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RESEARCH ARTICLE

Phenotypic characterization and assessment of genetic variability and genetic diversity of elite mutants of *Jasminum auriculatum* Vahl and induction of homeotic mutants

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Abstract

Jasmine is commonly propagated vegetatively, representing a poor genetic diversity base for effective selection to make further improvements in yield and quality. Hence, research conducted at TNAU during 2021-2023 aimed to induce genetic variation in *Jasminum auriculatum* through the application of physical (gamma rays) and chemical (Ethyl Methane Sulphonate; EMS) mutagens. The M_1V_3 generation putative mutants of *J. auriculatum* cv. CO.1 was evaluated under field condition. It was observed that mutants derived from treatments 10 Gy gamma irradiation and 35 mM EMS exhibited maximum vegetative growth parameters, including plant height, stem girth, internodal length, number of leaves, leaf width and leaf thickness and flower quality parameters *viz*., flower bud length and corolla tube length. These values surpassed those of parent CO.1. The phenotypic coefficient of variation (PCV) was prominent than genotypic coefficient of variation (GCV) for all the traits studied, indicating appreciable influence not only by the genetic factor but also highly influenced by the environment. The higher magnitude of broad sense heritability coupled with high genetic advance as % of mean was observed for corolla tube length at 15 Gy, 35 mM and 40 mM, bud girth at 10 Gy and 35 mM, flower diameter at 35 mM. Homeotic mutants were identified and isolated from the mutated population. This study further explored the reliability of the observed traits for making simple selection for efficient improvement of jasmine.

Keywords

Jasminum auriculatum; elite mutants; morphological traits; flowering traits; genetic variability; homeotic mutants

Introduction

Jasminum auriculatum, belonging to the family Oleaceae, is one of the important species of jasmine commercially grown in India. Tamil Nadu is the leading producer and exporter of Jasmine flowers. It is one of the most important commercial species among the 200 species of Jasmine that have been documented earlier (1). Due to the limited genetic diversity in *J. auriculatum* and the absenteeism of high-yielding varieties accessible to farmers, there is a pressing need to enhance its yield and related traits through crop improvement initiatives. This entails implementing programs aimed at increasing genetic variation, thereby facilitating more effective

selection processes (2). The success of any crop improvement programme heavily depends on the presence of genetic variability within the base population. Mutation is acknowledged as a pivotal breeding tool in the creation of novel varieties *via* genetic manipulation. Mutation breeding entails enhancing the genetic makeup of crop plants to cultivate desired economic traits through induced mutations (3). Induced mutation has been identified as the most effective technique for creating morphological and genetic variability in jasmine which is a vegetatively propagated crop. Induced mutation can be done either by physical means or chemical means and it is highly effective in triggering natural genetic changes and creating mutations in plants (4). Homeotic mutants in jasmine refer to genetic variants that cause abnormal development in the floral structure of the jasmine plant. Typically, jasmine flowers have a characteristic arrangement of sepals, petals, stamens and pistils. However, homeotic mutants exhibit changes in the identity or arrangement of these floral organs, leading to altered flower morphology. These mutations can result in a variety of phenotypic changes, such as extra petals. Studying these mutants can provide valuable insights into the genetic regulation of flower development in jasmine and other related plant species (5).

Hence, the objective of this study is assessment of putative mutants in *J. auriculatum* cv. CO.1 from the M_1V_3 generation obtained through physical and chemical mutation using different dosages of gamma radiation and EMS. These findings hold potential for further exploitation in crop improvement efforts, these findings hold potential for further exploitation in crop improvement efforts.

Materials and Methods

Experimental site and planting material

The present study was carried out at the Department of Floriculture and Landscaping, Tamil Nadu Agricultural University, Coimbatore (Latitude of 11000'N, Longitude of 77000'Eand an elevation of 412 m above MSL), Tamil Nadu during 2021-2023.

Mutagenesis (from M_0V_0 generation to M_1V_3 generation)

The semi-hardwood cuttings of CO.1 Mullai were collected from the existing germplasm maintained in under the Department of Floriculture and Landscaping, Tamil Nadu Agricultural University, Coimbatore district, Tamil Nadu The putative mutants were subjected to the various doses of Gamma irradiation (10 to 25 Gy) and Ethyl Methane Sulphonate (EMS) at 35 to 50 mM. The Lethal Dose (LD_{50}) (M_0V_0 generation) was estimated based on the mortality rates in the regression method adopting the probit analysis. The most effective and efficient mutagenic doses for gamma irradiated mutants was between 10 to 20 Gy and EMS treated mutants was between 10 to 20 mM. Based on the doses, the higher frequency of putative mutants was observed in the successive generation *viz*., dwarf mutant, profuse branching mutant, higher yielding mutant and early flowering mutant and these mutants were further utilized for the development of M_1V_1 generation. The M_1V_1 generation mutants were individually screened for variations of phenotypic characters and identified putative mutants from the M_1V_1 generation were forwarded to the M_1V_2 generation through 2-3 nodal cuttings and the resulting M_1V_2 putative mutants were also screened for the variations in the phenotypic characters in comparison with the wild type for various traits to identify and confirm the new variations in the putative mutant population. The M_1V_3 generation mutants were screened on the basis of variations identified in the putative mutants from the M_1V_2 generation.

Data analysis

The morphological and flowering parameters were analyzed using IBM-SPSS software. The coefficient of phenotypic and genotypic variations was calculated according to the formula (3). Broad sense heritability was computed to know the extent of variation due to genotype in the phenotypic variance expressed in percentage (4). The expected genetic advance as expressed in % of mean was calculated (5). Statistical analysis was performed using the statistical package 'TNAUSTAT'. The breeding tool GRAPES 1.1.0 was used to conduct the correlation studies (6). Principal component analysis and basic descriptive statistics were carried using the statistical program STAR 2.0.1.

