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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(8): 2595-2599

www.thepharmajournal.com
Received: 10-05-2023
Accepted: 15-06-2023

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Effect of gamma irradiation on morphological and floral characters of tuberose (*Polianthes tuberosa* L.) under Tarai conditions

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Abstract
Bulbs of Suvasini and Prajwal varieties of tuberose were exposed to six doses of gamma rays to assess the impact of mutagenesis on vegetative and floral traits. The treatment of bulbs with higher doses i.e., 3.5 and 4.0 Kr were found to delay/inhibit the germination. The gamma radiation doses of 2.0 Kr to 3.0 Kr have been found beneficial in triggering commercial traits with 2.0 Kr increased plant height and number of leaves in both the varieties. Moreover, early spike emergence and first floret opening, length of spike, rachis length, Number opened florets were recorded maximum at 2.0 Kr dose of gamma rays. The number of florets per spikes, number of unopened florets and blooming duration was maximum at 2.5 Kr. However, size and length of basal florets along with days to full bloom, was highest at 3.5 Kr. gamma doses.

Keywords: Tuberose, gamma irradiation, vegetative growth, flowering, yield

Introduction
Floriculture is an Agri-business having great potential for employment generation and economic progress of the country. The demand of floricultural products has been steadily increasing both in domestic as well as in export markets. The total area under floriculture in India is about 303.21 thousand ha and a production of about 2263.20 thousand tons of loose flowers and 762thousand tons of cut flowers [1]. The total export of floricultural products from India during 2021-22 was about 23,597.17 MT which is worth Rs 771.41 crores [2]. Tuberose (*Polianthes tuberosa* L.) is one of the important cut-flower crops. It can successfully be grown in pots, borders and beds and commercially cultivated for its various uses. The flower spikes of tuberose remain fresh for a longer time and find a distinct place in the flower market. In Uttarakhand, producers can grow and sell tuberose flower spikes throughout the year and fetch remunerative income.

Mutation breeding has been highly successful in ornamental plants because changes in any of the phenotypic characters like flower colour, shape and size, chlorophyll variegation in leaves, and growth habit can be easily detected, and any change will be of commercial importance. Mutation induces a sudden heritable change in the desirable traits [3] though the rate of spontaneous mutation is very slow in natural populations [4]. In the last two decades, ion beam radiation has emerged as an highly effective method for crop improvement in ornamental plants since it produces higher mutation frequencies compared to X-rays and gamma rays. Mutation breeding is still an important tool for creating genetic variability and has been a regular technique in vegetatively propagated ornamental plants [5]. Induced mutagenesis has been successful in inducing new traits in a variety of ornamental plants like chrysanthemum, dahlia, gerbera, rose, bougainvillea and gladiolus, with altered flower and leaves characters (colour, shape, size) and physiological traits [6]. The effects of mutagens on tuberose var Suvasini was studied [7] and variation induced in morphological parameters and isolation of mutants have been reported. Further, an increase in number of bulbs per clump, bulb diameter and weight of bulbs when bulbs were reported with 0.50% EMS with 4 hours dipping duration. However, lower doses of EMS coupled with shorter dipping duration recorded to extend the vase-life of tuberose cut flowers [8]. The present study was carried out to induce genetic variability through different doses of gamma rays in tuberose varieties and to assess the effects of different doses of gamma rays on morphological and floral characteristics of tuberose.

Materials and Methods

The investigation was conducted for two consecutive years (2021 and 2022) at Model Floriculture Centre of the university. The field experiment was laid out in two-factor randomized block design with six treatments and three replications. The bulbs of uniform size (1.5-2.0 cm dia.) of two tuberose varieties Suvasini (V_1) and Prajwal (V_2) were taken from the germplasm of Model Floriculture Centre. The selected bulbs of both varieties were subjected to gamma radiation doses (1.5 kr, 2.0 kr, 2.5 kr, 3.0 kr, 3.5 kr and 4.0 kr) and immediately planted in April 2021 in the already prepared field at a spacing of 30 x 30 cm. The crop was raised under uniform cultural practices. Observations pertaining to various morphological and floral characters were recorded using standard protocol and results pertaining to pooled over data for two years have been presented in this paper.

