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CHARACTERIZATION OF MUTANT TUBEROSE LINES INDUCED BY GAMMA RAYS AND EMS IN WESTERN UTTAR PRADESH, INDIA

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ABSTRACT

The floriculture industry is experiencing rapid growth, expanding annually at 10-15%. Tuberose (*Polianthes tuberosa* Linn.), a perennial bulbous flowering plant from the Asparagaceae family, holds significant economic value due to its use in cut flowers, garlands, and the extraction of high-value essential oils. Despite its commercial importance, tuberose faces challenges in genetic improvement due to limited genetic variability, self-incompatibility, and seed sterility. Traditional breeding methods are thus constrained. Mutation breeding, utilizing ionizing radiation and chemical mutagens such as Ethyl- methanesulphonate (EMS), offers a potential solution by inducing genetic variability. This study investigates the effects of gamma rays and EMS on tuberose variety Single Mexican to enhance its growth and floral characteristics. Twelve bulbs per treatment were exposed to varying doses of EMS (0.25%, 0.5%, 0.75%, 1%) and gamma rays (5 Gy, 10 Gy, 15 Gy, 20 Gy), with controls for each mutagen. The bulbs were grown in a Randomized Block Design over two growing seasons (2022-2023, 2023-2024) at the Horticulture Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, India. Parameters such as days to bulb sprouting, survival percentage at 30 days, plant height at 60 days, leaf number, leaf length, days to first flower, spike number and length, rachis length, floret number, diameter, and weight were recorded. Results showed that lower doses of gamma rays (5 Gy) and EMS (0.25%) significantly improved these traits, while higher doses had adverse effects. These findings suggest that controlled application of lower doses of gamma rays and EMS can effectively enhance the growth and ornamental quality of tuberose, offering a valuable approach for its genetic improvement in floriculture.

***Key words*:** EMS, Gamma ray, Mutagen, Single Maxican, Tuberose.

Introduction

Floriculture is rapidly growing, expanding at a rate of 10-15% annually. Tuberose (*Polianthes tuberosa* Linn.), a perennial bulbous flowering plant of economic importance in the family Asperagaceae, is native to tropical and subtropical regions, specifically Mexico. The genus Tuberosa consists of 12 species, nine of which have white flowers. Tuberose is utilized as a cut flower, loose flower, and raw material for extracting high-value natural flower oil. Single-type tuberose flowers are used for garlands, floral decorations, and concrete extraction, while Double-type flowers are used for vase decorations, hand bunches, and bouquets. The essential oil of tuberose is among the most expensive in the perfume industry.

However, tuberose has limited genetic variability and a narrow genetic base, presenting a significant challenge for traditional breeding programs aimed at crop improvement. The genetic improvement of tuberose is constrained by self-incompatibility and seed sterility, hindering conventional breeding efforts.

The advent of the atomic age post-World War II spurred interest in using ionizing radiation for peaceful applications, including the induction of mutations for crop improvement. This method involves altering plant genes by treating seeds or other plant parts with physical or chemical mutagens. For modern and industrialized floriculture, there is a continuous demand for new ornamental crop varieties, and induced mutagenesis can help breeders improve crops through mutant induction. While ionizing radiation can damage plant cells, plants can compensate for this damage, and inducing somatic mutations through mutagenesis is advantageous for vegetatively propagated crops as it allows for the alteration of specific characteristics without changing the overall genotype.

Mutation breeding has been particularly successful in ornamental plants due to its ability to create visible changes in phenotypic characteristics, such as flower color, shape, size, and leaf variegation. This method has produced many new promising varieties in various ornamental plants using both physical and chemical mutagens. The National Botanical Research Institute (NBRI) in India has successfully used induced mutagenesis to improve vegetatively propagated ornamentals, resulting in numerous new varieties beneficial to the floriculture trade. Research on mutagenesis in ornamental plants includes studies on radio sensitivity, exposure methods, suitable radiation doses, chemical treatments, and the commercial exploitation of mutants.

Tuberose, widely cultivated in Asia and India, is a popular cut flower due to its tall spikes of white flowers with an exquisite fragrance. Despite its commercial importance, tuberose lacks natural variability in flower color and type. Induced mutations through physical and chemical mutagens have played a role in developing new cultivars in ornamental plants, though limited work has been done on tuberose improvement. Some scientists have attempted to induce mutations in tuberose using ionizing radiation and EMS with limited success. As tuberose cultivars are vegetatively propagated, any beneficial mutations can be perpetuated without the changes associated with seed propagation.

