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Effect of Gamma Irradiation on Vegetative and Floral Traits in French Marigold (*Tagetes patula* L.)

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Abstract

A study was carried out in the Floriculture unit, Department of Horticulture, University of Agricultural Sciences, GKVK, Bengaluru from 2022-2024 on 'Effect of gamma irradiation on vegetative and floral traits in French marigold (*Tagetes patula* L.)'. The experiment was laid out in a randomized complete block design with seven treatments replicated thrice. Six gamma doses *i.e.,* 50 Gy, 100 Gy, 150 Gy, 200 Gy, 250 Gy and 300 Gy and control (untreated) as treatments were imposed on seeds of marigold. In M1 generation, maximum plant height (19.50, 21.50 and 24.50 cm), number of primary branches per plant (4.50, 5.50 and 6.57), number of secondary branches per plant (13.50, 18.50 and 22.50), plant spread at EW (10.50, 14.60 and 18.50 cm), plant spread at NS (12.70, 14.67 and 20.50 cm) was recorded by 50 Gy gamma ray dosage at 30, 60 and 90 DAT, respectively. Minimum days taken for flower bud initiation (36.27), days to fifty per cent flowering (82.60), days taken for full flowering (90.50), maximum flower size (5.07 cm), shelf life (2.17 days), number of flowers per plant (19.50), fresh weight of flowers 10 in (g) (330), fresh weight of flower per m^{-2} (g) (3960), fresh weight of flower per hectare (t/ha) (16.30) were recorded at 50 Gy. Among all the treatments 50 Gy had performed better over other treatments.

Keywords : French marigold, Mutagens, Gamma irradation, Vegetative, Floral traits

Marigold is a promising ornamental plant of family Asteraeae, grown commercially in distant parts of the world retrieved from different species of *Tagetes viz., T. tenuifolia, T. erecta, T. patula, T. lucida.* French marigold (*Tagetes patula* L.) native of Central and South America, especially, Mexico. This is an annual, upright, dense, moderately sized herb, height ranging from 1 to 3 ft having odd-pinnately compound, dentate, oblong green leaves. Flowers are brightly coloured, showy, capitulate inflorescence having ray and disc florets. Marigold plants thrive best in hot and dry as well as humid weather conditions. They grow best throughout the year under both tropical and subtropical conditions, but require mild climatic conditions for optimum growth and flowering. The colours of marigold range from yellow to gold to orange, red and mahogany.

Mutation breeding has paved a way to create genetic diversity and induce desirable characters in existing varieties. Conventional breeding is a time-consuming process for genetic improvement of the floriculture crops. Mutation breeding has emerged as an alternative, efficient and an innovative methodology to produce heritable changes particularly for flower color and quality. Genetic variation is essential in any plant breeding programme for crop improvement. Induced mutations are highly effective to enhance natural genetic resources (Jain, 2006). The initial phase in any crop enhancement initiative involves evaluating genetic variability, achievable through hybridization or induced mutation. Induced mutagenesis emerges as a potent mechanism for instigating intrinsic genetic diversity, crucial for cultivating high-yielding varieties.

Mutation breeding employs both chemical and physical mutagens to induce novel recombination, fostering variability (Smitha *et al*., 2022). Mutations may arise spontaneously or due to exposure to radiation or chemicals. Extensive studies across various crops underscore the efficacy of mutation in provoking variability and crafting cultivars with enhanced traits. This approach plays a pivotal role in crop improvement programs, contributing to the development of resilient and high-performing plant varieties. (Alka *et al*., 2013 and Suna *et al*., 2016). Mutagenic agent like gamma has been widely used for the development of assorted traits of crops but the success of mutation depends on its dose applied. An induced mutation takes lesser time for release of new variety. New varieties developed through mutation breeding are identical to parent variety except for the character improved. Gamma rays are known to influence plant growth and development by inducing cytological, genetical, biochemical, physiological and morphogenetic changes in cells and tissues (Tiwari *et al*., 2010).

