



Effect of acute gamma irradiation on flower, bulb characters and stability of mutants in tuberose (*Polianthes tuberosa*)

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ABSTRACT

Genetic variability is the prerequisite for any crop to be improved. Mutation breeding is a best method identified to enhance the genetic variability in crops within short time. Knowing the limited variability in tuberose (*Polianthes tuberosa*), present investigation was undertaken for the improvement in this crop by utilizing the cultivars Phule Rajani and Prajwal. To induce variation, gamma radiation (2.5 – 15 Gy) was applied and the effect on flower and bulb characters were assessed in M₁ generation. With increase in doses of gamma irradiation, gradual reduction in number of spikes, flower number, number of bulb, weight of bulb and bulb diameter was observed. In some cases lower dose was found stimulative, while higher dose had inhibitory effect on morphological variation. Various macro mutations were scored for uniform flowering, reduced number of bulbs and spike number in M₁ population. The mutants of VM₁ generation not found stable in VM₂ generation. But we could able to find the some more mutants from the maintained gamma irradiated population of VM₁ generation related to change in flower shape. In general, freshly harvest tuberose bulbs of cv. Prajwal and Phuel Rajani responded more to gamma irradiation. From this study, it has found that gamma irradiation level, 7.5 Gy and 10.0 Gy were found optimal for mutation induction in these two tuberose cultivars.

Key words: Acute gamma radiation, Mutation, Stable mutants, Tuberose

Tuberose (*Polianthes tuberosa*) is one of the most important bulbous flowering plant of tropical and subtropical areas, it is monocot genus, perennial bulbous plant (Rose 1903, Bailely 1939). It is found to be originated at Mexico, Hutchinson (1960) placed it under the family Agavaceae. It occupies second position in area and production after gladiolus in India. Tuberose occupies a prime position owing to its popularity as a cut flower, loose flower, landscape gardening and also for extraction of the highly valued natural flower oil. The serene beauty of the flower is because of its tall and straight spikes which bear bright white florets. The variation observed out of seventeen cultivars which are developed in India, there are the cultivars that bears flower bud with pink tinge, e.g. Prajwal, Shringar, Sikkim Selection and cultivars bears flower bud with green tinge, e.g. Vaibhav, Phule Rajani and Mexican Single.

New commercially interesting cultivars can be bred in two ways. First is a cross between two existing cultivars which would result in highly variable off spring from which good cultivars can be selected. Second is using quest means of breeding approaches like chemical mutagens and physical mutagens. In few single type cultivars of tuberose seed

setting observed in a quite erratic manner with very low seed germination. Seed setting was absent in double type of tuberose cultivars. So one has to select always single type of tuberose cultivar as a female parent for breeding programme. In sexual breeding method of tuberose obtained seed takes about three seasons to come into blooming, and further many years for multiplying the stock. Mutation induction with radiation has been the most frequently used method to develop mutant cultivars, accounting for about 90% of obtained cultivars (64% with gamma-rays, 22% with X-rays; Jain 2006). Gamma radiation has provided a large high number of useful mutants (Predieri 2001) and is still showing a higher potential for improving vegetatively propagated plants.

Genetic variability is necessary in any plant breeding programme for crop improvement. Induction of mutation is an important pathway for the production of new genotypes in vegetatively propagated species (Broertjes 1972) and to enhance natural genetic resource (Jain 2006). The genetic variability in tuberose is very limited (Anu *et al.* 2003) and it has narrow genetic base. Genetic improvement of tuberose is hampered by meager variability, self incompatibility and seed sterility. Eventhough there is not much genetic variability in this plant, it is highly heterozygous and hence variability can be created by any quickest means of breeding approaches like mutation induction using gamma irradiation. In this context, mutation assisted breeding (MAB) can

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contribute greatly for genetic improvement of tuberose. Mutation breeding may also provide unusual strains of curiosity (Misra and Choudhury 1979) which is normally difficult through conventional breeding methods, therefore, the present study for inducing variability through mutation breeding which offers a comparatively shorter duration was taken up. With this above background, our present study was emphasized on mutagenic effect of gamma irradiation of different flower and bulb parameters and stability of mutants in tuberose cultivars Phule Rajani and Prajwal.