Spontaneous and induced mutations by physical and chemical mutagens have played an important role in the origin of new cultivars in ornamental plants. Much work on mutation breeding has not so far been done in this plant for its improvement. Attempts were made by a few scientists (Younis *et al*., 1975; Abraham *et al*., 1976; Gupta *et al*., 1984) to induce mutation by ionizing radiation and by EMS (Singh *et al*., 2013) with limited success.

This investigation highlights the potential of using EMS to induce genetic variability in tuberose, providing a basis for further research and development in the floriculture industry.

Material Method

The experimental material for the present study comprised prominent tuberose Cultivar Singal Maxican. The chemical mutagen, Ethyl-methanesulphonate ($CH_3SO_2OC_2H_5$) with molecular weight 124.16, from the sigma chemical company, USA and Gamma rays treated planting material was used as treatment. The bulbs of cultivar of tuberose (*Polianthes tuberosa* L.) received from Govind Vallabh Pant University of Agriculture and Technology, Patnagar (UK) 12 bulb for each treatment were treated with different dosage of EMS (0.25%, 0.5%, 0.75% and 1% concentration)for treated bulbs washed thoroughly with running tap water for the 1 hour to remove the residues of the chemical, and then used for rising M1 generation. Similarly, Gamma ray (5 Gy, 10 Gy, 15 Gy and 20 Gy) bulbs were treated with different exposure doses and used as planting material for M1 generation (Table 2). Control treated with water for EMS and without radiation for Gamma rays were used. A total of 10 treatments of variety combinations in M1 generation including water treated and untreated for Gamma ray bulbs used as control. 12 bulbs of each treatment including untreated control were grown at Horticulture Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh (India) in the experiment field following Randomized Block Design with three replications to raise M1 and M2 generations during rainy season of 2022-23 and 2023-24. Data representing (Table 1) relating to different parameters *i.e.* days at bulb sprouting, survival percentage at 30 days, plant height at 60 days, number of leaves per plant at 60 days, length of the longest leaves, days required for the opening of the first flower, number of spikes, spike length, rachis length, number of florets per spike, floret diameter, floret weight were recorded from entire plant population during M1 & M2 generation. Finally, significance testing was performed by comparing the calculated F-value with the critical F-value from the F-distribution table at the desired level of significance (*e.g.*, 0.05). Data's were analyzed by the help of an online statistical software (Sheoran *et al*., 1988).

Result and Discussion

Days at Bulb Sprouting

The study examined the effect of gamma rays and EMS on the days to bulb sprouting in Tuberose variety

Table 1: Morphological and Floral Parameters of Tuberose Utilized in the Study.

S. no.	Parameter	Measurement Unit	Procedure	Remarks
1	Days at Bulb Sprouting	days	Observation	Number of days from planting to bulb sprouting
2	Survival Percentage at 30 Days	percentage	Observation	Percentage of plants that survived after 30 days
3	Plant Height at 60 Days	cm	Measurement	Height of the plant measured from base to the top
4	Number of Leaves per Plant at 60 Days	count	Counting	Total number of leaves on each plant
5	Length of the Longest Leaves	cm	Measurement	Measurement of the longest leaf on each plant
6	Days Required for the Opening of the First Flower	days	Observation	Days from planting to the first flower opening
7	Number of Spikes	count	Counting	Total number of spikes per plant
8	Spike Length	cm	Measurement	From the emergence site to the top of upper floret when one or two basal pair of florets was opened
9	Rachis Length	cm	Measurement	Measurement of the rachis lengthfrom the emergence point of first basal flower to tip of the spike
10	Number of Florets per Spike	count	Counting	Total number of florets on each spike
11	Floret Diameter	mm	Measurement	Measurement of the diameter of each floret
12	Floret Weight	gm	Measurement	Weight of individual florets

Single Mexican for two years (2022-2023 and 2023-2024). The results showed that the control group consistently took the longest duration to bulb sprouting, ranging from 30.07 to 30.67 days across both years and pooled data (Table 3). In contrast, the lowest doses of gamma rays (5Gy) and EMS (0.25%) resulted in the shortest duration, ranging from 25.33 to 27.67 days. The data suggests that the application of gamma rays and EMS can reduce the days to bulb sprouting in Tuberose, with the lowest doses having the most significant impact. As mutagenic dose increases, percentage sprouting decreases. The results are similar with findings of Kainthura *et al*., (2016) while working on both physical and chemical mutagens on Tuberose and Patil and Dadhuk (2009) on Gladiolus. Sprouting percentage or survival rate is directly proportional the concentration of mutagen.

