Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(1): 1298-1302
Received: 20-11-2018
Accepted: 25-12-2018

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Phenotypic variation and genetic divergence in marigold (*Tagetes erecta* L.) based on agro-morphic traits

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Abstract
Sixteen morpho-agronomic traits were used to study the phenotypic variation and genetic diversity analysis in marigold. The findings revealed significant differences in quantitative and qualitative traits among the genotypes. All the 20 genotypes were grouped in five clusters based on multivariate analysis. Among the clusters, cluster II was the largest group with 06 genotypes followed by cluster III and V each having 04 genotypes and remaining clusters had each 03 genotypes. The maximum intra-cluster distance exhibited by f cluster I, while the lowest by the cluster IV. The inter-cluster distance was highest between the cluster I and III and lowest between cluster II and V. The different clusters have higher mean values for different traits. Among the different clusters mean value, genotypes "Farmer sel-4" from Cluster I, "Af. sel14" from cluster II and "PNG, PBG" or "Farmer sel-7" from cluster III, "Farmer sel-5and Af. sel10" from cluster IV, "Farmer sel-8 and Farmer sel-3" from cluster V respectively deserve to be considered as potent parents for further utilization in marigold improvement programme.

Keywords: triclosan, TCS, determination, detection, sensor

Introduction
Among the flowering crops grown in India, marigold ranks first among the loose flowers followed by chrysanthemum, jasmine, tuberose and crossandra (Kavitha and Anburani, 2009) [12]. Marigold (*Tagetes* species), a member of family Asteraceae, is the native of Central and South America, especially Mexico. It was first introduced into Spain in the early 16th century, while in India, it was introduced by Portuguese. It is found growing wild in South Africa, Australia, India, Uruguay, Kenya, Brazil, France, *etc*. The name *Tagetes* was given after 'Tages', a demigod known for his beauty. The king Curtez after conquering Mexico got fascinated by the beauty of flowers and carried it to Spain. It was then offered to the attar of Virgin "Mary" and thus named as Mary's gold, now, popularly known as marigold (Marshal, 1969) [18]. There are about 33 species of the genus *Tagetes*. The important species are *Tagetes erecta*, *T. patula*, *T. tenuifolia*, *T. lucida*, *T. lacera*, *T. lemmonii*, *T. minuta*, *T. psyilla* and *T. corymbosa*. The basic chromosome number (2n) of diploid species, *i.e*., *Tagetes erecta*, *T. tenuifolia*, *T. lucida*, *etc*. is 24, however, the chromosome number in tetraploid species, *i.e*., *Tagets patula*, *T. minuta*, *T. biflora*, *etc*. is 48. The two commercially important species are *Tagetes erecta* L., commonly called African marigold, and *Tagetes patula* L. popular as French marigold.

It is popular among flower growers due to wide spectrum of attractive colours, shape, size and good keeping quality has attracted the attention of flower growers. They are extensively used as loose flower, potted plant and also as a bedding plant. Loose flowers are in great demand for garland making as well as in religious and social functions. Globular shaped flowers with long stalks are used for cut flower purposes. The plant is very useful as both the leaves and the flowers are equally important from medicinal point of view. The paste and extracts from plant are used as cure for boils, ear ache, eye disease and ulcers. The oil is reported to have bronchodilatory, tranquilizing and anti-inflammatory properties (Chandhoke and Ghatak, 1969) [5]. Marigold cultivation controls the nematode population in soil and is used for making mosquito repellent products (Gupta *et al*., 2001). Flower extract is used as a blood purifier as well as a good remedy for eye diseases and ulcer. The carotenoids extracted from petals of marigold are the major source of pigment for poultry industry as a feed additive to intensify the yellow colour of egg yolks and broiler skin (Narsude *et al*., 2010 and Kaul *et al*., 1997) [19, 11].

Moreover, new varieties/cultivars also come from different places, and the performance of these varieties depends upon climatic conditions of the region under which they are grown. As a result, cultivars which perform well in one region, may not perform same in other regions of varying climatic conditions (Kamble *et al*. 2004) [9]. It is also important to study the performance of existing cultivars for their superior desirable characters (Archana *et al.* 2007) [1]. Hence, it becomes very much necessary to study the morphological variation and evaluation of genotypes and also to identify the suitable germplasm for further improvement programme in Meerut region.

