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Field Evaluation of Gamma Irradiated M_1 Population of Papaya (*Carica papaya* L.) cv. Arka Prabhath

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Abstract

Papaya (*Carica papaya* L.) cv. Arka Prabhath is an advanced generation gynodioecious cultivar developed at ICAR-IIHR, Bengaluru. Seeds of Arka Prabhath were treated with various doses (T_3-50Gy, T_4-100Gy, T_5-150Gy, T_6- 250Gy and T_7-500Gy) of Gamma radiation to study its influence on morphological and quality parameters of papaya along with T_1-control (non-mutagenized Arka Prabhath) and T_2-Red Lady among the M_1 population Highest germination per cent was recorded in T_1 and T_2 (80% and 76%), followed by T_5-75%, T_3-70%, T_4-66%, T_6-39% and no germination (0%) was recorded in T_7. Similarly, T_1 recorded the highest survival per cent (78 %), followed by T_5 (74%). Days taken for first flowering were lowest in T_3 (45 days). Plant height at first flowering was lowest in T_3 (50 cm) which could generate a ultra-dwarf mutant line. Highest trunk circumference was observed in T_6 (23 cm), which can endure wind damage and provides strength to withstand heavy fruit bearing. The fruit yield ranged from 34.86 to 43.04 kg/plant and highest yield recorded in T_4 (87.50 kg/plant). Most irradiated progenies produced fruits with higher weight. M_1 population of papaya cv. Arka Prabhath were selected based on desirable morphological and quality traits and forwarded to M_2 and assigned into different families. Studies revealed that significant variation was observed for morphological and yield parameters among the mutant progenies. Plants with desirable traits were selfed, sib-mated and were forwarded to next generation for breeding purpose. The gynodioecious cv. Arka Prabhath which was found to be a good combiner needs to be fully exploited for the transfer of disease resistant genes from the wild species.

Keywords : Gamma Radiation, Mutation Breeding, Arka Prabhath, Gynodioecious

Papaya (*Carica papaya* L.) is an economically important fruit crop belongs to family *Caricaceae*. It is having commercial importance because of its high nutritive and medicinal value (Azad *et al*., 2012). Papaya fruit is a rich source of vitamin A and C. It is an excellent source of β-carotene which prevents cancer, diabetes and heart disease (Aravind *et al*., 2018). Papaya is the third most cultivated fruit crop in the world and India leads the world in papaya production. It has been successfully cultivated in India, USA, Brazil, Mexico, Nigeria, Jamaica, Indonesia, China, Taiwan & Philippines (Tulsigeri *et al.,* 2017a). Area under papaya in India is around 142.000 Ha and annual production stood at 6011 thousand MT (Anonymous, 2020). In 2020, India produced 43 per cent of the world supply of papayas. In India, it is commercially cultivated large scale in Andhra Pradesh, Gujurat, Maharashtra, Karnataka, West Bengal, Assam, Odisha, Madhya Pradesh, Manipur, Tamil Nadu, Bihar and to a certain extent in Kerala (Granier *et al.,* 2015).

Post-harvest losses are high (40-70%) in papaya mainly due to its high perishable nature which leads

to rapid ripening (short shelf-life) (Kheta Ram Tak and Anitha Peter, 2016) in plants affected by papaya ring spot virus (Kheta Ram Tak and Anitha Peter, 2016). The incidence of PRSV has been reported to be more than 90 per cent in India (Henry *et al.,* 2014). Control measure includes rouging of diseased plants, cultural practices, cross protection and planting of tolerant cultivars (Gonsalves, 1994). But these methods are not successful in developing virus resistant/tolerant cultivars through conventional breeding and it is the only reliable tool for long term control of this disease (Tulsigeri *et al.,* 2017b).

Mutation breeding is one of the approaches to create variability through novel recombination's using both chemical and physical mutagens. Pusananha (mutant dwarf) an ultra-dwarf variety of dioecious nature was developed by ICAR-IARI, New Delhi, through mutation breeding using gamma irradiation. Hence, the same approach can be used for developing gynodioecious types, as there may be a chance of getting a dwarf mutant with tolerance or resistance for Papaya Ring Spot Virus (PRSV) along with good yield, quality and prolonged shelf life. The present study evaluates the effect of gamma irradiation on the growth and yield parameters of papaya.

