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Research Article

Effect of Gamma Radiation for Improving Quality in Papaya (*Carica papaya* L.) Cv. Arka Prabhath in M_1 Generation

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ABSTRACT

The papaya Arka Prabhath is an advanced generation gynodioecious cultivar developed at IIHR-Bengaluru. The seeds of this hybrid were treated with various doses (0 Gy, 50 Gy, 100 Gy, 250 Gy, 500 Gy and 750 Gy) of Gamma radiation to study the treatment influence on quality parameters viz., days to flowering, sex type, height to first flowering, trunk circumference, canopy spread, shelf life and yield. The radio sensitivity test on survival (%) among M_1 progenies showed that highest survival per cent was recorded in control treatment (82%) followed by 78% (50 Gy), 74% (100 Gy), 72 % (250 Gy) 28% (500 Gy) and 0 % (750 Gy). The data on days to first flowering recorded among the M_1 progenies revealed significant differences among the treatments, which ranged from 0.00 to 132.00 days. Among the seeds germinated under various treatments, significantly lower number of days (120.00) was recorded in the treatment 500 Gy, which was on par with control recording (122.33 days). Sex type among mutagenic population did not show any significant difference; they segregated as females and hermaphrodites. The data shows number of nodes to first flowering revealed significant difference among the treatments. It was in the range of 0.00 to 7.91 between treatments. Height to first flowering ranged from 0.00 to 90.41cm, trunk circumference ranged from 0.0 to 31.79 cm, canopy spread ranged from 0.00 to 164 cm. The data on fruit yield showed significant difference among treatments, which ranged from 0.00 to 35.52 kg/tree.

Key words: *Papaya, Gamma radiation, Yield, Genomics*

INTRODUCTION

Papaya (*Carica papaya* L.) belongs to the family Caricaceae, is one of the most economically important fruit crops of the tropical and subtropical regions of the world. It has gained commercial importance in recent years, due to its high nutritive value and productivity, varied medicinal and industrial uses, round the year availability, short duration nature and its suitability for the preparation of several value-added products.

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It is also known as paw-paw, papaw, tree melon and fruit of angels. It requires warmth through the year and temperature below 12 to 14^{o} C strongly retards fruit maturation and adversely affects fruit production. An ambient temperature range between 21 to 33^{o} C is ideal. It is a dicotyledonous, polygamous species with three basic sex forms as male (staminate), female (pistillate) and hermaphrodite forms of inflorescence[1]. It is a diploid species with a small genome of 372 Mbp/1C and nine pairs of chromosomes[9]. The area under papaya in India is estimated at 1,36,000 ha and production at 61,08,000 metric tons[2].

In recent years, the most destructive disease of *C. papaya* worldwide is papaya ringspot virus (PRSV) type P, a definitive potyvirus in potyviridae. However resistance to transgenic technology, particularly in Europe has pushed non transgenic method like TILLING (Targeting Induced Local Lesion In Genomics) a powerful reverse genetic strategy[3], that allows the detection of induced point mutations in individuals of the mutagenized populations and can address the major challenge of linking sequence information to the biological function of genes and can also identify novel variation for crop breeding and improving quality and shelf life of the crop species. Mutation breeding is one of the approaches to create variability through novel recombinations using both chemical and physical mutagens. Pusa Nanha (earlier it was named as a mutant dwarf) an ultra-dwarf (60 cm fruit bearing height, 106 cm total plant height) variety of dioecious nature developed by ICAR-IARI, New Delhi, through mutation breeding by 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 PRSV, good yield, quality and shelf life.

