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Stability analysis and genotype x environment interaction for flower yield and quality traits in marigold (*Tagetes* spp.)

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Abstract

The stability analysis of 26 diverse genotypes of marigold (*Tagetes* spp.) carried out over three different environments, revealed that the differences among genotypes and environments were highly significant for all the characters when tested against both pooled error as well as pooled deviation. The analysis further revealed that component of G x E (linear) had most contribution for plant height, number of secondary branches per plant, days to first flowering, flower diameter, flower weight, number of flowers per plant and flower yield per plant indicating significant differences among the genotypes for their regression on environmental indices. Considering the three stability parameters, Local Selection 13 for flower yield (414.40 g/plant); F_1 White Dwarf, Local Selection 2 and Namdhari African Orange for earliness and Local Selection 9, Local Selection 14 and Local Selection 13 for individual flower weight were identified as promising genotypes for further improvement programme.

Key words: Marigold, stability, genotypes, environments

Introduction

Marigold (*Tagetes* spp.) is one of the most important traditional flower crops grown in India, owing to its ornamental and industrial uses. It is grown for landscaping and occupies an ever increasing demand in medicinal and industrial sector. It is widely grown for its loose flowers used for religious offerings and making garlands during social functions and as a bedding plant in landscape gardening. The extraction of carotenoides from petals for industrial uses raised the importance of this crop and increased the area under its cultivation. Marigold is also suggested as trap crop for monitoring the *Helicoverpa* incidence in vegetable crops and has nematicidal properties also.

The loose flowers are regarded as the backbone of the Indian floriculture industry as it holds the major share in area and production. In breeding programme, it is necessary to screen and develop stable genotypes which perform more or less uniform under varying environmental conditions. Thus, knowledge of genotype x environment interactions helps the breeder to select high yielding and more adaptable varieties or hybrids. Looking at the importance and commercial potential, there is an urgent need to identify potential genotypes, which would result in further improvement and to develop cultivar for specific uses.

Keeping this background in view, the present study was undertaken to assess the performance of genotypes over environments.

Materials and methods

The investigation was carried out during *Rabi* season (November 2014 - April 2015) at three different locations, *viz.,* Floriculture Research Farm, Navsari (Dist. Navsari), Regional Rice Research Station, Vyara (Dist. Tapi), Hill Millet Research Station, Waghai (Dist. The Dangs) of Navsari Agricultural University (Gujarat). Twenty six (26) genotypes collected from diverse source were grown in a randomized block design (RBD) with three replications. The 26 genotypes of marigold comprised four F_1 hybrids (Inca Gold, Inca Yellow, F_1 White Dwarf and Sonata Orange); fifteen local genotypes (Local Sel. 1, Local Sel. 2, Local Sel. 3, Local Sel. 4, Local Sel. 5, Local Sel. 6, Local Sel. 7, Local Sel. 8, Local Sel. 9, Local Sel. 10, Local Sel. 11, Local Sel. 12, Local Sel. 13, Local Sel. 14 and Local Sel. 15) as well as seven open pollinated varieties (Pusa Narangi Gainda, Summer Sugat, Namdhari African Orange, Hawaii Orange, Swati Orange, Indus Orange Bunch and Suvarna Orange).

Seeds of all the genotypes were sown on the raised beds in the month of November to raise seedlings. Transplanting of seedlings was done when they attained three to four true leaves stage. The genotypes were planted in a single-row of 20 plants under each replication with a spacing of 60 x 45 cm with all the recommended agronomical practices and plant protection measures. The observations were recorded on five randomly tagged plants from each genotype of each replication. For all the characters under study, the mean values of five randomly selected plants were calculated for each observation under individual location. The analysis of variance representing the mean square due to different sources of variation for various traits including magnitude of G x E interactions and stability parameters were estimated as per the procedure outlined by Eberhart and Russell (1966) to understand the genotype x environment interactions of different genotypes and to assess stability of individual genotype. The mean sums of squares for phenotypic stability for different characters are presented in Table 1.

Table 1. Analysis of variance for phenotypic stability pertaining to various characters in marigold (pooled)

Source	d.f.	Plant height (cm)	Plant spread (cm)	Number of primary branches/ plant	Days to first flowering	Duration of flowering (days)	Flower diameter (mm)	Flower weight (g)	Number of flowers / plant	Flower yield / plant (g)
Genotypes (G)	25	631.64 $^{**++}$	190.32^{**++}	4.28^{**++}	132.17^{**++}	738.68^{**++}	319.18^{**++}	15.28^{**++}	201.39^{**++}	48596.40^{**++}
Environments (E)	2	10487.35^{**++}	1358.35^{**+}	32.51^{**+}	262.28*	2218.75^{**+}	2992.00^{**+}	103.48^{**+}	4650.70^{**+}	936241.33^{**++}
Environments (Lin.)	1	20974.70^{**++}	2716.69^{**++}	65.02^{**++}	524.55^{**++}	4437.50^{**++}	5984.01^{**++}	206.95^{**++}	9301.41^{**++}	1872482.66^{**++}
G x E	50	99.86^{**++}	21.35**	0.77**	30.21^{**+}	67.45**	28.89^{**++}	3.86^{**++}	58.84^{**+}	17532.69^{**++}
G x E (Lin.)	25	171.93^{**++}	23.67**	0.83**	40.31^{**+}	78.37**	45.86^{**++}	5.65^{**++}	77.23^{**+}	29336.18^{**++}
Pooled deviation	26	26.72	18.29**	0.68**	19.33**	54.35**	11.46	1.99**	38.89**	5508.85**
Pooled error	150	18.75	2.80	0.21	5.27	9.64	12.59	0.25	2.50	716.59