MATERIALS AND METHODS

The present study was carried out at the Research Farm of Division of Floriculture and Landscaping, IARI, New Delhi during 2009-2011. In the present study in first season, Bulbs of three different stages (B_0 - Freshly harvested bulbs, B_1 - three weeks after uprooting, B_2 - six weeks after uprooting) of tuberose cv. Prajwal and Phule Rajani treated with different gamma irradiation levels, viz. G_1 - 2.5Gy, G_2 - 5.0 Gy, G_3 - 7.5 Gy, G_4 - 10.0 Gy and G_5 - 15 Gy along with control (G_0 - 0 Gy) without irradiation at Gamma Chamber, Nuclear Research Laboratory, IARI, New Delhi. Both the tuberose cultivars are of Single type with superior quality of loose and cut flower production.

The layout was prepared in consideration of randomized block design. There were six RBD layout replicated thrice for each of the three bulb stages in both the tuberose cultivars. Gamma irradiated bulbs are planted in 2 m × 2 m plots. The B_0 and B_1 stages bulbs of both tuberose cultivars were planted on 12 March 2009. The B_2 stage bulbs of both tuberose cultivars were planted on 2 April 2009. Each treatment replication contained 36 bulbs. In total 3888 bulbs were irradiated from all three bulb stages of cultivars Prajwal and Phule Rajani.

In the subsequent study, once the radiosensitivity and optimal level of acute gamma irradiation on these two cultivars were observed. After the first season observation, gamma irradiation doses, 2.5, 5.0, 7.5 and 10.0 Gy were taken in to consideration because in first research area it was observed that 15 Gy was completely given the lethal effect with respect to both the cultivars and across the bulb stages of tuberose.

The observations of five plants from each of three replications were recorded on eleven flowering characteristic like days to flower spike appearance, opening of first floret, flower duration, number of florets/spike, vase life, total number of spike, spike length (cm), fresh weight of spike (g), floret diameter, length (cm) and fresh weight (g) of individual florets were recorded in both the cultivars with three different bulb stages. The four bulb characters, viz. number of bulbs and fresh weight, diameter and length of bulbs were also recorded in both the cultivars of tuberose in all three bulb stages.

Any variations or abnormality in different treatments were also recorded. Careful observations were made to record any change in flower character of gamma irradiated plants with respect to each treatment. On the basis of this,

also some useful mutants were selected.

The experiment data were analyzed statistically by the technique of analysis of variance (ANOVA) as applicable to randomized block design (Snedecor and Cochran 1967) using a computerized package (windostat) to find out the significance level of each of parameter, Critical Difference (CD) values at 5% level of significance.

RESULTS AND DISCUSSION

Gamma irradiation effect on flower parameter

To make the interpretation easy these flower characters were divided into four groups. In the first group gamma irradiation effect on the spike appearance and days to flowering were recorded (Table 1). In general spike appearance in tuberose occur in 3-4 months from the date of planting, in gamma irradiated bulbs in general days to spike appearance was increased with increased in gamma irradiation in all the bulb stages (B_0 , B_1 and B_2) of both the tuberose cultivars used eventhough there was no critical difference found. Radiation may indirectly delay sprouting and slows down the growth rate during early period of growth or it may be due to the deleterious effects of radiation on growth hormones like auxins and gibberellins induction. Similar results were earlier described in tuberose by Anu *et al.* (2003) they reported that cv. Suvasini took maximum time for first spike emergence (200.92 days). But in the present study we were not end up with these many days delay in spike appearance, the maximum days found was around 133.43 days in freshly harvested bulb stage (B_0) of both the tuberose cultivars. But in the three weeks after uprooted (B_1) bulb stage of cv. Prajwal, there was no spike initiation occurred at 2.5 Gy. This bulb stage was found highly sensitive to gamma irradiation as there was no survival observed beyond 2.5 Gy. Similar results were reported by Banerji *et al.* (1981) in their study where the survived plants did not produce any spike after exposure of 12.5 kR of gamma rays.

