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EVALUATION OF THE LETHAL DOSE (LD_{50}) AND GROWTH STIMULATION THRESHOLDS OF GAMMA RADIATION IN GLADIOLUS VARIETIES

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ABSTRACT

The present investigation was carried out during the year 2024-25 and 2025-26 at the Instructional farm of Department of Floriculture and Landscape Architecture, College of Horticulture, Banda University of Agriculture and Technology, Banda, Uttar Pradesh in Factorial Randomized Block Design (FRBD) with 25 treatment combinations, consisting of five varieties (V_1-Nova Lux, V_2-Punjab Dawn, V_3-American Beauty, V_4-Priscillia and V_5-Oscar) and five gamma irradiation doses (T_1-00 kR, T_2-2.00 kR, T_3-3.50 kR, T_4-5.00 kR and T_5-6.50 kR). Effect of different gamma irradiation doses on sprouting behaviour and survival of five gladiolus varieties during M_1 and M_2 generations were evaluated. Increasing gamma irradiation dose progressively delayed sprouting with reduced sprouting and survival percentages. Among the varieties, Oscar exhibited the earliest sprouting with highest sprouting and survival percentages, whereas Priscilla and Punjab Dawn showed comparatively lower highest sprouting and survival percentages. The results indicated that lower gamma doses were comparatively favourable, while higher doses adversely affected the sprouting and survival in gladiolus.

Key words : Gladiolus, Gamma irradiation, Mutation breeding, Sprouting and Survival percentage.

Introduction

Gladiolus (*Gladiolus hybrid* L.) the queen of bulbous flowers is one of the major commercial flowers, which is being cultivated in various parts of the country and has ever increasing demand in the flower markets. It is a monocotyledonous flowering bulbous plant, belonging to family Iridaceae (2n = 30). It is mainly grown for cut spikes, garden decoration and for exhibition (Shukla *et al.*, 2018). The rising demand for gladiolus in the floriculture market underscores the importance of genetic improvements, particularly aimed at enhancing vase life and facilitating rapid development. Given that gladiolus is primarily vegetatively propagated, mutation breeding offers a promising avenue for innovation. This approach allows for the targeted modification of specific traits in outstanding varieties without disrupting other desirable characteristics, which is particularly beneficial given the crops complex genetic structure and high heterozygosity. By utilizing corms and cormels for propagation, growers can effectively perpetuate beneficial mutations identified in irradiated plants. This method not only helps in developing new forms of gladiolus with improved qualities but also enables the preservation of genetic diversity within the species (Sharma *et al.*, 2017). As the floriculture industry continues to evolve, such genetic advancements will be crucial in meeting consumer preferences and enhancing the overall appeal of gladiolus. Mutation breeding offers an alternative by inducing variability, often altering one or two traits without affecting the entire plant. This method employs induced mutagenesis using physical and chemical mutagens, leading to the creation of new and promising ornamental plant. Although ionizing radiation is commonly used to induce variability (Chemagin *et al.*, 1997). Based on this awareness, this study aims to induce

physical mutations in the Gladiolus crop and examine their effects on various morphological traits at different mutagenic doses.

