



RESEARCH ARTICLE

Genetic analysis in pink and white flower mutants of royal jasmine (*Jasminum grandiflorum* L.)

S M Soundarya^{1*}, M Ganga¹, K Iyanar² & D Malarvizhi³

¹Department of Floriculture and Landscape Architecture, Tamil Nadu Agricultural University (TNAU), Coimbatore 641 003, Tamil Nadu, India

²Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University (TNAU), Coimbatore 641 003, Tamil Nadu, India

³Department of Plant Genetic Resources, Centre for Plant Breeding and Genetics (CPBG), Tamil Nadu Agricultural University (TNAU), Coimbatore 641 003, Tamil Nadu, India

*Correspondence email - soundaryasmtnu@gmail.com

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Abstract

The present investigation was carried out to identify the high yielding mutants in pink and white pitchi ecotypes of royal jasmine (*Jasminum grandiflorum* L.), based on vegetative traits viz., number of primary and secondary branches, internodal length, number of leaves, leaf length and leaf width as well as flowering traits viz., days to flowering, number of flowering cymes/branch, flower bud length, corolla tube length, bud girth, flower diameter and 100 flower bud weight than control. Based on high phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV), selection can be affected for the traits viz., flower yield per plant, number of secondary branches per plant, number of flowering cymes/branches, plant height, internodal length, stem girth, number of primary branches per plant, leaf length, leaf breadth and 100 bud weight. High heritability for all the 16 traits and high genetic advance in 13 traits were observed whereas, the genetic advance was moderate for corolla tube length, days to flowering and flower bud length indicating additive gene effects and selection will be very effective when these traits are considered. The correlation results are in desirable direction for flowering cymes, plant height, secondary branches and 100 bud weight, hence these traits can be given more preference during selection. This extensive growth habit of morphological as well as reproductive growth traits may be due to mutation, that finally increased flower yield. Six mutants viz., PPM-12, PPM-72, PPM-96, PPM-115, WPM-2 and WPM-25 of pink and white pitchi were identified as the best and promoted to advanced yield trials, for confirmatory results on yield and flowering traits.

Keywords: economic traits; elite mutants; genetic studies; pink and white pitchi; royal jasmine

Introduction

The genus *Jasminum* belonging to the family Oleaceae comprises of around 200–300 species out of which 40 species are found to occur in India (1). The species *Jasminum grandiflorum* L. commonly called as 6321/royal jasmine, Spanish jasmine and Sicilian jasmine, is one of the most important fragrant traditional flower, native to South Asia and is traditionally grown for its fresh flowers in the Arabian peninsula, East and Northeast Africa, the Yunnan and Sichuan regions of China, Thailand, Sri Lanka and Philippines. In India, its commercial cultivation is extended in Tamil Nadu, Karnataka, Andhra Pradesh, Uttar Pradesh and some parts of Bihar and West Bengal for its flowers and buds, for making garlands, flower strings veni and for religious offerings. This royal jasmine has a rich history of medicinal and cosmetic uses. Research on this plant has focused on its potential therapeutic properties, including anti-inflammatory, antimicrobial, antioxidant and wound-healing effects as well as its traditional uses in treating various ailments. Additionally, it's a significant source of essential oils used in perfumery and cosmetics. In Europe and Mediterranean countries, jasmine flowers are used in large scale exclusively for extraction of essential oils. Apart from domestic consumption, India is the largest exporter of jasmine oil in the world accounting for over 40%

of total world export and Tamil Nadu is the leading producer and exporter of jasmine flowers to other countries.

Owing to its wide range of uses, the demand for jasmine flowers is growing day by day. Since, high yielding varieties are not available for cultivation to the farmers, which arise an urgent need for development of high yielding varieties/hybrids in jasmine. The success of a crop improvement programme is highly dependent on the genetic diversity present among the available genotypes. But there is only limited variability exists in Spanish jasmine, as it is propagated vegetatively. Hence for developing improved varieties with novel floral traits, breeding programmes that increases genetic variation is highly needed to improve the yield and yield contributing traits of jasmine.

In the recent years, mutation and molecular breeding methods offers sound and attractive choice for plant breeders to develop desired traits in plants. Upgrading the well-adapted plant varieties by improving a few desirable traits is the principal strategy in mutation breeding (2). The process of induced mutation can be performed either physically or chemically and it is very effective in the production of natural genetic resources for the formation of mutation in plants. Two major factors viz., the rate of mutation and

the mutation efficiency decide the success of mutation breeding. The phenotypic variation is largely in response to the environment particularly the temperature which implies on the development of mutants (3). The most effective technique for the creation of morphological and genotypic variability in plants is induced mutation. Therefore, like other crop plants, mutation breeding would be a successful tool to generate genetic variation for breeding new varieties. Keeping this in view, the present investigation on phenotypic characterisation and genetic variability assessment was carried out to identify the high yielding promising mutants of M_1V_3 generation evolved through mutation breeding of pink and white pitchi of royal jasmine.

Materials and Methods

The experiment was conducted at the Department of Floriculture and Landscape Architecture, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu (Latitude of 11°00' N, longitude of 77°00' E and an elevation of 412 m above mean sea level), India during 2020–23. The released cultivar *J. grandiflorum* cv. CO.1 (pitchi), commonly called as pink pitchi, released during 1980 is a clonal selection from the germplasm collection maintained at Tamil Nadu Agricultural University (TNAU), Coimbatore and *J. grandiflorum* cv. white pitchi, is a region-specific cultivar of jasmine popularly cultivated in the southern districts of Tamil Nadu were used as the plant materials for mutagenic treatments.

Terminal cuttings (13–15 cm long with 3 pairs of nodes) were irradiated with 10, 15, 20 and 25 Gy of gamma rays at the dose rate of 5000 rad/min in gamma chamber - 1200 available at Centre for Plant Breeding and Genetics, TNAU, Coimbatore. After irradiation, the treated cuttings were planted in polybags filled up to 3/4th of the height with rooting medium consisting of red soil + farmyard manure + sand (1:1:1) and the top 1/4th with sand along with untreated cuttings as control for comparison. Another set of cuttings treated with EMS (25, 30, 35 and 40 mM). After shade drying, the cuttings were incubated in respective concentrations of ethyl methanesulfonate (EMS) solutions at room temperature (1 hr) and then rinsed with running tap water for 1 hr to wash out the chemical residues. The cuttings were then planted into polybags filled with the rooting medium. The mutagenised M_1V_1 population was screened for deviation in the various traits in comparison with the control plants, with respect to vegetative growth and flowering parameters. Analysis was carried out to find out mean, range, standard error, coefficient of variation using MS Excel, 2010.

The M_1V_1 generation plants of *J. grandiflorum* cv. white pitchi were further raised for the next vegetative generation namely, M_1V_2 through vegetative propagation using terminal stem cuttings and placed under poly-tunnels with average temperature of 28–30 °C and relative humidity 80 % to induce rooting. After root formation, the M_1V_2 putative mutants were transferred to grow bags filled with potting mixture and then maintained in field for evaluation of various growth parameters and economic traits that contributing to flower yield.

The M_1V_3 generation of the mutant genotypes were raised through vegetative propagation of the M_1V_2 generation plants with semi-hardwood cuttings rooted under poly-tunnels with average temperature of 28–30 °C and relative humidity 80 %. The M_1V_3 generation plants were replanted in larger grow bags filled with potting mixture after root development and the rooted cuttings

were transplanted to the field for assessing the growth, flowering and quality characteristics.

A total of 156 genotypes (128 mutants of pink pitchi and 26 mutants of white pitchi derived using gamma rays and EMS and two check varieties pink pitchi and white pitchi) were evaluated for 3 seasons from 2020–23 in randomized block design (RBD) with 2 replications. Each entry was raised with a spacing of 2 × 2 m. All recommended package of practices were followed under irrigated condition. Observations recorded for various quantitative traits at vegetative stage viz., plant height, number of primary branches, number of secondary branches, number of leaves/plant, leaf length, leaf width, internodal length, stem girth and at flowering stage viz., days to 50 % flowering, number of flowering cymes, flower bud length, corolla tube length, flower bud girth, 100 flower bud weight, diameter of open flower and flower yield, were subjected to statistical analysis using TNAU STAT. Phenotypic and genotypic coefficients of variation (PCV and GCV) were calculated (4). Broad-sense heritability (H^2), representing the proportion of phenotypic variance attributable to genotypic differences, were estimated (5). Furthermore, the expected genetic advance, expressed as percentage of the mean (GAM), was determined (6).

Results and Discussion

The derived putative mutants of Pink and White Pitchi cultivars were evaluated for three seasons and studied for various phenotypic traits, mean performance, variability, heritability, genetic advance, correlation and path analysis for various vegetative and flowering traits of economic value in order to identify the desirable mutant genotypes with stable performance across the seasons and the results obtained are discussed hereunder.

Genetic studies for various economic traits in pink pitchi and white pitchi mutants

Variation is the basic tool that aid in selection of desirable genotypes by assessment of various variability parameters among the genotypes. The analysis of variance (ANNOVA) indicated the presence of substantial amount of variation among the genotypes for all the studied traits (Table 1, 2).

Mean performance of the mutant genotypes for various economic traits

In any crop improvement programme, the genotypes are primarily evaluated based on their phenotypic values. Best genotypes are generally identified based on their higher *per se* performance, the main selection criterion in many breeding programs. The mutant genotypes that recorded higher mean than the check variety pink pitchi and white pitchi were considered as superior genotypes for vegetative traits (Table 3) and for flowering traits (Table 4).

Per se performance for vegetative traits

Among the 154 mutant genotypes studied, 62 pink genotypes recorded higher mean than the check variety pink pitchi (162.17 cm) for plant height. Four genotypes viz., PPM-58 (172.22 cm), PPM-86 (162.85 cm), PPM-94 (162.73 cm) and PPM-96 (162.67 cm) were found to be significantly superior to the check. In white pitchi mutants, 12 genotypes recorded more plant height than the overall mean and one genotype WPM-25 (156.48 cm) was found to be higher than the check white pitchi (121.28 cm).

More number of primary branches is one of the important traits that directly impacts the flower yield. For this trait, a total of 37

Table 1. Analysis of variance for yield and yield contributing vegetative growth traits

Source	df	Mean sum of squares							
		Plant height	No. of primary branches	No. of secondary branches	Stem girth	Internodal length	No. of leaves/plant	Leaf length	Leaf breadth
Replication	1	3011.43*	4.24	62.052	144.19	0.54	880.83	4.33	1.29
Treatment	155	10536.81**	13.78**	346.92**	480.05**	40.07**	7087.10**	23.08**	4.54**
Environment	2	452.11*	165.23**	393.84**	428.28**	0.04	2492.42**	26.08**	2.01**
Interaction	2	569.36*	0.79	0.68	6.81	0.01	226.07	0.02	0.11
Error	775	10.19	0.37	0.78	2.41	0.05	17.15	0.06	0.02

* Significant at 0.05 probability level; ** Significant at 0.01 probability level; df: degree of freedom.

Table 2. Analysis of variance for yield and yield contributing flowering traits

Source	df	Mean sum of squares							
		Days to flowering	No. of flowering cymes	Flower diameter	Flower bud length	Flower bud girth	Corolla tube length	100 bud weight	Total flower yield
Replication	1	1318.71*	6.00	0.32	2.11*	0.76*	1.16	0.65	4643.40
Treatment	155	637.22**	260.72**	1.45**	0.51**	1.15**	0.31**	20.49**	4025072.54**
Environment	2	1318.71*	173.29*	1.45**	3.24**	0.21	3.68**	1.05	358264.71*
Interaction	2	81.76	1.31	0.28*	0.71*	0.01	0.26*	0.29	2601.45
Error	775	14.24	7.48	0.01	0.01	0.00	0.01	0.06	4809.63

* Significant at 0.05 probability level; ** Significant at 0.01 probability level; df: degree of freedom.