MATERIAL AND METHODS

The present investigations "Effect of gamma radiation for Improving Quality in papaya (*Carica papaya* L.) Cv.Arka Prabhath in M_1 generation" was carried out at the ICAR-Indian Institute of Horticultural Research (ICAR-IIHR) station, Bengaluru during 2017-2019. The field and laboratory experiments were carried out at the ICAR- Indian Institute of Horticultural Research, Hessaraghatta lake post, Bengaluru located at 13º 58' North latitude and 78º East longitude and at an altitude of 890 m above mean sea level. The soil is red sandy loam with a pH 5.2-6.4. The climate of Hessaraghatta is moderately warm with mild summer months. The maximum mean temperature ranges from 30.6ºC to 30.7ºC with a mean of 30.65ºC while, the minimum mean temperature ranges from 15.3ºC to 15.5ºC with a mean of 15.4ºC. The mean relative humidity, mean wind speed and total rainfall was 59.41 per cent, 4.38 km/hr and 478.70 mm respectively.

This experiment was carried out using the gynodioecious cultivar like Arka Prabhath. It is an advanced generation hybrid derivative from the cross of (Arka Surya x Tainung-1) x Local Dwarf has released from ICAR- Indian Institute of Horticultural Research. It is gynodioecious in nature, with large sized fruits of 900-1200 g and smooth skin. The pulp is an attractive deep pink colour with good keeping quality and high TSS (13-14˚B). Plant material was collected from the Division of Fruit crops, Indian Institute of Horticultural Research, Bengaluru-560089. The seeds of Arka Prabhath are gamma-irradiated with the 50 Gy, 100 Gy, 250 Gy 500 Gy and 750 Gy Gamma rays and sown the seeds in polyethylene bag in green house. The seedlings were planted 45 days after sowing in RCBD design and the following quantitative traits like plant height at Fruiting, trunk circumference, Canopy spread (E-W), canopy spread (N-S), number of leaf at first flowering, cumber of nodes to first flowering, height to first flowering, yield (Kg/plant) and qualitative traits viz. date of flowering, sex type, type of leaf, type of branch, PRSV at flowering, intensity of PRSV were recorded.

RESULTS AND DISCUSSION

The results of experiments on "Effect of gamma radiation for quality improvement in

papaya (*Carica papaya* L.) Cv. Arka Prabhath in M_1 generation'' carried out during 2017-2019 at the Division of Biotechnology, ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru. Mutagenic work on papaya was carried out using gamma facility provided by Institute are presented here.

Nursery parameters

The different nursery parameters like germination percentage, days taken for germination and survival percentage differed significantly among various treatments which are presented in Table1.

Germination percentage:

The data on germination percentage among different doses of gamma radiation revealed significant difference among the treatments. It ranged from 0.00 to 79.00 per cent. Highest germination was recorded in control treatment (T_1, 79.00 %) which was found to be significantly superior to other treatments. The next best treatments were T_4, 250 Gy (73.00 %) followed by T_2, 50 Gy (68.00 %) and T3, 100 Gy (65.00 %). The lowest germination was recorded in the treatments T_5, 500 Gy (35.00 %), where the higher doses T6, 750 Gy of gamma rays treatments resulted in complete lethality (Table 1). lower per cent of germination was recorded in most of the mutagen treated seeds and with increased dose and concentration of gamma radiations[4].

Days taken for germination

Data on days taken for germination recorded among mutagenic treatments revealed significant difference, which was in the range of 0 to 31 days. Control treatments took significantly lower number of days (T_1, 16 days) compared to other treatments. The next best treatment recorded lower number of days was 50 Gy irradiated seeds (T_2, 26.00) which were on par with 100 Gy, 250 Gy treatments (T_3, 28.00 and T_4, 29.00 days). The treatment T_5, 500 Gy has recorded higher number of days (31.00) .None of the seeds germinated under high dose of gamma radiation (750 Gy) (Table 1). Control treatments which were not treated with any mutagens has 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[5].

Survival (%)

The data on survival (%) recorded among the M_1 progenies also recorded similar trend. Significantly highest survival percentage was recorded in control treatment (T_1, 78.00 %) followed by the treatment T_2:50 Gy (66.00 %), T3:100 Gy (64.00), and T_4:250 Gy (72.00 %). Among the seeds germinated, the lowest survival percentage was recorded in T_5: 500 Gy (26.00). There was no seed germination in T_6:750 Gy (Table 1). This is probably because of the induction of mutations will results in accumulation of some deleterious genes or alleles in population that may lead to lethality of mutagen treated seedlings. This result is in accordance with Bharati, who also recorded low survival percentage after induction of mutation[6].