Material and Methods

The present study was carried out at ICAR - Indian Institute of Horticultural Research (ICAR-IIHR) Station, Hesaraghatta, Bengaluru during 2020-2022. The soil is red sandy loam with a pH 5.2-6.4. The climate of Hesaraghatta, Bengaluru is moderately warm with mild summer months.

Gamma Chamber

Gamma chamber 5000 (Plate 1) installed at the ICAR-IIHR, Bengaluru was used for induction of mutation *via* gamma rays for dry papaya seeds. Specifications of Gamma chamber includes Maximum Co-60 source capacity of 518 TBq (14000 Ci) and having dose rate at maximum capacity of nearly ~9 kGy/hr (0.9 Mega Rad/hr) at the center of sample chamber.

This experiment was carried out using the gynodioecious cultivar Arka Prabhath. It is an advanced generation of hybrid derivative from the cross of (Arka Surya × Tainung-1) × Local Dwarf released from ICAR-IIHR, Benagluru. It is gynodioecious in nature, with large sized fruits of 900-1200g and smooth skin. The pulp is an attractive deep pink color with good keeping quality and high TSS (13-14ºB) (Santhosh *et al.,* 2010). The seeds extracted from fully ripe fruits of papaya cv. 'ArkaPrabhath' obtained by controlled pollination were used for the experiment.

Plate 1 : View of Gamma chamber used for mutation induction in Papaya

Methodology

The seeds of papaya (*Carica papaya* L.) cv. ArkaPrabhath are gamma-irradiation with different doses of gamma rays (Table 1). For seed treatment (100 seeds / treatment) healthy seeds of uniform size were used. These papaya seeds were kept in 0.2 mm thick polyethylene bag sand the sealed bags were

Table 1

Treatment details of gamma irradiation

T1	ArkaPrabhath	(0.0 Gy, control)
T2	Red lady	(0.0 Gy, control)
T3	Gamma-ray (Co^{60})	50 Gy
T4	Gamma-ray (Co^{60})	100 Gy
T5	Gamma-ray (Co^{60})	150 Gy
T6	Gamma-ray (Co^{60})	250 Gy
T7	Gamma-ray (Co^{60})	500 Gy

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exposed to different doses of gamma irradiation, temperature and exposure time of each sample were recorded. Seeds of non-mutagenized and mutagenized Arka Prabhath along with non-mutagenized Red Lady were sown in polyethylene bags in green house condition.

The observations on germination percentage, days taken for germination and survival percentage were recorded among the replications. The count of a number of seeds germinated out of a number of seeds sown was recorded and expressed in percentage (%). Days taken for germination from sowing were recorded. Observations were recorded when 50 per cent of seeds started germinating and expressed in days. A number of seedlings emerged out of a number of seed sown was counted and expressed in percentage.

Transplanting

The seedlings non-mutagenized and mutagenized Arka Prabhath along with non-mutagenized Red Lady were transplanted 45 days after sowing and the following quantitative traits like days taken for first flowering, plant height, trunk circumference, number of nodes and yield (kg/plant) were recorded (Plate 2).

Plate 2 : An overview of experimental field - M_1 population

The number of days taken for first flowering from the date of transplanting in the main field was counted and expressed in days. Total plant height was measured from ground level to the apical meristem of a plant during the first flowering with the help of measuring tape and expressed in centimetre (cm). The trunk circumference was measured 10 cm above ground level using measuring tape at first flowering and expressed in centimeter (cm). The number of nodes on the trunk were counted from ground level up to first flowering and expressed in numbers. The fruit weight of randomly collected individual fruits was recorded and expressed in gram. The fruits were harvested from the tree and weighed and expressed in terms of kg/tree.

Statistical Analysis

The data on germination of seeds, days taken for germination and survival percentage were analyzed using Fisher's method of analysis of variance (ANOVA) as given by Sundarraj *et al.,* 1972. The field observations of M_1 populations were analyzed using descriptive analysis. The observations on Mean, Standard error of mean, Standard Deviation, Minimum value, Maximum value and Co-efficient of Variance (0.05%) were recorded.

