Horticultural Science (Prague), 53, 2026 (3): 249–258 *Original Paper*

https://doi.org/10.17221/108/2024-HORTSCI

Determination of LD_{50} and GR_{50} for gamma irradiation in dragon fruit (*Hylocereus* spp.): Comparative study of red and white cultivars

Ganesan Karunakaran[1]*, *Gopavaram Pavithra*[2], *Vangala Sivaramakrishna*[2], *Thandavarajan Sakthivel*[1], *Manivannan Arivalagan*[3], *Duraisamy Kalaivanan*[4], *Anbazhagan Thirugnanavel*[5], *Thimmarayappa Ruchitha*[6], *Kumarswamy Abhilash*[6]

[1]*Division of Fruit Crops, ICAR-Indian Institute of Horticultural Research, Bengaluru, Karnataka, India*
[2]*Department of Fruit Science, Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh, India*
[3]*Division of Basic Sciences, ICAR-Indian Institute of Horticultural Research, Bengaluru, Karnataka, India*
[4]*Division of Soil Science and Agricultural Chemistry, ICAR-Indian Institute of Horticultural Research, Bengaluru, Karnataka, India*
[5]*Division of Fruit Crops, ICAR, Central Citrus Research Institute, Nagpur, Maharashtra, India*
[6]*Department of Fruit Science, University of Horticultural Sciences, Bagalkot, Karnataka, India*

**Corresponding author: avojack2023@gmail.com*

Citation: Karunakaran G., Pavithra G, Sivaramakrishna V., Sakthivel T., Arivalagan M., Kalaivanan D., Thirugnanavel A., Ruchitha T., Abhilash K. (2026): Determination of LD_{50} and GR_{50} for gamma irradiation in dragon fruit (*Hylocereus* spp.): Comparative study of red and white cultivars. Hort. Sci. (Prague), 53: 249–258.

Abstract: Dragon fruit (*Hylocereus* spp.), an exotic vine cactus valued for its vitamin C and antioxidant content, shows limited genetic improvement through conventional breeding, making mutation breeding a promising alternative. The present study assessed the radiosensitivity of two cultivars ('Red' and 'White') using cobalt-60 gamma irradiation at 100–1 000 Gy. Seeds were pre-soaked, irradiated, and evaluated for germination, survival, and growth parameters. Linear regression analysis revealed lethal dose (LD_{50}) values of 674.28 Gy ('Red') and 731.06 Gy ('White'), while growth reduction (GR_{50}) values for seedling height, shoot length, and root length ranged from 653.76–738.22 Gy in 'Red' and 616.08–855.08 Gy in 'White' cultivars. Increasing radiation doses had a significant negative effect on seedling growth and survival. This is the first report on dragon fruit radiosensitivity in India, providing a baseline for mutation breeding. The findings have broad implications for developing cultivars with novel traits, improved resilience, enhanced nutrition, and greater market potential.

Keywords: genetic improvement; radiation sensitivity; mutation; lethal dose; growth reduction

Dragon fruit (*Hylocereus* spp.), also known as pitaya, is a perennial climbing cactus native to Southern Mexico and Central-South America. Owing to its drought tolerance and adaptability to diverse soils, light, and temperatures, its cultivation has spread across tropical and subtropical regions of America, Asia, Australia, and the Middle East (Nie et al. 2015; Mercado-Silva 2018). Species of *Hylocereus* are recognised for their triangular cladodes with aerial roots, large

https://doi.org/10.17221/108/2024-HORTSCI

white flowers, and red fruits (Tel-Zur et al. 2004). The fruit is valued for its vibrant appearance and high nutritional content, being rich in fibre, vitamins, polyphenols, amino acids, phytochemicals, betalains, and unsaturated fatty acids with applications in the pharmaceutical and cosmetic industries (Verona-Ruiz et al. 2020; Al-Mekhlafi et al. 2021). Increasing consumer preference for exotic, phytonutrient-rich fruits has secured its strong position in international markets (De Oliveira et al. 2020).

In India, only red and white cultivars of dragon fruit are commercially grown. Its floral structure often limits self-pollination, causing self-incompatibility and restricting variability through conventional breeding. To enhance the gene pool, nuclear techniques such as mutation breeding can be exploited. Induced mutation, widely practised for decades, promotes genetic recombination and creates variability without affecting consumer or processing requirements (Mahadevamma et al. 2012). Mutagenesis has been used globally to develop fruit crop mutants with traits like dwarfness, early maturity, and pest or disease resistance (Janick, Moore 1996). Effective mutation depends on species, radiation dose, and growth stage, with recovery influenced by plant survivability. Early estimation of lethal dose (LD_{50}) improves the chances of obtaining desirable mutants. In this view, the present study was designed to determine the lethal dose and biological responses as influenced by gamma irradiation for effective mutagenesis induction in dragon fruit cultivars. This is the first systematic attempt to standardise gamma radiation sensitivity in dragon fruit under Indian conditions. The novelty of this work lies in generating baseline LD and growth reduction (GR) values for dragon fruit, which can accelerate mutation breeding efforts. These findings have broader implications for improving the genetic variability, adaptability, and commercial value of dragon fruit, a crop with increasing global demand.

MATERIAL AND METHODS

Experimental site and planting materials. The present research was conducted under laboratory and greenhouse conditions in the controlled environmental facility at Central Horticulture Experimental Station, Hirehalli, Karnataka, India (latitude: 28°38'N, longitude: 77°11'E and altitude: 845 m a.s.l.) during 2020–2021. Freshly extracted seeds of two dragon fruit cultivars *viz*., 'Hirehalli Red' and 'Hirehalli White' were used in this study. These two cultivars were chosen because they are the predominant types cultivated commercially in India, representing the genetic diversity available to growers. Including both cultivars provides comparative insights into radiosensitivity, which can guide breeding efforts more effectively.