Table 2: Details of the Treatments Utilized in the Study.

Sr. No.	Treat-ment	Dose	Mutagen
1	T1	5 Gy	Gamma-ray
2	T2	10 Gy	Gamma-ray
3	T3	15 Gy	Gamma-ray
4	T4	20 Gy	Gamma-ray
5	T5	Control	Control
6	T1	0.25%	Ethyl- methanesulfonate(EMS)
7	T2	0.50%	Ethyl- methanesulfonate(EMS)
8	T3	0.75%	Ethyl- methanesulfonate(EMS)
9	T4	1.00%	Ethyl- methanesulfonate(EMS)
10	T5	Control	Control

Survival Percentage at 30 Days

The results showed that the lowest dose of gamma rays (5Gy) and EMS (0.25%) resulted in the highest sprouting rates, ranging from 88.89% to 94.44% for two years (2022-2023 and 2023-2024), while the control group and highest doses had lower sprouting rates, ranging from 61.11% to 80.56% (Table 3). The pooled data also showed similar trends, with the lowest dose of gamma rays and EMS having the highest sprouting rate of 93.06% and 90.28%, respectively, indicating that lower doses of gamma rays and EMS can enhance bulb sprouting in Tuberose. The application of gamma irradiation on the tuberose resulted in reducing growth and increasing mortality at higher does. The reason reduced survival could be due to severe damage to genetic material, cell damage and cellular components. Rupture of cellular organelles is another rationale behind mortality (Navabi *et al.,* 2016).

Plant Height at 60 Days

Lowest dose of gamma rays (5Gy) and EMS (0.25%) resulted in the highest plant heights, ranging from 38.07 cm to 39.57 cm, while the highest doses (20Gy and EMS 1.00%) had the lowest plant heights, ranging from 31.61

Table 3: Morphological and Floral Parameters of Tuberose Utilized in the Study.

		Gamma ray							EMS						
Para-meters	**Duration**	**5 Gy**	**10 Gy**	**15 Gy**	**20 Gy**	**Cont-rol**	**SEm**	**CD**	**0.25 %**	**0.50 %**	**0.75 %**	**1.00 %**	**Cont-rol**	**SEm**	**CD**
Days to bulb sprouting	2022-23	27	27.33	28.4	29.33	30.67	0.46	1.06	27.67	28.2	29.4	29.67	30.67	0.44	1.02
	2023-24	25.33	27.2	27.4	28.67	30.07	0.54	1.25	26.33	27.87	28.4	29.33	30.07	0.61	1.4
	Pooled	26.17	27.27	27.9	29	30.37	0.44	1.02	27	28.03	28.9	29.5	30.37	0.4	0.91
Survival % at 30 Days	2022-23	91.67	86.11	80.56	72.22	80.56	3.17	7.3	88.89	83.33	72.22	61.11	80.56	3.51	8.1
	2023-24	94.44	88.89	80.56	75	69.44	4.73	10.91	91.67	86.11	77.78	69.44	69.44	4.65	10.72
	Pooled	93.06	87.5	80.56	73.61	75	2.11	4.86	90.28	84.72	75	65.28	75	2.37	5.45
Plant Height at 60 Days (cm)	2022-23	39.34	37.37	35.73	35.31	37.42	0.54	1.24	38.07	37	35.03	35.07	37.42	0.38	0.88
	2023-24	39.57	37.7	36.73	36.61	37.75	0.42	0.97	38.27	35.7	33.47	31.61	37.75	0.5	1.15
	Pooled	39.46	37.53	36.23	35.96	37.59	0.45	1.03	38.17	36.35	34.25	33.34	37.59	0.38	0.88
No. of Leaves per Plant at 60 Days	2022-23	12	10.13	7.73	7.33	10.67	0.58	1.33	10	8.87	7.07	6.33	10.67	0.84	1.94
	2023-24	14.33	11.53	10.07	9.67	11.33	0.54	1.25	12.33	10.53	9.4	9	11.33	0.55	1.27
	Pooled	13.17	10.83	8.9	8.5	11	0.46	1.07	11.17	9.7	8.23	7.67	11	0.64	1.48

cm to 36.61 cm for two years (2022-2023 and 2023-2024) (Table 3). The control group had intermediate plant heights, ranging from 37.42 cm to 37.75 cm. The pooled data also showed similar trends, with the lowest dose of gamma rays and EMS having the highest plant height of 39.46 cm and 38.17 cm, respectively. Findings were similar as Fowler *et al.,* 1972.

