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HORTICULTURE

Effect of Gamma Irradiation on Vegetative and Propagule Characters in Gladiolus and Induction of Homeotic Mutants

Kiran Kumari* and Santosh Kumar

Department of Horticulture (Floriculture and Landscaping), G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand-263145, India.

*Corresponding author: kiranflorihorti@gmail.com

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Abstract

Uniform and healthy corms of eight gladiolus varieties (Yellow Golden, Nathan Red, White Friendship, American Beauty, Red Majesty, Purple Flora and Algarve) were irradiated with different doses (0, 25, 40, 55 and 70 Gy) of gamma rays from ^{60}Co source and planted under open field condition in Randomized Block Design (RBD) with factorial concept. Each treatment was replicated thrice.Plants treated with higher doses (55 Gy and 70 Gy) showed deleterious effect of ionising radiations although at lowest dose (25 Gy) plants were not affected much. Plant height was reduced after irradiation as compare to untreated plants and was recorded minimum at highest doses. Number of shoots per plant was slightly increased at 25 Gy treatment (1.62) in vM_2 as compare to untreated plants (1.42). Significant effect of gamma irradiation on corm and cormel characters was noticed. Maximum number of corms per plant was recorded in plants treated with 25 Gy and minimum at 70 Gy. Among all the varieties Nathan Red had maximum number (1.75, 1.97) and weight (73.29gm, 79.33gm) of corms per plant in vM_1 as well as vM_2 generation. Number of cormels per plant was also reduced with the increase in gamma rays dose. Maximum number of cormels per plant (227.83) was recorded in the interaction of Algarve variety with 25 Gy gamma ray dose in vM_2. Homeotic mutants were isolated from all the varieties at 55 and 70 Gy except American Beauty and Red Majesty variety.

Highlights

- Dose of 55 and 70 Gy drastically reduced the vegetative growth, corm &cormel number as well as weight
- Among all the varieties maximum number of corms per plant was recorded in Nathan Red and Algarve had maximum number of cormels per plant
- Homeotic mutants were induced at 55 and 70Gy dose in six varieties

Keywords: Gladiolus, gamma rays, corm &cormel, homeotic mutants

Gladiolus is a monocotyledonous flowering bulbous plant, belonging to family Iridaceae and subfamily Ixoideae. **It** is the largest genus in the family Iridiaceae with 260 species, which are mainly native to South Africa. Several species are distributed in western and central Europe, the Mediterranean to Southwest and Central Asia, and Northwest and East Africa (Goldblatt and Manning 1998). Gladiolus, the queen of bulbous ornamentals, is leading geophytes grown worldwide and is very popular because of its majestic spikes having florets of dazzling colours which opens in sequence for longer duration. In floriculture, there is always a demand for new varieties with unique ornamental traits. The primary objective of plant breeding programme is to create variability and to select the best recombinants possessing desirable characteristics. The variability created by any breeding method (hybridization or mutation) enhances the scope for selection. Mutation breeding has played a major role in the development of many new colour/shape mutants in ornamental plants (Broertjes and Van Harten 1988). Gladiolus is vegetatively propagated by corms and its highly heterozygous nature and polyploidy makes the crop ideal material for genetic manipulation through mutation breeding. Therefore, the present experiment was conducted to study the effect of gamma rays on growth and propagule characters and to induce mutants for ornamental traits.

Materials and Methods

The present investigation was carried out during 2012-13 and 2013-14 at Model Floriculture Centre, G.B. Pant University of Agriculture and Technology, Pantnagar. Uniform and healthy corms of gladiolus varieties *viz.* Yellow Golden, Nathan Red, White Friendship, American Beauty, Red Majesty, Purple Flora and Algarve were irradiated with different doses (0, 25, 40, 55 and 70 Gy) of gamma rays at Department of Horticulture, Punjab Agricultural University, Ludhiana. Source of gamma rays was (^{60}Co) Low Dose Irradiator 2000 ANSI- N 433.1. On the following day the irradiated corms were planted on raised beds under open field condition in randomized block design with factorial concept and each treatment was replicated thrice. Untreated plants (0Gy) were considered as control. Data were recorded for different vegetative and propagule characters in the field. Height of plants was recorded at 30 and 60 days. Number of shoots and leaves per mother corm were recorded at full bloom stage. Observations on corm and cormel characters were recorded fifteen days after harvesting of corms and cormels after proper cleaning. Corm diameter was taken with the help of digital vernier caliper in two directions and average was calculated. Corms harvested from vM_1 generation (2012-13) were stored in cold store from June-October and again planted as vM_2 generation in November (2013-14). Data were recorded on all the characters in both years. The analysis of variance of data was done as per design of the experiment as suggested by Gomez and Gomez (1984).

