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Gamma irradiation effect on germination and quantitative traits in M₁ generation of sesame (*Sesamum indicum* L.)

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Abstract

Three sesame (*Sesamum indicum* L.) genotypes namely GT-10, TKG-22, and Gophya Local were irradiated with gamma rays at doses of 400 Gy, 500 Gy, 600 Gy, and 700 Gy at the Bhabha Atomic Research Centre (BARC), Trombay, Mumbai, and grown alongside a control at the experimental farm of the Dept. of Agril. Botany, Dr. PDKV, Akola. The study examined the effects on seed germination percentage and various quantitative traits, such as days to 50% flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, capsule length, number of seeds per capsule, 1000 seed weight (g), and seed yield per plant. Seed germination decreased progressively with increasing gamma ray doses, with a more pronounced effect observed at higher doses in all three genotypes. The LD₅₀ was determined to be at a 500 Gy dose for GT-10 and TKG-22, and at 600 Gy for Gophya Local. The varieties also displayed differential responses to the mutagen treatment, with GT-10 exhibiting greater sensitivity compared to TKG-22 and Gophya Local. In the M₁ generation, all the studied characters were significantly reduced relative to the control, with higher doses causing a more substantial reduction. The results from this study indicate that varying doses of gamma rays can be effectively utilized to induce variability in the crop's quantitative traits.

Keywords: Gamma rays, germination, M₁ generation, quantitative traits, sesame, yield

1. Introduction

Sesame (*Sesamum indicum* L.) is one of the oldest known oilseed crops, domesticated nearly 3,000 years ago, and believed to be the first oil used by humans. It is often referred to as the "Queen of Oilseeds" and is considered an orphan crop due to the limited research attention it receives. However, in the last two decades, the demand for sesame has increased owing to its high-quality oil, rich protein content, antioxidant compounds, and adaptability to extreme climatic and soil conditions (Myient *et al.*, 2020) ^[21].

Sesame oil consists of approximately 85% unsaturated and 15% saturated fatty acids. Among the unsaturated fatty acids, linoleic acid (~46%) and oleic acid (~38%) are predominant, while palmitic acid (~12%) and stearic acid (~4%) make up the saturated portion. The high content of unsaturated fatty acids in sesame oil provides various health benefits and is believed to reduce the risks of cardiovascular diseases, cancer, and damage to the brain and liver. Globally, sesame is consumed in the form of processed oil (65%) and whole grain (35%) (Teklu *et al.*, 2022) ^[36].

Most of the yield improvement efforts in sesame have been carried out using conventional breeding methods by utilizing the natural variability present in the germplasm. However, the available genetic variability is often insufficient to isolate highly desirable genotypes. As a result, the progress in yield improvement through conventional breeding has been limited. In such a situation, induced mutagenesis serves as a valuable alternative or supplement (Brock, 1971) ^[7] to enhance variability in quantitative traits.

At present, plant breeders have access to a wide range of physical and chemical mutagens that can induce genetic variation when applied effectively. Among these, physical mutagens such as ionizing radiation have been frequently and successfully used to create variability in several crop species, including sesame (Saha and Paul, 2017) ^[32]. Mutation breeding has proven to be a useful technique for generating new and additional variation in both qualitative and quantitative

traits. In this context, the present investigation was conducted to study the effect of gamma irradiation on quantitative traits to induce variability in three sesame genotypes, namely GT-10, TKG-22, and Gophya Local.

2. Materials and Methods

The experimental material used in the present investigation included three sesame genotypes, namely GT-10, TKG-22, and Gophya Local. Dry, uniform seeds of all three varieties were exposed to gamma radiation doses of 400Gy, 500Gy, 600Gy, and 700Gy at the Bhabha Atomic Research Centre (BARC), Trombay, Mumbai. Untreated seeds of each variety were maintained as control. The treated and control seeds were sown in a field experiment laid out in a Randomized Block Design (RBD) with five replications. Row-to-row and plant-to-plant spacing of 30 cm and 10 cm, respectively was maintained. All recommended agronomic practices and plant protection measures were followed uniformly across all treatments. The objective of this study was to assess the impact of gamma irradiation on seed germination (%) and a range of quantitative traits in the M_1 generation, including days to 50% flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, capsule length, number of seeds per capsule, 1000-seed weight (g), and seed yield per plant.