Irradiation treatment. Freshly extracted 100 seeds (dry method) of 'Hirehalli White' and 'Hirehalli Red' each were irradiated with varying doses of gamma radiation *viz*., 100, 200, 300, 400, 500, 600, 700, 800, 900, 1 000 Gy with a radioisotope cobalt-60 (^{60}Co) source exposed for a duration of 1 min for every 100 Gy in the gamma chamber at ICAR-Indian Institute of Horticultural Research, Bengaluru, India. The chamber was routinely calibrated with Fricke dosimetry, and the dose rate was maintained to deliver 100 Gy per minute of exposure. For each treatment, seeds were placed in thin, uniformly spread layers in irradiation containers to avoid shielding effects and ensure uniform exposure. The dose uniformity within the chamber was within ±2% as per the instrument specifications, ensuring consistency across treatments.

Experimental design and radiosensitivity test. The experiment was conducted in a greenhouse using a completely randomised design (CRD) with eleven treatments (ten radiation doses and one control), each replicated three times. For each treatment, 100 seeds per replicate were irradiated. Germination, survival percentage, and seedling growth traits were recorded, with growth data taken from 10 randomly selected seedlings per replicate. Seeds of both cultivars were germinated in petri plates (47–98% germination) and transplanted after one month into portrays containing cocopeat and farm yard manure (FYM, 1 : 1), following a uniform protocol to minimise root disturbance. Radiation sensitivity was assessed based on survival percentage, germination (20 and 30 days after sowing; DAS), and determination of LD_{25} and LD_{50} three weeks after germination.

Measurement of plant growth characters. The plant morphological characters like plant height, shoot and root length, seedling fresh and dry weight were recorded at 90 days after sowing. Seed vigour index I and II were estimated based on the formulae proposed by Abdul-Baki and Anderson (1973). The vigour indices show seedling growth and survival

https://doi.org/10.17221/108/2024-HORTSCI

potential. The mean lethal dose (LD_{25} and LD_{50}) was computed through a regression equation from the germination percentage. The seedling vigour indices, germination rate and seedling survival were computed as follows:

$$\text{Seed vigour index I} = \text{seed germination (\%)} \times \text{seedling total length (cm)} \quad (1)$$

$$\text{Seed vigour index II} = \text{seed germination (\%)} \times \text{seedling dry weight (g)} \quad (2)$$

$$\text{Germination percentage (\%)} = \frac{\text{number of germinated seeds}}{\text{total number of treated seeds}} \times 100 \quad (3)$$

$$\text{Survival percentage (\%)} = \frac{\text{number of survived seedlings after germination}}{\text{total number of treated seeds}} \times 100 \quad (4)$$

Statistical analysis. Analysis of variance (ANOVA) was computed for the observations recorded. Significant differences were evaluated at 5% level of significance. Probit analysis was done using USD Polo software (version 2.0, 2016) to determine the relative toxicity of chemicals to living organisms by examining the response of an organism to different levels of gamma radiation. Probit analysis was employed as it provides a robust method for analysing dose–response relationships, particularly in mutation and toxicity studies. Unlike simple linear regression, probit analysis accounts for the cumulative distribution of responses across doses, thereby offering a more precise estimation of LD_{25}, LD_{50}, LD_{75} and GR values. This makes it especially valuable when biological responses are variable and non-linear.

RESULTS AND DISCUSSION

Germination, survival and survival reduction percentage of seedlings in 'Red' and 'White' cultivars of dragon fruit. The germination percentage is a significant trait in a mutagenesis experiment as it indicates the radiation-induced damage to the seed. Results of the present experiment indicated a gradual decrease in germination percentage with a rise in gamma irradiation dose (Table 1). The per cent reduction in germination ranged between 98.00% to 47.68% in 'Red' and 99.50% to 48.63% in 'White' cultivar in control and 1 000 Gy gamma irradiation treatment, respectively. They showed linear trends with an increase in mutagen dose. Highly significant (P < 0.05) results were obtained

Table 1. Germination, survival and survival reduction percentage of dragon fruit cultivars 'Red' and 'White' exposed to gamma radiation

Gamma irradiation doses (Gy)	Germination (%)				Survival (%)				Survival reduction over control (%)			
	Red		White		Red		White		Red		White	
	20 DAS	30 DAS	20 DAS	30 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
0	98.00	98.00	99.50	99.50	98.10	98.10	99.70	99.70	0.00	0.00	0.00	0.00
100	92.39	90.54	94.24	92.35	93.31	91.45	95.18	93.28	4.88	6.78	4.53	6.44
200	83.66	81.98	85.33	83.62	84.49	82.80	86.18	84.46	13.87	15.59	13.56	15.29
300	76.33	74.80	77.86	76.30	77.09	75.55	78.64	77.06	21.41	22.99	21.13	22.71
400	69.50	68.11	70.89	69.47	70.20	68.79	71.60	70.17	28.45	29.88	28.19	29.62
500	56.58	55.45	57.71	56.56	57.15	56.00	58.29	57.12	41.75	42.91	41.53	42.70
600	55.53	54.42	56.64	55.51	56.64	55.51	57.77	56.62	42.26	43.42	42.05	43.21
700	53.43	52.36	54.50	53.41	54.50	53.41	55.59	54.48	44.44	45.56	44.24	45.36
800	51.80	50.76	52.84	51.78	52.84	51.78	53.89	52.81	46.14	47.22	45.95	47.03
900	49.70	48.71	50.69	49.68	50.69	49.68	51.71	50.67	48.32	49.36	48.14	49.17
1 000	48.65	47.68	49.62	48.63	49.62	48.63	50.62	49.60	49.42	50.43	49.23	50.25
SEM	0.40	0.39	0.51	0.50	0.50	0.49	0.56	0.58	0.46	0.46	0.46	0.46
CD@5%	1.19	1.16	1.53	1.49	1.48	1.44	1.66	1.71	1.36	1.36	1.36	1.36
CV	1.03	1.03	1.30	1.30	1.28	1.27	1.40	1.47	2.57	2.47	2.58	2.49

