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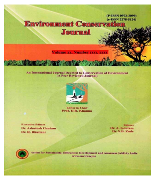

Influence of gamma radiation on growth, flowers and morphological changes in Gladiolus

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ABSTRACT

An experiment was conducted at Sam Higginbottom University of Agriculture Technology And Sciences, Allahabad in the year 2017-2018 to check the effect of different doses of Gamma radiation (0kR, 1.5kR, 3kR, 4.5kR, and 6kR) on corms of three different gladiolus cultivars namely Praha, Tiger flame, and Snow Princess, it was established that till 3 kR most of the characters were stimulated but started to sink from 4.5kR. However, 6kR treated corms produced leathery and narrower leaves with shorter plant height (57.41 cm), less leaf number (6.75), less sprouts/corm (1.57), and least spikes/plant (1.14) with an abnormal spike. While 1.5 kR treatment proved the most beneficial for various growth parameters including Plant height (87.21cm), the number of leaves (10.76), early sprouting (14.40 days), Early flowering (72.37 days), Longest flower spike (75.41 cm) and more spikes per plant (2.90). Among the Cultivars Tiger flame and Praha were found to respond well to lower doses of gamma radiation and consider being more suitable for gamma treatment. Moreover, discolor basal floret was found in Praha in 1.5kR treated corms, and Chimera was found on Tiger Flame variety at 3kR.

Introduction

The Indian Floriculture sector is undergoing a rapid transformation. Floriculture adds up to a major component of the total agricultural production in India and it plays an important role in increasing the GDP. And Cut flower industry dominates the Indian Floriculture sector. Among the cut flowers bulbous flowers are considered one of the most important categories and have become an integral part of the floriculture wealth. Gladiolus which is considered the "Queen of Bulbous" crop has become one the most popular commercial cut flower crop in India. Gladiolus offers a range of colors, shapes, and sizes that are deemed ideal as cut flowers, good for bed and herbaceous borders beside grown as a pot plant. However these traits are considered rare among flowering plants and gladiolus can be cultivated in almost all countries of the world where summer and spring conditions are favorable including both plain and hills areas, (Cantor and Tolety, 2011). Meanwhile, the spikes of Gladiolus are considered alluring and elegant with subtle florets of various shades that follow the sequential opening of the floret. This permits the flower to grow for an extended period and delivers a good vase life of cut spikes (Singh, 2006). Due to this reason, there is a growing demand for Gladiolus flowers in both Domestic and International Market. As the demand for gladiolus flower is increasing gradually genetic improvement of the crop has become a prerequisite and gladioli have mostly evolved through conventional breeding and a few through mutation breeding. As, Gladiolus has many characteristics of economic significance like flower traits which include novelty, doubleness, petaloid, vase life,

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biotic and abiotic resistance, etc. they are considered ideal for the application of mutation induction techniques and they can be easily monitored after the mutagenic treatment. Besides Gladiolus are heterozygous and are raised through vegetative propagation. The main advantage of mutation induction in vegetatively propagated crops is the ability to alter one or a few characters of otherwise outstanding cultivars without changing the remaining and often unique part of the genotype. So, this makes Gladiolus a potential test material for inducing physical mutagenesis that further creates variability for further improvement (Datta, 2012). The mutation is credited as one of the best approaches for the development of new varieties through genetic manipulation. In different ornamental plants, mutation techniques like ionizing radiations, chemicals, and other mutagens, have produced and released a large number of new promising varieties. Approximately 70% of the world's mutant varieties have been induced through gamma-rays (Sisodia and Singh, 2014). Gamma radiation is high-frequency rays consisting of high-energy protons that penetrate the cell and cause ionization leading to disruption of the normal processes of the cell. Hence, the present research was conducted and the experiment aimed to find out desirable variations caused by different gamma doses on morphological characters and flowering of gladiolus varieties.

