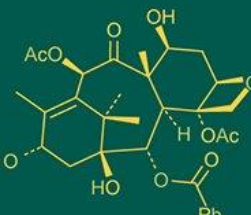
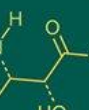
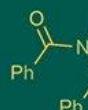
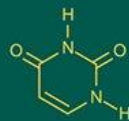


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Study of induced mutagenesis of gamma rays, EMS and their combinations in M₁ generations of Soybean [*Glycine max* (L.) Merr.]

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Abstract

Soybean [*Glycine max* (L.) Merr.] is a vital legume crop valued for its high protein and oil content. However, its genetic improvement is limited due to self-pollination and low natural variability. The present study evaluated the mutagenic effects of gamma rays, Ethyl Methane Sulphonate (EMS) and their combinations on two prominent soybean varieties, GJS 3 and G.Soy 4, to induce genetic variability. Treatments included two doses of gamma rays (30 kR and 40 kR), two concentrations of EMS (0.3% and 0.4%) and two combinations (15 kR + 0.1% EMS and 20 kR + 0.2% EMS). Seeds were sown in a Randomized Block Design (RBD) during summer 2023 to raise the M₁ generation. Observations on germination percentage, survival percentage, days to first flowering, days to maturity, plant height, sterile plant and biological damage *i.e.*, lethality and injury were recorded. Results indicated a dose-dependent decline in germination and survival percentage, delayed maturity, reduced plant height and increased rates of biological damage and sterile plants. Combination treatment of both mutagens exhibited the most pronounced effects, with 20 kR gamma rays + 0.2% EMS inducing the highest biological damage. While EMS alone caused more pronounced effects than gamma rays, combination treatments proved most effective in inducing significant mutagenic effects. The study highlights the potential of induced mutagenesis in creating genetic variability and provides a foundation for future soybean breeding programs aimed at trait improvement.

Keywords: Soybean, mutation, gamma rays, EMS

Introduction

Legume crops, especially soybean [*Glycine max* (L.) Merr.], play a vital role in human nutrition, sustainable agriculture and industry due to their high protein, oil and mineral content. It is widely consumed in vegetarian diets, especially in India, where a large portion of the population depends on plant-based proteins. On a dry weight basis, soybean seeds usually have an oil content of 20% (Baria *et al.*, 2022) [2]. Different glycerolipids, mainly phospholipids, diacylglycerol and triacylglycerol are found in crude oil (Wilson, 2004) [18]. Soybeans are rich in essential amino acids like lysine, fatty acids, fibers and phytosterols, making them ideal for both human consumption and livestock feed. Soybean cultivation is prominent in countries like Brazil, USA, Argentina, China and India. In India major soybean producing states are Madhya Pradesh, Maharashtra and Gujarat. Due to its widespread usage as a key component in a wide range of diets, feeds and industrial products, soybean demand is continuing to rise. However, despite its high potential, genetic improvement in soybean is challenging due to its self-pollinating nature and limited natural variability. Traditional hybridization methods are tedious and often ineffective due to the delicate floral structure and high flower shedding. To overcome these challenges, induced mutagenesis through chemical and physical mutagens offers a promising alternative for creating genetic variability (Bhatnagar and Tiwari, 1991) [3]. These mutagens can efficiently introduce desirable traits without compromising the adaptability and yield of existing cultivars. Gamma rays and EMS are well-documented for their effectiveness in inducing mutations across a wide range of crops. This study aims to explore the diverse response of widely cultivated soybean varieties, GJS 3 and G. Soy 4, to different chemical and physical mutagens.

Material and Method

The present investigation was carried out at the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh during the summer 2023 for M1 generations. The promising soybean varieties namely GJS 3 and G.Soy 4 were obtained from Agricultural Research Station, Junagadh Agricultural University, Amreli (Gujarat). Both of these varieties are extensively cultivated in Gujarat state. Two mutagenic agents were used, physical mutagen viz., gamma rays (ionizing radiation) as well as chemical mutagen viz., Ethyl Methane Sulphonate (EMS). Three hundred seed of both the variety were treated with two doses of gamma rays (30 kR and 40 kR), two concentrations of EMS (0.3% and 0.4%) as well as two combination treatments of gamma rays and EMS (15 kR gamma rays + 0.1% EMS and 20 kR gamma rays + 0.2% EMS). The pure and healthy dried seeds of the two soybean varieties were treated with gamma ray at Bhabha Atomic Research Centre, Trombay, Mumbai (Maharashtra). Treated seeds with different doses of gamma rays, EMS and their combinations along with their respective controls were sown in Randomized Block Design (RBD) with three replications each containing one hundred seeds to raise the M1 generation. Seeds were sown by keeping a distance of 45 cm between rows and 10 cm within a row. The recommended agronomic practices and plant protection measures were followed uniformly for all the treatments at appropriate stages during the entire crop growth period. Both Treated, as well as untreated control plant were carefully monitored from the day of emergence for growth parameters, including Germination percentage, Survival percentage, Days to first flowering, Days to maturity, Plant height (cm), Biological damage and the percentage of sterile plants to assess the mutagenic sensitivity of genotypes to different mutagen treatments. The observations recorded on various characters in M1 generation were analyzed according to Randomized Block Design (RBD) separately for variety GJS 3 and G.Soy 4 along with ANOVA as per the procedure given by Panse and Sukhatme (1995). Based on critical differences, the significance of the treatment effect was estimated [9].