Materials and Methods

Seeds of all genotypes were sown in the nursery beds to raise seedlings. Transplanting of these seedlings was done after one month of sowing of the seeds in the nursery. All the 20 genotypes of marigold were planted at the Horticultural Research Centre (HRC) of Sardar Vallabhbhai Patel University of Agricultural and Technology, Meerut, UP, India during the year of 2015-16 and 2016-17. The experimental site is located at 29º 01 latitude in the North and 77º 43 longitudes in the Eastern elevation of about 219.75 meters above mean sea level. The material was planted in randomized design with three replications. Each cultivar was assigned to ten rows per plot with a distance of 60 cm line to line and 60 cm plant to plant. Data were recorded on 16 morphological traits, namely (1) Days to first flowering (DFF), (2) Plant height (PH), (3) Plant spread (PS), (4) Stalk length (SL), (5) Stem diameter (SD), (6) Number of primary branches (NPB), (7) Number of secondary branches (NSB) (8) Duration of flowering (DF), (9) Number of flowers per plant (NFPP), (10) Flower diameter (FD), (11) Fresh weight per flower (FWPF), (12) Dry weight per flower (DWPF), (13) Flower yield per plant (FYPP), (14) Number of seeds per head (NSPH), (15) Thousand seed weight (TSW) and (16) Yield per hectare (YPH). Five competitive plants were randomly selected from every alternate line (total fifteen plants per line from three replications) for recording field observations for all the traits including the diameter and weight of corms per plant.

The mean values of the genotypes in each replication for quantitative and qualitative characters were used for statistical analysis (Table 1). The data were processed with the help of the software programme SPAR-1 (Doshi and Gupta, 1991) [8] utilizing standard statistical procedures. The data recorded on sixteen different traits was subjected to the D^2 statistic of Mahalanobis, (1936) [16] and average intra- and -inter cluster distances were calculated by (Rao, 1952) [21].

Table 1: Mean performance for growth flowering and yield of marigold genotypes (pooled data of 2 years)