With respect to gamma radiation effect on the days to flowering, in both freshly harvested (B_0) and six weeks after uprooted (B_2) bulb stage of cv. Prajwal all the gamma irradiation doses except 2.5 Gy decreased the days to flowering. In cv. Phule Rajani across the bulb stages (B_0 , B_1 and B_2) 2.5 Gy and 5 Gy doses were showed no significant difference. Days to flowering were very least in 10 Gy of gamma irradiation across the bulb stages and cultivars. This effect could be due to less number of florets/spike in irradiated plants than florets in spikes of control plants. Based on the high CV for these two flowering character, B_0 bulb stage of both Prajwal and Phule Rajani has showed higher response to gamma irradiation.

When the effect of gamma irradiation doses on second group, viz. number of florets/spike, duration of the flower in field and vase life of cut spike (Table 2) was observed, gradual decrease in the number of florets/spike was observed with increased gamma irradiation doses. For number of florets/spike gamma irradiation dose 2.5 Gy showed non

Table 1 Effect of gamma irradiation on days to spike appearance and days to flowering in tuberose cv. Prajwal and Phule Rajani

Treatment	Days to spike appearance						Days to flowering					
	Prajwal			Phule Rajani			Prajwal			Phule Rajani		
	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂
Control	118.44	123.15	103.53	114.00	128.88	101.78	13.83	13.87	15.77	16.00	14.40	17.53
2.5 Gy	116.78	0.00	105.00	120.55	132.77	107.78	9.93	0.00	13.95	16.73	13.67	16.40
5 Gy	129.00	0.00	102.00	132.99	132.89	106.89	6.67	0.00	8.50	15.60	13.20	15.67
7.5 Gy	129.55	0.00	102.56	133.43	131.55	103.89	3.97	0.00	9.60	10.27	9.33	11.10
10 Gy	133.44	0.00	110.78	88.78	87.44	70.44	1.67	0.00	1.73	1.00	1.80	1.87
Mean	125.44	24.63	104.77	117.95	122.71	98.15	7.21	2.77	9.91	11.92	10.48	12.51
CV	6.94	7.55	6.67	8.71	7.28	8.05	6.78	2.94	6.73	9.76	9.17	9.16
SE	3.03	1.07	1.61	3.55	3.33	3.90	0.78	0.53	1.07	0.91	0.59	0.95
CD (P=0.05)	5.26	3.50	NS	NS	NS	NS	2.55	1.72	3.50	2.96	1.93	3.10

NS = Non significant, B₀- Freshly harvested bulbs, B₁- Three weeks after uprooting, B₂- Six weeks after uprooting

Table 2 Effect of gamma irradiation on number of florets/spike, flowering duration and vase life in tuberose cv. Prajwal and Phule Rajani