Results and Discussion

Vegetative characters

Gamma irradiation had significant effect on plant height at 30 and 60 days as well as number of shoots per plant in both the generations (Table 1). Untreated plants exhibited maximum plant height in vM_1 generation in all the varieties whereas minimum plant height was recorded in plants treated with 70 Gy. Similar trend was recorded after 60 days in both the generations. The difference between height of control and 25 Gy treated plants was very less whereas a drastic reduction in plant height was recorded at 55 Gy and 70 Gy in both the generation after 30 as well as 60 days which shows that effect of gamma rays was more pronounced at higher doses in all the varieties. These results corroborate observation made by Tiwari *et al.* (2010). Reduction in growth following mutagenic treatments was explained due to auxin destruction and inhibition of auxin synthesis (Gorden 1954) and chromosomal aberration (Gunkel and Sparrow 1961).Number of shoots per plant was counted at full bloom stage.No significant difference was recorded for number of shoots in untreated plants and plants treated with 25 Gy in vM_1 whereas in vM_2 there was slight increase in number of shoots at 25 Gy (1.62) as compare to untreated plants (1.45). A gradual decrease in shoot number was recorded as the dose increased above 25 Gy leading to minimum number of shoots at 70 Gy in both the generations (1.08 and 1.13 shoots per plant in vM_1 and vM_2 respectively). Varietal differences shows that Nathan Red variety exhibited significantly more number of shoots as compare to all other varieties whereas minimum number was exhibited by American beauty which was at par with White Friendship. The interaction of variety Nathan

Table 1. Effect of gamma rays on plant height (cm) at 30 and 60 daysand number of shoots per plant in different varieties of gladiolus