SL.	Genotypes	DFF	PH	PS	SL	SD	NPB	NSB	DF	NFPP	FD	FWPF	DWPF	FYPP	NSPH	TSW	YPH
1	Farmer sel-1	75.24	55.60	51.55	4.85	1.43	11.25	31.27	58.07	51.80	3.24	2.56	0.78	185.35	113.05	2.70	6.98
2	Farmer sel-2	89.00	52.80	55.95	5.98	1.44	10.52	32.93	64.64	56.40	3.01	5.26	1.14	190.12	128.72	3.58	5.61
3	Farmer sel-3	74.60	48.70	58.55	8.28	1.69	10.59	26.38	63.73	46.82	5.39	6.95	1.23	212.28	132.72	3.88	8.64
4	Farmer sel-4	77.20	56.30	57.15	7.35	1.60	10.97	30.94	64.07	43.82	5.34	4.80	1.11	327.05	133.05	2.61	10.06
5	Farmer sel-5	80.40	57.70	60.75	8.32	1.82	11.19	38.94	61.73	45.48	6.03	5.71	1.34	282.82	150.72	2.99	8.11
6	Farmer sel-6	83.60	59.80	62.25	6.15	1.57	12.19	29.94	63.07	52.82	5.60	8.04	1.13	237.62	139.72	3.43	7.72
7	Farmer sel-7	82.10	62.20	54.19	6.55	1.70	11.19	39.28	72.07	59.98	5.89	6.99	1.40	327.78	129.05	2.90	9.15
8	Farmer sel-8	96.20	55.87	60.56	6.72	1.41	11.52	29.15	67.07	60.32	3.04	5.65	1.17	195.18	146.38	3.87	6.76
9	PNG	85.58	67.00	59.81	6.45	1.48	13.52	43.12	77.70	68.50	6.73	7.58	1.38	489.75	150.05	3.29	9.87
10	PBG	88.92	61.50	55.26	8.72	1.39	9.78	33.78	76.02	61.32	6.55	8.08	1.42	482.82	145.89	2.38	10.02
11	Af.Sel1	83.58	44.02	44.72	6.48	1.23	11.12	24.12	65.68	48.32	5.85	6.99	1.30	330.38	134.47	3.09	8.40
12	Af.Sel4	101.92	57.07	50.96	7.88	1.17	14.95	26.78	53.80	45.32	6.14	4.84	1.11	214.88	134.80	3.25	9.09
13	Af.Sel5	88.58	42.03	52.09	7.43	1.21	10.78	31.89	63.68	58.32	5.64	5.75	1.19	329.65	136.47	3.43	8.87
14	Af.Sel6	90.65	64.50	48.64	7.62	1.62	13.78	32.60	64.02	44.11	5.59	6.72	1.25	285.42	135.13	2.90	8.37
15	Af.Sel8	93.98	58.70	59.21	8.89	1.80	13.70	33.93	61.68	44.68	6.14	5.26	1.13	239.59	139.80	3.57	8.79
16	Af.Sel10	101.55	52.63	53.69	7.56	1.81	10.03	41.27	63.02	34.02	5.32	5.31	1.16	177.52	152.47	3.88	6.78
17	Af.Sel11	73.61	55.56	54.69	9.59	1.47	12.73	36.27	72.02	45.68	4.94	4.23	0.95	188.12	141.47	2.61	7.97
18	Af.Sel12	102.85	55.23	55.66	8.96	1.47	16.73	25.93	67.02	53.02	4.74	5.47	1.16	279.75	126.13	2.99	8.72
19	Af.Sel14	79.02	68.50	62.19	5.42	1.50	10.07	33.83	70.60	58.68	5.33	7.49	1.36	439.08	130.80	3.35	11.21
20	Af.Sel16	91.02	43.13	45.36	7.92	1.10	11.07	29.93	66.68	37.02	5.37	5.31	1.15	191.15	148.13	2.89	5.86
	Mean	86.98	55.94	55.16	7.36	1.50	11.88	32.61	65.82	50.82	5.29	5.95	1.19	280.32	137.45	3.18	8.35
	Range	73.61	42.03	44.72	4.85	1.10	9.78	24.12	53.80	34.02	3.01	2.56	0.78	177.52	113.05	2.38	5.61
		102.85	68.50	62.25	9.59	1.82	16.73	43.12	77.70	68.50	6.73	8.08	1.42	489.75	152.47	3.88	11.21
	S. Ed	2.16	1.28	1.23	0.20	0.03	0.22	0.69	1.33	1.23	0.11	0.14	0.03	6.00	3.43	0.07	0.26
	CD at 5%	4.39	2.59	2.50	0.41	0.07	0.45	1.40	2.71	2.49	0.21	0.29	0.05	12.19	6.96	0.14	0.53
	CV (%)	3.04	2.79	2.73	3.34	2.72	2.28	2.59	2.48	2.95	2.43	2.93	2.61	2.62	3.05	2.62	3.84

Results and Discussion

The analysis of variance (pooled data) based on morphological data (Table-1) showed significant differences for all the traits indicating considerable amount of phenotypic variations among the genotypes studied. The minimum days to first flowering (73.61) were recorded in Af.sel 11, which was at par with Farmer sel-2 (74.60 days) and maximum days taken to flowering (102.85) recorded with Af.sel 112. The time required for days taken to first flowering is an important genotypic character in marigold that might be primarily governed by the genetic makeup of the genotypes. The results observed were in line with earlier findings of (Beniwal and Dahiya, 2012) [3] in marigold. Plant height showed significant difference among the genotypes ranged between 42.03-68.50 with mean value of 55.94 cm, plant spread varied from 44.72-62.25 with an average of 55.16 cm. Plant height is attributed to be an important varietal character that depends upon the genetic constitution of individual plant. Variations among marigold genotypes with respect to plant height have been reported by various workers i.e. Deepa *et al*., 2016; Manik and Sharma, 2016) [7, 17] in marigold, Kumar *et al*., (2007) [13] in gladiolus and (Kumar *et al.*, 2014) [15] in chrysanthemum.

