gene and its enzymatic properties, the isolated and cloned *rLP* gene of *Pseudomonas fluorescences* was subcloned in pET-28a expression vector and *Escherichia coli* BL21 (DE3) host cells. The induction was achieved at 37 ºC and the obtained insoluble *rLP* fraction was partially purified with a molecular mass of 52 kDa and immobilized in sodium alginate beads to determine its enzymatic activity. The results displayed highest total lipase activity in the immobilized fraction with 97 U/ mL at 37 ºC. The parameters like methanol to oil ratio, temperature and agitation speed were optimized for biodiesel production. The crude lipase immobilized by entrapment (with 4% (w/v) sodium alginate beads) was more stable than the purified lipase. The gas chromatographic quantification showed maximum yield of FAME (74.43 per cent) for immobilized lipase. The kinetic properties of biodiesel obtained from *Pongamia* oil was compared with ASTM standards. The property analysis of biodiesel revealed that the *rLP* mediated transesterified biodiesel has high potential to be utilized as a biofuel either in neat or blended form but requires further purification and processing.

In-vitro and *In-vivo* Regeneration Protocols in Black Turmeric (*Curcuma caesia* Roxb.) and Molecular Profiling Using SSR Markers

Subhas Picheli and S. Shyamalamma
Department of Plant Biotechnology, College of Agriculture, UAS, GKVK, Bengaluru

Black turmeric (*Curcuma caesia* Roxb.) is an important medicinal plant containing many phytochemicals, which are used widely in local medicines to treat many diseases. Thus, black turmeric is over exploited and listed under endangered species by National Medicinal Plant Board of India. The present study aimed to multiply the plants by *in-vitro* and *in-vivo* regeneration methods and identifying the genetic diversity among twenty black turmeric accessions. Rhizome buds of 1-2 cm from healthy rhizomes were found optimum for shoot development. Multiple shoot development was observed in treatment T_7 (BAP 3 mg/L + NAA 0.5 mg/L) and T_{11} (BAP 3 mg/L + NAA 1 mg/L) upto 4 shoots. Higher number of roots was also observed in T_7 and T_{11} upto 5 roots. *In-vivo* pro-tray technique was used as multiplication method. T_3S_3 (Rhizome weight 10 g + Coir pith, FYM, vermicompost and *Trichoderma*) and T_2S_3 (Rhizome weight 8 g + Coir pith, FYM, vermicompost and *Trichoderma*) showed higher number of shoots (2), number of leaves (8), leaf length (29.50 cm), leaf width (8.33 cm), shoot length (29.48 cm) and root number (18.37). Molecular diversity analysis carried out using 10 SSR primers which revealed similarity coefficient ranging from 0.31- 1.00 and PIC values ranging from 0.18 to 0.69. CuMiSat-23 (0.63) and CuMiSat-19 (.60) showed higher PIC.

Molecular and Insecticidal Characterization of Novel Cry Toxins from *Bacillus thuringiensis* (Berliner) against the Fall Army Worm (*Spodoptera frugiperda*) and Brinjal Ash Weevil (*Myllocerus subfasciatus*)

D. ANUSHA AND S. N. NAGESHA
Department of Plant Biotechnology, College of Agriculture, UAS, GKVK, Bengaluru

TWELVE *Bt* strains were isolated from root nodules using six approaches, *viz.,* analysis of crystal protein production by microscopy; detection of *cry* gene content by PCR, Plasmid profiling, SDS-PAGE profiling; cloning and sequencing, phylogenetic analysis; and toxicity testing. Under a light microscope, all 12 *Bt* strains examined were gram-positive, endospore-forming and had normal *Bt* crystal structures. A bipyramidal inclusion was predominant in 42.2 per cent. Five distinct plasmids were observed in the present study. Universal primers and gene specific primers were used to detect *Cry*-type genes by the PCR. The nucleotide sequences of amplified new *cry* genes were BLASTed against NCBI database sequences, and they were labeled as native *Bt* strains with high homology (60–100%) to existing *Bt* strains. The nucleotide sequences of new *Btcry* genes were deposited in the NCBI GenBank database. Three new *cry* genes *viz.,cry1*, *cry3A* and *cry26* were isolated with complete sequence. *cry* genes were cloned and expressed in the pRSET vector. The inferred 3-D structural model of the novel *cry* gene, which was predicted using Phyre2 homology modeling, demonstrates that the gene has three domains that participate in the development of a pore and define the receptor's binding selectivity. The new *Bt* strains were highly pathogenic, with pathogenicity ranging from 93 to 100 per cent against fall army wormlarvae and Brinjal ash weevil adults. In conclusion, native *Bt* strains from root nodules were shown to have bio-insecticidal activity on larvae of fall army worm and adults of brinjal ash weevil.

Population Improvement for High Seed Yield and Oil Content in Niger [*Guizotia abyssinica* (L. f.) Cass] Using Mass Selection

M. GURURAJA AND R. NANDINI
Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru

FIFTY FOUR germplasm lines of niger were evaluated using augmented design and base population was developed during summer 2018 by bulking the seeds of all germplasm lines to develop a populations with high seed yield and oil content using mass selection. Five hundred plants were selected from base population and were further classified into three populations based on seed yield per plant A1 (≤ 2.5 g), A2 (2.5 to 3.5 g) and A3 (≥ 3.5 g) populations.and subjected to two cycle of mass selection during *kharif* and *rabi* of 2018 in agrid sowing manner. The results revealed that seed yield increased from 2.33 g per plant to 3.43 g per plant in A1, from 2.98 g to 4.51 g per plant in A2 and from 3.11 g to 5.38 g per plant in A3 population in first cycle of selection over a base population. After second cycle of mass selection seed yield increased from 3.43 g per plant to 3.98 g per plant in A1, from 4.51g to 5.23 g per plant in A2 and from 5.38 g to 5.99 g per plant in A3 population over first cycle of selection. After two cycle of mass selection mean value of oil content increased from 34.18 to 37.32 per cent in A1, 35.68 to 38.12 per cent in A2, 36.02 to 38.86 per cent in A3 population. All the three developed populations were again compared with three check for their performance for yield and oil. The results revealed that seed yield per plant showed 69.36, 122.55 and 154.89 per cent improvement in A1, A2 and A3 population, respectively over local check, while it was 46.32, 92.27 and 120.22 per cent improvement over No-71 check and 21.34, 59.45 and 82.62 per cent improvement over KBN-1 check variety.

Identification of Stable Sources of, and Genetic Determinants Controlling Resistance to Leaf Curl Virus and Anthracnose Diseases through Genome Wide Association Mapping in *Capsicum* spp.

GANESH PRASAD AND A. MOHAN RAO
Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru

AMONG biotic stresses, chilli leaf curl virus disease (ChiLCVD) and anthracnose are most devastating diseases in chilli. Genetic resistance is eco-friendly and effective approach to mitigate yield losses. Mapping genomic determinants underlying resistance with identification of co-segregating markers further catalyse pace of trait transfer to desirable susceptible genome. With this background, 188 *Capsicum* genotypes (association panel) belonging to six species were evaluated for responses to *ChiLCV* infection during 2019 and 2021 summer, for fruit yield and attributes during 2019, 2020, 2021 *kharif* along with responses to anthracnose infection during 2020 and 2021 *kharif* and genotyped using 112 SSR markers. Three consistently 'highly resistant' genotypes to ChiLCVD belonging to *C. chinense* and four 'immune' genotypes for anthracnose resistance belonging to *C. baccatum* were identified from the panel. Genotypes belonging to *C. annuum*; LCVT#8 and BDL-2 and BDL-3 and ADL-4 were identified as 'highly resistant' to *ChilCV* and anthracnose, respectively. These genotypes can be utilized as donors of genetic resistance for developing *ChiLCV* and anthracnose resistant chilli cultivars. Two distinct SSR marker-based sub-populations were identified. Number of SSR alleles varied linearly with expected heterozygosity and polymorphic information content. None of the markers were found associated with *ChiLCV* resistance. However, two and three SSR markers were putatively associated with overall and true lesion sizes, respectively across six statistical models used in the study, for two years and for pooled data through BLUPs. These SSRs were associated with eliciting response upon pathogen infection in *Capsicum* genome. Three SSR markers were found putatively associated with genomic regions governing fruit length, nine with fruit width, two with green fruits plant^{-1}, 12 with average green fruit weight, nine with green fruit yield plant^{-1} and one with red dry fruit yield plant^{-1}. These SSR markers with prior validation could be used in marker assisted selection.

QTL Mapping and Genomic Prediction for Resistance to Fusarium Stalk Rot (*Fusarium verticilloides*) in Maize (*Zea mays* L.)

B. M. SHOWKATH BABU AND H. C. LOHITHASWA
Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru

FUSARIUM stalk rot disease (FSR) caused by *Fusarium verticillioides* is emerging as a potential production constraint in maize. As a first step in understanding the genetics of resistance, an experiment was conducted employing six generation mean analysis in six crosses *viz.,* VL1043×CM212, VL108867×CM202, VL1218×CM212, VL1218×CM202, VL121096× CM212 and VL121096×CM202 through artificial disease inoculation during *rabi* 2018 and *summer* 2019 season. The study revealed the polygenic inheritance coupled with additive, dominance and additive × additive gene effects with duplicate epistasis in the inheritance of FSR in all the six crosses. Hence, quantitative trait loci (QTL) explaining variation for FSR resistance were identified using two doubled haploid (DH) populations induced from F_2 of the crosses VL1043 × CM212 and VL121096×CM202 which were challenged with FSR during *rabi* 2019 and *summer* 2020 seasons at the College of Agriculture, V. C. Farm, Mandya. A total of 164 and 132 polymorphic SNPs markers were used to genotype DH lines derived from F_2 of the crosses VL1043×CM212 and VL121096×CM202. Two and one QTL was identified in *rabi* 2019 and *summer* 2020, respectively. Only one QTL (qFSR_1_1) was common across two seasons in DHs derived from the cross VL1043×CM212. Similarly, two QTL each in *rabi* 2019, *summer* 2020 and one common QTL (qFSR_6_2) in *rabi* 2019, *summer* 2020 and combined analysis were identified for FSR resistance in DHs derived from F_2 of the cross VL121096 × CM202. Seven di-QTL interactions were detected for FSR resistance in DHs induced from F_2 of VL1043 × CM212 and VL121096 × CM202 crosses. Prediction accuracies of genomic estimated breeding values (GEBVs) were estimated individually and it was higher in DHs induced from F_2 of VL121096× CM202 followed by DHs induced from F_2 of VL1043 × CM212 and DHs induced from F_1 of VL1043 × CM212, respectively for resistance to FSR.

Studies on Combining Ability and Heterosis in Green Gram [*Vigna radiata* (L.) Wilczek]

D. S. Pooja and R. Nandini
Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru

An investigation was carried out in green gram to assess the general combining ability (*gca*) of lines and testers, specific combining ability (*sca*), heterosis and gene action of hybrids generated by crossing four lines SML 032, BM 63, China mung and LM 1668 with five testers (HUM-12, PS-16, RMG-353, TJM-3 and IC 314851) following line × tester mating design. The generated twenty hybrids along with 9 parents and two checks (China mung and LM 1668) were evaluated in RCBD with three replications to assess combining ability for seed yield and its component traits, reaction to mung bean yellow mosaic disease and heterotic effect during summer 2021 at the experimental field, Department of Genetics and Plant Breeding, UAS, Bangalore. Among the lines, SML 032 and BM 63 and among the testers, RMG-353 and TJM 3 were identified as good general combiners for seed yield and its component traits. The hybrids of crosses SML-032 × RMG-353 (10.27g) and BM 63 × TJM 3 (9.89g) were identified as best top hybrids based on *per se*, *sca* and standard heterosis for seed yield plant^{-1}, can be utilized for isolation of transgressive seggregants in further breeding programme to develop high yielding varieties with desirable traits. F_2 generated out of these developed twenty hybrids can be utilized to workout the genetics of MYMY disease. The testers *viz.,* HUM 12, PS 16, RMG 353, TJM 3 and IC 314851 identified as resistant sources to MYMV disease can further be exploited for developing resistant genotypes.

Assessment of Genetic Diversity and Evaluation of Selected Genotypes for Resistance Against Shoot Fly in Sorghum [*Sorghum bicolor* (Linn.) Moench]

R. Divya and G. Somu
Department of Genetics and Plant Breeding, College of Agriculture, V. C. Farm, Mandya

An investigation was carried out to estimate the genetic variability, character association, genetic diversity and reaction to shoot fly *A. soccata* in 81 germplasm lines including three checks of sorghum at AICRP on sorghum, KVK, Haradanahalli, Chamarajanagara during 2020-21. Analysis of variance showed significant variation for all 13 quantitative traits. High estimates of GCV, PCV, heritability and genetic advance as per cent of mean was observed for plant height, panicle width, panicle weight, test weight, number of primary branches per panicle and seed yield per plant indicating the preponderance of additive gene action. Association studies revealed that characters like number of leaves, panicle width, panicle weight and test weight exerted positive direct effect and a significant positive correlation with seed yield per plant. So, simple selection based on these characters would be rewarding. 81 lines were grouped into eight clusters using Mahalanobis D^2 statistic in which cluster II and III comprised of maximum lines. Maximum inter cluster distance was seen between the clusters VI and II. Seed yield contributed highest to the total diversity. The field evaluation of 81 sorghum genotypes against shoot fly resulted in identifying six highly resistant, nine resistants, thirty-one moderately resistants, twenty-four susceptible and eleven highly susceptible lines. Biochemical components like total phenols and tannins had negative association with shoot fly while, total and reducing sugars, amino acids and crude proteins were positively correlated. IC- 289568, EC- 485858, EC- 486790 and IC- 289511 were identified as promising lines for yield and shoot fly resistance traits.

Assessment of Genetic Variability and Identification of Zinc Rich and High Yielding Genotypes from Cowpea [*Vigna unguiculata* (L.) Walp.] Germplasm

PULIGUNDLA THARUN AND N. MARAPPA
Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru

TO assess genetic variability for yield and to identify zinc rich genotypes the present study was carried out using 263 cowpea germplasm accessions sown in augmented block design. Analysis of variance was significant for yield and its attributes indicating the sufficient variability among the genotypes used for study. Genetic variability estimates, PCV and GCV were found to be high for seed yield plant^{-1}, moderate for clusters plant^{-1}, pods cluster^{-1}, pods plant^{-1} and 100-seed weight. Characters seed yield plant^{-1}, 100-seed weight, pods plant^{-1} and clusters plant^{-1} recorded high heritability coupled with genetic advance as *per cent* of mean indicating the influence of additive genes in controlling these traits. Cowpea germplasm were grouped into 3 clusters following K-mean clustering maximum number of (167) accessions were grouped in cluster II. Maximum inter cluster distance (53.20) was observed for cluster I and III and maximum intra cluster distance (22.70) was observed for cluster II. The nearest cluster distance (46.4) was observed for cluster I & II and farthest distance (53.2) for cluster I and III. Sixty promising genotypes were used for estimation of zinc content. Germplasm accessions EC100087, IC426801 (Cluster I) and EC18118 (Cluster III) were identified as genetically divergent with zinc rich and high seed yield plant^{-1}. These accessions could be used as parents in cowpea biofortification programmes.

Genetic Variability and Identification of the Germplasm Accessions for High Grain Yield and Powdery Mildew Resistance in Black Gram [*Vigna mungo* (L.) Hepper]

M. HARSHITHA AND J. SHANTHALA
Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru

BLACK GRAM, one of the important pulses, has a remarkable extent of usage for daily consumption that partly fulfills per day protein requirements of human beings. However, it is limited by less availability of genetic variability coupled with narrow genetic base, which is further restricted by the presence of the most destructive disease powdery mildew (*Erysiphae polygoni*) causing a yield loss of 90 per cent. Hence, genetic interventions is considered as substantial approach to minimize losses caused by the disease. With this back ground, an investigation was carried to identify black gram accessions resistant to powdery mildew with high yield potential. Two sets of 100 black gram germplasm accessions were evaluated for seed yield and response to powdery mildew disease infestation under natural condition using infector row technique during *kharif* 2020 at the experimental plots of K block, University of Agricultural Sciences, GKVK, Bengaluru. KU-1-662 shown to have highest seed yield, IC-436773, IC-436758, VBN-3, TU-98-18, VBN-9, KU-11-668 and Rashmi were promising for multiple quantitative traits. Higher heritability and narrow differences between the estimates of PCV and GCV indicated effectiveness of selection for seed yield and their component traits. Out of 100 accessions evaluated for response to powdery mildew disease. M-414, RFU-1303, KU-12-35 and IC-281977 were identified as highly resistant genotypes coupled with comparable seed yield. These accessions after further confirmation of responses to disease could be utilized as donor parents in breeding program for development of black gram varieties resistant to powdery mildew coupled with high yield.

Identification of Heterotic Blast Tolerant Restorers from Advanced Breeding Lines of Rice (*Oryza sativa* L.)

S. Sharadhi and N. Shivakumar
Department of Genetics and Plant Breeding, College of Agriculture, V. C. Farm, Mandya

In order to develop blast tolerant restorers with good general combining ability and further to produce high yielding heterotic blast tolerant hybrids, screening of 105 advanced breeding lines was conducted at Zonal Agriculture Research Station, V. C. Farm, Mandya during *kharif* 2020. The advanced breeding lines, KMR3/Tetep(3-2-3) and KMR3/Tetep(3-3-1) were moderately resistant to leaf blast while KMR3/Tetep(35-1) was resistant to neck blast. Further, molecular screening for *Pi54* locus confirmed its presence in 88 advanced breeding lines. Validation of SSR markers *viz*., RM-SF21-5 and RM6100 was performed to identify possible restorers, which revealed that 101 advanced breeding lines had either *Rf3* or *Rf4* or both genes. Among them, 37 were selected as testers and crossed to seven new WA-CMS lines producing 259 hybrids which were evaluated for yield related traits *viz*., plant height, number of productive tillers per plant, panicle length, panicle weight, number of filled grains per panicle, seed set percentage and grain yield along with blast tolerance during summer 2021. The ratio of GCA to SCA variance showed the preponderance of non-additive gene action for all the characters under study. The high overall general combining ability was present in 15 testers, among which, MSN36/Tetep(7-4-2-1), KMR3/Tetep(45-1-1) and KMR3/Tetep(4-1-1) were identified as having appreciable amount of tolerance to blast. Among the crosses, KCMS 54A × IET20919/MSN99(26-1-1-1-1-3-1), KCMS 53A × MSN36/Tetep(49-2) and KCMS 61A × KMR3/Tetep(4-1-1) were identified as promising hybrids based on mean *per se* performance, standard heterosis and *sca* effects for yield besides favourable reaction to blast.

Host Plant Resistance in Chilli Against Thrips, *Scirtothrips dorsalis* Hood (Thysanoptera : Thripidae) and its Management

T. R. Sunitha and C. Chinnamade Gowda
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru

Investigations were carried out on host plant resistance in chilli against thrips, *Scirtothrips dorsalis* Hood and its management at Hassan campus during 2019-2021 period. Out of 161 chilli genotypes evaluated, entries were categorised into four different categories as, 1. Highly susceptible-VI 012911 and VI012668; 2. Moderately susceptible-VI 012270 and VI 064769; 3. Moderately resistant-Sankeshwara, BhootJhalokia and 4. Highly resistant - AVPP 9824 (9852-123) and WBC SEL (E). Further, 8 entries were selected based on mean thrips population and leaf curl index from *rabi* and *kharif* seasons for detailed morphological and biochemical studies. Highly susceptible chilli line VI 012668 had higher trichome density both on adaxial (33.80 cm^{-2}) and abaxial (86.80 cm^{-2}) surfaces. While it's adaxial surface had longer trichome of 7.77 mm length. Susceptible chilli entries (VI 012911 and VI 012668) had higher total sugars and protein compared to the resistant entries AVPP 9824 (9852-123) and WBC SEL (E). Chlorophyll content in leaves did not show much impact on thrips infestation. Subsequent to thrips infestation, the levels of secondary chemicals like phenols, proline, peroxidase, PAL and SOD were found enhanced (3.14 to 4.17 mgg^{-1}; 0.08 to 0.09 $\mu molesg^{-1}$; 6.98 to 7.42 units g^{-1}; 1.39 to 1.60 $\mu molesg^{-1}$; 3.24 to 3.36 μgg^{-1} tissue), respectively attributed to hypersensitive reaction or induced resistance, more evident in resistant entries, AVPP9824 (9852-123) and WBC SEL (E). Bioefficacy study over two seasons (*rabi* and *kharif*), application of diafenthiuron resulted in maximum reduction (53-87%) in thrips population after 7 days followed by acephate (37-77%) and spinosad (33-69%). Also, diafenthiuron application resulted in higher dry chilli fruit yield of 41.37-42.20 q ha^{-1}. Ecofriendly products like NSKE 4 per cent (during *kharif*), *Metarhiziumanisopliae* $2x10^8$ $cfug^{-1}$ (during *rabi*) and *Lecanicilliumlecanii* $2x10^8$cfu g^{-1} (during *kharif* and *rabi*) were found quite promising and hence may be included in integrated pest management strategy.

