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Studies on Genetic Variability, Heritability, Genetic Advance and Correlation Analysis in Marigold (*Tagetes spp.*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted in the Department of Floriculture and Landscape Architecture, University of Horticultural Sciences, College of Horticulture, Bagalkot to evaluate twenty cultivars of marigold (*Tagetesspp*) during 2020-2021. The experiment was laid out RCBD (Randomised Complete Block Design) with two replications for growth and yield contributing characters to determine genetic variability, heritability, genetic gain and correlation among fourteen characters. The magnitude of phenotypic coefficient of variance (PCV) was higher than the genotypic coefficient of variance (GCV) for all characters under study. The estimates for the coefficients of variance related to genotype and phenotype varied from 10.87% to 50.65% and 11.48% to 50.96% respectively. Heritability was high for all the growth and flowering parameters ranged from 89.60% to 99.00%. The plant with the highest heritability was noticed in leaf width (99.00%), followed by the flowers yield per plant (98.90%). Plant height (42.08) and leaf width (96.34%) were showed high genetic advance and genetic advance as per cent of mean, respectively. Correlation coefficient analysis indicated that the characters viz., plant height, plant spread in east-west and north-south directions, number of primary and secondary branches per plant, leaf length, number of flowers per plant, individual flower weight, flower diameter and flowering duration exhibited positive significant correlation (genotypic and phenotypic) with flower yield per plant. Our investigation indicated that these characters are important in determining the flower yield per plant. Hence, these characters may be considered as selection indices for deciding flower yield per plant and might be considered as selection indices in a marigold improvement program.

Keywords: Marigold; genetic variability; heritability; genetic advance; correlation coefficient.

1. INTRODUCTION

Marigold (*Tagetes* spp.) belongs to the family asteraceae and native of South and Central America. *Tageteserecta* (African marigold) and *Tagetespatula* (French marigold) are commonly grow species for loose flower production which are either single, semi double or double types. The majority of the species are branching, annual or perennial herbs used for ornamental and industrial uses Singh et al. [1]. It's one of the most significant traditional flower crops grown across the nation, valued for its loose flowers that are used for social gatherings, religious offerings, bedding plants in landscape gardens and carotenoids extraction. These uses have increased the crop's significance and cultivated area. In addition to being planted for landscaping, it is in high demand in the medical and industrial sectors. It is also recommended as a trap crop to monitor the occurrence of helicoverpa in most vegetable crops and possesses nematicidal qualities. Marigold has been very well documented for phytoremediation of heavy metal polluted soil Madananet al. [2].

Genetic diversity is used as source of genes in crop improvement for production of high yielding varieties and hybrids [3]. Being able to access a varied germplasm pool is essential for successfully incorporating novel features into commercial ornamental crops [4,5]. Investigation, collection, assessment, preservation and resource utilization are crucial for the long-term use of the available germplasm [6,7]. The breeding program must take into account the level of genetic heterogeneity in a gene pool Bhujbal et al [6]. Each hybridization program's effectiveness depends heavily on understanding the heterogeneity that exists within a crop species [8,9].Therefore, a detailed investigation of genotypic and phenotypic variations is needed for efficient selection Kumari et al. [10]. It makes sense to use correlation studies and additional partitioning into different yield components and other characters to comprehend the type and extent of their interaction Dey et al. [11]. Breeders are frequently looking to increase a number of economic traits, such as yield, therefore understanding the connection between traits is crucial to understanding the changes that would occur in other traits concurrently with the selection of one trait Bennurmath et al. [12]. It is well-established that different traits in the plant system have complicated connections with one another. Keeping in view the above facts, current investigation was undertaken with an objective to identify and analyze the traits having greater interrelationshipwith flower yield per plant utilizing the correlation to help breeders in improvement of marigold.