Stalk length exhibited significant difference among the genotypes and varied from 4.85-9.59 with an average 7.36cm, while, stem diameter ranged between 1.10-1.82 with an average of 1.50 cm. It might be due to genetic makeup of individual genotype and such variation in stalk length among African marigold genotypes were reported by (Karuppaiah and Kumar, 2011) [10] in marigold. Number of primary branches had been observed in the range of 9.78-16.73 with an average of 11.88 branches per plant and number of secondary branches ranged 24.12-43.12 with an average of 32.61 branches per plant respectively. Variations in vegetaive traits might be due to genetic makeup and such variations in marigold have already reported by (Bharathi and Jawaharlal, 2014; Deepa and Patil, 2016 and Manik and Sharma, 2016) [4, 6, 17]. The flower and their contributing characters were varied from each genotype. Duration of flowering and number of flower per plant ranged from 53.80 to 77.70 and 34.02 to 68.50 with an average of 65.82 and 50.82 respectively. The flower diameter and fresh weight of flower varied from 3.10 to 6.73 and 2.56 to 8.08 with an average of 5.29 and 5.95 respectively. The variation in flower attributing traits might be due to hereditary traits of different genotypes. It might also be due to the genetic makeup of the varieties and their interaction with prevailing genotype and environment. Similar results were observed by (Narsude *et al.*, 2010; Deepa *et al.*, 2016) [19, 7] in marigold. Dry weight of flower and flower yield per plant varied in the range of 0.78 to 1.42 and 177.52 to 489.75 with an average of 1.19 and 280.32 respectively. However, number of seeds per head and thousand seed weight varied from 113.05 to 152.47 and 2.38 to 3.88 with an average 137.45 and 3.18 respectively. The yield of flowers ranged 5.61 to 11.21 with an average of 8.35 q/ha during the course of study. These results might be due to variation in production of flower yield among the genotypes. Similar results were also reported by Deepa *et al.*, (2016) [7].

Combined analysis of variance (pooled data) indicated that the magnitude of mean sum of square was maximum for flower yield per plant followed by number of seeds per head and this is also correlated with the total flower yield (Table 2). The pooled data findings indicated (Table-3) that the clustering based on morphological variance grouped all the 20 genotypes into five clusters. The cluster II had maximum of 06 genotypes followed by cluster III and V each having 04 genotypes and in cluster I and IV had the minimum number of (03) genotypes. Kavitha and Anburani (2009) [12] formed eight clusters in 30 genotypes of marigold on the basis of 9 characters. Similarly, Swaroop, (2010) [23] grouped 28 gladiolus genotypes into 8 clusters. Baliyan *et al.* (2014) [2] formed four clusters in twenty-four genotypes of chrysanthemum on basis of nine quantitative traits. Kumar *et al*. (2016) [14] developed 7 clusters on the basis of D^2 statistic in chrysanthemum. Similar findings were observed by Prakash *et al.* (2017) [20] in chrysanthemum. The intra-cluster and inter-cluster distance (Table 4) revealed that inter-cluster distance values were greater than the intra-cluster values. Maximum Intra-cluster distance (2.99) was noted in cluster I followed by, (2.97) in the cluster II, while minimum intra-cluster distance (2.25) was observed in cluster IV. The maximum inter cluster (5.85) was recorded in cluster I-III followed by, (5.26) in cluster III-IV and minimum inter cluster (3.50) distance noted with cluster II-V, indicating the resemblance among the genotypes of this group for all characters studied. Low magnitude of inter- cluster distance values suggested that very little domestication has occurred. Similar results had also been suggested by (Kavitha and Anburani, 2009) [12] in marigold and Kumar *et al*., (2014) [15] in chrysanthemum. As far as the cluster means are concerned, different clusters have higher mean values for different traits indicating that few of the cluster contained genotypes with most of the desirable characters. The cluster means of 16 traits under study revealed that maximum diameter of flower, number of flowers per plant, fresh weight of flower, dry weight of flower, flower yield per plant, number of seeds per head and maximum yield was observed for cluster III. However, the cultivars included in cluster I emerged earlier flower and maximum thousand seeds weight showed by cluster IV (Table 5). Based on the range means, it was possible to know the characters influencing divergence. The cluster having single or less genotypes revealed highest or lowest mean values for different characters as evident from mean data (Table 5). Although, the distance between various clusters was reflected in cluster means but it was not proportional for few characters. It seems that there were some other factors responsible for divergence. Therefore, a hybridization programme may be initiated involving the genotypes belonging to diverse clusters with high mean for almost all the component characters. Keeping in view the above aspects, the genotypes 'Farmer sel-4 from Cluster I, 'Af. sel14' from cluster II and 'PNG, PBG or Farmer sel-7' from cluster III, Farmer sel-5and Af. sel10 from cluster IV, Farmer sel-8 and Farmer sel-3 from cluster V respectively deserve to be considered as potent parents for further utilization in marigold improvement programme. Therefore, based on D^2 analysis, yield contributing characters showed higher value under clusters mean performance need to be given more weightage, while selecting parents for improvement. Sheikh and Khanday, (2008) [22] also observed similar findings when worked in gladiolus under two environments. Similar results had been suggested by Swaroop, (2010) [23] in gladiolus.