Variety	Generation	Plant height at 30 days (cm)						Plant height at 60 days (cm)						Number of shoots /plant					
		Gamma rays dose (Gy)						Gamma rays dose(Gy)						Gamma rays dose (Gy)					
		0Gy	25 Gy	40Gy	55Gy	70Gy	Mean	0Gy	25 Gy	40Gy	55Gy	70Gy	Mean	0Gy	25 Gy	40Gy	55Gy	70Gy	Mean
Yellow Golden	vM_1	28.25	27.00	19.88	18.48	16.25	21.97	44.28	42.26	40.37	36.25	34.10	39.45	1.21	1.33	1.15	1.21	1.03	1.19
	vM_2	29.83	29.53	22.73	21.32	19.07	24.50	44.86	49.03	44.23	39.20	38.53	43.17	1.38	1.46	1.24	1.24	1.18	1.30
Nathan Red	vM_1	26.83	26.13	18.15	17.77	14.98	20.77	40.30	39.47	36.32	36.07	32.63	36.96	1.89	2.03	1.67	1.55	1.31	1.69
	vM_2	29.27	28.91	20.93	20.62	17.80	23.51	42.36	44.03	41.43	38.12	35.63	40.32	2.10	2.31	2.05	1.47	1.38	1.86
White Friendship	vM_1	24.65	22.33	20.02	18.03	17.00	20.41	44.03	42.80	39.17	35.02	32.77	38.76	1.10	1.26	1.05	1.00	1.21	1.12
	vM_2	27.50	29.73	24.00	22.03	20.93	24.84	46.47	47.03	44.30	39.12	35.63	42.51	1.08	1.32	1.28	1.07	1.00	1.15
Jester Gold	vM_1	28.88	26.67	23.00	20.00	18.67	23.44	48.50	46.70	42.90	37.23	33.5	41.77	1.55	1.63	1.24	1.07	1.00	1.30
	vM_2	30.17	31.53	27.13	23.10	21.60	26.71	49.47	51.20	47.40	39.83	37.00	44.98	1.30	1.57	1.33	1.23	1.00	1.29
American Beauty	vM_1	29.9	30.00	24.00	19.42	17.97	24.26	50.78	49.90	45.20	38.00	34.33	43.64	1.26	1.27	1.00	1.00	1.00	1.11
	vM_2	31.56	32.33	25.47	22.33	20.88	26.52	51.67	53.87	47.50	42.00	37.33	46.47	1.17	1.37	1.10	1.00	1.00	1.13
Red Majesty	vM_1	31.00	29.23	25.78	22.90	19.58	25.70	54.42	52.73	47.07	41.80	36.77	46.56	1.48	1.30	1.10	1.15	1.00	1.21
	vM_2	32.07	33.80	28.70	25.87	22.50	28.59	55.60	57.20	51.43	43.27	39.43	49.39	1.30	1.43	1.17	1.13	1.00	1.21
Purple Flora	vM_1	31.57	28.67	24.67	21.60	17.33	24.77	55.17	52.53	47.43	44.37	38.83	47.67	1.55	1.65	1.24	1.27	1.10	1.36
	vM_2	34.43	34.87	28.53	25.07	22.93	29.17	58.17	57.38	52.47	47.10	41.78	51.38	1.73	1.75	1.49	1.37	1.20	1.51
Algarve	vM_1	30.07	27.67	26.00	21.00	15.30	24.01	46.57	44.17	40.17	36.07	30.50	39.49	1.63	1.80	1.27	1.15	1.00	1.37
	vM_2	30.60	31.90	29.00	23.00	18.37	26.57	49.47	49.43	44.47	38.47	32.13	42.79	1.57	1.73	1.47	1.38	1.30	1.49
Mean (vM_1)		28.89	27.21	22.69	19.9	17.14		48.01	46.32	42.33	38.10	34.18		1.46	1.53	1.22	1.17	1.08	
Mean (vM_2)		30.68	31.58	25.81	22.92	20.51		49.76	51.15	46.65	40.89	37.19		1.45	1.62	1.39	1.24	1.13	
		CD (p=0.05)						CD (p=0.05)						CD (p=0.05)					
		vM_1			vM_2			vM_1			vM_2			vM_1			vM_2		
Gamma Radiation		0.77			0.81			1.11			1.25			0.07			0.08		
Varieties		0.98			1.02			1.41			1.58			0.09			0.11		
Gamma Radiation * Varieties		2.19			2.29			3.15			3.53			0.91			NS		

NS: Non-significant

Table 2. Effect of gamma rays on number of leaves per plant, leaf length (cm) and width (cm) in different varieties of gladiolus