3. Results and Discussion

Physical mutagens can induce various types of alterations in biological materials during the M_1 generation, such as physiological injury, point mutations, and chromosomal aberrations. According to Gaul (1970) [11], the extent of biological damage may serve as an indicator of the mutagenic effect. The impact of gamma rays on germination percentage at doses ranging from 400Gy to 700Gy in the three sesame genotypes (GT-10, TKG-22, and Gophya Local) is presented in Table 1. Similarly, the effects of gamma irradiation on quantitative traits such as days to 50% flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, capsule length, number of seeds per capsule, 1000-seed weight (g), and seed yield per plant were studied for all the radiation treatments. The results for these traits are shown in Tables 2, 3, and 4 for genotypes GT-10, TKG-22, and Gophya Local, respectively.

3.1 Effect of different doses of gamma rays on germination in M_1 generation

The effect of various doses of gamma rays on germination in the M_1 generation is shown in Table 1. The data indicated that germination under laboratory conditions was reduced at all gamma ray doses in the GT-10, TKG-22, and Gophya Local genotypes compared to their respective controls. The greatest reduction in laboratory germination for genotype GT-10 was recorded at the 700Gy dose (28.40%), followed by 600Gy (37.80%), 500Gy (55.40%), and 400Gy (73.00%) compared to its control (92.80%). In genotype TKG-22, the maximum reduction was seen at 700Gy (30.20%), then 600Gy (44.00%), 500Gy (53.60%), and 400Gy (76.80%) compared to its control (94.80%). For genotype Gophya Local, the highest reduction was at 700Gy (33.80%), followed by 600Gy (51.40%), 500Gy (61.60%), and 400Gy (76.40%) compared to its control (93.40%). Under field conditions, the lowest germination in genotype GT-10 was recorded at 700Gy (26.65%), followed by 600Gy (35.82%), 500Gy (53.57%), and 400Gy (71.18%) compared to its control (90.43%). For TKG-22, the maximum reduction in field germination was observed at 700Gy (28.12%),

then 600Gy (42.02%), 500Gy (51.10%), and 400Gy (74.73%) compared to its control (92.73%). In Gophya Local, the highest reduction was at 700Gy (30.28%), followed by 600Gy (49.10%), 500Gy (59.33%), and 400Gy (73.88%) compared to its control (90.33%). The LD_{50} was found at 500Gy dose for GT-10 and TKG-22 genotypes, and at 600Gy dose for Gophya Local genotype.

In this study, the effects of gamma rays on germination in the M_1 generation of three sesame genotypes were recorded, showing that germination percentage decreased with increasing doses in all genotypes tested. Raja Ramadoss *et al.*, (2014) [27] reported similar results of reduced germination with higher gamma ray doses in sesame. The genotype GT-10 showed 55.40% germination at 500Gy, TKG-22 showed 53.60% at 500Gy, and Gophya Local showed 51.40% at 600Gy, indicating that LD_{50} was reached at 500Gy for GT-10 and TKG-22 and at 600Gy for Gophya Local. These findings align with previous studies such as Kumari *et al.* (2016) [19] who recorded LD_{50} between 450-600Gy for LKT-4 sesame variety; Uttarde *et al.* (2020) [37] at 500Gy; Ganesan (2001) [10] at 500Gy; Parthsarathi *et al.*, (2020) [22] at approximately 417Gy for TMV7 and 389Gy for SVPR1 sesame varieties; and Boureima *et al.*, (2009) [6] who determined LD_{50} at 550Gy for cultivar “32-15” and 740Gy for cultivar “38-1-7”.

The LD_{50} for Gophya Local genotype (600Gy) was higher than that of GT-10 and TKG-22 (500Gy). Although TKG-22 and Gophya Local are both white-seeded sesame, their responses to gamma ray mutagenesis varied. Different genotypes of the same crop often show varying LD_{50} values, as reported by Sandhiya *et al.*, (2020) [33] in sesame and Ramchandrar *et al.*, (2015) [28] in rice.

Seed germination percentage decreased progressively with increasing mutagen doses, with more notable reductions at higher doses across all three genotypes. This reduction may be due to cellular-level disturbances (physiological or physical), including chromosomal damage or a combination of these effects (Khan and Tyagi, 2010) [17]. Varietal differences in response to mutagen treatment were observed, with GT-10 showing higher sensitivity than TKG-22 and Gophya Local. Such differential responses could be attributed to the genotypic background and the degree of selection pressure experienced by the cultivars during evolution (Julia *et al.*, 2022) [15]. According to Chrispeds and Varner (1967) [8], seed germination reduction may result from delays or inhibition in physiological and biological processes essential for germination, hormonal imbalance (Ananthaswamy *et al.*, 1971) [1], or inhibition of mitosis (Sato and Gaul, 1967) [35].