Table 2: Analysis of variance mean sum square (pooled data of 2 year)

Source of Variation	DF	DFF	PH	PS	SL	SD	NPB	NSB	DF
Replication	2	1.05	0.78	0.38	0.07	0.001	0.11	0.72	1.75
Treatment	19	249.87**	161.67**	79.83**	4.78**	0.134**	9.90**	80.38**	97.87**
Error	38	7.01	2.44	2.27	0.06	0.002	0.07	0.71	2.67
Source of Variation	DF	NFPP	FD	FWPF	DWPF	FYPP	NSPH	TSW	YPH
Replication	2	4.77	0.038	0.03	0.005	6.84	0.04	0.003	0.12
Treatment	19	231.76**	3.402**	5.82**	0.072**	28941.89**	289.06**	0.596**	6.20**
Error	38	2.25	0.017	0.03	0.001	53.95	17.60	0.007	0.09

Table 3: Clustering pattern of 20 genotypes of marigold (pooled data of 2 year)

SL.	No of genotypes	Genotypes
I	3	1,4,17
II	6	11,12,13,14,18,20

III	4	7,9,10,19
IV	3	5,15,16
V	4	2,3,6,8

Table 4: Intra- and inter-cluster average D^2 values and D values (pooled data of 2 years)

SL.	I	II	III	IV	V
I	2.99				
II	3.83	2.97			
III	5.85	5.19	2.51		
IV	4.60	4.04	5.26	2.25	
V	4.00	3.50	5.07	3.65	2.48

Table 5: Cluster mean for different growth and flowering traits marigold (pooled data of 2 years)

Clusters		DFF	PH	PS	SL	SD	NPB	NSB	DF	NFPP	FD	FWPF	DWPF	FYPP	NSPH	TSW	YPH
I	Mean	75.35	55.82	54.46	7.26	1.50	11.65	32.83	64.72	47.10	4.51	3.87	0.95	233.51	129.19	2.64	8.34
	±SE	1.80	0.42	2.81	2.37	0.09	0.95	2.99	7.00	4.18	1.12	1.16	0.16	81.02	14.60	0.05	1.57
II	Mean	93.10	51.00	49.57	7.72	1.30	13.07	28.54	63.48	47.68	5.56	5.85	1.19	271.87	135.85	3.09	8.22
	±SE	7.67	9.25	4.18	0.81	0.20	2.47	3.44	4.93	7.40	0.48	0.84	0.07	57.92	7.06	0.21	1.19
III	Mean	83.91	64.80	57.86	6.79	1.52	11.14	37.50	74.10	62.12	6.13	7.53	1.39	434.86	138.95	2.98	10.06
	±SE	4.29	3.47	3.78	1.39	0.13	1.70	4.55	3.32	4.39	0.64	0.45	0.03	74.83	10.58	0.45	0.85
IV	Mean	91.98	56.34	57.89	8.26	1.81	11.64	38.05	62.14	41.39	5.83	5.43	1.21	233.31	147.66	3.48	7.89
	±SE	10.72	3.25	3.71	0.67	0.01	1.87	3.75	0.76	6.40	0.44	0.25	0.12	52.93	6.86	0.45	1.03
V	Mean	85.85	54.29	59.33	6.78	1.53	11.21	29.60	64.63	54.09	4.26	6.47	1.17	208.80	136.88	3.69	7.18
	±SE	9.10	4.70	2.71	1.05	0.13	0.80	2.69	1.75	5.73	1.43	1.27	0.05	21.42	7.79	0.22	1.30

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