Results and Discussions

Germination percentage

The percentage of seed germination reduced progressively with the increasing dose or concentration of mutagen and a greater reduction was observed at higher dose in both varieties of soybean, GJS 3 and G.Soy 4. The highest germination per cent was recorded in control 88.67% and 86.00% in variety GJS 3 and G.Soy 4, respectively but within the mutagenic treatments the germination per cent ranged from 36.33 to 55.33% in variety GJS 3 and 32.67 to 53.67% in variety G.Soy 4. Among the mutagenic treatments the lowest germination per cent was recorded by the treatment 20 kR gamma rays + 0.2% EMS and the highest was recorded by 30 kR gamma rays in both the varieties. The differences in germination percentage between varieties GJS 3 and G.Soy 4 were found to be negligible by different mutagenic treatments. The response of varieties GJS 3 and G.Soy 4 for gamma rays, EMS and their combination treatments in relation to germination percentage are presented in Table 1 and Figure 1.

The reduction in germination may be due to genetic and physiological processes inhibited by mutagens resulting in lethality. The increased lethality with the higher concentration observed in all the treatments may be due to the

action of mutagens interfering with seed metabolic processes. The combination treatment of gamma rays and EMS showed the maximum reduction in germination in both varieties of soybean as compared with gamma rays and EMS. Seed germination reduction was more pronounced with EMS than gamma rays, likely due to altered cell metabolism during pre-soaking, which reduced respiration and enzyme activity needed for normal germination. The reduction in seed germination due to the action of mutagens has been also reported by Kavithamani et al. (2008), Pavadai (2015) and Patil and Wakode, (2011) in soybean [7, 12, 13].

Survival percentage: An inverse relationship exists between the concentration of mutagens and plant survival. In the present investigation increase in doses or concentrations of gamma rays, EMS and combination treatment reduces the percentage of plant survival at maturity in both varieties of soybean, GJS 3 and G.Soy 4. The highest survival per cent was recorded in control 97.73% and 98.44% in variety GJS 3 and G.Soy 4, respectively but within the mutagenic treatments the survival per cent ranged from 74.22 to 80.46% in variety GJS 3 and 70.50 to 83.64% in variety G.Soy 4. Among the mutagenic treatments, 30 kR gamma rays resulted in the highest survival percentage. The results of various mutagenic treatments indicate that there is no more difference in the survival percentage between the GJS 3 and G.Soy 4 varieties. The effect of physical (gamma rays), chemical (EMS) mutagens and their combination treatments in M1 generation on the percentage of survival in field is presented in Table 1 and Figure 2.

The present results confirm these earlier reports in soybean by karthika and Lakshmi (2006). The enhanced lethality values at higher doses or concentrations of different mutagens have been attributed to the injuries generated by the physiological imbalance or chromosomal aberrations (Nilan et al., 1965) [6, 9].

Days to first flowering

All the mutagenic treatments showed higher or slightly more days to first flowering in both treated soybean varieties as compared to control. The days to first flowering increased considerably with increasing doses of mutagens. The lowest days to first flowering was observed in the control 33.00 and 35.33 in variety GJS 3 and G.Soy 4, respectively. In terms of mutagenic treatments, it was found that variety GJS 3 had a range of 34.00 to 38.00 days, while variety G.Soy 4 had a range of 36.00 to 42.33 days. Among the mutagenic treatments the lowest days to first flowering was recorded by the treatment 30 kR gamma rays and the highest was recorded by 20 kR gamma rays + 0.2% EMS in both the varieties. Combination treatment of gamma rays + EMS increased maximum days to first flowering in both varieties. With respect to varieties, higher days to first flowering were recorded in G.Soy 4 (38.24) as compare to GJS 3 (35.38). The response of varieties GJS 3 and G.Soy 4 for gamma rays, EMS and their combination treatments in relation to days to first flowering is presented in Table 1 and and Figure 3.

The higher dose of gamma rays affected the physiological process, which leads to induce late flowering. Physiological disproportion and different forms of chromosomal distortion could be the leading causes of the late flowering. The present results confirm the earlier reports in soybean by Dhole et al. (2003) [4].