Table 3. Mean performance of vegetative traits in mutants of pink pitchi and white pitchi

Sl. No.	Genotype	Plant height	No. of primary branches	No. of secondary branches	Stem girth	Inter-nodal length	No. of leaves/ plant	Leaf length	Leaf breadth
1	Pink pitchi	162.17	4.00	14.17	40.70	6.35	81.83	10.98	4.38
2	PPM- 1	74.78	2.83	8.17	23.62	5.37	20.17	8.65	4.90
3	PPM- 2	56.47	3.17	5.50	8.42	4.32	23.50	4.35	3.28
4	PPM- 3	48.95	3.50	6.67	9.08	4.25	24.50	6.00	3.42
5	PPM- 4	27.07	2.67	4.50	11.76	4.42	20.00	5.57	3.85
6	PPM- 5	87.63	4.00	6.50	32.82	5.55	20.83	6.73	3.20
7	PPM- 6	48.58	3.33	5.17	12.08	4.05	20.67	4.45	3.40
8	PPM- 7	44.47	2.83	5.17	16.62	4.52	18.67	4.93	3.62
9	PPM- 8	95.93	2.83	8.50	18.99	6.25	23.33	9.78	5.08
10	PPM- 9	30.35	3.00	6.33	14.46	4.62	33.00	5.65	3.42
11	PPM- 10	133.65	4.33	9.50	26.52	4.55	141.67	8.83	4.28
12	PPM- 11	37.48	3.50	7.50	10.64	4.35	52.17	4.65	4.08
13	PPM- 12	151.43	9.33	20.83	28.25	5.62	63.00	8.47	3.28
14	PPM- 13	54.92	2.83	5.50	8.80	4.05	32.50	4.93	3.68
15	PPM- 14	67.32	3.33	4.50	22.76	4.28	33.17	6.88	3.15
16	PPM- 15	44.78	3.00	6.83	10.27	4.58	29.83	5.37	4.32
17	PPM- 16	94.00	3.17	6.50	18.11	5.65	66.33	7.75	3.38
18	PPM- 17	73.83	3.00	4.50	31.39	5.95	86.00	7.02	3.65
19	PPM- 18	111.05	3.83	7.00	27.49	4.05	38.83	7.37	3.18
20	PPM- 19	119.37	6.83	8.00	22.02	5.82	95.33	8.73	4.38
21	PPM- 20	107.72	3.83	8.50	33.88	5.32	40.50	8.28	4.45
22	PPM- 21	67.55	3.50	7.33	11.65	4.75	22.83	4.18	3.35
23	PPM- 22	93.33	3.67	6.17	16.63	6.12	66.33	10.22	5.38
24	PPM- 23	24.33	3.67	4.67	17.83	8.88	58.00	9.85	4.72
25	PPM- 24	91.77	3.67	5.50	19.54	6.35	46.67	11.42	6.02
26	PPM- 25	35.57	3.00	6.50	13.16	4.45	11.50	5.92	3.58
27	PPM- 26	154.28	7.17	16.33	27.08	6.58	108.83	8.60	5.32
28	PPM- 27	50.18	3.83	8.33	15.17	4.15	23.17	4.87	4.15
29	PPM- 28	58.10	3.50	6.50	11.82	4.22	25.67	4.23	3.32
30	PPM- 29	43.53	3.33	7.33	11.71	4.52	25.67	5.00	3.72
31	PPM- 30	108.58	2.33	7.33	25.73	6.42	117.67	9.23	3.95
32	PPM- 31	92.97	1.83	6.33	24.40	5.05	84.33	5.30	3.32
33	PPM- 32	79.17	2.83	3.50	17.60	4.92	13.33	5.17	2.68
34	PPM- 33	32.03	2.83	5.50	13.85	4.32	17.83	5.80	2.88
35	PPM- 34	85.77	2.50	7.33	26.46	6.15	36.33	10.58	5.12
36	PPM- 35	86.63	3.67	5.50	13.09	6.22	147.17	11.15	5.82
37	PPM- 36	74.43	3.33	7.33	11.16	7.18	32.67	8.97	4.18
38	PPM- 37	92.07	4.50	12.83	16.10	4.78	57.00	7.50	3.82
39	PPM- 38	79.62	4.33	6.50	7.75	6.37	56.67	9.67	4.15
40	PPM- 39	40.05	2.50	6.17	13.29	4.82	38.83	6.02	2.95
41	PPM- 40	41.57	2.83	7.33	9.52	4.55	21.17	9.25	3.28
42	PPM- 41	56.85	3.50	7.50	7.77	4.72	41.17	5.52	3.72
43	PPM- 42	104.45	4.17	5.50	23.36	6.35	63.50	9.13	4.45
44	PPM- 43	57.55	3.67	4.67	15.39	4.38	28.50	4.82	2.75
45	PPM- 44	38.73	3.00	3.67	17.35	4.55	27.17	5.20	3.92
46	PPM- 45	32.23	4.17	6.00	15.91	4.22	29.50	4.72	3.75
47	PPM- 46	103.90	2.67	6.67	25.28	5.25	79.33	9.23	4.22
48	PPM- 47	138.07	7.67	12.17	31.43	7.58	55.00	6.92	3.37
49	PPM- 48	58.37	3.67	5.17	12.73	4.28	23.00	5.17	3.42
50	PPM- 49	90.72	3.67	5.17	25.06	6.05	77.17	7.65	3.98

51	PPM- 50	95.48	2.83	7.17	29.53	5.85	157.67	9.95	5.65
52	PPM- 51	45.77	2.50	6.83	11.93	4.22	28.17	5.93	4.18
53	PPM- 52	35.35	4.00	6.00	9.00	4.58	36.00	5.68	4.12
54	PPM- 53	82.02	3.00	7.83	17.00	7.45	70.83	9.78	4.55
55	PPM- 54	115.85	3.83	7.50	26.53	6.65	46.83	9.77	5.08
56	PPM- 55	58.62	3.83	6.67	10.73	4.82	23.50	5.65	4.02
57	PPM- 56	44.93	3.33	5.67	12.92	4.62	27.50	5.43	3.35
58	PPM- 57	34.20	2.83	4.67	15.70	4.32	24.67	4.48	3.20
59	PPM- 58	172.22	5.00	8.50	30.36	6.75	68.00	9.23	4.65
60	PPM- 59	63.20	3.00	6.50	13.40	4.25	29.33	5.70	3.88
61	PPM- 60	48.02	3.33	7.67	9.83	4.28	29.00	5.92	3.48
62	PPM- 61	108.62	2.50	6.17	32.40	6.78	27.67	7.87	3.72
63	PPM- 62	55.92	2.67	4.67	11.14	4.65	39.17	5.75	3.77
64	PPM- 63	113.52	3.83	6.00	22.76	5.98	34.67	6.05	3.47
65	PPM- 64	113.13	3.50	7.50	23.64	6.75	74.50	7.35	5.32
66	PPM- 65	129.82	4.67	13.00	19.52	6.05	66.50	9.78	4.25
67	PPM- 66	135.05	3.50	11.67	36.97	6.52	93.50	10.63	5.38
68	PPM- 67	43.63	3.33	4.33	8.20	4.85	51.17	4.95	4.32
69	PPM- 68	138.55	4.67	22.50	30.04	5.15	116.83	7.85	3.15
70	PPM- 69	57.12	3.33	5.33	15.13	4.35	49.50	4.62	3.67
71	PPM- 70	50.40	3.00	6.33	18.11	4.15	31.33	5.05	3.62
72	PPM- 71	101.80	4.17	8.67	18.95	6.08	106.67	9.28	4.55
73	PPM- 72	143.40	7.67	46.33	20.81	7.85	34.00	9.52	5.08
74	PPM- 73	39.97	3.17	6.67	16.05	4.18	38.50	4.22	4.17
75	PPM- 74	153.78	6.83	26.67	33.35	5.82	78.00	7.98	3.72
76	PPM- 75	53.68	3.50	4.83	14.18	4.45	35.33	6.23	4.23
77	PPM- 76	132.00	6.00	15.83	23.65	7.05	121.17	9.53	5.28
78	PPM- 77	53.25	3.50	5.67	13.87	4.88	39.83	5.58	2.68
79	PPM- 78	58.12	2.50	6.67	12.09	4.92	56.33	4.75	3.55
80	PPM- 79	77.72	2.50	6.67	32.65	5.22	26.67	9.02	3.87
81	PPM- 80	83.77	3.67	5.67	23.49	5.08	31.33	7.60	3.60
82	PPM- 81	135.18	3.00	10.50	22.84	6.58	65.33	9.18	4.32
83	PPM- 82	30.42	2.50	4.83	9.34	4.55	43.50	5.18	3.82
84	PPM- 83	84.77	3.50	5.17	27.50	6.55	85.00	5.72	3.37
85	PPM- 84	37.10	3.50	5.17	6.83	4.38	41.50	4.95	2.83
86	PPM- 85	140.33	4.67	24.83	20.09	6.85	91.50	8.75	3.65
87	PPM- 86	162.85	8.83	19.33	28.49	6.18	168.00	8.48	4.25
88	PPM- 87	68.55	3.17	5.17	24.85	4.65	23.83	6.32	3.33
89	PPM- 88	134.55	5.83	19.50	24.58	5.52	113.83	6.53	3.28
90	PPM- 89	31.93	3.50	6.83	10.22	4.12	55.33	4.83	4.30
91	PPM- 90	44.27	1.67	4.50	15.72	4.78	43.83	5.03	4.08
92	PPM- 91	136.03	4.17	17.83	32.30	4.68	97.50	7.70	3.87
93	PPM- 92	53.13	3.50	5.17	18.92	4.85	50.83	4.40	3.68
94	PPM- 93	123.45	5.17	25.33	29.60	6.88	125.83	9.72	4.75
95	PPM- 94	162.73	4.67	40.33	31.35	6.85	176.00	9.43	4.62
96	PPM- 95	58.58	3.50	7.17	14.11	4.68	67.33	5.58	3.32
97	PPM- 96	162.67	12.83	45.33	29.84	5.82	105.17	8.82	3.85
98	PPM- 97	138.15	5.50	27.00	35.84	6.22	107.50	9.85	4.75
99	PPM- 98	39.32	3.50	5.50	17.19	4.42	50.83	6.60	3.85
100	PPM- 99	155.43	6.83	15.50	38.71	6.75	41.33	8.65	4.42