Variety	Gene-ration	Number of leaves/plant						Leaf length (cm)						Leaf width (cm)					
		Gamma rays dose(Gy)						Gamma rays dose (Gy)						Gamma rays dose(Gy)					
		0Gy	25 Gy	40Gy	55Gy	70Gy	Mean	0Gy	25 Gy	40Gy	55Gy	70Gy	Mean	0Gy	25 Gy	40Gy	55Gy	70Gy	Mean
Yellow Golden	vM1	9.72	10.15	8.27	7.67	6.05	8.37	41.41	40.13	35.30	32.27	30.50	35.92	3.05	3.17	2.87	2.71	2.13	2.79
	vM2	11.21	11.24	8.77	7.38	6.98	9.12	40.67	37.70	36.70	34.22	32.05	36.27	3.78	3.53	3.55	3.28	2.64	3.36
Nathan Red	vM1	14.10	14.33	10.52	9.57	7.94	11.29	35.04	34.07	30.90	29.50	26.15	31.13	3.87	3.98	3.08	2.89	2.47	3.26
	vM2	15.76	16.58	13.15	9.07	8.52	12.62	35.90	34.23	33.17	30.73	28.89	32.59	4.23	4.26	3.50	3.32	2.90	3.64
White Friendship	vM1	8.10	8.84	6.98	6.50	7.28	7.54	36.78	35.93	33.45	29.50	27.27	32.59	2.85	3.07	2.72	2.51	2.15	2.66
	vM2	8.05	9.37	8.87	6.95	6.10	7.87	35.90	34.23	33.17	30.73	28.89	32.59	3.19	3.43	3.07	2.94	2.48	3.02
Jester	vM_1	11.02	11.01	7.81	6.39	5.52	8.35	40.08	37.27	35.80	32.60	30.18	35.19	3.74	3.83	3.64	3.13	2.72	3.41
Gold	vM_2	9.22	10.73	8.33	7.33	5.37	8.19	37.17	36.82	34.28	30.56	26.90	33.15	3.96	4.05	3.76	3.57	3.06	3.68
American Beauty	vM_1	10.31	9.96	7.35	6.91	6.48	8.20	36.35	35.93	33.00	30.20	28.07	32.71	3.51	3.65	3.38	3.23	2.70	3.29
	vM_2	9.65	10.91	8.22	6.97	6.49	8.45	37.46	35.72	34.48	31.11	30.82	33.92	3.48	3.71	3.22	2.80	2.72	3.19
Red Majesty	vM_1	10.64	8.37	6.65	6.69	5.69	7.61	40.45	39.83	37.73	36.05	33.43	37.50	3.13	3.23	2.83	2.39	2.35	2.79
	vM_2	9.36	9.36	7.16	6.66	5.75	7.66	41.47	40.75	39.67	36.93	34.55	38.67	3.75	3.80	2.74	2.35	2.22	2.97
Purple Flora	vM_1	11.16	10.78	7.82	6.55	5.61	8.39	36.75	35.10	33.35	30.52	25.07	32.16	3.26	3.37	2.47	2.12	2.00	2.65
	vM_2	12.65	11.59	9.24	7.01	6.03	9.30	37.48	36.60	35.17	32.17	27.43	33.77	4.21	4.70	4.18	3.80	3.38	4.05
Algarve	vM_1	13.05	12.98	8.94	7.59	5.54	9.62	37.65	35.95	34.25	31.42	27.67	33.39	3.90	4.15	3.55	3.07	2.79	3.49
	vM_2	12.55	12.65	10.52	9.25	7.20	10.44	38.96	37.35	35.87	32.42	28.50	34.62	3.84	3.96	3.51	3.20	2.84	4.05
Mean (vM_1)		11.02	10.80	8.04	7.24	6.26		38.06	36.78	34.22	31.51	28.54		3.41	3.56	3.07	2.76	2.41	
Mean (vM_2)		11.06	11.55	9.28	7.58	6.56		38.61	37.11	35.73	32.59	30.06		3.84	3.96	3.51	3.20	2.84	
		CD (p=0.05)						CD (p=0.05)						CD (p=0.05)					
	vM_1			vM_2			vM_1			vM_2			vM_1			vM_2			
Gamma Radiation		0.48			0.60			0.79			0.78			0.10			0.11		
Varieties		0.61			0.76			1.00			0.99			0.12			0.14		
Gamma Radiation * Varieties		1.37			1.71			NS			NS			0.27			0.32		

NS: Non- significant

Table 3. Effect of gamma rays on number of corm and cormels per plant in different varieties of gladiolus