Results and Discussion

a) M_1V_3 generation of gamma irradiated plants

i) Vegetative parameters

Mutants exposed to 10 Gy exhibited increased plant height (65.7 cm), stem girth (7.7 mm), internodal length (5.4 cm), number of leaves (64.4), leaf width (3.9 cm) and leaf thickness (0.6 mm) compared to the control. Additionally, the occurrence of abnormal leaves was lower in 10 Gy mutants (4.9 %) compared to 25 Gy mutants (27.7 %). In contrast, mutants exposed to 15 Gy showed higher numbers of primary and secondary branches and longer leaf length (4.2, 10.9 and 5.0 cm) compared to the control (3.8, 10.9 and 4.7 cm). Chlorophyll variations were also observed in putative mutants (Fig. 1). The reduction in growth may result from factors such as premature cell differentiation, inactivation, decreased auxin content and cumulative expression of delayed mitotic cycles due to increased radiation doses (7).

ii) Flowering parameters

In the 15 Gy dose, earliest flowering (121.2 days), highest number of flowering cymes / branch (11.0), largest bud girth (3.2 mm), and heaviest 100-flower bud weight (16.7 g) were observed compared to the control (140.0 days, 8.3 cymes per branch, 2.9 mm and 16.2 g). Additionally, maximum flower bud length (3.3 cm), corolla tube length (2.0 cm) and flower diameter (3.3 cm) were also observed in the 10 Gy group compared to the control (3.0 cm, 1.8 cm, and 2.4 cm) (Table 2 and Fig. 2). The decreasing trend in vegetative growth traits such as stem length, number of leaves and leaf length with increasing gamma irradiation dose can be attributed to the inhibitory influence of the

Fig. 1. Chlorophyll variations in putative mutants of gamma irradiated and EMS treated mutants

Table 1. Vegetative growth parameters of M_1V_3 generation of gamma irradiated plants of *J. auriculatum* cv. CO.1 Mullai

Gamma ray dose	Plant height (cm)	No. of primary branches	No. of secondary branches	Stem girth (mm)	Internodal length (cm)	No. of leaves	Leaf length (cm)	Leaf width (cm)	Leaf thickness (mm)	Abnormal leaves (%)
					Gamma irradiation					
Control	64.7 ± 0.46	3.8 ± 0.03	10.9 ± 0.10	7.0 ± 0.05	4.6 ± 0.04	56.5 ± 0.65	4.7 ± 0.03	3.1 ± 0.02	0.4 ± 0.05	8.2 ± 0.15
	(2.6)	(2.6)	(3.4)	(2.5)	(3.1)	(4.5)	(2.79)	(3)	(10.2)	(7.3)
10 Gy	65.7 ± 0.93	3.8 ± 0.07	9.2 ± 0.16	7.7 ± 0.28	5.4 ± 0.10	64.4 ± 1.26	4.5 ± 0.18	3.9 ± 0.25	0.6 ± 0.07	4.9 ± 0.27
	(5.5)	(7.0)	(6.8)	(14.4)	(7.5)	(7.6)	(15.3)	(24.9)	(14)	(20.7)
15 Gy	61.2 ± 1.01	4.2 ± 0.12	10.9 ± 0.22	7.5 ± 0.10	4.0 ± 0.10	59.4 ± 1.10	5.0 ± 0.08	3.1 ± 0.08	0.2 ± 0.04	10.6 ± 0.35
	(6.4)	(11.5)	(7.8)	(4.8)	(9.8)	(7.1)	(6.0)	(9.8)	(12.3)	(12.9)
20 Gy	55.9 ± 1.26	3.6 ± 0.07	8.2 ± 0.21	7.3 ± 0.08	3.3 ± 0.08	54.9 ± 1.45	4.8 ± 0.10	3.0 ± 0.07	0.4 ± 0.08	17.0 ± 0.21
	(8.7)	(7.4)	(10.0)	(4.4)	(9.2)	(10.2)	(7.8)	(8.6)	(9.4)	(4.8)
25 Gy	50.2 ± 0.78	3 ± 0.05	9.7 ± 0.16	6.8 ± 0.08	3.0 ± 0.07	57.6 ± 1.24	4.3 ± 0.06	2.7 ± 0.04	0.3 ± 0.07	27.7 ± 0.40
	(6.0)	(5.9)	(6.5)	(4.2)	(8.4)	(8.4)	(5.3)	(6.0)	(8.4)	(5.5)

Values are [Mean ± Standard Error]

(co-efficient of variation)

Table 2. Flowering parameters of M_1V_3 generation of gamma irradiated plants of *J. auriculatum* cv. CO.1 Mullai

Gamma ray dose	Days to flowering	No. of flowering cymes / branch	Flower bud length (cm)	Corolla tube length (cm)	Bud girth (mm)	Flower diameter (cm)	100 flower bud wt. (g)
				Gamma irradiation			
Control	140.0 ± 0.89	8.3 ± 0.06	3.0 ± 0.03	1.8 ± 0.01	2.9 ± 0.03	2.4 ± 0.03	16.2 ± 0.13
	(2.4)	(2.7)	(3.3)	(2.9)	(4.5)	(4.5)	(3)
10 Gy	128.8 ± 1.58	9.4 ± 0.10	3.3 ± 0.08	2.0 ± 0.03	2.3 ± 0.08	3.3 ± 0.09	15.7 ± 0.23
	(4.8)	(3.9)	(9.4)	(5.8)	(13.4)	(10.2)	(5.7)
15 Gy	121.2 ± 1.58	11.0 ± 0.16	2.9 ± 0.05	1.4 ± 0.05	3.2 ± 0.05	3.2 ± 0.06	16.7 ± 0.25
	(5)	(5.7)	(6.3)	(12.4)	(6.2)	(6.8)	(5.7)
20 Gy	132.8 ± 1.97	9.5 ± 0.16	2.7 ± 0.09	1.7 ± 0.05	2.8 ± 0.13	3.2 ± 0.05	12.9 ± 0.23
	(5.7)	(6.3)	(12.6)	(10.0)	(17.4)	(6.1)	(6.9)
25 Gy	143.8 ± 1.44	7.5 ± 0.09	3.0 ± 0.04	1.2 ± 0.04	3.1 ± 0.10	3.1 ± 0.06	12.6 ± 0.24
	(3.9)	(4.8)	(4.8)	(11.5)	(12.2)	(7.0)	(7.4)