Results and Discussion

Vegetative Parameters

A perusal of data pooled over two years presented in Table-1 on 'Days taken to 50 per cent sprouting' revealed that mutagenic treatments, varieties, and their interactions showed significant effect on days to 50 percent sprouting. Among varieties, the maximum (40.13) days taken in 50 per cent sprouting was recorded in cv. Prajwal (V_2) whereas it was minimum (39.10 days) in cv. Suvasini (V_1). Among treatments, highest days taken to 50 per cent sprouting was observed with G_6 (45 days) while the lowest (34.47) days taken to 50 percent sprouting was recorded with unirradiated control. Among interactions, maximum (45.0) days taken to 50 percent sprouting of bulbs were found in treatments G_3V_2 and G_6V_1 however, minimum (32.93) days taken for 50 per cent sprouting was observed with unirradiated (control) bulbs of cv. Prajwal (V_2). It was noted that with 3.5 Kr dose of gamma rays in cv. Suvasini (V_1) and with 4.0 Kr dose of gamma rays in cv. Prajwal (V_2) germination of bulbs was zero therefore, no plant was survived in these treatments. The data presented in Table-1 revealed that there was a significant effect of mutagenic doses among cultivars, treatments, and their interactions. Among varieties, maximum (55.28%) plant survival per cent was found in cv. Suvasini (V_1) (11.06 plant) and minimum (44.30%) plant survival was found in cv. Prajwal (V_2) (9.53 plant). Among treatments, highest per cent of plant survival (81.35%) (16.33 plants) was found in control, which was statistically at par with G_1 (73.35) whereas it was minimum (5.0%) in G_5 (3.5 Kr), and G_6 (4.0 Kr).Among interactions, highest plant survival (90%) was observed with G_1V_1 which was statistically at par with unirradiated control (81.65%) whereas minimum (5%) plant survival was found in G_5V_2 and G_6V_1. The maximum (26.93 cm) plant height among varieties was recorded in Prajwal (V_2) while minimum (26.66 cm) plant height was recorded in cv. Suvasini (V_1). Among mutagenic treatments, maximum (29.12 cm) plant height was observed in G_2 (2.0 Kr), which was statistically at par with G_1 (1.5 Kr) (28.00 cm), whereas minimum (24.81cm) plant height was observed with unirradiated control. The interaction between variety and treatments had non-significant effect. However, maximum (29.44 cm) plant height was recorded in G_2V_1 whereas minimum (23.74 cm) plant height was measured in G_3V_1 treatment combination (Table1). The data related to number of leaves among interactions of varieties and mutagenic doses showed a maximum (49.54) leaves per plant in G_2V_2, which was statistically at par with G_5V_2 (48.00 leaves), G_2V_1 (47.90 leaves), G_4V_2 (46.65 leaves) and G_1V_2 (44.54 leaves). However, minimum (31.50) leaves were observed with G_4V_1.

The mutagenic treatments showed differential response on days to sprouting among different cultivars. The lower mutagenic treatments triggered sprouting over control, while higher doses delayed it. The results conforms the earlier findings of [9] who reported similar results in different varieties of gladiolus treated with 0.5 and 1.5 Kr gamma rays. Mutagenic treatments highly influenced the percentage of sprouting. Percentage survival was lesser in treatments than in the control. Further, within variety, sprouting was less at higher doses as compared to lower doses and showed better sprouting at 1.5 Kr dose of gamma rays as compared to 4.0 Kr. The present findings are in agreement with the findings of [10, 11] hypothesized that with increase in mutagenic dose, there is reduction in leaf length, decrease in plant height, plant spread and number of leaves. In both the varieties, barring treatments, the number of leaves per plant decreased with increased doses of mutagen. The decrease in number of leaves per plant was lesser at lower dose as compared to higher dose of mutagenic treatment [12].