101	PPM- 100	91.32	3.00	7.50	27.11	5.75	28.50	6.88	3.48
102	PPM- 101	50.37	3.00	6.33	13.51	4.08	29.33	5.53	3.18
103	PPM- 102	76.67	2.50	3.50	30.02	6.45	74.50	7.65	4.18
104	PPM- 103	88.35	4.17	5.83	36.68	4.68	58.50	6.63	3.38
105	PPM- 104	100.98	3.33	9.67	21.42	6.78	47.17	10.77	6.08
106	PPM- 105	127.25	4.17	10.17	24.22	5.88	96.50	7.55	3.28
107	PPM- 106	144.60	7.83	24.17	21.95	5.75	42.50	8.57	4.08
108	PPM- 107	134.47	3.83	10.50	32.03	4.32	61.17	3.93	4.18
109	PPM- 108	114.63	3.00	7.50	25.51	5.45	19.83	5.70	2.62
110	PPM- 109	150.02	4.17	19.33	30.02	6.38	44.83	8.88	4.47
111	PPM- 110	151.80	8.50	29.50	28.06	6.42	150.67	9.45	4.68
112	PPM- 111	151.87	5.83	15.50	22.48	6.05	66.17	8.53	5.45
113	PPM- 112	158.07	3.83	26.83	36.23	6.20	104.67	8.98	4.92
114	PPM- 113	33.92	3.50	7.67	16.82	4.27	65.50	5.07	3.72
115	PPM- 114	141.52	4.67	28.17	33.13	6.02	90.17	7.33	3.70
116	PPM- 115	156.60	5.17	20.83	44.15	7.08	62.33	9.03	4.15
117	PPM- 116	120.08	4.33	14.17	30.48	5.68	71.00	9.03	4.62
118	PPM- 117	151.73	3.83	16.50	34.18	6.85	54.17	9.53	5.55
119	PPM- 118	157.27	3.33	5.17	32.22	6.85	27.83	10.82	5.58
120	PPM- 119	136.83	5.17	9.50	30.78	7.48	53.17	7.90	3.65
121	PPM- 120	151.08	3.83	17.50	26.32	7.15	54.17	11.02	5.75
122	PPM- 121	135.27	4.67	11.33	29.35	5.48	45.50	7.40	2.82
123	PPM- 122	103.45	2.50	8.50	38.09	6.58	37.50	7.87	3.50
124	PPM- 123	84.80	2.33	4.67	24.20	5.52	46.83	8.52	4.48
125	PPM- 124	110.88	3.67	10.50	28.80	4.78	58.67	9.55	5.15
126	PPM- 125	145.83	4.33	13.50	38.25	5.55	36.17	8.48	3.75
127	PPM- 126	151.22	3.50	7.33	46.91	6.42	41.33	10.23	5.18
128	PPM- 127	113.82	2.17	5.67	27.88	5.25	67.83	7.85	3.88
129	PPM- 128	107.02	3.33	8.50	20.69	6.53	57.00	10.68	5.48
130	White pitchi	121.28	3.50	13.67	27.95	4.68	49.50	6.60	2.78
131	WPM- 1	59.13	3.33	4.17	15.07	4.15	29.83	7.23	3.22
132	WPM- 2	97.68	5.33	12.50	20.01	7.18	109.00	7.62	4.38
133	WPM- 3	45.90	2.00	4.83	12.11	4.38	41.33	4.82	2.42
134	WPM- 4	41.35	3.83	5.17	9.83	4.35	28.17	5.47	2.22
135	WPM- 5	44.67	3.17	6.50	10.02	4.75	33.83	5.07	2.12
136	WPM- 6	97.62	3.33	10.67	14.28	5.18	33.50	5.17	4.95
137	WPM- 7	31.73	2.50	3.83	9.58	4.88	35.33	5.47	2.28
138	WPM- 8	28.40	3.33	4.67	8.71	4.25	29.83	4.95	2.45
139	WPM- 9	37.42	3.17	4.00	11.54	4.78	27.50	4.67	2.22
140	WPM- 10	103.93	4.50	10.83	20.65	5.35	20.83	6.75	3.18
141	WPM- 11	48.17	2.67	5.50	11.26	4.15	22.50	6.07	2.58
142	WPM- 12	95.02	3.50	9.33	16.05	5.58	104.17	6.98	3.18
143	WPM- 13	44.57	3.50	4.17	13.76	4.28	58.00	5.55	2.68
144	WPM- 14	57.32	3.00	5.50	12.45	4.78	47.83	5.35	2.38
145	WPM- 15	92.27	3.50	8.50	15.98	5.48	34.50	7.23	4.28
146	WPM- 16	27.92	2.50	4.50	13.32	4.15	32.50	4.73	2.48
147	WPM- 17	92.30	3.50	10.83	23.47	6.45	33.17	6.92	3.52
148	WPM- 18	83.30	2.00	10.67	21.93	6.55	21.67	5.85	3.18
149	WPM- 19	35.33	2.83	5.50	12.36	4.28	26.50	5.03	2.48
150	WPM- 20	81.77	2.50	4.17	21.93	5.75	39.33	7.18	3.85

151	WPM- 21	34.03	2.83	3.83	10.92	4.68	57.67	6.05	2.32
152	WPM- 22	106.22	4.00	17.50	21.34	5.50	95.83	7.32	4.32
153	WPM- 23	44.38	3.33	6.67	10.21	4.72	36.67	5.50	3.05
154	WPM- 24	112.23	3.83	7.00	26.60	5.12	31.67	7.68	3.72
155	WPM- 25	156.48	5.83	27.83	32.83	6.45	148.33	8.28	3.85
156	WPM- 26	58.65	3.00	6.17	13.18	4.55	43.83	5.10	2.28
Mean		88.10	3.83	9.85	20.95	5.42	55.23	7.16	3.88
CV		3.62	16.00	8.98	7.42	4.08	7.50	3.55	3.75
SE		1.30	0.25	0.36	0.63	0.09	1.69	0.10	0.06
CD (5 %)		3.62	0.69	1.00	1.76	0.26	4.69	0.29	0.16

Table 4. Mean performance of flowering traits in mutants of pink pitchi and white pitchi

Sl. No.	Genotype	Plant height	No. of primary branches	No. of secondary branches	Stem girth	Inter- nodal length	No. of leaves/ plant	Leaf length	Leaf breadth
1	Pink pitchi	121.67	20	3.53	4.07	4.01	2.37	10.93	3804.13
2	PPM- 1	103.67	11.5	3.65	4.37	4.62	2.48	9.20	503.08
3	PPM- 2	135.00	7.33	3.30	3.73	3.62	2.35	8.53	103.65
4	PPM- 3	139.83	5.83	3.50	4.17	3.94	2.00	7.97	108.40
5	PPM- 4	138.50	7.5	3.70	4.05	3.59	2.12	8.72	102.98
6	PPM- 5	119.50	13.67	4.20	4.00	4.48	2.23	9.25	387.84
7	PPM- 6	134.67	8.33	3.22	3.82	3.15	2.25	8.65	107.25
8	PPM- 7	139.83	6.67	3.53	3.70	3.59	2.07	7.35	120.34
9	PPM- 8	120.17	19.33	4.08	4.02	4.13	2.13	8.52	1082.91
10	PPM- 9	135.00	5.5	3.62	3.82	3.71	2.12	9.38	111.96
11	PPM- 10	119.83	21.83	4.92	4.55	4.43	2.60	11.88	1682.20
12	PPM- 11	139.83	7.5	3.37	3.70	3.53	2.42	8.96	112.26
13	PPM- 12	100.83	32.67	5.03	4.35	4.36	2.67	13.07	5348.33
14	PPM- 13	135.00	6.33	3.55	3.78	3.42	2.23	9.56	105.47
15	PPM- 14	139.33	13	3.65	3.82	4.62	2.28	8.67	175.10
16	PPM- 15	140.00	9.33	3.72	3.73	3.32	1.97	7.46	101.80
17	PPM- 16	135.00	12.50	4.28	3.73	4.38	2.32	8.56	421.16
18	PPM- 17	135.00	15.00	4.08	4.18	4.15	2.38	9.05	751.18
19	PPM- 18	119.83	16.83	4.27	4.08	4.51	2.52	9.48	522.74
20	PPM- 19	130.00	19.83	4.15	4.35	4.87	2.62	9.24	975.69
21	PPM- 20	127.17	18.33	4.22	4.15	4.40	2.32	9.57	1351.46
22	PPM- 21	135.50	8.00	3.78	3.95	3.78	2.33	8.29	109.23
23	PPM- 22	135.50	8.17	4.05	3.98	3.70	2.43	9.72	640.90
24	PPM- 23	119.83	10.00	4.08	4.07	3.66	2.43	9.37	208.33
25	PPM- 24	140.00	10.67	3.90	4.08	3.69	2.50	8.32	450.16
26	PPM- 25	140.00	6.83	3.62	3.75	3.55	2.53	7.22	108.09
27	PPM- 26	115.50	21.83	4.55	4.20	3.96	2.52	12.19	2147.50
28	PPM- 27	130.50	9.33	3.48	3.85	3.66	2.22	9.38	121.67
29	PPM- 28	135.50	6.00	3.63	3.85	3.18	1.88	7.69	118.86
30	PPM- 29	135.50	7.00	3.43	3.73	3.35	2.03	8.26	103.59
31	PPM- 30	105.50	16.50	4.13	4.07	3.99	2.40	10.43	1293.21
32	PPM- 31	130.33	14.17	4.18	3.97	4.82	2.42	9.23	1683.19
33	PPM- 32	135.50	9.17	3.38	3.82	4.29	2.37	8.13	168.53
34	PPM- 33	135.50	8.33	3.55	3.77	3.32	2.45	9.86	114.06
35	PPM- 34	139.83	10.00	3.45	3.98	4.43	2.28	8.44	549.90
36	PPM- 35	105.83	5.17	4.52	4.15	4.69	2.58	9.11	739.97
37	PPM- 36	135.50	7.67	3.72	3.98	4.38	2.33	9.17	436.69
38	PPM- 37	120.17	24.17	4.32	4.17	4.23	2.45	8.22	1700.78
39	PPM- 38	140.17	20.17	3.52	3.80	4.39	2.32	8.43	458.64
40	PPM- 39	135.50	7.67	3.43	3.98	3.13	1.95	7.13	103.69
41	PPM- 40	140.50	7.50	3.62	3.87	3.52	2.18	9.49	98.43
42	PPM- 41	135.83	7.67	3.45	3.95	3.22	2.02	8.44	111.53
43	PPM- 42	105.67	22.17	4.12	4.25	4.27	2.50	9.30	1253.40
44	PPM- 43	135.67	7.50	3.62	4.03	3.37	2.25	8.60	101.38
45	PPM- 44	140.17	7.00	3.53	3.83	3.72	2.30	7.83	98.97
46	PPM- 45	140.17	8.17	3.72	3.97	3.62	2.13	7.71	106.68
47	PPM- 46	135.50	11.33	4.55	4.27	4.42	2.38	12.15	508.52
48	PPM- 47	130.00	17.33	4.47	4.37	4.66	2.60	12.09	2044.37
49	PPM- 48	135.83	8.67	3.60	3.70	3.90	2.07	9.44	108.17
50	PPM- 49	135.83	12.17	3.62	4.15	3.99	2.62	9.83	510.34