Induced mutations in ornamentals comprise traits such as altered flower characters (color, size, morphology and fragrance), leaf characters (form, size and pigmentation), growth habit (compact, climbing and branching) and physiological traits such as changes in photoperiodic response, early flowering, free flowering, improved keeping quality and tolerance to biotic and abiotic stresses. The main advantage of mutation breeding in vegetatively propagated crops is the ability to change one or a few characters of an outstanding variety without altering the unique part of the genotype (Datta, 2014). Induced mutation may produce new genetic variation for plant types in the existing varieties (Anita *et al*., 2011).

Material and Methods

The present investigation was carried out at the Floriculture and Ornamental Section, Department of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru during 2022-24. Geographically the place is located in Eastern dry zone (Zone-5) of Karnataka. The experiment was laid out in randomized complete block design replicated thrice and gamma irradiation doses *viz.,* T_1 (control), T_2 (50 Gy), T_3 (100 Gy), T_4 (150 Gy), T_5 (200 Gy), T_6 (250 Gy) and T_7 (300 Gy) as treatments were imposed on seeds of marigold of variety *Arka Madhu*. The LD_{50} value obtained was 49.46 at 150 Gy.

The seeds of marigold were collected from ICAR - Indian Institute of Horticultural Research, Hesaraghatta, Bengaluru. The seeds were exposed to different doses of Co gamma rays *viz.,* 50Gy, 100Gy, 150Gy, 200Gy, 250 Gy and 300 Gy for 30 seconds at gamma chamber, ICAR - Indian Institute of Horticultural Research, Hesaraghatta, Bengaluru. Untreated seeds were used as control.

Results and Discussion

Plant Height (cm)

The effect of different doses of gamma irradiation had significant impact on plant height at different growth intervals of 30, 60 and 90 DAT (Fig. 1). Among the different doses, the maximum plant height of 19.50, 21.50 and 24.50 cm was recorded at the 50 Gy dose at 30, 60 and 90 DAT, respectively. This was followed by 100 Gy dose, in which plant height of 16.50, 18.53 and 22.53 cm at 30, 60 and 90 DAT, respectively was recorded. The minimum plant height of 12.50, 13.50 and 14.50 cm was recorded at the 300 Gy dose at 30, 60 and 90 DAT, respectively, when compared to the control (15.50, 18.50 and 20.50 cm at 30, 60 and 90 DAT, respectively) in the M_1 generation. This might be due to auxin degradation and inactivates auxin synthesis. These results are in conformity with the findings of Singh *et al.* (2009) in marigold, Banerji and Datta (2002) in chrysanthemum.

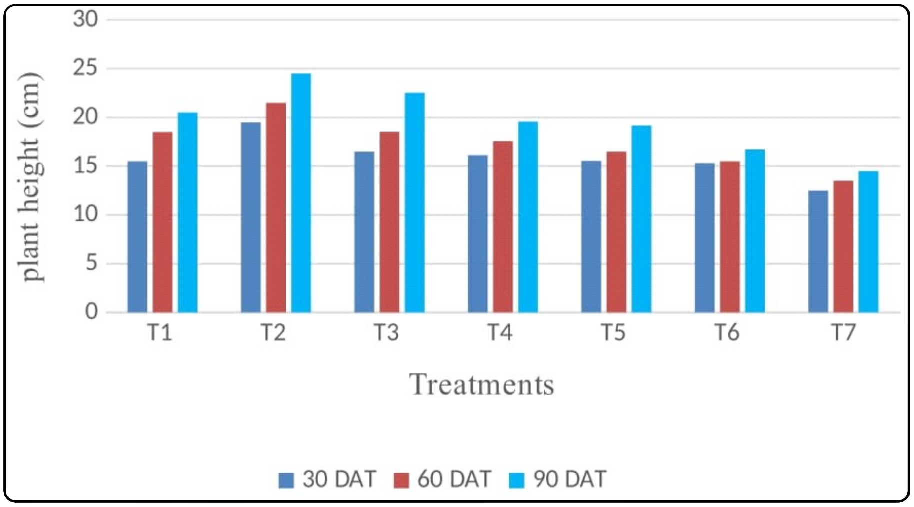

Fig. 1 : Effect of different doses of gamma irradiation on plant height (cm) at different interval in M_1 generation