Treatment	Number of florets/spike						Flowering duration (day)						Vase life (day)					
	Prajwal			Phule Rajani			Prajwal			Phule Rajani			Prajwal			Phule Rajani		
	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂
Control	33.73	33.87	37.44	38.00	37.07	42.53	16.87	16.93	18.72	16.17	15.53	18.27	8.57	8.62	9.30	8.07	7.73	8.83
2.5 Gy	30.17	0.00	33.95	41.07	34.53	40.07	15.08	0.00	16.97	17.70	14.27	17.00	7.50	0.00	8.33	8.83	7.10	8.17
5.0 Gy	26.20	0.00	28.13	37.93	34.93	38.07	13.10	0.00	14.07	15.97	14.47	16.07	6.53	0.00	6.70	7.73	7.00	7.93
7.5 Gy	16.30	0.00	24.67	30.27	29.27	32.77	8.15	0.00	12.33	12.97	11.63	13.37	3.83	0.00	6.13	6.40	5.67	6.47
10.0 Gy	1.80	0.00	3.40	1.67	3.47	3.93	1.10	0.00	2.03	0.67	1.63	1.47	0.00	0.00	0.00	0.00	0.00	0.00
Mean	21.64	6.77	25.52	29.79	27.85	31.47	10.86	3.39	12.83	12.69	11.51	13.23	5.29	1.72	6.09	6.21	5.50	6.28
CV	10.19	13.49	15.50	12.36	7.98	9.13	9.92	13.49	10.82	13.69	9.57	9.08	13.96	19.95	12.75	14.31	9.98	8.38
SE	1.27	0.53	2.28	2.13	1.28	1.66	0.62	0.26	1.10	1.00	0.64	0.69	0.43	0.20	0.45	0.51	0.32	0.30
CD (P = 0.05)	4.15	1.72	7.45	6.93	4.19	5.41	2.03	0.86	2.88	3.27	2.07	2.26	1.39	0.65	1.46	1.67	1.03	0.99

NS= Non significant, B₀- Freshly harvested bulbs, B₁- Three weeks after uprooting, B₂- Six weeks after uprooting

significant effect in B₀ and B₂ bulb stages of cv. Prajwal. In B₀ bulb stage of cv. Phule Rajani 2.5 Gy made a slight increase in the number of florets (41.07) as compared to control (38.00). 2.5 Gy and 5 Gy did not show significant difference in B₁ and B₂ bulb stages. At 10 Gy numbers of florets per spike were reduced to a greater extent in all the bulb stages of cv. Prajwal and Phule Rajani. Similar results were reported by Anu *et al.* (2003) in tuberose cv. Suvasini with increased number of florets (34.42) than the non-irradiated plant, and also in gladiolus by Haskins and Moore (1935), Johnson (1948) and Spancer (1955). Reduction in number of florets/spike following radiation was reported earlier by Seilleur (1975) and Gupta and Banerji (1977). The decreased number of florets as consequence of

somatic competition (Nybom 1970) which takes place in the course of intra somatic selection.

In cv. Prajwal, except 2.5 Gy in all other gamma irradiation doses (5 Gy, 7.5 Gy and 10 Gy) there was significant decrease in the flower duration in B₀ and B₂ bulb stages. Flower duration was found negligible in 10 Gy across the bulb stages and cultivars, because only few flowers in a spike was appeared as it mentioned earlier also. With respect to high CV observed in B₂ bulb stage of cv. Prajwal and B₀ bulb stage of cv. Phule Rajani response to gamma irradiation was more in these bulb stages.

Spikes are the economic part of the tuberose, the effect of gamma irradiation was also studied on third group, viz. spike characters like number of spike/plot, length of

spike, fresh weight of spike (Table 3). There was drastic reduction in the number spike/plot with the increased gamma irradiation doses in B₀ and B₂ bulb stages of cv. Prajwal. In B₁ bulb stage of cv. Prajwal all the plants were remained in the vegetative stage. In cv. Phule Rajani, 2.5 Gy has got stimulatory effect on number of spike (27.33) as compared to control (9.33) in B₀ bulb stage, but spike number got decreased with increased gamma irradiation doses in B₁ and B₂ bulb stages. Similar results presented by Misra and Mahesh (1993) in gladiolus, in their study above 4 K R, the spike/plot got reduced and remaining plants were in the vegetative phase only.

In general, spike length got decreased with increased gamma irradiation doses. Spike length was not affected by 2.5 Gy of gamma irradiation at B₀ bulb stage of cv. Prajwal. But in case on B₂ bulb stage of cv. Prajwal, there was a gradual decrease in spike length noticed with increased doses of gamma irradiation. Across the bulb stage, 2.5 Gy was differed non-significantly with control for spike length in cv. Phule Rajani. Spike length got reduced very much in 10 Gy across the bulb stages and cultivars. Similar results were reported by Anu *et al.* (2003) in tuberose, Misra and Mahesh (1993) and Banerji *et al.* (1994) in gladiolus.