Days to maturity: Days to maturity generally increased with an increase in the doses of all mutagenic treatments. In overall, mean performance of most of the mutated populations for days to maturity showed significant increase over their respective control in M1 generation. The lowest days to maturity was observed in control 100.00 and 103.67 in variety GJS 3 and G.Soy 4, respectively. In mutagenic treatments days to maturity ranged from 104.67 to 113.67 days in variety GJS 3 and 105.00 to 114.67 days in variety G.Soy 4. Within mutagenic treatments, highest days to maturity was found in 40 kR gamma rays treatment in GJS 3 and 20 kR gamma rays + 0.2% EMS treatment in G.Soy 4, while it was found lowest in 0.3% EMS treatment. Regarding the different varieties, higher days to maturity were noted in G.Soy 4 (109.29) as compare to GJS 3 (107.48). The data pertaining to effect of mutagen treatment on days to maturity are presented in Table 1 and Figure 4.

The features like early flowering and early maturity have always been considered important aims in the breeding of almost all crop plants. The earliness gets attained chiefly due to rapid growth taking place during the early stage of ontogeny and due to floral development at a very low position on the stem. Similar results were also reported by Aditya et al. (2017) in soybean [1].

Plant height: The differences between the treatments for plant height were statistically significant in both varieties but none of the treatment was found to be effective in increasing the plant height as compared to the control. Reduction of plant height was found more with increased doses of mutagens in both varieties. The maximum plant height was recorded in control 24.60 cm and 26.63 cm in variety GJS 3 and G.Soy 4, respectively. The plant height varied between 17.61 and 22.19 cm in GJS 3 variety, while it ranged from 19.41 to 23.91 cm in G.Soy 4 variety. Minimum reduction in plant height was observed in 0.3% EMS, while highest reduction in plant height was found in 20 kR gamma rays + 0.2% EMS in GJS 3 and in 40 kR gamma rays in G.Soy 4. The results obtained for plant height at maturity in M1 generation of both the varieties are presented in Table 1 and Figure 5.

Reduction in plant height after mutagenic treatment was evidenced from the reports of Karthika and Lakshmi (2006) [6] in soybean. Witherspoon and Corney (1970) [19] reported considerable meristem mortality, reduction in height and weight of seedlings after mutagenic treatments with beta and gamma rays, fast neutrons in soybean seeds.

While studying the effects of radiation on meristematic cells, Evans and Sparrow (1961) [5] concluded that the growth reduction is due to cumulative expression of mitotic cycle delays, formation of chromosomal structural changes and loss of proliferation capacity due to either premature differentiation or cell death.

Biological damage

Lethality: In case of lethality percentage, all mutagenic treatment showed huge increment in lethality in both varieties. In both varieties lethality percentage was computed as a decrease in plant survival at maturity. It was found increasing parallel with an increase in doses or concentrations of mutagens. The highest lethality per cent was observed in 20 kR gamma rays + 0.2% EMS (68.46% in GJS 3 and 72.83% in G.Soy 4) while, lowest lethality was observed in

30 kR gamma rays (48.46% in GJS 3 and 46.85% in G.Soy 4). Data with respect to lethality per cent are displayed in Table 2 and Figure 6.

The increased lethality with the higher concentration observed in all the treatments may be due to the action of mutagens interfering with seed metabolic processes. Similar result was reported by Kavithamani et al. (2008) and Rajdekar and Sakhare (2021) [7] in soybean. Nilan et al. (1965) [9] proposed that prime cause of lethality is physiological imbalances or different types of chromosomal aberrations. Damage in genetic material may be one of the prime causes.

Injury

In terms of injury percentage, all mutagenic treatment showed high increment in injury in both varieties. Injury per cent was recorded by reduction in plant height over control. It was found increasing parallel with an increase in doses or concentrations of mutagenic treatments. For variety GJS 3, highest injury percentage was observed in 20 kR gamma rays + 0.2% EMS (28.41%). Similar scenario was also observed in case of lethality percentage. Lowest injury per cent was observed in 0.3% EMS (9.80%). In variety G.Soy 4, highest injury per cent was observed in 40 kR gamma rays (27.12%) and lowest injury per cent was observed in 0.3% EMS (10.20%). Results with respect to injury per cent are displayed in Table 2 and Figure 7.

Similar results were reported by Kavithamani et al. (2008), Pavadai et al. (2009) and Rajdekar and Sakhare (2021) in soybean. The reduction in plant height may be ascribed to different factors. Kouser et al. (2007) believed that reduction in plant height or seedling growth with higher doses of Sodium azide, may be due to gross injury caused at the cellular level either due to gene controlled biochemical process or acute chromosomal aberration or both [7, 8, 14].