Materials and Methods

The investigation entitled "Studies on gamma rays induced morphological changes in Gladiolus" was carried out at the Instructional farm of the Department of Floriculture and Landscape Architecture, College of Horticulture, Banda University of Agriculture and Technology, Banda, Uttar Pradesh during the year 2024-2025 and 2025-26. The pure, bold and disease-free corms of five varieties of gladiolus namely, V_1-Nova Lux (Yellow), V_2-Punjab Dawn (Pink), V_3-American Beauty (Orange), V_4-Priscilla (Purple) and V_5-Oscar (Bright red) were taken for the present study. These varieties vary in their magnificent colours and genetic make-up. Gladiolus is a vegetatively propagated ornamental crop that commonly propagates via corms and cormels. Thus, healthy corms of about 3.5 to 4.5 cm in size were selected for mutagenic treatment in the present investigation. Corms of gladiolus Variety Nova Lux was obtained from Department of Horticulture, College of Agriculture, GBPUT, Pantnagar, Uttarakhand, India while Punjab Dawn was obtained from Department of Horticulture, College of Agriculture, MPUAT, Udaipur, Rajasthan, India. While variety American Beauty was procured from Department of Horticulture, SAST, BBAU, Lucknow whereas the corms of variety Priscilla and Oscar were collected from a private company (Bhargab & Co.), Kolkata. The corms were irradiated in Gamma Cell-5000 (Cobalt-60 source emitting 3600 rads per minute) at the Department of Radio and Isotopes Laboratory, College of Basic Science and Humanities, GBPUAT, Pantnagar, Uttarakhand during November, 2024. Two hundred corms of uniform size of each of these varieties in each treatment were irradiated with gamma rays at T_2-2.00, T_3-3.50, T_4-5.00 and T_5-6.50 kR doses. Untreated corms were used as control T_1-00 kR.

The gamma rays treated corms were planted in November, 2024. The corms were planted at 30 × 30 cm distance on the experimental field in Factorial Randomized Block Design (FRBD) of three replications with five gamma irradiation dose and five varieties. All the standard cultural practices were followed as per the university guidelines. The plants that had showed variation were isolated from the population of the M_1 generation and planted separately for M_2 generation however for non-variant plants again planting was carried out in Factorial Randomized Block Design (FRBD) in November 2025 to raise the M_2 population and to find out variants. Collection of corms and cormels were carried out from each variant separately, ensuring proper storage conditions. The crop was raised under uniform and standard cultural practices. To keep field free from weeds during the experimental period the field was periodically inspected and weeding was done manually. Irrigation was done periodically by flooding method of irrigation. The harvested corms of M_1 were used as base population in M_2 generation. Variations cause due to mutagenic treatments were observed carefully by inspecting the variations in vegetative growth and flowering characteristics between treated and non-treated corms in vM_1 and vM_2 generations. The observations recorded were further analysed statistically via SPSS and OPSTAT software. To estimate the performance of these five varieties at five different doses for 3 phenotypic characters *viz*., Days taken to sprouting, Sprouting percentage and Survival percentages. Further, heat map analysis has been used to graphically represent the effect of increasing gamma irradiation among different varieties and identification of V×T combinations suitable for subsequent mutant selection. Principal Component Analysis was also performed via R-software to examine the multivariate association among the 25 V×T combinations on the basis of the traits under study.

Results and Discussion

Days taken to sprouting

Perusal of data presented in Table 1 and depicted in Fig. 1 revealed that the number of days required for sprouting was influenced by the variety, dose of gamma irradiation and their interaction. In general, days taken to sprouting increased progressively with an increase in the dose of gamma irradiation. During M_1 generation, the minimum number of days to sprouting was recorded under T_1 (00 kR), with a mean of 12.93 days, whereas the maximum was observed under T_5 (6.50 kR), with a mean of 18.86 days. The intermediate doses, T_2 (2.00 kR), T_3 (3.50 kR) and T_4 (5.00 kR), recorded mean values of 14.38, 15.66 and 17.54 days, respectively. Among the varieties, V_5 (Oscar) recorded the earliest sprouting, with a mean of 14.12 days, whereas V_4 (Priscilla) recorded the maximum number of days to sprouting (17.42 days) during M_1 generation.

During M_2 generation, a similar trend was observed. The minimum mean number of days to sprouting was recorded under T_1 (00 kR) (13.70 days), while the maximum was recorded under T_6 (6.50 kR) (18.80 days). The mean values under T_2, T_3 and T_4 were 14.38, 16.07 and 17.56 days, respectively. Among the varieties, V_5 (Oscar) showed the earliest sprouting (13.33 days), while

Table 1 : Effect of gamma irradiation on days taken to sprouting of gladiolus varieties (days).