Material and Methods

The Gladiolus cultivars Praha (V_1), Tiger Flame (V_2), and Snow princess (V_3) were irradiated using ^{60}CO source with gamma chamber-900 model (Baba Atomic Research Centre, Mumbai) at National Botanical Research Institute, Lucknow. The five different gamma doses with irradiation durations i.e. 0 kR (T_1) , 1.5 kR (T_2) for 11seconds, 3 kR (T_3) for 22 seconds, 4.5 kR (T_4) for 33 seconds, 6 kR (T_5) for 44 seconds respectively. The irradiated corms were planted in the beds with a spacing of 35 cm x 35 cm. The trial was positioned out in a Factorial Randomized Block design and was replicated 3 times. Various morphological and flowering characters along with Morphological and physiological changes were observed and recorded at regular intervals which were then statistically analyzed.

Study area

The experiment was conducted in the Horticulture experimental field, the Sam Higginbottom University of Agriculture Technology And Sciences, Allahabad. Allahabad is positioned at 25° 45' North latitude, 81°85'East longitude, and at an altitude of 98m (322ft) above mean sea level (MSL). The area of Allahabad district comes under the sub-tropical belt in southeastern Uttar Pradesh, which experiences extremely hot summer and fairly cold winter. In cold winter, the temperature sometimes is as low as 4°C in the months of December-January and very hot summer with the temperature reaching up to 48°C in the month of May and June (Canty and Associates LLC, 2013).

Results and Discussion

Changes in vegetative characters of Gladiolus due to different doses of Gamma radiation

From Table 1 (a), it can be seen that the minimum days required for sprouting (14.40 days), was observed in corms treated with 1.5kR which was significant par with corms treated with 3kR (14.66 days) while the maximum days (17.67 days) was observed in irradiation dose 6kR. Cultivar Tiger flame, took minimum days (14.37 days) to sprout while maximum days were from cultivar Snow Princess (16.84 days) and followed by Praha (16.38 days). The maximum sprouting/corm (3.39) was recorded in corms irradiated with a dose of 1.5kR followed by 3kR which was significantly par with control. While minimum sprouts/corm (1.57) was recorded in irradiation dose 6kR and was significantly par with 4.5kR. Cultivar Praha recorded maximum sprouting/ corm (2.65), followed by a cultivar Tiger flame (2.53) and there was no statistical difference between them. While the minimum sprouting/ corm (1.74) was observed in cultivar Snow princess. The best interaction effect of cultivars and gamma doses as seen in Table 1 (b) was in the cultivar Tiger flame in 1.5kR dose and it took the least number of days to sprout the corms (12.55 days) and this data was significantly par 3kR irradiation of the same cultivar. Interaction effect of maximum sprout/ corm (4.04) was recorded in the cultivar Praha with irradiation dose at 1.5kR which was significantly par with cultivar Tiger flame (3.74) of the same dose. At lower doses of gamma radiation stimulate early sprouting due to activation of

Table 1(a): Effect of different doses of Gamma radiation on Vegetative growth of Gladiolus

Treatments	Days taken for sprouting	Number of sprouts/ corm	Plant height (cm)	Leaf / plant
Cultivar				
V_1: Praha	16.38	2.65	77.44	8.47
V_2: Tiger flame	14.37	2.53	78.68	10.05
V_3:Snow princes	16.84	1.74	67.11	7.54
S. Em. (±)	**0.140**	**0.063**	**0.509**	**0.138**
C.D. at 5%	**0.409**	**0.184**	**1.483**	**0.402**
Dose				
T_1: 0 kR	15.60	2.44	85.13	9.77
T_2 :1.5 kR	14.40	3.39	87.21	10.76
T_3: 3 kR	14.66	2.53	82.74	8.81
T_4: 4.5kR	16.99	1.69	60.54	7.29
T_5: 6kR	17.67	1.57	57.41	6.75
S. Em. (±)	**0.528**	**0.082**	**0.657**	**0.178**
C.D. at 5%	**0.181**	**0.238**	**1.914**	**0.519**

Table 1(b): Interaction effect of different doses of Gamma radiation and different Gladiolus Cultivar on Vegetative Growth

