GENETIC VARIABILITY AND CHARACTER ASSOCIATION STUDIES FOR YIELD AND YIELD TRAITS IN FRENCH MARIGOLD (*TAGETES PATULA* L.)

ABSTRACT

Twelve growth and flowering traits to study their genetic variability, correlation and path coefficients from twenty-five genotypes of French marigold (*Tagetes patula* L.) were evaluated in the growing season 2016/17. The analysis of variance for all the traits showed significant differences among genotypes for all the growing plants and flowering traits. The range in mean performance was observed for plant height (34.33-94.33 cm), plant spread (31.33-73.43 cm), number of flowers per plant (53.33-104.67), carotenoid content (19.43-74.57 mg/100g), days to 50% of flowering (49.43-82.40 days) and flower yield per plant (142.56 g - 526.15 g). The phenotypic coefficients of variation (PCV) were higher than the corresponding genotypic coefficients of variation (GCV) for all the characters. High heritability coupled with high genetic gain was observed for flower yield per plant, days to 50 % of flowering and plant height. Flower yield per plant had a positive and highly significant correlation both at genotypic and phenotypic levels with the number of flowers per plant, fresh weight of flower, plant height and shelf life. Path coefficient analysis revealed that traits like number of flowers per plant, fresh weight of flowers, plant height, number of primary branches per plant and the lifespan of flowering had positive effects on flower yield per plant. Hence, selection for these traits would be effective for flower yield in French marigold.

Keywords: Correlation coefficient, Genetic variability, Heritability, Path coefficient, Tagetes patula L.

1. INTRODUCTION

Marigold (*Tagetes spp.*) is one of the most popular and commercial loose flower crop cultivated in India and rank first among the loose flowers in area and production (Kavitha and Anburani 2009). In India, marigolds are cultivated in the states Karnataka, West Bengal, Tamil Nadu, Haryana, Punjab, Himachal Pradesh, Uttar Pradesh and Delhi. It gains its popularity due to its hardiness, easy culture, wide adaptability to different soil and climatic conditions and easy transportation attracts the attention of flower growers. Marigold is especially used for festive occasions, marriages, religious ceremonies, social functions and in landscaping owing to its wide range of attractive colours, shape, size and having good keeping quality. Currently, most of the varieties are open-pollinated which are less vigorous,

uneven height with low yield, and vulnerable to cross-pollination. This situation leads to the degeneration of open pollinated varieties. In recent years, growing F_1 hybrids is increasing in various countries due to numerous advantages over open-pollinated varieties.

Variability in a population with respect to various qualitative and quantitative traits is a pre-requisite for successful breeding programmes. The total variability can be partitioned into heritable and non-heritable components with the help of genetic parameters like phenotypic and genotypic coefficients of variation, heritability and genetic advance. Selection is effective only when the observed variability in the population is heritable in nature (John *et al*. 2006). Burton (1952) suggested that genetic variation along with heritability estimates would give a better idea about the efficacy of selection.

Yield is a complex character controlled by a large number of contributing characters and their interactions. Knowledge of the mechanisms underlying the correlations between different traits is fundamental for understanding the degree of integration of the phenotype and to solve the constraints imposed by evolutionary processes (Lynch and Walsh 1998). It is essential to know the degree of correlation between yield and its component characters, which forms a basis for selecting the desirable genotypes. The path coefficient technique developed by Wright (1921) helps in estimating direct and indirect contribution of various components in building up the total correlation towards yield. Therefore, the investigation was undertaken to assess the association of important flower yield and quality traits and their direct and indirect contribution towards yield.

2. MATERIAL AND METHODS

The treatments

Twenty five genotypes of French marigold were planted in the growing season *Rabi season* (October, 2016/April, 2017) at Research Farm, Division of Vegetable Sciences and Floriculture, SKUAST-Jammu. Healthy seedlings were transplanted in Randomized Block Design with three replications in experimental plots at the spacing of 30 cm x 30 cm thereby accommodating 25 seedlings per plot. Furthermore, we applied 20 t ha^{-1} of farm yard manure (FYM) and 120 kg N, 100 kg P_2O_5 and 100 kg K_2O per hectare , during the transplanting. Pinching was done 35 days after transplanting. Standard cultural practices were followed during the experiment. We collected data from five randomly selected plants from each plot for twelve different growth and flowering parameters.