51	PPM- 50	120.67	22.67	4.52	4.17	4.19	2.15	9.36	1692.16
52	PPM- 51	140.67	9.17	3.35	3.87	3.96	1.98	8.44	110.59
53	PPM- 52	140.67	7.67	3.65	3.72	4.05	2.15	8.73	105.79
54	PPM- 53	130.17	24.33	4.17	4.07	4.44	2.53	8.89	1607.40
55	PPM- 54	120.17	7.17	4.13	4.12	4.48	2.53	10.43	896.82
56	PPM- 55	135.17	9.33	4.00	3.98	3.69	2.25	7.37	98.30
57	PPM- 56	140.17	7.17	3.52	3.90	3.90	2.35	7.11	112.71
58	PPM- 57	135.17	7.00	3.72	3.67	4.00	1.97	8.31	98.18
59	PPM- 58	121.17	23.50	4.58	4.50	4.49	2.78	9.29	1995.70
60	PPM- 59	136.00	10.83	3.62	3.82	3.37	2.25	8.89	96.70
61	PPM- 60	130.17	19.17	3.55	3.73	3.35	1.98	8.56	1266.08
62	PPM- 61	105.17	9.83	3.70	3.78	4.24	2.30	8.53	775.73
63	PPM- 62	135.00	6.33	3.32	3.83	3.42	1.97	7.41	112.53
64	PPM- 63	136.00	14.00	4.68	4.30	4.37	2.45	12.00	507.30
65	PPM- 64	120.67	23.83	4.55	4.25	4.50	2.70	9.51	1286.68
66	PPM- 65	130.83	18.83	4.72	4.47	4.59	2.52	11.22	1488.65
67	PPM- 66	130.17	20.83	4.45	4.57	4.58	2.75	11.83	1859.72
68	PPM- 67	140.00	7.50	3.65	3.93	3.72	2.15	7.55	734.32
69	PPM- 68	119.67	19.00	4.22	4.12	4.58	2.62	9.99	2332.78
70	PPM- 69	140.17	6.17	3.40	3.65	3.19	2.03	8.59	90.96
71	PPM- 70	140.17	8.50	3.72	3.68	3.79	2.33	7.50	93.56
72	PPM- 71	105.00	15.17	4.27	4.03	4.54	2.38	10.11	1693.09
73	PPM- 72	101.67	33.00	5.05	4.65	4.67	2.68	12.67	5131.55
74	PPM- 73	134.67	8.50	3.77	3.75	3.91	2.12	8.45	111.28
75	PPM- 74	120.17	18.17	4.70	4.30	4.54	2.50	12.23	1639.71
76	PPM- 75	136.33	6.83	3.88	3.85	3.48	2.22	9.31	95.74
77	PPM- 76	131.17	16.00	4.63	4.17	4.56	2.55	11.98	1132.62
78	PPM- 77	136.33	8.17	3.70	3.72	3.46	2.00	8.68	102.10
79	PPM- 78	136.00	7.33	3.80	3.73	3.89	2.17	8.33	109.16
80	PPM- 79	140.67	10.50	4.27	3.75	4.57	2.37	7.98	699.00
81	PPM- 80	140.67	14.67	4.37	4.03	4.18	2.58	7.14	541.97
82	PPM- 81	121.33	17.33	3.90	4.13	4.15	2.52	9.19	2167.18
83	PPM- 82	131.50	7.50	3.67	3.55	3.22	2.42	8.45	120.83
84	PPM- 83	141.50	11.17	4.47	4.10	4.39	2.52	8.15	270.34
85	PPM- 84	136.33	7.17	3.82	3.78	3.62	2.05	9.66	103.51
86	PPM- 85	121.50	20.67	5.10	4.42	4.58	2.45	11.30	1453.91
87	PPM- 86	125.17	18.00	4.55	4.45	4.19	2.60	11.44	1663.46
88	PPM- 87	121.00	8.00	4.35	4.08	4.20	2.42	8.53	109.21
89	PPM- 88	126.50	16.83	4.60	4.23	4.41	2.32	12.29	1361.19
90	PPM- 89	130.17	9.00	3.83	3.87	3.71	2.17	9.51	116.37
91	PPM- 90	135.17	5.50	3.72	3.77	3.95	2.40	8.70	103.27
92	PPM- 91	125.83	24.83	4.15	4.20	4.28	2.30	10.72	1350.79
93	PPM- 92	135.67	7.17	3.53	3.65	3.20	2.50	7.69	101.94
94	PPM- 93	129.50	23.83	4.45	4.33	4.86	2.68	11.41	1313.92
95	PPM- 94	120.17	19.83	4.25	4.58	4.86	2.27	17.75	2499.46
96	PPM- 95	130.00	8.00	3.58	3.67	3.64	2.07	8.55	99.28
97	PPM- 96	102.33	31.50	4.62	4.52	4.45	2.45	12.70	5087.35
98	PPM- 97	120.83	18.50	4.95	4.48	4.59	2.77	13.06	2340.21
99	PPM- 98	136.00	11.33	3.92	3.88	3.77	2.22	9.52	112.40
100	PPM- 99	130.00	14.00	4.77	4.42	4.17	2.48	11.80	1263.94

101	PPM- 100	135.83	8.83	3.33	3.97	4.03	2.50	7.53	464.40
102	PPM- 101	130.83	14.17	3.38	3.57	3.72	2.23	8.78	1140.62
103	PPM- 102	140.50	13.00	3.50	3.75	3.84	2.48	8.42	329.08
104	PPM- 103	120.67	14.83	3.32	3.72	3.73	2.25	7.34	440.72
105	PPM- 104	120.33	10.50	3.40	3.88	3.76	2.47	8.52	863.81
106	PPM- 105	119.33	13.50	4.42	4.28	4.08	2.65	11.40	702.84
107	PPM- 106	120.67	18.33	4.58	4.47	4.40	2.80	11.76	1609.28
108	PPM- 107	135.17	8.17	4.08	4.32	4.30	2.70	10.70	209.73
109	PPM- 108	121.00	10.00	4.72	4.25	3.92	2.68	11.16	477.05
110	PPM- 109	131.00	15.33	4.97	4.47	4.32	2.70	11.32	1328.63
111	PPM- 110	126.00	25.33	5.12	4.48	4.73	2.65	11.60	2254.13
112	PPM- 111	126.67	22.50	4.15	4.28	4.25	2.53	11.78	1239.91
113	PPM- 112	105.33	25.67	3.43	4.42	4.22	2.52	12.01	1867.42
114	PPM- 113	135.17	6.33	3.53	3.75	3.51	2.22	8.56	322.02
115	PPM- 114	130.33	22.00	4.15	4.35	4.15	2.43	11.18	1122.66
116	PPM- 115	102.33	32.83	3.63	4.50	4.77	2.80	13.12	4527.38
117	PPM- 116	119.33	7.50	3.93	4.55	3.93	2.72	12.13	1407.47
118	PPM- 117	119.00	14.17	3.88	4.33	4.28	2.55	12.15	1280.21
119	PPM- 118	105.50	10.00	4.17	4.28	4.52	2.67	12.11	1582.86
120	PPM- 119	135.83	15.33	3.53	4.33	4.33	2.68	12.16	546.09
121	PPM- 120	121.17	17.67	4.00	4.15	4.28	2.70	11.61	1605.13
122	PPM- 121	130.67	12.50	3.52	4.47	4.20	2.70	10.97	815.81
123	PPM- 122	120.67	16.33	4.15	4.18	3.85	2.57	8.86	693.06
124	PPM- 123	130.67	19.17	4.07	4.45	4.27	2.85	12.54	87.17
125	PPM- 124	105.67	15.00	4.20	4.23	3.85	2.63	8.56	645.31
126	PPM- 125	126.00	27.33	3.80	4.32	4.02	2.72	11.88	1504.10
127	PPM- 126	125.83	20.83	4.17	4.12	4.26	2.47	11.75	1138.10
128	PPM- 127	131.67	13.50	3.97	3.98	4.26	2.47	7.94	818.74
129	PPM- 128	116.17	17.83	4.10	4.05	4.24	2.72	8.62	943.56
130	White pitchi	126.50	17.50	3.32	3.63	3.82	2.30	7.33	1082.34
131	WPM- 1	121.67	13.17	3.33	3.60	3.77	2.18	7.55	311.04
132	WPM- 2	111.83	22.67	3.98	4.00	4.28	2.58	9.46	2290.46
133	WPM- 3	116.67	13.67	3.40	3.60	3.57	1.97	7.12	102.83
134	WPM- 4	128.83	5.00	3.20	3.63	3.73	2.15	6.99	113.69
135	WPM- 5	132.83	6.83	3.20	3.43	3.46	2.23	6.52	109.12
136	WPM- 6	121.50	15.67	3.42	3.65	4.32	2.07	7.27	320.49
137	WPM- 7	124.67	9.67	3.17	3.53	3.66	2.00	6.62	98.90
138	WPM- 8	133.67	6.50	3.30	3.48	3.66	2.17	7.27	99.27
139	WPM- 9	132.17	12.50	3.33	3.62	3.71	2.13	7.46	98.21
140	WPM- 10	132.17	16.83	4.48	3.72	3.90	2.32	9.18	380.72
141	WPM- 11	133.83	10.50	3.55	3.73	3.51	2.10	6.16	95.86
142	WPM- 12	125.67	15.17	4.13	3.70	3.99	2.32	9.29	521.22
143	WPM- 13	125.83	7.17	3.20	3.67	3.35	2.28	6.63	99.01
144	WPM- 14	133.00	4.83	3.35	3.48	3.52	2.00	6.36	97.37
145	WPM- 15	115.67	14.50	3.33	3.77	4.21	2.05	9.37	221.95
146	WPM- 16	125.67	8.83	3.13	3.63	3.46	2.17	7.87	99.95
147	WPM- 17	122.33	20.50	3.37	3.95	3.98	2.38	7.98	500.11
148	WPM- 18	126.00	15.83	3.92	3.65	4.02	2.57	8.33	266.02
149	WPM- 19	133.50	8.00	3.35	3.60	3.55	2.60	7.41	67.99
150	WPM- 20	135.83	20.50	3.67	3.95	4.29	2.45	8.62	172.89

151	WPM- 21	130.00	11.50	3.20	3.65	3.36	2.10	6.60	61.63
152	WPM- 22	119.00	7.50	3.17	3.85	3.99	2.08	8.01	743.29
153	WPM- 23	122.67	9.67	3.25	3.60	3.76	2.08	6.71	112.27
154	WPM- 24	118.83	19.17	3.93	4.10	4.36	2.42	8.93	494.75
155	WPM- 25	107.17	33.83	4.20	4.20	4.43	2.60	10.08	2562.65
156	WPM- 26	122.33	8.50	3.27	3.60	3.35	2.17	7.12	91.65
Mean		127.80	13.62	3.90	4.00	4.01	2.37	9.35	818.07
CV		2.95	18.74	3.37	3.23	1.77	5.94	2.78	9.24
SE		1.54	1.12	0.05	0.05	0.03	0.06	0.11	28.31
CD (5 %)		4.28	3.10	0.15	0.15	0.08	0.16	0.29	78.60

genotypes were found to be significantly higher than the check variety pink pitchi (4.0) with the maximum mean exhibited by PPM-96 (12.83), PPM-12 (9.33) and PPM-86 (8.83), followed by remaining 34 genotypes. In white pitchi mutants, 6 genotypes were found to be superior than the check (3.50), with the maximum number of primary branches in WPM-25 (5.83), WPM-2 (5.33) and WPM-10 (4.50).

More number of secondary branches decides the number of flowering cymes which have direct influence on flower yield and found significantly superior in 24 genotypes than the check variety pink pitchi (14.17), with maximum number in the mutants viz., PPM-72 (46.33), PPM-96 (45.33) and PPM-94 (40.33), followed by remaining 21 genotypes. In white pitchi mutants, 6 genotypes had a greater number of secondary branches than the control (13.67), with the maximum in WPM-25 (27.83) and WPM-22 (17.50). More number of secondary branches is an important trait that contributes for increase in flower yield.

For stem girth, a total of 66 genotypes recorded higher mean than the check (40.7 mm) and 2 genotypes were found to be significantly superior with the maximum in PPM-126 (46.91 mm) and PPM-115 (44.15 mm). In white pitchi mutants, only one genotype WPM-25 showed higher mean (32.83 mm) when compared to the check white pitchi (27.95 mm).

In case of internodal length, 33 genotypes of pink pitchi mutants were found to be significantly superior than the check pink pitchi (6.35 cm) with the maximum in PPM-23 (8.88 cm) followed by PPM-72 (7.85 cm), PPM-47 (7.58 cm), PPM-119 (7.48 cm), PPM-53 (7.45 cm) and PPM-120 (7.15 cm) whereas in white pitchi mutants, 11 genotypes showed higher values for internodal length than check white pitchi (4.68 cm) with maximum in WPM-2 (7.18 cm), WPM-18 (6.55 cm), WPM-17 and WPM-25 (6.45 cm) followed by other 8 genotypes.

A total of 25 genotypes were found to be best for number of leaves per plant than the check variety pink pitchi (81.83) with a greater number of leaves observed in PPM-94 (176.0), PPM-86 (168.0) and PPM-50 (157.7) followed by remaining 22 genotypes. In white pitchi mutants, 6 genotypes were found to be superior to the control (49.50) with the maximum in WPM-25 (148.33), WPM-2 (109.0), WPM-12 (104.17) followed by others.

A total of 67 genotypes had greater leaf length and 3 genotypes were found to be significantly superior to the check variety pink pitchi (10.98 cm) with the maximum in PPM-24 (11.42 cm) followed by PPM-35 (11.15 cm) and PPM-120 (11.02 cm). In white pitchi mutants, 10 genotypes found to be superior to the check white pitchi (6.60 cm) with maximum leaf length observed in WPM-25 (8.28 cm), WPM-24 (7.68 cm) and WPM-2 (7.62 cm)

followed by other 7 genotypes.