Treatments	Days taken for sprouting	Number of sprouts / corm	Plant height (cm)	Leaves / plant (cm)
$V_1 \times T_1$	15.92	2.67	87.76	8.87
$V_1 \times T_2$	14.66	4.04	91.11	10.44
$V_1 \times T_3$	15.73	3.22	86.65	8.68
$V_1 \times T_4$	17.10	1.59	63.39	7.11
$V_1 \times T_5$	18.44	1.73	58.29	7.10
$V_2 \times T_1$	13.97	2.55	92.40	11.77
$V_2 \times T_2$	12.55	3.74	94.08	12.78
$V_2 \times T_3$	12.84	2.53	88.95	10.44
$V_2 \times T_4$	15.98	2.20	60.70	8.11
$V_2 \times T_5$	16.43	1.90	57.19	7.16
$V_3 \times T_1$	16.88	2.11	72.25	8.66
$V_3 \times T_2$	15.97	2.39	76.45	9.08
$V_3 \times T_3$	15.30	1.84	75.63	7.73
$V_3 \times T_4$	17.86	1.29	57.46	6.64
V_3 T_5	18.10	1.08	53.43	5.97
S. Em. (±)	**0.314**	**0.142**	**1.139**	**0.309**
C.D. at 5%	**0.914**	**0.412**	**3.316**	**0.402**

synthesis of RNA or enzyme or protein that are directly involved in auxin formation for germination and increased activity of gibberellins which break dormancy and thereby increase sprouting of corm. (Dilta *et al.*, 2003; Patil *et al.*, 2017; Sahariya *et al.*, 2017 reported that higher gamma doses adversely affect sprouting and sprout/ corm. This is because application of Gamma radiation higher doses generate detrimental effects on auxins and other growth substances affecting the chromosomes of the plant including the tissue (Srivastava *et al.*, 2007).

Gamma irradiation had a significant effect on plant height as seen from Table 1 (a). The growth data shows that 1.5kR irradiated corm produced a plant of height (87.21cm) which was the highest of all the treatments while 6kR irradiated corm produced the shortest plant height (57.41cm). Among the cultivar, the tallest plant was recorded from Tiger flame (78.68 cm) which was significantly par with Praha (77.44 cm) while Snow princess produced the shortest plant among the 3 cultivars with an average of (67.11cm) when irradiated with gamma radiation. The best interaction was recorded from Tiger flame irradiated with 1.5kR (94.08 cm) plant height and it was on par with control treatment of cultivar Tiger flame and 1.5kR treated corms of Praha while the shortest plants were from Snow princess treated with 6kR (53.43cm) and was in par with Snow princess treated with 4.5kR (57.46 cm) as seen in table 1 (b). Thus it can be noticed that a higher gamma dose retarded the growth and vice versa. The stimulating effect at a lower dose may be due to stimulation of cell division, and positive alteration of metabolic activities which affect the synthesis of nucleic acid, while higher doses of mutagen cause chromosomal and physiological impairment as reported by (Tiwari *et al.*, 2010; Kumari *et al.*, 2015) in gladiolus.

The number of leaves at 90 days was significantly affected under different irradiation treatments. As shown in Table 1 (a), corms irradiated with a 1.5kR dose of gamma rays produced the most number of leaves (10.76). It was observed that the number of leaf/plant decreased with an increase in irradiation dose and at 6kR, the minimum number of leaf/plant was recorded (6.75). Among the cultivar, Tiger flame produced the maximum leaves (10.05) and the least by Snow Princess (7.54) leaves. The best interaction between Cultivars and Gamma doses was found in Tiger flame treated (1.5kR dose) with 12.78 leaves and the minimum leaves in Snow princess (6kR) with 5.97 as seen in Table 1 (b). The present findings are in line with the findings of (Patel *et al.*, 2010; Sisodia, 2015a; Yadav *et al.*, 2016) in

Gladiolus. where higher gamma dose reduces the number of leaves. This is due to the fact that higher gamma doses causes inhibitory effect and retard cell division by arresting mitotic cells causing adverse effects on auxins synthesis thus significantly reducing the number of leaves.