Number of Leaves per Plant at 60 Days

The results showed for two years (2022-2023 and 2023-2024) that the lowest dose of gamma rays (5Gy) and EMS (0.25%) resulted in the highest number of leaves, ranging from 12.00 to 14.33, while the highest doses (20Gy and EMS 1.00%) had the lowest number of leaves, ranging from 6.33 to 9.67 (Table 3). The control group had intermediate numbers of leaves, ranging from 10.67 to 11.33. The pooled data also showed similar trends, with the lowest dose of gamma rays and EMS having the highest average number of leaves, 13.17 and 11.17, respectively, and the highest doses having the lowest average number of leaves, 8.50 and 7.67, respectively. The stimulative effect of Ethyi-Methanesulphonate (EMS) might be attributed to cell division rates as well as to activation of growth hormones, for example, auxin. Joshi *et al*., (2011).

Length of the Longest Leaves

The results showed for two years (2022-2023 and 2023-2024) that the lowest dose of gamma rays (5Gy) and EMS (0.25%) resulted in the longest leaves, ranging from 33.44 cm to 37.51 cm, while the highest doses (20Gy and EMS 1.00%) had the shortest leaves, ranging from 20.34 cm to 25.97 cm (Table 4). The control group had intermediate leaf lengths, ranging from 30.98 cm to 31.72 cm. The pooled data also showed similar trends, with the lowest dose of gamma rays and EMS having the longest average leaf length, 36.72 cm and 32.82 cm, respectively, and the highest doses having the shortest average leaf length, 25.37 cm and 22.56 cm, respectively.

Days Required for the Opening of the First Flower

For two years (2022-2023 and 2023-2024) studies the results showed that the highest dose of gamma rays (20Gy) and EMS (1.00%) resulted in the longest days to flower, ranging from 79.07 to 88.23, while the lowest dose of gamma rays (5Gy) and EMS (0.25%) had the shortest days to flower, ranging from 72.27 to 76.47 (Table 4). The control group had intermediate days to flower, ranging from 74.73 to 75.57. The pooled data also showed similar trends, with the highest dose of gamma rays and EMS having the longest average days to flower, 80.23 and 87.62, respectively, and the lowest dose having the shortest average days to flower, 72.77 and 76.14, respectively.

Numbr of Spikes

The lowest dose of gamma rays (5Gy) and EMS (0.25%) for two years (2022-2023 and 2023-2024) resulted in the highest number of spikes, ranging from 1.67 to 1.73, while the highest dose of gamma rays (20Gy) and EMS (1.00%) had the lowest number of spikes, ranging from 1.00 to 1.07 (Table 4). The control group had intermediate numbers of spikes, ranging from 1.40 to 1.47. The pooled data also showed similar trends, with the lowest dose of gamma rays and EMS having the highest average number of spikes, 1.70 and 1.37, respectively, and the highest dose having the lowest average number of spikes, 1.03 and 1.00, respectively.

Spike Length

The study for two years (2022-2023 and 2023-2024) reviled that the lowest dose of gamma rays (5Gy) resulted in the highest spike length, ranging from 73.01 cm to 75.51

Table 4: Morphological and Floral Parameters of Tuberose Utilized in the Study.