Studies on Varietal Response, Mechanism of Resistance and Physiological Factors Associated with Wing Polymorphism in Rice Brown Planthopper, *Nilaparvata lugen*s Stal. (Hemiptera: Delphacidae)

SHIVUKUMARA AND L. VIJAY KUMAR
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru

THE present investigation was carried out in the Department of Entomology, College of Agriculture, V.C. Farm, Mandya during 2019-21. The glasshouse evaluation of 1061 rice genotypes against BPH identified 6 highly resistant and 47 resistant, 76 moderately resistant, 86 moderately susceptible and 846 as susceptible genotypes. The five resistant genotypes recorded more probing marks, prolonged nymphal period, lower honeydew excretion, nymphal survival, adults' longevity, growth index and FPLI as compared to susceptible genotypes. These resistant genotypes had relatively higher amount of total phenols, tannins, total free amino acids and lower in total soluble sugars, total reducing sugars and crude proteins. A significant increase in total phenols, free amino acids in resistant and proline in susceptible genotypes was observed in BPH infested plants on 5, 7 and 14 DAI, as compared to control which concludes the substantial role of these biochemicals in host plant resistant. The TN 1 plants infested with 75 hoppers and above, experienced significant reduction in dry weight, moisture content, chlorophyll content, crude protein and starch contents in both leaf blades and leaf sheaths on 5, 7 and 14 DAI compared to control whereas, in 10 days of BPH feeding on plants resulted significant reduction in yield at vegetative stages than in reproductive stages of paddy. The increased BPH nymphal period and number of macropterans, respectively was noticed in plants with higher crowding and lower nitrogen application. Whereas, the increased BPH density and glucose content of plant increases the ratio of macropterous to brachypterous forms. The study concludes that the wing development in BPH is depends on insect density and host nutritional quality. The incidence of BPH population reached its peak between last week of October to first week of November in two years and it was found significant with maximum temperature, morning relative humidity and rainfall.

Potentiality of Utilizing Indian Honeybee, *Apis cerana* Fab. (Apidae : Hymenoptera) for Achieving Hybrid Seed Production in Sunflower (*Helianthus annuus* L.) as an Alternative to Hand Pollination

SANGANNA AND M.THIPPAIAH
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru

THIRTY species of pollinators were recorded on 12 parental lines of sunflower, among them 15 were hymenopterans, 7 lepidopterans, 5 coleopterans and 3 dipterans. *Apis* species were the most predominant on parental lines of selected sunflower hybrids. The highest pollinator Shannon-Weiner index of diversity of 1.32 was recorded at 0900-1000 hr. and highest Berger-Parker dominance index 0.61at1700-1800 hr. for *Apis cerana* and *Apis dorsata* on CMS line (CMS-38 A). More number of pollen foragers were recorded in fertility restorer RHA parental lines as compared with nectar foragers. Nectar foragers spent more time as compared with pollen foragers. The CMS parental lines of sunflower hybrids produced more quantity of nectar with higher TSS as compared with restorer lines. Numerically highest seed yield, yield attributing characters and benefit : cost ratio was recorded in 3 colonies per acre as compared with other treatments. Corolla length of disc florets of fertility restorer lines were longer as compared with CMS parental lines. The variation in the number of floral visitors may be due the variation in corolla length of disc floret and variation in the nectar production by the both parental lines. The highest pollen grains per floret were recorded in R-127-1 fertility restorer parental line. *A. dorsata* recorded more number of pollen grains deposition on different parts of the body from restorer lines as compared with other honey bees. Highest benefit : cost ratio was recorded in 3 colonies of *A. cerana* per acre treated plot as compared with other treatments in case of RSFH-1887, RSFH- 130, KBSH-53 and KBSH-44 sunflower hybrids. The pollination efficiency of honey bees was dependent upon corolla length of disc floret, production of floral rewards and environmental factors.

Tritrophic Interactions Between Host Plant-Herbivore-Natural Enemies : A Case Study with the Invasive Pest, Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera : Noctuidae)

T. D. Nidheesh and K. S. Jagadish
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) is an economically important polyphagous pest with a specific preference for Poaceae family. The objective of the present study was to understand its interaction with the most preferred host plant, *Zea mays* L. and its key parasitoids *viz*., *Trichogram mapretiosum* Riley, *Chelonus formosanus* Sonan and *Bracon brevicornis* Wesmael. Ovipositional preference of *S. frugiperda* to different host plants was in the following decreasing order: Maize > Jowar > Ragi > Cotton > Rice. Further, headspace samples were collected from different growth stages (pre-flowering, flowering and post-flowering) of *Z. mays* as well as oviposition induced (= OIPVs) and *S. frugiperda* infested (= HIPVs) plants of *Z. mays* and were subjected to olfactometer bioassays, GC-MS and GC-EAD with gravid females of *S. frugiperda* and its predominant parasitoids *viz*., *T. pretiosum* and *C. formosanus*. A positive behavioural response was observed when adults of *S. frugiperda* were exposed to pre-flowering stage volatiles (= Healthy Maize Plant Volatiles, HMPVs) and herbivore induced plant volatiles in olfactometer bioassays. GC-EAD with adult fall armyworm (= FAW) revealed a total of seven EAD-active compounds each from HMPVs (majorly Farnesane) and HIPVs (majorly Ethyl benzoate, Benzyl alcohol, n-Undecane and 3,5-Di-tert-butyl toluene). Similarly, GC-EAD with naïve females of *T. pretiosum* revealed a total of five and eleven EAD-active compounds from OIPVs (majorly n-Decanal) and HIPVs (majorly Farnesane, *β*-Cyclocitral, Benzoic acid, 4-ethoxy-ethyl ester and n-Dodecane), respectively. Similarly, GC-EAD with naïve females of *C. formosanus* revealed a total of 10 (majorly *p*-Cymene, Isopropyl myristate and *p*-Xylene) and 13 EAD-active compounds (majorly Benzyl alcohol, *β*-Ionone, Ethyl benzoate and n-Decanal) from OIPVs and HIPVs, respectively. The exogenous application of salicylic acid (0.5, 1.0, 3.0 & 4.0 mM) on *Z. mays* did not elicit any behavioural response either in *S. frugiperda* or in its parasitoids.

Studies on the Host Plant Interaction and Management of Insect Pests in Groundnut

T. Rudramuni and M. Thippaiah
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru

Groundnut (*Arachis hypogaea* Lin) is an annual legume crop and belongs to family leguminaceae. Insect pests are the major responsible for low productivity in groundnut among the several factors. Leaf miner, tobacco caterpillar, aphid,thrips, jassidsand whiteflies are the important insect pests causing damage to the crop. Seasonal incidence of insect pest on groundnut revealed that thrips, leafhoppers, leaf miner and tobacco caterpillar population was significant positively correlated with maximum temperature, minimum temperature, wind speed and sunshine hours, whereas negatively correlated with morning RH, evening RH and rainfall for both the years 2018 and 2019.Among 30 genotypes screened against thrips, leafhoppers, leaf miner and tobacco caterpillar only few genotypes shown resistant and moderately resistant and most of them prune to moderately susceptible and susceptible in both the years 2018 and 2019. Phenol content was negatively correlated with thrips, leafhoppers, leaf miner and tobacco caterpillar population, whereas total sugars and amino acid was positively correlated with same population during 2018 and 2019. Studies on groundnut based different intercropping system results indicated that groundnut+bajra, groundnut+ sorghum, groundnut+maize and groundnut+cowpea intercrops recorded least number of thrips, leafhoppers and leaf miner in both the years. Insecticide evaluation revealed that per cent reduction of thrips and leaf hoppers population over control was more with imidacloprid 17.8 SL (77.60 and 84.48%), while per cent reduction of leaf miner larvae was more with lambda-cyhalothrin 5EC (68.22%). Highest pod yield was recorded with imidacloprid 17.8 SL (18.60q/ha) and thiamethoxam 25WG (18.20 q/ha) and highest cost benefit ratio was recorded with above insecticides in both the years. The study concluded that integration of intercrops, resistant genotypes, bio pesticides and synthetic insecticides appears to be ideal strategies rather than any one individual component for management of insect pest of groundnut.

Reproductive Biology and Resistance to Insecticides in the Pink Bollworm, *Pectionophora gossypiella* (Saunders) (Lepidoptera : Gelechiidae)

T. N. Madhu and K. Murali Mohan
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru

Pink bollworm (*Pectinophora gossypiella*) (Lepidoptera : Gelechiidae) is an important pest of cotton. The present work aimed to study the reproductive biology and susceptibility level of PBW to various insecticides to unravel the mechanism of resistance. Our study reported that, Nutrient Rich Diet (NRD) had significant influence on larval period, pupal weight and fecundity of PBW over natural diets such as cotton and okra; further, PBW could thrive well at temperature ranging between 25-35^{0}C. Additionally, the effect of different host plants on the oviposition preference of PBW were varied significantly and copious number of eggs were laid on Non-Bt and Bt cotton plants (79.60 ± 4.83 and 73.80 ± 4.17) as compared to Okra and hibiscus due to high trichome density/cm^2. The PBW adult emergence reached peak before sunset (between 16:00 to 18:00 hrs), mating process begins under dark conditions and the duration was ranged from 42 to 130 minutes. PBW exhibits multiple mating system and the fecundity was significantly higher (271.60 ± 8.68) as compared to single mating (67.90 ± 4.61). PBW resistance level for different insecticides were varied among ten field populations. Fenvelarate, chlorantraniliprole and spinosad were least effective and showed moderate to high level of resistance in all populations, However, emamectin benzoate displayed higher efficacy and the resistance ratio ranged from 5.78 to 19.09. The activity of detoxifying enzymes was significant ranged from 84.76 ±1.91 to 158.92 ± 2.34 in esterase; 15.94 ± 0.96 to 38.89 ±1.68 in GSTs and 1.39 ±0.19 to 5.06 ±0.22 nmol/min/mg protein in cytochrome P450s. Furthermore, baseline susceptibility of broflanilide and fluxametamide ranged from 136.10 to 343.39 mg/L; 47.52 to 273.29 mg/L among field populations of PBW. Understanding the reproductive biology and susceptibility level of PBW is crucial to implement effective IPM practices.

Functional Diversity of Infochemicals Involved in Trophic Interactions among Host Plant-Herbivore-Parasitoid Complex: A Case Study with Cucumber Moth, *Dipahania indica* (Saunders)

U. Venugopal and P. D. Kamala Jayanthi
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru

Cucumber moth, *Diaphania indica* (Saunders) is a pest of cucurbitaceous crops and inflicts ~33 per cent yield loss. The ovipositional preference of *D. indica*, under choice/no-choice conditions revealed that the moth laid relatively more eggs on cucumber plant compared to other host plants. Dual-choice assays between the healthy host plant volatiles and oviposition induced plant volatiles (OIPVs) against egg parasitoid *Trichogramma chilonis* revealed that the female parasitoids did not respond to any of the treatments.The significant preference of female *D. indica* moths to pre-flowering cucumber plant was observed over other phenological stages (flowering and fruiting). Out of 14 EAD pre-flowering active compounds, moths showed significant response to ethyl benzaldehyde, allo-ocimene, n-pentadecane and α-pinene. The female moths showed preference towards pre-flowering GC-EAD active synthetic blend as compared to solvent control. However, when given a choice between the pre-flowering synthetic blend and natural sample, the moths were significantly attracted to former. The results of dual-choice four-arm olfactometer assays revealed that specialist parasitoid, *Apanteles machaerali*s females were attracted to HIPVs of cucumber, ridge gourd and bitter gourd compared their respective healthy plant volatiles. The GC-EAD studies revealed a total of ten cues from cucumber-HIPVs that elicited antennal response in female *A. machaeralis.* Of which ethyl benzaldehyde, n-decane and 2-butyl-1-octanol elicited significant response. In dual-choice assays between cucumber-HIPVs synthetic blend *vs.* solvent, the female parasitoids were attracted to former over control. Dual-choice assay between cucumber-HIPVs synthetic blend and natural sample, revealed greater preference of wasps towards to former. The generalist parasitoid. *Goniozus nephantidi*s females exhibited preference only towards the snake gourd-HIPVs. Olfactory bioassays revealed that the *G. nephantidis* females did not respond to snake gourd EAD active compounds and synthetic blend. The female parasitoids as well as cucumber moth did not respond to exogenous application of salicylic acid sprayed cucumber plant volatiles.

Seasonal Incidence, Leaf Damage Assessment and Management of Rugose Spiralling Whitefly, *Aleurodicus rugioperculatus* Martin in Coconut

SATYABRATA SARANGI AND B. S. BASAVARAJU
Department of Agricultural Entomology, College of Agriculture, V.C.Farm, Mandya

THE investigations on seasonal incidence, leaf damage assessment and management of rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin in coconut was undertaken at College of Agriculture, V. C. Farm, Mandya during *rabi* 2020-21 and summer 2021. The incidence of whitefly was higher in summer 2021 (April-May) than the initial stage of infestation during *rabi* 2020-21 (October-November). The pest incidence was positively correlated with maximum temperature and sunshine hours and negatively correlated with humidity, minimum temperature and rainfall. The temperature and rainfall showed a significant relationship, whereas the relative humidity and sunshine hours exhibited a non-significant relationship with the incidence. The infestation index was low (0.91) during *rabi* 2020-21, while it was found high *i.*e., 2.08 in summer 2021. The per cent damage was found very high during summer (May 2021) than *rabi*. The mean per cent reduction in chlorophyll content was higher in summer 2021 (84.62%) than *rabi* 2020-21 (71.19%) indicating that the chlorophyll per cent reduction was corelated positively with high temperature and low humidity. The nut-fall was 79.34 per cent (January) during *rabi* 2020-21 and 81.20 per cent in May during, summer 2021. The per cent reduction in nut-fall was significantly highest in *Isaria fumosorosea*-pfu-5 strain (70.02%) and lowest in castor oil (8.43%). The effective treatments for controlling the whitefly were in the order *i.e., Isaria fumosorosea*>Thiamethoxam 25% WG > Azadirachtin 10000 ppm > Acetamiprid 20% SP >Pymetrozine 50% WG whereas, the least effective treatments were, castor oil followed by Mahua oil and Pongamia oil.

Diversity of Microbial Symbionts in *Callosobruchus* spp. (Bruchidae : Coleoptera)

NAGARAJ SHETTAR AND B. SHIVANNA
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru

INSECTS have developed symbiotic relationship with microorganisms for the nutrition and other biological activities. The present study focused on diversity of microbial symbionts present in *Callosobruchus* spp. Endosymbiont bacteria were isolated from different life stages (eggs, larvae pupae and adults) of lab reared populations of three *Callosobruchus* spp. Gram staining was carried out to know gram reaction. The total genomic DNA of endosymbiotic bacteria was extracted from all life stages of three *Callosobruchus* spp. and amplified using PCR with 16S rDNA primers, sequences obtained were submitted to NCBI Gene Bank. The nucleotide sequences from all the life stages of three *Callosobruchus* spp. predominantly belonged to three phyla *viz., Firmicutes*, *Proteobacteria* and *Actinobacteria*. Isolates were assigned to 11 different genera, *viz., Staphylococcus, Bacillus, Anoxybacillus, Lysinibacillus, Enterococcus, Serratia, Ralstonia, Chromobacterium, Roseomonas, Microbacterium* and *Micrococcus.* Which belongs to five classes *Bacilli*, α-*Proteobacteria,* β-*Proteobacteria,* γ-*Proteobacteria* and *Actinobacteria*. Adult stage harbors more endosymbiont bacteria compare to all other life stages. Per cent reduction of endosymbiont bacteria population were seen across generations in all three *Callosobruchus* spp. Among all genera, *Staphylococcus* and *Bacillus* vertically transmitted across the three generations of *Callosobruchus* spp.

Investigation on the Feeding of Papaya Seeds on Reproduction in Male Rat, *Rattus rattus* L.

S. Asha and Mohan I. Naik
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru

Investigation on the feeding of papaya seeds on reproduction in male rat, *Rattus rattus* L. was conducted at AINP on VPM, Department of Agricultural Entomology, UAS, GKVK, Bengaluru. In untreated rats, during post-natal development there was a substantial rise in body weight, sperm parameters, bio-chemicals profile with age. In this study, the male rats were fed with papaya seeds powder at 1 g, 1.5 g and 2 g with 25 g normal bait (11.25 g rice + 11.25 g ragi + 1.25 g groundnut oil + 1.25 g jaggery) for 15, 30 and 60 days continuously in a separate cage. The results indicated that feeding of papaya seeds powder with the normal bait at 1.5 g and 2 g for 60 and 2 g for 30 days were found to be effective in inducing sterility by significantly reducing the weight of reproductive organs, sperm parameters, level of enzymes in testis, cholesterol, proteins and glucose contents of serum. Besides, there was a reduction in testosterone, FSH and LH which helps spermatogenesis. Mating success was reduced to 33.33 per cent when fed with 2 g papaya seeds with normal bait for 60 days, compared to control. Histological sections of testes revealed a remarkable decrease in diameter of seminiferous tubules, thickness of germinal epithelium in treated male rats. There was existence of reversible effect at 15 and 30 days exposure (partial recovery) and at 60 days exposure the irreversible effect was recorded even after 30 days of treatment withdrawal in sperm parameters and biochemicals.

Faunistic Studies on Syrphids in Different Agro-Ecosystems

Katta Subramanya Sai Teja and Prabhu C. Ganiger
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru

The study was carried out at GKVK campus of the University of Agricultural Sciences, Bangalore. Syrphid flies were collected using sweep net, malaise traps and rearing methods from different districts of Karnataka, Kerala, Uttarakhand and Andhra Pradesh between October 2019 - November 2021. A maximum of 90.34 per cent of the specimens were collected by sweepnet, followed by malaise trap (4.13%) and by rearing larvae on different hosts (5.51%). Syrphids were collected from seven different ecosystems of which the highest numbers (53.82%) were collected from agro-ecosystem. Whereas, numbers collected from forest land, grass land, meadows, flower ecosystem, fallow land and wet land were 15.27, 12.98, 11.45, 4.20, 1.53 and 0.76 per cent, respectively. Among the agricultural ecosystem, highest number of specimens were collected from finger millet ecosystem. Magggots of *Serratoparagus serratus* Fabricius, 1805, *Allobaccha amphithoe* Stuckenberg, 1954 and *Ischiodon scutellaris* Fabricius, 1805 were reared from ragi root aphid (*Tetraneura nigriabdominalis* Sasaki, 1899), flatid (*Siphanta* sp. Stal, 1860) and cabbage aphid (*Brevicoryne brassicae* Linnaeus, 1758), respectively. Whereas, three species of syrphids namely *Dideopsis aegrota* Fabricius, 1805, *Betasyrphus linga* Ghorpade, 1994 and *Ischiodon scutellaris* Fabricius, 1805 were reared on redgram aphid (*Aphis craccivora* Koch, 1854). A total of 289 specimens of syrphid flies belonging to 3 sub-families, 8 tribes, 18 genera and 23 species have been reported and described. Male genitalia of 16 of the 23 species have been illustrated. In the present study, the species *Microdon bellus* Brunetti, 1923 and *Monoceromyia eumenioides* Saunders, 1842 were first report from South India.

Life Table Studies of Pigeonpea Pod Borers in Organic and Inorganic Ecosystems of Pigeonpea [*Cajanus cajan* (L.) Millsp.]

K. Dharmanna and Mohan I. Naik
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru

Life table studies of pigeonpea pod borers in organic and inorganic ecosystems of pigeonpea [*Cajanus cajan* (L.) Millsp.] was undertaken atthe Zonal Agricultural Research Station, UAS, GKVK, Bengaluru during *kharif* 2017-18 and 2018-19. The parasitoids *Bassus relativus*, *Trathala flavoorbitalis*, *Apanteles* sp, *Chelonus* sp and *Tetrastichus* on *Maruca vitrata* and *Gonopthalmus halli* and *Campoletis chloridae* were recorded on *Helicoverpa armigera* where as, spider and coccinellids were the general predators recorded. Highest number of natural enemies were recorded in organic pigeonpea ecosystem than inorganic. Life table studies of *M. vitrata* and *H. armigera* in inorganic pigeonpea ecosystem revealed that mortality in egg stage was 78.12 and 25.92 per cent, larval period I 6.91 and 13.10 per cent, larval period II 7.41 and 15.08 per cent, larval period III 16.02 and 22.92 per cent, pupal period 27.92 and 19.99 per cent, adult stage 16.32 and 3.70 per cent, respectively. Whereas, in organic pigeonpea ecosystem revealed that mortality in egg stage was 81.66 and 35.13 per cent, larval period I 10.45 and 16.32 per cent, larval period II 11.02 and 20.08 per cent, larval period III 24.77 and 32.34 per cent, pupal period 41.73 and 31.89 per cent, adult stage 33.32 and 14.06 per cent, respectively. This indicated that mortality percentage in different stages of insects recorded highest in organic than inorganic pigeonpea ecosystem. Among organic molecules,GCKE is the effective bio pesticide in reducing pod borers population with highest yield (13.44 q/ha) and B: C ratio (1: 3.24). However, HaNPV and pongamia were safe to coccinellids and spider population, with moderate effect on both the pod borers.

Studies on Species Complex, Mechanism of Resistance and Management of Leaf Folders in Rice

B. K. Monika and L. Vijay Kumar
Department of Agricultural Entomology, College of Agriculture, V. C. Farm, Mandya

The studies on species complex, mechanism of resistance and management of leaf folders in rice was undertaken at College of Agriculture, V. C. Farm, Mandya during *summer* and *kharif* 2020. The seasonal incidence of leaf folders in a popular variety IR-64 revealed that, larval population varied from 0.00-1.10 and 0.00-0.70 larvae/hill during *summer* and *kharif,* respectively with peak activity recorded during May and November. The maximum per cent leaf damage of 21.84 and 12.32 per cent was recorded in 20th and 47th SMW, respectively during *summer* and *kharif.* Among 50 local landraces and 38 AVT genotypes of rice screened against leaf folders, none of them were found highly resistant. Whereas, majority of the genotypes showed resistant and moderately resistant reaction. Only one genotype, Navara was found highly susceptible (75.35% leaf damage). Among the morphological characters studied for resistance, width of flag leaf and number of tillers (r=0.62** and r=0.61**) showed a significant positive correlation with per cent leaf damage. While, plant height (r =-0.77**) and length of flag leaf (r=-0.56*) revealed a significant negative association. Biochemical constituents *viz.,* total sugars (r=0.86**), reducing sugars (r=0.86**) and crude proteins (r=0.89**) showed a significant positive association with per cent leaf damage while, total phenols (r=-0.62**), tannins (r=-0.90**) and potassium (r=-0.86**) showed a negative association. Among the insecticides evaluated for their efficacy, flubendiamide 39.35 SC @ 0.15 ml/l recorded the lowest larval population and per cent leaf damage during both the *summer* and *kharif* and was also found best in getting the highest B:C ratio.