Changes in flowering characters of Gladiolus due to different doses Gamma radiation

Floral characters of Gladiolus cultivars Praha, Tiger Flame, and Snow princess were significantly influenced by different gamma rays irradiation. From Table 2 (a) it can be seen that corms treated with 1.5kR gamma rays dose induced Spike initiation faster than the rest of the treatment with (72.37 days), faster color break stage with (90.07 days), and took only (93.35 days) for basal floret to open. It was then followed by corms treated with 3kR with (73.79 days) for spike initiation, (92 days) for color break Stage, and (95.47 days) for floret to open. However spike initiation, color break stage, and opening of basal floret were delayed when doses reach 4.5kR and 6kR took the maximum days for spike initiation (81.21 days), color break stage (100.37 days), and floret to open (104.37 days). From Table 2 (a), it is revealed that cv. Tiger flame flower earlier than Praha and Snow princess took the longest time. Meanwhile, from Table 2 (b) it can be seen that the best interaction between Cultivar and Gamma doses was found in the Tiger flame cultivar at 1.5kR (69.67 days) for Spike initiation, (86.57 days) for color break stage and (89.53 days) for basal floret opening. The result coincides with an experiment conducted by (Karki *et al*., 2010) in Gladiolus where application of lower doses of Gamma radiation produced the earliest spike. This may be because Gamma doses activate the growth regulators and block the growth inhibitors, this helps to increase the root and shoot length, thus helping to absorb more nutrients and performed more photosynthesis, which ultimately resulted in early spike emergence. And due to this reason, there is an early color break stage and early opening of floret (Cantor *et al*., 2002). While a delay in spike emergence with higher doses may be due to disturbance in biochemical pathways which are altered during the radiation process and these are directly or indirectly linked with the flowering physiology. The treatment of 1.5kR (13.33) was significantly par with 3kR (13.07) and shown to increase the number of florets per spike, as compared to control, while the least number was recorded from 6kR (9.54 floret/spike) as seen from Table 2 (a). The present data are in agreement with several findings that recorded the positive effect of gamma irradiation at lower doses and detrimental on higher doses and exhibited a negative response on the number of florets. A study conducted by (Kuldeep, 2017) showed reduced in the number of floret per spike at the higher dose and an increase in floret/ spike at lower doses of gamma rays in 10 varieties of Gladiolus. These results are in discord with the observation of (Singh *et al*., 2017) who recorded the maximum number of florets per spike in untreated plants in Tuberose. Meanwhile, the cultivars Tiger flame bear the maximum florets per spike (12.28) followed by Praha (11.71) and Snow princess bear the least floret (11.06). As seen from Table 2 (b), interaction of different Cultivars and Gamma doses was found significant on florets/spike. The best interaction was found in the Tiger flame cultivar at 1.5kR (14.88) florets/spike and was par with Tiger Flame at 3kR (13.97) florets/spike. While the least florets/spike was recorded from Snow princess treated with 6kR (8.64). The reduction of floret number at higher doses may be due to destruction of auxin, irregular synthesis of auxin, failure of assimilation, inhibition of mitotic and chromosomal changes, or due to damage linked with secondary physiological damage (Kole and Meher, 2005).

The size of basal floret was also influenced significantly by irradiation. As seen from Table 2(a), the maximum size (10.53 cm) diameter was recorded with 1.5kR treated plants and a smaller basal floret size (7.97 cm) was recorded at 6kR gamma rays treatment. The beneficial effect was seen till 3kR and floret size got drastically reduced as doses increased showing a detrimental effect. Among the cultivars, Praha bears the biggest size basal floret (9.69 cm) which was statistically par with Tiger flame (9.59cm). Snow princesses produced the smallest size floret (8.72cm). Meanwhile, the interaction between Cultivars and Gamma doses was also significant where the most effective was found in cultivar Tiger flame treated with 1.5kR producing a mean basal floret of (11.10cm) diameter and the smallest basal floret was recorded from Snow princess treated with 6kR (7.83) as seen in Table 2 (b).

Table 2 (a): Effect of different doses of Gamma radiation on flowering characters of Gladiolus