The gradual decrease in the fresh weight of spike has was observed with increased gamma irradiation doses in B₀ and B₂ bulb stages of cv. Prajwal. In B₀ bulb stage of cv. Phule Rajani, 2.5 Gy resulted in giving more fresh weight to spike (94.00 g) compared to control (76.76 g). In B₁ and B₂ Bulb stages of cv. Phule Rajani, 2.5 and 5 Gy showed no significant difference for fresh weight of spike. Beyond this radiation level, i.e. 7.5 and 10 Gy the fresh weight of spike got reduced.

In the present study, effect of gamma irradiation on fourth group, viz. individual flower characters were also studied (Table 4). For flower length and diameter, 2.5 Gy had not showed the significant difference in B₀ and B₂ bulb of cv. Prajwal. B₀, B₁ and B₂ bulb stages not responded significantly to 2.5 Gy and 5 Gy in cv. Phule Rajani for flower length and diameter. Fresh weight of individual floret was not affected much by gamma irradiation (2.5 Gy, 5Gy and 7.5 Gy) across the bulb stages and cultivars. Enhancement of flower size in Edword rose with 2.4 kR and below was reported by Irubappan and Rao (1981) and Valsamma (1989). Desai and Abraham (1978) found that low dose of radiation produced bigger flowers.

Decrease in flower size can be attributed to poor growth of flower on irradiated plants due to radiation damage (Gaul 1970). Gupta and Shukla (1971), Lata (1973) and Datta and Gupta (1982) reported reduction in flower size by irradiation in rose.

Gamma irradiation effect on bulb parameters

When effect of gamma irradiation on bulb characters were studied in both cv. Prajwal and Phule Rajani (Table 5 and 6), it was observed that number of bulbs was not affected much by lower dose of gamma irradiation, ie. 2.5 Gy in cv. Prajwal and 2.5 and 5 Gy in cv. Phule Rajani. Plants of

Table 3 Effect of gamma irradiation on spike parameters in tuberose cv. Prajwal and Phule Rajani

Treatment	Number of spikes/plot						Spike length (cm)						Fresh weight of spikes (g)					
	Prajwal		Phule Rajani		Prajwal		Phule Rajani		Prajwal		Phule Rajani		Prajwal		Phule Rajani			
	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂			
Control	22.33	11.00	29.67	9.33	29.67	35.00	71.68	78.51	88.28	68.01	66.73	69.04	108.41	143.73	161.71	76.76	85.74	94.02
2.5 Gy	6.00	0.00	12.33	27.33	25.67	31.00	67.73	0.00	76.80	63.41	60.10	70.47	92.66	0.00	99.90	94.00	82.78	82.01
5.0 Gy	9.00	0.00	9.33	22.33	11.00	24.67	55.44	0.00	71.70	56.81	56.08	59.24	86.47	0.00	89.24	76.51	70.99	81.22
7.5 Gy	6.33	0.00	7.00	16.67	10.67	13.00	45.31	0.00	56.01	49.65	50.21	50.22	67.68	0.00	60.30	62.40	59.98	56.52
10.0 Gy	1.67	0.00	1.67	2.00	6.67	1.67	9.93	0.00	5.27	9.56	7.11	3.79	7.40	0.00	11.99	18.38	14.39	6.11
Mean	9.07	2.20	12.00	15.53	16.73	21.07	50.02	15.70	59.61	49.49	48.04	50.55	72.53	28.75	84.63	65.61	62.78	63.97
CV	52.30	35.21	27.81	29.05	22.58	20.66	11.74	5.56	7.11	11.70	10.20	11.16	13.45	13.24	11.30	21.78	15.79	11.25
SE	2.74	0.45	1.93	2.61	2.15	2.51	3.39	0.50	2.45	3.34	2.83	3.26	3.63	2.20	3.52	3.25	3.72	3.16
CD (P = 0.05)	8.93	1.46	6.28	8.50	10.26	8.20	11.06	1.64	7.98	10.90	9.23	10.62	18.36	7.17	18.01	26.90	18.67	13.55