Results and Discussion

The experimental results on 'Field Evaluation of Gamma Irradiated M_1 Population of Papaya cv. Arka Prabhath' conducted during 2020-2022. Results include nursery and morphological parameters.

Nursery Parameters

The different nursery parameters like germination percentage, days taken for germination and survival percentage significantly differed among various treatments (Plate 3a).

Plate : 3a. Germinated mutant seedlings and hardening at nursery.

Germination Percentage

The data on germination percentage among different doses of gamma radiation revealed significant difference among the treatments. It ranged from 0 to 80 per cent (Table 2). Highest germination was recorded in T_1-80 and T_2-76 per cent which was found to be significantly superior over other treatments. The

TABLE 2

Effect of gamma radiation on germination, days taken for germination and survival of papaya in M_1 generation

Treatment	Germination (%)	Days taken for germination	Survival (%)
T_1 - Control	80.00	18.00	78.00
T_2 - Red Lady	76.00	23.00	59.00
T_3 - 50 Gy	70.00	20.00 *	68.00
T_4 - 100 Gy	66.00	21.00	64.00
T_5 - 150 Gy	75.00 *	22.00	74.00 *
T_6 - 250 Gy	39.00	24.00	37.00
T_7 - 500 Gy	0.00	0.00	0.00
S.Em ±	2.46	0.54	1.64
CD (p=0.05)	10.08	2.23	7.62
CV (%)	8.93	6.20	6.13

next best treatments were T_5-150Gy (75%) followed by T_3-50Gy (70%) and T_4-100Gy (66%) (Fig. 1). The lowest germination was recorded in T_6-250Gy (39%). The complete lethality was observed in T_7-500Gy gamma rays. Lower per cent of germination was recorded in most of the mutation treated seeds and with increased dose of gamma radiations, similar results were also recorded by Deepa *et al*., 2019; Ramesh *et al*., 2019 and Jayashree *et al.,* 2022.

Days Taken for Germination

Data on days taken for germination recorded among mutagenic treatments revealed significant difference, ranged from 0 to 24 days. T_1 (18 days) and T_2 (23 days) took significantly lower number of days for germination compared to other treatments (Table 2). The next best treatment recorded a smaller number of days was T_3-50Gy irradiated seeds (20 days) which were on par with 100Gy, 150Gy treatments (T_4, 21 days and T_5, 22 days). The treatment T_6-250Gy (24 days) has recorded a greater number of days (Plate 3b).

Plate 3b : Differences in days taken for germination by gamma irradiated seeds

None of the seeds germinated under high dose of gamma radiation T_7-500Gy (Fig. 1). Non-mutagenized seeds recorded early germination as there were no deleterious effects of mutagens on embryo development along with mutagen, followed by soaking of seeds helps in early initiation of germination. These results were in line with observations reported by Deepa *et al*., 2019 and Ramesh *et al*., 2019, as they obtained lesser germination percentage with mutation induced treatments than control.