A total of 36 mutants of pink pitchi recorded significantly higher leaf breadth than the check (4.38 cm) with maximum leaf breadth in PPM-104 (6.08 cm) followed by PPM-24 (6.02 cm), PPM-35 (5.82 cm), PPM-66 (5.38 cm) and PPM-76 (5.28 cm). In white pitchi mutants, 13 genotypes exhibited more leaf breadth than the check white pitchi (2.78 cm) with maximum leaf breadth in WPM-6 (4.95 cm), WPM-2 (4.38 cm), WPM-22 (4.32 cm) and WPM-25 (3.85 cm) followed by other 10 genotypes.

Per se performance for flowering traits

Contribution of desirable alleles for earliness is one of the desirable trait that can be utilised for developing short duration varieties. Forty one genotypes were found to have significantly more number of days for flowering than the check variety pink pitchi (121.67 days) indicating that they are late flowering mutants and remaining 85 genotypes recorded early flowering, the best among them were PPM-12 (100.83 days), PPM-72 (101.67 days) and PPM-96 (102.33 days) followed by remaining 82 genotypes for earliness. Among the white pitchi mutants, 9 genotypes were of late flowering types and 17 genotypes expressed earliness than the check white pitchi (126.50 days) and few among them are WPM-25 (107.17 days) WPM-2 (111.83 days) and WPM-3 (116.67 days) followed by others.

Number of flowering cymes is generally associated with higher flower production. For number of flowering cymes/branches, 23 genotypes were found to be significantly higher than the check variety pink pitchi (20.00) and the maximum number of flowering cymes were observed in PPM-72 (33.0), PPM-115 (32.83) and PPM-12 (32.67) followed by remaining 20 genotypes. In white pitchi mutants, 12 genotypes had higher mean than the check white pitchi (17.50) and 5 genotypes were found to be superior viz., WPM- 25 (33.83), WPM-2 (22.67), WPM-17 and WPM-20 (20.50) and WPM-24 (19.17).

Flower diameter is one of the desirable features and found to be significantly higher in 101 genotypes when compared to the check variety pink pitchi (3.53 cm) with the maximum in PPM-110 (5.12 cm) followed by PPM-85 (5.10 cm), PPM-72 (5.05 cm). In white pitchi mutants, 16 genotypes recorded higher flower diameter than the check white pitchi (3.32 cm). Maximum flower diameter was observed in WPM-10 (4.48 cm), WPM-25 (4.20 cm) and WPM-12 (4.13 cm) followed by 13 other genotypes.

Flower bud length in 60 genotypes was found to be significantly higher than the check variety pink pitchi (4.07 cm) with the maximum in PPM-72 (4.65 cm) followed by PPM-94 (4.58 cm), PPM-66 (4.57 cm) and PPM-96 (4.52 cm). In white pitchi mutants, 14 genotypes recorded higher flower bud length than

the check white pitchi (3.63 cm). The genotypes WPM-25 (4.20 cm), WPM-24 (4.10 cm), WPM-2 (4.00 cm) followed by 11 other genotypes had more flower bud length.

Seventy genotypes were found to be significantly higher than the check variety pink pitchi (4.01 mm) for flower bud girth with the maximum in PPM-19 (4.87 mm), PPM-93 (4.86 mm), PPM-94 (4.86 mm) and PPM-31 (4.82 mm) followed by remaining 66 genotypes. In white pitchi mutants, 11 genotypes were found to be higher than the check variety white pitchi (3.82 mm) with more flower bud girth observed in WPM-25 (4.43 mm), WPM-24 (4.36 mm), WPM-6 (4.32 mm) followed by other genotypes.

The mean performance for corolla tube length in 72 genotypes were found to be significantly higher than the check variety pink pitchi (2.37 cm) with the maximum in PPM-123 (2.85 cm) followed by PPM-106 and PPM-115 (2.80 cm). In white pitchi mutants, 9 genotypes recorded higher corolla tube length than the check white pitchi (2.30 cm) and the maximum flower bud length was observed in WPM-19 and WPM-25 (2.60 cm), WPM-2 (2.58 cm), WPM-18 (2.57 cm) and WPM-20 (2.45 cm) followed by 4 other genotypes.

Hundred flower bud weight is one of the important characters that influence flower yield. The mean performance for this trait was high in 37 genotypes and was significantly higher than the check variety pink pitchi (10.33 g) with the maximum in PPM-94 (17.75 g), PPM-115 (13.12 g), PPM-12 (13.07 g) followed by remaining 34 genotypes. In white pitchi mutants, 14 genotypes were found to be higher than white pitchi (7.33 g) with more weight of 100 flower buds observed in WPM-25 (10.08 g), followed by WPM-2 (9.46 g), WPM-15 (9.37 g), WPM-12 (9.29 g) and WPM-10 (9.18 g).

For flower yield, a total of 49 genotypes recorded higher mean than overall mean (902.35 g) and 4 genotypes were found to be significantly superior to the check variety pink pitchi (3804.13 g) and maximum yield observed in 4 mutant genotypes viz., PPM-12 (5348.33 g), PPM-72 (5131.55 g), PPM-96 (5087.35 g) and PPM-115 (4527.38 g) (Fig. 1; Plate 1). In white pitchi mutants, 7 genotypes recorded higher mean for yield than the overall mean (375.31 g) and 2 genotypes found to be significantly superior for flower yield than the check white pitchi (1082.34 g). The genotypes WPM-25 (2562.65 g) followed by WPM-2 (2290.46 g) were identified as the best genotypes for flower yield (Fig. 2; Plate 1).

Therefore, based on the yield performance, the 4 mutant genotypes viz., PPM-12, PPM-72, PPM-96 and PPM-115 in pink pitchi and 2 mutant genotypes, WPM-25 and WPM-2 in white pitchi were identified as the best and these mutants can be further evaluated for its performance in yield trials and flower quality (Plate 1 and 2). Similar results were obtained by previous researches in tuberose (7), mulberry (8) and increase in vegetative characters and yield in iasmine. (9, 10).

Pooled mean performance (monthly mean) for flower yield

The monthly mean for flower yield was recorded and pooled over three seasons from 2020–23, to observe the range of maximum and minimum flower yield and the peak flowering time of the mutant genotypes in all the 3 years. The overall mean during the flowering period from May–October revealed that, the parents and mutant genotypes had maximum flower yield between August–September indicating that this is the peak period of flowering in

pink pitchi.

It was observed that flowering initiation started during the month of May and gradually increased from May–July with peak flowering from July, August and September followed by leaning phase in flower yield from October–November. In case of white pitchi, there was gradual increase from July–August and peak flowering was noticed between September and October and sudden decline in flower production was noticed during November. Therefore, the monthly mean for flower yield pooled over 3 seasons showed that the peak flowering was during the months of July, August and September in pink pitchi whereas, in white pitchi, the peak flowering was observed during the months of August, September and October that contributes for increased flower yield in the cultivars of pink pitchi and white pitchi.

Genetic variability studies

A survey of genetic variability is essentially the first step in crop improvement. The success depends on the spectrum of genetic variability that is present in the germplasm (11). The extent and magnitude of variability present in most crop species forms the basis of selection in any crop improvement programme. Besides, estimation of quantitative traits would show the potentiality of germplasm from where the selection of desirable types with desirable characters for maximising the yield could be done. Phenotypic expression of a character is the result of interaction between genotype and environment. Therefore, the total variability needs to be partitioned into genetic and environmental components. The genotypic component being the heritable part of the total variability, is more important for selection of desirable genotypes (12).

In the present study the quantum of variability, heritability and genetic advance that provide basic information of variation present among the selected mutant genotypes. The ANOVA for 16 characters revealed highly significant differences for all the characters indicating the presence of wide variation among the 154 genotypes of pink and white pitchi taken for study.

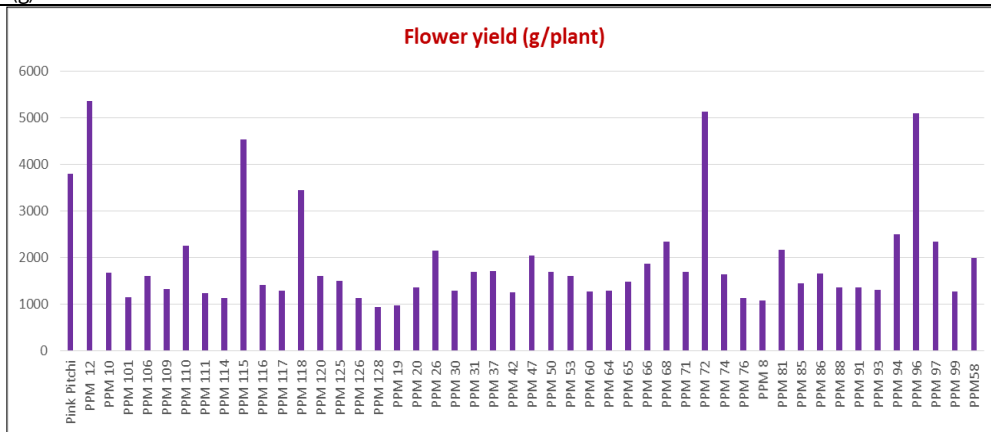
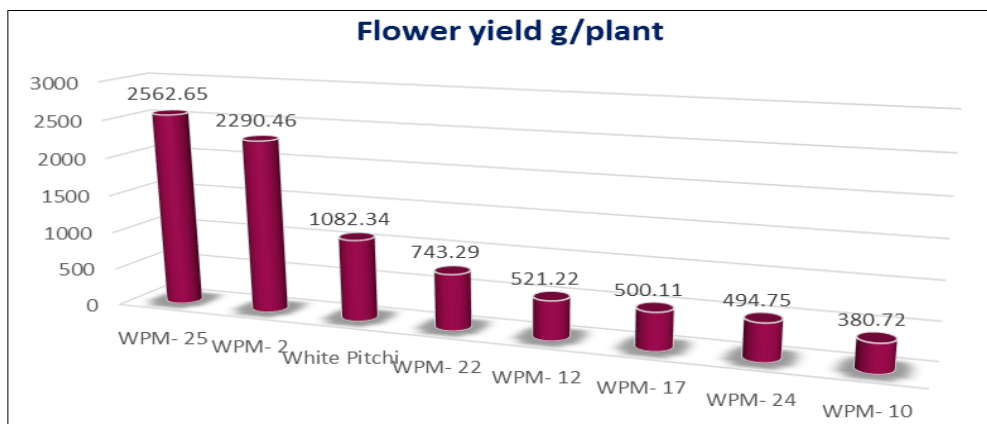
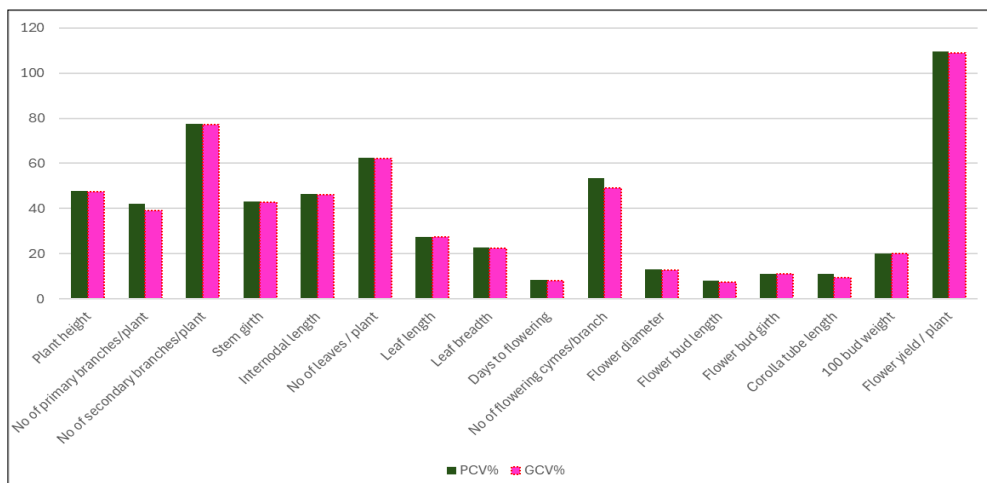
Phenotypic and genotypic coefficient of variation

The estimates of phenotypic coefficient of variation (PCV) were higher than their corresponding genotypic coefficient of variation (GCV) for all the characters (Table 5, Fig. 3). The PCV was found to be high (>20 %) for most of the traits like flower yield per plant (109.45 %), number of secondary branches per plant (77.65 %), number of leaves/plant (62.60 %), number of flowering cymes/branch (53.45 %), plant height (47.68 %), internodal length (46.34 %), stem girth (43.24 %), number of primary branches per plant (42.17 %), leaf length (27.57 %), leaf breadth (22.71 %) and 100 bud weight (20.12 %) whereas, moderate (10–20 %) PCV was observed for flower diameter (12.99 %), flower bud girth (11.05 %) and corolla tube length (11.13 %). The PCV was found to be low (<10 %) for days to flowering (8.50 %) and flower bud length (7.90 %). These findings are in accordance with earlier findings in *Jasminum sambac*, cv. Gundumalli (13), in rose (14) and in chrysanthemum (15). Therefore, the traits flower yield per plant, number of secondary branches per plant, number of leaves/plants, number of flowering cymes/branches, plant height, internodal length, stem girth, number of primary branches per plant, leaf length, leaf breadth and 100 bud weight with high PCV can be considered during selection.