Sterile plants: The sterile mutants were derived from both physical and chemical mutagen (gamma rays and EMS) and their combinations treated populations of GJS 3 and G.Soy 4. At the time of harvest, the number of sterile plants without any pod was recorded. The data on sterile plants showed that percentage of sterile plants varied between varieties and mutagenic treatments. The percentage of sterile plants was found highest in 20 kR gamma rays + 0.2% EMS (8.54%) where it was observed lowest in 0.3% EMS (2.50%) in case of GJS 3. While, in G.Soy 4 the percentage of sterile plants was highest in the doses of the 40 kR gamma ray, (8.25%) where as it was observed lowest in 0.3% EMS (1.59%). While studying percentage of sterile plants, it was observed that sterility showed the linear increase as the doses or concentrations increased in both the varieties GJS 3 and G.Soy 4. Similar results were reported by Karthika and Lakshmi (2006), Kavithamani et al. (2008) and Satpute and Faltambkar (2012) in soybean. Details of the plants harvested, the total number of sterile plants observed and their percentage in different mutagenic treatments with respect to both the varieties are given in Table 3 and Figure 8 [6, 7, 16].

According to Nilan et al. (1965) [9], the gross injury due to gene controlled biochemical processes or acute chromosomal aberrations or both may be the reasons for sterility. Sudhakaran (1971) [17] has concluded that sterility might represent the cumulative result of aberrant meiotic stages, physiological and genic damage induced by breakage of chromosomes through fragmentation caused by the production of antimetabolic agents in cell.

Table 1: Effect of mutagenic treatments on different characters of Soybean varieties GJS 3 and G.Soy 4 in M₁ generation

Treatments	Germination percentage		Survival percentage		Days to first flowering		Days to maturity		Plant height	
	GJS 3	G.Soy 4	GJS 3	G.Soy 4	GJS 3	G.Soy 4	GJS 3	G.Soy 4	GJS 3	G.Soy 4
30 kR gamma rays	55.33	53.67	80.46	83.64	34.00	36.00	109.67	109.33	21.57	22.50
40 kR gamma rays	43.33	44.00	74.56	73.42	35.33	38.00	113.67	111.67	19.89	19.41
0.3% EMS	50.33	51.67	79.51	81.32	34.67	38.00	104.67	105.00	22.19	23.91
0.4% EMS	37.33	40.67	74.22	74.74	36.00	39.67	107.00	108.00	18.57	21.39
15 kR gamma rays + 0.1% EMS	47.00	45.33	77.77	71.97	36.67	38.33	107.67	112.67	20.25	21.71
20 kR gamma rays + 0.2% EMS	36.33	32.67	75.39	70.50	38.00	42.33	109.67	114.67	17.61	19.65
Control	88.67	86.00	97.73	98.44	33.00	35.33	100.00	103.67	24.60	26.63
Mean	51.19	50.57	79.95	79.15	35.38	38.24	107.48	109.29	20.67	22.17
S.Em ±	2.51	2.73	3.80	3.00	0.65	0.55	1.43	2.08	0.97	0.80
CD at 5%	7.72	8.42	11.71	9.24	2.01	1.69	4.40	6.40	2.98	2.46
CV%	8.48	9.36	8.23	6.56	3.19	2.49	2.30	3.29	8.09	6.24

Table 2: Lethality and Injury percentage induced by mutagen treatment in M₁ generation.

Treatments	Total plants studied in M ₁ generation	Survival reduction Lethality (%)	Plant height (cm)	Height reduction over control: Injury (%)
GJS 3				
30 kR gamma rays	134	48.46	21.57	12.34
40 kR gamma rays	96	63.08	19.89	19.14
0.3% EMS	120	53.85	22.19	9.80
0.4% EMS	83	68.08	18.57	24.51
15 kR gamma rays + 0.1% EMS	110	57.69	20.25	17.69
20 kR gamma rays + 0.2% EMS	82	68.46	17.61	28.41
Control	260	--	24.60	--
G.Soy 4				
30 kR gamma rays	135	46.85	22.50	15.51
40 kR gamma rays	97	61.81	19.41	27.12
0.3% EMS	126	50.39	23.91	10.20
0.4% EMS	90	64.57	21.39	19.68
15 kR gamma rays + 0.1% EMS	97	61.81	21.71	18.45
20 kR gamma rays + 0.2% EMS	69	72.83	19.65	26.20
Control	254	--	26.63	--

Table 3: Percentage of sterile plants in M₁ generation of soybean

Treatment	Total plant harvested	Number of sterile plants	Sterility (%)
GJS 3			
30 kR gamma rays	134	6	4.48
40 kR gamma rays	96	7	7.29
0.3% EMS	120	3	2.50
0.4% EMS	83	5	6.02
15 kR gamma rays + 0.1% EMS	110	5	4.55
20 kR gamma rays + 0.2% EMS	82	7	8.54
Control	260	--	--
G.Soy 4			
30 kR gamma rays	135	5	3.70
40 kR gamma rays	97	8	8.25
0.3% EMS	126	2	1.59
0.4% EMS	90	4	4.44
15 kR gamma rays + 0.1% EMS	97	3	3.09
20 kR gamma rays + 0.2% EMS	69	5	7.25
Control	254	--	--