Treatments	Spike emergence (DAP)	Color break stage (DAP)	Basal floret opening (DAP)	Floret/ spike	Diameter of first floret (cm)	Spike length (cm)	Rachis length (cm)	Number of Spikes/ plant	Vase life (days)
Cultivar									
V_1:Praha	77.21	96.13	99.82	11.71	9.69	64.03	31.18	2.33	11.45
V_2: Tiger flame	74.08	92.28	95.85	12.28	9.59	65.90	32.61	2.12	11.87
V_3: Snow princes	78.16	97.20	101.25	10.86	8.72	55.23	25.84	1.53	9.87
S. Em. (±)	**0.097**	**0.302**	**0.195**	**0.155**	**0.136**	**0.179**	**0.200**	**0.063**	**0.062**
C.D. at 5%	**0.284**	**0.881**	**0.567**	**0.452**	**0.397**	**0.522**	**0.583**	**0.182**	**0.181**
Dose									
T_1: 0 kR	76.29	95.62	98.51	11.7	9.91	68.44	32.10	2.17	11.74
T_2: (1.5 kR)	72.37	90.07	93.35	13.33	10.53	75.41	37.47	2.90	13.28
T_3:(3 kR)	73.79	92.00	95.47	13.07	9.55	74.113	37.10	2.40	12.34
T_4:(4.5kR)	78.77	97.96	102.84	10.44	8.71	47.322	22.22	1.33	9.30
T_5: (6kR)	81.21	100.37	104.68	9.54	7.97	43.65	20.49	1.14	8.64
S. Em. (±)	**0.126**	**0.391**	**0.251**	**0.201**	**0.176**	**0.674**	**0.259**	**0.081**	**0.080**
C.D at 5%	**0.336**	**1.137**	**0.732**	**0.584**	**0.512**	**0.232**	**0.375**	**0.235**	**0.233**

Table 2(b): Interaction effect of different doses of Gamma radiation and Gladiolus Cultivar on flowering characters

Treatments	Spike emergence (DAP)	Color break stage (DAP)	Basal floret opening (DAP)	Number of Floret/ spike	Diameter of first floret (cm)	Spike length (cm)	Rachis length (cm)	Number of Spikes/ plant	Vase life (Days)
V_1 x T_1	77.22	98.11	99.44	11.66	10.91	70.88	33.52	2.40	11.55
V_1 x T_2	72.97	91.43	94.45	12.53	11.04	75.51	37.58	3.44	13.98
V_1 x T_3	74.67	93.67	96.67	12.99	9.62	76.89	38.71	2.89	12.76
V_1 x T_4	79.09	96.11	103.24	11.11	8.81	50.22	23.49	1.57	9.75
V_1 x T_5	82.11	101.34	105.32	10.23	8.09	46.66	22.59	1.33	9.19
V_2 x T_1	74.23	90.97	94.47	12.43	10.08	73.73	34.5	2.33	13.00
V_2 x T_2	69.67	86.57	89.53	14.88	11.10	82.52	42.06	3.06	14.63
V_2 x T_3	71.13	88.11	91.87	13.97	9.94	79.14	40.73	2.67	13.33
V_2 x T_4	76.78	97.33	100.96	10.33	8.82	48.31	24.02	1.44	9.52
V_2 x T_5	78.63	98.47	102.42	9.78	7.99	45.76	21.75	1.11	8.87
V_3 x T_1	77.43	97.77	101.64	11.00	8.73	60.69	28.3	1.78	10.69
V_3 x T_2	74.47	92.23	96.09	12.55	9.44	68.21	32.77	2.22	11.24
V_3 x T_3	75.61	94.22	97.89	12.23	9.10	66.31	31.85	1.65	10.92
V_3 x T_4	80.44	100.47	104.31	9.88	8.52	43.43	19.15	1.00	8.64
V_3 x T_5	82.89	101.33	106.31	8.64	7.83	38.52	17.14	1.00	7.87
S. Em. (±)	**0.218**	**0.676**	**0.435**	**0.347**	**0.305**	**0.401**	**0.44**	**0.140**	**0.139**
C.D. at 5%	**0.635**	**1.969**	**1.268**	**1.012**	**0.887**	**1.168**	**1.03**	**0.408**	**0.404**