Table 1: Effect of gamma radiation on germination, days taken for germination and survival of papaya var. Arka Prabhath

Treatments	Germination (%)	Days taken for germination	Survival (%)
T1 Control	79.00	16.00	78.00
T2-50 Gy	68.00	26.00	66.00
T3-100 Gy	65.00	28.00	64.00
T4-250 Gy	73.00	29.00	72.00
T5-500 Gy	35.00	31.00	26.00
T6- 750 Gy	0.00	0.00	0.00

Morphological parameters

The results pertaining to morphological parameters such as days to first flowering, height to first flowering, plant height, trunk circumference, canopy spread (E-W and N-S), number of leaves, number of nodes to first flowering, sex type, type of leaf and branching pattern recorded during first flowering among the M_1 progenies of Arka Prabhath are presented in (Table 2).

Plant height at first flowering (Cms)

The data on height to first flowering revealed significant difference among the treatments and ranged from 0.00 to 90.41 cm. The highest plant height (90.41 cm) was recorded in the treatment T_4: 250 Gy and lowest height to first flowering observed in T_3:100 Gy (73.41cm) which was on par with T_5:500 Gy (75.12 cm). Gamma irradiated plants has recorded significantly higher fruit bearable height compared to other treatments[7].

Trunk circumference (Cms)

Data on trunk circumference among different mutagenic treatments revealed significant differences, which varied from 0.00 to 31.79 cm (Table 2). Significantly superior trunk circumference (31.79cm) was recorded in the treatment T_4: 250 Gy. Fallowed by treatment was T_5: 500 Gy (31.25 cm), which was on par with both control treatments (T_1, 28.04 and T_3, 29.41 cm). Gamma irradiation with 250 Gy has resulted in lower plant height[8], hence it has recorded increased trunk circumference.

Canopy spread (E-W) (Cms)

The data on canopy spread in east to west direction recorded among the progenies revealed a significant difference which was in the range of 0.00 to 110.33 cm (Table 2) (Fig. 3e). Significantly more (110.33 cm) canopy spread was recorded in plants irradiated with gamma radiations of 500 Gy (T_5) compared to other treatments. However, less canopy spread (79.75 cm) was recorded in control treatment (Fig. 3e).

Canopy spread (N-S) (Cms)

The data on canopy spread in north to south direction showed significant differences among the treatments and ranged from 0.00 to 114.58 cm. As recorded in east to west direction, similar trend was noticed here. Significantly more (114.58 cm) canopy spread was recorded in plants irradiated with gamma radiation of 500 Gy (T_5) compared to other treatments. The best treatment was T_3:100 Gy (114.55 cm) However, less canopy spread (82.75 cm) was recorded in control treatment (Fig 3f). The reason behind this might be due to both gamma and EMS are strong mutagens that can act on chromosome resulting in chromosomal aberrations which might have exhibited higher canopy spread than normal canopy[8].

Number of leaves at first flowering

The data on number of leaves at first flowering presented revealed significant difference among the treatments. It ranged from 0.00 to 25.62 between treatments. Highest number of leaves was produced in 250 Gy irradiated plants (T_4, 25.62) which was on par with 500 Gy irradiated plants (T_5, 25.52) and 100 Gy irradiated plants (T_3, 24.91) (Fig 2b).

Number of nodes to first flowering

The data on number of nodes to first flowering presented, revealed significant difference among the treatments. It was in the range of 0.00 to 7.91 between treatments. Significantly highest number of nodes to first flowering (7.91) was recorded in (T_5:500 Gy). However, lowest number of nodes to first flowering (6.04) was recorded in (T_1:100 Gy) irradiated plants (Table 2). However lower number of nodes were recorded in gamma irradiated plants. This result is in contradictory with results of Bharati, recorded higher number of nodes were recorded in gamma irradiated plants (Fig 2 c).