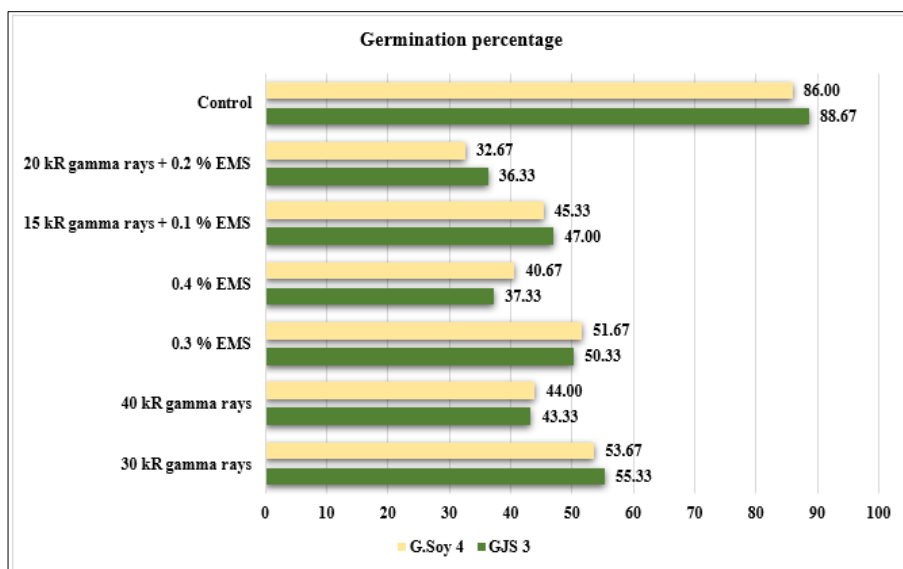


Fig 1: Effect of mutagenic treatments on germination percentage of Soybean varieties GJS 3 and G.Soy 4 in M1 generation

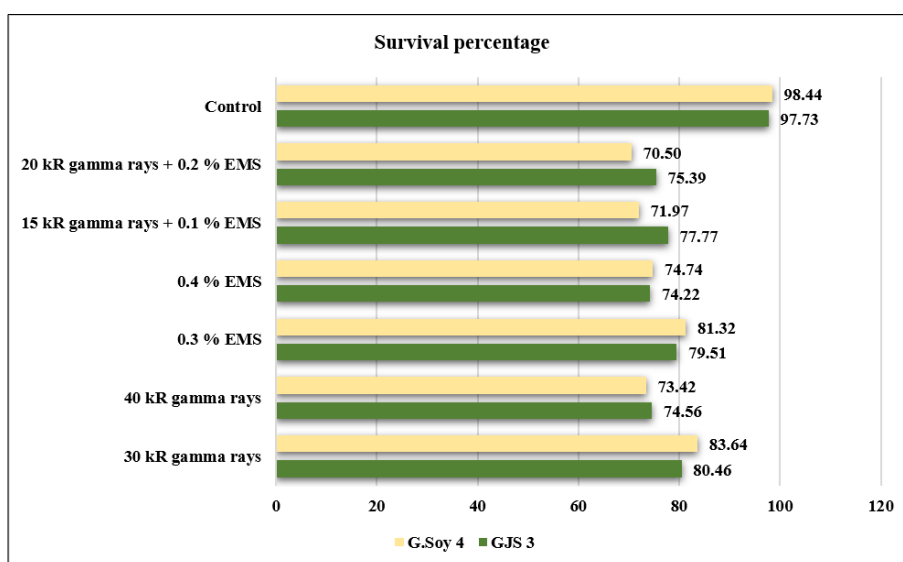


Fig 2: Effect of mutagenic treatments on survival percentage of Soybean varieties GJS 3 and G.Soy 4 in M1 generation