Statistical Analysis

The mean value of all the observations was subjected to statistical analysis using MS-Excel, OPSTAT and R studio package. The analysis of variance was carried out by the method described by Gomez and Gomez (1983) for Randomized Block Design. The phenotypic coefficient of variability (PCV) and genotypic coefficient of variability (GCV) were calculated according to formulae given by Burton and De-Vane (1953). Broad sense heritability (H) and expected genetic advance was computed by using the formulae proposed

by Allard (1960). Genetic gain expressed as per cent of population mean, was calculated by the method given by Johnson (1955). The genotypic and phenotypic correlation coefficients were calculated as given by Al-Jibouri *et al.* (1958) by using analysis of variance and covariance matrix in which total variability has been split into replications, genotypes and errors. The characters showing significant correlation with yield were utilized to compute direct and indirect contribution as illustrated by Dewey and Lu (1959).

3. RESULTS AND DISCUSSION

Mean performance of genotypes

Growth and flowering traits as plant height, plant spread, days to flowering, stalk length, number of primary branches, lifespan of the flowering period, number of flowers per plant, flower diameter, fresh weight per flower, carotenoid content, flower yield per plant and shelf life exhibited significant variation among genotypes which shows the existence of wide range of variability (Table 1).

Plant height varied significantly among the genotypes at all the stages of plant growth. Genotype Gulzafri Orange recorded maximum plant height (94.33 cm) and number of primary branches (21.33), while minimum was recorded in genotype Durango Red (34.33 cm). Plant spread varied from 'French Royal' (73.43cm) to Gulzafri Yellow (31.33 cm). The variation in plant characters among the various genotypes might be due to genotypic differences in phenotypic expressions and variations in different genotype-environmental interaction effects on these characters. Similar findings were also reported by Narsude *et al*. (2010), Singh and Singh (2010) and Raghuvanshi and Sharma (2011) also reported variation in plant characters due to the inherent character of marigold genotypes.

Among all the genotypes, 50 per cent flowering was earliest in the genotype French Scarlet Red followed by Durango Red. The genotype Nana Patula Yellow took the maximum number of days for 50 per cent flowering. Highest flower diameter was observed in genotype FM-2 (6.40) and lowest was observed in Nana Patula Yellow (4.63). Carotenoid content was highest in genotype FM-11 (74.57) and lowest in FM-4 (19.43). All the genotypes differed significantly for flower stalk length. Maximum stalk length (14.47 cm) was recorded in Gulzafri Orange while minimum flower stalk length (5.93 cm) was obtained in Durango Red.

Number of flowers per plant is also important trait determining the flower yield. Number of flowers per plant was observed highest in genotype French Royal (104.67) and lowest in Durango Red (53.33). The maximum fresh weight of flower (6.38 g) was recorded in FM-1 which was at par with French Bolero Red (6.19 g). The weight of flower appeared to be associated with diameter of flower as evident from the results. The genotype French Yellow recorded longest duration of flowering (50.47 days). Genotypes FM-8 (49.53 days) and FM-10 (49.37 days) were statistically at par with French Yellow for duration of flowering. Results further revealed maximum flower yield (526.15 g) in French Bolero Red which was followed by Single Petal Red (466.32 g) and French Royal (464.73 g). Minimum flower yield was obtained in the genotype Nana Bonita (142.56 g). The maximum shelf life (6.43 days) was recorded in French Royal which was statistically at par with the shelf life obtained in Nana Patula Orange, French Double Bicolor, French Bolero Red, FM-4, FM-10, FM-11 and FM-12. The genetic control of all these characters and modification in their expression due to environmental conditions might be the possible causes of observed variation. Similar findings have been also reported by Raghuvanshi and Sharma (2011) and Beniwal and Dahiya (2012) in marigold; Kumari *et al.* (2012) and Bhayani *et al.* (2008) in gerbera.