DAS – days after sowing; CD@5% – critical difference @5%; *CV* – coefficient of variation

https://doi.org/10.17221/108/2024-HORTSCI

for survival percentage in both cultivars at 60 days after germination. The survival percentage declined with the increase in gamma radiation dose, which varied from 98.10% (control) to 48.63% (1 000 Gy gamma irradiation) in dragon fruit cv. 'Red', whereas from 99.70 % (control) to 49.62 % (1 000 Gy gamma irradiation) in cv. 'White'. Reduction in survival percentage in comparison with the control ranged from 0 to 50.43% in cv. 'Red' and 0 to 50.25% in cv. 'White' (Table 1).

The dragon fruit cultivars showed a significant response to gamma irradiation dose. Exposure of dragon fruit seeds to gamma radiation at > 100 Gy showed reduction in seedling germination, survival and other growth parameters in M_1 generation as reported by Gunckel and Sparrow (1967). In the present study, maximum reduction in germination per cent was reported in the mutagen dose more than the LD_{50} value, and the dosage above the LD_{50} led to deleterious effects in the plant. These findings are in line with the earlier work reported in Bambara ground nut (Muhammada et al. 2021), acid lime (Kumar et al. 2023) and Tuberose (Sharavani et al. 2019). At greater dose of gamma radiation (> 100 Gy), inhibitory effect on germination was due to negative impact of cytochrome oxidase content affecting cellular respiration (Swaminathan et al. 1962), damage to cell constituents, slower plant growth caused by alteration and rapid degradation of enzymatic activity and interruption in the formation of cellular DNA (Usuf, Nair 1974; Khan, Goyal 2009; Monica, Seetharaman 2016). The survivability would have declined due to its genetic constitution, replication time, moisture content, nature and extent of chromosomal disruption, affecting cellular function or a combination of both and mainly due to ionisation in the nuclei, which leads to cell death.

Determination of LD_{25} and LD_{50} value of gamma irradiation in dragon fruit cultivars. The lethal dose is vital to analyse the LD_{50} value, so that the optimum dose of mutagen responsible for viable mutagens with the least damage to the plant can be identified. The lethal dose or LD_{50} value of gamma irradiation for 'Red' and 'White' cultivars of dragon fruit was estimated through probit analysis on the basis of seed germination recorded at 30 days after sowing. The response curve based on probit units was drawn and presented in Figure 1. Based on the regression equation, gamma irradiation dose and germination percentage of seeds of dragon fruit cultivars showed an inverse relationship. The result of this experiment indicates that the LD_{25} value was 399.33 Gy and 413.64 Gy gamma irradiation for 'Red' and 'White' cultivars, respectively and LD_{50} value was 674.28 Gy and 731.06 Gy gamma irradiation in 'Red' and 'White' cultivars of dragon fruit, respectively.

Choosing the optimum mutagen dose (LD_{50}) is necessary for the induction of mutation and the raising of the M_0 population. The germination percentage of treated seeds gives an initial idea about mutagenic potency. If the percentage

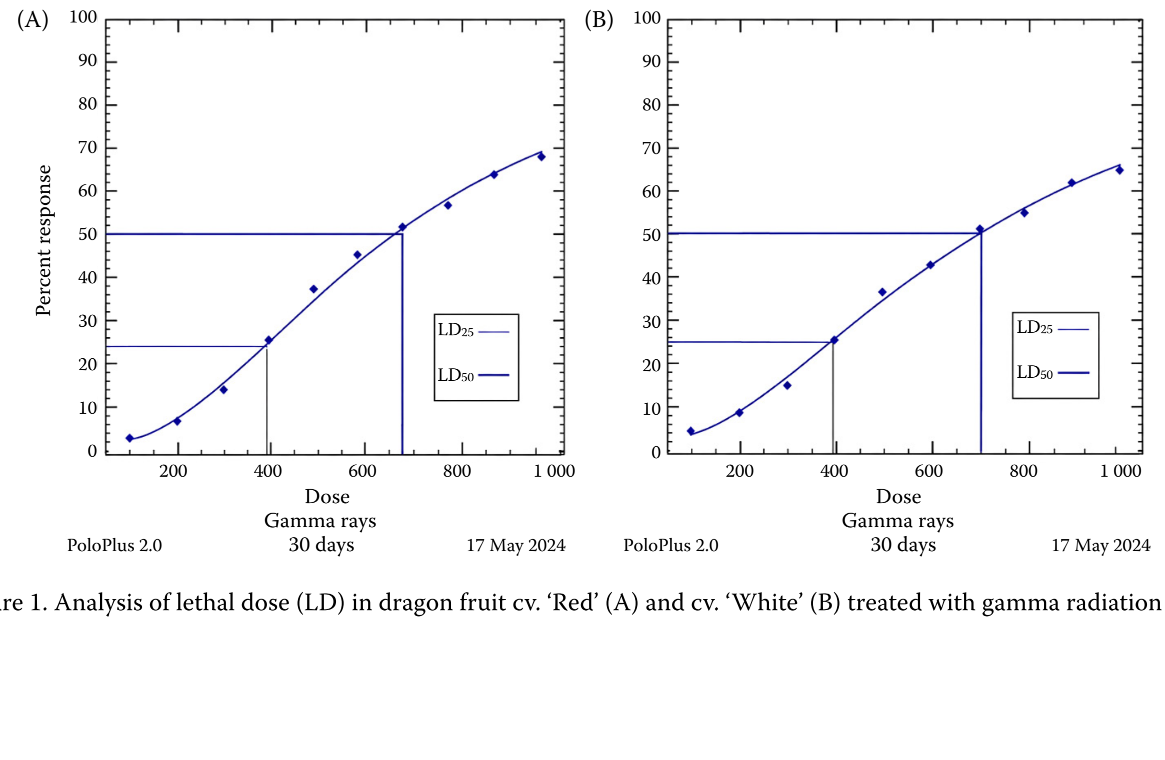

Figure 1. Analysis of lethal dose (LD) in dragon fruit cv. 'Red' (A) and cv. 'White' (B) treated with gamma radiation

https://doi.org/10.17221/108/2024-HORTSCI

Table 2. Consolidated lethal dose (LD) values and growth reduction (GR) values estimates for 'Red' and 'White' cultivars (in Gy)