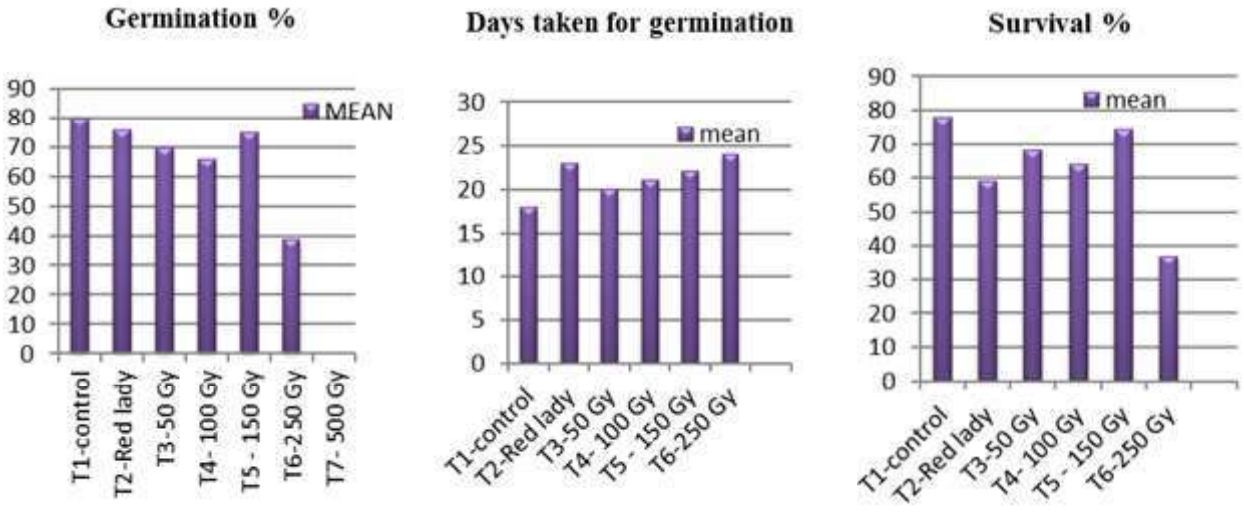

Fig: 1. Graph depicting germination %, days taken for germination and survival %

Survival Percentage

The data on survival per cent recorded among the M_1 progenies also recorded similar trend. Significantly highest survival percentage was recorded in T_1-78 and T_2-59 per cent followed by the T_5-150Gy (74%), T_3-50Gy (68%) and T_4-100Gy (64%) (Table 2). Among the seeds germinated, the lowest survival percentage was recorded in T_6-250Gy (37%) (Fig. 1).

This is probably because of the induction of mutations that results in accumulation of some deletions genes or alleles in the population that may lead to lethality of mutagen treated seedlings. This result in accordance with Deepa *et al*., 2019 and Ramesh *et al*., 2019, their experiments also recorded low survival percentage after induction of mutation.

Morphological Parameters

The results pertaining to morphological parameters such as days to first flowering, plant height, trunk circumference, number of nodes to first flowering and plant yield were recorded among the M_1 progenies of papaya cv. Arka Prabhath.

Days Taken for First Flowering

The data on days taken for first flowering results revealed mean difference among the treatments ranging from 61 to 112 days. Lesser days to first flowering was recorded in T3-50Gy (45 days). Whereas, T1 (non-mutagenized Arka Prabhath) took 167 days longer to first flower (Table 3). The higher error of variance was recorded in T3 treatment (Fig. 2). Days taken for first flowering will help in identification of mutant progenies which can able to bear fruits earlier (Plate 4).

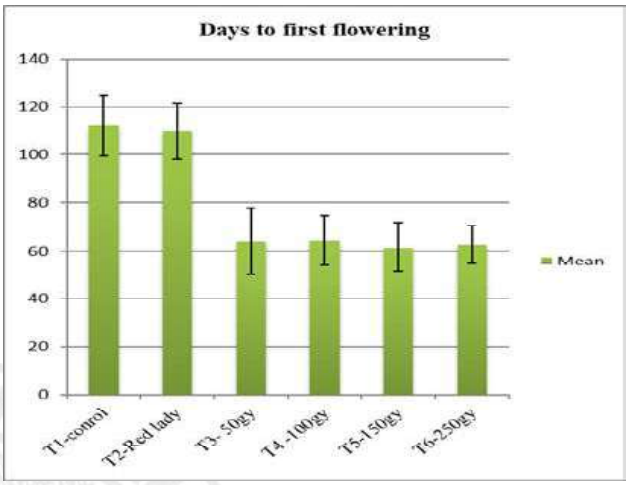

Fig. 2 : Graph depicting days to first flowering among M_1 population.

Plate 4 : Flowering at early stage and fruit set

Early flowering is a good indication for varietal improvement and quality enhancement in papaya. This may due to genetical response of cv. Arka Prabhath.

TABLE 3

Effect of gamma radiation on days to first flowering of papaya in M_1 generation

Treatments	Days to first flowering (No's)					
	Mean	Std. Error	Std. deviation	Min.	Max.	CV (%)
T_1 - Control	112.05	1.88	12.750	80.00	167.00	14.94
T_2 - Red Lady (Control)	109.84	3.46	11.688	80.00	167.00	16.10
T_3 - 50 Gy	63.89	1.25	13.905	45.00	107.00	20.19
T_4 - 100 Gy	64.22	1.13	10.560	46.00	92.00	16.44
T_5 - 150 Gy	61.51	1.21	10.308	46.00	87.00	16.75
T_6 - 250 Gy	62.44	0.93	8.254	49.00	87.00	13.21
T_7 - 500 Gy	00	00	00	00	00	00

This variation can be utilized for breeding purpose, as earlier varieties for flowering which ultimately results in early fruit set. Similar results were obtained by Deepa *et al*., 2019, where they found early flowering with gamma irradiated papaya mutants.