Variability studies:

The analysis of variance indicated highly significant differences among genotypes for all the traits studied. The phenotypic coefficients of variation (PCV) were higher in magnitude than the corresponding genotypic coefficients of variation (GCV) for all the characters studied (Table 2), but differences were less in majority of cases. It indicated that environmental factors had played less influence on the expression of these characters.

The PCV and GCV were higher for flower yield per plant, number of flowers per plant, number of primary branches and carotenoid content indicating the presence of high amount of genetic variability for these traits and effective for selection because the response to selection is directly proportional to the variability present in the experimental material. However, low values of PCV and GCV were observed for days to 50 % flowering and duration of flowering. These results are in conformity with the previous results as reported by Namita *et al*. (2008) and Mathew *et al*. (2005) in marigold, and Kameswari *et al*. (2015) in chrysanthemum.

High heritability was recorded for days to 50% flowering, carotenoid content, duration of flowering, plant height, stalk length, number of flower per plant, flower yield per plant, shelf life, plant spread and fresh weight per flower. This indicates good correspondence between genotypic and phenotypic values and thereby low environmental effect on the expression of these characters. These results are in agreement with the findings of Kavitha and Anburani (2010), Yuvraj and Dhatt (2014) and Karuppaiah and Kumar (2011) who reported results from marigold.

Heritability estimates alone do not provide reliable information about the gene action governing the expression of a particular character. The heritability estimates along with expected genetic advance is more useful than heritability alone for improving a particular trait (Johnson *et al*. 1955). High heritability coupled with high genetic gain was observed for flower yield per plant, days to 50 % flowering and plant height. High heritability along with moderate genetic gain was observed for plant spread, carotenoid content, number of flowers per plant and duration of flowering. Panse (1957) suggested that the genotypic variations for such characters are probably due to high additive gene effects and least influenced by the environment. The phenotypic selection based on such a character is likely to be more effective for the improvement of the genotype. Similar results were also reported by Singh *et al.* (2007), Singh and Singh (2010), Singh and Kumar (2008) in marigold and Bhatia *et al*. (2013) in tulips. High heritability along with low genetic gain was observed for number of primary branches, flower diameter, stalk length, shelf life and fresh weight per flower indicating the role of non-additive gene action in the transmission of these traits from parents to off springs.

Correlation studies:

Yield is not an independent trait but resultant of the interactions of a number of component traits among themselves as well as with the environment in which the plant grow. Each trait is likely to be modified by action of genes present in the genotypes of plant and also by the environment so it becomes difficult to evaluate this complex trait directly. Therefore, correlation study of yield with its component traits has been executed, to find out the yield contributing traits.

Correlation analysis was done to find out association among flower yield and different yield contributing parameters both at phenotypic and genotypic levels and the data have been

presented in Table 3. In general, the magnitude of correlation coefficient at genotypic level was found higher than the corresponding correlation at phenotypic level, thereby indicating a strong inherent association between various characters under study.

Flower yield per plant had a positive and highly significant correlation both at genotypic and phenotypic levels with number of flowers per plant, fresh weight of flower, plant height and shelf life. This indicates that flower yield in marigold can be improved by direct selection of these characters. Whereas, plant spread and number of primary branches per plant shows positive and significant correlation only at genotypic level with flower yield per plant. Bhaskaran *et al*. (2004) also got similar results in chrysanthemum.

Flower yield per plant had a positive and non-significant association both at genotypic and phenotypic levels with days to 50% flowering, flower diameter, carotenoid content, stalk length and duration of flowering. Similar observations were also made by Karuppaiah *et al.* (2006), Singh and Saha (2009) and Kavitha and Anburani (2010) in marigold.

Path Coefficient Analysis

In present study, path coefficient analysis was carried out by taking flower yield per plant as dependent variable to partition correlation coefficients into direct and indirect effects in order to determine the contribution of different characters towards the flower yield per plant. Direct and indirect effects of various characters on flower yield per plant indicated that there is an agreement between direction and magnitude of direct effect of various character and correlation with flower yield per plant. Thus, a significant improvement in flower yield per plant can be expected through selection in the component traits with high positive direct effects. The estimates of path coefficient for different attributes on flower yield were presented in Table 4.