Variety	Gene-ration	Number of corms/ plant						Number of cormels /plant					
		Gamma rays dose (Gy)						Gamma rays dose(Gy)					
		0Gy	25 Gy	40Gy	55Gy	70Gy	Mean	0Gy	25 Gy	40Gy	55Gy	70Gy	Mean
Yellow Golden	vM_1	1.50	1.63	1.32	1.23	1.03	1.34	31.33	23.00	14.75	11.97	11.07	18.42
	vM_2	1.67	1.70	1.48	1.37	1.37	1.52	28.00	19.15	13.06	11.38	10.93	16.50
Nathan Red	vM_1	1.80	2.28	1.93	1.45	1.28	1.75	41.75	32.60	27.27	17.28	16.60	27.10
	vM_2	2.21	2.46	2.05	1.62	1.50	1.97	38.23	33.85	28.64	16.45	18.68	27.17
White Friendship	vM_1	1.23	1.37	1.13	1.05	1.00	1.16	46.08	33.67	23.20	19.50	7.35	25.96
	vM_2	1.31	1.40	1.20	1.07	1.00	1.20	44.16	32.05	24.96	18.02	11.47	26.13
Jester Gold	vM_1	1.27	1.30	1.20	1.03	1.00	1.16	20.50	9.67	7.08	5.79	5.11	9.63
	vM_2	1.33	1.44	1.33	1.25	1.18	1.31	19.97	8.90	8.25	6.73	6.55	10.08
American Beauty	vM_1	1.37	1.43	1.13	1.00	1.00	1.19	15.18	12.05	9.25	9.00	4.67	10.03
	vM_2	1.42	1.37	1.12	1.00	1.00	1.18	14.22	12.63	10.60	9.42	4.97	10.37
Red Majesty	vM_1	1.40	1.47	1.33	1.13	1.00	1.27	32.73	19.75	17.00	12.48	6.18	17.63
	vM_2	1.60	1.63	1.46	1.31	1.22	1.45	31.37	20.87	17.67	12.52	5.72	17.63
Purple Flora	vM_1	1.77	1.83	1.47	1.13	1.00	1.44	77.73	39.90	25.25	10.67	8.15	32.34
	vM_2	2.10	2.23	1.79	1.67	1.30	1.82	76.33	41.63	27.08	13.62	9.27	33.59
Algarve	vM_1	1.45	1.52	1.40	1.28	1.10	1.35	199.90	208.45	167.97	95.73	55.90	145.59
	vM_2	1.57	1.70	1.49	1.23	1.10	1.42	204.01	227.83	170.81	109.14	63.23	155.00
Mean (vM_1)		1.47	1.60	1.37	1.16	1.05		58.15	47.39	36.47	22.80	14.38	
Mean (vM_2)		1.65	1.74	1.49	1.32	1.21		57.04	49.61	37.63	24.66	16.35	
		CD (p=0.05)						CD (p=0.05)					
		vM_1			vM_2			vM_1			vM_2		
Gamma Radiation		0.10			0.15			3.58			3.80		
Varieties		0.13			0.19			4.53			4.81		
Gamma Radiation * Varieties		NS			NS			10.13			10.75		

NS: Non-significant

Table 4. Effect of different doses of gamma rays on corm diameter (mm), weight of corms and cormels per plant (gm) in different varieties of gladiolus