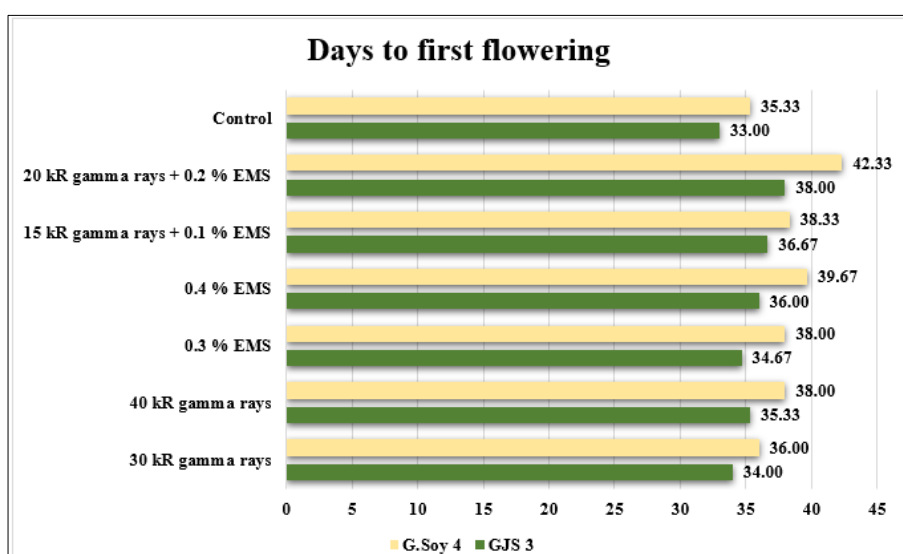


Fig 3: Effect of mutagenic treatments on days to first flowering of Soybean varieties GJS 3 and G.Soy 4 in M1 generation

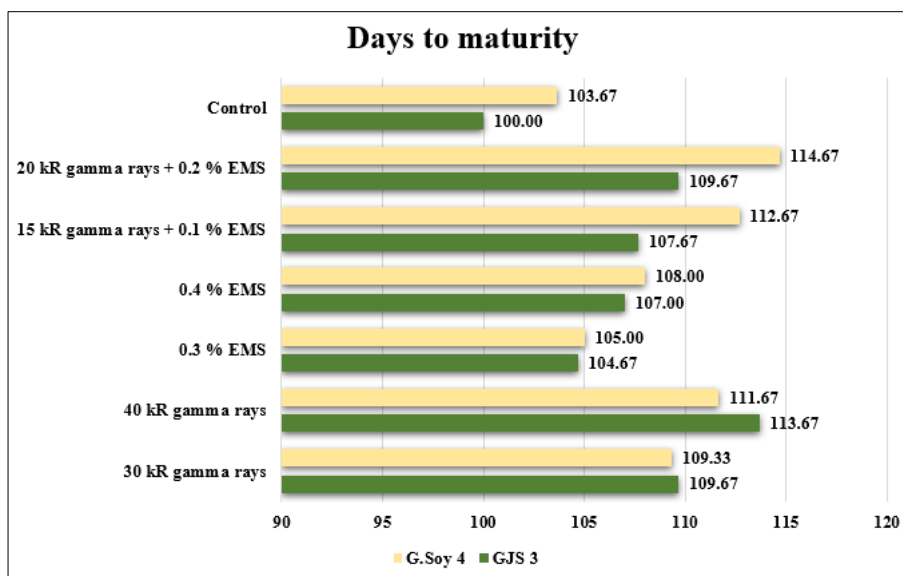


Fig 4: Effect of mutagenic treatments on days to maturity of Soybean varieties GJS 3 and G.Soy 4 in M1 generation

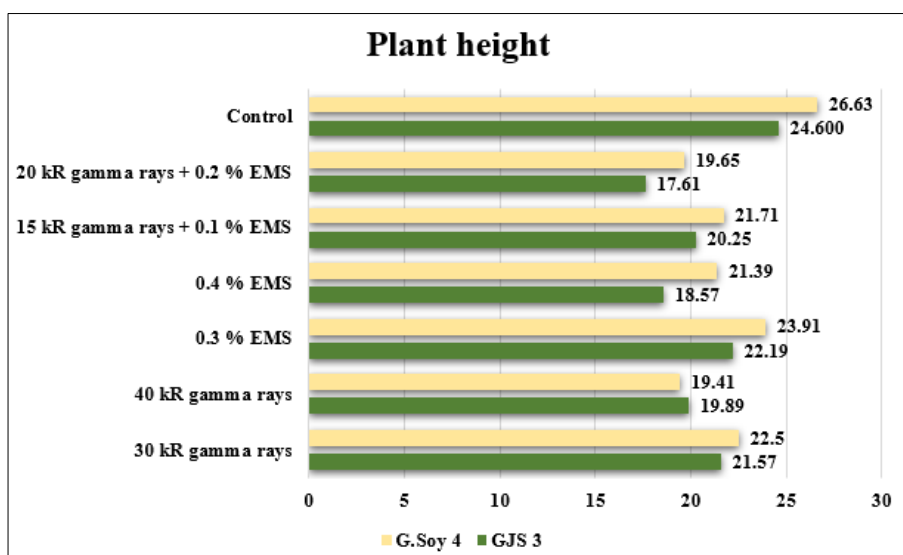


Fig 5: Effect of mutagenic treatments on plant height of Soybean varieties GJS 3 and G.Soy 4 in M1 generation