Parameter	Red	White
LD_{25}	399.33	413.64
LD_{50}	674.28	731.06
GR_{25} (seedling height)	242.63	366.00
GR_{50} (seedling height)	656.27	818.54
GR_{75} (seedling height)	932.28	929.04
GR_{25} (shoot length)	266.24	352.49
GR_{50} (shoot length)	738.22	855.58
GR_{75} (shoot length)	944.22	949.57
GR_{25} (root length)	270.91	374.77
GR_{50} (root length)	653.76	616.08
GR_{75} (root length)	985.79	1 012.76

germination is below 50, it can be considered as lethal. The huge, mutagenised population was raised to screen the viable mutants thereby discarding the undesirable treatments with lower germination percentage to ensure high frequency of mutation. The use of physical and chemical mutagens at the right dosage helps in producing a wide range of variability caused by the mutagenic effect. The LD_{50} value differed for both cultivars, as the lethal dose depends upon the genetic constitution and pedigree of that particular cultivar. The above statement is in conformity with the reports in fruit crops *viz*., papaya (Yadav et al. 2008; Santhosh et al. 2010; Mahadevamma et al. 2012; Sahu et al. 2019), rough lemon (Saini, Gill 2009), acid lime (Devi et al. 2021), pummelo (Sankaran et al. 2021) and grape (Ghasemi-Soloklui et al. 2023).

Table 2 presents the estimated lethal dose (LD) and growth reduction (GR) values for the 'Red' and 'White' dragon fruit cultivars subjected to gamma irradiation. The LD_{25} and LD_{50} values were higher in the 'White' cultivar (413.64 and 731.06 Gy, respectively) than in the 'Red' cultivar (399.33 and 674.28 Gy), indicating comparatively greater tolerance of the 'White' cultivar to gamma irradiation. Similarly, the 'White' cultivar exhibited higher GR_{25} and GR_{50} values for seedling height and shoot length, suggesting reduced sensitivity to irradiation-induced growth inhibition. For root length, the 'White' cultivar showed a higher GR_{25} value, whereas the 'Red' cultivar exhibited a slightly higher GR_{50} value. Overall, the results indicate differential responses of the two cultivars to gamma irradiation, with the 'White' cultivar generally demonstrating greater tolerance than the 'Red' cultivar.

Impact of gamma irradiation on seedling height, shoot length, root length and their growth reduction percentage. The growth parameters of gamma-irradiated seedlings were recorded at 90 days after sowing (Table 3). Seedling height showed a significant difference among all

Table 3. Effect of gamma irradiation on growth parameters of 'Red' and 'White' cultivars of dragon fruit

Gamma irradiation dose (Gy)	Seedling height	Shoot length	Root length
		(cm)	
Red			
0	33.30	15.65	17.65
100	29.88	14.48	15.39
200	27.32	13.71	13.63
300	22.87	11.74	11.13
400	20.41	10.52	9.90
500	8.50	5.13	3.37
600	8.19	5.12	3.07
700	6.42	4.06	2.35
800	5.79	3.73	2.06
900	4.15	2.78	1.37
1 000	3.39	2.31	1.07
SEM	0.29	0.13	0.16
CD@5%	0.85	0.38	0.47
CV%	3.21	2.75	3.71
White			
0	68.83	36.05	32.78
100	64.39	33.96	30.43
200	59.09	31.36	27.72
300	55.36	29.47	25.89
400	52.88	28.30	24.57
500	22.97	13.41	9.55
600	18.62	11.24	7.38
700	16.93	10.35	6.59
800	13.42	8.22	5.21
900	10.10	6.90	3.20
1 000	7.25	5.08	2.18
SEM	0.61	0.31	0.31
CD@5%	1.82	0.91	0.91
CV%	2.99	2.73	3.32

DAS – days after sowing; CD@5% – critical difference @5%; *CV* – coefficient of variation

https://doi.org/10.17221/108/2024-HORTSCI

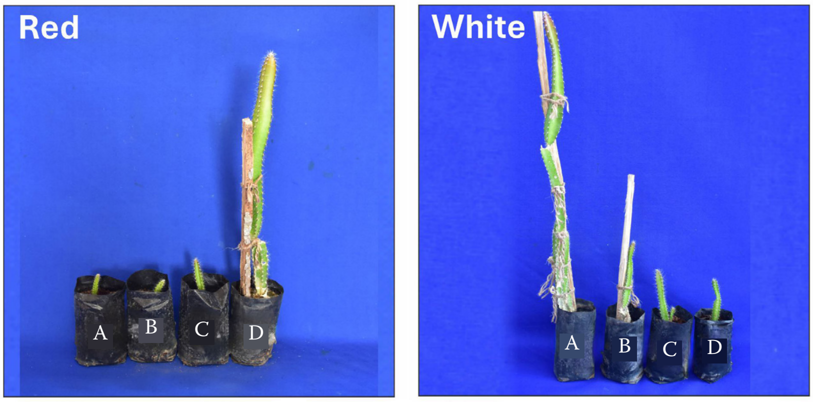

Figure 2. Influence of gamma radiation on seedling height of dragon fruit cv. 'Red' and 'White' at 90 days after germination: Red cultivar 750 Gy (A), 700 Gy (B), 650 Gy (C), control (D); White cultivar: control (A), 750 Gy (B), 700 Gy (C), 650 Gy (D)