Plant Spread (N-S) (cm)

The effect of different doses of gamma irradiation had significant effect on plant spread (N-S) at different growth intervals of 30, 60 and 90 DAT (Table 1). Among the different doses, the maximum plant spread of 12.70, 14.67 and 20.50 cm was recorded at the 50 Gy dose at 30, 60 and 90 DAT, respectively. This was followed by the 100 Gy dose, in which plant spread of 9.57, 12.50 and 18.57 cm at 30, 60 and 90 DAT, respectively was recorded. The minimum plant spread of 8.33, 8.50 and 14.60 cm was recorded at the 300 Gy dose at 30, 60 and 90 DAT, respectively, when compared to the control (8.50, 11.50 and 12.50 at 30, 60 and 90 DAT, respectively) in the M_1 generation. These results are in accordance with findings of Singh *et al.* (2009) in marigold, Banerji and Datta (1993) in chrysanthemum and Dhange *et al*., (2023) in stevia.

Plant Spread (E-W) (cm)

The effect of different doses of gamma irradiation had significant impact on plant spread (E-W) at different

Table 1

Effect of gamma irradiation on plant spread (N-S) & (E-W) at different interval in M_1 generation

Gamma rays	Plant spread (N-S) & (E-W) (cm)					
	30 DAT (N-S)	30 DAT (E-W)	60 DAT (N-S)	60 DAT (E-W)	90 DAT (N-S)	90 DAT (E-W)
T_1 (Control)	8.50 ^{b}	8.50 ^{a}	11.50 ^{bc}	12.50 ^{b}	12.50 ^{e}	14.60 ^{b}
T_2 (50 Gy)	12.70 ^{a}	10.50 ^{a}	14.67 ^{a}	14.60 ^{a}	20.50 ^{a}	18.50 ^{a}
T_3 (100 Gy)	9.57 ^{b}	9.57 ^{a}	12.50 ^{b}	12.63 ^{b}	18.57 ^{a}	15.50 ^{b}
T_4 (150 Gy)	9.33 ^{b}	7.57 ^{b}	11.50 ^{bc}	10.57 ^{bc}	17.53 ^{b}	13.57 ^{b}
T_5 (200 Gy)	8.50 ^{b}	7.50 ^{b}	10.57 ^{c}	9.50 ^{c}	16.63 ^{c}	12.60 ^{c}
T_6 (250 Gy)	8.40 ^{b}	7.40 ^{b}	9.50 ^{c}	8.50 ^{d}	15.50 ^{d}	10.57 ^{d}
T_7 (300 Gy)	8.33 ^{c}	7.27 ^{c}	8.50 ^{d}	8.07 ^{d}	14.60 ^{e}	10.10 ^{d}
Grand mean	9.33	8.33	11.25	10.91	16.55	13.63
F test	*	*	*	*	*	*
SEm±	0.09	0.06	0.13	0.11	0.05	0.17
CD (5 %)	0.28	0.20	0.39	0.35	0.15	0.52

growth interval of 30, 60 and 90 DAT (Table 1). Among the different doses, the maximum plant spread of 10.50, 14.60 and 18.50 cm was recorded at the 50 Gy dose at 30, 60 and 90 DAT, respectively. This was followed by the 100 Gy dose, in which plant spread of 9.57, 12.63 and 15.50 cm at 30, 60 and 90 DAT, respectively was recorded. The minimum plant spread of 7.27, 8.07 and 10.10 cm was recorded at the 300 Gy dose at 30, 60 and 90 DAT, respectively, when compared to the control (8.50, 12.50 and 14.60 at 30, 60 and 90 DAT, respectively) in the M_1 generation. These findings were well supported by the work of Singh *et al.* (2009) in marigold and Dhange *et al*., (2023) in stevia.