Variety	Generation	Corm diameter (mm)						Weight of corms/ plant (gm)						Weight of cormels/ plant (gm)					
		Gamma rays dose (Gy)						Gamma rays dose(Gy)						Gamma rays dose(Gy)					
		0Gy	25 Gy	40Gy	55Gy	70Gy	Mean	0Gy	25 Gy	40Gy	55Gy	70Gy	Mean	0Gy	25 Gy	40Gy	55Gy	70Gy	Mean
Yellow Golden	vM_1	50.03	43.20	40.20	38.25	36.73	41.68	35.93	38.76	27.68	23.76	23.21	29.87	10.83	8.35	6.40	4.64	3.53	6.75
	vM_2	47.23	43.23	41.18	38.83	37.90	41.68	36.07	37.04	28.15	26.32	24.03	30.32	9.88	8.29	6.71	4.57	3.61	6.61
Nathan Red	vM_1	54.23	49.47	47.23	46.00	45.80	48.55	75.45	86.54	78.66	74.93	50.85	73.29	8.01	6.42	5.06	4.03	2.78	5.26
	vM_2	52.09	50.86	49.88	47.14	46.64	49.32	89.20	92.73	82.49	78.76	53.48	79.33	8.13	6.48	4.97	4.23	2.84	5.33
White Friendship	vM_1	46.50	43.70	42.50	41.00	40.17	42.77	35.80	38.23	31.53	28.87	24.68	31.83	10.03	8.63	5.51	4.9	2.71	6.36
	vM_2	47.96	44.77	42.39	41.93	39.20	43.25	36.15	35.04	32.73	31.42	27.26	32.52	9.92	8.59	5.41	5.19	2.50	6.32
Jester Gold	vM_1	52.27	48.00	42.17	36.50	35.67	42.92	44.79	45.23	35.00	27.92	23.82	35.35	5.69	2.76	0.84	0.66	0.48	2.09
	vM_2	50.74	48.47	42.49	36.57	35.44	42.74	53.22	50.81	28.69	26.52	23.58	36.56	5.60	3.16	0.91	0.78	0.46	2.19
American Beauty	vM_1	51.50	50.77	40.00	38.67	36.77	43.54	38.66	39.05	33.02	27.8	25.70	32.84	5.11	3.30	1.81	1.20	0.42	2.37
	vM_2	52.17	51.43	40.77	38.30	37.20	43.97	40.95	36.45	31.06	27.07	25.29	32.17	5.25	3.44	1.79	1.26	0.49	2.45
Red Majesty	vM_1	47.50	46.43	44.83	37.67	35.83	42.45	52.34	54.33	42.94	32.07	23.04	40.94	4.99	3.39	2.54	1.39	0.67	2.60
	vM_2	46.87	46.07	45.73	38.15	36.47	42.66	61.78	60.22	45.99	31.59	23.20	44.56	5.08	3.54	2.58	1.43	0.6	2.65
Purple Flora	vM_1	47.37	43.17	42.50	40.33	36.83	42.04	57.42	56.50	42.43	35.62	34.26	45.25	8.76	4.81	2.80	0.91	0.72	3.60
	vM_2	47.69	45.96	44.85	40.66	35.95	43.02	61.88	55.80	46.00	38.31	32.15	46.83	8.92	4.70	2.88	1.02	0.69	3.64
Algarve	vM_1	52.77	50.00	49.83	48.33	45.23	49.23	65.08	66.26	60.29	50.82	39.96	56.49	20.2	19.15	12.69	10.88	7.05	13.99
	vM_2	52.04	53.67	50.98	48.99	44.54	50.04	67.61	70.39	59.49	53.96	36.95	57.68	20.36	19.74	12.63	10.75	6.91	14.08
Mean (vM_1)		50.27	46.84	43.66	40.84	39.13		50.69	53.11	43.95	37.72	30.69		9.20	7.10	4.71	3.58	2.29	
Mean (vM_2)		49.60	48.06	44.78	41.32	39.17		55.86	54.81	44.32	39.24	30.74		9.14	7.24	4.74	3.66	2.26	
		CD (p=0.05)						CD (p=0.05)						CD (p=0.05)					
		vM_1			vM_2			vM_1			vM_2			vM_1			vM_2		
Gamma Radiation		1.52			1.72			3.52			3.72			0.62			0.69		
Varieties		1.92			2.18			4.45			4.7			0.78			0.87		
Gamma Radiation * Varieties		4.29			4.87			NS			10.52			1.74			1.94		

NS: Non-significant

Red with 25 Gy dose resulted in maximum number of shoot during both the years (2.03, 2.31 in vM_1 and vM_2 respectively). Stimulatory effect of lower doses of gamma rays on number of shoots was also reported by Patil and Dhaduk (2009).

A significant reduction in number of leaves per plant (Table 2), leaf length and leaf width was recorded with the gradual increase in gamma rays dose. Maximum number of leaves per mother corm (11.02, 11.06) was recorded in control which was at par with leaf number at 25 Gy (10.80, 11.55) whereas minimum number of leaves were recorded (6.26, 6.56 in vM_1 and vM_2, respectively) at 70 Gy. Maximum number of leaves was recorded in variety Nathan Red (11.29, 12.92) whereas variety White Friendship had minimum number (7.54, 7.87) of leaves and was at par with Red Majesty (7.61, 7.66). Leaf length was reduced at all the gamma rays doses as compare to control whereas leaf width was slightly increased at 25 Gy and further decreased with subsequent increase in gamma rays dose in both the generations. Maximum leaf length (37.50, 38.67) was recorded in variety Red Majesty whereas Jester Gold variety exhibited maximum leaf width (3.41, 3.68). These results are in concurrent with findings of Kumari *et al.* (2013), who reported reduction in leaf length in chrysanthemum after 10, 15 and 20 Gy gamma irradiation. Raghava *et al.* (1988) also reported reduction in leaf number, length and width in gladiolus varieties after 5, 10 and 15 krad gamma rays treatment. This significant reduction might be due to poor growth of plant due to radiation damage, which could be due to physiological, morphological and cytological disturbance caused by ionizing radiations.