NS = Non, significant, B₀- Freshly harvested bulbs, B₁- Three weeks after uprooting, B₂- Six weeks after uprooting

Table 4 Effect of gamma irradiation on average individual floret parameters in tuberoses cv. Prajwal and Phule Rajani

Treatment	Average floret length (cm)						Average floret diameter (cm)						Average fresh weight of individual floret (g)					
	Prajwal		Phule Rajani		Prajwal		Phule Rajani		Prajwal		Phule Rajani		Prajwal		Phule Rajani			
	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂
Control	5.59	5.24	5.66	6.74	6.61	7.15	4.50	4.51	4.54	3.61	3.62	3.64	2.64	2.48	2.51	0.76	0.76	0.77
2.5 Gy	5.33	0.00	5.55	6.78	5.91	6.53	4.48	0.00	4.45	3.72	3.41	3.52	2.54	0.00	2.49	0.76	0.75	0.75
5.0 Gy	5.29	0.00	5.50	6.72	5.27	6.12	4.35	0.00	4.49	3.65	3.05	3.44	2.39	0.00	2.39	0.85	0.76	0.77
7.5 Gy	5.06	0.00	5.37	6.01	6.22	5.91	4.31	0.00	4.36	3.48	3.47	3.40	2.38	0.00	2.26	0.82	0.71	0.74
10.0 Gy	0.00	0.00	0.00	0.00	2.24	1.12	0.00	0.00	0.00	0.00	1.40	0.82	0.00	0.00	0.00	0.00	0.27	0.33
Mean	4.26	1.05	4.42	5.25	5.25	5.36	3.53	0.90	3.57	2.89	2.99	2.96	1.99	0.50	1.93	0.64	0.65	0.67
CV	6.00	5.99	1.40	5.96	8.82	5.70	1.52	1.59	0.78	3.31	2.88	2.19	6.16	3.64	3.80	6.94	6.48	6.02
SE	0.15	0.04	0.04	0.18	0.57	0.49	0.03	0.01	0.02	0.06	0.36	0.36	0.11	0.04	0.04	0.03	0.07	0.08
CD (P=0.05)	0.48	0.12	0.12	0.59	1.86	1.59	0.10	0.03	0.05	0.18	1.18	1.18	0.34	0.19	0.14	0.08	0.24	0.24

NS = Non-significant, B₀ - Freshly harvested bulbs, B₁ - Three weeks after uprooting, B₂ - Six weeks after uprooting

7.5 Gy and 10 Gy yielded in less number of bulbs across the bulb stages and cultivars. Nehvi *et al.* (2007) recorded decreased corm yield in saffron and Halevy and Shoud (2005) also observed decreased bulb yield in wedgewood iris with higher dose of gamma irradiation. All the gamma irradiation doses not showed any critical difference for fresh weight bulb in freshly harvested (B₀) and six weeks after uprooted (B₂) bulbs of cv. Prajwal and freshly harvested (B₀) bulbs of cv. Phule Rajani, fresh weight of bulbs at 10 Gy was found less in all three bulb stages of both the cultivars. Three weeks after uprooted (B₁) and six weeks after uprooted (B₂) bulbs of cv. Phule Rajani showed critical difference for fresh weight of bulbs related to gamma irradiation doses. There was no critical difference for diameter of the bulbs between control and gamma irradiation doses in freshly harvested (B₀) and six weeks after uprooted (B₂) bulbs of cv. Prajwal and cv. Phule Rajani. In general length of the bulbs was also not affected much across the bulb stages and cultivars by gamma irradiation doses (2.5 Gy, 5 Gy and 7.5 Gy). But at 10 Gy significant reduction in length of bulb was observed.