Plant Height at First Flowering (cm)

The data on plant height at first flowering resulted significant difference among the treatments and mean ranged from 101 to135 cm (Table 4). The highest plant height at first flowering was recorded in control $T_1$9190 cm) whereas, lowest plant height at first flowering was observed in treatment T_3 – 50Gy (50 cm) (Table 5). The highest error of variance was observed in mutation induced T_6-250 Gy population (Fig 3).

In papaya, dwarf stature is an important character as crop is prone to wind damage. So, any mutations which can induce dwarfness in plant will be beneficial in breeding dwarf varieties. In this experiment significant lower plant height at first flowering was observed in less doses 50Gy gamma irradiated mutants when compared to other treatments and control population (Plate 5). Similar results were reported by Nhat and Chau, 2010, where plant height at first flowering was 50-60cm by gamma irradiation with lesser dose of 10-60Gy were recorded.

Trunk Circumference (cm)

The data on trunk circumference among the different treated mutant population revealed significant differences, mean values ranged from 13.99 to 19.07 cm (Table 5). The highest trunk circumference was

TABLE 4

Effect of gamma radiation on plant height at first flowering of papaya in M_1 generation

Treatments	Plant Height (cm)					
	Mean	Std. Error	Std. deviation	Min.	Max.	CV (%)
T_1 - Control	102	2.51	22.29	66.00	190.00	21.80
T_2 - Red Lady (Control)	135	1.80	19.17	73.00	107.00	9.61
T_3 - 50 Gy	118	2.34	23.99	50.00	170.00	20.24
T_4 - 100 Gy	101	2.51	23.29	73.00	178.00	19.28
T_5 - 150 Gy	112	2.76	23.38	92.00	175.00	17.74
T_6 - 250 Gy	105	3.27	28.87	68.00	181.00	23.05
T_7 - 500 Gy	00	00	00	00	00	00

TABLE 5

Effect of gamma radiation on trunk circumference of papaya in M_1 generation.

Treatments	Trunk circumference (cm)					
	Mean	Std. Error	Std. deviation	Min.	Max.	CV (%)
T_1 - Control	15.67	0.67	6.00	6.30	30.00	38.31
T_2 - Red Lady (Control)	15.03	0.74	3.82	6.80	20.00	15.26
T_3 - 50 Gy	19.07	0.70	2.68	6.90	21.10	25.15
T_4 - 100 Gy	15.29	1.38	12.84	5.30	20.90	23.98
T_5 - 150 Gy	13.99	0.39	3.39	6.30	22.00	24.23
T_6 - 250 Gy	15.01	0.39	3.48	7.90	23.00	23.18
T_7 - 500 Gy	00	00	00	00	00	00

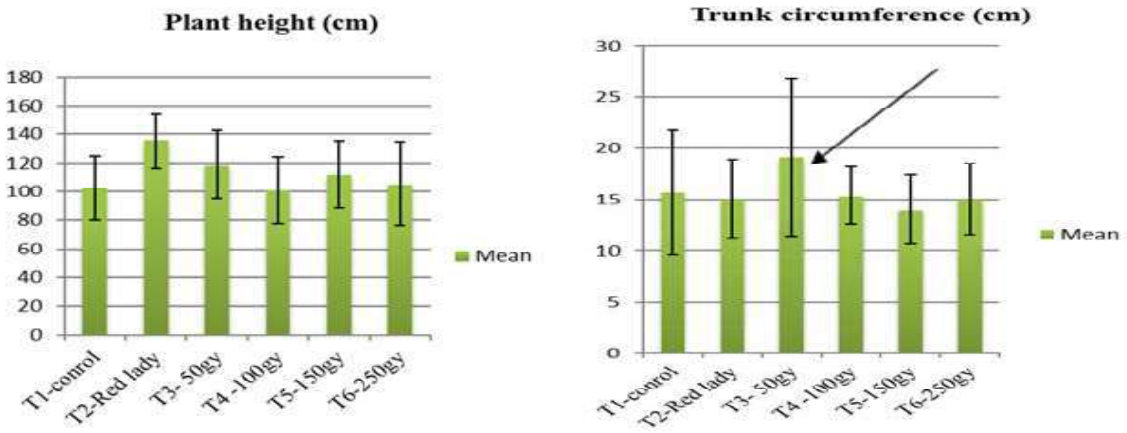

Fig. 3 : Graph depicting days to plant height and trunk circumference among M_1 population