Perusal of data indicated that maximum positive direct effect towards flower yield per plant was contributed by number of flowers per plant, followed by fresh weight of flower and plant height. The other traits which showed positive direct effect with flower yield per plant were number of primary branches per plant and duration of flowering indicating that more the plant height and number of primary branches per plant the more will be the number of flowers through better vegetative growth, thus, ultimately increasing the flower yield. These findings are in agreement with the findings of Mathad *et al.* (2005), Karuppaiah and Kumar (2011) and kumar *et al*. (2014) in marigold. Whereas, plant spread, days to 50 % flowering, flower diameter, carotenoid content, stalk length and shelf life had negative direct effect on flower yield per plant. This suggests that emphasis must be given on such traits while selection to improve the flower yield.

The magnitude of residual effect was low, which indicated that major portion of contribution towards flower yield per plant might be explained on the basis of characters included in the present study. However, some more characters not included in the present study may contribute to account for the residual effect. Similar findings were also reported by the finding of Panwar *et al.* (2013), Namita *et al.* (2009) in marigold, Anuja and Jahnavi (2012) and Ushabharti *et al.* (2014) in African marigold.

Table 1 Mean performance of genotypes for different characters in French marigold

Treatments	Plant height (cm)	Plant spread (cm)	Number of primary branches	Days to 50 % flowering	Flower diameter (cm)	Carotenoid content (mg/100 g)	Stalk length (cm)	Number of flowers per plant	Fresh weight per flower (g)	Duration of flowering (days)	Flower yield per plant (g)	Shelf life (days)
Gulzafri Orange	94.33	65.60	21.33	72.57	5.20	44.43	14.47	63.67	4.32	42.33	275.05	5.63
Gulzafri Yellow	75.67	31.33	11.00	70.33	5.30	47.57	12.57	55.00	4.50	39.43	247.50	5.67
Durango Red	34.33	35.00	7.00	51.57	5.57	34.57	5.93	53.33	3.53	38.43	188.25	4.50
Nana Patula Orange	34.67	33.70	7.00	68.57	4.83	21.60	6.23	64.33	3.28	45.40	211.00	6.33
Nana Patula Yellow	37.00	55.20	8.00	82.40	4.63	33.90	8.33	54.67	3.25	46.50	177.68	3.30
French Scarlet Red	34.33	34.93	7.67	49.43	6.33	47.40	6.13	64.67	3.43	42.63	221.82	3.50
French Yellow	37.67	40.37	8.67	77.53	5.63	32.70	11.17	64.67	4.61	50.47	298.13	5.40
Nana Bonita	44.00	43.67	8.67	61.73	5.53	28.53	9.40	54.00	2.64	46.53	142.56	2.37
French Double Bicolor	63.33	63.80	13.33	67.57	5.43	47.33	8.37	64.00	4.39	36.87	280.96	6.40
French Royal	84.33	73.43	14.00	69.43	5.57	39.30	7.57	104.67	4.44	44.33	464.73	6.43
French Giant Bicolor	53.33	64.27	14.00	65.43	5.47	46.53	7.33	84.33	4.20	48.43	354.19	5.63
French Bolero Red	72.00	55.83	11.33	61.47	5.67	48.37	7.13	85.00	6.19	45.13	526.15	6.37
Single Petal Red	94.33	34.13	11.67	67.47	4.67	48.40	13.63	87.00	5.36	45.37	466.32	5.57
FM-1	71.67	44.00	12.67	67.60	5.50	36.63	10.47	65.67	6.38	43.50	418.97	4.47
FM-2	65.00	34.13	9.00	69.67	6.40	22.63	9.43	55.67	4.36	46.63	242.72	5.47
FM-3	53.00	52.67	7.33	68.47	5.27	42.50	7.73	57.33	3.55	43.37	203.52	5.37
FM-4	63.33	48.07	9.33	56.40	5.40	19.43	9.37	70.33	4.68	47.47	329.14	6.33
FM-5	66.33	53.67	7.67	59.57	4.63	20.63	9.03	56.33	3.48	48.53	196.03	5.37
FM-6	73.67	43.70	7.33	55.60	5.40	42.50	6.93	66.67	3.31	39.03	220.68	5.73
FM-7	83.00	56.17	11.33	81.43	5.50	46.53	7.47	55.33	4.13	47.50	228.51	5.43
FM-8	84.33	55.03	7.33	80.60	5.43	44.40	11.60	66.33	4.72	49.53	313.08	5.43
FM-9	81.33	45.33	11.33	74.43	5.57	34.57	11.63	75.33	3.38	48.47	254.62	5.37
FM-10	76.67	35.80	9.67	78.53	6.23	37.47	8.53	80.67	4.31	49.37	347.69	6.37
FM-11	64.00	42.97	6.67	76.60	5.50	74.57	9.33	71.00	4.60	45.63	326.60	6.37
FM-12	56.00	51.47	13.67	62.70	5.47	33.63	10.10	59.00	4.57	45.93	269.63	6.33
Mean	**63.91**	**47.77**	**10.28**	**67.88**	**5.45**	**39.04**	**9.20**	**67.16**	**4.22**	**45.07**	**288.22**	**5.41**
SE+ (m)	1.649	2.166	0.957	0.178	0.131	0.175	0.170	1.637	0.162	0.174	10.649	0.170
$CD_{0.05}$	4.704	6.177	2.731	0.508	0.374	0.499	0.486	4.668	0.462	0.496	30.374	0.485
CV	4.470	7.852	16.131	0.455	4.168	0.776	3.208	7.628	6.642	0.668	11.415	5.445