Varieties / Dose of gamma irradiation	Days taken to sprouting (days)											
	2024-25 (M_1 generation)						2025-26 (M_2 generation)					
	V_1	V_2	V_3	V_4	V_5	Mean	V_1	V_2	V_3	V_4	V_5	Mean
T_1 (00 kR)	13.20	11.06	14.33	15.26	10.80	12.93	15.82	13.22	14.00	14.98	10.49	13.70
T_2 (2.00 kR)	14.93	13.20	15.60	16.73	11.46	14.38	14.31	14.93	15.36	15.37	11.94	14.38
T_3 (3.50 kR)	16.73	14.00	17.00	16.40	14.20	15.66	16.40	16.31	16.53	17.38	13.75	16.07
T_4 (5.00 kR)	18.66	15.66	17.86	19.26	16.26	17.54	19.05	16.78	18.78	18.84	14.32	17.56
T_5 (6.50 kR)	20.00	17.73	19.26	19.46	17.86	18.86	20.08	18.12	19.81	19.86	16.16	18.80
Mean	16.70	14.33	16.81	17.42	14.12	15.88	17.13	15.87	16.89	17.28	13.33	16.10
	SEm±		CD at 5%		CV (%)		SEm±		CD at 5%		CV (%)	
V & T	0.26		0.75		6.50		0.27		0.76		6.50	
V × T	0.59		1.69				0.60		1.71			

V – Varieties T - Dose of gamma irradiation V × T - Interaction of varieties and gamma irradiation.

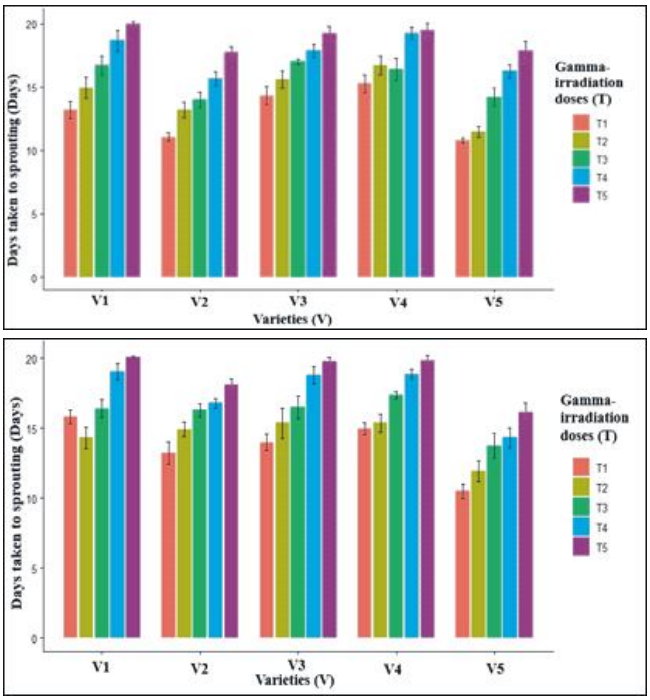


Fig. 1 : Effect of gamma irradiation on days taken to sprouting of gladiolus varieties in M_1 and M_2 generations.

V_4 (Priscilla) required the maximum time (17.28 days) during M_2 generation.

Overall, the results demonstrated that higher doses of gamma irradiation delayed sprouting in gladiolus, with the maximum delay generally occurring at 6.50 kR, whereas the untreated control showed comparatively early sprouting. As the gamma irradiation doses increased the days taken for sprouting also increased in all the varieties (Dogra *et al.*, 2018; Satyanarayana *et al.*, 2019 & 2022). Lower mutagen concentrations alone do not play any role in sprouting however the enzymes may play crucial role in plant metabolism, chemicals like those released by irradiation and low doses induce stimulations in gladiolus (Cantor *et al.*, 2002). Auxins and other growth factors that affect chromosomes and plant tissue may be harmed by higher irradiation dosages in gladiolus (Srivastava *et al.*, 2007).