The genotypic coefficient of variation (GCV) was found to be high (>20 %) for most of the traits like flower yield per plant

Table 5. Genetic parameters of variability for various quantitative traits of mutant genotypes in *Jasminum grandiflorum*

Characters	Phenotypic variance	Genotypic variance	PCV%	GCV%	Heritability (%)	Genetic advance	Genetic advance as percent of mean
Plant height (cm)	1764.63	1754.44	47.68	47.54	99.00	86.04	97.66
No. of primary branches/plant	2.61	2.24	42.17	39.01	86.00	2.85	74.36
No. of secondary branches/plant	58.47	57.69	77.65	77.13	99.00	15.54	157.83
Stem girth (mm)	82.03	79.61	43.24	42.60	97.00	18.11	86.45
Internodal length (cm)	6.72	6.67	46.34	46.16	99.00	5.30	94.71
No. of leaves / plant	1195.48	1178.33	62.60	62.15	99.00	70.20	127.11
Leaf length (cm)	3.90	3.84	27.57	27.34	98.00	4.00	55.85
Leaf breadth (cm)	0.78	0.75	22.71	22.40	97.00	1.77	45.51
Days to flowering	118.07	103.83	8.50	7.97	88.00	19.68	15.40
No. of flowering cymes/branch	49.69	42.21	53.45	49.26	84.90	12.33	93.52
Flower diameter (cm)	0.26	0.24	13.00	12.55	93.30	0.97	24.97
Flower bud length (cm)	0.10	0.08	7.90	7.21	83.30	0.54	13.55
Flower bud girth (mm)	0.20	0.19	11.05	10.90	97.40	0.89	22.17
Corolla tube length (cm)	0.07	0.05	11.13	9.41	71.50	0.39	16.38
100 bud weight (g)	3.43	3.41	20.12	20.01	98.10	3.764	40.25
Flower yield / plant (g)	674853.44	670043.81	109.45	109.06	99.00	1680.22	223.85

**Fig. 1.** Mean performance of high yielding mutant genotypes of pink pitchi.**Fig. 2.** Mean performance of high yielding mutant genotypes of white pitchi.**Fig. 3.** Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for various quantitative traits of pink and white flower mutants.

Pink pitchi mutants



PPM-12



PPM-72



PPM-96



PPM-115

White pitchi mutants



WPM-25



WPM-2

Plate 1. Promising mutants of pink and white flower mutant genotypes.

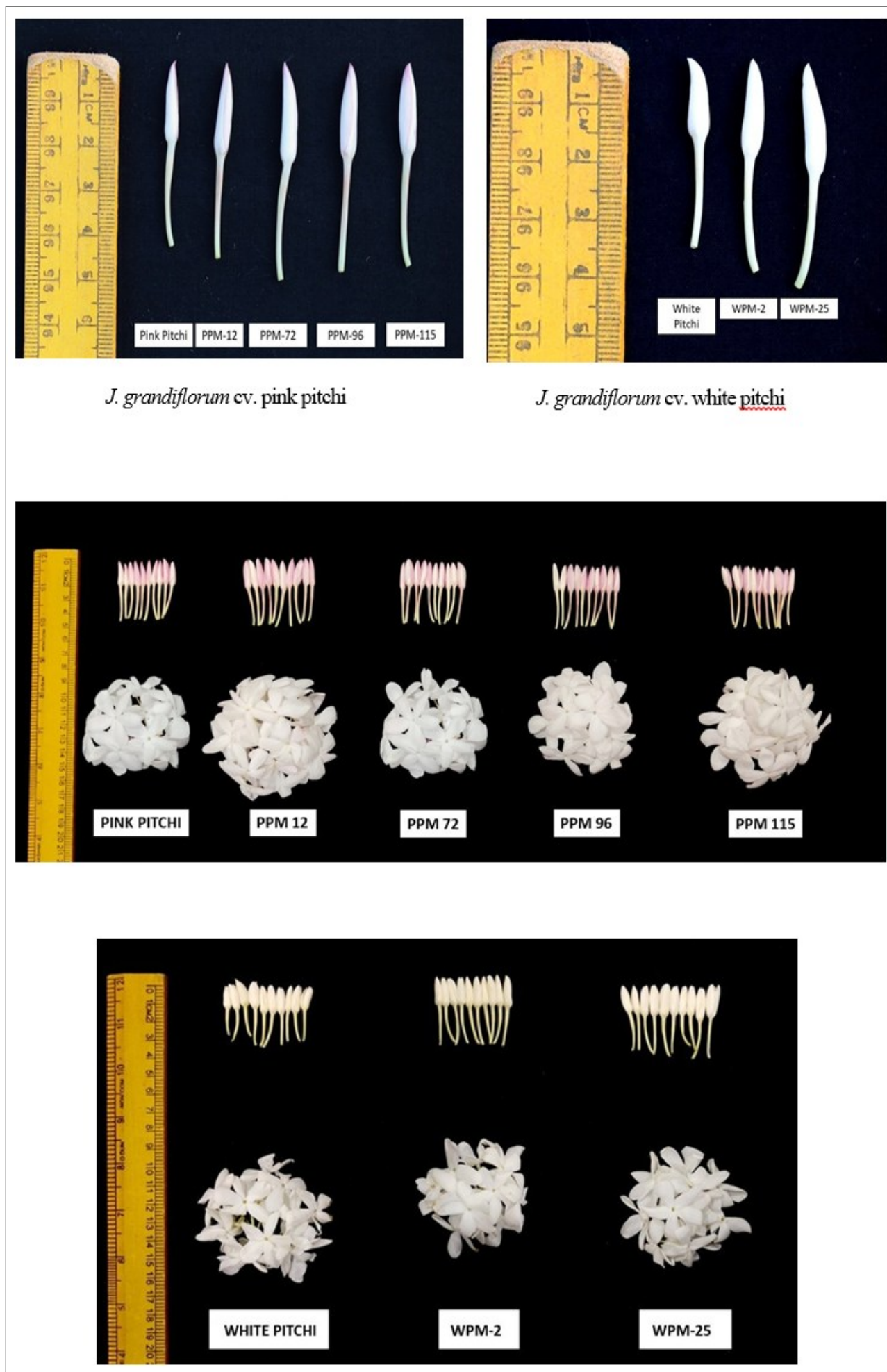


Plate 2. Flower bud and corolla tube length variation in promising mutant genotypes.

(109.06), number of secondary branches per plant (77.13), number of flowering cymes/branch (49.26), plant height (47.54), internodal length (46.16), stem girth (42.60), number of primary branches per plant (39.01), leaf length (27.34), leaf breadth (22.40) and 100 bud weight (20.01). The estimates of PCV were higher than GCV estimates for every character under the study, indicating that the variation was not only due to the genotypes, but environment had also played a major role in the expression of the traits. These results are in accordance with earlier findings in *Jasminum auriculatum* Vahl (16) wherein the PCV was higher than GCV with respect to all the quantitative traits studied.

Moderate GCV (10–20 %) was observed for flower diameter (12.55) and flower bud girth (10.90) whereas it was low (<10 %) for corolla tube length (9.41), days to flowering (7.97) and flower bud length (7.21). The deviation between PCV and GCV for these traits was low indicating the least influence of environment on these traits. Similar results with moderate PCV and GCV ranging from 10–20 % was reported earlier in jasmine (17) and in African marigold (18) for the traits viz., number of primary branches, flower diameter, flower bud weight, number of flowers in chrysanthemum (19). This indicates that there is high scope for the plant breeders to utilise the existing variability in future jasmine improvement programme.

Hence, based on high GCV, selection can be effected for the traits viz., flower yield per plant, number of secondary branches per plant, number of flowering cymes/branches, plant height, internodal length, stem girth, number of primary branches per plant, leaf length, leaf breadth and 100 bud weight.

Heritability and genetic advance

The selection of traits based on variation is not sufficient for selecting the trait of importance in any breeding programme. It should be influenced by both the degree of variability present in the population and the degree of heritability of the trait. The most significant component is heritable variability, which is dependent on the genetic makeup of the breeding material which has direct impact on how the selection is effective for the improvement of the trait. Heritability acts as a gauge for the transmissibility of traits to the subsequent generation (20). The variation must be highly

heritable and the traits selected should have more variation with high heritability and genetic advance and to some extent moderate variability with high genetic advance can be considered during selection.

Heritability along with genetic advance is very much useful in estimating the influence of environment. Genetic advance refers to the improvement in the mean genotypic value of selected plants over the base population. In the present study, higher estimate of broad sense heritability (more than 60 %) was exhibited by all the genotypes for all the traits and the heritability range was between 71.50 % in corolla tube length and 99.00 % in plant height, number of secondary branches per plant, internodal length and number of leaves per plant. The highest genetic advance over mean (>20 %) was observed for the following 13 traits like viz., flower yield per plant (223.85 %), number of secondary branches per plant (157.83 %), number of leaves per plant (127.11 %), plant height (97.66 %), internodal length (94.71 %), number of flowering cymes per branch (93.52 %), stem girth (86.45 %), number of primary branches per plant (74.36 %), leaf length (55.85 %), leaf breadth (45.51 %), 100 bud weight (40.25 %), flower diameter (24.97 %) and flower bud girth (22.17 %) whereas, moderate (10–20 %) genetic advance over mean was observed for corolla tube length (16.38 %), days to flowering (15.40 %) and flower bud length (13.55 %) (Table 5, Fig. 4). These results are in accordance with earlier findings in tuberose (21) and in marigold (22) indicating that these traits can be further exploited for breeding new plant types with novel traits. In gladiolus, high heritability coupled with high genetic advance as percentage of mean for number of flowers/plant and flower diameter in combination with the amount of variability present in the mutant population and the intensity of selection influence the genes to be targeted in the breeding programme (23).

Therefore, it can be concluded from the above results that the traits having high heritability of > 60 and >20 % level of genetic advance indicate that the traits are most likely governed by additive gene effects and selection will be very effective when these traits are considered during the selection process (24).