Values are [Mean ± Standard Error]

(co-efficient of variation)

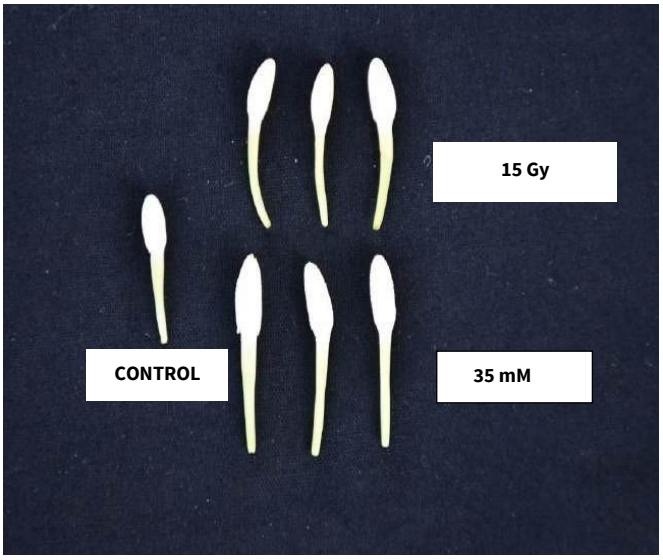

Fig. 2. Variations for flower bud size and corolla tube length in putative mutants of gamma irradiated and EMS treated mutants

mutagenic agents (8).

b) M_1V_3 generation of EMS treated plants

i) Vegetative parameters

The height of the plant (66.9 cm), number of primary (4.0) and secondary branches (14.5), stem girth (6.1 mm), internodal length (5.2 cm), number of leaves (62.6), leaf length (4.5 cm), leaf width (3.0 cm) and leaf thickness (0.2 mm) were found to be maximum in the 35 mM treated plants when compared to control with plant height (62.0 cm), number of primary (3.0) and secondary branches (8.2), stem girth (5.0 mm), internodal length (5.0 cm), number of leaves (51.7), leaf length (3.4 cm), leaf width (2.5 cm) and leaf thickness (0.1 mm). The minimal number of abnormal leaves was found (6.9 %) in 35 mM and the maximum of 17.2 % was observed in 50 mM (Table 3). Leaf variations were also observed in putative mutants (Fig. 1). A similar trend was reported earlier in tuberose, wherein enhancement in vegetative characters with the increase in dosage of mutagen to a certain level (9).

ii) Flowering parameters

Fig. 3. Variations in flower petal number in putative mutants of gamma irradiated plants (10 Gy)

The chemical mutagen EMS at the dosage of 35 mM induced earlier flowering mutants with significant enhancements in various floral traits compared to the control. These mutants exhibited shorter flowering time (133.0 days), higher number of flowering cymes per branch (11.4), increased flower bud length (2.8 cm), longer corolla tube length (1.6 cm), wider bud girth (2.8 mm) and larger flower diameter (3.3 cm). However, the 100-flower bud weight was highest in plants treated with 40 mM EMS (17.2 g) compared to the control (11.0 g) (Table 4). Notably, variations in flower bud and corolla tube length were observed among the putative mutants, indicative of the stimulatory effect of EMS on growth rate and early reproductive phase initiation.

c) Variability parameters of M_1V_3 generation of cv.CO 1 Mullai mutants

Progeny selection would be effective for the traits controlled by additive gene effect The M_1V_3 generation mutants showed significant variability in flowering traits, indicating a prevalence of additive gene effects. This suggests that simple selection methods would effectively enhance these traits. Optimal dosages of gamma (10 Gy and 15 Gy) and EMS (35 mM and 40 mM) treatments positively impacted vegetative growth and flowering traits compared to the control, despite wide variations observed

Table 3. Vegetative growth parameters of M_1V_3 generation of EMS treated plants of *J. auriculatum* cv. CO.1 Mullai