Molecular Characterization, Vector Relationship of *Chilli Leaf Curl Virus* (Chilcv), Epidemiology and Management of Chilli Leaf Curl Disease

Gunda V N S Madhu Kiran and N. Nagaraju
Department of Plant Pathology, College of Agriculture, UAS, GKVK, Bengaluru

Chilli is an important vegetable cum spice crop, known as wonder spice. Chilli leaf curl disease (ChiLCD) is major concern to chilli production and begomovirus-betasatellite complex infecting ChiLCD shared maximum nucleotide identity with *Chilli leaf curl virus* (98.1%) (ChiLCV) and *Tomato leaf curl Bangladesh betasatellite* (95.1%). The whitefly species shared highest nucleotide identity with Asia-1 cryptic species (99%). Single Asia-1 whitefly transmits ChiLCV and 100 per cent transmission was achieved with 24 h of AAP and IAP each. Female whitefly (86.60%) transmits ChiLCV with higher efficiency than males (53.0%) and susceptibility of seedlings to ChiLCV decreases with age. Correlation studies revealed that Maximum temperature (Tmax), minimum temperature (Tmin), evening relative humidity (RHe) had significant correlation with ChiLCD incidence and whitefly population dynamics. The best fit stepwise regression model to forecast ChiLCD incidence and whitefly population dynamics is y=-297.306+0.81xRHe+8.04xTmin and y=-19043.72+585.52xTmax, respectively. Five chilli genotypes (NS-2560, NS-2572, AVPP-508, AVPP-1111 and AVPP-9813) found to be resistant under high ChiLCD pressure in open field conditions during both *kharif* and summer seasons. The plant protection measures operated in module-3 (Healthy seedlings, border crop with maize, silver reflecting mulch, alternate spray of LBS–6 (1.5 mL L^{-1}), LBD-12 (1.5 mL L^{-1}), neem oil (0.4%), imidacloprid 17.8 % SL (0.05%) and LBD–12 (1.5 mL L^{-1}), at week intervals) supressed the whitefly population below ETL level and recorded lowest ChiLCD severity (11.55, 19.47, 13.86, 16.17) during *kharif* 2019, summer 2020, *kharif* 2020 and summer 2021, respectively.

Characterization, Epidemiology, Host Plant Resistance and Management of *Urdbean Leaf Crinkle Virus* (ULCV) in Blackgram [*Vigna mungo* (L.) Hepper]

P. Aishwarya and H. K. Ramappa
Department of Plant Pathology, College of Agriculture, UAS, GKVK, Bengaluru

Urdbean Leaf Crinkle Virus (ULCV) is a major threatening disease in blackgram. The biological characterisation of ULCV revealed the sap transmission between 92-100 per cent, seed transmission between 55-95 per cent and *Aphis craccivora* C.L. Koch transmission upto100 per cent with 10 minute of acquisition feeding period, 12 and 24 hours of inoculation feeding period with 10 aphids per plant. The host range studies revealed that soybean, field bean, horsegram, cowpea, greengram and weed *Euphorbia geniculata* to be hosts for ULCV disease. The rate of infection was severe at younger stages upto 35 DAS and reduced at later growth stages upon sap inoculation. Transmission electron microscopic observations of ULCV infected blackgram indicated isometric particles with size of 25-30 nm. The ULCV samples of blackgram showed no amplification for any of the primers of potyvirus, geminivirus and viroids. Metagenomic sequencing of ULCV samples showed nucleotide and amino acid identity of 76.44 and 90.66 per cent with *Cotesia glomerata bracovirus (putative histone 4 gene),* respectively which can be validated further. None of the 124 blackgram genotypes screened under controlled conditions showed resistant reaction for ULCV disease. The minimum (16-18^{0}C) and maximum (32-34^0 C) temperature range co-related negatively and positively during late *kharif* and summer for ULCV disease incidence, respectively. Seed treatment of thiamethoxam 30 per cent FS @ 10 ml^{-kg} of seeds with neem (oil based) spray 10,000 ppm @ 2 ml^{-L} of water at 30, 45 and 60 DAS reduced the ULCV disease incidence compared to control.

Molecular Characterization of Tomato Mosaic Virus and Cucumber Mosaic Virus Infecting Tomato (*Solanum lycopersicum* L.) and Induction of Defense Using Biomolecules

B. N. Ashwini and N. Nagaraju
Department of Plant Pathology, College of Agriculture, UAS, GKVK, Bengaluru

Tomato mosaic virus (ToMV) and cucumber mosaic virus (CMV), are considered as the most important virus diseases infecting tomato. The characterized ToMV-To-Kar isolate genome had 6380 nucleotides and shared 97.00-99.56 per cent nucleotide identitywith other ToMV isolates/strains. Tripartite CMV-To-Kar isolate comprised of RNA1 (3360 nt), RNA2 (3050 nt) and RNA3 (2217 nt) shared 92.00-98.58, 91.12 -98.84 and 92.03 - 98.23 per cent nucleotide identity with subgroup IB of CMV, respectively. Among 20 different biomolecules tested for induced defense, least mean ToMV disease severity (3.33 %) was observed in plants primed with milk and *Simarouba glauca* (5.00 %) correspondingly with higher defense enzyme activities *i.e.,* PO (2.10 and 4.95 fold), PPO (3.06 and 1.74 fold) and PAL (1.45 and 1.37 fold) and with 3.59 and 3.22 fold increased accumulation of SA, respectively. Similarly, a great reduction in CMV disease severity was observed in *S. glauca* and milk *i.e.,* 100.0 and 87.50 per cent, respectively. They recorded enhanced PO (4.57 and 2.67 fold), PPO (1.47 and 3.05 fold) and PAL (1.13 and 1.17fold) activities with 3.82 and 3.29 fold change accumulation of SA, respectively. The defined biomolecules showed restrictive activity of *Myzus persicae* with relative deterrence index between 0-1 in detached leaf assay, whole plant assay and also least number of aphids in leaf disc assay. Out of 35 entries screened for resistance against ToMV and CMV under glasshouse conditions, TLB-409-1-2, LA3924 and Sankranti showed resistant and moderately resistant reaction to CMV and ToMV, respectively.

Epidemiology and Management of Root Rot Complex Disease in Groundnut (*Arachis hypogaea* L.) in Karnataka

P. Palaiah and T. Narendrappa
Department of Plant Pathology, College of Agriculture, UAS, GKVK, Bengaluru

Groundnut root rot complex diseases caused by *Aspergillus niger*, *Rhizoctonia bataticola* and *Sclerotium rolfsii* from seedling to maturity stage and the survey conducted in *kharif* 2017 and 2018 in major groundnut growing districts of Karnataka revealed that Kalaburagi had the highest collar rot (16%), Chitradurga had the highest of stem rot (22.72%), and Koppal had the maximum dry root rot (25.25%) disease. Plants up to ten days old were more susceptible to collar rot, while plants 60-90 days old were highly susceptible to both dry root rot and stem rot. The incidence of collar rot and stem rot was higher in sandy loamy soil and whereas, dry root rot disease was more in coarse soil. Collar rot and dry root rot disease incidence was high at pH 5.0. wherein stem rot disease was more at pH of 6.5-7.5. Collar rot pathogen favoured 25 per cent soil moisture but stem rot pathogen preferred 15 per cent soil moisture and dry root disease preferred 20 to 25 per cent soil moisture. Potassium and phosphorus applications lowered the occurrence of all root rot disease. Out of thirty-three groundnut varieties tested for resistance to root rot complex disease and non of varieties were found to be resistant. Bio agents *viz., Trichoderma harzianum, T. viride* and *Pseudomonas fluorescens* reduced maximum mycelial growth in *in vitro* and root rot causing pathogens are highly sensitive to Mancozeb 75% WP, Thiram 80% WP, Tebuconazole 25.9% EC, Carbendazim 12% +Mancozeb 63% WP and Carboxin 37.5% + Thiram 37.5% WP effectively suppressed the growth at 500 ppm. Seed treatment with Tebuconazole 2% DS at 1.5g kg^{-1} followed by PGPR at 625g ha^{-1} seeds + Soil application of Neem cake 250 kg ha^{-1} enriched with *Trichoderma* at 35-40 DAS reduces root rot complex disease incidence and increases the yield of groundnut.

Unravelling Population Structure, Virulence Diversity and Host Range of Vegetable Soft Rot Bacteria

B. S. CHANDRASHEKAR AND M. K. PRASANNA KUMAR
Department of Plant Pathology, College of Agriculture, UAS, GKVK, Bengaluru

BACTERIAL soft rot disease is a serious threat to vegetable production in India, in this study, biochemical and molecular characterization of associated bacterial soft rot pathogens was carried out. A total of 16 pathogens were isolated of which 7 were from carrot, {*Klebsiella variicola* (CRT1), *K. pneumonia* (CRT2, CRT3), *Pseudomonas plecogloccida* (CRT4, CRT5), *P. lini* (CRT6, CRT7)}. Three from radish, {*Enterobacter cloacae* (RDH1, RDH3), *Pectabaterium carotovorum* pv. *brasiliense* (RDH3)}, two from tomato {*K. variicola* (TMT1), *Acinetobacter radioresistance* (TMT2)}, one each from chilli, bellpepper, knolkhol and cauliflower {*K. variicola* (CHL1), *A. pitti* (CPM), *P. carotovorum* (KK) and *A. johnsonii* (CLF)}. The whole genome sequencing revealed the genome size of 5.8Mb, 5.9Mb, 4.9Mb, 4.8Mb and 3.8Mb of CRT2, CRT5, RDH2, RDH3 and CPM isolates, respectively. Transcriptome analysis revealed 968 uniquely up-regulated genes at 24HAI and 665 at 48HAI. All the isolates were capable of infecting the ten different vegetable slices indicating broad host range. While RDH2 showed wide host range in coir enrichment and the hypodermal syringe method in the glasshouse. The isolates produced pectate lyase, polygalacturonase, cellulase and protease enzymes on media. The isolates elucidated hypersensitive reaction on *Nicotiana tabacum* cv. Xanthi, biofilm production was observed in *in-vitro* and exhibited a hydrophobic surface. The animal pathogenicity was performed for *Klebsiella* strains, which did not show any infection in mice. The antimicrobial susceptibility assay showed resistance to some antibiotics and complete susceptibility was seen in *Pseudomonas* spp. All the isolates possessed an extended spectrum of β-lactamase activity except KV2 and produced biofilm on BHI agar media. The LAMP technique was developed for rapid detection of *P. carotovorum* helps quick detection in the field. This is the first study to show that the bacterial soft rot disease is a complex disease caused by many bacterial pathogens.

Understanding the Interaction Between *Cucumber mosaic virus* (CMV) and *Capsicum annuum* L. through Multi-Omics and Virus-Phytochemicals by Computational Biology

SHRIDHAR SHIVAKUMAR HIREMATH AND C. N. LAKSHMINARAYANA REDDY
Department of Plant Pathology, College of Agriculture, UAS, GKVK, Bengaluru

To decipher the mechanisms involved in interaction between *Cucumber mosaic virus* (CMV) and *Capsicum annuum* L. transcriptome and metabolome analysis was carried out. Investigation of resistance (R) genes and transcription factors (TFs) in different host plants of CMV and other crops was done through *in-silico* analysis. All of the R gene proteins and TFs of *C. annuum* were shown to be closely clustered with the R gene proteins of *Solanum lycopersicum* and *Nicotiana tabacum*. Comparative transcriptome and metabolome analysis of resistant (IIHR-3476) and susceptible (IIHR-2541) chilli lines generated at 5, 24, 72 and 120 hours post inoculation with CMV and its mock was done. For all time points, 1418 genes were up-regulated in the resistant lines compared to their respective mocks, while 2498 genes were down-regulated. Compared to the susceptible to its mock, it was found that 3152 genes were up-regulated and 922 genes were down-regulated. A total of 13 differentially expressing metabolites had higher abundance in resistant compared to susceptible chilli line and were designated as resistant related metabolites. Among the CMV inoculated resistant and susceptible chilli lines, 18, 14, 9 and 13 metabolites were significantly induced in resistance line after 5, 24, 72 and 120 hours post inoculation of CMV, respectively. Using computational biology, potential plant secondary metabolites for the management of *Sunflower leaf curl virus* through *in-silico* docking were identified. Staphidine, a terpenoid originally isolated from *Delphinium staphisagria* showed the strongest binding affinity of –10 kcal/mol. Similar kind of study was extended to find out potential of phytochemicals present in *Phyllanthus amarus* and *Andrographis paniculata* used in Ayurveda against COVID 19 causal agent, *Severe acute respiratory syndrome coronavirus*-2 (SARS-CoV-2) proteins and were shown inhibitory effect on them.

Molecular Characterization and Host-Plant Resistancein Blast [*Magnaporthe grisea* (Hebert) Barr.] of Finger Millet

M. R. SWATHI AND K. B. PALANNA
Department of Plant Pathology, College of Agriculture, UAS, GKVK, Bengaluru

FINGER millet is a highly nutritious crop affected by several diseases of which blast is a major disease hampering its productivity. A total of 15 blast isolates from diseased specimens of different regions of Karnataka were isolated by the spore drop technique and identified as *Magnaporthe grisea.* BLAST results of ITS, ACT and CAL sequences confirmed that *M. grisea* is the causal organism of finger millet blast. *Ragi* straw extract agar and oat meal agar were the ideal solid media for culturing *M. grisea* as higher mycelial growth (> 8 cm) and a fair amount of sporulation (> 10 conidia/microscopic field) were recorded. Mating type analysis using MAT gene specific primers revealed the presence of 26 per cent male fertile (MAT1-1), 20 per cent female fertile (MAT1-2), 8 per cent hermaphrodite and 46 per cent unknown mating type. Out of the 123 genotypes screened for their reaction to blast under natural conditions, 80 were resistant, 38 were moderately resistant and none of the genotypes were highly resistant to leaf blast. For neck blast, 22 were highly resistant, 65 were resistant and 31 were moderately resistant. For finger blast, 16 were highly resistant, 82 were resistant and 24 were moderately resistant. Only 32 genotypes found resistant to all types of finger millet blast. The loss in grain yield varied from 14.44 to 58.47 per cent whereas, the loss in fodder yield varied from 4.43 to 28.79 per cent due to blast in unprotected plot under different levels of disease intensity.

Studies on the Leaf Spot Disease of Ginger (*Zingiberi officinale* Rosc.) Caused by *Phyllosticta zingiberi* Ramakr.

S. SAMPRITHA AND N. S. PANKAJA
Department of Plant Pathology, College of Agriculture, V. C. Farm, Mandya

GINGER (*Zingiberi officinale* Rosc.) is an important tropical spice belonging to the family Zingiberaceae. Among the diseases of ginger, leaf spot disease caused by *Phyllosticta zingiberi* Ramakr. is considered to be one of the important foliar diseases appearing in mild or severe form in all the ginger growing tracts of the country. Investigations were carried out on disease severity of leaf spot of ginger, morphological and molecular characterization, cultural and physiological studies, efficacy of fungicides, botanicals and bioagents against *Phyllosticta zingiberi* Ramakr. Roving survey was conducted in four major ginger growing districts and the results showed that disease severity was highest in Hassan district (31.32%) and lowest in Kodagu district (19.73%). The mycelia of all the five isolates appeared septate with hyaline in colour. The conidia were hyaline, ellipsoidal in shape with a size ranging from 9.15-11.98 × 3.58-6.33 µm.Molecular study revealed that all the isolates showed similarity with *Phyllosticta citricarpa*, whereas maximum per cent similarity (95.96%) was observed in HNP isolate. Cultural and physiological studies revealed maximum mean mycelial growth on potato dextrose agar, temperature 30^{0}C, pH 4.0, alternate cycles of light and dark, dextrose and potassium acetate. Among the fungicides tested maximum mycelial inhibition of 100.00 per cent was recorded in Mancozeb 75% WP, Propiconazole 25% EC and Carbendazim 12% + mancozeb 64% WP. Among the different plant extracts tested maximum per cent mycelial inhibition of 100.00 per cent was recorded by garlic clove extract. Among the bioagents tested, *B. subtilis* recorded maximum mycelial inhibition of 100 per cent.

Combining Ability and Heterosis in Relation to Genetic Diversity in Cucumber (*Cucumis sativus* L.)

M. Venugopala Reddy and P. Venkatesha Murthy
Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru

In cucumber, the knowledge on combining ability of parents is relevant for the choice of parents to develop the heterotic hybrids and design the breeding strategies. One hundred five hybrids derived involving fifteen parental genotypes were evaluated along with their corresponding parents and standard check (Chitra) in alpha lattice design with three replications during *kharif* 2019 and 2020 at the Horticulture Research Station, Department of Horticulture, GKVK, UAS, Bangalore to assess combining ability and extent of heterosis. Analysis of variance revealed significant differences among parents and crosses for all yield attributing traits during *kharif* 2019 and 2020, justifying the materialused in the study. The parent SKY/AC-265-613480 exhibited the highest GCA effects and *per se* performance for fruit yield per plant during *kharif*-2019 and 2020 seasons followed by parents JB/11-028-595504 and SKY/AC-247-613476. Among the crosses, the cross combination SKY/AC-247-613476 × SKY/AC-265-613480 recorded the highest SCA effects and fruit yield per plant during both seasons. Genetic variation in cucumber collections was assessed using morpho-physiological and SSR markers and this showed that, collections displayed considerable diversity in morpho-physiological traits but the genetic diversity at the molecular level was relatively low. The separate crop was raised during *rabi* 2020 to screen the hybrids and their parents for downy mildew disease under natural epiphytic condition and it confirmed that, two parents and seven cross combinations showed resistance with less disease progression. The hybrid SKY/AC-270-613481 × JB/11-197-613470 was heterotic for vine length, fruit set, fruit length, average fruit weight, fruits per plant and fruit yield per plant. This hybrid may be evaluated in station trials to confirm its superiority and multilocation trials for its adaptability.

Studies on the Influence of Organic Manures and Bio-Fertilizers on Plant Growth, Yield, Quality and Storage of Dragon Fruit [*Hylocereus undatus* (Haworth) Britton & Rose and *Hylocereus polyrhizus* (F.A.C. Weber) Britton & Rose]

Ayesha Siddiqua and K. N. Srinivasappa
Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru

An experiment was conducted to study the influence of organic manures and bio-fertilizers on plant growth, yield, quality and storage of dragon fruit during the years 2019 to 2021. The experiment consisted of thirteen treatments and replicated thrice using randomized complete block design (RCBD). The pooled data from two successive years for red fleshed dragon fruit revealed that treatment T_{13} comprising of 100 per cent N through vermicompost + PSB at 10 kg ha^{-1}+ VAM at 10 kg ha^{-1} had significantly greater impact on parameters like plant height (409.85 cm), number of branches per plant (9.43), plant spread in N-S (180.96 cm), E-W (168.33 cm) directions, days to first flower open (418.74 days), duration of flowering (9.61 hours), length of the fruit (9.68 cm), diameter of fruit (9.37 cm), weight of the fruit (497.91 gm), volume of the fruit (420.10 cc), number of fruits per plant (37.50), fruit yield (93.42 t ha^{-1}), TSS (11.56ÚB), Vit-C (9.57 mg $100g^{-1}$), acidity (0.36 %), shelf life (9.71 days) having benefit cost ratio of 3.81 and maximum overall acceptability score was recorded in treatment T_5 (3.34). White fleshed type dragon fruit also showed similar results and recorded superior values for plant height (396.73 cm), number of branches per plant (9.32), plant spread in N-S (175.00 cm), E-W (170.16 cm) directions, days to first flower open (441.77 days), maximum duration of flowering (9.32 hours), length of the fruit (9.55 cm), diameter of fruit (8.74 cm), weight of the fruit (430.70 gm), volume of the fruit (415.41 cc), number of fruits per plant (33.42), fruit yield (72.26 t ha^{-1}), TSS (10.35^{0}B), Vit-C (7.39 mg $100g^{-1}$), acidity (0.38 %), shelf life (9.70 days) with benefit cost ratio of 3.78 and maximum overall acceptability score of 3.95 was given to treatment T_{12}.

Effect of Foliar Application of Zinc and Boron on Growth and Yield of Anthurium

ARUNA TOTAD AND R. VASANTHA KUMARI
Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru

ANTHURIUM (*Anthurium andraeanum*) is the best known in global market for its flower which is colored modified leaf (spathe) and a pencil-like protrusion (spadix) borne on leafless stalk or peduncle. A field trial was conducted in Department of Horticulture, College of Agriculture, University of Agricultural Sciences, GKVK, Bengaluru during 2020-21 to assess the 'Effect of foliar application of zinc and boron on growth and yield of anthurium'. The experiment was laid out in complete randomized design and use of micronutrients *viz.,* zinc (zinc sulphate) and boron (boric acid). The treatments were replicated thrice and the foliar application was carried out on 30th, 60th and 90th day after transplanting. Foliar application of Zinc (0.4 ppm) + Boron (0.4 ppm) showed overall better performance, the vegetative parameters like tall statured plants (35.93 cm), number of leaves per plant (13.94), leaf length (19.83cm), leaf breadth (12.83 cm) and leaf area (224.87 cm^2). Same treatment showed highest flower parameters like stalk length (38.64 cm), spathe length (12.50 cm), spathe width (9.00 cm) and spadix length (6.22 cm), among post harvest studies the parameters like solution uptake (18.33 ml), spadix discoloration (26.50 days) and vase life of flower (31.33 days) and yield parameters like number of flowers (6.94 per plant), (62.46 per m^2 area), (25678 per 500 m^2 area), (514073.56 per hectare) and the maximum economic return was (1: 1.71) were recorded maximum in the same treatment.