Table 2 Estimation of phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic gain for various traits in French marigold (*Tagetes patula* L.).

Observations/Traits	Mean±S.E.	Range	Coefficient of variation		Heritability (%)	Genetic Advance (%)	Genetic Advance as percent of mean
			PCV	GCV			
Plant height (cm)	63.91±1.649	34.33-94.33	29.83	29.49	0.98	0.60	63.91
Plant spread (cm)	47.77±2.166	31.33-73.43	25.24	23.99	0.90	0.47	47.77
Number of primary branches	10.28±0.957	6.67-21.33	35. 17	31.25	0.79	0.57	10.28
Days to 50 % flowering	67.88±0.178	49.43-82.40	13.41	13.40	0.99	0.28	67.88
Flower diameter (cm)	5.45±0.131	4.63-6.40	8.93	7.93	0.79	0.14	5.44
Total chlorophyll content	18.23±0.489	6.11-49.83	51.66	51.45	0.99	1.06	18.23
Carotenoid content (mg/100 g)	39.04±0.175	19.43-74.57	30.46	30.45	0.99	0.63	39.04
Stalk length (cm)	9.20±0.170	5.93-14.47	25.28	25.07	0.98	0.51	9.20
Number of flowers per plant	67.16±1.637	53.33-104.67	35.10	34.26	0.95	0.69	37.16
Fresh weight per flower (g)	4.22±0.162	2.64-6.38	21.70	20.64	0.90	0.40	4.22
Duration of flowering (days)	45.07±0.174	36.87-50.47	8.13	8.10	0.99	0.17	45.07
Flower yield per plant (g)	288.22±10.649	142.56-526.15	48.56	47.20	0.94	0.94	161.57
Shelf life (days)	5.41±0.170	2.37-6.43	20.04	19.26	0.92	0.38	5.40

Table 3 Genotypic (G) and phenotypic (P) correlation coefficients for various traits in French marigold (*Tagetes patula* L.)