Dose	Plant height (cm)	No. of primary branches	No. of secondary branches	Stem girth (mm)	Internodal length (cm)	No. of leaves	Leaf length (cm)	Leaf width (cm)	Leaf thickness (mm)	Abnormal leaves (%)
					EMS treatment					
Control	62.0 ± 1.89 (8.9)	3.9 ± 0.06 (5.9)	8.1 ± 0.25 (11.8)	5.9 ± 0.21 (8.9)	5.1 ± 0.04 (3.0)	81.7 ± 1.89 (8.9)	3.4 ± 0.13 (9.2)	2.5 ± 0.10 (5)	0.2 ± 0.03 (4.2)	7.4 ± 0.17 (8.9)
35 mM	66.9 ± 3.50 (19.2)	4.0 ± 0.13 (12.6)	14.5 ± 0.49 (13.1)	6.1 ± 0.40 (12.6)	5.2 ± 0.08 (5.6)	62.6 ± 3.65 (12.6)	4.5 ± 0.25 (14.4)	3.0 ± 0.19 (7.9)	0.2 ± 0.02 (4.4)	6.9 ± 0.25 (14.1)
40 mM	62.8 ± 3.17 (19.5)	3.8 ± 0.11 (11)	1.0 ± 0.44 (14.2)	6.0 ± 0.35 (18.7)	4.9 ± 0.11 (8.2)	61.2 ± 3.12 (19.7)	4.1 ± 0.24 (18.3)	2.9 ± 0.17 (9.2)	0.1 ± 0.05 (5)	8.6 ± 0.20 (8.9)
45 mM	54.3 ± 3.14 (20.4)	3.3 ± 0.10 (11.6)	10.1 ± 0.41 (15.4)	6.1 ± 0.34 (18.8)	4.6 ± 0.12 (9.8)	53.9 ± 3.40 (20.4)	4.1 ± 0.22 (20.0)	2.3 ± 0.19 (11.3)	0.2 ± 0.05 (6.7)	13.8 ± 0.24 (6.6)
50 mM	53.8 ± 3.08 (20.8)	3.5 ± 0.21 (12.3)	10.6 ± 0.27 (9.8)	6.2 ± 0.21 (13.0)	5.0 ± 0.07 (5.0)	57.9 ± 1.92 (12.8)	4 ± 0.16 (13.9)	2.8 ± 0.12 (16.5)	0.1 ± 0.04 (7.3)	17.2 ± 0.21 (4.6)

Values are [Mean ± Standard Error]
(co-efficient of variation)

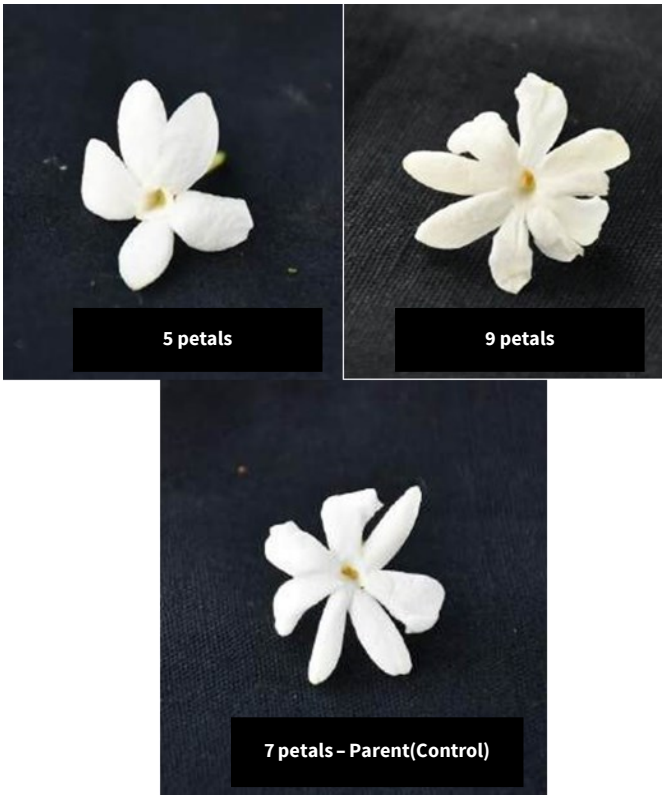

Fig. 4. Variations in flower petal numbers of putative mutants of EMS treated plants (35 mM)

in all treated plants.

i) Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV)

The Tables 1 and 2 show the variability in the vegetative characters and flowering characters of the treated mutants in which the estimates of phenotypic coefficient of variation (PCV) were higher than genotypic coefficient of variation (GCV) for all the characters under the study, indicating that the variation was not only due to the genotypes but it was also influenced by the environment. These results were in accordance with the research in Mysuru Mallige (11).

The high magnitude for PCV (%) and GCV (%) observed for most of the characters *viz*., stem girth, leaf length, leaf width, leaf thickness and corolla tube length (Table 5 and 6) showed the wider diversity for these characters and selection of the above traits would be effective with a high scope for genetic improvement of the crop.

ii) Broad sense heritability (%) and genetic advance as percent of mean (%)

The selection of any trait depends not only on the amount of variability, but it also depends on the extent to which the variability of the character is heritable. In genetic variability studies, basis of broad sense heritability and genetic advance analysis is to assess the extent to which phenotypic variation within a population is attributable to genetic factors and to estimate the potential for genetic improvement by simple selection.

High genetic advance as % of mean (more than 20 %) was observed for traits *viz*., plant height, number of primary and secondary branches, stem girth, internodal length, number of leaves, leaf length and width, leaf thickness, corolla tube length, bud girth and flower diameter at 35 mM (Table 6). These findings are in accordance with earlier observation in marigold with respect to certain traits *viz*., plant height, number of branches and flower diameter (13). In the present study, the highest estimates of broad sense heritability (more than 60 %) coupled with high genetic advance as % of mean (more than 20 %) indicate that most likely the broad sense heritability is due to additive gene effects and hence selection may be effective for the improvement of traits *viz*., plant height, number of primary and secondary branches, stem girth, number of leaves, leaf length, leaf width, leaf thickness, corolla tube length, bud girth and flower diameter (Table 5 and 6). This result is in accordance with the findings of black gram (14). Broad sense heritability and genetic advance are regarded as the fundamental metrics in quantifying the genetic variability

Table 4. Flowering parameters of M_1V_3 generation of EMS treated plants of *J. auriculatum* cv. CO.1 Mullai