This was supported by (Dobanda, 2004) in Gladiolus; (Mahure *et al*., 2010) in Chrysanthemum cultivar 'Red Gold' and Chrysanthemum variety 'Maghi'; (Kapadiya *et al*., 2014) who reported that higher gamma doses decreases the size of the floret while lower doses enhance. The decrease in flower size could be credited to the poor growth of the plant as a result of physiological, morphological, or cytological interruption caused by gamma rays on the irradiated plants. As compared to control corms, longer spikes length and Rachis length were observed in corms treated with 1.5kR and 3kR while the corms treated with 4.5kR and 6kR shows detrimental effect where both the spike and rachis length got considerably shorter compared to control. The length of the spikes was measured (75.41 cm) in 1.5 Kr and (43.65 cm) in 6kR treated corms. In the case of Rachis length, the data shows that the corm treated with 1.5kR and 3kR were statistically par measuring (37.47 cm) and (37.10 cm) respectively while the shortest measured (20.49 cm) which was 6kR treated corms. Meanwhile the cultivar Tiger Flame produced the longest Spikes (65.90 cm) and Rachis length (32.61cm) and Snow princess recorded the lowest among the 3 cultivars measuring (55.23 cm) for Spikes and (25.84 cm) for Rachis as shown in Table 2(a).The Cultivars and Gamma doses too showed a significant effect, the best interaction for Spike length (82.52 cm) and Rachis length (42.06 cm) was recorded in cultivar Tiger flame treated with 1.5kR. While the shortest Spike length (38.52 cm) and Rachis length (17.14 cm) was recorded from Snow princess treated with 6kR as shown in Table 2 (b). A similar finding was observed by (Sisodia, 2015b) in 8 Gladiolus varieties and (Singh and Kumar, 2013) in 10 varieties of Gladiolus**.**

The increase in Spike length and Rachis length may be due to rapid activation of necessary growth regulators which in turn increase the plant growth and photosynthetic process

Similarly, the number of spikes per plant was significantly higher in corms that were treated with lower doses of gamma radiations and significantly reduced at higher doses. The number of spikes /plant in 1.5kR treated corms was statistically higher compared to all the treatments recording (2.90 spikes/plant) while the least number was recorded from 6kR treated corms with (1.14 spikes/plant). Besides, both 4.5kR and 6kR doses were found to have a detrimental effect on the corms as they produced fewer spikes beside some plant remains blind. Among the cultivar, spike production was highest in Praha (2.33 spikes/plant) followed by Tiger flame (2.21 spikes/plant) while Snow Princess produced the least spike at (1.53 spikes/plant) as shown in Table 2 (a).In all the cultivars some plants produced blind shoot at higher gamma doses and did not flower at all. The best interaction was recorded from cultivar Praha treated with 1.5kR (3.44 Spikes/Plant) which was statistically par with Tiger flame irradiated with 1.5kR (3.06 spikes/plant) and a mean of 1 spike/plant was recorded from Snow princess treated with 4.5kR and 6kR which was considered the least and it was par with both Praha (1.33 spikes/plant) and Tiger flame (1.11 spikes/plant) treated with 6kR as sown in Table 2(b).. The observation also coincides with finding made by (Patil and Dhaduk, 2009; Karki and Srivastva, 2010; Patil, 2014) who reported spike yield increases in lower doses and decreases in lowers doses. Irradiations increase the photosynthetic and enzyme activities that help to trigger gibberellins and auxins action causing a higher rate of sprouting percentage which produced many spikes per plant. However, at higher irradiation, there are changes in plant metabolic activities that trigger a negative response of plant hormones which led to no or less flower production

From Table 2 (a) it can be seen that, Gamma radiation treatments at lower doses increases the vase life of gladiolus. Corms irradiated with 1.5kR produced higher vase life of (13.28 days) followed by 3kR with (12.34 days). Higher doses reduced the vase life of cut spikes and minimum vase life was recorded from 6kR irradiated with (8.64 days). Cultivar Tiger flame and Praha had recorded maximum vase life of (11.87 days) and (11.45 days), respectively, in comparison to Snow princess (8.97 days). As seen in Table 2(b), Cultivars and Gamma doses were statistically significant and the best interaction was from variety Praha treated with 1.5kR with a vase life of (13.98 days) which is statistically par with the same dose in Tiger flame with (13.33 days). A similar observation was made by (Kumar *et al*., 2003; Misra *et al*., 2006) in Tuberose. An increase in Vase life may be due to a rise in sugar content when irradiated which might have boosted some metabolic processes in the plant subsequently resulting in increasing vase life and longevity of flower in gladiolus.