2. MATERIALS AND METHODS

The present investigation was carried out during Rabi season at Department of Floriculture and Landscape Architecture research block, College of Horticulture, Bagalkot, University of

Horticultural Sciences, Bagalkot. Twenty cultivars collected from diverse source comprising of eleven African marigold cultivars namely, Pusa Narangi Gainda, NS 119 F_1, NS 104 F_1, NS 66 F_1, Double Orange, Majestic Yellow, Pusa Bahar, Arka Bangara-2, Culcutta Orange, Pusa Basanti Gainda, Arka Agni and nine French marigold cultivars namely, Pusa Arpita, SFR-5, UHSFm-2, UHSFm-3, UHSFm-4, UHSFm-7, Chintamani red, Pusa Deep, French marigold Durango mix were grown in a randomized complete block design (RCBD) with two replications. Seeds of all the cultivars were sown on the nursery trays to raise seedlings. Transplanting of seedlings was done when they attain three to four true leaves stage. The cultivars were planted with a spacing of 60 x 45 cm with all the agronomical practices and plant protection measures. The observations were recorded on five randomly tagged five plants from each cultivar of each replication. For all the characters were taken under grand growth stage (60 days), the mean values of randomly selected plants were calculated for each observation. The methods recommended by Burton and De vane [7]were used to compute the genotypic and phenotypic coefficients of variance (GCV and PCV). Weber and Moorthy [13-15] provided an estimate for the broad sense heritability (h^2bs) and Robinson et al. [16] classified heritability percentages. The formula provided by Johnson et al. [15] was used to compute genetic advance and genetic advance over mean. As recommended by Panse and Sukhatme[16], genotypic and phenotypic correlation coefficients were computed. The software's OPSTAT and Indostat 9.1 versions were used for the statistical analysis.

3. RESULTS AND DISCUSSION

Analysis of variance showed that there were significant differences in growth and flowering between the twenty cultivars (grand growth stage, 60 days). The wide range of diversity amongst the cultivars allows for the crop to be significantly improved.

3.1 Estimation of Genetic Parameters for Growth and Flowering

Table 1 displays the results of the analysis of variance for the morphological features of marigolds. It shows that the various morphological characters showed extremely significant differences. The degree of variability was assessed using the following metrics: range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), percent heritability (h^2) and genetic advance above percent mean. The results are shown in Table 2.

For each of the fourteen characters in the study, the PCV was more than the GCV and the PCV-to-GCV percentage was seen to be narrow for all of the characters, indicating that the characters were less influenced by environment. In marigold, similar results were also reported by Namita et al. [17]and Kumari et al. [10]. The estimates of the coefficients of variation for genotype and phenotype varied from 10.87 to 50.65% and 11.48 to 50.96%, respectively. Plant height, plant spread in both east and west directions, number of primary and secondary branches, stem diameter, leaf length, leaf width, number of flowers per plant, flower yield per plant, individual flower weight, flower diameter, flowering duration, and shelf life were found to have high heritability estimates associated with high genetic advance mean of percent. These findings suggest that selecting for these traits based on phenotype would be highly appropriate and effective. Findings by Santhosh et al. [18], Kumar et al. [19]in marigold and Sushma et al. [20] in chrysanthemum are consistent with this. A plant breeder will be able to create criteria based on phenotypic performance only if high estimates of heredity are available. When a trait has a high heritability, selection for that trait is relatively simple since the genotype and phenotype closely coincide because the environment contributes little to the phenotype. The combination of high heritability and low genetic advancement suggests that non-additive gene activities have a role in the inheritance of trait and that simple selection may not be sufficient to achieve the desired effects. According to Namita et al. [17], cultivar selection may not be effective for traits, so the high heritability is being displayed as a result of the environment's positive influence.

3.2 Genotypic and Phenotypic Correlation Coefficient Analysis

Tables 3 and 4 present an analysis of the correlation coefficients among various characters. Genotypic correlation coefficient was generally greater than the phenotypic correlation value. The degree of link between the characters is indicated by these correlation coefficients. Plant height, plant spread in both east and west and north and south directions, number of primary and secondary branches, leaf length, number of flowers per plant, individual flower weight, flower diameter and length of flowering duration all positively and significantly correlated with the flower yield per plant (Tables 3 and 4).