Dose	Days to flowering	No. of flowering cymes / branch	Flower bud length (cm)	Corolla tube length (cm)	Bud girth (mm)	Flower diameter (cm)	100 flower bud wt. (g)
				EMS treatment			
Control	147.0 ± 2.28 (5.9)	7.9 ± 0.18 (8.9)	2.1 ± 0.05 (9.2)	2 ± 0.05 (9.1)	2.3 ± 0.06 (9.2)	2.1 ± 0.05 (9.1)	11.0 ± 0.26 (9.2)
35mM	133.0 ± 3.87 (11.2)	11.4 ± 0.33 (11.3)	2.8 ± 0.09 (12.3)	1.6 ± 0.08 (19.3)	2.8 ± 0.11 (14.8)	3.3 ± 0.12 (14.0)	15.2 ± 0.50 (12.7)
40mM	142.4 ± 3.93 (10.6)	10.1 ± 0.30 (11.6)	2.7 ± 0.09 (12.7)	1.3 ± 0.09 (20.0)	2.4 ± 0.09 (15.0)	3.2 ± 0.10 (11.5)	17.2 ± 0.44 (10.0)
45mM	139.4 ± 3.71 (10.2)	9.0 ± 0.30 (12.9)	2.6 ± 0.09 (10.7)	1.5 ± 0.10 (20.5)	2.7 ± 0.13 (18.4)	3.1 ± 0.09 (10.9)	15.5 ± 0.43 (10.8)
50mM	143.8 ± 2.45 (12.2)	9.0 ± 0.57 (14.2)	2.6 ± 0.10 (14.3)	1.4 ± 0.07 (19.2)	2.4 ± 0.06 (7.2)	2.7 ± 0.09 (12.7)	12.9 ± 0.34 (10.1)

Values are [Mean ± Standard Error]
(co-efficient of variation)

Table 5. Estimates of genetic variability in morphological parameters of mutants

Sl. No.	Characters	Treatment	PCV(%)	GCV(%)	H (%)	GAM(%)
1	Plant height (cm)	10 Gy	5.5	4.7	75.2	8.5
		15 Gy	6.3	5.6	78.7	10.3
		35 mM	20.2	17.0	70.7	29.5
		40 mM	19.5	15.6	64.2	25.8
2	Number of primary branches	10 Gy	7.0	6.5	86.3	12.5
		15 Gy	11.4	11.2	95.6	22.5
		35 mM	12.6	11.2	78.3	20.4
		40 mM	11.0	9.1	69.1	15.7
3	Number of secondary branches	10 Gy	6.7	5.4	65.2	9.1
		15 Gy	7.8	7.0	81.4	13.1
		35 mM	13.1	11.3	74.2	20.1
		40 mM	14.2	11.7	67.7	19.8
4	Stem girth (mm)	10 Gy	14.3	14.1	97.3	28.8
		15 Gy	4.8	4.2	77.7	7.7
		35 mM	24.6	21.0	73.2	37.1
		40 mM	20.7	16.8	65.8	28.1
5	Internodal length (cm)	10 Gy	7.4	6.9	86.9	13.3
		15 Gy	9.8	9.1	86.4	17.5
		35 mM	5.6	4.8	72.4	8.4
		40 mM	22.5	18.7	85.7	14.5
6	Number of leaves	10 Gy	7.5	6.4	72.9	11.3
		15 Gy	7.1	5.7	64.5	9.5
		35 mM	22.6	19.3	73.3	34.1
		40 mM	8.9	4.6	63.5	25.8
7	Leaf length (cm)	10 Gy	15.3	15.0	96.4	30.4
		15 Gy	6.0	5.4	81.6	10.1
		35 mM	23.7	20.0	71.6	35.0
		40 mM	22.5	18.7	69.3	32.1
8	Leaf width (cm)	10 Gy	24.9	24.8	99.0	50.9
		15 Gy	9.8	9.3	90.2	18.2
		35 mM	24.5	20.7	71.4	36.0
		40 mM	22.3	17.6	62.0	28.6
9	Leaf thickness (mm)	10 Gy	47.0	34.3	63.3	51.6
		15 Gy	72.3	56.5	61.0	90.9
		35 mM	33.9	33.3	96.9	67.7
		40 mM	89.0	70.9	63.5	86.5
10	Abnormal leaves (%)	10 Gy	20.7	16.8	36.1	28.2
		15 Gy	12.9	11.5	40.7	21.4
		35 mM	14.1	10.2	53.0	15.4
		40 mM	8.9	4.6	27.0	5.0