Number of Primary Branches Per Plant

The effect of different doses of gamma irradiation had significant effect on number of primary branches per plant at different growth intervals of 30, 60 and 90 DAT (Table 2). Among the different doses, the highest number of primary branches, 4.50, 5.50 and 6.57 was recorded at the 50 Gy dose at 30, 60 and 90 DAT, respectively. This was followed by the 100 Gy dose, in which number of primary branches, 3.63, 4.63 and 5.67 at 30, 60 and 90 DAT, respectively was recorded. The lowest number of primary branches, 3.17, 4.10 and 5.27 was recorded at 300 Gy dose at 30, 60 and 90 DAT, respectively, when compared to the control (3.40, 4.17 and 5.47 at 30, 60 and 90 DAT, respectively) in the M_1 generation. These results are in accordance with findings of Singh *et al.* (2009) in marigold and Banerji and Datta (1993) in chrysanthemum.

Number of Secondary Branches Per Plant

The effect of different doses of gamma irradiation had significant impact on number of secondary branches per plant at different growth intervals of 30, 60 and 90 DAT (Table 3). Among the different doses, the highest number of secondary branches, 13.50, 18.50 and 22.50, was recorded at the 50 Gy dose at 30, 60 and 90 DAT, respectively. This was followed by the 100 Gy dose, in which 12.60, 15.60 and 18.57 secondary branches at 30, 60 and 90 DAT, respectively was recorded. The lowest number of secondary branches, 10.07, 12.57 and 13.50 was recorded at the 300 Gy dose at 30, 60 and 90 DAT, respectively, when compared to the control (11.50, 14.53 and 16.47 at 30, 60 and 90 DAT, respectively) in the M_1 generation. These results are in accordance with

TABLE 2

Effect of gamma irradiation on number of primary branches per plant at different interval in M_1 generation

Gamma rays	Number of primary branches per plant		
	30 DAT	60 DAT	90 DAT
T_1 (Control)	3.40 ^{b}	4.17 ^{c}	5.47 ^{b}
T_2 (50 Gy)	4.50 ^{a}	5.50 ^{a}	6.57 ^{a}
T_3 (100 Gy)	3.63 ^{b}	4.63 ^{b}	5.67 ^{ab}
T_4 (150 Gy)	3.53 ^{b}	4.40 ^{b}	5.53 ^{b}
T_5 (200 Gy)	3.50 ^{b}	4.27 ^{c}	5.40 ^{bc}
T_6 (250 Gy)	3.33 ^{b}	4.20 ^{c}	5.30 ^{c}
T_7 (300 Gy)	3.17 ^{b}	4.10 ^{d}	5.27 ^{c}
Grand mean	3.58	4.47	5.60
F test	*	*	*
SE.m±	0.09	0.15	0.08
CD (5 %)	0.27	0.46	0.26

TABLE 3

Effect of gamma irradiation on number of secondary branches per plant at different interval in M_1 generation

Gamma rays	Number of secondary branches per plant		
	30 DAT	60 DAT	90 DAT
T_1 (Control)	11.50 ^{c}	14.53 ^{bc}	16.47 ^{c}
T_2 (50 Gy)	13.50 ^{a}	18.50 ^{a}	22.50 ^{a}
T_3 (100 Gy)	12.60 ^{b}	15.60 ^{b}	18.57 ^{b}
T_4 (150 Gy)	11.50 ^{c}	14.50 ^{bc}	16.60 ^{c}
T_5 (200 Gy)	10.60 ^{d}	14.27 ^{c}	15.73 ^{d}
T_6 (250 Gy)	10.40 ^{d}	13.53 ^{d}	14.23 ^{d}
T_7 (300 Gy)	10.07 ^{d}	12.57 ^{e}	13.50 ^{e}
Grand mean	11.45	14.79	16.80
F test	*	*	*
SE.m±	0.12	0.06	0.13
CD (5 %)	0.38	0.19	0.40

findings of Singh *et al.* (2009) in marigold and Banerji and Datta (1993) in chrysanthemum.