Morphological changes due to gamma irradiation

Several qualitative changes were observed in the gladiolus plants and flowers in all the three Gladiolus cultivars. In cultivar Praha, plant abnormal spike growth was observed at 4 .5 kR and 6kR dose of gamma irradiation (Figure 1 & 2) and the nodal distance was noticeably decreased, the floret was not grown in sequential order and two flower buds emerged from the nodes in a spike (Figure 3).

Figure 1: Abnormal spike growth in cv. Praha at 4.5

Figure 2: Abnormal spike growths in cv. Praha at 6 kR Irradiation

Whereas in cultivar Tiger flame twining of spike was observed at 4.5kR of gamma irradiation (Figure 4). Emergences of two flower buds from the same nodes in a spike at 4.5kR gamma dose (As shown in Figure 5) and an abnormal emergence of new spike growth from the main spike were observed (Figure 6). And in cultivar snow princess the node length was considerably decreased from 4.5kR and 6kR (Figure 7). In the Praha cultivar, a discolored basal floret was seen at 1.5kR (Figure 8). Flower color mutation was detected in Tiger flame irradiated with 3kR as sectorial chimeric forms, changed in color was only in one or two floret in a spike (Figure 9) which may be due to physiological disturbances caused by reshuffling of histogen layers (Banerji and Datta, 2003). While flower shape variation was observed in the Snow Princess cultivar at 4.5kR, (Figure 10). However, these changes in flower color might be due to the effect of radiation treatments along with the temperature and light that impacted the flower pigmentation. Several studies reported the ionizing radiation effects on the shape, form, and color of the floral organs (Khalaf, 2008) on *Amaranthus caudatus* ; (Singh *et al*,. 2009) in Marigold; (Kumari *et al.*, 2013b and Tarek *et al.*, 2014) in *Chrysanthemum morifolium*; (El-Mokadem and Hoda, 2014) in *Catharanthus roseus*; (Sathyanarayana *et al*., 2019) in Gladiolus. Changes in flower form may be due to chromosomal deletion or change of the factor governing the normal form or structure, as well as to the effect of gamma-rays on the ontogeny of flower organ tissue through the selective destruction of one or more cell layers in the apical floral meristem (Abdel-Maksoud, 1992). However, some of the irradiation responses may be due to point mutations or chromosomal aberrations, and in most cases, the abnormality in plants reverts to normal growth during a recovery period suggesting the basic cause to be a non-genetic physiological disturbance.

Figure 3: Disorder in florets arrangement in cv. Praha at 4.5 kR

Figure 4: Twining of spike in cv. Tiger Flame at 4.5 kR Irradiation

Figure 5: Appearance of double buds from same node in cv. Tiger Flame at 4.5 kR Irradiation

Figure 6: Development of abnormal emergence of new spike from main spike in cv. Tiger Flame at 4.5 kR.

Figure 7: Shortened nodal length in cv. Snow Princess at 6 kR Irradiation

Figure 8: Discolored basal florets in cv. Praha at 1.5 kR Irradiation

Figure 9: Sectorial chimeric in cv. Tiger Flame at 3kR Irradiation

Figure 10: Flower variations in cv. Snow princess at 4.5 kR Irradiations.

Conclusion

From the experimental findings, it can be concluded, that the low doses of gamma rays i.e., 1.5kR to 3kR produced superior vegetative and floral growth compared to control as well as the higher doses of irradiation treatments. The low dose of irradiations ranging from 1.5 to 3 kR was found to be desirable treatments for inducing phenotypical changes. Whereas, at 4.5kR and 6kR irradiation treatment showed a detrimental effect on the overall performance of the plant. The best interaction among the cultivars and Gamma doses was found in V_2 x T_2 (Tiger flame X 1.5kR) with the highest No. of sprout (3.74), Plant height (94.08cm), No. of leaves (12.78), Early spike emergence (69.67 days), Floret per spike (14.88), Spike length (82.52cm) and Vase life (14.63 days). Color changes at the basal floret were observed in Praha from Red to light orange at 1.5kR and chimera was found at 3kR in the Tiger Flame cultivar. And among the cultivars, it was observed that Tiger Flame and Praha responded well to various gamma-ray doses for inducing vegetative and floral characters and may be used for the improvement of varieties.

Conflict of interest

The authors declare that they have no conflict of interest.

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