Traits	???	Plant height (cm)	Plant spread (cm)	Number of primary branches	Days to 50 % flowering	Flower diameter (cm)	Carotenoid content (mg/100 g)	Stalk length (cm)	Number of flowers per plant	Fresh weight per flower (g)	Duration of flowering (days)	Shelf life (days)	Flower yield per plant (g)
Plant height (cm)	(G)	-	0.29	0.52**	0.32	-0.06	0.29	0.57**	0.43*	0.46*	0.04	0.45*	0.50*
	(P)	-	0.36	0.47*	0.35	-0.04	0.29	0.60**	0.39	0.46*	0.08	0.48*	0.47*
Plant spread (cm)	(G)		-	0. 65**	0.18	-0.21	0.14	-0.04	0.45*	0.10	0.04	0.20	0.44*
	(P)		-	0. 55**	0.16	-0.14	0.19	-0.01	0.32	0.23	0.04	0.22	0.27
Number of primary branches	(G)			-	0.13	-0.03	0.14	0.47*	0.50*	0.37	-0.13	0.25	0.50*
	(P)			-	0.12	0.00	0.17	0.33	0.31	0.34	-0.15	0.39	0.37
Days to 50 % flowering	(G)				-	-0.13	0.22	0.39*	0.05	0.14	0.45*	0.15	0.07
	(P)				-	-0.10	-0.22	0.38	0.06	0.13	0.46*	0.16	0.07
Flower diameter (cm)	(G)					-	0.09	-0.23	0.10	0.11	0.03	0.08	0.08
	(P)					-	-0.05	-0.20	0.15	0.24	0.16	0.09	0.20
Carotenoid content (mg/100 g)	(G)						-	0.09	0.27	0.29	-0.27	0.17	0.32
	(P)						-	0.19	0.24	0.22	-0.27	0.15	0.27
Stalk length (cm)	(G)							-	0.00	0.33	0.17	0.06	0.12
	(P)							-	0.00	0.37	0.15	0.15	0.13
Number of flowers per plant	(G)								-	0.41*	0.19	0.46*	0.91**
	(P)								-	0.39*	0.16	0.46*	0.91**
Fresh weight per flower (g)	(G)									-	0.05	0.43*	0.73**
	(P)									-	0.08	0.48*	0.73**
Duration of flowering (days)	(G)										-	0.02	0.15
	(P)										-	0.03	0.14
Shelf life (days)	(G)											-	0.50*
	(P)											-	0.50*

*Significant at 5% level of significance **Significant at 1% level of significance

Table 4 Estimates of direct and indirect effects of different traits on yield in French marigold (Diagonal bold value is direct effect)

Traits	Plant height (cm)	Plant spread (cm)	Number of primary branches	Days to 50 % flowering	Flower diameter (cm)	Carotenoid content (mg/100 g)	Stalk length (cm)	Number of flowers per plant	Fresh weight per flower (g)	Duration of flowering (days)	Shelf life (days)	Flower yield per plant (g)
Plant height (cm)	**0.0372**	-0.0051	0.0022	-0.0052	0.0017	-0.0027	-0.0414	0.2934	0.2308	0.0001	-0.0411	0.50*
Plant spread (cm)	0.0134	**-0.0141**	0.0031	-0.0024	0.0059	-0.0017	0.0007	0.3386	0.1154	0.0001	-0.0188	0.44*
Number of primary branches	0.0175	-0.0092	**0.0047**	-0.0018	0.0000	-0.0016	-0.0228	0.3762	0.1706	-0.0003	-0.0334	0.50*
Days to 50 % flowering	0.0130	-0.0023	0.0006	**-0.0147**	0.0042	-0.0020	-0.0262	0.0451	0.0652	0.0008	-0.0137	0.07
Flower diameter (cm)	-0.0015	0.0020	0.0000	0.0015	**-0.4204**	0.0005	0.0138	0.1129	0.1204	0.0003	-0.0077	0.08
Carotenoid content (mg/100 g)	0.0088	-0.0022	0.0008	-0.0032	0.0022	**-0.0092**	-0.0047	0.1809	0.1077	-0.0005	-0.0128	0.32
Stalk length (cm)	0.0223	0.0001	0.0016	-0.0056	0.0084	-0.0008	**-0.0690**	0.0000	0.1856	0.0003	-0.0128	0.12
Number of flowers per plant	0.0145	-0.0063	0.0024	-0.0009	-0.0063	-0.0022	0.0000	**0.7523**	0.1956	0.0003	-0.0394	0.91**
Fresh weight per flower (g)	0.0171	-0.0032	0.0016	-0.0019	-0.0101	-0.0020	-0.0255	0.2934	**0.5016**	0.0001	-0.0411	0.73**
Duration of flowering (days)	0.0030	-0.0006	-0.0007	-0.0068	-0.0067	-0.0025	-0.0104	0.1204	0.0401	**0.0017**	-0.0026	0.15
Shelf life (days)	0.0179	-0.0031	0.0018	-0.0024	-0.0038	-0.0014	-0.0103	0.3461	0.2408	0.0001	**-0.0856**	0.50*