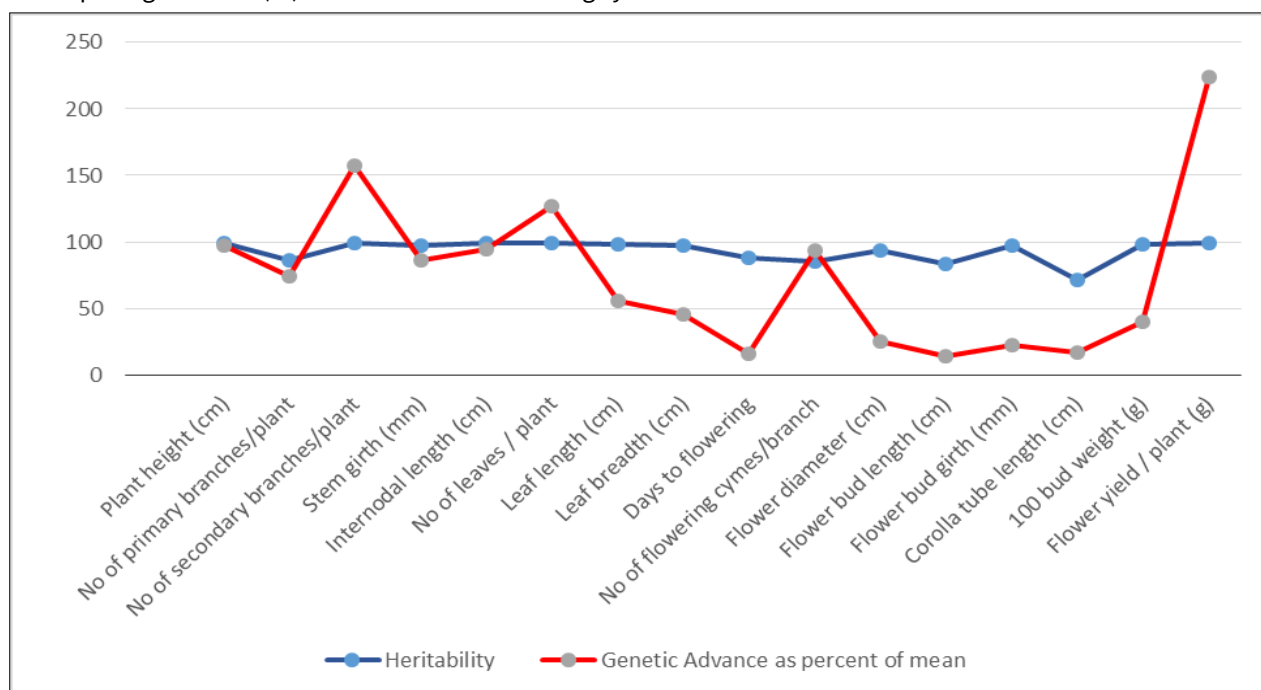


Fig. 4. Heritability and genetic advance as percent of mean for various quantitative traits of pink and white flower mutants.

Correlation studies

Flower yield being complex in inheritance and subjected to environmental fluctuations, direct selection based on *per se* performance does not give expected results as high genotype and environment interaction will restrict improvement. Selection based on simply inherited and highly heritable yield attributes is most effective and reliable approach as compared to direct selection on yield itself. Understanding the nature and extent of association of different yield components with yield and inter relationship among themselves is an essential prerequisite for the formulation of breeding procedure for effective improvement of yield and its components.

The aim of correlation studies is primarily to know the suitability of various characters for indirect selection. Correlation studies provide information on the nature and extent of association between any two metric traits and it will be possible to bring about genetic improvement in one trait by selection of the other. The correlation between characters may exist due to various reasons such as pleiotropy, genetic linkage and association of loci or blocks of loci governing variability for different characters located on same chromosome. The extent of observed relationship between two characters is known as phenotypic correlation. Phenotypic correlation among traits is influenced by genotype and environment. Genotypic correlation is usually attributed to pleiotropy and measure the association due to additive and additive x additive gene action and phenotypic correlations measure the environmental deviation together with

the non-additive gene action (25). Study of inter relationships of the yield components among themselves besides their correlation with yield itself would be more revealing and useful as correlation between any two characters is influenced by other inter related characters.

In the present study, a high magnitude of genotypic correlations compared to the corresponding phenotypic correlations indicated that there was a strong inherent genetic association between the various characters studied and the expression of traits was sensitive to environmental fluctuation. The phenotypic correlation is reduced by the significant interaction of environment and this may confirm the considerable role of environment in modifying the total expression of genotypes (Table 6).

The total flower yield per plant was highly significant and recorded positive phenotypic and genotypic correlation respectively with flowering cymes (0.761, 0.828), plant height (0.761, 0.765), secondary branches (0.736, 0.745) followed by the traits 100 bud weight (0.664, 0.673), primary branches (0.657, 0.715), stem girth (0.562, 0.574), internodal length (0.313, 0.316), leaves per plant (0.552, 0.557), leaf length (0.589, 0.597), leaf breadth (0.377, 0.384), flower bud length (0.637, 0.696), flower bud girth (0.598, 0.608) and corolla tube length (0.465, 0.554) displayed highly significant and positive correlation with flower yield per plant whereas days to flowering had highly significant and negative correlation (-0.583, -0.626) with flower yield. The results revealed that all the 14 quantitative characters were highly significant and positively correlated with flower yield at both

Table 6. Phenotypic and genotypic correlation for various quantitative traits in mutant genotypes of *Jasminum grandiflorum*

Traits		PH	NPB	NSB	SG	IL	NL	LL	LB	DF	NFC	FD	FBL	FBG	CTL	100 BW	FY
PH	P	1.000	0.564	0.679	0.797	0.384	0.552	0.687	0.465	-0.526	0.688	0.638	0.735	0.712	0.600	0.736	0.761**
	G	1.000	0.610	0.686	0.811	0.386	0.558	0.695	0.472	-0.563	0.748	0.663	0.807	0.724	0.716	0.746	0.765**
NPB	P		1.000	0.687	0.329	0.134	0.416	0.307	0.179	-0.331	0.518	0.501	0.497	0.382	0.309	0.520	0.657**
	G		1.000	0.742	0.356	0.147	0.454	0.333	0.200	-0.388	0.616	0.561	0.588	0.416	0.413	0.567	0.715**
NSB	P			1.000	0.453	0.333	0.523	0.410	0.269	-0.454	0.622	0.503	0.570	0.475	0.345	0.653	0.736**
	G			1.000	0.463	0.337	0.532	0.416	0.276	-0.485	0.681	0.523	0.627	0.485	0.407	0.665	0.745**
SG	P				1.000	0.342	0.401	0.578	0.359	-0.416	0.564	0.483	0.614	0.609	0.552	0.589	0.562**
	G				1.000	0.348	0.411	0.593	0.370	-0.448	0.617	0.508	0.679	0.626	0.666	0.606	0.574**
IL	P					1.000	0.274	0.364	0.306	-0.316	0.329	0.132	0.315	0.275	0.246	0.313	0.313**
	G					1.000	0.277	0.368	0.312	-0.339	0.360	0.137	0.348	0.279	0.293	0.317	0.316**
NL	P						1.000	0.469	0.357	-0.359	0.486	0.492	0.460	0.467	0.304	0.495	0.552**
	G						1.000	0.477	0.364	-0.387	0.530	0.511	0.508	0.477	0.360	0.504	0.557**
LL	P							1.000	0.693	-0.467	0.540	0.512	0.598	0.618	0.510	0.536	0.589**
	G							1.000	0.749	-0.500	0.591	0.536	0.658	0.631	0.606	0.546	0.597**
LB	P								1.000	-0.274	0.316	0.387	0.474	0.423	0.359	0.430	0.377**
	G								1.000	-0.298	0.349	0.407	0.533	0.435	0.430	0.422	0.384**
DF	P									1.000	-0.578	-0.311	-0.379	-0.394	-0.304	-0.361	-0.583**
	G									1.000	-0.569	-0.350	-0.438	-0.428	-0.390	-0.388	-0.626**
NFC	P										1.000	0.518	0.569	0.563	0.439	0.542	0.761**
	G										1.000	0.591	0.678	0.619	0.570	0.593	0.828**
FD	P											1.000	0.669	0.631	0.505	0.622	0.627**
	G											1.000	0.750	0.660	0.612	0.653	0.652**
FBL	P												1.000	0.622	0.599	0.737	0.637**
	G												1.000	0.691	0.734	0.811	0.696**
FBG	P													1.000	0.521	0.582	0.598**
	G													1.000	0.621	0.596	0.608**
CTL	P														1.000	0.507	0.465**
	G														1.000	0.600	0.554**
100 BW	P															1.000	0.664**
	G															1.000	0.673**

**Significant at 0.01 level.

PH: Plant height (cm); NPB: No. of primary branches/plant; NSB: No. of secondary branches/plant; SG: Stem girth (mm); IL: Internodal length (cm); NL: No. of leaves / plant; LL: Leaf length (cm); LB: Leaf breadth (cm); DF: Days to flowering; NFC: No. of flowering cymes/branch; FD: Flower diameter (cm); FBL: Flower bud length (cm); FBG: Flower bud girth (mm); CTL: Corolla tube length (cm); 100 BW: 100 bud weight (g); FY: Flower yield / g/plant; P: Phenotypic correlation; G: Genotypic correlation.

phenotypic and genotypic level in all three seasons, except for days to flowering, hence all the traits except days to flowering can be utilised for indirect selection for improving the flower yield.

Association between flower yield and its contributing characters

For most of the traits, the GCV were slightly greater than the PCV, suggesting on the limited impact of the environment on the total expression of genotypes. Total flower yield per plant was highly significant and recorded positive correlation with flowering cymes, plant height, secondary branches followed by 100 bud weight. Plant height exhibited highly significant positive correlation with flower yield per plant. The parameter days to flowering was highly significant and negatively correlated with flower yield. Therefore, except days to flowering, the rest of the characters viz., primary branches, stem girth, internodal length, leaves per plant, leaf length, leaf breadth, flower bud length, flower bud girth and corolla tube length displayed highly significant and positive correlation with flower yield per plant.

Inter correlation between flower yield and other contributing characters

The character flowering cymes recorded positive association with plant height, primary branches, secondary branches, stem girth, internodal length, leaves per plant, leaf length, leaf breadth, flower diameter, flower bud length, flower bud girth, corolla tube length and 100 bud weight whereas this trait had negative association with days to flowering. The character days to flowering exhibited negative association with all the characters viz., plant height, primary branches, secondary branches, stem girth, internodal length, leaves per plant, leaf length, leaf breadth, flowering cymes, flower diameter, flower bud length, flower bud girth, corolla tube length and 100 bud weight.

The flower related traits viz., flower diameter, flower bud length, flower bud girth, corolla tube length and 100 bud weight recorded positive association with all the traits namely plant height, primary branches, secondary branches, stem girth, internodal length, leaves per plant, leaf length, leaf breadth and flowering cymes whereas they had negative association with days to flowering. Negative association of various flower traits with days to flowering was also reported in rose (26) and in marigold (27, 28).

The above correlation results are in desirable direction for the characters like flowering cymes, plant height and secondary branches are selection indices for enhancing the total flower yield per plant. The results agree with the findings in marigold (29) and in chrysanthemum (30).

Path analysis

Flower yield is an interaction of many mutually associated component characters hence change in any one component may disturb the other component. Correlation coefficients help in determining the yield component however they do not provide an exact picture about the relative importance of direct and indirect influence of each component characters towards yield. Path coefficient analysis furnishes the cause and effect of different yield components which would provide better index for selection rather than correlation coefficients. Studies on correlation of characters along with their relative direct and indirect effects on yield are of immense value in selection of superior genotypes from the population (31).

Direct effect of yield components on flower yield per plant

Among all the traits studied, number of flowering cymes (0.378), number of primary branches (0.197), flower diameter (0.119) and 100 bud weight (0.118) displayed positive direct effects on total flower yield per plant therefore for increasing total flower yield per plant, these traits can be given most preference while going for selection. The highest negative direct effect on total flower yield per plant was exhibited by days to flowering (-0.171), flower bud length (-0.082) followed by corolla tube length (-0.020), stem girth (-0.017) and internodal length (-0.014) suggesting that these traits are not considered while going for selection to flower yield.