Evaluation of Cucumber (*Cucumis sativus* L.) Genotypes for Growth, Yield and Quality Traits

B. SWATHI AND SIDDAGANGAIAH
Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru

CUCUMBER is an important vegetable belongs to family Cucurbitaceae. It is grown for its tender fruits, which are consumed either raw or as salad. Around seventeen diverse genotypes of cucumber were collected from different indigenous sources and were laid out in randomized complete block design with three replications during the period of January to April 2020-21 in the Department of Horticulture, GKVK, Bengaluru and were assessed to know variability, correlation, path analysis, divergence studies, sex expression, yield and quality parameters. High heritability coupled with high genetic gain was observed for average fruit weight, number of fruits per vine and fruit yield per vine. Fruit yield per vine was positively and significantly correlated with average fruit weight, number of male flowers per vine, fruit length, number of female flowers per vine, days to last harvest of the fruit and fruit diameter. Fruit yield per vine had the maximum positive direct contribution towards average fruit weight followed by number of fruits per vine, number of male flowers per vine, internodal length and fruit length. Different genotypes of cucumber were grouped in five major clusters. Cluster 1 was the largest group consisting of 11 genotypes which was followed by cluster 3 (3 genotypes), cluster 2, cluster 4 and cluster 5 had single genotype. Fruit yield per vine showed positive and high significant correlation with TSS, flesh thickness and physiological loss in weight. Maximum fruit yield per vine was observed for Sirsi Local-1 followed by Sirsi Local-2 and Davangere Local.

Evaluation of Promising Black Turmeric (*Curcuma caesia* Roxb.) Genotypes for Growth, Yield, Quality and Antibacterial Properties

NITEESHKUMAR AND K. N. SRINIVASAPPA
Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru

EIGHT promising black turmeric genotypes were studied for growth, yield, quality and antibacterial properties. Considerable variation was observed for all the DUS descriptors. Out of 25 characters studied, four were monomorphic, thirteen were dimorphic and eight were polymorphic characters. The growth parameters like days taken for field sprouting, plant height, number of leaves, number of shoots, leaf lamina length, leaf lamina width, leaf petiole length, plant diameter and leaf area was recorded periodically. The yield parameters like mother rhizome, primary rhizome and secondary rhizome characters, fresh rhizome yield and quality parameters such as dry recovery percentage, cured rhizome yield and biochemical profiling of methanolic rhizome extracts were studied. The findings of the study indicated that among eight genotypes, the genotype GKJ-5 recorded significantly superior values for plant height (123.07 cm), number of leaves (38.20), number of shoots (7.46), leaf lamina length (17.72 cm), lamina width (49.40 cm), leaf petiole length (28.24 cm), plant diameter (16.98 cm), leaf area (6434.17 cm^2), fresh rhizome yield (48.07 t/ha) and cured rhizome yield (9.85 t/ha) followed by genotypes GKB-3 & GKM-2 for growth, yield and quality parameters. Three genotypes out of eight such as GKM-2, GKB-3 & GKJ-5 were noted as adaptable genotypes to local condition. Biochemical profiling of methanolic rhizome extract confirmed intraspecific diversity in the chemical composition of genotypes with respect to the geographical distribution. The antibacterial activity for selected bacteria was also studied. The extracts exhibited positive results against the clinically important selected Gram positive bacteria.

Vegetable Based Farming Systems in Koramangala - Challaghatta (KC) Valley Project Area : An Econometric Analysis

K. N. PAVITHRA AND G. M. GADDI
Department of Agricultural Economics, College of Agriculture, UAS, GKVK, Bengaluru

THE present study on econometric analysis of selected vegetable based farming systems was undertaken in Koramangala-Chellaghatta valley project (KCVP) area using data from a sample of 160 farmers comprising 80 vegetable growers each from KCVP area and NKCVP area. The study was intended to analyze crop diversification, factors affecting crop diversification, economics, resource use efficiency and risk associated with different vegetable based farming systems, externalities associated with KCVP and willingness to pay for the use of treated sewage water in KCVP area. Results on herfindahl index used to know the crop diversification showed higher diversification in KCVP area (0.42) than NKCVP area (0.68). Four major vegetable based farming systems were selected for indepth analysis. Growing of vegetables gave higher profits and resources were found to be more efficiently used in KCVP area. The results on income variability analyzed using the Co-efficient of variation (CV) showed higher variability in FS-III (51.15%) followed by FS-II (38.22%), FS-IV (36.88%) and FS-I (32.21%) in KCVP area, similarly the descending order of income variability for NKCVP area included FS-IV (101.83%), FS-II (95.94%), FS-III (92.95%) followed by FS-I (49.46%). FS-I dominated over other farming systems at all levels of risks as revealed by the stochastic efficiency with respect to function (SERF) analysis based on absolute risk aversion coefficients [r_a(w)] in both KCVP and NKCVP areas. Positive externalities were found higher compared to negative externalities due to KC valley project. The result on willingness to pay for the use of treated sewage water through groundwater recharge was Rs.713.58 per acre per year. Thus study advocated the need for replicating the KCVP model in other feasible areas, development and adoption of risk efficient farming systems for sustained income through demonstrations and effective extension services.

An Economic Study of Rural Women Empowerment through Women Dairy Cooperatives in Eastern Dry Zone of Karnataka

R. S. GEETHA AND P. S. SRIKANTHA MURTHY
Department of Agricultural Economics, College of Agriculture, UAS, GKVK, Bengaluru

PRESENT study on nature and establishment of women dairy cooperatives (WDCs), profitability of dairy farming, impact of WDCs on women empowerment and future potential of WDCs was conducted in eastern dry zone of Karnataka. A total of 240 sample women respondents, comprising of 100 respondents each from WDCs and general dairy co-operatives (GDCs) were selected and 40 respondents from among private sellers (PSs) were included as control group. Compound growth rate, cost and return analysis, women empowerment in livestock index, regression analysis, decision tree and rank based quotient were used for analysis of data. The major variable and fixed costs involved in dairy production among the overall respondents was feed and fodder cost (Rs.120.05) and amortised cost of animals (Rs.15.93), respectively. The net returns from dairying per crossbred cow per day were found higher in GDCs (Rs.48.16), followed by WDCs (Rs.43.91) and PSs (Rs.34.86). Overall, returns per rupee of expenditure (1.17, 1.23 and 1.28) had a positive relationship with the small, medium and large herd size categories, respectively. The results indicate that concentrates, number of milch animals, labour use and experience in dairy farming exhibited positive influence on milk yield in all the models. The members of WDCs were empowered at higher percentage (64 %) than members of GDCs (54 %) and PSs (51 %). The women empowerment increased with increase in herd size by discharging additional responsibilities in care and maintenance of livestock.The respondents with higher education, nuclear family and increase in herd size had higher probability of achieving empowerment status. The demand for milk and its products are growing with increase in per capita consumption and population and thus there is an opportunity to expand the market share of WDCs.

Agro-tourism, Eco-system Services and Farm Income : A Study in Karnataka

M. GEETHA AND K. B. UMESH
Department of Agricultural Economics, College of Agriculture, UAS, GKVK, Bengaluru

AGRO-ECOTOURISM is the latest concept in Indian tourism industry and can be defined as the symbiotic association of farming sector, tourism industry and farm business along with ecosystem services. The present study was carried out in Chikkamagaluru and Kodagu districts of Karnataka. Purposive random sampling technique was employed for the selection of sample respondents. To fulfil the objectives, data was collected from 40 sample farmers practicing agro-ecotourism, 40 local people and 40 visitors through personal interview using pre-tested well-structured schedule. Annual income from agro-ecotourism (Rs.18,72,820) was comparatively higher than income from agriculture (Rs.8,21,667). The establishment cost of agro-ecotourism unit was Rs.32,55,440. The working cost was Rs.5,67,371 and fixed cost was Rs.3,22,008 with a net returns of Rs.9,83,441 which was higher than farming. The area under agriculture had reduced due to construction of buildings, roads and ponds coupled with increase in wastelands and grasslands in 2019 depicting urbanization in comparison to 2011. Indebtedness, gender, distance from taluk, off-farm income and land holding were significantly affecting the establishment of agro-ecotourism by farmers. Income and organizational participation of the farmers affected their willingness to pay for the protection of ecosystem positively. In the research area, agro-ecotourism had provided additional employment and income for local people through wage labour and own business. Employment status and income of the visitor affected positively whereas age had negative influence on willingness to pay for the protection of ecosystem. The number of visits by the visitor was significantly influenced by their age, distance travelled and amount paid by them. Most of them visited agro-ecotourism unit for recreation purpose. The study emphasized that agro-ecotourism initiative had contributed employment and additional income to the rural people through forward and backward linkages which must be strengthened to reduce migration of youths from rural area.

Commercialisation of Agriculture and its Impact on Food, Nutrition and Health Security of Farm Households in Rural-urban Interface of North Bengaluru

H. N. Thejashree and K. B. Umesh
Department of Agricultural Economics, College of Agriculture, UAS, GKVK, Bengaluru

The prime focus of the study is to assess the extent of agricultural commercialisation and impact of the same on farm households. Data of 182 farm households from rural (65), transition (54) and urban (63) gradients were considered for study. The higher level of commercialisation was found in urban gradient with commercialisation index of 33 per cent followed by rural (32 %) gradient. The variables namely non-farm income, organizational participation, agricultural asset value, land size and fertilizer usage were positively contributing to commercialisation and variables like pesticide usage and survey stratification index were found hindering the extent of commercialisation. The highly commercialised farm households are having high welfare status (79 %) followed by moderately commercialised (65 %), depicting commercialisation increases the welfare of farm households. The results of regression adjustment showed that the diversification can increase the extent of commercialisation by 11.34 per cent unfolding the significant effect of diversification on commercialisation. The household dietary diversity score (HDDS), food consumption score (FCS) and household food insecurity access scale score (HFIAS) classified one per cent of farm households as insecure and those were less commercialised farm households. The coping strategy index classified four per cent of farm household as highly food insecure which was also found among less commercialised farm households. The composite food security index (CFSI) classified 44 per cent of households as food insecure. The quantile regression results showed positive effect of commercialisation on height for age Z scores of children in lower quantile (25th) of the distribution. Commercialisation has contributed farmers to have better food, nutrition and health security.

Comparative Economics of Sugarcane Cultivation by Small and Marginal Farmers under Different Methods of Irrigation in Vijayapura District of Karnataka

Manjunath Hanamantaraya Atthani and Jagannath Olekar
Department of Agricultural Economics, College of Agriculture, UAS, GKVK, Bengaluru

The study aimed at analysing the sugarcane cultivation under drip and flood irrigated situation and compare cost and returns, profitability, resource use efficiency and the constraints. The study is based on primary data collected from 60 drip and 60 flood irrigated farmers in Muddebihal and Sindhagi taluks of Vijayapura district, Karnataka. The descriptive statics, production functions and decomposition analysis were used to analyse the data. The study revealed that the cost of cultivation of sugarcane under drip irrigated method was Rs.82,582/acre and Rs.76,378/acre in flood irrigated method. The difference in total cost was mainly due to the difference in use of fertilizers, human labour and irrigation cost between these two groups. The net return realized was Rs.70,996/acre in drip irrigated method and it was Rs.46,822/acre in flood irrigated method. The resource use efficiency analysis revealed that micro nutrient, seed sets and irrigation water were underutilized in drip irrigated method. The decomposition analyses revealed that the total yield difference between drip and flood irrigation method estimated was 24.63 per cent. The differences in drip irrigation technology contributed17.12 per cent, when compared to other inputs (7.51 %). The flood irrigated sugarcane farmers were expressed insufficient supply of water through canals was a major constraint (90.32%) and the drip irrigated farmers reported that the higher initial cost for installation of drip irrigation (82.35%). There should be wide spread promotion of drip irrigation and encourage all farmers to adopt it and improve their income levels.

Production and Marketing of Cocoa in Dakshina Kannada District of Karnataka – An Economic Analysis

K. S. Deeksha and T. M. Gajanana
Department of Agricultural Economics, College of Agriculture, UAS, GKVK, Bengaluru

The present study on cocoa cultivation was undertaken in Dakshina Kannada district (Puttur and Sullia taluk) which has the highest area and productivity of cocoa in the state. The study assessed the economics, investment feasibility, marketing practices, constraints and global competitiveness of cocoa. Primary data were collected from thirty-three farmers from Puttur and thirty-two farmers from Sullia taluk. The results indicated that the cost of cultivation of cocoa in Sullia was slightly higher (Rs.22979/ac) than in Puttur taluk (Rs.22530/ac). The cultivation of cocoa was economically feasible with IRR of 18 per cent and 21 per cent and with benefit cost ratio of 1.34 and 1.41 in Puttur and Sullia, respectively. Puttur taluk farmers incurred higher marketing cost (Rs.1.21/kg) than Sullia taluk farmers (Rs.0.87/kg) which was mainly due to transportation. Seasonality was observed in arrival and price realised by the sample farmers over the months. Rodent's attack, insect and disease attack and unremunerative price were the major constraints in cocoa cultivation. The nominal protection coefficient (NPC) of cocoa was 0.98 in 1994-2020 and 0.93 during 2010-2020 thereby indicating that cocoa was competitive in the international market. Adoption of improved varieties along with associated good production management practices, incentives for promotion of these for enhancing productivity and improving the efficiency of the marketing channels would go a long way in increasing the production of cocoa in India.

Production Potentiality of Bengalgram in North Eastern Dry Zone of Karnataka : An Economic Analysis

Umesh and M. N. Venkataramana
Department of Agricultural Economics, College of Agriculture, UAS, GKVK, Bengaluru

Bengalgram plays an important role in Indian diet, as it contains protein and supplement to cereal based diet. Bengalgram is gaining economic importance due to increase in area (4.18 lakhs hectares) and production (2.31 lakh tonnes) in Karnataka. North eastern dry zone accounts 43 per cent of production in the state. The present study was carried out to examine the production potentiality of bengalgram in north eastern dry zone of Karnataka. The data was collected by employing purposive random sampling technique with a total sample of 60. The findings revealed that Karnataka state as well as North eastern dry zone showed a significant growth in area with 7.86 and 5.90 per cent, production with 8.59 and 7.65 per cent and productivity with 1.75 and 2.47 per cent, respectively, during 1999-2000 to 2018-19 period. The total cost, gross returns, net returns and return per rupee of expenditure were Rs.17,088/ ac, Rs.21,620 /ac, Rs.4,532/ ac. and 1.27, respectively. Farmers were not efficient in resources allocation as machine labour, fertilizer, farm yard manure and micronutrients were underutilized. Yield gap-II (1.58 q/ac) was higher than yield gap-I (0.32 q/ac) in JG -11 variety and yield gap-II (0.60 q/ac) was greater than yield gap-I (0.51 q/ac) in Annigeri-1 variety. The high cost of labour during peak season was a major constraint faced by bengalgram growers. The findings suggest that good extension strategies in transferring technologies, mechanization and timely execution of farm operations will help in better realization of income by the farmer.

A Study on Knowledge and Perception of Aromatic Black Rice Growers towards Mission Organic Value Chain Development Scheme in Manipur

MEGHAJIT SHARMA SHIJAGURUMAYUM AND M. T. LAKSHMINARAYAN
Department of Agricultural Extension, College of Agriculture, UAS, GKVK, Bengaluru

THE present research study was conducted in Bishnupur and Thoubal districts of Manipur to analyze the knowledge and perception of aromatic black rice growers towards mission organic value chain development scheme. One hundred and eighty aromatic black rice growers were interviewed using a pre-tested interview schedule. The results revealed that a greater proportion of the aromatic black rice growers (44.55%) had better perception, whereas more than one-third (37.22%) and less than one-fifth (18.33%) of them had good and poor perception towards mission organic value chain development scheme, respectively. Over 85.00 per cent of the aromatic black rice growers had correct knowledge on the benefits provided under mission organic value chain development scheme. Education, organic farming experience, livestock possession, crop productivity, achievement motivation, aspiration, management orientation, economic motivation, risk orientation, innovative proneness, mass media exposure, training on organic farming, extension agency contacts and extension participation of aromatic black rice growers had a significant association with the knowledge and perception towards mission organic value chain development scheme. Scarcity of organic manure, inadequate financial assistance provided for off-farm inputs (biofertilizers, biopesticides and neem cake), lack of credit facilities to invest on organic agriculture and allied activities, inaccessible to organic produce outlets, lack of access to reliable market information and irregular collection of organic produces from farmgate were the major problems faced by the respondents in mission organic value chain development scheme.

Crisis Management by Sugarcane Growers of Northern Karnataka – An Analysis

MUTTEPPA CHIGADOLLI AND Y. N. SHIVALINGAIAH
Department of Agricultural Extension, College of Agriculture, UAS, GKVK, Bengaluru

THE present study was conducted in Belagavi and Bagalkot districts of Karnataka during 2020-21 to know the crisis management behaviour, adoption of crisis mitigation mechanisms and awareness of sugarcane growers about crisis and its management. Data was collected from 80 head reach, 80 mid reach and 80 tail end sugarcane growers constituting to the total sample size of 240. The results revealed that little more than two-fifth (40.42 %) of growers belonged to the average crisis management behaviour category followed by better (30.41 %) and poor (29.17 %) categories. More than one-third of respondents belonged to moderate (36.25 %) and better (33.75 %) decision-making ability categories, respectively followed by poor (30.00 %) category. More than one-third of respondents belonged to moderate (37.92 %) adaptability category followed by better (31.25 %) and poor (30.83 %). Majority (71.25 %) of respondents were under the moderate to poor economic performance categories followed by better (28.75 %). More than two-fifth of respondents (41.25 %) belonged to high adoption of crisis mitigation mechanisms followed by medium (33.75 %) and low (25.00 %). Significant percentage (40.83%) of growers belonged to moderate awareness category followed by poor (30.42 %) and better (28.75 %) categories. The stepwise regression analysis indicated that fifteen independent variables out of twenty-three are influencing the crisis management behaviour to an extent of 80.70 per cent. The major constraints of growers at different phases of crisis management were delay in disbursement of fair and remunerative price bonus, load shedding during the summer and disconnection of electricity for long duration led to crop losses. The top suggestions to overcome these constraints were fair and remunerative price and sugarcane price should be disbursed immediately, government should provide atleast eight hours' regular supply of electricity for irrigation and measures should be taken for faster installation of electricity lanes to start water supply.

Impact of Agricultural Development Programmes on Farmer Progressiveness in Andhrapradesh

D. V. KUSUMALATHA AND N. S. SHIVALINGE GOWDA
Department of Agricultural Extension, College of Agriculture, UAS, GKVK, Bengaluru

THE present study was undertaken to measure farmer progressiveness and to assess the impact of various agricultural development programmes. Data was collected from 180 beneficiaries and 30 non-beneficiaries from Chittoor and Ananthapur districts of Andhrapradesh. Data set retained an equal representation of beneficiaries in the selected crops *viz.,* paddy, groundnut and mango. Standardized scale to measure farmer progressiveness was developed and used in the study. The data was collected using the structured pre-tested interview schedule. The results revealed that nearly two-fifth (37.78 %) of beneficiaries had high level of progressiveness. Paddy (40.00 %) and Groundnut (43.33 %) beneficiaries had low level of progressiveness whereas mango (58.33 %) beneficiaries had high level of progressiveness. Beneficiaries and non-beneficiaries had a mean progressiveness score of 66.27 and 46.24, respectively. Beneficiaries of agricultural development programmes exhibited higher mean index scores for all dimensions *viz.,* agricultural, economic, social, individual, household and environmental than non-beneficiaries. About 41.67 per cent of beneficiaries had good level of perception towards agricultural development programmes. Economic orientation explained about 22 per cent of variation in farmer progressiveness whereas extension participation explained about 14 per cent of variation in perception. The study had elucidated different constraints of agricultural development programmes and recorded the farmer suggestions. Constraints like collecting and keeping all the bills to get the subsidy, need to spend more time and money to get the benefits and untimely fund allocation were the major constraints. Information regarding the procedures to avail subsidies, supply of critical inputs throughout the year and collaboration of different developmental departments were the suggestions given by beneficiary farmers for better progressiveness of the farming community.

Knowledge and Perception on Online Education among Post Graduate Students of SAUs in Karnataka

SAKSHI SHRIVASTAV AND S. GANESAMOORTHI
Department of Agricultural Extension, College of Agriculture, UAS, GKVK, Bengaluru

THE study was conducted in four farm-universities of Karnataka state during 2020-21 to analyze the knowledge and perception of post graduate students on online educational platforms. A total of 160 respondents comprising of 120 (30 from each university) post graduate students and 40 faculty members (10 from each university) were selected by using simple random sampling. Mailed questionnaire method was used to collect data and appropriate statistical tools were applied to analyze the data. Zoom and Google meet were most popular educational apps used in all selected universities. About less than one third (35.83%) belonged to low knowledge category and similar proportion of students (33.66%) and 30.83 per cent belonged to medium knowledge category and high knowledge category, respectively. It was also found that, majority (71.16%) belonged to medium perception category whereas 20.00 per cent and 8.33 per cent belonged to low perception category and high perception category, respectively. Variables rural/urban background, academic achievement, ICT environment and time spent on e-platforms were found to have significant association with the knowledge and perception of PG students. The major problems expressed by students were poor internet speed and lack of ICT facilities. Majority of the respondents suggested, provision for uninterrupted high-speed internet and power, budgeting mechanism for paid versions of educational apps.