Plant height at fruiting

The data on plant height at fruiting presented, revealed significant difference among the treatments. It was in the range of 0.00 to 143.75 between treatments. Significantly highest plant height at fruiting (143.75) was recorded in (T_4:250 Gy). However, lowest (123.81) was recorded in control plants (Table 2) (Fig 2a).

Yield per tree (kg)

The data on fruit yield showed significant difference among treatments, which ranged

from 0.00 to 35.52 kg/tree (Table 2). The (T_5:500 Gy) plants recorded high yield which was on par with T_4:250 (32.00 kg/tree), followed by the yield at 100 Gy (T_3) 30.9 kg/tree. However, low (23.77 kg/tree) yield was recorded in 50 Gy irradiated plants (T_2). Most irradiated plants produced fruits with higher weight and size. The main reason being deleterious effects of mutagens on yield and yield attributes which was supported by results of Shailendra (Fig 2d).

Seedlings in nursery

Papaya field photo

Variation in leaf

Table 2: Effect of Gamma radiation on morphological characteristics of papaya var.Arka Prabhath in M_1 generation

Treatments	Plant Height at Fruiting (Cms)	Trunk Circumference (Cms)	Canopy spread (E-W) (Cms)	Canopy spread (N-S) (Cms)	Height to first flowering (Cms)	Number of Leaf at first flowering	No. of nodes to first flowering	Yield (Kg/pt)
T1(Control)	123.81	28.04	79.75	82.75	82.73	23.33	7.66	25.60
T2(50Gy)	132.16	28.62	100.66	101.70	84.25	22.45	7.12	23.77
T3(100Gy)	132.79	29.41	104.25	114.55	73.41	24.91	6.04	30.97
T4(250Gy)	143.75	31.79	109.30	105.79	90.41	25.62	6.5	32.08
T5(500Gy)	126.25	31.25	110.33	114.58	75.12	24.52	7.91	35.52
T6 (750 Gy)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEM	0.98	0.21	1.55	1.63	0.74	0.23	0.09	0.61
CD	2.74	0.59	4.34	4.57	2.09	0.65	0.26	1.73
CV	17.84	16.90	36.92	37.74	22.15	23.09	32.41	50.13
Varitaion@5%	S	S	S	S	S	NS	S	S

Papaya fruits with different shelf life (days)