Days Taken for Flower Bud Initiation

The effect of different doses of gamma irradiation on the days taken for flower bud initiation was significant (Table 4). Among the different doses, early flower bud initiation was recorded in the control group (34.50 days), followed by the 50 Gy dose (36.27 days). In contrast, the 300 Gy dose was the late to attain flower bud initiation (40.17 days) in the M_1 generation. This might be due to higher doses of gamma rays inactivate auxins and gibberellins which control flowering and it may also activate inhibitors that delay flowering in marigold. These results are in accordance with findings of Misra and Mahesh (1993) in gladiolus, Misra and Bajpai (1983) and Kumari *et al.* (2013) in chrysanthemum.

Days to 50 Per Cent Flowering

The effect of different doses of gamma irradiation had a significant impact on the days to 50 per cent flowering (Table 4). Among the different doses, the early 50 per cent flowering, 82.60 days, was recorded at the 50 Gy dose. In contrast, the 300 Gy dose recorded the late, 87.50 days, to achieve 50 per cent flowering, when compared to the control (83.50 days) in the M_1 generation. This might be due to higher doses of gamma rays inactivate auxins and gibberellins which control flowering and it may also activate inhibitors that delay flowering in marigold. The days to 50 per cent flower increased with increase in doses of gamma rays in marigold. These results are in accordance with Kumari *et al.* (2013) in chrysanthemum and Dilta *et al.* (2003) in chrysanthemum.

Table 4

Effect of gamma irradiation on days taken for flower bud initiation, days to 50 per cent flowering and days taken for full flowering in M_1 generation

Gamma rays	Days taken for flower bud initiation	Days to 50 per cent flowering	Days taken for full flowering
T_1 (Control)	34.50 ^{d}	83.50 ^{c}	89.50 ^{e}
T_2 (50 Gy)	36.27 ^{cd}	82.60 ^{d}	90.50 ^{d}
T_3 (100 Gy)	37.60 ^{c}	83.53 ^{c}	92.50 ^{c}
T_4 (150 Gy)	38.50 ^{b}	84.53 ^{b}	93.50 ^{bc}
T_5 (200 Gy)	39.50 ^{ab}	85.60 ^{b}	94.50 ^{b}
T_6 (250 Gy)	39.83 ^{ab}	86.50 ^{a}	95.50 ^{ab}
T_7 (300 Gy)	40.17 ^{a}	87.50 ^{a}	96.00 ^{a}
Grand mean	38.05	84.82	93.14
F test	*	*	*
SE.m±	0.20	0.04	0.11
CD (5 %)	0.61	0.14	0.34

Days Taken for Full Flowering

The effect of different doses of gamma irradiation had significant effect on days taken for full flowering (Table 4). The shortest duration to attain full flowering (89.50 days) was recorded in the control, followed by (90.50 days) at the 50 Gy dose. In contrast, the 300 Gy dose resulted in the late to attain full flowering (96.00 days) when compared to the control (89.50) in the M_1 generation. These results are in accordance with Singh *et al.* (2009), they observed that day to bloom increased with increase in doses of gamma rays in marigold. Dilta *et al.* (2003), in chrysanthemum.

Flower Size (cm)

Flower size is one of the important parameters that determines the consumer preference for a specific size of flower. The effect of different doses of gamma irradiation had a significant impact on flower size (Fig. 2). The results clearly indicated that the maximum flower size (5.07 cm) was recorded at the 50 Gy dose, which was significantly better compared to other doses. Conversely, the minimum flower size (3.27 cm) was recorded at 300 Gy dose, when compared to the control (3.74 cm) in the M_1 generation. These results were in confirmation with study of Singh *et al.* (2009) in marigold and Kumari *et al.* (2013) in chrysanthemum.