These features have positive correlations with the flower yield per plant, hence choosing these traits could eventually increase the yield. These outcomes agree with those of Bharathi et al*.* [21] and Choudhary et al*.* [22]. Environmental factors can affect the relationships between characters. Selection is often based on the association of quantitatively significant and economically significant yield characteristics. It is impossible to assess the population for every quantitative attribute since breeders must manage a very large population to meet their goals. Thus, estimations of the yield correlation with other traits for which genotypes could be readily quantified or evaluated visually are required. When a breeding program for crop genetic improvement is implemented, this correlation study helps in investigating the prospect of increasing yield through indirect selection of its highly correlated component characteristics. Acquiring knowledge about the relationships between various plant characteristics and yield is essential, as it enables the selection procedure to assign high-yielding genotypes more quickly. Only through genotypic correlation, which removes the influence of the environment, can true or actual link be determined Choudhary et al*.* [22].

Table 1. Analysis of variance for morphological characters in marigold

Sl. No	Characters	Mean Sum of Squares		
		Replication	Treatment	Error
	Degrees of Freedom	1	19	19
1	Plant height (cm)	5.26	625.30**	6.16
2	Plant spread East-West (cm)	3.10	121.27**	7.17
3	Plant spread North-South (cm)	1.70	113.04**	6.62
4	Primary branches	10.10	18.53**	1.26
5	Secondary branches	9.22	28.33**	3.54
6	Stem diameter (cm)	0.14	0.06*	0.02
7	Leaf length (cm)	1.03	14.84**	0.48
8	Leaf width (cm)	0.04	10.40**	0.16
9	Number of flowers per plant	0.82	253.62**	26.34
10	Flower yield per plant (g)	163.28	43,575.76**	479.19
11	Individual flower weight (g)	0.08	8.77**	0.11
12	Flower diameter (cm)	0.01	4.17**	0.05
13	Flowering duration (days)	0.84	223.12**	14.18
14	Shelf life (days)	0.17	3.11**	0.13

** Significant at 5% level; ** Significant at 1% level*

Table 2. Genetic variability estimates for growth, yield and quality parameters in different marigold cultivars

Sl. No	Characters	Mean	Range		GCV (%)	PCV (%)	h^2(%)	GA	GAM (%)
			Max	Min					
1	Plant height (cm)	56.00	80.77	26.94	36.71	37.17	98.70	42.08	75.14
2	Plant spread [E-W] (cm)	40.35	50.55	28.43	18.14	18.62	94.90	14.68	36.39
3	Plant spread [N-S] (cm)	38.58	49.28	25.80	17.60	18.11	94.40	13.59	35.23
4	Primary branches	17.18	22.70	12.30	17.88	18.50	93.40	6.11	35.59
5	Secondary branches	26.62	33.45	19.75	14.42	15.18	90.20	7.51	28.20
6	Stem diameter (cm)	1.27	1.53	0.99	33.00	33.76	95.60	0.90	66.46
7	Leaf length (cm)	6.72	14.90	3.46	41.58	42.21	97.00	5.67	84.36
8	Leaf width (cm)	5.15	12.47	2.65	47.01	47.26	99.00	4.96	96.34
9	Number of flowers per plant	98.10	122.60	77.60	10.87	11.48	89.60	20.79	21.19
10	Flower yield per plant (g)	399.01	604.26	178.44	36.79	37.20	98.90	30.73	75.37
11	Individual flower weight (g)	4.11	7.14	1.09	50.65	50.96	98.80	4.26	71.30
12	Flower diameter (cm)	4.36	6.57	2.20	32.93	33.13	94.50	2.94	67.42
13	Flowering duration (days)	54.21	71.45	39.25	18.85	19.48	93.60	20.38	37.59
14	Shelf life (days)	4.41	6.33	2.22	27.66	28.27	95.70	2.46	55.74

GCV: Genotypic coefficient of variance, PCV: Phenotypic Coefficient of Variance, h^2: Heritability (Broad sense), GA: Genetic Advance, GAM: Genetic Advance as Percent Mean

GCV and PCV were classified and suggested as, < 10% - Low, 10-20% - Moderate, >20%- High

Heritability Percentage was Categorised as, <30% - Low, 30-60% - Moderate, >60% - High

GAM was categorised as, 0-10% : Low, 11-20%: Moderate, 21% and above: High

Table 3. Genotypic correlation of flower yield and its contributing traits in different marigold cultivars