Variation of pulp colour in papaya fruits

Papaya plants showing variation in field

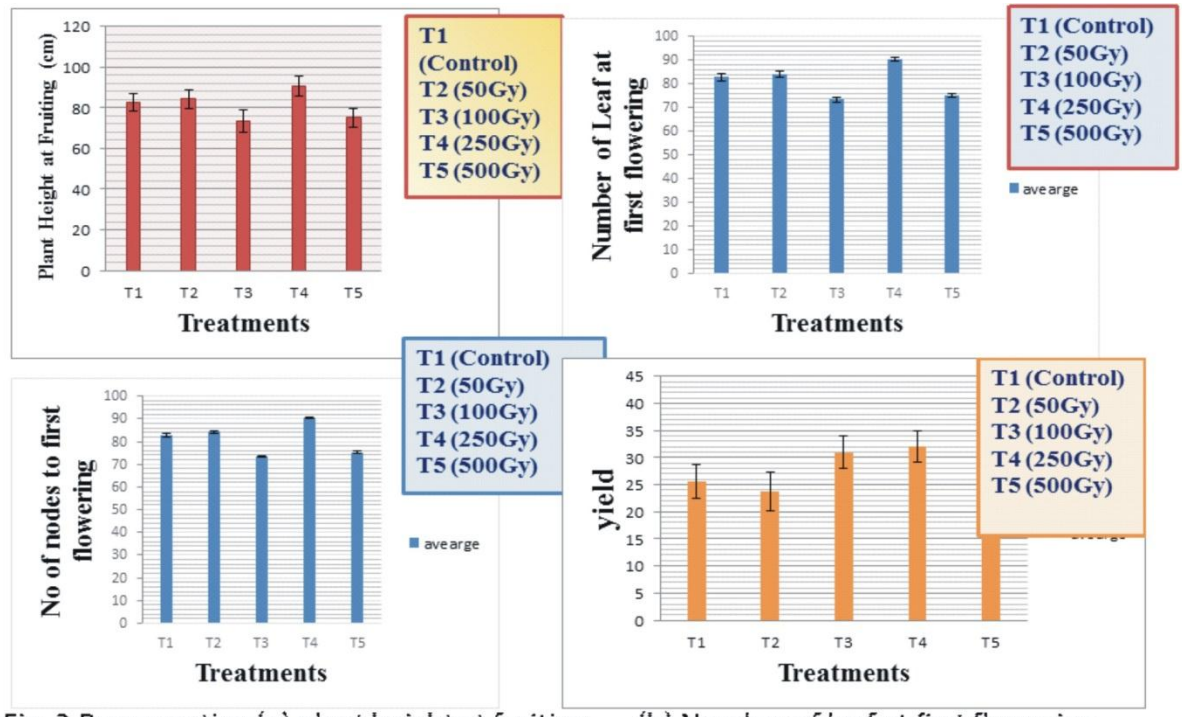

Fig. 2 Representing (a) plant height at fruiting (b) Number of leaf at first flowering (c)Number of nodes to first flowering (d) yield

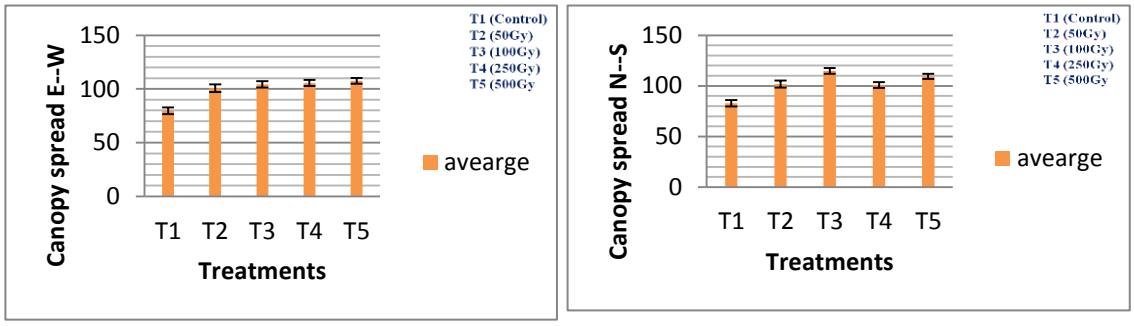

Fig. 3: representing (e) canopy spread E-W . (f) canopy spread N-S direction

Effect of Gamma radiation on sex type and leaf characteristics of papaya var. Arka Prabhath in M1 generation

Plants	T1		T2		T3		T4		T5	
	ST	LT	ST	LT	ST	LT	ST	LT	ST	LT
P1	F	N	F	N	B	N	B	N	B	N
P2	H	N	F	N	B	N	B	N	F	N
P3	F	N	H	N	B	N	B	N	B	N
P4	F	N	H	N	F	N	B	N	B	N
P5	H	N	H	N	B	N	B	N	B	N
P6	H	N	H	N	B	N	B	N	F	N
P7	F	N	F	N	F	N	B	N	B	N
P8	H	N	F	N	B	N	B	N	B	N

P9	F	N	H	N	F	N	B	N	F	N
P10	H	N	H	N	F	N	B	N	B	N
P11	H	N	H	N	B	N	B	N	B	N
P12	H	N	H	N	B	N	B	N	B	N
P13	F	N	F	N	B	N	F	N	B	N
P14	H	N	H	N	F	N	F	N	B	N
P15	H	N	F	N	F	N	F	N	F	N
P16	H	N	F	N	F	N	F	N	B	N
P17	H	N	H	N	B	N	B	N	F	N
P18	H	N	H	N	B	N	B	N	F	N
P19	H	N			B	N	B	N	B	N
P20	F	N	H	N	B	N	B	N	B	N
P21	H	N	F	N	B	N	B	N	B	N
P22	H	N	F	N	B	N	B	N	B	N
P23	H	N	H	N	B	N	F	N	F	N
P24	H	N	H	N	F	N	F	N	F	N

