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

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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

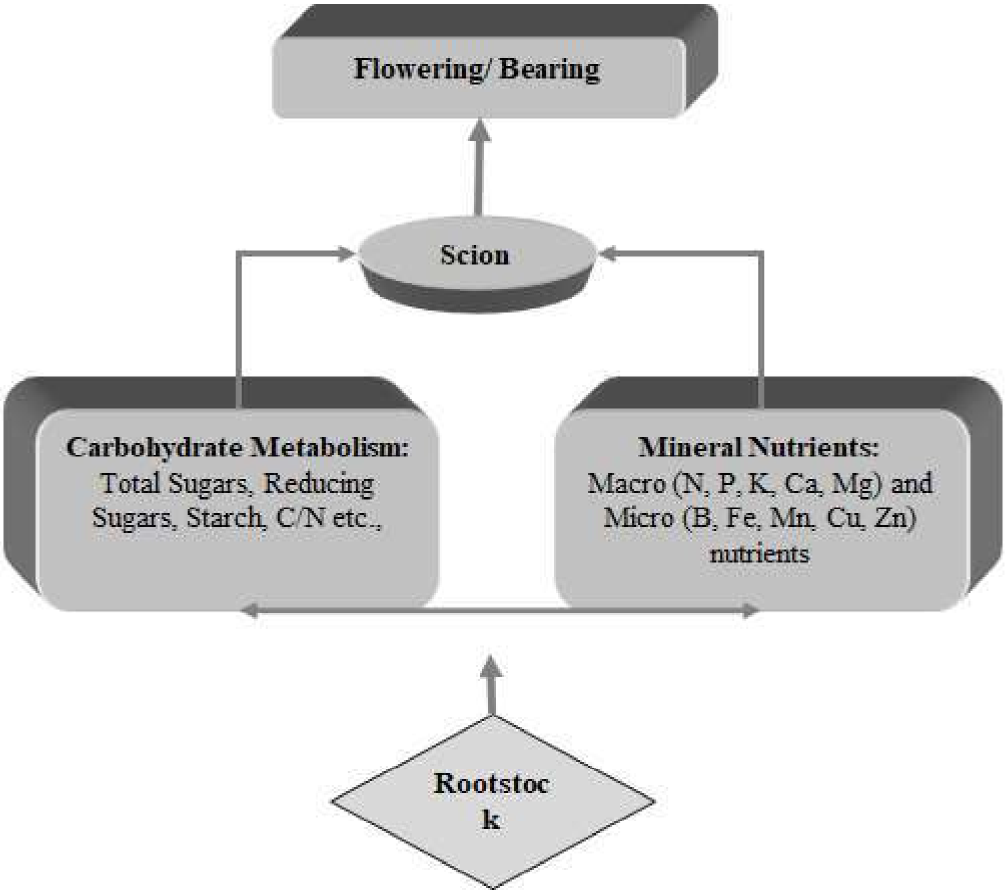

Fig. 1 : Rootstock influence on flowering or bearing habit of fruit crops *via* CHO metabolism and mineral nutrients.

(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 enhancement 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