Flower and spike variations in VM₁ generation

In the present study, flower variations like reduced petal number and increased petal number than the normal one was observed and change in the flower tube in both the cultivar. Deformed spikes and change in the florets arrangement was observed in some irradiated plants.

Mutants during VM₁ generation and their stability

Tall flowering mutant: This mutant was derived from freshly harvested bulb stage (B₀) at 7.5 Gy of gamma irradiation in cv. Prajwal. The spike was grown up to 146 cm height which is 34 cm more than the normal Prajwal spike (112 cm). The spike was also contained more number of florets (76) which is also more than the florets of normal spike (42). The spike was remain straight and no lodging was observed up to opening of last floret.

Dwarf mutant: This dwarf mutant was from cv. Phule Rajani in three weeks after uprooted (B₁) bulb stage at 7.5 Gy gamma irradiation. The spike length was reduced up to 34 cm. The number of florets were found as same as that of normal Phule Rajani spike. But the length of the floret was reduced.

Flower colour mutant: flower color mutant, i.e. slightly pinkish was derived from cv. Prajwal in freshly harvested bulb stage (B₀) at 7.5 Gy. The colour was more intense than the normal flower bud of cv. Prajwal which is also show pinkish ting at bud stage. But this mutant was retained the colour after opening of the flower also. But the opened florets were not in good form and spike was also not straight.

Double spike head mutant: This mutant was derived from cv. Prajwal in six weeks after uprooted (B₂) bulb stage at 10 7.5 Gy of gamma irradiation dose. It was observed that two spike heads were fused from the neck and there was no demarcation on the stock of the spike. It yielded

Table 5 Effect of gamma irradiation on number of bulbs and fresh weight of bulbs/clump in tuberose cv. Prajwal and Phule Rajani

Treatment	Number of bulbs/clump						Fresh weight of bulbs/clump					
	Prajwal			Phule Rajani			Prajwal			Phule Rajani		
	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂
Control	13.89	11.56	15.89	16.55	16.11	19.22	400.50	435.87	482.68	357.67	355.81	398.53
2.5 Gy	13.89	1.78	15.33	14.78	14.11	17.44	347.45	203.31	394.38	325.33	356.76	373.41
5.0 Gy	10.78	0.00	13.56	12.78	14.22	15.00	247.17	0.00	366.88	303.00	339.71	331.42
7.5 Gy	7.00	0.00	15.22	11.78	6.00	14.55	247.33	0.00	424.22	343.17	220.47	378.41
10.0 Gy	5.33	0.00	4.22	5.55	1.89	8.00	156.00	0.00	274.72	186.33	93.19	231.78
Mean	10.18	2.67	12.84	12.29	10.47	14.84	279.69	127.84	388.58	303.10	273.19	342.71
CV	11.15	9.96	6.09	10.66	6.30	9.99	36.88	45.98	18.74	21.22	9.38	12.99
SE	0.66	0.46	0.45	0.76	0.99	0.86	59.56	33.93	42.04	37.13	14.80	25.71
CD (P = 0.05)	2.14	1.50	1.47	2.47	3.21	2.79	NS	110.66	NS	NS	48.27	83.85

NS = Non-significant, B₀- Freshly harvested bulbs, B₁- Three weeks after uprooting, B₂- six weeks after uprooting

Table 6 Effect of gamma irradiation on average bulb diameter and length in tuberose cv. Prajwal and Phule Rajani