A Study on Performance and Perception of Farmer Producer Organizations in Kalaburagi District of Karnataka State

POOJA AND H. K. PANKAJA
Department of Agricultural Extension, College of Agriculture, UAS, GKVK, Bengaluru

THE present study was conducted to analyze the performance of farmer producer organizations and perception of FPO members in Kalaburagi district of Karnataka state. *Ex-post facto* research design was used for the study, total sample size was 125. Out of five FPOs selected for the study, 25 respondents were selected randomly from each FPOs. Personal interview method was used to collect the data. The study revealed that most of the respondents were belonged to middle age category (53.60%), small farmers category (44.00 %), 35.00 per cent of them have completed their high school level of education, majority of them had medium level of achievement motivation (53.60 %), management orientation (49.60 %), cosmopoliteness (56.80 %), mass media exposure (44.00 %), extension contact (52.80%) and organizational participation (52.80%). Most of the FPOs (47.20%) were having an average level of performance, followed by better (27.20%) and poor (25.60%) level of performance. With respect to perception of members, the study revealed that most of the members (43.20 %) were having average perception followed by better (30.40 %) and poor (26.40 %) level of perception about functioning of FPOs. The major constraints faced by FPO members were lack of processing units, custom hiring services and poor credit facilities. Establishment of fully equipped processing units and custom hiring services and ensuring credit facilities for the members were major suggestions expressed by FPO members. There has been substantial increase in number of FPOs in India, hence infrastructural and logistic facilities shall be provided for growth of FPOs.

A Study on Production and Marketing of Paddy in Mandya District of Karnataka

H. S. MANASA AND M. S. GANAPATHY
Institute of Agri-Business Management, College of Agriculture, UAS, GKVK, Bengaluru

THE main objective of the study is to analyse the area and production, cost and returns of conventional and Rajamudi paddy, marketing channels and constraints in production and marketing of paddy in Mandya and Krishnarajpete taluks of Mandya district. The primary data collected from 60 paddy growers and 20 traders. The study revealed that, area and production of paddy in Mandya district was decreased at a CAGR of 5.29 per cent and 6.55 per cent, respectively. The total cost of cultivation of conventional paddy per acre was Rs.35,978.54. The net returns was Rs.7,687.51. The B:C ratio was found to be 1.21. The total cost of cultivation of Rajamudi paddy per acre was and Rs.26,837.11, the share of variable cost (Rs.19,538) was higher when compared to the share of fixed cost (Rs.7,299.11), net returns was Rs.9,948.35 and the B:C ratio was found to be 1.37, which reveals that the paddy cultivation is financially feasible. Majority (35 %) of the paddy farmers marketed paddy through channel I followed by channel II which was used by 30 per cent of the farmers. The major problems faced by the paddy growers are scarcity of labour, high wage rate, high transportation cost and inadequate storage facility. Hence, there is a need to establish an extension counter at Mandya for procurement of paddy directly from the growers during the harvest period to facilitate the small and marginal growers to realise better price.

Production and Marketing of Maize in Hassan District of Karnataka - An Economic Analysis

S. R. Meghana and G. M. Gaddi
Institute of Agri-Business Management, College of Agriculture, UAS, GKVK, Bengaluru

The present study on production and marketing of maize in Hassan district used both the secondary data (relating to area, production, productivity, arrivals and prices of maize) and primary data (60 maize growers and 30 market intermediaries). Results of the study indicated that area and production of maize decreased by 7.90 per cent and 7.10 per cent while productivity was marginally increased (0.94 %) during 2007-2017 in Karnataka. Maize arrivals and prices in Channaraypatna market showed variation during study period (2008 to 2019) with higher seasonal indices for arrivals and prices during the month of January (After harvesting) and the least during the month of August (coinciding with sowing season). The Johansen co-integration test revealed long run equilibrium between Hassan, Davangere and Bagalkot markets. Farmers incurred a total cost of Rs.37044 per acre in maize cultivation with B:C ratio of 1.20 indicating cultivation of maize is profitable. Majority (73.33 %) of the farmers preferred channel I (Farmers→Village traders→Wholesalers→ Processing unit) compared to channel II (16.67 %) and channel III (10 %). However, the PSCR (31.68 %) and acharya's marketing efficiency coefficient (0.46) were relatively higher in channel-III compared to other channels. Scarcity of labour, high wage rate, fluctuation in price and high commission charges were the problems reported by respondents. Hence, there is a need to establish agro-processing which would benefit all the stakeholder in maize marketing *viz.,* producer-farmers by ensuring better prices, traders and processors to enjoy benefits of economies of scale.

Food Safety Standards and Management Strategies for Exports of Dairy Products of India

Nour Allahham and M. R. Girish
Institute of Agri-Business Management, College of Agriculture, UAS, GKVK, Bengaluru

The present study aimed to analyse the destination-wise exports of selected dairy products of India, examine the export competitiveness of selected dairy products of India and assess the impact of food safety standards on exports of dairy products. The study found that India's total exports of dairy products increased at a CAGR of 5.10 per cent for the period 2009-10 to 2019-20. Based on constant market share analysis, the growth in India's exports of selected dairy products due to world trade effect was found to be 48.61 per cent; with commodity composition effect being 11.59 per cent; market distribution effect being 9.03 per cent; and competitiveness effect being 30.77 per cent. As per gravity model analysis, an increase in India's GDP by 10 per cent will result in an increase in its value of dairy exports by 17.67 per cent while a 10 per cent increase in the GDP of the importing country will increase the value of Indian exports by 3.33 per cent. It was observed that if the importing countries decrease the MRL for aflatoxins by 10 per cent, the value of India's dairy exports will fall by 5.95 per cent. The study revealed that the MRL of aflatoxins is a major concern in dairy exports of India. Therefore, the Government as well as other authorities concerned need to take cognizance of this fact and act accordingly by sensitizing the dairy farmers about the issue.

Impact of Soil Health Card Scheme on Enhancing Farm Productivity and Farmers Income in Shivamogga District – An Economic Analysis

S. A. SHABAREESH AND S. C. RAMESH KUMAR
Institute of Agri-Business Management, College of Agriculture, UAS, GKVK, Bengaluru

THIS study was conducted in Shivamogga district of Karnataka state with the objective of analysing the economic impact soil health card (SHC) scheme on cost of cultivation and income of major crops. The study was based on primary data collected from 60 SHC farmers and 60 control farmers of Soraba and Sagara taluks during 2020-21. The study revealed that more than 66.66 per cent of soil tested farmers had a positive opinion on SHC. Among the SHC holders, 72 per cent of farmers were applying recommended doses of fertilizer fully or partially. About 28 per cent of SHC farmers and 18 per cent of control farmers were loyal to particular brands (IFFCO, SPIC and Mangala) of fertilizers. SHC holders obtained higher yields in all the major crops *i.e.,* areacanut 96.06 qtls/acre; paddy 22.92 qtls/acre; maize 23.89 qtls/acre and ginger 158.88 qtls/acre compared to control farmers arecanut 80.90 qtls/acre; paddy 20.05 qtls/acre; maize 22.71 qtls/acre and ginger 142.50 qtls/ acre. Profitability of SHC holders over control farmers was found to be a net gain of Rs.51,529/ acre from arecanut; Rs.4,725/ acre from paddy; Rs.2,850/ acre from maize and Rs.73,706/ acre from ginger cultivation. About 93 per cent of the farmers were facing a constraint of faraway located soil testing laboratories to get soil test done. It is suggested that agricultural extension services to be taken up in large scale to improve the knowledge of farmers towards SHC.

Economic Evaluation of Sheep Enterprise in North Transect of Bengaluru

K. R. PAVITHRA AND MAMATHA GIRISH
Institute of Agri-Business Management, College of Agriculture, UAS, GKVK, Bengaluru

The present study was conducted in north transect of Bengaluru to examine the backward and forward linkages of sheep enterprise; to estimate the cost and returns of sheep enterprise; to analyse the production efficiency and marketing of sheep; to examine the constraints in sheep enterprise. The primary data was collected from 40 sheep farmers. The average size of sheep flock maintained by sheep farmers was 46 comprising of 20 rams followed by 19 ewes and 7 lambs. The annual total cost incurred per farm was found to be Rs.2,77,752.03/- and the annual gross returns obtained from sale of sheep, lamb and manure was Rs.3,45,792.50/- resulting in net returns of Rs.68,040.47/-. The NPV, BCR and IRR at 12 per cent discount rate was found to be Rs.1,48,769.51/-, 1.47 and 29 per cent, respectively demonstrating the financially viability of sheep farming. The cobb-douglas production function analysis indicated that flock size, fodder, feed and experience in sheep farming had significant positive impact on gross returns while costs of lamb and labour had negative impact on gross returns. The returns to scale was found to be 1.002 (greater than one) indicating that sheep farming is a profitable venture. Two marketing channels for sale of sheep, lamb and manure, *viz*., channel I: Farmer - fellow farmers and channel II: Producer - butcher - consumer were found in the study area. Inadequate availability of grazing land was the major production constraint and inadequate availability of market information was the major marketing constraint.

Model Based Statistical Evaluation of Major Cereals Produced in Karnataka State

Apoorva Raj and V. Manjunath
Department of Agricultural Statistics, Applied Mathematics and Computer Science,
College of Agriculture, UAS, GKVK, Bengaluru

An attempt has been made to study the trend in area, production and productivity of major cereals (rice, maize, jowar, ragi and bajra) grown in Karnataka state. For this study 22 years secondary data were collected on area, production and productivity for the selected cereals. In order to study the temporal variation, linear, quadratic, cubic, logarithmic, inverse, compound, power, logistic, log-logistic and exponential models were utilized. An appropriate model chosen based on the model adequacy criteria R^2, AIC, RMSE and MAPE. Log-logistic model was the best fit model in majority of situation for rice and maize which indicated a steady increase during initial periods and reaching stagnation, whereas linear and exponential model was best fit for most of the characteristic in case of jowar, ragi and bajra indicating steady increase or decreasing trend. Rice and maize were mainly grown in *kharif* season so same trend was observed for pooled data over all the season whereas in case of jowar and ragi were mainly grown in *rabi* season so same was depicted in pooled data. Further the spatial variations in area, production and productivity across districts during the study period were analysed by computing Coefficient of variation (CV%), Coppock's instability index (CII%) and Cuddy Della Valle index (CDI%). It was observed that instability was more for production of all the cereals than area and productivity in their respective districts. Larger instability was seen in period III for all the cereals except bajra which showed highest stability during period II.

Statistical Appraisal of Production Trends in Major Pulses Grown Across Karnataka State

N. Sahana and V. Manjunath
Department of Agricultural Statistics, Applied Mathematics and Computer Science,
College of Agriculture, UAS, GKVK, Bengaluru

In order to assess the trend in area, production and productivity of major pulses (red gram, bengal gram, horse gram, green gram and black gram) across Karnataka, 22 years secondary data were used. To know growth trends different polynomial linear models (linear, quadratic, cubic), intrinsically linear models (logarithmic, inverse, compound, power) and non-linear models (log-logistic, exponential) were fitted. Appropriate models were selected on the basis of important model adequacy tests. All the characteristics in red gram showed an exponentially increasing trend, while in bengal gram productivity was linearly increasing whereas area and production showed exponential trend. Cubic and linear models was performed well in majority of situation for green gram and black gram. Quadratic model was well suited for productivity of horse gram, while different models were found to be best fit for other characteristics. By trend analysis it can be inferred that different growth trends were observed in each of the crops studied. Further to study the spatial variations in area, production and productivity across major pulses growing districts of the State in different study period, Coefficient of variation (CV%), Coppock's instability index (CII) and cuddy della valle index (CDI) were adopted. Bengal gram and black gram showed high instability during period II. More instability in area, production and productivity was noticed in Vijayapura, Gadag, Mysuru, Bagalkot and Bidar districts for red gram, bengal gram, horse gram, green gram and black gram, respectively, it may be due to these crops are grown in these districts under rainfed conditions.

Statistical Analysis of Area, Production and Productivity of Arecanut in Selected Districts of Karnataka

S. R. Anusha and K. N. Krishnamurthy
Department of Agricultural Statistics, Applied Mathematics and Computer Science,
College of Agriculture, UAS, GKVK, Bengaluru

Arecanut is an important plantation crop and Karnataka is the leading arecanut growing state in India. The current study was undertaken to evaluate the growth rates and trends in area, production and productivity of arecanut in selected districts of Karnataka, *viz*., Shivamogga, Dakshina Kannada and Chikkamagaluru. The study was based on secondary data over 29 years (1990 to 2018) which were collected from the Directorate of Economics and Statistics, Government of Karnataka. To examine the trend in area, production and productivity of arecanut, linear (linear, quadratic and cubic) models and non linear (log logistic and exponential) models were fitted. The model adequacy statistics such as adjusted R^2, AIC, BIC and MAPE were used to find the appropriate model. The study revealed that the growth rates for area, production and productivity of arecanut increased at a significant rate in all the three selected districts. The exponential model was found to be the best fit for area, production and productivty of arecanut in Shivamogga, Dakshina Kannada and Chikkamagaluru district. Further, forecasting for production of arecanut was made on the basis of best fitted model. The forecasting of production was carried out with the help of exponential model. The forecasted production of arecanut for the period 2019-20 to 2023-24 indicated an increasing trend in arecanut for all the selected districts of Karnataka.

Production Dynamics of Paddy in Udupi District of Karnataka - A Statistical Study

Ravi and S. N. Megeri
Department of Agricultural Statistics, Applied Mathematics and Computer Science,
College of Agriculture, UAS, GKVK, Bengaluru

An effort was made to analyze the trends in area, production and productivity of paddy in Udupi district of Karnataka using linear, quadratic, cubic, generalized additive model (GAM), exponential and log-logistic models. The best fit model was selected based on the least RMSE. Generalized additive model was found to be the best fit model for area, production and productivity of paddy during *kharif* season, area and productivity during *rabi* season and for annual production and productivity. For *rabi* production, the linear model was the best fit. Cubic model was the best fit model for area and productivity during *summer* season and for the annual area. The best fit model for paddy production during the *summer* was found to be the log-logistic model. It was concluded that area and production showed decreasing trend, whereas productivity increased. The best model for forecasting production was found to be GAM for *kharif* and annual, linear for *rabi* and log-logistic model for *summer* season according to minimum value of MAPE. Further, an attempt was made to predict the production of paddy using area, rainfall, maximum and minimum temperature and relative humidity as independent variables. Huge amount of multicollinearity was seen among the independent variables. The models like stepwise multilinear regression (SMLR), principal component analysis (PCA), GAM, the ridge regression, LASSO and the elastic net were tried to predict the production. The elastic net model was found to be the best based on minimum value of MAPE among all the models mentioned above.

Statistical Models for Analysing Fruit Fly Incidence of Bitter Gourd in Bengaluru Rural District

M. N. Karthik and T. L. Mohan Kumar
Department of Agricultural Statistics, Applied Mathematics and Computer Science,
College of Agriculture, UAS, GKVK, Bengaluru

The present study was undertaken to analyse the distribution pattern, correlation with weather parameters and prediction of fruit fly incidence on bitter gourd during *kharif* season for the data collected from IIHR, Hessaraghatta, Bengaluru for the period of three years (2018-2020). The average, maximum and minimum incidences of fruit fly was observed 47.81, 138 and 2 number, respectively over the study period. One way ANOVA revealed that the average fruit fly incidence was found to be non-significant among the three study years. To determine the distribution pattern of fruit fly incidence, discrete probability distributions *viz.,* Poisson, geometric, negative binomial, logarithmic, zeta and Yule-Simon distributions were employed. The negative binomial distribution was found to be the best fitted distribution during 2018 and 2019, whereas geometric distribution was best fitted distribution during 2020. Correlation analysis revealed that the fruit fly incidence across the year showed positive correlation with maximum temperature, morning relative humidity, evening relative humidity and evaporation whereas, minimum temperature, wind speed and rainfall showed negative correlation. Multiple linear regression (MLR), Support vector regression (SVR) and Artificial neural network (ANN) models were employed to predict fruit fly incidence based on weather parameters. Based on the lowest MAPE value, ANN model was found to be best-fitted model followed by SVR and MLR models on both training (16.82 %) and testing datasets (6.33 %), which indicates superiority of ANN model over other models. Therefore, ANN model can be used for predicting fruit fly incidence in bitter gourd.

Studies on Effect of Nano Zinc Oxide and Nano Ferric Oxide on Growth and Yield of Rice Under Aerobic Condition (*Oryza sativa* L.)

C. Naveen Kumar and H. M. Jayadeva
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru

To optimize the quantity of nano ZnO and nano Fe_2O_3 required for higher yield in aerobic rice, three experiments were carriedout in the laboratory, field and pot experiments during 2019-20 at Agronomy field unit, Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK, Bengaluru. Laboratory experiment with twenty-one treatments were laid out in CRD and replicated thrice. Seed priming with 800 ppm of nano ZnO and nano $Fe_2O_3$for 30 minutes was recorded higher germination (96.73%), root length (13.89 cm), shoot length (5.17 cm) and SVI (1843). In field, nine treatments were laid out in RCBD with three replications. Results revealed that seed priming with 800 ppm of nano ZnO and nano Fe_2O_3 for 30 minutes followed by foliar application of nano ZnO and nano Fe_2O_3@800 ppm recorded significantly higher plant height at 60, 90 DAS and at harvest (49.18, 61.96 and 62.68 cm, respectively), leaf area at 60 and 90 DAS (1509.7 and 3436.2 cm^2 $plant^{-1}$, respectively), higher grain yield (4927 kg ha^{-1}), straw yield (5383 kg ha^{-1}) and higher gross return (Rs.1,03,923 ha^{-1}). Whereas, higher B:C ratio was recorded in seed priming with nano ZnO and nano Fe_2O_3 @ 800 ppm for 30 minutes (2.89). In pot experiment, twelve treatments were laid out in CRD with three replications. Foliar application of nano ZnO and nano Fe_2O_3@ 600 ppm recorded significantly higher plant height at 60, 90 DAS and at harvest (44.63, 57.57 and 60.45 cm, respectively), number of productive tillers (21.04), total grains (165.40), grain yield (8560 kg ha^{-1}) and straw yield (9989 kg ha^{-1}).

Potentials of Buckwheat for Food Security in Changing Climatic Situation

R. M. SALMANKHAN AND B. S. LALITHA
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru

A field experiment was conducted at Agronomy field unit, Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK, Bengaluru during 2019 and 2020 *kharif* to evaluate the 'Potentials of buckwheat for food security in changing climatic situation'. The experiment was laid out in split-split plot design with eighteen treatments replicated thrice. Main plots includes three different dates of sowing (July 1st fortnight, July 2nd fortnight and August 1st fortnight), two sub plots on spacing (30 cm x 10 cm and 45 cm x 15 cm) and three sub-sub plots on nutrients level (50:10:10, 60:20:20 and 70:30:30 N:P_2O_5:K_2O kg ha^{-1}). Among different dates of sowing, July 1st fortnight recorded significantly higher plant height (82.08 cm), number of leaves (34.53 plant^{-1}), number of branches (7.86 plant^{-1}), dry matter accumulation (10.51 g plant^{-1}), seed yield (880 kg ha^{-1}), uptake of nitrogen (61.46 kg ha^{-1}), phosphorus (18.34 kg ha^{-1}), potassium (55.79 kg ha^{-1}), gross returns (Rs.44006 ha^{-1}), net returns (Rs.27606 ha^{-1}) and cost benefit ratio (2.68). Narrow spacing of 30 cm x 10 cm recorded significantly higher plant height (82.64 cm), seed yield (948 kg ha^{-1}), uptake of nitrogen (67.14 kg ha^{-1}), phosphorus (19.87 kg ha^{-1}), potassium (61.64 kg ha^{-1}), gross returns (Rs.47408 ha^{-1}), net returns (Rs.30746 ha^{-1}) and cost benefit ratio (2.84). Application of 70:30:30 N:P_2O_5:K_2O kg ha^{-1} recorded significantly higher plant height (80.03 cm), number of leaves (34.04 plant^{-1}), number of branches (8.27 plant^{-1}), dry matter accumulation (11.08 g plant^{-1}), seed yield (891kg ha^{-1}), uptake of nitrogen (63.66 kg ha^{-1}), phosphorus (18.92 kg ha^{-1}), potassium (59.15 kg ha^{-1}), gross returns (Rs.44551 ha^{-1}), net returns (Rs.27684 ha^{-1}) and cost benefit ratio (2.64).

Green Synthesis, Characterization and Evaluation of Boron and Sulphur Nano Fertilizers to Enhance the Growth and Productivity of Sunflower (*Helianthus annuus* L.)

N. PRUTHVIRAJ AND K. N. GEETHA
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru

THE synthesis of nano (0-100 nm) fertilizers using plant extract is termed as green synthesis and its application found to enhance the yield in crops. In this context studies of both laboratory and field experiments, were conducted to optimize the concentration of green synthesised nano boron and sulphur on growth and productivity of sunflower. A lab experiment was conducted during 2018 to synthesise nano boron using *Cassia fistula* leaf extractant and nano sulphur using *Simarouba glauca* leaf extractant. Green synthesised nano particles were characterised using particle size analyser, atomic force microscope and scanning electron microscope. A field experiment was conducted at Zonal Agricultural Research Station, UAS, Bangalore during *rabi* 2019-20 and 2020-21 in randomized complete block design with the factorial concept (Factor-I: seed priming and Factor-II: foliar application of green synthesised and commercially available nano boron and sulphur fertilisers with different concentrations) with three replications. Pooled data (2019 and 2020) reveals that significantly higher growth parameters *viz*., number of green leaves (13.12 plant^{-1}), root to shoot ratio (0.208), stem girth (3.73 cm) and total dry matter production (154 g plant^{-1}) at harvest stage were recorded in 1500 ppm green synthesised nano boron seed priming treatment. Application of green synthesised nano sulphur (600 ppm) + nano boron (1500 ppm) as foliar application at ray floret stage recorded significantly higher head weight (91.2 g plant^{-1}), head diameter (17.82 cm) and pollen fertility (94.8 %). Among interactions, seed priming with 1500 ppm nano boron nitride + foliar application of 600 ppm nano sulphur + 1500 ppm nano boron nitride green synthesised fertilisers recorded significantly higher seed yield (3588 kg ha^{-1}) and oil content (43.6 %). The same combination also recorded higher economics *viz*., gross returns (161438 Rs.ha^{-1}), net returns (110798 ha^{-1}) and B:C ratio (3.19).