Residual value: 0.0645

4. CONCLUSION

The results of the present investigation suggested that the French marigold genotypes could be effectively categorized and characterized based on morphological characters and as such, these traits could be utilized as good descriptors in the identification and maintenance of genotypes. The variation present could be utilized for crop improvement programme through direct selection and hybridization. Flower yield per plant had a positive and highly significant correlation with number of flowers per plant, fresh weight of flower, plant height and shelf life which can be utilized for future breeding program in French marigold

REFERENCES

Al-Jabouri R A, Miller P A and Robinson H F. 1958. Genotypic and environmental variance in upland cotton crosses of interspecific origin. *Agronomy Journal* **50**: 633-637.

Allard R W. 1960. *Principle of Plant Breeding*, p 485, John Wiley and Sons, Inc. New York.

Anuja S and Jahnavi K. 2012. Variability, heritability and genetic advance studies in French marigold (*Tagetes patula* L.). *The Asian Journal of Horticulture* **7**(2): 362–364.

Beniwal B S and Dahiya S S. 2012. Variability studies in marigold (*Tagetes* spp.). **In**: Abstracts of National Seminar on Sustainable Agriculture and Food Security: Challenges in Changing Climate, 298p.

Bhaskaran V, Janakiram T and Jayanthi R. 2004. Correlation and path coefficient analysis studies in chrysanthemum. *Journal of Ornamental Horticulture* **7**(3-4): 37-44.

Bhayani H N, Parmar B R, Tandel Y N and Vahora A M. 2008. Evaluation of different varieties of gerbera in low cost polyhouse. **In**: *Abstracts of National Symposium on Recent Advances in Floriculture,* Navsari Agricultural University, Navsari, Gujarat p.51.

Bhatia R, Dhiman M R, Chander Prakash and Dey, S S. 2013. Genetic variability and character association in tulip (*Tulipa gesneriana*) for various quantitative traits. *Indian Journal of Agricultural Sciences* **83**(7): 773-780.

Burton G W and De-vane E H. 1953. Estimating heritability in tall fescue (*Festuca arundinaceae)* from replicated clonal material. *Agronomy Journal* **45:** 478-481.

Burton G W. 1952. Quantitative inheritance in grasses. *Proceeding of the International Grassland Congress* **6**: 277-283.

Dewey D R and Lu K H. 1959. A correlation and path coefficient analysis of crested wheat grass seed production. *Agronomy Journal* **51**: 515-18.

Gomez K A and Gomez A A. 1983. *Statistical Procedures for Agricultural Research*, pp. 357- 427. John Wiley and Sons Inc., New York.

Jhon A Q, Khan F U and Rather Z A. 2006. Genetic variability studies in tulip. *Applied Biological Research* **8** (1-2): 37–9.

Johnson H W, Robinson H F and Comstock R L. 1995. Estimates of genetic and environmental variability in soybean. *Agronomy Journal* **47**: 314-28.

Kameswari P L, Hameedunnisabegum M P and Anuradha G. 2015. Studies on genetic variability and character association for yield and its attributes in chrysanthemum (*Dendranthema grandiflora* Tzvelev). *Agriculture Science Digest* **35**(1) 2015: 25-30.

Karuppaiah P and Kumar P S. 2011. Variability, heritability and genetic advance for yield, yield attributes and xanthophyll content in African marigold (*Tagetes erecta* L.). *Crop Research* **41**(1/3): 117-119.