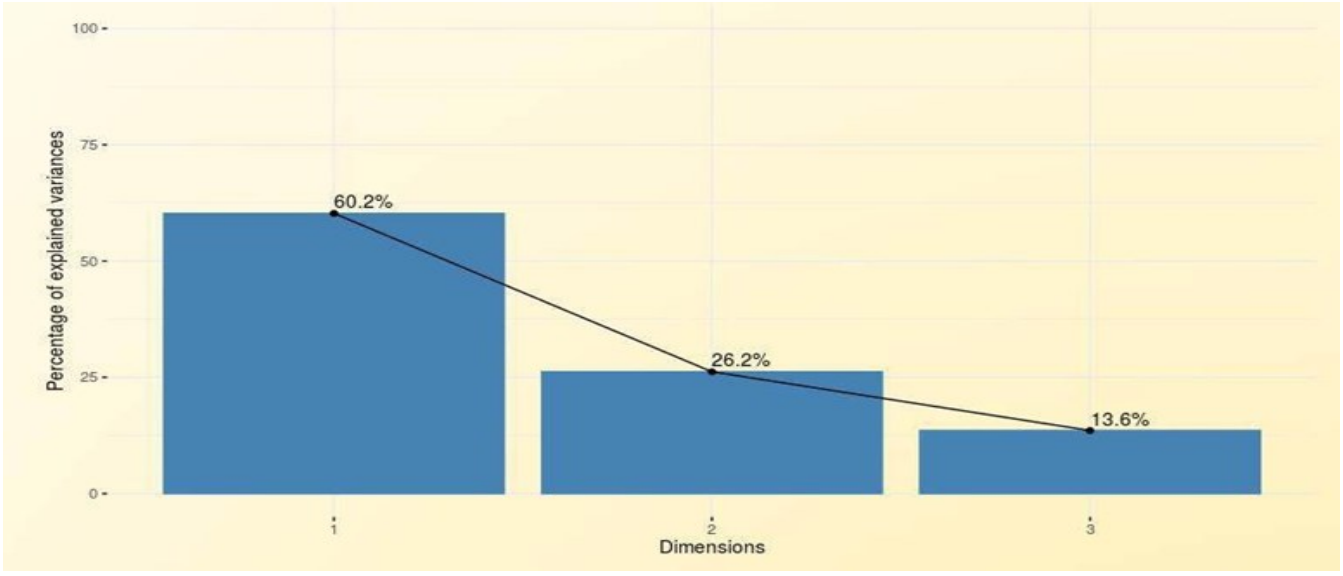

Fig. 5. Screen plot of variables of gamma irradiated plants

Table 6. Estimates of genetic variability in flowering parameters of mutants

Sl. No.	Characters	Treatment	PCV (%)	GCV (%)	H (%)	GAM (%)
1	Days to flowering	10 Gy	4.7	3.9	68.7	6.7
		15 Gy	5.0	4.0	68.7	7.1
		35 mM	11.2	9.1	65.3	15.1
		40 mM	10.6	8.7	66.4	14.6
2	Number of flowering cymes / branches	10 Gy	3.9	3.1	64.9	5.2
		15 Gy	5.7	5.3	87.5	10.2
		35 mM	11.3	9.4	69.5	16.1
		40 mM	11.6	9.2	63.4	15.1
3	Flower bud length (cm)	10 Gy	9.4	8.9	89.1	17.3
		15 Gy	6.3	5.3	70.7	9.2
		35 mM	12.3	10.0	66.3	16.9
		40 mM	12.7	10.3	66.5	17.4
4	Corolla tube length (cm)	10 Gy	5.8	5.2	79.8	9.5
		15 Gy	12.4	11.8	91.6	23.4
		35 mM	19.3	15.4	63.8	25.4
		40 mM	25.0	20.6	67.8	35.0
5	Bud girth (mm)	10 Gy	13.4	12.2	82.5	22.8
		15 Gy	6.2	4.6	55.4	7.1
		35 mM	14.8	12.6	73.2	22.3
		40 mM	15.0	12.0	64.4	19.9
6	Flower diameter (cm)	10 Gy	10.2	9.6	89.4	18.8
		15 Gy	6.8	6.0	77.9	11.0
		35 mM	14.0	12.7	82.6	23.8
		40 mM	11.5	9.9	74.3	17.6
7	100-flower bud weight (g)	10 Gy	5.7	4.8	70.7	8.3
		15 Gy	5.7	4.8	73.8	8.6
		35 mM	12.7	10.8	72.6	19.0
		40 mM	10.0	8.0	64.8	13.3

of traits within a population and guiding breeding efforts to enhance desirable traits in crops.

d) Genetic diversity

Principal component analysis

Principal component analysis (PCA) is used to determine the extent of genetic diversity among the mutated population. It is used to determine which plant attributes account for the majority of the observed variation among the mutated population. It was done to reduce the dimensionality of the parameter dataset and to identify the new underlying variables (15).

i) Gamma irradiated plant

Eigen values, % of variation and % contribution of each variable

Eigen values of more than 1 was observed in all 3 principal components (PC1 to PC3), *viz.,* 9.63, 4.19 and 2.17 respectively, that contributed 60.24 % of the total divergence in this study (Table 7). The % of variation in relation with each principal component could be demonstrated by a screen plot, obtained by a graph between eigen values and principal component numbers (Fig. 5). From the graph, it could be observed that the first principal component PC1 had eigen value 9.63, with 60.24 %. The graph gradually decreased with decreasing eigen value with increasing principal components. The maximum contribution to the variance was due to PC1 (60.24 %) followed by PC2 (26.19 %) and PC3 (13.56 %). The PC1 showed maximum contribution of variables on principal components with traits *viz*., such as plant height number of primary and secondary branches,

Table 7. Eigen values of Gamma irradiated plants

Principal component	Eigen value	% of variance	Cumulative % of variance
PC1	9.6	60.2	60.2
PC2	4.1	26.1	86.4
PC3	2.1	13.5	100.0

stem girth, number of leaves, leaf length, leaf width, days to flowering, number of flowering cymes / branch, flower bud length, corolla tube length, flower diameter and 100-flower bud weight as given in the Table 8 (Fig 6). These results are in accordance with the principal component analyses for contributing characters in Mysuru jasmine (16).

ii) EMS treated plants

Eigen values, % of variation and % contribution of each variable

Eigen values of more than 1 was recorded in all 3 principal components (PC1 to PC3), *viz.,* 9.26, 4.25 and 2.47 respectively, that contributed 60.2% of the total divergence in this study (Table 9). The % of variation in relation with each principal component could be demonstrated by a screen plot, obtained by a graph between eigen values and principal component numbers (Fig. 7). From the graph, it could be observed that the first principal component PC1 had eigen value 9.268, with 60.2 %. The graph gradually decreased with decreasing eigen value with increasing principal components. The maximum contribution to the variance was due to PC1 (60.2 %) followed by PC2 (26.2 %) and PC3 (13.6 %). The PC1 showed maximum contribution of variables on principal components with traits such as plant height, number of primary branches, number of secondary branches, number of leaves, leaf length, leaf width, days to flowering, number of flowering cymes / branch, flower bud length, corolla tube length, flower diameter and 100-flower bud