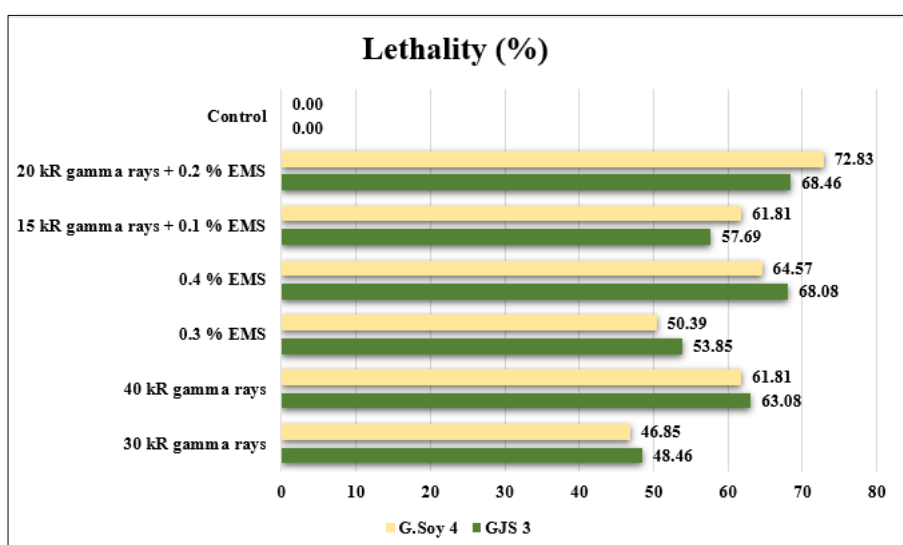


Fig 6: Lethality percentage induced by mutagen treatments in M1 generation of Soybean varieties GJS 3 and G.Soy 4

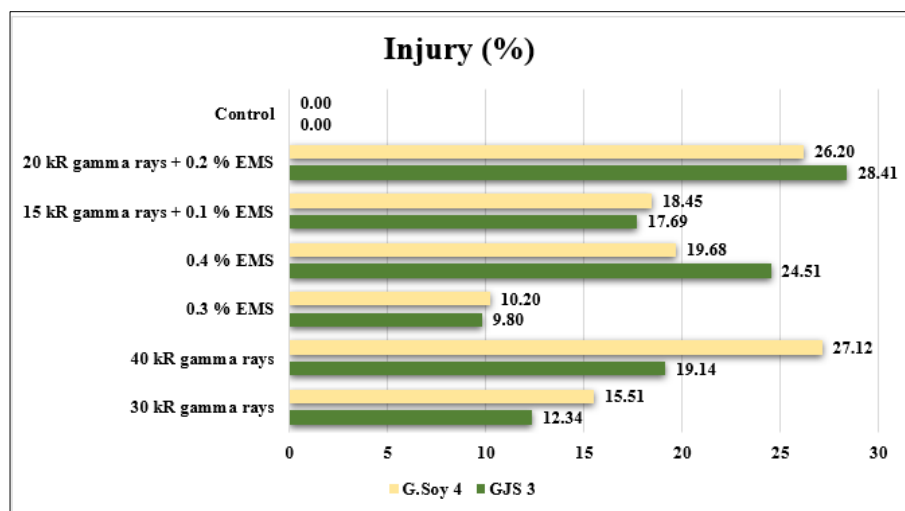


Fig 7: Injury percentage induced by mutagen treatments in M1 generation of Soybean varieties GJS 3 and G.Soy 4

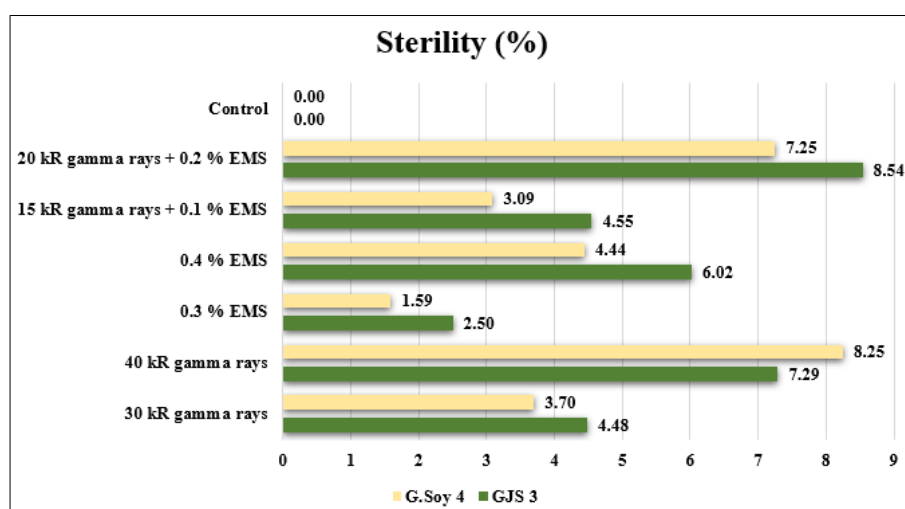


Fig 8: Percentage of sterile plants in M1 generation of Soybean varieties GJS 3 and G.Soy 4