Flowering parameters

The data pertaining to days to spike emergence presented in Table-2 envisage a significant effect of mutagenic doses among varieties, treatments and their interaction. Barring treatments, days to spike emergence was maximum (81.70 days) in Suvasini (V_1) whereas it took minimum days in Prajwal (80.10 days). However, the differences were non-significant. Among treatments, days to spike emergence was maximum (88.44 days) in the untreated control (C), which was statistically at par with G_1 (1.5 Kr gamma rays) (84.41 days) but significantly higher than rest of the treatments. However, it was minimum (74.65 days) in G_2. Among interactions of variety and mutagenic treatments, there were non-significant differences in days to spike initiation. However, maximum (88.90) days to spike emergence was recorded in untreated bulbs of Suvasini variety (CV_1) whereas it was minimum (72.90 days) in G_2V_1 (2.0 Kr gamma rays in Suvasini variety). Among varieties barring treatments, days taken to spike emergence increased with increased doses of mutagen when compared to control. Increase in days taken to spike emergence was lesser in lower doses as compared to higher doses of mutagenic treatment. Similar results were reported in chrysanthemum [13]. A decreasing trend in days to spike emergence was also reported [14] while working on gladiolus variety Prince of Orange.

Days taken to first floret opening were significantly affected by mutagenic doses but non-significant effect among varieties and variety-treatment interactions (Table2). However, among varieties, the maximum (95.14) days to first floret opening were noted in cv. Suvasini (V_1) while minimum (91.58) days was noted in Prajwal (V_2). Among treatments, the highest (97.63) days to first floret opening was recorded with G_1 which was statistically at par with control (97.58) but significantly higher than rest of the treatments whereas, minimum days to first floret opening was recorded with G_3 (89.01). Among interactions, maximum (99.03) daysto first floret opening was recorded in non-irradiated control (CV_1) whereas it was minimum (85.75 days) in G_3V_2. The data pertaining to size of basal floret revealed non-significant effect on size of lowest floret as influenced by gamma irradiation doses among varieties, treatments and their interactions (Table2). However, among varieties, the largest (4.01cm) basal floret size was noted in cv. Prajwal (V_2) and smallest (3.94 cm) size of the basal floret was recorded in Suvasini (V_1). Among treatments, maximum (4.05 cm) size was recorded in G_5 and G_6 while minimum (3.90 cm) size of the lowest floret was noted in untreated control. Among interactions, though the differences were non-significant, maximum (4.05 cm) size of lowest floret was recorded in treatments G_3V_2, G_5V_2 and G_6V_1 whereas it was minimum (3.81 cm) in G_2V_1. Likewise, the length of basal floret exhibited non-significant effect of mutagenic doses among varieties and varieties-treatments interaction. Among varieties, maximum (6.47 cm) length of basal floret was recorded in Suvasini (V_1) however, minimum (6.44 cm) length was recorded in Prajwal (V_2). Among treatments, highest (6.70 cm) length was recorded with 3.5 Kr dose (G_5) while minimum (6.19 cm) length of basal floret was found with G_1. Among interactions, length of basal floret was recorded maximum (6.71cm) in G_4V_2 whereas it was minimum in G_1V_2 (5.83cm) (Table-2).The findings of the present investigation are in agreement with the work of [15, 16]. reported inverse relation between size of basal floret to dose of gamma radiation in gladiolus variety Prince of Orange.

The spike length among treatments was maximum (87.35 cm) in G_2 whereas the minimum (77.00 cm) spike length was observed with 4.00 Kr (G_6). Amongvarieties, maximum (82.36cm) spike length was recorded in cv. Prajwal (V_2), and minimum (81.24 cm) spike length was in cv. Suvasini (V_1). The effect of mutagen on rachis length on varieties was found statistically significant. Barring treatments, rachis length was found maximum (31.27 cm) in Prajwal while minimum (26.56 cm) in Suvasini, but the differences were found non-significant. Among treatments, maximum (33.45cm) rachis length was found in G_2, which was statistically at par with 3.0 Kr G_4 (30.38cm). However, the minimum length of the rachis (25.50cm) was recorded in G_6.Among interactions, maximum rachis length (36.00cm) was recorded in G_2V_2 followed by G_4V_2 (34.72cm) and G_3V_2 (33.44 cm) while it was minimum (25.20 cm) in CV_1 (Table 3). The results of the present investigation revealed a variable response of gamma doses among varieties for spike and rachis length [14]. Reported a decrease in spike length with increase in dose of mutagen as compared to control. Overall, there was a declining trend in rachis length with increased dose of gamma rays. Similar results were reported by (17)) while investigating the effect of physical and chemical mutagen on four different varieties of tuberose.