Investigations on Herbicide Resistance in *Echinochloa colona* and *Eleusine indica* and their Management Strategies Under Direct Seeded Rice

Kommireddy Poojitha and K. N. Kalyana Murthy
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru

In the field investigations carried out to assess the herbicide resistance in *Echinochloa colona* and *Eleusine indica* at the Agronomy field unit, Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK, Bengaluru, it is found that both the weeds have developed moderate level of resistance to pyrazosulfuron ethyl and very low level of resistance to bispyribac sodium at the recommended dose of application *i.e.*, at 20 g a.i. ha^{-1}. The pyrazosulfuron resistant population of *Echinochloa colona* and *Eleusine indica* have not shown any cross and multiple resistance to other herbicides used in the investigation *viz*., bensulfuron methyl + pretilachlor, imazythapyr, oxadiargyl, penoxsulam + cyhalofop, quizolofop-p-ethyl, cyhalofop-p-butyl, glyphosate, metamifop, topramezone, azimsulfuron, tembotrione, paraquat dichloride and atrazine. With respect to allelochemical control of herbicide resistant population of *Echinochloa colona* and *Eleusine indica,* whole plant aqueous extracts of *Eucalyptus*, *Leucas aspera*, *Hyptis suaveolens* and *Crotalaria juncea* at 10 per cent w/v were effective under laboratory conditions in reducing the dry weight of weeds but the magnitude of reduction was far lesser than chemical herbicides. A field experiment was conducted to test the efficiency of best proven herbicides from previous investigations under DSR. Application of bispyribac sodium 10 SC 40 g a.i. ha^{-1} as post emergence at 2-3 leaf stage or bensulfuron methyl + pretilachlor 6.6 GR 660 g a.i. ha^{-1} as pre emergence were found to be efficient weed management practices in reducing total weed density and dry weight as well as for obtaining higher productivity (4987 and 4866 kg ha^{-1}, respectively) and profitability (B:C ratio of 2.61 and 2.57, respectively) of DSR without any phytotoxic effects on crop.

Studies on Agro techniques in Semi Dry Rice for Higher Productivity Under Southern Dry Zone of Karnataka

K. K. Ajmal and P. S. Fathima
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru

A field experiment entitled 'Studies on agrotechniques in semi dry rice for higher productivity under southern dry zone of Karnataka' was conducted at College of Agriculture, V. C. Farm, Mandya during *kharif* season of 2019 and 2020. The soil of the experimental site was sandy loam in texture, alkaline in reaction, low in organic carbon with low available N, K and high available P. The experiment on 'Evaluation of rice varieties and planting geometry for semi dry rice' was laid out in split plot design with three replications. Row spacing at 20 cm recorded significantly higher grain yield (4606 kg ha^{-1}), straw yield (6389 kg ha^{-1}) and net returns (Rs.54606 ha^{-1}) over 30 cm row spacing. Among different varieties, KMP-175 was recorded higher grain yield (5086 kg ha^{-1}), straw yield (7139 kg ha^{-1}) and net returns (Rs.64764 ha^{-1}) compared to other varieties. Experiment on 'Studies on split application of nitrogen and potassium levels and time of application for higher productivity in semi dry rice' was laid out in split plot design with three replications. The results revealed that application of 125% RDNK recorded higher grain yield (5515 kg ha^{-1}), straw yield (7408 kg ha^{-1}), nutrient uptake (130.86 kg ha^{-1}, 45.89 kg ha^{-1} 84.43 kg ha^{-1}, respectively), net returns (Rs.73410 ha^{-1}) and B: C ratio (2.77) compared to 100% RDNK. Among the different split applications, N at 4 splits as, 25 per cent each at sowing, early tillering, tillering and panicle initiation, K at 2 splits (50% at basal and 50% at panicle initiation) resulted in higher grain yield (5567 kg ha^{-1}), straw yield (7541 kg ha^{-1}), net returns (Rs.71764 ha^{-1}) and B: C ratio (2.71) compared to other treatments. Interaction between nitrogen levels and time of application was non significant.

Studies on Influence of Organic Sources on Productivity and Nutrient Dynamics in Maize - Cowpea Cropping Sequence

G. K. PRAJWAL KUMAR AND C. RAMACHANDRA
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru

A field experiment was conducted at research and demonstration block of Research Institute on Organic Farming, UAS, GKVK, Bengaluru during 2020-21 to study the influence of organic sources on growth and yield of maize-cowpea cropping sequence. The experiment was laid out in factorial randomised block design with three replications. The experiment consisted of 15 treatment combinations of three levels of N equivalent and five organic sources along with absolute control and UAS-B package. The experimental soil was red sandy loam having medium organic carbon (0.65 %), medium in available N (289.4 kg ha^{-1}), medium in available P_2O_5 (28.6 kg ha^{-1}) and medium in available K_2O (235.2 kg ha^{-1}) content. The experimental results indicated that application of bio-compost at 125 per cent N equivalent for maize crop resulted in higher plant height (221.5 cm), leaf area (7949 cm^2 plant^{-1}), total dry matter accumulation (201.1 g plant^{-1}), kernel (107.47 q ha^{-1}) and stover yield of maize (154.60 q ha^{-1}) followed by poultry manure at 125 per cent N equivalent and found significantly superior over other treatments in the study. However, UAS-B package (150:75:40 kg N: P_2O_5: K_2O ha^{-1}) recorded significantly higher plant height (229.9 cm), leaf area (8197 cm^2 plant^{-1}), total dry matter accumulation (213.6 g plant^{-1}), kernel (111.96 q ha^{-1}) and stover yield of maize (161.13 q ha^{-1}) and was on par with application of bio-compost at 125 per cent N equivalent. In maize-cowpea cropping sequence, cowpea recorded significantly higher grain yield, haulm yield and B:C ratio (15.06 q ha^{-1}, 14.61 q ha^{-1} and 3.11, respectively) in 125 per cent N equivalent bio-compost applied plots and was on par with the application of poultry manure at 125 per cemt N equivalent (14.12 q ha^{-1}, 13.89 q ha^{-1}and 2.92, respectively).

Weed Management Practices for Higher Productivity in Direct Seeded Finger Millet [*Eleusine coracana* (L.) Gaertn.]

MADEENA MEHABOOB SHAIKH AND M. T. SANJAY
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru

A field experiment was conducted during *rabi*-2020 at Main Research Station, Hebbal, UAS, Bangalore. The experiment was laid out in RCBD comprising twelve treatments, replicated thrice. The treatments were consisting of seven pre-emergence herbicides (oxadiargyl, oxyflourfen, butachlor, atrazine, isoproturon, bensulfuron methyl + pretilachlor and pendimethalin), three post-emergence herbicides (bispyribac sodium, 2,4 D sodium salt and ethoxysulfuron), passing cycle weeder and hand weeding at 20 and 40 DAS and weedy check. Major weeds observed were *Cyperus rotundus*, *Cynodon dactylon*, *Eleusine indica, Dactyloctenium aegyptium*, *Ageratum conyzoides*, *Alternanthera sessilis*, *Commelina benghalensis*. Among different herbicides, pre-emergence application of bensulfuron methyl 0.6% + pretilachlor 6% GR at 330 g a.i. ha^{-1} recorded lower total weed density, weed dry weight, weed index and higher weed control efficiency (99.03 m^{-2}, 76.23 g m^{-2}, 4.48% and 49.92%, respectively) and registered significantly higher grain and straw yield (3945 and 7985 kg ha^{-1}, respectively), which may be attributed to significantly higher plant height (93.10 cm), number of tillers per meter row length (39.50) and total dry weight of plant (193.20 g per 0.25 m row length) at harvest, number of productive tillers per meter row length (36.60 m^{-1}), finger length (10.70 cm) and grain yield per plant (25.70 g) and this treatment also resulted in higher net returns (Rs. 83,210 ha^{-1}) and B:C ratio (3.56) and found to be most economical and comparable with the treatment of passing cycle weeder and hand weeding at 20 and 40 DAS in direct seeded finger millet.

Studies on Next Generation Technology for Nutrient and Water Management in Maize (*Zea mays* L.) – Lablab (*Lablab purpureus* L.) Cropping System

KRISHNA DESAI AND MUDALAGIRIYAPPA
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru

A field experiment on next generation technologies for nutrient and water management in maize-lablab cropping sequence was carried out during 2019-20 and 2020-21 at agroforestry field unit, UAS, GKVK, Bengaluru. The experiment consisted of twelve treatments replicated three times, assigning three levels of irrigation in main plot with four nutrient management practices in sub plots was laid out in a split plot design. The results revealed, that sensor based drip irrigation at 50 per cent depletion of available soil moisture (DASM) along with nutrient expert software based nutrient management approach in maize at harvest recorded significantly higher leaf area (9020 cm^2 $plant^{-1}$), total dry matter production (435.53 g $plant^{-1}$), kernel yield (9725 kg ha^{-1}) and stover yield (10352 kg ha^{-1}) on pooled basis during *kharif*. Treatment received surface irrigation along with recommended dose of fertilizers recorded significantly lowerleaf area (5817 cm^2 $plant^{-1}$), total dry matter production (271.79 g $plant^{-1}$), kernel (6916 kg ha^{-1}) and stover yield (7820 kg ha^{-1}). After harvest of the maize, lablab was grown as residual crop during *rabi* and the results revealed that at 90 DAS, sensor based drip irrigation at 50 per cent DASM recorded significantly higher leaf area (797.2 cm^2 $plant^{-1}$), total dry matter (36.54 g $plant^{-1}$), green pod yield (4647 kg ha^{-1}) and haulm yield (5623 kg ha^{-1}) on pooled basis as compared to surface irrigation. The nutrient management using nutrient expert saved 26.6 and 20.0 per cent nutrients as compared to recommended dose of fertilizer. Sensor based drip irrigation saved 32.6 and 32.2 per cent of irrigation water as compared to surface irrigation during first and second year, respectively.

Investigations on Major Pollinator Profile of Chia (*Salvia hispanica* L.)

K. G. R. CHANDRAMANU AND A. N. SHYLESHA
Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru

SCIENTIFIC field investigation aimed to document the insect visitors of Chia (*Salvia hispanica* L.) flowers was carried out at three different locations *viz*., crop raised in the experimental plots at ICAR, NBAIR - Attur campus - Bengaluru, Organic farming unit, UAS, GKVK, Bengaluru and also at the farmer field, Nijayappanadoddi, Ramanagara district during 2021. A total of 107 insect visitors were collected and recorded on chia during flowering season at three different selected locations. The collected insect visitors belonged to 41 different insect species, 24 insect genera, nine insect families and three insect orders. The Hymenopterans were dominant (82%) followed by the dipterans (14%) and lepidopterans (4%). Among, 41 different insect species, the honeybees, *Apis dorsata*, *Apis cerana* and *Apis florea* were dominant visitors in all the locations. The mitochondrial DNA from the legs of the floral visitors was used for the amplification of the CO-I gene at 53^0C to identify the specimens using molecular taxonomy. Total 5 species confirmed their identity in the molecular taxonomy. The activity of floral visitors, started from 06:00 hours and ended at 18:00 hours. The peak activity of floral visitors was maximum between 13:00 to 15:00 hours with maximum Shannon-Weiner diversity index of 1.754. Among honeybees, *Apis dorsata* was the dominant visitor of chia flowers with an 0.986 Berger-Parker dominance index. The alighting patterns were very clear in *Apis dorsata* with the mirror images of 'C' and '7' shapes on flowers compared to *Apis cerana* with mirror images of 'C' shapes. But for *Apis florea* it was not clear.

Development of Herbal Jaggery for Enhanced Quality and Shelf Life

POOJA KOLAR AND K. V. JAMUNA
Department of Food Science and Nutrition, College of Agriculture, UAS, GKVK, Bengaluru

JAGGERY is the natural sweetener available in solid, liquid and powder form. Jaggery contain micronutrients which has many nutritional and medicinal properties. Medicinal herbs or plants have been known to be an important potential source of therapeutic or curative aids. The present study was undertaken to develop herbal jaggery for enhanced quality and shelf life. In the current study, sugarcane variety VCF0517 was selected for jaggery preparation. Jaggery was enriched with tulsi, mint and ginger in powder form and aqueous extract at the concentration 1.0, 1.5 and 2.0 per cent and developed herbal jaggery subjected for physical and sensory parameter. Powder, liquid and cube form of jaggery were developed. Flavored *chikki*, jaggery chocolates and in tea preparation herbal jaggery was used and products were subjected to sensory evaluation. Results showed that on initial day the physical characteristics including pH, moisture, hardness and insoluble solids were found to be unchanged in both forms of jaggery. Sensory evaluation of developed herbal jaggery record good at 2 per cent concentration. Storage study showed that, as the storage period increased the pH of herbal jaggery decreased from 6.13 to 5.20. Compared to control and aqueous extract the dried herb powder jaggery had less content of total sugar (81.23 to 82.30), reducing sugar (6.42 to 6.59) and sucrose (72.62 to 74.10). Whereas, herb powder based jaggery had higher mineral composition, polyphenol, flavonoid and also exhibited more antioxidant activity at 300 µg/ml (76.37 to 88.18) compared to aqueous extract. Different forms of jaggery can be used in traditional recipes in the preparation of sweets. Herbal jaggery was also found to be highly suitable for tea preparation as it had very good mouthfeel. Herbal jaggery enriched with tulsi, mint and ginger enhanced the overall quality of jaggery with respect to nutrition content and bioactive properties.

Development of Value Added Probiotic Beverages from Millets

VINUTA R. YADAGOUDA AND USHA RAVINDRA
Department of Food Science and Nutrition, College of Agriculture, UAS, GKVK, Bengaluru

AT present probiotic products are dairy based, are expensive and consumer seek change. Objective of the present study was to develop value added probiotic products from millets. Composite mixes were developed using foxtail/ little millet and subjected for probiotication with *Lactobacillus acidophilus* and *Saccharomyces boulardii* separately. The proximate composition revealed that irrespective variations values ranged for moisture 5.44 to 5.71, protein 18.66 to 19.55, fat 5.91 to 5.96, ash 3.53 to 3.55, fibre 3.42 to 3.46, carbohydrate 65.25 to 65.53 g/100 g, respectively and energy 393 to 394 Kcal per 100 g. *In vitro* protein digestibility of foxtail and little millet probiotic composite mixes was between 58.31- 58.41 and 57.77 - 58.78 per cent, respectively. *In vitro* bioaccessibility for iron and zinc of foxtail millet probiotic composite mixes was between 0.72 - 0.99 and 0.65- 0.79 mg/ml, respectively while, in little millet probiotic composite mixes, iron ranged from 0.75 - 0.92 and zinc was 0.53 to 0.88 mg/ml, respectively. SEM analysis depicted particle size of probiotic mixes with more air space, micro particles (poly-dispersed), heterogeneous and were larger in size. The probiotic composite mixes with *L. acidophilus* (7.15×10^7 and 7.00×10^7) and *S. boulardii* (6.21×10^7 and 6.41×10^7) CFU/g were found capable of multiplying in foxtail and little millet composite mixes at one per cent inoculum level respectively. Total cost of probioticated foxtail and little millet mixes was Rs.17.25/- and 18.59 /- per 100 g. The cost is very low compared to commercial products. Hence, foxtail and little millet probiotic composite mixes proved to be best substrate for development of non diary based probiotic products with good amounts of fibre, protein, minerals, polyphenols and low levels of fat and heavy metals.

Processing and Development of Value Added Products from Indian Pennywort (*Centella asiatica*)

V. SHRUTHI AND K. G. VIJAYALAXMI
Department of Food Science and Nutrition, College of Agriculture, UAS, GKVK, Bengaluru

Centella asiatica, a tropical herb of the apiaceae family is used in the Indian ayurvedic medicine due to its wide therapeutic potential. Developing value added products help in popularizing the consumption of *Centella asiatica* in the society. The present study was undertaken to standardize the process of dehydration and to develop acceptable shelf stable products from *Centella asiatica*. Leaves were analyzed for physical and nutritional composition. The mean weight, length and width of the leaves were 4.1g, 4.47cm and 7.26cm, respectively. The leaves pre-treated with 0.5 per cent potassium metabisulphite for 5 minutes dried in tray drier at 60^0C was best accepted and hence considered for further study. Nutrients analysis revealed that dried leaves had 13.12g protein, 2.26g fat, 19.76g crude fibre, 16.13 total ash 43.03g carbohydrates and 244.94 kcal energy. Dried leaves contained 2060 mg, 4750 mg, 380 mg, 164 mg, 841 mg, 49.9 mg and 15.8 mg calcium, potassium, sodium, phosphorus, magnesium, iron and zinc per 100 g, respectively. Value added products soup mix and *masala* biscuit from dried leaves, chutney and RTS beverage from fresh leaves were prepared at different incorporation levels. Sensory evaluation revealed that, soup mix (CLPS2), *masala* biscuit (CLPB3), chutney (CLC4) and RTS beverage (CLRTS4) were best accepted compared to other variations. The shelf life results revealed that soup mix powder and *masala* biscuit were safe and acceptable upto 60 days. The costs of products per 100g were found to be high for *masala* biscuit (Rs.37) and least for chutney (Rs.13). Thus, *Centella asiatica*, could be dehydrated and processed into shelf-stable value added products.

Assessment of Nutritional Status, Life Style and Occupational Health Hazards of Dal Mill Workers in Kalaburagi District of Karnataka State

DEEPAK AND K. V. JAMUNA
Department of Food Science and Nutrition, College of Agriculture, UAS, GKVK, Bengaluru

THE present study was undertaken to analyse the nutritional status, life style and occupational health hazards faced by dal mill workers. Three hundred dal mill workers were selected from different mills in Kalaburagi district. Assessment of health and nutritional status, dietary intake, nutritional adequacy, occupation health hazards, pulmonary health parameters and use of protective measures in dal mills were assessed. A subsample of 30 mill workers were selected for intervention programme. During intervention programme necessary inputs were provided and awareness was created regarding nutrition, health and protection from hazards in milling area. Results revealed that, nearly half of the mill workers (46.33 %) were belonged to the age group 25-35 years. Majority of the mill workers belonged to the upper lower class (77.3 %) and 80.33 per cent workers were vegetarians. Among mill workers 82.67 per cent had normal body mass index of (22.6 kg/m^2) and it was noteworthy that most of the respondents were having normal nutritional status. A nutrition education training programme was conducted to create awareness about nutrition, health and use of PPEs to reduce occupational health hazards for a subsample of 30 workers. Before nutrition education most of them had coughing and sneezing (63.33 %), breathlessness (46.67 %), watery nose (60.0 %) due to dust exposure. Post intervention results showed that the problems were reduced by use of PPEs with respect to coughing and sneezing, breathlessness, and watery nose. The intervention programme has brought a positive change in the knowledge regarding consumption of protective foods and use of safety measures in working area. This positive trend indicates that the training has created the awareness among mill workers as well as owners and also importance of protective measures in the mill premises.

Development of Value Added Products from Underutilized *Chakramuni* Greens (*Sauropus androgynus*)

K. Rashmi and Lata R. Kulkarni
Department of Food Science and Nutrition, College of Agriculture, UAS, GKVK, Bengaluru

Chakramuni (*Sauropus androgynus*) leaves, an underutilized green leafy vegetable, is a perennial shrub known for its nutritional and medicinal value. The present study was undertaken to standardise the process of dehydration and to develop shelf stable value added products. The *chakramuni* leaves were subjected for blanching and steam blanching. Steam blanching for 5 min. and dried at 65^0C had better colour and nutrient retention compared to blanching for 3 min. and dried at 55^0C. Value added products like *khakhra* and *chutney* powder were developed by incorporating dried *chakramuni* leaves at 5, 7.5 and 10 per cent levels. Organoleptic evaluation scores for developed products were in the range of like moderately to like extremely. Both *Chakramuni khakhra* and *chutney* powder were the best accepted at 7.5 per cent incorporation level compared to other variations. Among the products, the *chakramuni chutney* powder recorded higher protein (19.59 g), fat (3.06 g), ash (3.62 g),crude fiber (12.67g), β-carotene (562.60 µg), vitamin C (0.57 mg), calcium (70.57 mg) and iron (8.29 mg) compared to *chakramuni khakhra*. Both *Chakramuni khakhra* and *chutney* powder had higher amount of calcium, iron and β-carotene compared to control *khakhra* and *chutney* powder. The developed products were within safe permissible limits and accepted upto 60 days at room temperature when stored in aluminium pouches. The cost of *chakramuni khakhra* and *chutney* powder per 100 g was Rs.17/- and Rs. 30/-, respectively. Thus, dehydrated *Chakramuni* leaves could be better utilized for development of value added products.

Development of Functional Foods Using Chia Seed Mucilage as Fat Replacer

Sadashiv Naik and Chandrakala Hanagi
Department of Food Science and Nutrition, College of Agriculture, UAS, GKVK, Bengaluru

Chia seed (*Salvia hispanica* L.) is an ancient oil seed used by Mayas and Aztecs as food stuff. This seed is a natural source of omega-3 fatty acids (α-linolenic acid), soluble and insoluble fiber in addition to other important nutritional components. Hence, the current study was conducted for optimization of chia seed mucilage as a fat replacer, standardization of functional foods with chia mucilage and quality analysis along with consumer acceptability of developed products. The best method for extracting the mucilage was found to be treatment T_2 with 80^0C for 10 min with drying temperature of 60^0C (4-5 hr). The highest percentage of mucilage yield of 5 g was extracted from water seed ratio 1:20. Sponge cake and coconut cookies were prepared as a functional food by incorporating chia seeds mucilage. The overall acceptability was highest in case of T_3 sample (8.47) with 75 per cent fat and 25 per cent mucilage. And also, in case of coconut cookies the best overall acceptability was observed in T_5 sample with 8.30 having 70 per cent fat and 30 per cent mucilage. The overall acceptability of products does not get affected by change in physical parameters during storage. Microbial count was within permissible limits during 8 days of storage. Peroxide value was found to be in line when stored for 8 days. The consumer found to like the developed products equally as in case of control products. Hence, chia seed mucilage could be utilized effectively as a fat replacer.