Table 8. % contribution of variables on principal components of Gamma irradiated plants

Variables	PC1	PC2	PC3
Plant height	8.0	5.3	0.05
Number of primary branches	9.8	0.3	1.7
Number of secondary branches	4.7	5.5	14.1
Stem girth	10.0	0.5	0.2
Internodal length	7.0	7.5	0.2
Number of leaves	9.0	0.5	4.5
Leaf length	5.7	8.2	4.7
Leaf width	5.7	1.2	18.2
Leaf thickness	0.7	20.4	3.2
Days to flowering	9.0	0.8	4.3
Number of flowering cymes / branch	7.4	6.6	0.3
Flower bud length	1.3	16.3	8.6
Corolla tube length	3.9	2.3	24.1
Bud girth	0.6	20.7	2.9
Flower diameter	8.9	3.0	0.3
100-flower bud weight	7.5	0.2	12.3

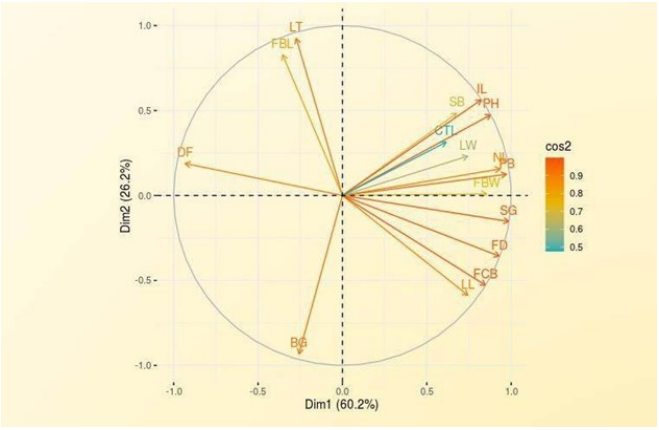

Fig. 6. Contribution of varibles on principal component of gamma irradiated plants

Table 9. Eigen values of EMS treated plants

Principal component	Eigen value	% of variance	Cumulative % of variance
PC1	9.2	57.9	57.9
PC2	4.2	26.6	84.5
PC3	2.4	15.4	100.0