3.2 Effect of different doses of gamma rays on quantitative traits of sesame genotypes in M_1 generation

Significant differences were observed in all quantitative traits studied in the M_1 generation of the three sesame genotypes (GT-10, TKG-22, and Gophya Local). Mean values for these traits are presented in Table 2 (GT-10), Table 3 (TKG-22), and Table 4 (Gophya Local).

The maximum days to 50% flowering were recorded at 700Gy dose for all three genotypes, indicating delayed flowering compared to controls. These results are consistent with previous reports by Prabhakar (1985) [25], Rahman and Das (1989) [26], Ganesan (1995) [9], Govindarasu (1995) [13], Boureima *et al.*, (2009) [5], Saha and Paul (2017) [32], RajaRamadoss *et al.*, (2014) [27], and Ravichandran and Jayakumar (2018) [30]. Gamma rays caused delayed flowering regardless of dose in cowpea (Girija and Dhanavel, 2013) [12] and black gram (Yasmin *et al.*, 2016)

[41].

All three genotypes exhibited delayed maturity at all gamma ray doses compared to controls, similar to observations by Saha and Paul (2017) [32].

Plant height decreased with increasing gamma ray doses in GT-10, TKG-22, and Gophya Local, with maximum reduction at 700Gy. Similar findings were reported by Boureima *et al.*, (2009) [5], RajaRamadoss *et al.*, (2014) [27], Anbarasan *et al.*, (2015) [2], and Ravichandran and Jayakumar (2018) [30] in sesame, Girija and Dhanavel (2013) [12] in cowpea, and Pepol and Pepo (1989) [23] in soybean. Plant height reduction may result from chromosomal damage affecting cell division and elongation (Walther, 1969) [40]. Negative shifts in mean plant height after mutagen treatment have been attributed to deleterious mutations occurring more frequently than beneficial ones (Virupakshappa *et al.*, 1980) [39].

The number of branches per plant declined with higher gamma ray doses in all genotypes, with the highest dose (700Gy) having the strongest effect. This reduction may be due to mutagen toxicity affecting physiological parameters. Possible causes include auxin destruction (Rizwana *et al.*, 2005) [31]; Ravichandran *et al.*, 2014 [29], impaired assimilatory functions, mitotic inhibition, and chromosomal damage with associated physiological changes (Saha and Paul, 2017) [32].

A decreasing trend was also observed for the number of capsules per plant in the M₁ generation. The 700Gy dose caused the greatest reduction across genotypes. RajaRamadoss *et al.*, (2014) [27] reported similar reductions in capsules per plant in sesame genotype TTVS-51 after gamma ray treatment. This reduction may be related to enzyme inhibition, changes in enzyme activity, or toxic effects of mutagens. Differential responses to gamma rays for this trait have been noted by Anbarasan *et al.*, (2015) [2]. Capsule length decreased gradually with increasing gamma

radiation doses in all genotypes, possibly due to physiological disturbances or genetic damage such as disrupted chromosomal coiling or pairing.

The number of seeds per capsule also declined progressively with higher gamma radiation doses in all genotypes. Capsule traits including number of capsules per plant, capsule length, and seeds per capsule were all dose-dependently reduced. The highest gamma ray dose had the most significant impact, while the lowest dose (400Gy) showed effects similar to the control. Similar results have been reported by RajaRamadoss *et al.*, (2014) [27], Ravichandra and Jayakumar (2018) [30], and in other crops such as safflower (Mallik Arjunaradhay, 1978) [20], bhendi (Sasi, 2004) [34], and cluster bean (Velu *et al.*, 2007) [38].

The 1000 seed weight was notably reduced at the highest gamma ray dose compared to lower doses, which showed comparable effects. This reduction with increased gamma ray doses in M₁ generation has been reported by RajaRamadoss *et al.*, (2014) [27], Ariharasutharsan *et al.*, (2022) [4] in sesame, Gunasekaran and Padavai (2015) [14] in peanut, and Girija and Dhanavel (2013) [12] in cowpea.

Seed yield per plant declined with increasing gamma ray doses across all genotypes. This is consistent with findings by Anbarasan *et al.*, (2014) [3], RajaRamadoss *et al.*, (2014) [27], Ravichandran and Jayakumar (2018) [30], and Ariharasutharsana *et al.*, (2022) [4] in sesame, and also reported in green gram (Koteswara Rao *et al.*, 1983) [18] and soybean (Kalpande *et al.*, 2020) [16].

The reduction in seed yield caused by mutagens may be attributed to increased seed sterility due to physiological and biochemical disruptions during seed development (Prabhakaran, 1992) [24]. The yield decline might also be an indirect effect of altered yield-contributing components (RajaRamadoss *et al.*, 2014) [27].