Figure 3. Seedlings of gamma irradiated plants showing root length of dragon fruit cv. 'Red' and 'White' at 90 days after germination: Red cultivar 750 Gy (A), 700 Gy (B), 650 Gy (C), control (D); White cultivar 750 Gy (A), 700 Gy (B), 650 Gy (C), control (D)

treatments of gamma irradiation over the control (Figure 2). Seedling height displayed a broad range of variation from 3.39 (1 000 Gy gamma irradiation) to 30.30 cm (control) in cv. 'Red' and 7.25 (1 000 Gy gamma irradiation) to 68.83 cm (control) in cv. 'White'. The data with respect to shoot length showed a significant decline upon an increase in gamma radiation dose. Untreated plants showed a mean seedling height of 15.65 cm in cv. 'Red' and 36.05 cm in cv. 'White', while increasing the dose of gamma radiation to 1 000 Gy gamma irradiation it drastically reduced the length of shoot *i.e.,* 2.31 and 5.08 cm in cv. 'Red' and 'White', respectively. The results unveiled that there was a drastic reduction in root length *i.e.,* from 17.65 to 1.07 cm in cv. 'Red' and 33.78 to 2.18 cm in cv. 'White' at higher gamma irradiation doses (1 000 Gy) when compared with control (Table 3, Figure 3).

A large mutant population was developed through gamma irradiation of dragon fruit planting material and maintained under greenhouse conditions (Figure 4). The population exhibited substantial phenotypic variability in plant vigour, stem growth, branching pattern, and overall morphology, indicating the effectiveness of mutagenesis in generating genetic diversity for selection and crop improvement. The GR in seedlings of the gamma-irradiated dragon fruit cv. 'Red' and 'White' were analysed using a regression equation. It was calculated for 25% (GR_{25}), 50% (GR_{50}) and 75% (GR_{75}) as shown in Figures 5 and 6. From the study, it was clear that the gamma radiation dose had a significant negative effect on dragon fruit by decreasing seedling height, shoot and root length. The GR_{25} value for seedling height, shoot and root length was

Figure 4. Dragon fruit mutant population

https://doi.org/10.17221/108/2024-HORTSCI

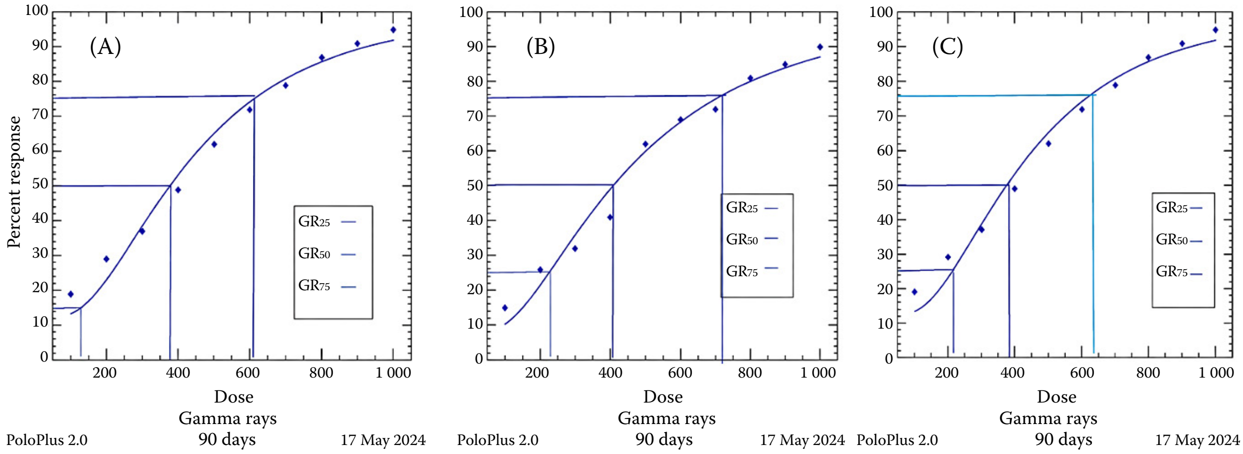

Figure 5. The growth reduction curve showing the negative response of cv. 'Red' at higher dose of different gamma radiation on growth reduction of seedling height (A), shoot length (B), root length in (C)
GR – growth reduction