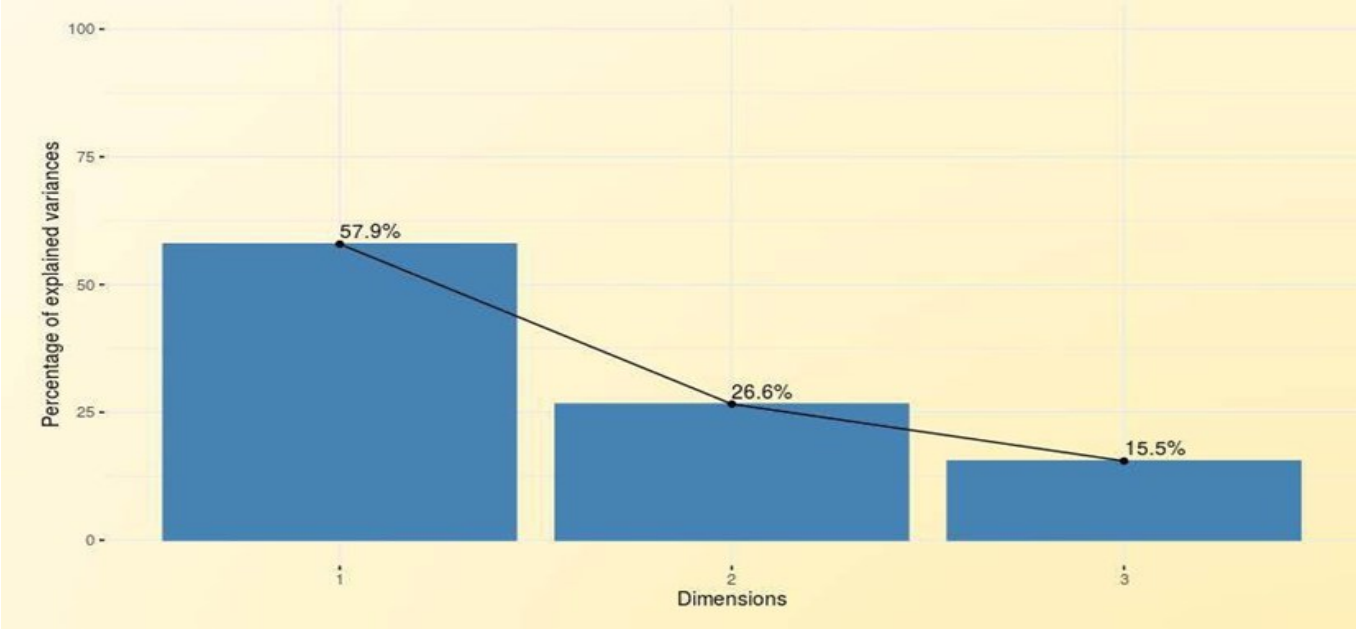

Fig. 7. Screen plot of variables of EMS treated plants

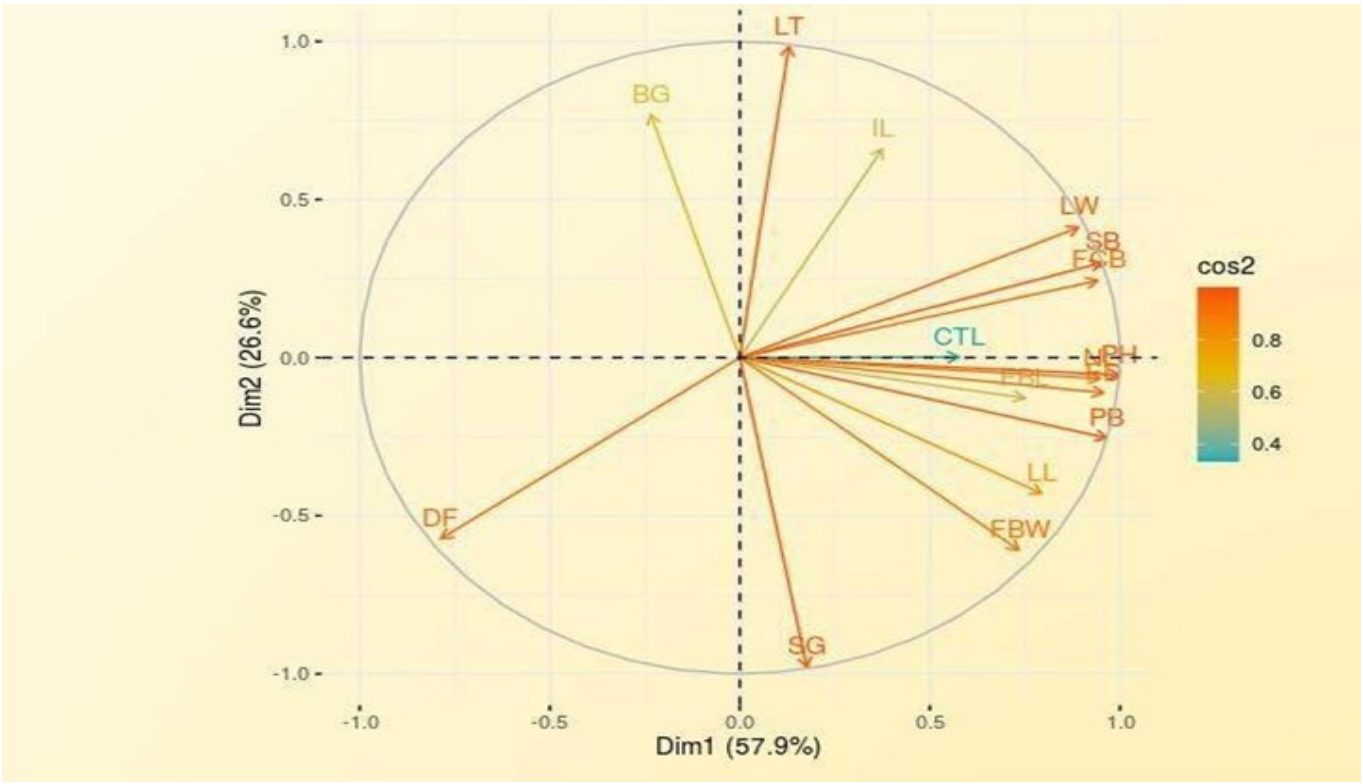

Fig. 8. Contribution of varibles on principal component of EMS treated plants

Table 10. % contribution of variables on principal components of EMS treated plants

Variables	PC1	PC2	PC3
Plant height	10.7	0.07	0.04
Number of primary branches	10.0	1.5	0.05
Number of secondary branches	9.8	2.1	0.02
Stem girth	0.3	22.5	0.4
Internodal length	1.5	10.2	17.1
Number of leaves	9.7	0.1	3.8
Leaf length	6.8	4.3	7.4
Leaf width	8.5	3.9	1.4
Leaf thickness	0.1	22.7	0.6
Days to flowering	6.6	7.6	2.1
Number of flowering cymes / branch	9.5	1.3	2.1
Flower bud length	6.0	0.1	16.9
Corolla tube length	3.5	13.8	26.9
Bud girth	0.5	0.2	14.2
Flower diameter	9.8	8.7	2.8
100-flower bud weight	5.8	8.7	3.6

weight (Table 10) (Fig. 8). These results were in accordance with the principal component analyses for economic characters in Mysuru jasmine (16).

Homeotic mutants

Due to homeotic mutations, mis-division of cells occurs in the early stage of flower development. Mutants exhibiting alterations in floral morphology were identified after exposure to varying levels of gamma radiation. Changes were noticed randomly in 10 Gy and 35 mM EMS treated plants. Among the 10 Gy mutated plants, one homeotic mutant having 6 petals and another homeotic mutant having 8 petals were observed and isolated (Fig. 3) whereas in 35 mM mutated plants, one homeotic mutant having 5 petals and another homeotic mutant having 9 petals were recorded and isolated than the parent plant (control) which showed 7 petals (Fig. 4). This was earlier confirmed in gladiolus in which homeotic mutants were observed and isolated for the changes in floral organs by (17). These homeotic mutants can be further utilized to study the phenomenon of development of different flower organs.

Conclusion

In M_1V_3 generation, 15 putative mutants (8 from gamma irradiated plants and 7 from EMS treated plants) of *J. auriculatum* which expressed distinct morphological features with respect to vegetative and flowering traits were selected and compared with the parent. This study confirmed the reliability of the selection for the investigated traits and those selected mutants are currently involved in jasmine improvement programme.

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Authors' contributions

SPM carried out the experiment, took observations and analysed the data. **MG** guided the research by formulating the research concept, helped in securing research funds and approved the final manuscript. **KR** reviewed the manuscript and helped in procuring research grants. **BM** contributed by imposing the experiment, helped in editing, summarizing and revising the manuscript. **MS** helped in summarizing and revising the manuscript. **NMB** contributed by developing the ideas, helped in editing, summarizing and revising the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

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