Karuppaiah P, Sudhakaran K, Kumar P S and Kathiravan J. 2006. Correlation and path analysis for yield, yield attributes and xanthophyll content in African marigold (*Tagetes erecta* L.). *South Indian Horticulture* **54**(1-6): 304-310.

Kavitha R and Anburani A. 2009. Genetic diversity in African marigold (*Tagetes erecta* L.) genotypes. *Journal of Ornamental Horticulture* **12**(3):198-201.

Kavitha R and Anburani A. 2010. Genetic variability in African marigold. *The Asian Journal of Horticulture* **5**(2): 344–346.

Kumar A, Pratap B and Beer K. 2014. Studies on Genetic variability and character association in French marigold (*Tagetes patula* L.). *Trends in Biosciences* **7**(2): 122–124.

Lynch M and Walsh B. 1998. Genetics and analysis of quantitative traits. *Sunderland, MA, USA: Sinauer Associates.*

Kumari A, Patel K S, Choudhary M and Yadav R K. 2012. Performance of gerbera (*Gerbera jamesonii*) cultivars under fan and pad cooled greenhouse conditions. *Research on crops* **13**(1): 299-301.

Mathad G, Hegde B S and Mulge R. 2005. Correlation and path coefficient analysis in African marigold (*Tagetes erecta* L.*). The Karnataka Journal of Horticulture* **1**(3): 22-29.

Mathew R, Beniwal B S, Bhatia S K and Deswal D P. 2005. Variability and correlation studies in African marigold (*Tagetes erecta* L.) *Research on Crops* **6**(2): 322-327.

Namita, Singh K P, Bharadwaj C, Prasad K V and Raju D V S. 2009. Studies on character association and path analysis of quantitative traits among parental lines of marigold (*Tagetes erecta* and *Tagetes patula*) and their interspecific F_1 hybrids. *Indian Journal of Horticulture* **66**(3): 348-352.

Namita, Singh K P, Raju D V S, Prasad K V and Bharadwaj C. 2008. Studies on genetic variability, heritability and genetic advance in French marigold (*Tagetus patula* L.) genotypes. *Journal of Ornamental Horticulture* **12**(1): 30-34.

Narsude P B, Kadam A S and Patil V K. 2010. Studies on the growth and yield attributes of different African marigold genotypes under Marathwada conditions. *The Asian Journal of Horticulture* **5**(2): 284-286.

Panse V G. 1957. Genetics of qualitative characters in relation to plant breeding. *Indian Journal of Genetics* **17**: 318-328.

Panwar S, Singh K P, Janakiram T and Namita. 2013. Genetic variability, heritability and genetic advance in African marigold (*Tagetes erecta* L.) genotypes. *Progressive Horticulture* **45**(1): 135–140.

Raghuvanshi A and Sharma B P. 2011. Varietal evaluation of French marigold (*Tagetes patula* L.) under mid-hill zone of Himachal Pradesh. *Programme Agriculture* **11**(1): 123-126.

Singh A K and Singh D. 2010. Genetic variability, heritability and genetic advance in marigold. *Indian Journal of Horticulture* **67**: 132–6.

Singh D and Kumar S. 2008. Studies on genetic variability, heritability, genetic advances and correlation in marigold. *Journal of Ornamental Hort*iculture **11**(1): 27-31.

Singh K P and Saha T N. 2009. Character association and path analysis studies in French marigold. *Annals of Horticulture* **2**(1): 39-42.

Singh S R P, Syamal M M and Sharma O. 2007. Studies on genetic variability in marigold. *Indian Journal of Horticulture* **64**(4): 483-485.

Usha Bharati, T. U., Jawaharlal, M., Kanan, M., Manivannan, N. and Raveendran, M. 2014. Correlation and path analysis in African marigold (*Tagetes erecta* L.). *The Bioscan*, **9**(4): 1673-1676.

Wright S. 1921. Correlation and causation. *Journal of Agricultural Research* **20**: 557- 585.

Yuvraj and Dhatt K K. 2014. Studies on genetic variability, heritability and genetic advance in marigold. *Indian Jounal of Horticulture* **71**(4): 592-594.