recorded in T_6-250 Gy (23 cm) whereas, lowest trunk circumference was recorded in T_4-100 Gy with 5.3 cm. The highest error of variance was observed in treatment T_3-50 Gy (Fig. 3). Significant differences observed among the treatments and control population.

Plate 5: Ultra dwarf mutant line observed in papaya cv. Arka Prabhath M_1 population

Gamma irradiated plants had reported higher trunk circumference and lower plant height when compared to control plants. This is well known trait as it combines the dwarfness and thicker collar girth to bear and with stand good sized fruits as it is cauliflorous nature in bearing. These results are supported by Veena, 2012, where her experiment also recorded higher trunk circumference in mutation induced population. Similar results with thicker girth and lower plant height to first flowering were observed in gamma irradiated mutants by Deepa *et al*., 2019.

Number of Nodes to First Flowering

The data on number of nodes to first flowering analysis revealed significant difference among the treatments. The mean values ranged from 11 to 21 nodes (Table 6). The more number of nodes to first flowering was recorded in T_2- Red Lady (32) whereas, less number of nodes to first flowering was noted in

TABLE 6

Effect of gamma radiation on number of nodes of papaya in M1 generation

Treatments	No. of nodes					
	Mean	Std. Error	Std. deviation	Min.	Max.	CV (%)
T_1 - Control	13.46	0.46	4.07	8.00	30.00	30.27
T_2 - Red Lady (Control)	21.69	1.03	5.27	8.00	32.00	24.32
T_3 - 50 Gy	12.93	0.26	2.66	6.00	19.00	20.60
T_4 - 100 Gy	13.03	0.24	2.21	7.00	20.00	16.99
T_5 - 150 Gy	11.29	0.37	3.15	6.00	25.00	27.86
T_6 - 250 Gy	12.64	0.29	2.55	8.00	24.00	20.20
T_7 - 500 Gy	00	00	00	00	00	00

TABLE 7

Effect of gamma radiation on yield of papaya in M1 generation.

Treatments	Yield kg/plant					
	Mean	Std. Error	Std. deviation	Min.	Max.	CV (%)
T_1 - Control	34.86	1.51	13.41	13.20	75.00	38.46
T_2 - Red Lady (Control)	43.04	3.51	17.89	18.00	72.00	41.58
T_3 - 50 Gy	38.23	2.62	26.80	18.00	286.00	70.08
T_4 - 100 Gy	37.29	1.76	16.36	15.00	87.50	43.89
T_5 - 150 Gy	36.23	1.59	13.46	15.00	77.00	37.14
T_6 - 250 Gy	39.88	1.92	16.94	14.25	80.00	42.48
T_7 - 500 Gy	00	00	00	00	00	00

gamma radiation induced treatments T3-50Gy and T_5-150 Gy with 6 number of nodes followed by T_4-100Gy with 7 number of nodes at first flowering (Fig. 4). All the gamma radiation induced mutants or treatments showed a smaller number of nodes at first flowering whereas, treatments T_1 and T_2 (Red Lady) showed a greater number of nodes at first flowering. Number of nodes parameter is directly proportional to the plant height. These results were similar with the observations reported by Bharati *et al*., 2011, in which they reported that gamma irradiated mutant progenies exhibited a smaller number of nodes to first flowering.