Corm and cormel characters

Different doses of gamma rays, gladiolus varieties and their interactionhad significant effect on propagule characters i.e. corm and cormel characters (Table 3 &4). Amongst all the treatments, maximum number of corms per plant in vM_1(1.60) generation was recorded in plants irradiated with 25 Gy gamma rays which was significantly higher than the corm number in untreated plants (1.47) as well as rest of the doses. The minimum number of corms per plant (1.05) was recorded at highest dose of gamma rays (70 Gy).Similar trend was recorded in vM_2 generation. In vM_2 generation maximum number of corms (1.75) was recorded at 25 Gy treatment which was at par with control (1.63) while minimum number of corms was recorded at 70 Gy treatment (1.21). A comparison among response of different varieties reveals that Nathan Red had maximum number of corms per plant in vM_1 (1.75) and vM_2 generation (1.97) which was significantly higher than rest of the varieties. The variety American Beauty had minimum number of corms in both the generation.The interaction of varieties Nathan Red with 25 Gy of gamma rays treatment resulted in maximum number of corms (2.28) in vM_1 and (2.46) vM_2 generation. At higher doses of gamma rays corm number was reduced significantly whereas at lower dose (25 Gy) it was increased (vM_1 generation) or at par with untreated plants (vM_2 generation).These results are in close conformity with the work of Misra and Bajpai (1983). The changes in number of corms per plant may be attributed to the fact that due to irradiation treatment, physiology of the plant at higher doses was disturbed which affected photosynthesis and root system resulting in the improper growth of the plants by hampering root system (Grabowska and Mynett 1970) thus adversely affected corm number.

Number of cormels per plant also decreased with gradual increase in gamma rays dose resulting in minimum number at highest dose. Among all the varieties Algarve had maximum number of cormels in vM_1 (145.59) and vM_2 (155) where as Jester Gold and American Beauty exhibited minimum number of cormels (9.63, 10.08 and 10.03, 10.37, respectively). Interaction of different doses of gamma rays with all the varieties shows reduction in cormel number whereas interaction of variety Algarve with 25 Gy gamma rays in vM_2 resulted in more number of cormels (227.83) as compare to control (204.01).

In vM_1 generation maximum corm diameter (50.27 mm) was recorded in control which was significantly higher than the rest of the gamma irradiation

Plate 1.a.Change of stamen into tepal in Yellow Golden b. Twinfloret in Yellow Golden c. Purple Flora mutant without pistils d.Five tepals mutant in Algarvae. e. Purple Flora mutant with increased number of floral organs f.Stamens changing into extra whorl of tepals in Nathan Red g,h. Increase in floral organs in Jester Gold

treatments whereas minimum corm diameter (39.13 mm) was recorded at highest dose i.e. 70 Gy. Further, it is also clear from the data that corm diameter gradually decreased as the gamma irradiation dose increased. In both the generations (vM_1 and vM_2) Algarve variety had maximum corm diameter (49.23mm and 50.04 mm respectively) which was significantly higher than other varieties and statistically at par with Nathan Red variety in both the generations. With the increase in dose of gamma rays weight of corms as well as cormels per plant decreased. Maximum weight of corms was observed in 25 Gy treatment in vM_1 (49.35 gm) and at 0 Gy (53.21) in vM_2 whereas minimum weight of corms was recorded at 70 Gy treatment. Corm weight at 0 Gy and 25 Gy was statistically at par in both the generations**.** Among the varieties, Nathan Red exhibited maximum weight of corms per plant in vM_1 (73.29 gm) as well as vM_2 generation (79.04 gm) while minimum corm weight was exhibited by variety Yellow Golden (29.87, 30.32 in vM_1 and vM_2 respectively). Interaction of variety Nathan Red with 25 Gy gamma irradiation resulted in maximum corm weight per plant in vM_1 (86.54 gm) and M2 (92.73gm) generation while variety Red Majesty with 70 Gy gamma irradiation resulted in minimum corm weight (23.04 gm) in vM_1 and vM_2 (23.20 gm). These results substantiate the findings of Mubarok *et al.* (2011) who reported reduction in bulb characters after gamma irradiation in tubrose.