A perusal of data in Table 4 showed a non-significant effect on days to full bloom among varieties, treatments, and their interactions. Among varieties, maximum (113.51 days) days to full bloom was recorded in Prajwal (V_2) while it was noted minimum (111.37 days) in cv. Suvasini (V_2). Among treatments, the highest days to full bloom (118.17 days) was found with G_5. However, the lowest (104.21 days) days to full bloom was recorded with G_1. Among interactions, maximum (118.50 days) days to full bloom was observed with G_2V_2. The minimum (98.37) days to full bloom was found with G_1V_1. It is evident that there was non-significant effect of mutagenic doses among varieties and variety-treatment interaction (Table 4). Among variety, Prajwal (V_2) had maximum (5.03) days to withering of first floret, whereas minimum days was recorded in cv. Suvasini (V_1) (4.84 days). Among treatments, maximum (5.85 days) duration to basal floret withering was noted with 2.0 Kr, (G_2), which was statistically at par with 2.5 Kr, G_3 (5.35 days). However, it was minimum (2.50 days) in G_6 treatment. Among interactions, a maximum (6.20) days to first floret withering was found with G_3V_1. However, minimum 2.50 days to wither first floret was found with G_6V_1.

The data pertaining to number of florets per spike showed non-significant effect of mutagenic doses on number of florets per spike, among cultivars, mutagenic treatments, and their interactions. Among varieties, maximum (32.50) number of florets per spike was found in cv. Prajwal (V_2), whereas minimum (30.89) number of florets per spike was noted in cv. Suvasini (V_1). Among treatments highest number of florets per spike was found with G_3 (36.90), while minimum (29.50) number of florets was found with 4.0 Kr (G_6). Among interactions of treatments and cultivars, the number of florets per spike had non-significant effect. However, maximum (39.50) number of florets per spike was found with G_3V_2 and minimum (28.00) number of florets per spike was in CV_1. The data pertaining to number of open florets per spike revealed non-significant effects of mutagenic treatment among treatments, varieties, and their interaction. Among varieties, the highest (24.73) number of opened florets was found in cv. Suvasini (V_1), and it was lowest (24.51) in cv. Prajwal (V_2). Among treatments barring varieties, maximum (27.65) number of opened florets was observed with 2.0 Kr. (G_2) while minimum (21.86) number of opened florets was found with unirradiated control. Among interactions, maximum (29.48) number of opened florets per spike was observed with G_2V_1, however, minimum (21.47) number of open florets per spike was found with control plants of cv. Suvasini (CV_1) (Table 4). The number of opened florets per spike exhibited significant reduction in the number of flowers per plant in the plants treated with 2 Kr gamma rays as compared to untreated plants as reported by [13] in chrysanthemum and [9] in gladiolus.

The number of unopened florets per spike showed significant effect of mutagenic treatment while non-significant effect on varieties and interaction of treatments and varieties. Among varieties, highest (8.10) number of unopened florets per spike was observed in cv. Suvasini (V_1) and minimum (7.92) number of unopened florets per spike was counted in cv. Prajwal (V_2). Among treatments, highest (8.87) number of unopened florets was recorded with G_3 which was statistically at par with G_1 (8.64) and G_4 (8.51) while minimum (6.36) number of unopened florets per spike was recorded with G_2. Among interactions, maximum (9.28) number of unopened florets was recorded with G_3V_1 whereas the minimum (5.64) number of unopened florets per spike was observed with G_2V_2. However, the differences were statistically non-significantly. A perusal of data pertaining to blooming duration presented in Table4 revealed significant differences in blooming duration among varieties, treatments and their interaction as influenced by mutagenic doses. Among varieties, Prajwal (V_2) showed maximum (18.89 days) duration of flowering, which was significantly higher than Suvasini (V_1) and recorded minimum (18.40) days of flowering duration. Among treatments, maximum (20.44 days) duration of flowering was recorded with G_3, which was statistically at par with G_4 (19.09) and G_2 (19.08 days). The minimum flowering duration was observed with unirradiated control (17.49 days). Among interactions, maximum (20.90