Plate 6 : Continuous fruit column observed in papaya cv. Arka Prabhath mutant population

Yield (kg/plant)

The data on fruit yield showed difference among treatments mean values ranged from 34.86 to 43.04 kg/plant (Table 7). Highest yield per plant was recorded in T_4-100Gy with 87.50 kg/plant followed by T_3-50Gy with 86 kg/plant, T_6-250Gy with 80kg/ plant. Lowest yield per plant was recorded in T_1 (72 kg/plant) (Plate 6). These observations significantly

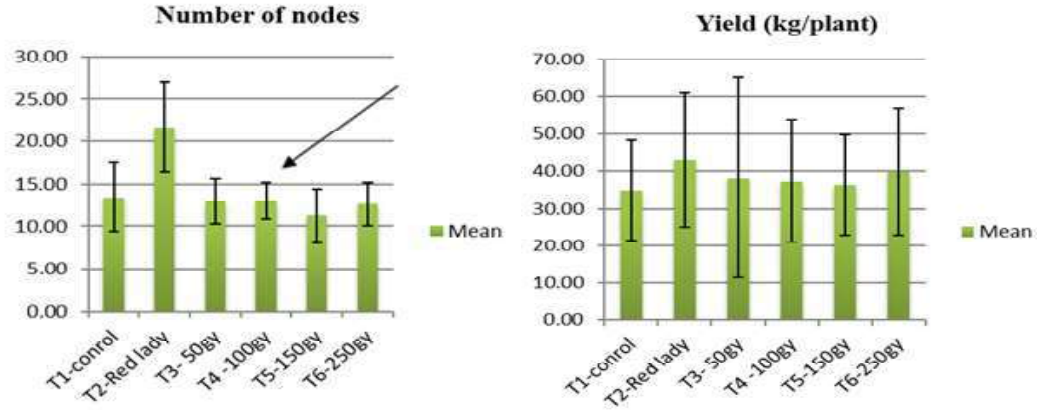

Fig. 4 : Graph depicting number of nodes and yield per plant among M_1 population

TABLE 8

Special Characteristics of selected mutant lines of Papaya cv. ArkaPrabhath in M_1 Generation

Mutant line	Special characters
$R_{12}P_{14}$	Perfect hermaphrodite, continuous fruit column, elongated fruits
$R_{13}P_{19}$	Continuous fruit column, high yielding, dwarf plant
$R_{14}P_{15}$	Dwarf, high yielding
$R_{15}P_{19}$	multiple branching (branches-6)
$R_{16}P_{14}$	High yielding, continuous fruit column, uniform shape of fruits, more seeds per fruit, elongated fruits, good shelf life
$R_{17}P_{18}$	High pulp thickness, high yielding mutant line
$R_{19}P_{14}$	uniform sized fruits, more seeds per fruit, dwarf statured

result revealed that all gamma radiation induced mutants showed higher yield per plant when compared to untreated control population.

Varied yield was recorded among mutant population. The highest error of variance was observed in mutation induced T_3-50Gy and lowest error of variance was recorded in control population (Fig. 4). Apart from control, T_5 showed lowest error of variance among the treated population. So, there might be some direct relation between mutation with yield attribute hence gamma radiation induced population showing higher yield per plant with good fruit size when compared to non-mutagenized control population. These results are in line with the experiments reported by Ramesh *et al.,* 2019, where gamma radiated progenies showed higher yield per plant of 57.90 kg/plant than control population.

Mutation was induced to create variability for plant height, days taken for first flowering, branches, yield and other desirable traits. Studies revealed that significant variation was observed for all characters *viz.,* days taken for first flowering, plant height at first flowering, trunk circumference, number of nodes at first flowering and yield parameters studied among the mutant progenies. Most irradiated progenies produced fruits with higher weight. Different desirable traits were observed among mutant population *viz.,* $R_{12}P_{14}$(100Gy) - perfect hermaphrodite with elongated and continuous fruit column, $R_{13}P_{19}$ and $R_{14}P_{15}$(100Gy) - high yielding and dwarf plant, $R_{15}P_{19}$(150Gy)- multiple branching with 6 branches. $R_{16}P_{14}$ (150Gy) – ultra dwarf mutant line, $R_{17}P_{18}$ and $R_{19}P_{14}$(150Gy) – high yielding with uniformed fruit size and continuous fruit column (Table 8). Plants with desirable traits were selfed, sib-mated and were forwarded to next generation for breeding purpose. The gynodioecious cv. ArkaPrabhath which was found to be a good combiner needs to be fully exploited for the transfer of PRSV resistant genes from the wild species. The desirable mutants identified in this study needs to be further evaluated for morphological and fruit traits, yield attributes, shelf life and PRSV resistance.

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