Sprouting percentage (%)

data presented in Table 2 and depicted in Fig. 2 revealed that sprouting percentage was significantly influenced by variety, gamma irradiation dose and their interaction (V × T) during both generations. In M_1 generation, the highest sprouting percentage was recorded under T_1 (00 kR) with a treatment mean of 95.80%, followed by T_2 (2.0 kR, 91.53%), T_3 (3.5 kR; 89.13%), T_4 (5.0 kR; 85.33%) and T_5 (6.5 kR; 78.60%). Among the varieties, V_5 (Oscar) recorded the highest mean sprouting percentage (90.73%), whereas V_4 (Priscilla) recorded the lowest (85.40%).

During M_2 generation, a similar trend was observed. The maximum sprouting percentage was recorded with T_1 (91.27%) followed by T_2 (89.27%), T_3 (84.93%), T_4 (81.60%) and T_5 (77.53%). Among the varieties, V_5 (Oscar) showed the highest mean (88.60%), while V_2 (Punjab Dawn) recorded the lowest (79.60%).

In 1955, Sax observed that low doses of radiation stimulate sprouting by enhancing oxygen uptake and enzyme activity. Apte (1958) later found that high radiation doses negatively affect plant growth by disrupting auxins,

Table 2 : Effect of gamma irradiation on sprouting percentage of gladiolus varieties (%).

Varieties / Dose of gamma irradiation	Sprouting percentage (%)											
	2024-25 (M_1 generation)						2025-26 (M_2 generation)					
	V_1	V_2	V_3	V_4	V_5	Mean	V_1	V_2	V_3	V_4	V_5	Mean
T_1 (00 kR)	96.33	97.33	94.33	91.67	99.33	95.80	91.67	85.67	90.00	94.33	94.67	91.27
T_2 (2.00 kR)	92.67	91.00	90.33	89.33	94.33	91.53	87.33	83.33	91.00	90.33	94.33	89.27
T_3 (3.50 kR)	91.67	92.33	85.33	85.33	91.00	89.13	86.33	79.67	84.67	85.33	88.67	84.93
T_4 (5.00 kR)	86.00	87.33	82.67	84.00	86.67	85.33	81.33	77.00	81.67	84.00	84.00	81.60
T_5 (6.50 kR)	79.67	77.33	77.00	76.67	82.33	78.60	77.67	72.33	77.33	79.00	81.33	77.53
Mean	89.27	89.07	85.93	85.40	90.73	88.08	84.87	79.60	84.93	86.60	88.60	84.92
	SEm±	CD at 5%	CV (%)	SEm±	CD at 5%	CV (%)						
V & T	1.36		3.88		6.00		1.32		3.74		5.98	
V × T	3.05		8.68				2.94		8.36			

V – Varieties T - Dose of gamma irradiation V × T - Interaction of varieties and gamma irradiation