Studies on Seed Invigoration Techniques and Micronutrient Spray on Seed Yield and Quality in Greengram (*Vigna radiata* L.)

ADHITHYA GUNTHA AND R. SIDDARAJU
Department of Seed Science and Technology, College of Agriculture, UAS, GKVK, Bengaluru

FIELD and laboratory studies were conducted to study the influence of micro and macronutrients on seed quality and packaging materials, seed treatment chemicals, solarisation on seed storability in greengram at NSP, UAS, Bangalore during 2020-21. Seed invigoration with 1 per cent $ZnSO_4$ in summer season recorded the highest in field emergence (96.6 %), plant height 60 DAS (32.7 cm), number of nodules per plant (40.3) number of pods per plant (16.9), seed yield per plot (273 g), seed yield per ha (4.3 q), seed recovery (97.7 %), seed germination (95.7 %) and 100 seed weight (4.21 g). Effect of foliar application of ferrous sulphate (0.5%) in KKM-3 recorded the highest in plant height at 60 DAS (32.73 cm), number of nodules (35.4), seed yield per plot (285.6 g), seed yield per ha (4.53 q). Seed germination (97.3 %) was highest in WGG-42 and seed recovery (97.0 %) and protein (25.48 %) in TRCRM-147. WGG-42 recorded significantly less number of hard seeds (16.2 %) compared to KKM-3 (18.5 %) and TRCRM-147 (19.9 %) after imposing treatments. Among treatments, Conc. sulphuric acid for 2 min recorded highest seed germination of three varieties (95.3, 97.3 and 95.3 per cent) compared to control (36.3, 32.0 and 29.0 per cent), respectively, also in other seed quality parameters. Seeds stored in super grain bag with spinetoram (0.4 ml/kg seed) treatment recorded lowest in seed moisture content (8.12 %) and seed infestation (1.67 %) and highest in seed germination (87.0 %) were recorded seeds treated with Chlorantraniliprole (0.10 ml/kg) compared to control (67.3 %) during ten months. Fresh seeds exposed to four hours of solarisation for three days was significantly better in number of eggs (192.3), number of adults (37.0), seed germination (79.6 %) compared to control (237.3, 62.6, 63.0 per cent, respectively) during nine months.

Evaluation of New Parental Lines for Hybrid Seed Production Potential and Longevity in Rice (*Oryza sativa* L.)

R. RENUKA AND S. N. VASUDEVAN
Department of Seed Science and Technology, College of Agriculture, UAS, GKVK, Bengaluru

FIELD experiments were conducted at V.C. Farm, Mandya during *kharif* 2019 and *summer*2020. The results revealed that among seven CMS lines studied, four CMS lines *viz*., KCMS57A, KCMS61A, KCMS60A and KCMS59A were identified as promising lines as they showed high panicle exsertion, seed setting (%) and seed yield per plant in both the seasons. Predominance of non-additive gene action for all the characters studied was noticed from the ratio of GCA to SCA variance. The B lines, CMS 3B, CMS 5B and CMS 6B and four testers *viz.,* MSN 36×Tetep (3-1), IET20919 × MSN99 (3-1-1-1-1-1-1), MSN36 × Tetep (22-1) and MSN 36 × Tetep 35 identified as good general combiners as they recorded high (H) overall *gca status*. Among hybrids, CMS 1A×MSN 36×Tetep 1 and CMS 3A×MSN36×Tetep (22-1) were best specific combiners. The parental lines and newly developed hybrids were stored in super grain bag (C_2) and cloth bag (C_1). Higher seed quality parameters were recorded in super grain bag. Among A, B, R lines and hybrids, maximum seed germination, root length, shoot length, dry weight of seedling, seedling vigour index and total dehydrogenase activity were noticed in A_1 (75.83%, 14.82 cm, 12.22 cm, 6.20 mg, 2016, 0.384 OD value, respectively) followed by B_7 (74.17 %, 13.44 cm, 11.71 cm, 6.04 mg, 1865, 0.332OD value, respectively), R_{13} (79.50 %, 14.17 cm, 13.61 cm, 6.89 mg, 2249, 0.429OD value, respectively) and H_1 (80.10 %, 15.51 cm, 14.53 cm, 7.01 mg, 2409, 0.502OD value, respectively). Whereas, lower seed quality was noticed in cloth bag at 10th month of storage. Among all 12 hybrid combinations, the seeds of KCMS57A×MSN36×Tetap-35 stored in super grain bag performed well throughout the storage period. Hybrid purity testing was carried out using 35 SSR markers, out of which 14 markers (RM 584, RM 276, RM 216, RM 209, RM 337, RM 297, RM 21, RM 228, RM 206, RM 202, RM 211, RM 280, RM 331 and RM 448) showed polymorphism for differentiating parental lines.

Endophytes : A Potent Seed Bio-Priming Agents for Abiotic Stress Mitigation in Selected Crops

B. Roopashree and S. Rajendra Prasad
Department of Seed Science and Technology, College of Agriculture, UAS, GKVK, Bengaluru

Drought is a major limiting factor influencing plant growth and development. In recent years there have been several studies to demonstrate the use of endophytes in mitigating stress tolerances. Endophytes include symptomless bacteria and fungi that are ubiquitously present in the intercellular spaces of the host plants. Endophytes isolated from extreme habitats are able to colonize the non-host plants and impart stress tolerance response. Against this background area of knowledge, the present study was taken up to study the role of selected 8 endophytes on early seedling growth of maize, green gram, soybean and brinjal. Among 8 fungal endophytes, K-23, LAS-6 and P-37 had shown increased seedling growth of pre-germinated maize seeds both under control and PEG-8000 induced drought stress conditions. Not only in the seedling level but also in the greenhouse conditions these selected endophytes (K-23, LAS-6 mad P-37) have been reported a significant increase in the plant height, stem girth, leaf area, root volume, photosynthetic rate, chlorophyll content, antioxidant enzyme activity and yield content when plants were subjected to drought stress. In order to unravel the molecular mechanism, maize plants inoculated with K-23 were subjected to comparative transcriptome analysis. It revealed that genes involved in the photosynthetic pathway, synthesis of secondary metabolites, starch and sucrose metabolism were upregulated in endophyte enriched seedlings when subjected to drought stress. This study set as proof of concept to demonstrate endophytes adapted to extreme habitats can be effectively used to modulate non-host plant responses to abiotic stresses such as drought.

Standardization of Seed Bio Priming Technique by Using Endophytes for Selected Crops

Oba Usha Rani and P. J. Devaraju
Department of Seed Science and Technology, College of Agriculture, UAS, GKVK, Bengaluru

Endophytes are the microorganisms that are present inside the plant system *i.e.,* associated intercellularly inside the plant tissue. Bio priming is a process of treating seeds with the bio-agents or other beneficial microorganisms which proved to improve the performance of the respective treated seeds for early seedling growth and development. An attempt has been made to standardize the bio priming technique in cowpea, sorghum and capsicum crops using four endophytes with three different spore doses at three durations. Fungal endophyte cultures *viz*., SF-5 (*Fusarium incarnatum*), V_6E (*Fusarium* sp.), K23 (*Fusarium equiseti*) and LAS-6 (*Chetomium* sp.) were obtained from the endophytic fungal library, School of Ecology and Conservation Laboratory, UAS, Bangalore. Results were conclusively showed that cowpea seeds bio primed with *Chetomium* sp. recorded highest germination (100 %), shoot length (22.33 cm), root length (7.23 cm), seedling dry weight (51.33 mg) and vigour Index-I, II *i.e.,* 2957, 513, respectively at spore dose of 4.5×10^8 spore/ml with 4 h duration, Whereas capsicum and sorghum did not show any response to the bio priming. The highest chlorophyll content (5.54 mg g^{-1} FW) and amylase activity (33.8IU mg^{-1} protein) was observed in cowpea seeds bio priming with *Chetomium* sp. at 4.5×10^8 spore/ml with 4 h duration. Likewise, *in vivo* treatment of cowpea seeds with same conditions, highest number of flowering clusters/ plant, number of fruits/plant, fruit length (cm), pod weight (g), number of seeds/pod and seed yield/plant (6, 10, 14.67, 3.67, 15.67 and 156.33 g, respectively) was recorded over control.

Studies on Efficacy of Biological Seed Coating with Biopolymer on Seed Quality and Longevity in Bell Pepper (*Capsicum annuum* L.) and Tomato (*Solanum lycopersicum* L.)

LAKSHMI CHIMMAD AND K. VISHWANATH
Department of Seed Science and Technology, College of Agriculture, UAS, GKVK, Bengaluru

THE experiment was conducted to study the efficacy of biological seed coating with biopolymer on seed quality and longevity in bell pepper and tomato, during 2020-21. Among eight different biologically coated treatments, seeds coated with (*T. viride* + *P. fluorescens* + *B. subtilis* + Mycorrhiza + Multinutrient-mix) 20 g + Biopolymer 25 g + Water 50 g / kg seed (T_6), (*T. viride* + *P. fluorescens* + *B. subtilis* + Mycorrhiza + Multinutrient-mix) 10 g + Chitosan 5 g + Biopolymer 25 g + Water 55 g/kg seed (T_8) and *T. viride* + *P. fluorescens* + *B. subtilis* + Mycorrhiza + Multinutrient-mix) 10 g + Thiamethoxam 3.5 g) + Biopolymer 25 g + Water 55 g/kg seed (T_7), showed highest germination in bell pepper (94.67, 94.00 and 93.67%), SVI-I (936, 905 and 889), seedling emergence in protray (96.00, 95.67 and 95.00%) and seedling length @30 DAS (23.04, 22.98 and 22.45cm) over control. Above three treatments showed highest germination (95.00,94.00 and 93.67%), SVI-I (1734,1668 and 1656), seedling emergence inprotray (97.00, 95.67 and 94.33 %) and seedling length @30 DAS (33.88, 33.51 and 33.10 cm) in tomato. Best three seed treatments were stored for evaluation of seed longevity. After two-months storage, reduction of 9.16 and 8.83 per cent germination was recorded in T_6 in bell pepper and tomato, respectively. Biologically coated seeds should be sown immediately after seed treatment, as it can be stored for short period because long term storage leads to seed deterioration and decrease in shelf-life of biologicals. However, treatment T_6 maintained seed quality of bell pepper and tomato even after six months of storage (92.33 and 92.17%, respectively).

Influence of Seed Priming on Morpho-Physiological Traits, Seed Yield and Quality in French Bean (*Phaseolus vulgaris* L.)

GANESH PRASAD AND PARASHIVAMURTHY
Department of Seed Science and Technology, College of Agriculture, UAS, GKVK, Bengaluru

SEED priming is one of the economic and feasible technology for uniform crop development in most of the field crops. The field and laboratory experiments were conducted during *rabi* 2020 at Department of Seed Science and Technology, UAS, GKVK, Bengaluru to study influence of seed priming on morpho-physiological traits, seed yield and quality in French bean cv. Arka Arjun with ten treatments and three replications. Among the priming treatments, *Trichoderma viride* 10 per cent for 5 hours recorded higher growth and yield parameters *viz*., plant height at 30 and 45 DAS (50.07 and 61.33 cm), number of leaves at 45 DAS (35.53), leaf chlorophyll content at 45 and 60 DAS (37.22 and 37.49), number of pods per plant (32.4), clusters per plant (12.67), seed yield per plant (14.0g), per plot (299.87g) and per hectare (11.09q) compared to control (35.8 cm and 48.06 cm, 22.80, 34.16 and 32.67, 21.2, 7.87, 10.92 g, 235.0 g and 8.66 q), respectively. Seeds primed with $GA_3$50 ppm + *Trichoderma viride*10 per cent for 5 hours recorded highest seed quality parameters *viz*., germination (79.33 %), mean seedling length (41.97 cm), mean seedling dry weight (133.33mg), SV - I (3024), SV - II (10320) and TDH (2.35 nm) compared to control (67.33 %, 30.93 cm, 110.0 mg, 2109 ,7306 and 2.28 nm). Among the treatments highest B:C ratio of 2.7 was observed in *Trichoderma viride*10 per cent enhances the growth, seed yield of french bean and in turn provides highest returns to farmers. Among the treatments highest B:C ratio of 2.7 was observed in *Trichoderma viride*10 per cent enhances the growth, seed yield of french bean and in turn provides highest returns to farmers.

Influence of Growth Regulators on Growth, Seed Yield and Quality Attributes in Soybean [*Glycine max* (L.) Merrill.]

Santosh Devanagaon and P. J. Devaraju
Department of Seed Science and Technology, College of Agriculture, UAS, GKVK, Bengaluru

The experiment was conducted at Karajagi (village), Afzalpur (taluk), Kalaburagi (district) under the Department of Seed Science and Technology, UAS, GKVK, Bengaluru during 2020-21 to know the influence of growth regulators on growth, seed yield and quality attributes in soybean. The experiment was consisting of ten different growth regulator treatments and replicated three times in a randomized complete block design. Significant differences were noticed between the treatments for crop growth, seed yield and quality parameters. Among treatments imposed, the treatment TIBA @ 50 ppm recorded highest growth and yield parameters *viz*., number of leaves per plant at 60 DAS (33.20), number of branches per plant at 60 DAS (9.00) and at harvest (9.25), days taken 50 per cent flowering (40.89), days taken to maturity (86.49), pod weight (22.15 g), number of pods per plant (56.22) and seed yield (1.85 kg/ plot) when compared to control (27.0, 7.20, 7.45, 44.95, 89.30, 16.55 g, 33.85, 1.32 kg/ plot), respectively. The treatment GA_3 @ 100 ppm recorded higher seed quality parameters *viz*., germination (92.0 %), mean germination time (2.45 days), mean seedling length (30.44 cm), mean seedling dry weight (52.42 mg), SV - I (2802) and SV - II (4826) when compared to control (81.0 %, 24.37 cm, 43.79 mg, 1964 and 3530), respectively. It concluded that treatment TIBA @ 50 ppm showed positive influence on crop growth, yield attributes of soybean and GA_3 @ 100 ppm on quality attributes of soybean.

Effect of Pre-Sowing Seed Treatments on Germination and Seedling Growth in *Melia dubia*

Shashikumar Umarani and P. Venkappa
Department of Seed Science and Technology, College of Agriculture, UAS, GKVK, Bengaluru

Melia dubia is a species of highly medicinal and industrial value, commonly referred to as Malabar neem tree. It's natural germination through seeds is less than 25.0 per cent, which is one of the major hurdles for the production of quality planting stock for large scale planting. So, there is a need to find an appropriate pre-sowing treatment to enhance seed germination. Four experiments were conducted in laboratory and poly house condition in the Department of Seed Science and Technology, UAS, GKVK, Bengaluru. Among the two-experiments *i.e.,* chemical and hormonal treatments under laboratory condition, seeds scarified with H_2SO_4 @ 2 per cent for 20 minutes showed highest germination of 22.0 per cent, followed by 17.0 per cent GA_3 @ 1000 ppm for 6 h in hormonal treatment, when compared to control (7.0 %). This clearly indicates the role of hormones and chemicals on germination and seedling growth. Among the two-experiments *i.e.,* cow dung slurry and physical treatments under poly house condition, seeds soaked in cow dung slurry for 15 days and dried for 4 days and repeated 3 times showed maximum field emergence, speed of germination and germination energy of 73.0 per cent, 2.27 and 29 days followed by boiling water treatment @ 100°C for 10 min in physical treatment 48.3 per cent, 1.58 and 33 days as compared to control 27.0 per cent, 0.66 and 46 days. This indicates the role of cow dung slurry and physical treatments on germination and seedling growth in *Melia dubia*.

Assessment of Thermotolerant Bivoltine Silkworm Breeds through Biochemical and Molecular Responses of Serine Protease Inhibitors and Prophenoloxidase Challenged with *Beauveria bassiana* (Bals. - Criv.) Vuill.

K. P. SAHANA AND MANJUNATH GOWDA
Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru

A study was conducted to assess the performance of thermotolerant bivoltine silkworm breeds against *Beauveria bassiana* infection by understanding the activities of serine protease inhibitors (SPI) and prophenoloxidase (PPO) in relation to susceptibility *vis-a-vis* resistance of silkworms to the fungus, during 2019-2021 at the Department of Sericulture, UAS, Bangalore. The *B. bassiana* isolate used in the study was originally collected from Shidlagatta in Karnataka and named as SHDL. *In-vitro* assessment of *B. bassiana* protease showed highest subtilisin-like (Pr1) activity than trypsin-like (Pr2) activity in both intracellular and extracellular fractions. Standardization of working protocol for determining the SPI and PPO activities revealed that succinyl-(alanine) 2-prolinephenylalanine-*p*-nitroanilide and DOPA to be better substrates, respectively. Upon injection of extra cellular fraction of *B. bassiana* protease to ten silkworm breeds *viz.,* B1, B2, B4, B6, B8, APS12, APS45, CSR2, CSR4 and Pure Mysore, B1 and B6 breeds recorded highest SPI activity both in the cuticle and the haemolymph. B1 and B2 breeds exhibited highest PPO activity in the cuticle, whereas its activity in the haemolymph was highest in B4 and CSR2 breeds. Phenotypic performance of the breeds under high temperature and fungal stress conditions showed that, the thermotolerant breeds B1 and B4 thrived well with respect to both survival and quantitative parameters under both the stresses. The expression of *Bm*SPI38 and *Bm*PPO1 genes in B1, CSR4 and Pure Mysore showed strong expression of *Bm*PPO1 gene in B1 breed than the other two. Further, prophenoloxidase gene expression markedly corresponded to resistance of silkworm breeds to *B. bassiana* inoculation. Thus, the thermotolerant breed B1 could be dual stress resistant as revealed by SPI and PPO activities, phenotypic performance and immune genes expression under *B. bassiana* infection.

Influence of Liquid Organic Manures on Growth, Yield and Quality of Mulberry Leaf and Rearing Performance of Silkworm (*Bombyx mori* L.)

S. U. HEMAVATHI AND S. CHANDRASHEKHAR
Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru

AN experiment was conducted at Department of Sericulture, University of Agricultural Sciences, GKVK, Bengaluru during 2020-21. The results of the experiment revealed that the soil application of bio digested liquid organic manure equivalent to 100 per cent N ha^{-1} recorded significantly higher available nitrogen, phosphorous, potassium and sulphur (316.36, 51.51, 164.52 kg ha^{-1} and 7.78 ppm), respectively in Victory-1 variety mulberry garden soil. The same treatment recorded higher plant growth parameters such as plant height, number of shoots plant^{-1}, number of leaves plant^{-1} and leaf area (138.48 cm, 25.00, 330.53 and 165.20 cm^2), at 60 DAP, respectively, leaf yield and associated parameters such as individual leaf weight and yield plant^{-1} at 45 DAP (2.39 g and 826.66 g), respectively, leaf quality parameters like total chlorophyll, crude protein, carbohydrates, nitrogen, phosphorous and potassium contents at 45 DAP (2.14 mg/g fresh weight, 22.72, 12.35, 3.64, 0.34 and 2.13 %), respectively. Further significantly higher rearing parameters of double hybrid silkworm FC1 × FC2 such as fifth instar larval weight, cocoon weight, cocoon shell weight, cocoon shell ratio, single cocoon filament length and filament denier of 41.15 g/10 larvae, 24.76 g/10 cocoons, 5.89 g/10 cocoon shells, 23.78 per cent, 1138.80 m and 3.65, respectively were recorded in silkworms fed mulberry leaves produced from bio digested liquid organic manure equivalent to 100 per cent N ha^{-1} also in the same treatment higher net returns and B:C ratio of both PM × CSR$_2$ and FC1 × FC2 cocoon production were encountered.

Studies on Yield and Income Maximisation in Tree Mulberry Based Legume Intercropping System

G. M. Banu Priya and C. Doreswamy
Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru

'Studies on yield and income maximisation in tree mulberrybased legume intercropping system' was carried out during 2020-21 at KVK, V.C. Farm, Mandya. The results revealed that, higher soil pH (7.51) and EC (0.15 dS m^{-1}) were recorded in sole tree mulberry. Higher organic carbon (0.72%), available nitrogen, phosphorous & potassium (377.15, 66.17 and 232.06 $kgha^{-1}$, respectively), plant height (261.13 cm), shoot length (170.20 cm), number of shoots $plant^{-1}$ (23.80), number of leaves $plant^{-1}$ (367.80), leaf yield (71.90 t ha^{-1} $year^{-1}$), leaf moisture content (75.09%), moisture retention capacity (83.50 %), total chlorophyll (1.74 mg/g), leaf nitrogen (3.48 %), phosphorous (0.36 %) and potassium (2.14 %) contents were recorded in tree mulberry and black gram intercropping. Significantly maximum larval weight (38.65 g/10 larvae), cocoon weight (25.28 g/10 cocoons), pupal weight (19.34 g/10 pupae), shell weight (5.85 g/10 shells), cocoon shell ratio (23.14%), single cocoon filament length (1268.27 m) and denier (3.47) were observed in FC1 x FC2 double hybrid silkworm fed with tree mulberry leaves raised with black gram. The least incidence of white muscardine (0.67 %) was observed in tree mulberry intercropped with black gram. Among the intercrops, higher number of pods (90.40) and seed yield (812.12 kg ha^{-1}) were recorded in horse gram and cowpea, respectively. Black gram mulched tree mulberry plot recorded higher growth, yield, quality and rearing performance of silkworms. Maximum net returns (Rs.3,31,204 ha^{-1}) and B:C ratio (4.68) was recorded in tree mulberry and black gram intercropping.