Significant decrease in cormel weight was recorded as the gamma irradiation dose increased (Table 4). Untreated plants exhibited maximum weight of cormels per plant during vM_1 and vM_2 generation where as 70 Gy treatment resulted in minimum cormel weight during both the generations (2.29 gm and 2.26 gm, respectively). Irrespective of gamma rays, variety Algarve had maximum cormel weight in vM_1 (13.99 gm) and vM_2 (14.08 gm) which was significantly high than the cormel weight of other varieties during both generations. Minimum cormel weight was recorded in variety Jester Gold which was at par with cormel weight of varieties American Beauty, and Red majesty in both generations. Interaction of variety Algarve with 0Gy treatment resulted in maximum weight of cormels per plant in vM_1 (20.20 gm) and vM_2 (20.36 gm) which was at par with cormel weight of Algarve at 25 Gy during both the generations (19.15 gm and 19. 74 gm respectively). American Beauty at 70 Gy resulted in minimum cormel weight in vM_1 (0.42 gm) whereas Jester Gold variety at 70 Gy exhibited minimum cormel weight in vM_2 (0.46gm).

Reduction in corm size and weight after irradiation was also recorded by Banerji *et al.* (2000) in gladiolus cultivars 'Kajal' and "Nilofar'. The low yield at higher doses can be due to the reduced vegetative growth as a result of gamma treatments. The reduction in photosynthethic organs i.e. leaves might be the reason for poduction of less photosynthets which further cased reduction in corm and cormel yield.The reduction in vegetative growth at highest dose (70 Gy) has been so drastic that it failed in translocation of limited photosynthates to the storage organ. Reduction in corm diameter after irradiation was also reported by Bhajantri and Patil (2013) in two gladiolus cultivar when exposed to gamma radiation.

Homeotic mutants

Mutants having change in flower morphology were isolated after exposure to different doses of gamma rays. These mutants were homeotic mutants, having changes in the floral organs i.e. number, size and shape of sepals and petals which are collectively also called tepals in gladiolus and reproductive parts *viz.*stamens and pistils. These changes were noticed in both the generations. Changes were noticed randomly in 55 and 70 Gy treated population and no homeotic mutant was recorded at 25 and 40 Gy. As evident from Plate 1a and 1f, after gamma irradiation in variety Yellow Golden and Nathan red respectively, stamens were changed into petals giving rise to more petals in the whorl. In variety Yellow Golden, stamen was converted to full petal and rest of the stamens were not fully developed where as in Nathan Red some stamens were converted to petals and some were noticed as half developed petal and rudimentary stamen. In Yellow Golden, mutated spikes having twin florets were isolated (Plate 1b). Twin florets and floral abnormalities were also recorded by Sisodia and Singh (2014) in gladiolus at 4.5 krad gamma dose. In Purple Flora variety one homeotic mutant having eight petals and six stigmas was isolated at 55 Gy (Plate 1e). Increase in anthers and petal number was also recorded in one plant of Jester Gold (Plate g and h). In variety Algarve one mutant with five petals and no stigma and anthers was isolated (Plate 1d).

Flowers exist in a tremendous range of forms and sizes. However, this tremendous diversity is underpinned by a surprisingly robust basic floral structure in which a central group of carpels forms on an axis of determinate growth, almost invariably surrounded by two successive zones containing stamens and perianth organs, respectively (Scutt and Vandenbussche 2014). During flower development the meristem verticiles follow an acropital development giving rise to sepal, petal stamen and carpals. The organs present in floral verticils are consequence of interaction of three types of gene products according to ABC model. Homeotic mutations cause cells to misinterpret their positions in early flower development (Bowman *et al.* 1991).Many homeotic mutants, developing defective flowers have been isolated in Arabidopsis, Petunia, Antirrhinum and Lycopersican (Ahloowalia and Maluszynski 2001).In Goethe's theory, stamens are defined as contracted petal so the change of stamens into petals might also be due to the reason that gamma irradiation caused some changes in stamens to expand them into petals again.These homeotic mutants can be further utilized to study the phenomenon of development of different flower organs.

Conclusion

From the present study it is concluded that flower mutants can be induced by gamma rays treatment in gladiolus and higher doses of 55 and 70 Gy are harmful for corm and cormel characters.

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