Shelf life (days)

Shelf life is a significant factor in determining the keeping quality of flowers, as they often need to be

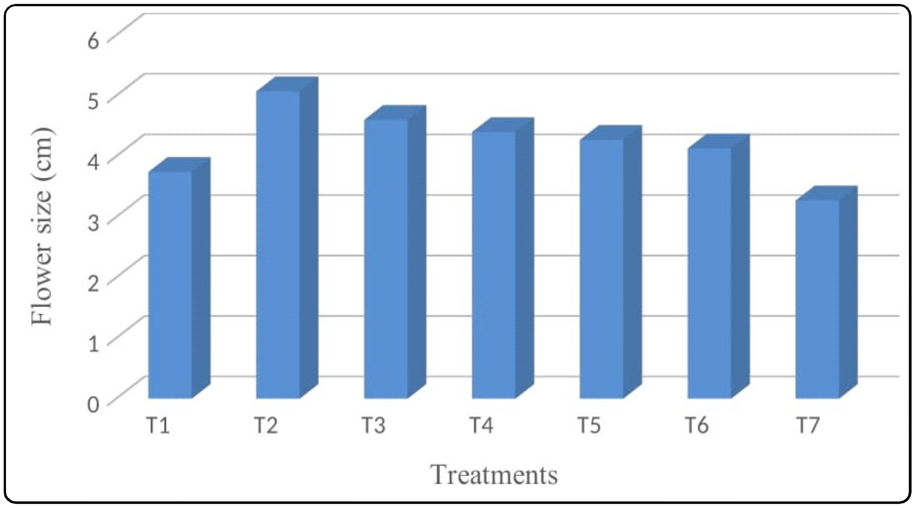

Fig. 2 : Effect of gamma irradiation on shelf life (days) at different interval in M_1 generation

transported over great distances. Longevity indicates whether flowers are suitable for distant markets; otherwise, market values would decline due to a reduction in quality. The effect of different doses of gamma irradiation on the shelf life of marigold had a significant impact (Fig.3). The treatment that provided the best shelf life (4.27 days) was recorded in control, followed by 2.17 days at the 50 Gy dose. In contrast, the lowest shelf life (1.13 days) was recorded at the 300 Gy dose, in the M_1 generation. This might be due to the influence of gamma irradiation on the shelf life of flowers by altering their physiological and biochemical properties.

Number of Flowers Per Plant

The effect of different doses of gamma irradiation had significant effect on number of flowers developed per plant (Table 5). Significant differences were observed among the various treatments of gamma irradiation studied. Among them the highest number of flowers per plant (40.33) was recorded at 50 Gy dose. The least (29.67) production of flowers was noticed at 300 Gy dose when compared to control in M_1 generation. These results are in line with findings of Sisodia and Singh (2014) recorded in gladiolus and Latha and Dharmatti (2018) in marigold.

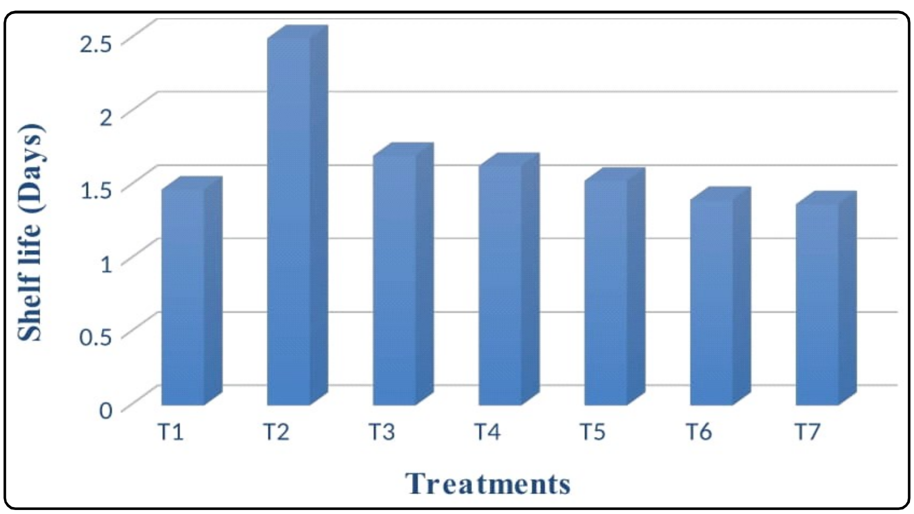

Fig. 3 : Effect of gamma irradiation on shelf life (days) at different interval in M_1 generation