		Gamma ray							EMS						
Para-meters	**Duration**	**5 Gy**	**10 Gy**	**15 Gy**	**20 Gy**	**Cont-rol**	**SEm**	**CD**	**0.25 %**	**0.50 %**	**0.75 %**	**1.00 %**	**Cont-rol**	**SEm**	**CD**
Length of Longest Leaf (cm)	2022-23	35.94	29.45	26.33	24.77	30.98	0.69	1.6	33.44	28.85	26.43	24.77	30.98	0.6	1.38
	2023-24	37.51	31.6	28.9	25.97	31.72	0.47	1.09	32.21	27.3	22.5	20.34	31.72	0.6	1.39
	Pooled	36.72	30.52	27.62	25.37	31.35	0.5	1.16	32.82	28.08	24.47	22.56	31.35	0.51	1.17
Days Required for Opening of First Flower	2022-23	73.27	76.2	78.87	81.4	75.27	1.34	3.1	75.8	82.27	84.4	87	75.53	0.58	1.34
	2023-24	72.27	75.27	78.07	79.07	74.73	1.04	2.4	76.47	81.86	85.5	88.23	75.57	0.56	1.3
	Pooled	72.77	75.73	78.47	80.23	75	1.1	2.55	76.14	82.06	84.95	87.62	75.55	0.44	1.02
Number of Spike per Plant	2022-23	1.73	1.47	1.27	1.07	1.47	0.1	0.23	1.4	1.27	1	1	1.47	0.06	0.15
	2023-24	1.67	1.27	1.2	1	1.4	0.1	0.24	1.33	1.2	1.13	1	1.4	0.05	0.12
	Pooled	1.7	1.37	1.23	1.03	1.43	0.07	0.16	1.37	1.23	1.07	1	1.43	0.04	0.1
Spike Length (cm)	2022-23	73.01	67.95	61.17	59.87	70.05	0.68	1.56	69.07	63.49	58.33	57.21	70.05	0.77	1.78
	2023-24	75.51	69.9	62.27	60.84	68.69	0.79	1.82	69.07	65.37	58.6	57.61	68.69	0.62	1.44
	Pooled	74.26	68.92	61.72	60.36	69.37	0.6	1.37	69.07	64.43	58.47	57.41	69.37	0.62	1.43

cm, while the highest dose of gamma rays (20Gy) had the lowest spike length, ranging from 59.87 cm to 60.84 cm (Table 4). Similarly, the lowest dose of EMS (0.25%) resulted in the highest spike length, ranging from 69.07 cm to 70.05 cm, while the highest dose of EMS (1.00%) had the lowest spike length, ranging from 57.21 cm to 57.61 cm. The control group had intermediate spike lengths, ranging from 68.69 cm to 70.05 cm. The pooled data also showed similar trends, with the lowest dose of gamma rays and EMS having the highest average spike length, 74.26 cm and 69.07 cm, respectively, and the highest dose having the lowest average spike length, 60.36 cm and 57.41 cm, respectively.

Rachis Length

Regarding Rachis length, the results showed that the lowest dose of gamma rays (5Gy) for two years (2022-2023 and 2023-2024) resulted in the longest rachis length, ranging from 17.27 cm to 18.57 cm, while the highest dose of gamma rays (20Gy) had the shortest rachis length, ranging from 12.04 cm to 12.84 cm (Table 5). Similarly, the lowest dose of EMS (0.25%) resulted in the longest rachis length, ranging from 14.87 cm to 16.64 cm, while the highest dose of EMS (1.00%) had the shortest rachis length, ranging from 11.87 cm to 12.07 cm. The control group had intermediate rachis lengths, ranging from 15.21 cm to 15.25 cm. The pooled data also showed similar trends, with the lowest dose of gamma rays and EMS having the longest average rachis length, 17.92 cm and 15.76 cm, respectively, and the highest dose having the shortest average rachis length, 12.44 cm and 11.97 cm, respectively.

Number of Florets per Spike

Number of floret per spike showed that the lowest dose of gamma rays (5Gy) for two years (2022-2023 and 2023-2024) resulted in the highest number of florets, ranging from 16.33 to 18.00, while the highest dose of

Table 5: Morphological and Floral Parameters of Tuberose Utilized in the Study.