Table 1: Effect of different doses of Gamma rays on germination in M₁ generation of sesame genotypes

Genotypes	Doses	Seed Germination (Laboratory %)	Seed Germination (Field %)
GT-10	400Gy	73.00	71.18
	500Gy	55.40	53.57
	600Gy	37.80	35.82
	700Gy	28.40	26.65
	Control	92.80	90.43
TKG-22	400Gy	76.80	74.73
	500Gy	53.60	51.10
	600Gy	44.00	42.02
	700Gy	30.20	28.12
	Control	94.80	92.73
Gophya Local	400Gy	76.40	73.88
	500Gy	61.60	59.33
	600Gy	51.40	49.10
	700Gy	33.80	30.28
	Control	93.40	90.33

Table 2: Mean performances of the genotype GT-10 for various quantitative traits in M₁ generation

Genotype	Doses	Days to 50% flowering	Days to maturity	Plant height (cm)	No. branches / plant	No. of capsules/ plant	Capsule length (cm)	No. of seeds / capsule	1000 seed weight (g)	Seed yield / plant (g)
GT-10	400Gy	48.00	95.20	91.40	3.30	50.10	2.06	42	2.53	4.30
	500Gy	49.20	96.20	87.80	3.15	44.08	1.95	39	2.46	3.92
	600Gy	51.40	99.00	82.60	2.96	41.20	1.88	37	2.42	3.57
	700Gy	52.20	101.80	79.60	2.68	36.00	1.77	35	2.28	2.28
	Control	44.60	92.00	101.00	4.10	56.48	2.10	48	2.60	4.81
	SE (m)	0.92	1.65	4.34	0.18	2.87	0.06	2.13	0.03	0.24
	CD @ 5%	2.76	4.95	13.00	0.54	8.60	0.19	6.38	0.10	0.73
	C.V. %	4.19	3.81	10.96	12.34	14.07	7.30	11.73	3.09	14.34

Table 3: Mean performances of the genotype TKG-22 for various quantitative traits in M₁ generation

Genotype	Doses	Days to 50% flowering	Days to maturity	Plant height (cm)	No. branches / plant	No. of capsules/ plant	Capsule length (cm)	No. of seeds / capsule	1000 seed weight (g)	Seed yield / plant (g)
TKG-22	400Gy	45.40	84.60	89.80	3.68	36.40	2.25	48	2.84	4.90
	500Gy	46.60	86.60	86.40	3.26	33.80	2.08	44	2.69	4.67
	600Gy	47.60	89.60	81.40	2.98	29.40	1.88	39	2.54	4.29
	700Gy	49.80	93.40	71.40	2.42	22.20	1.72	34	2.44	3.43
	Control	42.40	83.20	97.60	3.92	42.36	2.39	53	2.90	5.38
	SE (m)	0.81	1.28	3.89	0.21	1.96	0.06	2.17	0.05	0.33
	CD @ 5%	2.43	3.84	11.66	0.64	5.87	0.18	6.5	0.14	0.99
	C.V. %	3.91	3.27	10.19	14.70	13.33	6.40	11.13	3.89	16.26

Table 4: Mean performances of the genotype Gophya Local for various quantitative traits in M₁ generation

Genotype	Doses	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of capsules / plant	Capsule length (cm)	No. of seeds / capsule	1000 seed weight (g)	Seed yield / plant (g)
Gophya Local	400Gy	52.40	104.60	106.20	38.36	2.24	42.76	2.65	4.47
	500Gy	54.60	105.40	100.80	34.36	2.11	39.64	2.58	4.24
	600Gy	55.80	109.40	96.00	29.04	1.94	35.28	2.47	3.86
	700Gy	59.40	112.00	90.40	21.60	1.78	32.88	2.39	3.24
	Control	50.40	102.20	110.00	41.52	2.31	45.32	2.83	4.93
	SE (m)	1.11	1.48	4.08	1.54	0.07	1.96	0.04	0.28
	CD @ 5%	3.31	4.43	12.24	4.6	0.21	5.87	0.13	0.85
	C.V. %	4.53	3.10	9.07	10.41	7.6	11.17	3.65	15.34

4. Conclusion

In this study, seed germination percentage decreased progressively with increasing gamma ray doses, with a more significant reduction at higher doses. Similarly, all quantitative traits showed considerable reduction compared to controls, decreasing proportionally with higher gamma ray doses across the three sesame genotypes. The lowest dose of gamma rays had effects comparable to controls, while the highest dose significantly reduced quantitative traits. The reduction in these traits is likely due to physiological disturbances or chromosomal damage induced by gamma rays in plant cells. These results suggest that varying doses of gamma rays can be effectively used to induce variability in several quantitative traits of sesame.

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