TABLE 5
Effect of gamma irradiation on number of flowers per plant, fresh weight of flower (10) in g, fresh weight of flower per plot, fresh weight of flower per hectare in M_1 generation

TreatmentDoses of gamma ray (Gy)	Number of flowers per plant	Fresh weight of flower (10) in g	Fresh weight of flower per plot	Fresh weight of flower per hectare
T_1 (Control)	31.67 ^{d}	270 ^{e}	3240 ^{f}	13.33 ^{bc}
T_2 (50 Gy)	40.33 ^{a}	330 ^{a}	3960 ^{a}	16.30 ^{a}
T_3 (100 Gy)	37.00 ^{b}	312 ^{b}	3744 ^{b}	15.41 ^{ab}
T_4 (150 Gy)	34.67 ^{b}	280 ^{c}	3360 ^{c}	13.83 ^{b}
T_5 (200 Gy)	33.67 ^{c}	264 ^{c}	3168 ^{d}	13.04 ^{b}
T_6 (250 Gy)	32.33 ^{c}	258 ^{d}	3096 ^{e}	12.74 ^{bc}
T_7 (300 Gy)	29.67 e	196 ^{f}	2352 ^{g}	9.68 ^{d}
Grand mean	34.19	272.85	3274.28	13.47
F test	*	*	*	*
SEm±	0.91	1.304753	15.65704	0.043219
CD (5 %)	2.79	4.020345	48.24414	0.13317

Fresh Weight of 10 - Flowers (g)

The effect of different doses of gamma irradiation had significant effect on fresh weight of 10- flowers (g) (Table 5). The lower doses *i.e.,* 50 Gy gamma irradiation succeeded in achieving a higher fresh weight of flower (330 g) which was significantly higher than all the other treatments. Apart from 50 Gy, good yield performance was exhibited by 100 Gy with (312 g) followed by 150 Gy. Among the treatments, 300 Gy was ranked with the lowest fresh weight (196 g) in M_1 generation. These results are in line with findings Latha and Dharmatti (2018) in marigold.

Fresh Weight of Flowers Per m-^{2} (g)

The effect of different doses of gamma irradiation on fresh weight of flowers per m-^{2} (g) (Table 5). Higher fresh weight of flowers per m-^{2} (g) was recorded at 50 Gy dose (3960 g per m-^{2}), which was due to higher flower weight obtained per plant. On the other hand, lowest fresh weight of flowers per m-^{2} (g) was recorded at 300 Gy dosage of gamma irradiation (2352 g per m-^{2}) due to lower flowers attributed per plant and was significantly different from other treatments studied. These results are in line with findings Latha and Dharmatti (2018) in marigold.

Fresh Weight of Flowers Per Hectare (t/ha)

The effect of different doses of gamma irradiation had significant effect on fresh weight of flowers per hectare (Table 5). Higher fresh flower weight per hectare was recorded at 50 Gy dosage of gamma irradiation (16.30 t/ha) which was considerably superior when compared to the other treatments. Since 300 Gy dosage of gamma irradiation recorded lower fresh flower weight per m-^{2} consequently the fresh flower weight per hectare was found to be lowest (9.68 t/ha). Differences among the doses for fresh flower weight per hectare were highly significant. 50 Gy was followed by 100 Gy with yield (15.41 t/ ha) and 150 Gy (13.83 t/ha) in M_1 generation. These results are in line with findings Latha and Dharmatti (2018) in marigold.

On the basis of present investigation, it may be concluded that gamma irradiation had exerted the significant effect on vegetative and floral traits in Marigold. Gamma irradiation doses at 50 Gy found beneficial for various growth, flowering traits in Marigold. Lower doses of gamma rays *i.e.,* below 50 Gy can be applied in marigold for further crop improvement. There are limited studies on gamma irradiation in marigold using seeds, so the findings of this study on vegetative and floral traits could be used as reference for mutation breeding in other cultivars of marigold.

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