		Gamma ray							EMS						
Para-meters	**Duration**	**5 Gy**	**10 Gy**	**15 Gy**	**20 Gy**	**Cont-rol**	**SEm**	**CD**	**0.25 %**	**0.50 %**	**0.75 %**	**1.00 %**	**Cont-rol**	**SEm**	**CD**
Rachis Length (cm)	2022-23	17.27	15.21	12.97	12.84	15.21	0.39	0.91	14.87	13.49	11.97	11.87	15.21	0.36	0.83
	2023-24	18.57	15.2	12.87	12.04	15.25	0.47	1.08	16.64	13.6	12.2	12.07	15.25	0.3	0.69
	Pooled	17.92	15.21	12.92	12.44	15.23	0.35	0.82	15.76	13.54	12.08	11.97	15.23	0.3	0.69
Number of florets per Spike	2022-23	16.33	13.8	11.4	10.67	14	0.47	1.08	14.33	12.53	10.73	10.67	14	0.68	1.56
	2023-24	18	14.87	13.4	12.33	16.33	0.78	1.79	15.33	13.87	11.4	9.67	16.33	0.57	1.31
	Pooled	17.17	14.33	12.4	11.5	15.17	0.46	1.06	14.83	13.2	11.07	10.17	15.17	0.51	1.18
Floret Diameter (mm)	2022-23	36.44	33.13	31.7	30.67	33.41	0.53	1.22	33.64	31.19	29.87	29.74	33.41	0.42	0.97
	2023-24	34.64	32.7	30.93	30.44	34.95	0.43	1	32.44	31.1	29.47	28.61	34.95	0.68	1.57
	Pooled	35.54	32.91	31.32	30.55	34.18	0.35	0.82	33.04	31.14	29.67	29.17	34.18	0.52	1.2
Floret Weight (gm)	2022-23	1.41	1.37	1.26	1.23	1.14	0.01	0.03	1.38	1.35	1.25	1.22	1.18	0.02	0.04
	2023-24	1.42	1.38	1.26	1.24	1.14	0.01	0.03	1.39	1.36	1.26	1.23	1.19	0.02	0.04
	Pooled	1.42	1.38	1.26	1.24	1.14	0.01	0.03	1.39	1.35	1.26	1.22	1.18	0.02	0.04

gamma rays (20Gy) had the lowest number of florets, ranging from 10.67 to 12.33 (Table 5). Similarly, the lowest dose of EMS (0.25%) resulted in the highest number of florets, ranging from 14.33 to 15.33, while the highest dose of EMS (1.00%) had the lowest number of florets, ranging from 9.67 to 10.67. The control group had intermediate numbers of florets, ranging from 14.00 to 16.33. The pooled data also showed similar trends, with the lowest dose of gamma rays and EMS having the highest average number of florets, 17.17 and 14.83, respectively, and the highest dose having the lowest average number of florets, 11.50 and 10.17, respectively.

Floret Diameter

The results showed that the lowest dose of gamma rays (5Gy) for two years (2022-2023 and 2023-2024) resulted in the largest floret diameter, ranging from 36.44 mm to 35.54 mm, while the highest dose of gamma rays (20Gy) had the smallest floret diameter, ranging from 30.67 mm to 30.44 mm (Table 5). Similarly, the lowest dose of EMS (0.25%) resulted in the largest floret diameter, ranging from 33.64 mm to 32.44 mm, while the highest dose of EMS (1.00%) had the smallest floret diameter, ranging from 29.74 mm to 28.61 mm. The control group had intermediate floret diameters, ranging from 33.41 mm to 34.95 mm. The pooled data also showed similar trends, with the lowest dose of gamma rays and EMS having the largest average floret diameter, 35.54 mm and 33.04 mm, respectively, and the highest dose having the smallest average floret diameter, 30.55 mm and 29.17 mm, respectively.

Floret Weight

Floret weight showed for two years (2022-2023 and 2023-2024) that the lowest dose of gamma rays (5Gy) resulted in the highest floret weight, ranging from 1.41 to 1.42 gm, while the control group had the lowest floret weight, ranging from 1.14 to 1.14 gm (Table 5). Similarly, the lowest dose of EMS (0.25%) resulted in the highest floret weight, ranging from 1.38 to 1.39 gm, while the control group had the lowest floret weight, ranging from 1.18 to 1.18 gm. The pooled data also showed similar trends, with the lowest dose of gamma rays and EMS having the highest average floret weight, 1.42 gm and 1.39 gm, respectively, and the control group having the lowest average floret weight, 1.14 gm and 1.18 gm, respectively.

Conclusion

The study demonstrates for two years (2022-2023 and 2023-2024) that lower doses of gamma rays (5 Gy) and EMS (0.25%) significantly enhance various growth and flowering parameters in the Tuberose variety Single Mexican. These include reduced days to bulb sprouting, increased survival percentage, plant height, number of leaves, length of the longest leaves, earlier flowering, increased number of spikes, spike length, rachis length, number of florets per spike, floret diameter, and floret weight. Conversely, higher doses of mutagens had detrimental effects, reducing growth and increasing mortality. This suggests that careful application of lower doses of gamma rays and EMS can be an effective strategy for improving the growth and ornamental quality of Tuberose.

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