Effect of Nitrogenous Nano-Fertilizer on Growth and Yield of Mulberry and its Impact on Cocoon Production

L. Pooja and R. Narayana Reddy
Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru

A study on 'Effect of nitrogenous nano-fertilizer on growth and yield of mulberry and its impact on cocoon production' was conducted in the established V-1 mulberry garden at Department of Sericulture, GKVK, Bengaluru during 2020-21. On 45 DAP, significantly highest shoot height (55.63 cm), number of leaves per plant (275.10) and total leaf area (26443.30 cm2 / plant) were recorded when mulberry plants raised with foliar application of 0.6 per cent nitrogen nano-fertilizer on 25 DAP + 50 per cent N through soil application. The leaf yield (928.53 g /plant on 60 DAP) and leaf biochemical and elemental compositions at 45 DAP *viz.,* crude protein (28.44 %), total chlorophyll content (2.56 mg /g), nitrogen (4.55 %), phosphorus (0.32 %) and potassium (1.72 %) were highest in foliar spray of 0.4 per cent nitrogen nano-fertilizer on 25 DAP. However, significantly lowest larval duration (24.42 days), highest fifth instar larval weight (36.66 g /10 larvae), ERR (97.78 %), single cocoon weight (2.69 g), single cocoon shell weight (0.63 g), cocoon shell ratio (23.28 %), filament length (1510.19 m) and lowest denier (2.74) were recorded when silkworms fed with mulberry leaves with foliar application of 0.4 per cent nitrogen nano-fertilizer on 25 DAP. Net returns per hectare of mulberry (Rs.1,77,590 ha^{-1} $crop^{-1}$) and B:C ratio (3.29) were more with foliar application of 0.4 per cent nano nitrogen fertilizer on 25 DAP and found to be cost effective as compared to other treatments.

Assessment of Chemicals with Insecticidal and Acaricidal Property on Safety of Silkworm, *Bombyx mori* L.

S. KALPANA AND K. G. BANUPRAKASH
Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru

AN experiment was carried out in the Department of Sericulture, UAS, GKVK, Bengaluru during 2020-21 to assess the chemicals with insecticidal and acaricidal property on safety of silkworms, *Bombyx mori* L. Among the pesticides evaluated, abamectin along with diafenthiuron performed better than the rest of the pesticides but were on par with the standard checks [wettable sulphur 80 % WP @ 2.5 g/l and dimethoate 30 % EC @ 2 ml/l]. Fenpropathrin 30 % EC @ 0.3 ml/l did not perform well in mulberry as well as rearing performance of silkworms at both 15 and 20 DAS. Abamectin and diafenthiuron did not exhibit any visual phytotoxic symptoms on mulberry and also did not affect the population of natural enemies which resulted in increased leaf yield at both 25 and 30 DAP spray schedule. When the treated leaves from these two pesticides were fed to the silkworms, it was found safer to the worms as they recorded zero mortality and cent per cent larval progression were observed at 15 and 20 DAS. Better rearing [shortest larval duration, maximum larval weight, ERR (%)] and reeling [cocooning percentage, cocoon weight, cocoon shell weight, longest filament length and maximum filament weight] performances were observed at 20 DAS when compared to 15 DAS. Hence, abamectin 1.9 % EC @ 0.75 ml/l and diafenthiuron 50 % WP @ 1 g/l can be verified as an alternate molecule to DDVP for managing both mulberry thrips and mites, where they found safer to the silkworms at 20 DAS.

Effect of Pruning Heights on Quality of Mulberry and Outbreak of Bacterial Flacherie Disease in Silkworm, *Bombyx mori* L.

C. LAVANYA AND R. N. BHASKAR
Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru

THE field experiment was conducted at Department of Sericulture, GKVK during 2020- 21 by introducing different heights of pruning to V-1 mulberry and the results revealed that, mulberry pruned at 150 cm above the ground level was recorded highest shoot height (95.60 cm), number of shoots (23.35), number of leaves (162.35) and leaf yield (479.25 g/ plant) per plant at 60 DAP. However, pruned at 30 cm and significantly more moisture content (78.59 %), total chlorophyll (2.32 mg/g) content, leaf nutrient elements like N (3.90 %), P (0.58 %), K (2.04 %), Ca (1.20 %), Mg (0.13 %) and S (0.17 %) content were recorded at 30 DAP. Further, the leaf harvested from V-1 and fed to IV and V instar PM × CSR2 and FC1× FC2 hybrids revealed maximum V instar fifth day larval weight of 19.77 and 20.60 g/10 in healthy and 14.76 and 18.13 g/10 in inoculated batches where as in FC1 × FC2 the values were 31.61 and 32.45., 27.05 and 26.64 g/ 10, respectively. Further, T_6 (150 cm) with bacterial inoculation revealed less larval weight reduction (11.52 and 15.63 %) in V instar inoculated batch than remaining treatments. It is vivid from the data that, bacterial per cent disease outbreak was found more in the batches of silkworm fed on leaves from 60 cm above the ground level on contrary less (150 cm) was noticed in both the hybrids. As the pruning height increased, from 30 - 150 cm the cocoon parameters were decreased.

Knowledge and Adoption Level of Bivoltine Hybrid Silkworm Rearing Practices by Sericulturists of South Eastern Dry Zone of Karnataka

M. Narmada and N. Amarnatha
Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru

The study was conducted during 2020-21 to analyze the knowledge and technology adoption of bivoltine hybrid silkworm rearers in Kolar and Chikkaballapur districts of Karnataka state. Thirty silkworm rearers practicing bivoltine hybrid silkworm rearing and another thirty silkworm rearers practicing multi × bivoltine hybrid silkworm rearing were randomly selected in the two districts. With regard to the recommended mulberry cultivation and improved silkworm rearing practices there was a highly significant difference in respect of mean knowledge score and adoption scores between bivoltine and multi × bivoltine hybrid silkworm rearers. It was also found from the study that, there existed a highly significant difference in respect of yield (mulberry leaf and cocoon) and income between the bivoltine and multi × bivoltine hybrid silkworm rearers. Lack of knowledge on pruning method, scarcity of irrigation water and availability of fertilizers in time were the three major mulberry production constraints faced by the bivoltine and multi × bivoltine hybrid silkworm rearers. Whereas, lack of knowledge on size of rearing hall and rearing equipment were the major silkworm rearing constraints encountered by both bivoltine and multi × bivoltine hybrid silkworm rearers. Further, it was found that the major marketing constraints faced by the respondents were lack of knowledge on cocoon grading and fluctuating market prices for cocoons. Providing minimum support price, timely and adequate supply of quality inputs and need based training programmes to the sericulturists are the major suggestions expressed by them to increase the production and improve the quality of bivoltine silk.

Evaluation of Self Mounting Spiral Mountages on Silkworm (*Bombyx mori* L.) at Farmers' Field

Amruth Kumar Kanti and K. S. Vinoda
Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru

Applicability of a new bamboo self mounting spiral mountages for handling the matured silkworms with more ease and comparatively less labor was done from 2018 in Kolar and Chikkaballapur distrcits. The current study was planned to conduct field trials of the same at the farmers' rearing house in Kolar and Chikkaballapur districts to determine the performance of a new spiral self mountage (2'x3.5') for effective cocooning in comparison to a self mounting plastic collapsible mountage (2'x3.5') and the regular bamboo mountage (Manual type). Both cross breed (CB) and bivoltine double hybrid (Krishnaraja) silkworms were allowed to self-mount on a bamboo spiral mountage and the plastic collapsible mountage while the ripened silkworms were manually collected and distributed on the normal bamboo mountage. The cocoons harvested from spiral self mountage recorded maximum number of total cocoons (190.34, 223.13 cocoons/mountage) and heavier cocoon weight (1.801, 2.005 g/cocoon), respectively for CB and Krishnaraja, compared to self mounting plastic collapsible mountage which rewarded least number of total cocoons (183.54, 186.57 cocoons/mountage) and lighter cocoons (1.680, 1.848 g/cocoon) in CB and Krishnaraja, respectively. The cocoon filament length (808.17 m/cocoon in CB and 1213.09 m/cocoon in Krishnaraja) and NBFL (723.20 in CB and 873.52 in Krishnaraja) reported maximum on spiral mountage reflecting its superiority. The economic parameters (cocoon and reeling parameters) of cocoons constructed on spiral mountage were comparable with that of regular bamboo mountage indicating that spiral mountages can be used for self mounting in both silkworms *viz*., CB and Krishnaraja for successful mounting along with significant in the reduced labour requirement.

Performance of V-1 Mulberry Saplings (*Morus* Sp.) Under Aeroponic System

G. A. Nishchitha and R. N. Bhaskar
Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru

Investigation on the growth and quality parameters of mulberry saplings (*Morus* sp.) grown under aeroponic system and nursery condition were assessed at 15, 30, 45 and 60 days after transplanting. The plants grown under aeroponic system were recorded maximum for all the growth and quality parameters except leaf area, total chlorophyll content and leaf carbohydrate percentage which were found maximum under nursery conditions. However, the per cent leaf moisture and moisture retention capacity after 6 hours were found on par under both systems. Among treatments, T3 (three buds per cutting) recorded maximum for all growth and quality parameters followed by T2 (two buds per cutting) and T1 (one bud per cutting). The interaction effect between propagation systems and number of buds per cutting showed significant results. S1T3 (Three budded cuttings under aeroponic system) recorded maximum for growth and quality parameters *viz*., number of primary roots (46.80), longest root length (26.90 cm), root biomass (1.17 g), number of shoots (6.63), longest shoot length (24.55 cm), internodal length (4.27cm), plant height (44.39 cm), number of leaves (16.91), leaf yield (10.79 g/plant), leaf nutrient contents (N,P,K,Ca,Mg,S) (2.18, 0.49, 3.48, 0.45, 0.37 and 0.27%) and protein percentage (13.65%) whereas least was recorded by S2T1 (One budded cuttings under nursery) at 60 DAT. However, S2T3 recorded maximum leaf area (95.96cm^2) and carbohydrate content (18.03%). There was no significant difference with respect to leaf moisture percentage and retention capacity after 6 hours and total chlorophyll content. From these results it can be concluded that, the aeroponic system could be effectively used for the production of V-1 mulberry saplings.

Studies on Zinc and Boron Application on the Paddy – Cowpea Cropping Sequence in Acid Soils of Hassan District, Karnataka

Chetana Banasode and S. Channakeshava
Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru

Field experiments were conducted in the farmer's field at Bhairapura village, Alur taluk, Hassan district of Karnataka during the *kharif* and *rabi* season of 2019-20 to studies on zinc and boron application on the paddy - cowpea cropping sequence in acid soils of Hassan district, Karnataka. Paddy was the test crop to study the direct effect and cowpea crop was raised to study the residual effect. The experiments were laid out in randomized complete block design with thirteen treatments and replicated thrice. The experimental results revealed that significantly higher grain yield of paddy (60.45 q ha^{-1}) and seed yield of 1358.54 kg ha^{-1} in the succeeding cowpea crop was recorded with the application of NPK (100:50:50 kg ha^{-1}) + FYM (10 t ha^{-1}) + $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 5 kg ha^{-1} (T_5) which was on par with NPK + FYM + 25 kg ha^{-1} $ZnSO_4$ + 10 kg ha^{-1} Borax (T_7). The increase in yield in both the crops was due to improvement in growth and yield parameters and uptake of nutrients. Direct and residual effect of NPK + FYM + $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 5 kg ha^{-1} recorded significantly higher available S, Zn, B content in soil after harvest of paddy and cowpea. However, significantly higher soil available nitrogen, phosphorus and potassium content were observed in the treatment that received NPK+ FYM in paddy - cowpea cropping system after harvest of both the crops. Study revealed that application NPK + FYM + 25 kg ha^{-1} $ZnSO_4$+ 10 kg ha^{-1} Borax (T_7) recorded significantly higher zinc fractions (WSEX, OC, CRYOX, AMOX, MN and RES Zn) and boron fractions (RS, SA, Oxide, Org and RES B) at harvest of paddy and cowpea crops and it was on par with T_5 treatment.

Phytolith Production, Stability and Dissolution in Different Rice Soils of Karnataka

MOHSINA ANJUM AND N. B. PRAKASH
Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru

To understand the phytolith production in rice, plant and soil samples were collected from Tungabhadra, Bhadra and Cauvery command areas of Karnataka besides conducting a field experiment to assess the efficacy of different sources of silicon (Si) on plant phytolith production. A pot experiment was also conducted with the application of different phytogenic Si (PhSi) sources (rice straw, rice husk, rice straw biochar and rice husk biochar) in acidic, neutral and alkaline soils to study the dissolution and stability of phytoliths. Relatively higher plant phytolith, phytolith occluded carbon (PhytOC) content and plant available Si (PASi) were recorded in the Cauvery command area. Pearson's correlation between plant phytolith and phytOC content and soil analytical data revealed that the pH and clay are the major edaphic factors that control the acetic acid extractable Si (AASi) content. Calcium chloride extractable Si (CCSi) depends on the cultivation practices. CCSi content in the soil affects the spatial variability of phytolith and phytOC production. Field experiment results revealed that application of diatomaceous earth, silicic acid and rice husk biochar recorded significantly higher phytolith and phytOC content in rice crop and AASi, CCSi and amorphous Si (ASi) content in post-harvest soils over control. Redundancy analysis (RDA) revealed that the production of plant phytolith and phytOC content was significantly correlated with the soil organic carbon, available nitrogen and potassium, CCSi and ASi content which was enhanced by the application of external Si. Increased Si uptake in the treatment receiving PhSi sources in all three soils over control revealed that Si released during the decomposition of these materials are plant available. The Si uptake and phytolith content in post-harvest soil were lower in acidic soil compared to neutral and alkaline soil. Addition of PhSi materials increased the Si bioavailability, which may further depend on soil properties and processes.

Development of Targeted Yield Equation for Aerobic Rice and its Evaluation on Alfisols of Eastern Dry Zone of Karnataka

N. BHAVYA AND P. K. BASAVARAJA
Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru

Development of soil test crop response (STCR) targeted yield equations and post-harvest soil test value prediction equations for aerobic rice and its evaluation through verification trial were conducted on *Alfisols* of ZARS, GKVK, Bengaluru during *kharif* 2018, 2019 and 2020. The fodder yield of maize and available NPK status recorded higher in high fertility (L3) strip followed by medium (L_2) and low fertility (L_1) strip, which formed basis for conducting STCR main experiment on aerobic rice. Initial soil analytical data, yield and NPK uptake by aerobic rice in main experiment were used for obtaining four important basic parameters, *viz.,* nutrient requirement (NR), nutrients contribution from fertilizers (CF%), soil (CS%) and poultry manure (%C-OM). From these basic parameters, the following STCR fertilizer prescription equations under inorganics and IPNS were developed and evaluated through verification trial.

STCR-Inorganics	**STCR-IPNS equations**
FN= 3.02879T-0.20314STV	FN= 2.89282T-0.20320STV- 0.72978OM
FP_2O_5= 1.24589T -0.07368STV	FP_2O_5 = 1.13206T -0.06960STV - 0.4891OM
FK_2O= 1.51168T -0.22617STV	FK_2O= 1.50402T -0.21105STV-0.42410OM

Significantly higher yield and yield attributes of aerobic rice were recorded in STCR inorganic approach for the targeted yield of 65 q ha^{-1} based on predicted soil test values compared to LMH approach and RDF. Similarly, higher nutrient use efficiency, uptake and response yard stick (RYS) were recorded in STCR inorganic approach based on predicted soil test values. However, the better profit was recorded (VCR: 10.99) in STCR target of 55 q ha^{-1} through inorganics based on predicted soil test values. The per cent achievement at both the yield target levels (65 and 55 q ha^{1}) based on actual and predicted soil test values was within ± 10 per cent variation, proving the validity of the fertilizer prescription equations developed for aerobic rice and suitable for Agro climatic Zone -5 of Karnataka.

Evaluation of Incineration Ash as a Source of Potassium and its Effect on Soil Properties and Yield of Maize (*Zea mays* L.)

J. VEENA AND A. SATHISH
Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru

A field experiment was carried out to evaluate incineration ash as a source of potassium and its effect on soil properties and yield in K. M. Doddi, Maddur with maize (*Zea mays* L.) as test crop consisting of ten treatments replicated thrice in a RCBD during the year 2019-20 and 2020-21. FYM and PMC (pressmud compost) was used as a source of organic manures and incineration ash (IA) as a source of potassium (12.34 %). The results revealed that significantly higher maize kernel (8,715 kg ha^{-1}) and stover yield (12,050 kg ha^{-1}) was observed in PMC with higher level of IA (125 %) along with recommended dose of N and P (T_{10}) and nutrient uptake of N, P, K, Na, Ca, Mg and S was noticed in the same treatment (T_{10}). The available N content in soil was higher (282.2 kg ha^{-1}) in FYM + 100% NP + 100% K through IA (T_5) and available P_2O_5 (322.6 kg ha^{-1}), K_2O (624.9 kg ha^{-1}), S (65.92 mg kg^{-1}) and Mn (14.77 mg kg^{-1}) in T_{10}. Maximum dehydrogenase, urease and alkaline phosphatase activity was recorded with T_{10} and FYM + 100% NP + 50% K through inorganic + 50% K through IA (T_2). Among the different forms of potassium, significantly higher Exch-K (137.6 mg kg^{-1}) was observed in control plot (T_1) but non-significant difference was recorded for water soluble potassium (WSK). The distribution of potassium fractions was in the order of WSK < exchangeable K < non-exchangeable K < lattice K < total K. The higher agronomic and apparent recovery efficiency of N, P and K with higher profitability (2.82) and value cost ratio (19.84) was recorded in T_{10} and it can be used as a substitute for MOP wherever its availability exists without affecting the maize yield and value cost ratio.

Effect of Soil and Water Conservation on Soil Properties and Preparation of Action Plan for Halayapura-1 Micro-Watershed of Tumkur District Using Remote Sensing and GIS Techniques

J. SAMREEN AND T. CHIKKARAMAPPA
Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru

THE investigation was carried out to evaluate the effect of soil and water conservation on soil properties and to prepare action plan for Halayapura-1 micro-watershed. The area is covering about 503 ha. Surface soil samples were collected at 320 m grid interval for laboratory analysis and the results were compared with the previous study of 2017. The soils of micro-watershed were moderately shallow to very deep, non-gravelly to very gravelly, nearly slope to very gently sloping with sandy loam to clay texture. Conservation practices like mulching, intercropping, FYM application, construction of bunds and conservation structures restored the soil moisture, reduced leaching of nutrients and improved the nutrient levels in the soil. The pH of the soil varied from strongly acidic to strongly alkaline with EC less than 0.99 dS m^{-1}. Soil was low in N, P_2O_5 and sulphur, medium in organic carbon and K_2O with sufficient content of Ca^{2+}, Mg^{2+} and micronutrients. The mean values of soil microbial biomass carbon and nitrogen were 346.50 µg g^{-1} and 40.40 µg g^{-1}, respectively. In comparison with earlier study of 2017, significant variation was observed in P_2O_5, K_2O, Ca^{2+} and Mg^{2+} levels and no significant difference between the means of pH, EC, OC, N, S and micronutrients. Study area was classified under land capability classes II and III and soils were evaluated for the suitability of crops using Arc GIS software. Depending on the constraints of the area, the best action plan was suggested to safeguard the resources for the future.

Design and Development of Phase Change Material (PCM) Based Self Chilling Thermostein for Chilling of Beverages and Liquid Foods

J. Rakshit Reddy and Er. Babu RM Ray
Department of Processing and Food Engineering, College of Agricultural Engineering, UAS, GKVK, Bengaluru

People prefer to drink beverages and liquid foods in chilled state using ice cubes. Ice cubes, prepared using un-hygiene and non-potable water, used for chilling liquids foods pose health risks and reduce taste. Therefore, the present investigation was taken to develop phase change material (PCM) based thermostein for chilling of beverages and liquid foods to replace ice cubes. The module similar to mug with a serving volume of 300 ml was developed using stainless steel 316 material and cooling performance of the thermostein filled with PCM's (DW, PW, DDW, TW, DDW+2 per cent salt and DDW+2 per cent sugar) was evaluated. Temperature profile of PCM inside the thermostein and the sample was monitored during their freezing and cooling. Double distilled water attained -15.8°C in 180 min and cooled the water by 24°C during cooling followed by DDW+2 per cent salt (-11.2°C in 180 min with temperature drop of 2°C). Performance of the thermostein filled with the DW and DW+2 per cent salt was evaluated for cooling lassi, buttermilk, flavoured milk, orange juice, apple juice, soft drink, beer and whisky. The thermostein containing distilled water cooled soft drink with highest temperature drop of about 22°C within ten minutes, followed by DW+2 per cent salt (20.9°C). Chillness of the samples cooled using the thermostein was well above the acceptable sensory score. The developed cooling thermostein is durable, easy to handle and sterilize, simple in design, hygiene and safe to use as compared to ice cubes for cooling beverages and liquids.

FORM IV (See Rule 8)

1.	Name of the Publication	—	The Mysore Journal of Agricultural Sciences
2.	ISSN	—	0047 - 8539
3.	Place of Publication	—	Bengaluru
4.	Periodicity of the Publication	—	Quarterly
5.	Publisher's Name	—	University of Agricultural Sciences GKVK, Bengaluru - 560 065
6.	Editor's Name	—	Dr. K. H. Nagaraj
	Nationality	—	Indian
	Address	—	Editor Communication Centre University of Agricultural Sciences GKVK, Bengaluru - 560 065
7.	Names and addresses of individuals who own the newspaper and partners or shareholders holding more than one per cent of the total capital	—	University of Agricultural Sciences GKVK, Bengaluru - 560 065

I, Dr. K. H. Nagaraj, Editor hereby declare that the particulars given above are true to the best of my knowledge and belief.

Sd/-
Editor

THE MYSORE JOURNAL OF AGRICULTURAL SCIENCES Vol. 57 (1)

UN REGISTERED PARCEL

To

If undelivered please return to :
THE EDITOR
Communication Centre
University of Agricultural Sciences
GKVK, Bengaluru-560 065