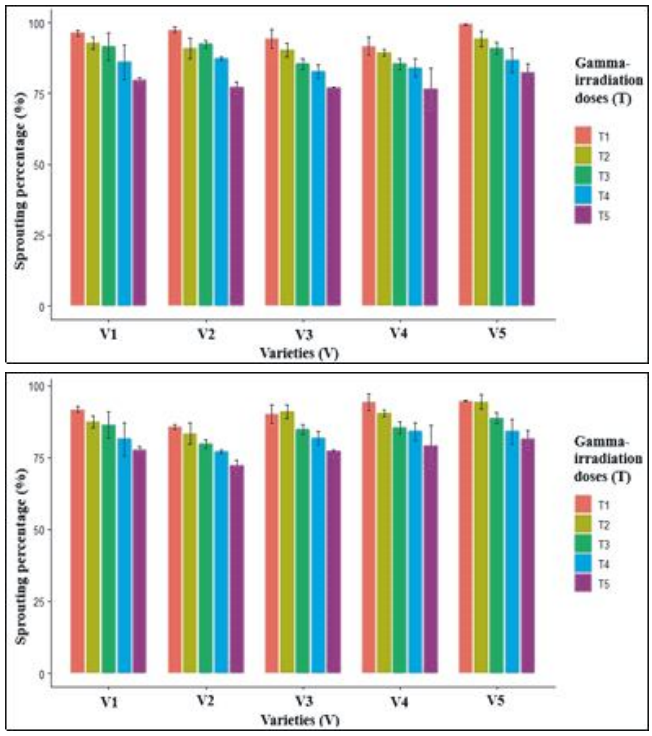


Fig. 2 : Effect of gamma irradiation on sprouting percentages of gladiolus varieties in M_1 and M_2 generations.

growth substances, chromosome structure, and cell division, leading to delayed sprouting or plant death. Grabowska and Mynett (1970) further confirmed that higher radiation doses produce toxic substances, which harm the plant and suppress growth Similar results were obtained by Shukla *et al.* (2018), Deshmukh *et al.* (2024) and Rawat *et al.* (2024). At low doses, certain plant chemicals promote sprouting and germination (Sax, 1955), but higher doses can produce toxic substances, damaging cells and hindering growth (Grabowska and Mynett, 1970). Pandey and Gaur (1984) found that low-dose irradiation of cormels increased sprouting by stimulating enzyme activity and sugar content, while high doses delayed sprouting by inhibiting enzyme activity. Srivastava *et al.* (2007) suggested that low-dose irradiation stimulates enzymes crucial for plant metabolism, aiding sprouting.

Survival percentages (%)

The survival percentage was also significantly affected by variety, gamma irradiation dose and their interaction during both generations are presented in Table 3 and graphically depicted in Fig. 3. During M_1 generation, the highest survival percentage was recorded under T_1 (00 kR) with a treatment mean of 92.80 per cent, followed by T_2 (2.0 kR; 89.06%), T_3 (3.5 kR; 85.20%), T_4 (5.0 kR; 82.66%) and T_5 (6.5 kR; 77.60%). Among the varieties, V_5 (Oscar) showed the highest mean survival (87.73%), whereas V_4 (Priscilla) recorded the lowest (82.40%).

In M_2 generation, the same general trend was observed. The maximum survival percentage was recorded under T_1 (00 kR; 89.13%), followed by T_2 (86.67%), T_3 (82.40%), T_4 (79.67%) and T_5 (76.67%). Among varieties, V_5 (Oscar) had the highest survival percentage (86.47%), whereas V_2 (Punjab Dawn) recorded the lowest (77.67%).

Various levels of mutagens were not responded well on early sprouting but physical mutagens influence the activity of enzymes. Enzymes play a vital role in various

Table 3 : Effect of gamma irradiation on survival percentage of gladiolus varieties (%)

Varieties / Dose of gamma irradiation	Survival percentage (%)											
	2024-25 (M_1 generation)						2025-26 (M_2 generation)					
	V_1	V_2	V_3	V_4	V_5	Mean	V_1	V_2	V_3	V_4	V_5	Mean
T_1 (00 kR)	93.00	95.33	90.66	88.33	96.66	92.80	89.67	84.00	88.00	91.33	92.67	89.13
T_2 (2.00 kR)	89.33	89.33	88.00	86.00	92.66	89.06	84.67	80.67	88.67	87.67	91.67	86.67
T_3 (3.50 kR)	87.66	90.00	81.33	80.66	86.33	85.20	84.33	77.67	82.67	80.67	86.67	82.40
T_4 (5.00 kR)	84.66	85.00	79.33	82.00	82.33	82.66	79.67	75.33	79.67	81.67	82.00	79.67
T_5 (6.50 kR)	82.66	75.66	74.00	75.00	80.66	77.60	75.67	70.67	80.67	77.00	79.33	76.67
Mean	87.46	87.06	82.66	82.40	87.73	85.46	82.80	77.67	83.93	83.67	86.47	82.91
	SEm±		CD at 5%		CV (%)		SEm±		CD at 5%		CV (%)	
V	0.77		2.20		3.51		0.65		1.86		3.06	
V × T	1.73		4.93				1.46		4.16			