ST- Sex type: F-Female, B- Bisexual
LT-Leaf type: N-Normal leaf, B-Broad leaf

Sex type

Sex type among mutagenic population was not shown any significant difference; they were segregated for female and hermaphroditism (Table 3). Since ArkaPrabhath is a gynodioecious line Since ArkaPrabhath is gynodioeciousline which had segregated for female and hermaphrodite plants. Apart from this there were some abnormalities were recorded like sterile hermaphrodite flowers and some pentandria type hermaphrodites. This might be due to mutagens might have targeted some sex related genes leading to variation in sex forms among mutant populations. This result were in close proximity with Chan.

Type of leaf

The leaf type recorded among the mutagenic population revealed narrow leaved progenies (papaya type) except some which have shown broad leaf (castor type) and some variation with petiole colour and erect growth habit also observed (Table 3). This might be due to with mutations some ancestor genes might have up regulated resulting in production of broad castor type leaves. This is in contradictory with Veena, recorded papaya type leaf among mutant populations.

Type of branching

Branching was observed among mutant populations. Extent of branching was ranged from 2-5 to the main stem (Table 4). This result was in accordance with research findings of Froneman[11], observed higher frequency of branches by gamma irradiation (30-75 Gy).

PRSV incidence

Disease (PRSV) incidence was recorded by scoring technique. The data on PRSV scoring showed that most mutant progenies during M_1 generation have not shown any tolerance or resistance towards PRSV. Even though there was no symptom expression in some of the M_1 progeny but all the progenies after field planting expressed symptoms after 7 months of planting. For most of mutant progenies disease score was ranged from 3-5 indicating susceptibility for PRSV (Table 4). There is a chance of getting resistant or tolerant mutants to PRSV, which was achieved in peppers and tomato for broad spectrum viruses.

Table 4: Effect of Gamma radiation on branching type and PRSV incidence of papaya var. Arka Prabhath in M1 generation

Plants	T1		T2		T3		T4		T5	
	BT	PI	BT	PI	BT	PI	BT	PI	BT	PI
P_1	S	M	S	L	S	L	S	L	S	M
P_2	S	L	S	L	S	M	S	L	B	L
P_3	S	L	S	L	S	M	S	L	S	L
P_4	S	L	S	L	S	L	S	L	S	M
P_5	S	M	S	L	S	M	S	L	B	L
P_6	S	M	S	M	S	L	S	L	S	L
P_7	S	L	S	M	S	L	S	M	S	L
P_8	S	L	S	M	S	M	S	L	S	L
P_9	S	L	S	M	S	L	S	M	S	L
P_{10}	S	M	S	L	S	L	S	M	S	L
P_{11}	S	L	S	L	S	L	S	L	S	L
P_{12}	S	L	S	L	S	L	S	M	S	L
P_{13}	S	L	S	M	B	L	S	L	S	L
P_{14}	S	M	S	M	S	L	B	M	S	L
P_{15}	S	L	S	M	S	M	S	L	B	L
P_{16}	S	L	B	L	S	L	S	L	S	L
P_{17}	S	L	S	L	S	L	S	VL	S	L
P_{18}	S	L	S	L	S	L	S	L	S	L
P_{19}	S	L	S		S	L	S	L	S	L
P_{20}	S	M	S	L	S	M	S	L	S	L
P_{21}	S	M	S	L	S	L	S	L	S	L
P_{22}	S	M	S	L	S	L	S	L	S	L
P_{23}	B	M	S	M	S	L	S	L	S	L
P_{24}	S	S	S	L	S	H	S	L	S	L

BT- Branching type: **S**-single**, B-** Branched, **PI-PRSV intensity**: low and margina

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