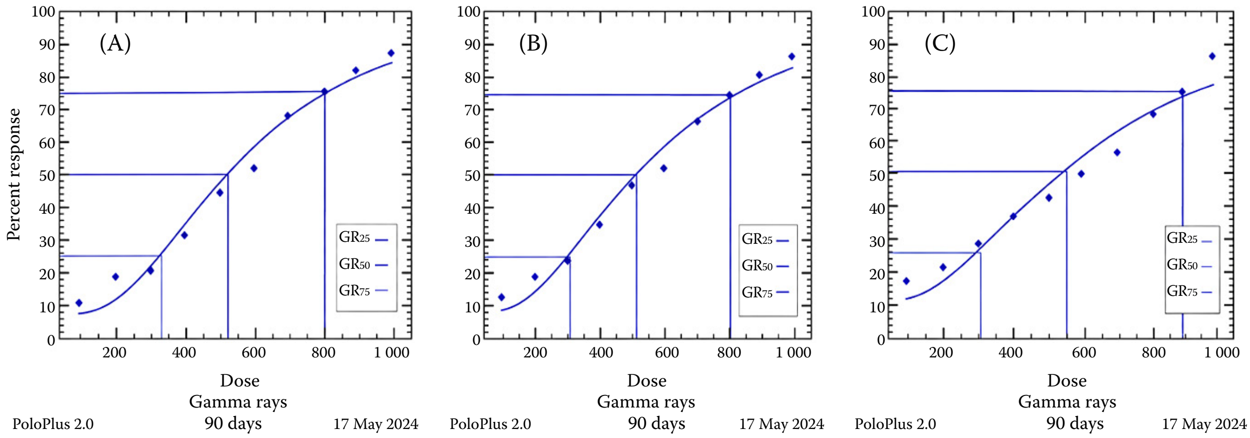

Figure 6. The growth reduction curve showing the negative response of cv. 'White' at higher dose of different gamma radiation on growth reduction of seedling height (A), shoot length (B), root length in (C)
GR – growth reduction

seen in 242.63, 266.24 and 270.91 Gy in cv. 'Red', while 366.00, 352.49 and 374.77 Gy in cv. 'White', respectively.

The GR_{50} value for seedling height, shoot and root length was observed in 656.27, 738.22 and 653.76 Gy in 'Red' cultivars, whereas 818.54, 855.58 and 616.08 Gy in 'White' cultivars. Whereas the GR_{75} values for all the three parameters *viz.*, seedling height, shoot and root length of 'Red' cultivar were 932.28, 944.22 and 985.79 Gy gamma radiation and in 'White' cultivars the GR_{75} was observed in 929.04, 949.57 and 1 012.76 Gy gamma radiation. The observed decline in seedling height, shoot and root length, and biomass is consistent with earlier reports that gamma radiation disrupts normal cellular and physiological processes. Ionising radiation impairs mitotic activity and DNA replication, leading to reduced cell division and elongation (Sato, Gaul 1967). Furthermore, radiation-induced damage to mitochondria and chloroplasts alters energy metabolism and photosynthetic efficiency, thereby lowering seedling vigour and biomass accumulation (Swaminathan et al. 1962; Khan, Goyal 2009). Hormonal imbalance, particularly reduced auxin and gibberellin activity, has also been associated with suppressed shoot elongation and root development (Ananthswamy et al. 1971). Together, these physiological disruptions explain the dose-dependent decline in growth traits observed in both 'Red' and 'White' cultivars.

https://doi.org/10.17221/108/2024-HORTSCI

Table 4. The seedling fresh weight, dry weight and seed vigour index in 'Red' and 'White' cultivars of dragon fruit as influenced by gamma radiation

Gamma irradiation dose (Gy)	Seedling fresh weight (g)		Seedling dry weight (g)		Seed vigour index I		Seed vigour index II	
	Red	White	Red	White	Red	White	Red	White
0	14.03	35.57	6.22	15.77	3 265.85	6 850.31	610.02	1 569.51
100	12.60	33.27	4.95	13.10	2 764.11	6 075.80	457.91	1 236.11
200	11.33	30.53	4.11	11.09	2 288.49	5 048.54	344.28	947.51
300	10.85	28.61	3.50	9.27	1 747.88	4 315.79	267.49	722.68
400	5.54	13.30	0.50	1.19	1 420.29	3 753.41	34.79	84.47
500	4.82	11.87	0.32	0.79	481.54	1 327.28	18.13	45.65
600	4.30	10.09	0.20	0.48	455.37	1 055.97	11.12	27.22
700	3.85	8.75	0.13	0.30	343.46	923.853	6.96	16.37
800	3.11	6.94	0.07	0.24	300.30	710.01	3.63	12.70
900	2.59	6.06	0.06	0.21	206.52	512.617	2.98	10.66
1 000	2.14	4.31	0.05	0.15	165.13	360.2	2.44	7.45
SEM	0.11	0.305	0.06	0.15	51.36	104.76	9.91	24.14
CD@5%	0.33	0.906	0.178	0.46	152.58	311.21	29.43	71.70
CV	2.83	3.069	5.678	5.61	7.28	6.45	10.73	9.83

SEM – standard error of mean; CD@5% – critical difference @5%; *CV* – coefficient of variation

Radiosensitivity responses in 'Red' vs. 'White' cultivars. The observed differences in LD_{50} and GR_{50} values between 'Red' and 'White' cultivars suggest that radiosensitivity is genotype dependent. Such variation has been widely attributed to factors including seed coat thickness, DNA repair efficiency, antioxidant enzyme activity, and metabolic reserves (Nie et al. 2015; Al-Mekhlafi et al. 2021). Cultivars with higher endogenous levels of catalase and peroxidase may better mitigate oxidative stress caused by gamma-induced reactive oxygen species (ROS), while differences in seed coat structure or tissue hydration can influence radiation penetration and damage severity. The 'White' cultivar, which showed relatively higher tolerance at equivalent doses, may possess stronger antioxidative defence or structural attributes conferring partial protection, whereas the 'Red' cultivar exhibited greater sensitivity. These explanations underscore the importance of considering cultivar-specific physiology when optimising mutagenic doses in dragon fruit."

Fresh weight, dry weight of the seedling and seed vigour indices. The data revealed that the reduction in seedling fresh weight with increases in gamma irradiation dosage ranged from 2.14 to 14.03 g in cv. 'Red', 4.31 to 35.57 g in cv. 'White' (Table 4). The dry weight of the seedling showed significant variation, ranging from 0.05 to 6.22 g in cv. 'Red' and 0.15 to 15.77 g in cv. 'White'. In the case of the seed vigour index, the seedling growth and survival potential are considered for depiction. Of the two indices, seed vigour index-I ranged from 165.13 to 3 265.85 in cv. 'Red' and 360.20 to 6 850.31 in cv. 'White'. However, seed vigour index-II ranged from 2.44 to 610.02 in cv. 'Red', while it was 7.45 to 1 569.51 in cv. 'White'. This shows the strong inverse relation of seed vigour indices and mutagen doses.