V – Varieties T - Dose of gamma irradiation V × T - Interaction of varieties and gamma irradiation

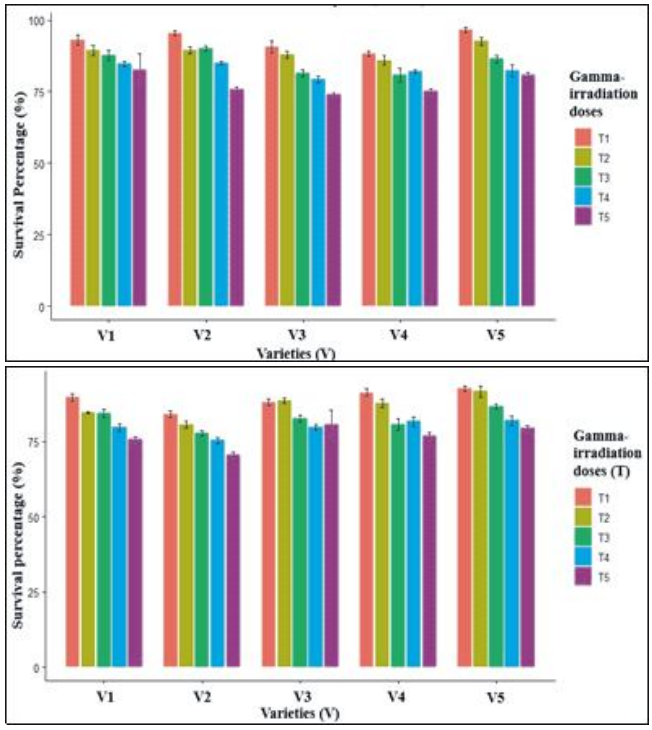


Fig. 3 : Effect of gamma irradiation on survival percentages of gladiolus varieties in M_1 and M_2 generations.

plant metabolism activities consequently result in stimulating plant growth by Misra and Bajpai (1983), which some growth parameters increased due to different levels of gamma irradiation. It has been documented that auxin played some role in plant growth. Various growth parameters increased at lower doses of gamma irradiation, whereas, decreased as doses of gamma irradiation increased. It might be due to some enzyme activities and related to the increased activity of gibberellins and auxins and disappearance of the inhibitors. Present finding is also experimentally substantiated with the observation made by earlier workers (Gendle *et al*., 2024; Yadav *et al*., 2016; Dogra *et al*., 2018; Kumari and Kumar, 2020). A significant decrease in survival percentage after irradiation with gamma rays due to inactivation or decrease in auxin concentration that disturb cell division and resulting in poor survival and growth (Sahariya *et al*., 2017). The reduction in plant survivability after irradiation might have causes due to the effect of mutagen on meristematic cell or due to acute chromosomal damage, chromosomal aberration, delay mitosis, induce enzyme activity such as lipase catalyse and production (Rawat *et al*., 2024 and Tiwari *et al*., 2010).

Heatmap and PCA

The colour gradients in the heat map graph generated via R-software provides an estimate about the effect of gamma doses on the sprouting potential and the survival efficiency of the Gladiolus. The treatment combinations viz., 2×5, 3×5, 4×5 and 1×5 expressed in the upper portion of the graph indicates delayed sprouting with high positive values for days taken to sprouting while the lower portion of the heat map graph showed combinations with lower days to sprouting, increased survival percentage and enhanced sprouting percentage, which are regarded to be better combinations established during early M_1 stage. A similar trend in the reduction of sprouting percentage with increased gamma radiation was reported by the study of Sisodia and Singh (2015), Dogra *et al.* (2018) and