days) duration of flowering was found with G_3V_2, which was statistically at par with G_3V_1 (19.97) and G_4V_2 (19.85) whereas the minimum (17.37 days) flowering duration was recorded with Suvasini variety with no radiation treatment (CV_1) (Table 4). The irradiated plants showed delayed flowering. The interruptions in the biosynthesis of bio-chemicals that assist in flower induction might have lead to delayed flowering [18]. The delayed effect of gamma radiation for flowering at higher doses while studying the mutagenic effects on four varieties of tuberose have been reported [19].

Table 1: Effect of doses of gamma radiations on survival and vegetative parameters in tuberose varieties

Treatment/ Replication	Days to 50 percent Sprouting		Plant Survival Percentage		Plant Height (cm)		Number of leaves per plant	
	Suvasini (V_1)	Prajwal (V_2)	Suvasini (V_1)	Prajwal (V_2)	Suvasini(V_1)	Prajwal (V_2)	Suvasini(V_1)	Prajwal (V_2)
C (0.0 Kr)	36.00	32.93	16.33 (81.65%)	16.33 (81.65%)	24.74	24.89	34.44	32.50
G_1(1.5 Kr)	39.50	39.60	18.00 (90.00%)	11.33 (56.65%)	28.97	27.04	47.93	44.54
G_2(2.0 Kr)	35.40	40.20	12.00 (60.00%)	12.00 (40.00%)	29.44	28.80	37.98	49.54
G_3(2.5 Kr)	38.67	45.00	7.67 (38.35%)	7.00 (35.00%)	23.74	27.64	36.21	43.75
G_4(3.0 Kr)	40.00	42.60	11.33 (56.65%)	9.50 (47.50%)	26.55	28.22	31.50	46.64
G_5(3.5 Kr)	-	40.47	-	1.00 (5.00%)	-	25.00	-	48.00
G_6(4.0 Kr)	45.00	-	1.00 (5.00%)	-	26.50	-	35.00	-
mean	39.10	40.13	11.06 (55.28%)	9.53 (44.30%)	26.66	26.93	37.18	44.16
	CD at 5%	SE(m)±	CD at 5%	SE(m)±	CD at 5%	SE(m)±	CD at 5%	SE(m)±
Treatments	2.656	0.909	2.617 (13.103)	0.895 (4.483)	1.546	0.501	6.013	1.948
Varieties	1.420	0.486	N/S (N/S)	0.479 (2.396)	0.826	0.268	N/S	1.041
Interaction (VxT)	3.756	1.285	3.702 (18.530)	1.266(6.339)	N/S	0.708	8.401	2.755

Table 2: Effect of doses of gamma radiations on flowering parameters in tuberose varieties

Treatment/ Replication	Days taken to spike initiation		Days to first floret opening		Size of basal floret (cm)		Length of basal floret (cm)	
	Suvasini (V_1)	Prajwal (V_2)	Suvasini (V_1)	Prajwal (V_2)	Suvasini(V_1)	Prajwal (V_2)	Suvasini(V_1)	Prajwal (V_2)
C (0.0 Kr)	88.90	87.97	99.03	96.13	3.89	3.91	6.29	6.33
G_1(1.5 Kr)	84.05	84.77	98.40	96.85	3.94	3.98	6.54	5.83
G_2(2.0 Kr)	72.90	76.40	93.10	90.24	3.81	4.02	6.61	6.40
G_3(2.5 Kr)	78.60	74.50	92.27	85.75	4.03	4.05	6.56	6.68
G_4(3.0 Kr)	84.73	75.45	97.01	87.99	3.91	4.04	6.28	6.71
G_5(3.5 Kr)	-	81.50	-	92.50	-	4.05	-	6.70
G_6(4.0 Kr)	81.00	-	91.00	-	4.05	-	6.54	-
mean	81.70	80.10	95.14	91.58	3.94	4.01	6.47	6.44
	CD at 5%	SE(m)±	CD at 5%	SE(m)±	CD at 5%	SE(m)±	CD at 5%	SE(m)±
Treatments	4.153	1.345	3.457	1.120	N/S	0.048	0.337	0.109
Varieties	N/S	0.719	N/S	0.599	N/S	0.025	N/S	0.058
Interaction (VxT)	N/S	1.903	N/S	1.584	N/S	0.067	N/S	0.154