Fresh weight and dry weight depend on seedling growth and development (Akanbi et al. 2010). Inhibitory effect of gamma radiation on physiological and enzymatic activity showed decline in seedling traits this might be the cause for reduced fresh and dry weight of dragon fruit seedlings when exposed to different doses of gamma radiation. The deleterious effect of gamma radiation at higher doses showed the cultivar's sensitivity to carry out physiological activity that is required for normal growth and development at higher doses of mutagen. These results are in line with the work of other researchers in crops *viz.*, okra (Hegazi, Hamideldin 2010; Hazra et al. 2021),

https://doi.org/10.17221/108/2024-HORTSCI

chick pea (Laskar et al. 2015), mung bean (Wani et al. 2017), lentil (Laskar et al. 2017, 2018), chilli (Aisha et al. 2018) and cow pea (Raina et al. 2018).

CONCLUSION

Each genotype has a distinctive genetic structure, physiological and enzymatic activities that make it respond differently when exposed to a certain mutagen. The study determined the LD_{50} value for gamma radiation in two cultivars of dragon fruit and estimated the optimum dosage of mutagen. The findings of the experiment are in line with the above statement, in which two cultivars of dragon fruit showed different LD_{50} values and growth reduction for seedling parameters upon treatment with varying doses of gamma radiation. The LD_{50} value for the 'Red' cultivar was 674.28 Gy gamma radiation, and for the 'White' cultivar was 731.06 Gy gamma radiation. The hypothesis of the study proved the interaction of a specific cultivar with a mutagen that depicts the chances of achieving viable, unique and favourable mutants with wide genetic variability. The LD_{50} and GR_{50} values determined in this study provide a practical reference for selecting suitable gamma irradiation doses in mutation breeding of dragon fruit. These optimised doses will serve as a framework for future mutant selection and breeding programs, facilitating the development of dragon fruit cultivars with improved agronomic performance, stress tolerance, and novel fruit quality traits." While the present study focused on seeds to determine the LD and GR values of gamma irradiation, it is noteworthy that stem cuttings are the predominant mode of dragon fruit propagation in commercial orchards. Therefore, future studies should explore radiosensitivity and mutation induction in stem cuttings to directly enhance the practical application of mutation breeding in dragon fruit.

Acknowledgements: The authors are much thankful to the Chairman, Department of Fruit Crops, ICAR-IIHR, Bangalore, India, for his guidance and support to carry out this research work.

REFERENCES

Abdul-Baki A.A., Anderson J.D. (1973): Physiological and biochemical deterioration of seed. In: Kozlowski T.T. (ed.): Seed Biology. 2nd Ed., New York, London Academic Press: 283–315.

Aisha A.H., Rafii M.Y., Rahim H.A., Juraimi A.S., Misran A., Yusuff O. (2018): Radio-sensitivity test of acute gamma irradiation of two variety of chili pepper Chili Bangi 3 and Chili Bangi 5. International Journal of Scientific & Technology Research, 7: 90–95.

Akanbi W.B., Togun A.O., Adediran J.A., Ilupeju E.A.O. (2010): Growth, dry matter and fruit yields components of okra under organic and inorganic sources of nutrients. American-Eurasian Journal of Sustainable Agriculture, 4: 1–13.

Al-Mekhlafi N.A., Mediani A., Ismail N.H., Abas F., Dymerski T., Lubinska-Szczygeł M., Verasilp S., Gorinstein S. (2021): Metabolomic and antioxidant properties of different cultivars and origins of Dragon fruit. Microchemical Journal, 160, Part B: 105687.

Ananthaswamy H.N., Vakil U.K., Sreenivasan A. (1971): Biochemical and physiological changes in gamma-irradiated wheat during germination. Radiation Botany, 11: 1–12.

De Oliveira M.M.T., Lu Shuhua, Divya S.K., Zurgil U., Raveh E., Tel Zur N. (2020): Performance of *Hylocereus* (Cactaceae) species and interspecific hybrids under high-temperature stress. Plant Physiology and Biochemistry, 153: 30–39.

Devi D.M., Subesh, Kumar R.C., Rajangam J., Santha S., Sankar C. (2021): Determination of lethal dose (LD_{50}) and effect of physical and chemical mutagenesis in acid lime var. PKM 1. Pharma Innovation Journal, 10: 583–588.

Ghasemi-Soloklui A.A., Kordrostami M., Karimi R. (2023): Determination of optimum dose based of biological responses of lethal dose ($LD_{25,\ 50,\ 75}$) and growth reduction ($GR_{25,\ 50,\ 75}$) in 'Yaghouti' grape due to gamma radiation. Scientific Reports, 13: 2713.

Gunckel J.K., Sparrow A.H. (1967): Ionizing radiations: Biochemical, physiological and morphological aspects of their effects on plants. In: Ruhland W. (ed.): Encyclopaedia of Plant Physiology. Vol. 16., Berlin, Springer-Verlag: 556–611.

Hazra S., Shouvik G., Umesh V., Sudip B., Anirban M., Sanjay J., Nasim A., Arup C. (2021): Optimization of gamma radiation dose for induction of mutations in okra. International Journal of Vegetable Science, 27: 574–584.

Hegazi A.Z., Hamideldin N. (2010): The effect of gamma irradiation on enhancement of growth and seed yield of okra [*Abelmoschus esculentus* (L.) Monech] and associated molecular changes. Journal of Horticulture and Forestry, 2: 38–51.

Janick J., Moore J.N. (1996): Fruit Breeding. Tree and Tropical Fruits. New York, John Wiley & Sons.

https://doi.org/10.17221/108/2024-HORTSCI

Khan S., Goyal S. (2009): Improvement of mung bean cultivars through induced mutations. African Journal of Plant Science, 3: 174–180.