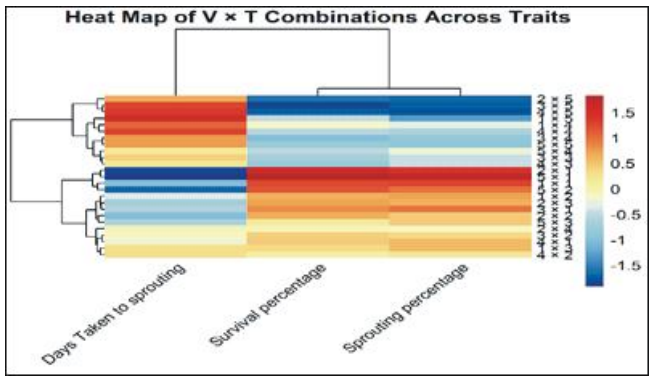


Fig. 4 : Heatmap depicting the effects of different V×T combinations for days taken to sprouting, sprouting percentage and survival percentage.

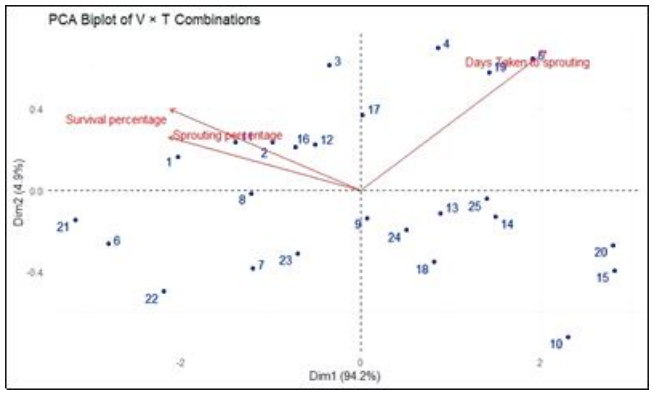


Fig. 5 : PCA biplot depicting the vectors of days taken to sprouting, sprouting percentage and survival percentage.

Pawadashetti *et al*. (2022). In the PCA, the first principal component alone explains 94.2% of the total variation whereas the second one explains only 4.9% of the total variation demonstrating that majority of the variations among different treatments can be explained by the single dominant multivariate gradient. The PCA biplot clearly reflected a separation between the V×T combinations along the first principal component. The orientation of the vector of the days taken to sprouting was projected on the positive side of the coordinate, while the vector of the survival percentage and sprouting percentage were projected on the negative sides indicating an inverse relationship of days taken to sprouting with the other two traits. Simultaneously, a positive association was recognised between the survival percentage and the sprouting percentage as their vectors are closely associated to each other making an acute angle in the graph. This signifies that the rapid increase in the sprouting percentage is associated with better establishment or survival percentage. Hence, the results of the PCA compliments the outcome of the heatmap as they both confers the response observed across different treatments combinations.

Conclusion

Gamma irradiation had a clear effect on sprouting potential and survival efficiency of gladiolus, with higher doses causing delayed sprouting followed by reduced sprouting and survival percentages. The untreated control recorded the earliest sprouting and highest survival, while 6.50 kR showed the most adverse effects. Among the varieties, Oscar generally performed better, showing earlier sprouting and higher sprouting and survival percentages, whereas Priscilla and Punjab Dawn were comparatively more sensitive. The interaction between variety and irradiation dose indicated that the response varied among varieties. Overall, lower doses showed comparatively less adverse effects, while higher gamma irradiation doses caused greater physiological and growth inhibition.

Author's contribution

Conceptualization of research (Piyush Singh); Designing of the experiments (Ajay Kumar Singh); Contribution of experimental materials (Amit Kanawjia); Execution of field experiments and data collection (D.K. Singh); Analysis of data and interpretation (K.S. Tomar); Preparation of the manuscript (Priya Awasthi & Vaishali Gangwar). All authors reviewed and approved the final manuscript.

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