At the phenotypic level, the flowering cymes (0.266), secondary branches (0.177) followed by primary branches (0.162) exhibited highest direct effect on total flower yield per plant. Negative direct effect was revealed by days to flowering (-0.133), stem girth (-0.032), flower bud length (-0.022), leaf breadth (-0.017), internodal length (-0.010) followed by corolla tube length (-0.004) (Table 7, Fig. 5).

Indirect effect of yield components on flower yield per plant

The parameter number of flowering cymes exhibited positive indirect effect through plant height, primary branches, secondary branches, leaves per plant, leaf length, days to flowering, flower diameter and 100 bud weight and negative indirect effects through stem girth, internodal length, flower bud length, flower bud girth, corolla tube length.

The character 100 bud weight revealed positive indirect effect through plant height, primary branches, secondary branches, leaves per plant, leaf length, days to flowering, flowering cymes and flower diameter.

Days to flowering showed negative indirect effects through plant height, primary branches, secondary branches, leaves per plant, leaf length, leaf breadth, flowering cymes, flower diameter, flower bud girth and 100 bud weight. Hence, the above results showed that for increasing total flower yield per plant, characters like flowering cymes and 100 bud weight can be given most preference while going for selection. This might be due to more growth habit of some of the genotypes resulting in higher proportion of morphological growth as well as reproductive growth due to mutation that finally resulted in increased flower yield. These results are in conformity with the earlier reports in chrysanthemum (30–32).

Conclusion

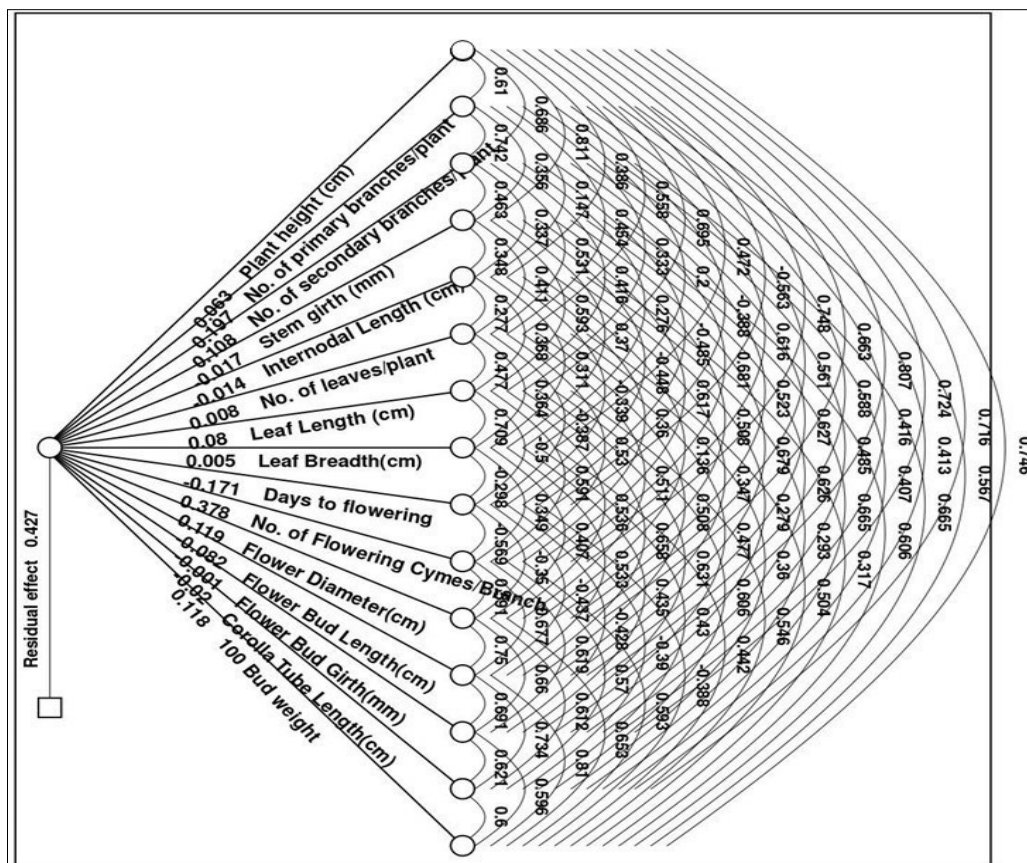
The mutant genotypes derived from the pink and white flower ecotypes of *Jasminum grandiflorum* L. in M_1V_3 generation that expressed distinct variations through mutation for plant growth and different traits contributing to yield were selected on comparison with the control of pink and white pitchi. The study confirmed the reliability of the selection for the investigated traits contributing for flower yield and based on the yield performance, 6 mutant genotypes viz., PPM-12, PPM-72 (ethyl methanesulfonate (EMS) derived mutants), PPM-96 and PPM-115 (gamma ray derived mutants) of pink pitchi and two EMS derived mutant genotypes WPM-2 and WPM-25 of white pitchi were identified as the best mutants. At present the selected mutants of pink and white pitchi have been identified for release and promoted to final evaluation in

Table 7. Phenotypic and genotypic path analysis: Direct and indirect effects for quantitative traits in mutant genotypes of *Jasminum grandiflorum*

Traits		PH	NPB	NSB	SG	IL	NL	LL	LB	DF	NFC	FD	FBL	FBG	CTL	100 BW	FY
PH	P	0.126	0.071	0.086	0.101	0.049	0.070	0.087	0.059	-0.066	0.087	0.081	0.093	0.090	0.076	0.093	0.761
	G	0.063	0.039	0.043	0.051	0.024	0.035	0.044	0.030	-0.036	0.047	0.042	0.051	0.046	0.045	0.047	0.765
NPB	P	0.092	0.162	0.112	0.054	0.022	0.068	0.050	0.029	-0.054	0.084	0.081	0.081	0.062	0.050	0.084	0.657
	G	0.120	0.197	0.146	0.070	0.029	0.089	0.066	0.039	-0.077	0.121	0.111	0.116	0.082	0.081	0.112	0.715
NSB	P	0.121	0.122	0.177	0.080	0.059	0.093	0.073	0.048	-0.081	0.110	0.089	0.101	0.084	0.061	0.116	0.736
	G	0.074	0.080	0.108	0.050	0.036	0.057	0.045	0.030	-0.052	0.073	0.056	0.068	0.052	0.044	0.072	0.745
SG	P	-0.025	-0.010	-0.014	-0.032	-0.011	-0.013	-0.018	-0.011	0.013	-0.018	-0.015	-0.019	-0.019	-0.017	-0.019	0.562
	G	-0.014	-0.006	-0.008	-0.017	-0.006	-0.007	-0.010	-0.006	0.008	-0.010	-0.009	-0.011	-0.010	-0.011	-0.010	0.574
IL	P	-0.004	-0.001	-0.003	-0.003	-0.010	-0.003	-0.004	-0.003	0.003	-0.003	-0.001	-0.003	-0.003	-0.002	-0.003	0.313
	G	-0.006	-0.002	-0.005	-0.005	-0.014	-0.004	-0.005	-0.004	0.005	-0.005	-0.002	-0.005	-0.004	-0.004	-0.005	0.316
NL	P	0.017	0.012	0.016	0.012	0.008	0.030	0.014	0.011	-0.011	0.015	0.015	0.014	0.014	0.009	0.015	0.552
	G	0.005	0.004	0.004	0.003	0.002	0.008	0.004	0.003	0.003	0.004	0.004	0.004	0.004	0.003	0.004	0.557
LL	P	0.070	0.031	0.042	0.059	0.037	0.048	0.101	0.070	-0.047	0.055	0.052	0.061	0.063	0.052	0.054	0.589
	G	0.056	0.027	0.033	0.048	0.030	0.038	0.080	0.057	-0.040	0.047	0.043	0.053	0.051	0.049	0.044	0.597
LB	P	-0.008	-0.003	-0.005	-0.006	-0.005	-0.006	-0.012	-0.017	0.005	-0.005	-0.007	-0.008	-0.007	-0.006	-0.007	0.377
	G	0.002	0.001	0.001	0.002	0.002	0.002	0.004	0.005	-0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.384
DF	P	0.070	0.044	0.061	0.056	0.042	0.048	0.062	0.037	-0.133	0.077	0.042	0.051	0.053	0.041	0.048	-0.583
	G	0.096	0.066	0.083	0.076	0.058	0.066	0.085	0.051	-0.171	0.097	0.060	0.075	0.073	0.066	0.066	-0.626
NFC	P	0.183	0.138	0.165	0.150	0.088	0.129	0.144	0.084	-0.154	0.266	0.138	0.151	0.150	0.117	0.144	0.761
	G	0.283	0.233	0.258	0.233	0.136	0.201	0.224	0.132	-0.215	0.378	0.224	0.256	0.234	0.216	0.224	0.828
FD	P	0.073	0.058	0.058	0.055	0.015	0.056	0.059	0.044	-0.036	0.059	0.115	0.077	0.072	0.058	0.071	0.627
	G	0.079	0.057	0.063	0.061	0.016	0.061	0.064	0.049	-0.042	0.071	0.119	0.090	0.079	0.073	0.078	0.652
FBL	P	-0.016	-0.011	-0.012	-0.013	-0.007	-0.010	-0.013	-0.010	0.008	-0.012	-0.014	-0.022	-0.013	-0.013	-0.016	0.637
	G	-0.067	-0.048	-0.052	-0.056	-0.029	-0.042	-0.054	-0.044	0.036	-0.056	-0.062	-0.082	-0.057	-0.061	-0.067	0.696
FBG	P	0.006	0.003	0.004	0.005	0.002	0.004	0.005	0.003	-0.003	0.004	0.005	0.005	0.008	0.004	0.005	0.598
	G	-0.001	-0.001	-0.001	-0.001	0.000	-0.001	-0.001	-0.001	0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.608
CTL	P	-0.003	-0.001	-0.002	-0.002	-0.001	-0.001	-0.002	-0.002	0.001	-0.002	-0.002	-0.003	-0.002	-0.004	-0.002	0.465
	G	-0.014	-0.008	-0.008	-0.013	-0.006	-0.007	-0.012	-0.008	0.008	-0.011	-0.012	-0.014	-0.012	-0.020	-0.012	0.554
100 BW	P	0.060	0.042	0.053	0.048	0.025	0.040	0.043	0.035	-0.029	0.044	0.050	0.060	0.047	0.041	0.081	0.664
	G	0.088	0.067	0.078	0.071	0.037	0.059	0.064	0.052	-0.046	0.070	0.077	0.095	0.070	0.071	0.118	0.673

Residual effect P: 0.472; Residual effect G: 0.427.

PH: Plant height (cm); NPB: No. of primary branches/plant; NSB: No. of secondary branches/plant; SG: Stem girth (mm); IL: Internodal length (cm); NL: No. of leaves / plant; LL: Leaf length (cm); LB: Leaf breadth (cm); DF: Days to flowering; NFC: No. of flowering cymes/ branch; FD: Flower diameter (cm); FBL: Flower bud length (cm); FBG: Flower bud girth (mm); CTL: Corolla tube length (cm); 100 BW: 100 bud weight (g); FY: Flower yield / g/plant; P: Phenotypic correlation; G: Genotypic correlation.

**Fig. 5.** Genotypical path diagram for total flower yield of mutant genotypes.

yield trials, to get repeatability of results for yield and flower quality traits.

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Authors' contributions

SMS prepared the research concept, carried out the experiment, took observations, analysed the data and prepared the results of the manuscript. KI guided in analysing the data and interpretation of results. MG and DM guided the research work, contributed ideas in formulating the research concept, helped in summarising the results and edited the manuscript. All authors have read and approved the final manuscript.

Compliance with ethical standards

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

Ethical issues: None

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