@	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_1	**1**	0.994**	0.993**	0.425	0.897**	0.949**	0.757**	-0.436	0.735**	0.986**	0.359	0.439	0.597**	0.971**
X_2		**1**	0.780**	0.609**	0.969**	0.981**	0.822**	-0.300	0.878**	0.781**	0.976**	0.915**	-0.388	0.594**
X_3			**1**	0.746**	0.716**	0.550*	0.633**	0.412	0.574**	0.471*	0.639**	0.625**	0.774**	0.570**
X_4				**1**	-0.350	0.433	0.521*	0.628**	0.630**	0.801**	0.786**	0.877**	0.542*	0.528*
X_5					**1**	0.703**	-0.389	0.619**	0.664**	0.423	0.361	-0.402	-0.431	0.524*
X_6						**1**	-0.335	0.692**	-0.381	0.383	-0.257	0.482*	-0.303	0.424
X_7							**1**	0.575**	0.643**	-0.290	-0.432	0.363	0.544*	0.461*
X_8								**1**	0.422	0.485*	0.598**	-0.448*	0.651**	0.433
X_9									**1**	0.789**	0.340	-0.810**	0.496*	0.608**
X_{10}										**1**	0.992**	-0.417	0.879**	0.583**
X_{11}											**1**	0.900**	-0.335	0.987**
X_{12}												**1**	0.642**	0.903**
X_{13}													**1**	0.250
X_{14}														**1**

Table 4. Phenotypic correlation of flower yield and its contributing traits in different marigold cultivars

@	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_1	**1**	0.976**	0.965**	0.397	0.852**	0.927**	0.741**	-0.389	0.697**	0.969**	0.328	0.410	0.574**	0.951**
X_2		**1**	0.720**	0.579**	0.912**	0.932**	0.790**	-0.279	0.836**	0.759**	0.936**	0.885**	-0.350	0.580**
X_3			**1**	0.726**	0.645**	0.511*	0.594**	-0.396	0.568**	0.459*	0.607**	0.580**	0.741**	0.564**
X_4				**1**	-0.324	0.402	0.490*	0.593**	0.579**	0.776**	0.749**	-0.821**	0.523*	0.504*
X_5					**1**	0.684**	-0.350	0.604**	0.585**	-0.395	0.323	-0.382	-0.418	0.486*
X_6						**1**	-0.273	0.656**	-0.355	-0.358	-0.231	0.453*	-0.285	0.418
X_7							**1**	0.481*	0.622**	0.264	-0.419	0.337	0.515*	0.435
X_8								**1**	0.412	0.468*	-0.587**	-0.433	0.629**	0.422
X_9									**1**	0.758**	0.318	-0.785**	0.456*	0.578**
X_{10}										**1**	0.977**	-0.384	0.856**	0.566**
X_{11}											**1**	0.861**	-0.316	0.957**
X_{12}												**1**	0.626**	0.875**
X_{13}													**1**	0.235
X_{14}														**1**

** Significant at 5% level;** Significant at 1% level*

X_1-Plant height (cm), X_2-Plant spread [East-West] (cm), X_3-Plant spread [North-South] (cm), X_4-Primary branches, X_5-Secondary branches, X_6-Stem diameter (cm), X_7-Leaf length (cm), X_8-Leaf width (cm), X_9-Number of flowers per plant, X_{10}-Individual flower weight (g), X_{11}-Flower diameter (cm), X_{12}-Flowering duration (days), X_{13}-Shelf life (days), X_{14}-Flower yield per plant (g)

4. CONCLUSION

High estimates of PCV and GCV were observed, indicating a sufficient degree of variety in the available germplasm and a broad spectrum of genetic variability. Elevated heritability estimates combined with strong genetic evidence point to the importance of additive gene action in character inheritance as well as a significant positive association (genotypic and phenotypic) with flower yield per plant. Hence, the environment has less impact on traits, there is a good chance that they will be enhanced through selection and responsiveness to proper selection for the evolution of improved marigold cultivars, whereas traits had a greater value for selection in breeding programs.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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