Conclusion

The study demonstrated that increasing doses of gamma rays, EMS and in combination treatments of both mutagens had a detrimental impact on germination, survival and morphological traits in the M1 generation of soybean varieties GJS 3 and G. Soy 4. Delayed flowering and maturity, reduced plant height and increased lethality, injury and sterility were observed with higher mutagenic doses, especially under combination treatments of gamma rays and EMS. Among all treatments, the combined treatment of 20 kR gamma rays + 0.2% EMS was the most potent in inducing significant biological changes. These findings indicate the potential of induced mutagenesis for generating genetic variability, which can be harnessed for future soybean improvement programs.

References

- Aditya K, Verma N, Srivastava N, Chakraborty M, Prasad K. Effect of gamma rays on seed germination, plant survival and quantitative characters on two varieties of soybean *Glycine max* (L.) Merrill in M1 generation. Bull Environ Pharmacol Life Sci. 2017;1:259-265.
- Baria AR, Akabari VR, Gohil VN. Variability study for seed yield and its components in soybean. Journal of Genetics, Genomics and Plant Breeding. 2022;6(2):54-59.
- Bhatnagar PS, Tiwari SP. Soybean improvement through mutation breeding in India. In: Plant Mutation Breeding for Crop Improvement. Vienna: IAEA; 1991. p. 381-391.
- Dhole VJ, Maheshwari JJ, Patil S. Studies on mutations induced by EMS in soybean *Glycine max* (L.) Merrill. Agric Sci Digest. 2003;23(3):226-228.
- Evans HJ, Sparrow AH. Nuclear factors affecting radiosensitivity, II. Dependence on nuclear and chromosome structure and organization. In: Brookhaven Symposium. 1961;14:101-127.
- Karthika IR, Lakshmi BS. Effect of gamma rays and EMS on two varieties of soybean. Asian J Biol Sci. 2006;5(4):721-724.
- Kavithamani D, Kalamani A, Vanniarajan C, Uma D. Mutagenic effectiveness and efficiency of gamma rays and EMS in soybean *Glycine max* (L.) Merrill. Madras Agric J. 2008;95(7-12):448-451.
- Kouser M, Babu GS, Lavanya GR. Effect of mutagenesis on M1 population in urdbean. J Food Legumes. 2007;20(1):109-110.
- Nilan CFRA, Wagner J, Foster RJ. Efficient chemical mutagenesis. In: The Use of Induced Mutations in Plant Breeding. Oxford: Pergamon Press; 1965. p. 49-70.

10. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers. New Delhi: ICAR; 1995.
11. Patil A, Taware SP, Raut VM. Induced variation in quantitative traits due to physical (γ rays), chemical (EMS) and combined mutagen treatments in soybean *Glycine max* (L.) Merrill. Soybean Genet Newsl. 2004;31:6-11.
12. Patil GP, Wakode MM. Effect of physical and chemical mutagens on soybean. Curr Bot. 2011;2(4):12-14.
13. Pavadai P. Studies on quantitative characters for gamma rays treatment in soybean *Glycine max* (L.) Merrill var. Co-1. Int J Modern Cell Mol Biol. 2015;4(1):1-10.
14. Pavadai P, Girija M, Dhanavel D. Effectiveness, efficiency and biochemical content of physical and chemical mutagens in soybean *Glycine max* (L.) Merrill. J Phytol. 2009;1(6):444-447.
15. Rajderkar S, Sakhare SB. Studies on effective mutagen using physical and chemical mutagens in soybean *Glycine max* (L.) Merrill. J Pharm Innov. 2021;10(6):256-259.
16. Satpute RA, Fultambkar RV. Effect of mutagenesis on germination, survival and pollen sterility in M1 generation of soybean *Glycine max* (L.) Merrill. Int J Recent Trends Sci Technol. 2012;2(3):30-32.
17. Sudhakaran IV. Meiotic abnormalities induced by gamma rays in *Vinca rosea* Linn. Cytologia. 1971;36(1):67-79.
18. Wilson RF. Seed composition. In: Soybeans: Improvement, Production and Uses. 2004;16:621-677.
19. Witherspoon JP, Corney AK. Differential and combined effects of beta, gamma and fast neutron irradiation of soybean seedlings. Radiat Bot. 1970;10(5):429-435.