Treatment	Average diameter of bulb (cm)						Average length of bulb (cm)					
	Prajwal			Phule Rajani			Prajwal			Phule Rajani		
	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂	B ₀	B ₁	B ₂
Control	28.22	29.17	30.34	24.86	24.46	26.24	5.81	5.76	5.70	3.29	3.25	3.81
2.5 Gy	26.25	31.12	28.30	24.19	24.10	25.50	6.01	4.54	5.34	3.25	3.14	3.47
5.0 Gy	23.37	0.00	26.09	23.78	23.15	24.16	5.53	0.00	5.07	3.06	3.11	3.38
7.5 Gy	26.40	0.00	28.12	25.34	23.91	27.65	5.30	0.00	5.42	3.31	3.07	3.32
10.0 Gy	24.96	0.00	29.57	23.12	17.78	21.18	4.44	0.00	4.22	2.58	2.08	2.65
Mean	25.84	12.06	28.49	24.26	22.68	24.94	5.42	3.34	5.15	3.10	2.93	3.33
CV	10.80	6.98	10.05	9.51	5.57	8.99	4.71	9.18	15.34	5.94	1.57	10.04
SE	1.61	0.49	1.65	1.33	0.73	1.45	0.15	0.18	0.46	0.11	0.03	0.19
CD (P = 0.05)	NS	1.58	NS	NS	2.38	NS	0.48	0.58	NS	0.35	0.09	0.63

NS = Non-significant, B₀- freshly harvested bulbs, B₁- three weeks after uprooting, B₂- six weeks after uprooting

more number of florets (54) than the control (42).

Bulbs of these mutants were uprooted during mid of January 2010 and stored for 30 days and planted in 1 × 1 m plots at the end of February 2010. There was no reduction in the per cent germination and survival of the bulbs observed. But these mutants were not found stable as they revert back to original cultivar form.

Mutants in VM₃ generation from the primary gamma irradiated population

The below mentioned mutants were derived from the primary gamma irradiated population which was maintained after observing the gamma irradiation effect of VM₁ generation.

Flower shape mutant: Two flower mutants change in flower shape was derived from cv. Prajwal. In one of the mutant, the shape of the petal has been changed from elongated to round shape. All the florets of the spike have showed the same petal shape. This was observed in B₂ bulb stage, i.e. six weeks after uprooting of bulbs, at 10 Gy of gamma irradiation dose. In the second flower shape mutant increased petal length was observed. And the florets were very big than the normal floret of cv. Prajwal. This was observed in B₁ bulb stage, i.e. three weeks after uprooting at 2.5 Gy of gamma irradiation dose.

Variegated leaf mutant: This mutant was derived from cv. Phule Rajani from freshly harvested bulb stage (B₀) at 10 Gy gamma irradiation dose. In this mutant white color

band formed at the middle of the leaf. All the leaves which has emerged from the bulb showed the same pattern. This mutant was separated from the mother bulb and transferred to pot and maintained.

Tall mutant: This mutant was derived from the cv. Phule Rajani from freshly harvested bulb stage (B_0) at 7.5 Gy gamma irradiation dose. The spikes were grown up to 94 cm where as normal spike is around 70-74 cm in general.

Flower colour mutant: This mutant was same as that one which was observed in VM_1 generation. This was derived from the same plot at 7.5 Gy gamma irradiation dose in cv. Prajwal from freshly harvested bulb stage (B_0).

Mutant with higher rachis length: This mutant was derived from cv. Prajwal from freshly harvested bulb stage (B_0) at 7.5 Gy gamma irradiation dose. In this mutant, the individual florets become small and are arranged at equal space intervals.

The identified mutants in the VM_3 generation were assumed to be putatively stable because they were from second cycle of propagation of primarily irradiated bulbs. In general, freshly harvested bulbs comparably showed higher response to gamma irradiation in most of the flower and bulb parameters in both the tuberose cultivar Prajwal and Phule Rajani. Most of the mutants isolated in the present study were general from 7.5 Gy and 10.0 Gy doses of gamma irradiation. In future, solid stable mutants may be met with these attractive characters from *in vitro* mutagenesis method using meristematic tissues from freshly harvested bulbs of tuberose.

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