Kumar P., Madhumathi C., Madhavi M., Priya B., Rao M., Kavitha M., Naik E.K. (2023): Mutagenic impacts and LD_{50} determination in acid lime (*Citrus aurantifolia*) Cv. Petlur acid lime. The Pharma Innovation Journal, 12: 661–664.

Laskar R.A., Khan S., Khursheed S., Raina A., Amin R. (2015): Quantitative analysis of induced phenotypic diversity in chickpea using physical and chemical mutagenesis. Journal of Agronomy, 14: 102–111.

Laskar R., Amin R., Khan S. (2017): Evaluation of optimal doses for gamma radiation and hydrazine hydrates in lentil genotypes. BioScience Trends, 10: 5822–5825.

Laskar R.A., Laskar A.A., Rainaa A., Khana S., Younus H. (2018): Induced mutation analysis with biochemical and molecular characterization of high yielding lentil mutant lines. International Journal of Biological Macromolecules., 109: 167–179.

Mahadevamma M., Dinesh M.R., Kumari R.V., Shankarappa T.H. (2012): Evaluation of induced variability in papaya (*Carica papaya* L.) by physical mutagenesis. CIBTech Journal of Biotechnology, 1: 66–71.

Mercado-Silva E.M. (2018): Pitaya – *Hylocereus undatus* (Haw). In: Exotic Fruits Reference Guide. 1st Ed., Mexico, Academic Press: 339–349.

Monica S., Seetharaman N. (2016): Effect of gamma irradiation and ethyl methane sulphonate (EMS) mutagenesis in early generation of garden bean (*Lablab purpureus* L. Sweet var. *typicus*). International Journal of Advanced Science and Research, 6: 2249–2254.

Muhammada I., Mohd Rafii A.C., Muhamad Hazim Nazli C., Shairul I.R., Abdul R.H., Yusuff O. (2021): Determination of lethal (LD) and growth reduction (GR) doses on acute and chronic gamma- irradiated Bambara groundnut [*Vigna subterranea* (L.) Verdc.] cultivars. Journal of Radiation Research and Applied Sciences, 14: 133–145.

Nie Q., Gao G.L., Fan Q., Qiao G., Wen X.P., Liu T., Cai Y.Q. (2015): Isolation and characterization of a catalase gene "HuCAT3" from pitaya (*Hylocereus undatus*) and its expression under abiotic stress. Gene, 563: 63–71.

Raina A., Khursheed S., Khan S. (2018). Optimisation of mutagen doses for gamma radiation and sodium azide in cowpea genotypes. BioScience Trends, 11: 2386–2389.

Sahu P., Dash D.K, Lenka J.S.N., Dash S.N., Tripathy S.K.A., Mishra A., Sahu A. (2019): Standardisation of gamma dose in papaya cv. Ranchi Local and Arka Surya. International Journal of Current Microbiology and Applied Sciences, 8: 361–373.

Saini H.K., Gill M.I.S. (2009): Induction of mutation in Rough lemon (*Citrus jambhiri* Lush.) using gamma radiation. Journal of Horticulture Sciences, 4: 41–44.

Sankaran M., Kalaivanan D., Sunil Gowda D.C. (2021): Studies on mutagenic sensitivity of seeds of pummelo (*Citrus maxima* Merr.). Journal of Horticulture Sciences, 16: 121–124.

Santosh L.C., Dinesh M.R., Rekha A. (2010): Mutagenic studies in papaya (*Carica papaya* L.). Acta Horticulturae., 851: 109–112.

Sato M., Gaul H. (1967): Effect of EMS on fertility in barley. Radiation Botany, 7: 7–10.

Sharavani C.S.R., Kode S.L., Priya B.T., Bharathi T.U., Sekhar M.R., Ruth C., Ramakrishna M. (2019): Standardization of lethal dose of gamma radiation and its effect on flowering and postharvest quality of tuberose. Bulletin of Environment, Pharmacology and Life Sciences, 8: 105–109.

Swaminathan M.S., Chopra V.L., Bhaskaran S. (1962): Chromosome aberrations and the frequency and spectrum of mutations induced by ethyl methane sulphonate in barley and wheat. Indian Journal of Genetics and Plant Breeding, 22: 192–207.

Usuf K.K., Nair P.M. (1974): Effect of gamma irradiation on the indole acetic acid synthesizing system and its significance in sprout inhibition of potatoes. Radiation Botany, 14: 251–256.

Verona-Ruiz A., Urcia-Cerna J., Paucar-Menacho L.M. (2020): Pitahaya (*Hylocereus spp.*): Culture, physicochemical characteristics, nutritional composition, and bioactive compounds. Scientia Agropecuaria, 11: 451–453.

Wani M.R., Dar A.R., Tak A., Amin I., Shah N.H., Rehman R., Baba M.Y., Raina A., Laskar A.R., Kozgar M.I., Khan S. (2017): Chemo-induced pod and seed mutants in mungbean (*Vigna radiata* L. Wilczek). SAARC Journal of Agriculture, 15: 57–67.

Yadav M., Kushwah M.S., Singh D.B., Roshan R.K., Pebam N. (2008): Effect of γ-irradiation on germination, growth, sensitivity and survivability of papaya cv. Kesar King. Journal of Horticultural Sciences, 3: 68–71.

Tel-Zur N., Shahal Abbo, Zvi D.B., Mizrahi Y. (2004): Genetic relationships among *Hylocereus* and *Selenicereus* Vine Cacti (Cactaceae): Evidence from hybridization and cytological studies. Annals of Botany, 94: 527–534.

Received: May 31, 2024
Accepted: December 6, 2025
Published online: September 8, 2026