Table 3: Effect of doses of gamma radiations on flowering parameters in tuberose varieties

Treatment/ Replication	Spike Length (cm)		Rachis Length (cm)		Days to full bloom		Days to first floret wither	
	Suvasini (V_1)	Prajwal (V_2)	Suvasini(V_1)	Prajwal (V_2)	Suvasini(V_1)	Prajwal (V_2)	Suvasini (V_1)	Prajwal (V_2)
C (0.0 Kr)	78.97	82.30	25.20	26.80	114.83	111.17	5.04	4.64
G_1 (1.5 Kr)	79.73	82.77	25.70	29.67	98.37	110.05	4.93	4.74
G_2 (2.0 Kr)	86.10	88.57	30.90	36.00	114.90	118.50	5.65	6.04
G_3 (2.5 Kr)	82.70	83.03	26.01	33.44	117.41	109.27	6.20	4.50
G_4 (3.0 Kr)	82.94	79.14	26.03	34.72	115.18	113.89	4.74	5.27
G_5 (3.5 Kr)	-	78.34	-	27.00	-	118.17	-	5.00
G_6 (4.0 Kr)	77.00	-	25.50	-	107.50	-	2.50	-
mean	81.24	82.36	26.56	31.27	111.37	113.51	4.84	5.03
	CD at 5%	SE(m)±	CD at 5%	SE(m)±	CD at 5%	SE(m)±	CD at 5%	SE(m)±
Treatments	N/S	1.717	3.145	1.019	N/S	3.652	0.594	0.192
Varieties	N/S	0.918	N/S	0.545	N/S	1.952	N/S	0.103
Interaction (VxT)	N/S	2.428	N/S	1.441	N/S	5.165	N/S	0.272

Table 4: Effect of doses of gamma radiations on flowering parameters in tuberose varieties

Treatment/ Replication	Number of florets per spike		Number of opened florets per spike		Number of unopened florets per spike		Blooming duration (days)	
	Suvasini (V_1)	Suvasini (V_1)	Suvasini (V_1)	Prajwal (V_2)	Suvasini (V_1)	Prajwal (V_2)	Suvasini (V_1)	Prajwal (V_2)
C (0.0 Kr)	28.00	28.00	21.47	22.24	7.23	7.80	17.37	17.60
G_1 (1.5 Kr)	29.10	29.10	27.21	22.45	9.25	8.03	17.40	17.70
G_2 (2.0 Kr)	35.75	35.75	29.48	25.82	7.07	5.64	19.36	18.80
G_3 (2.5 Kr)	34.30	34.30	24.45	26.85	9.28	8.45	19.97	20.90
G_4 (3.0 Kr)	28.69	28.69	23.52	24.27	7.92	9.09	18.33	19.85
G_5 (3.5 Kr)	-	-	-	25.42	-	8.50	-	18.50
G_6 (4.0 Kr)	29.50	29.50	22.22	-	7.83	-	17.99	-
mean	30.89	30.89	24.73	24.51	8.10	7.92	18.40	18.89
	CD at 5%	SE(m)±	CD at 5%	SE(m)±	CD at 5%	SE(m)±	CD at 5%	SE(m)±
Treatments	N/S	2.028	N/S	1.623	1.647	0.534	0.753	0.244
Varieties	N/S	1.084	N/S	0.868	N/S	0.285	0.403	0.130
Interaction (VxT)	N/S	2.868	N/S	2.295	N/S	0.755	1.066	0.345

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