*, ** Significant at 5 % and 1 % level, respectively against pooled error.
+, ++ Significant at 5 % and 1 % level, respectively against pooled deviation.

Results and discussion

Analysis of variance for phenotypic stability: The results of stability analysis over three locations presented in Table 1 revealed that all the genotypes differed significantly among them and exhibited significant differences when tested against both pooled error and pooled deviation for all the characters under study as well as significant variation existed among the environments (except days to first flowering) when tested against pooled deviation. Similar results have been reported by Naik *et al.* (2005) in marigold, Sreenivasulu *et al.* (2007) in china aster and Kirtimala *et al.* (2011) in gladiolus.

The genotype x environment (G x E) components were also found significant to highly significant for most of the characters *viz.*, plant height, days to first flowering, flower diameter, flower weight, number of flowers per plant and flower yield per plant when tested against pooled error and pooled deviation, which satisfied the requirement of stability analysis suggesting differential reaction of genotypes to varied environments. Therefore, stability for these characters was tabulated. Significance of G x E interaction has also been reported by Nalawadi (1982) in marigold, Desh Raj and Misra (1998) in gladiolus and Misra and Gupta (2005) in carnation, Sreenivasulu *et al.* (2007) in china aster and Kirtimala *et al.* (2011) in gladiolus.

A variety having good adaptability is one that consistently gives stable performance over wide range of environments (Frey, 1964). Thus, stability depends upon the relative sensitivity of a genotype to varied environments. An individual may react to variable environments in such a way that its development is buffered against environmental variation and the same adaptive phenotype being produced in varying environments. This situation has been named as canalization (Waddington, 1942); developmental stability (Mather, 1943); phenotypic stability (Lewis, 1954) and developmental homeostasis (Lerner, 1954).

Mean squares due to environment (linear) were highly significant for all the characters, which indicated considerable differences among the environments and their predominant effects on these characters. The linear response of genotype to varying environments showed significant mean squares for all the characters indicating significant differences among the genotypes for their regression on environmental indices. Pooled deviation were significant for all the characters when tested against pooled error suggesting that deviation for linear regression also contributed substantially towards the differences in stability of genotypes. However, considerable portion of G x E interactions was attributable to linear components (predictable) for plant height, days to first flowering, flower diameter, flower weight, number of flowers per plant and flower yield per plant. Thus, this study indicated that both linear and non-linear functions play an important role in building up total G x E interaction. These findings are in agreement with the results of Desh Raj and Misra (1998) in gladiolus, Sreenivasulu *et al.* (2007) in china aster and Kirtimala *et al.* (2011) in gladiolus.

Stability parameters: The mean, regression coefficient (bi) and mean square deviation from linear regression line (S^2di) are the three stability parameters proposed by Eberhart and Russel (1996) in their stability model. The parameters estimated to evolve related stability of different population types over a range of environmental conditions are presented character wise in Table 2 and 3.

Eberhart and Russell (1966) defined stable genotypes as one which showed a high mean yield, regression coefficient (b_i) around unity and deviation from regression (S^2di) equal to zero. Later on, Breese (1969) advocated that linear regression (b_i) could be simply be regarded as measure of response of a particular genotype, whereas the deviation from regression (S^2di) as a measure of stability. If regression co-efficient (b_i) is greater than unity with high mean values, the genotype is considered to possess below average stability and is highly sensitive to environments. Regression co-efficient (b_i<1) with high mean values indicates above average stability and can adapt to poor environments. If regression co-efficient (b_i) is equal to unity (b_i = 1) with high mean values, this indicates average sensitivity to environmental changes and adaptation to various environments.

Among the 26 genotypes, Local Selection 15 (70.29 cm), Local Selection 14 (70.11 cm), Local Selection 12 (64.91 cm) and Local Selection 13 (64.38 cm) registered higher mean value for plant height, b_i value around unity and lower S^2di value. These findings suggested that these genotypes were stable and showed predictable performance under various environments.

Table 2. Stability parameters of individual genotype for different characters

Genotype	Plant height (cm)			Number of secondary branches per plant			Days to first flowering (days)			Flower weight (g)		
	Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di
Pusa Narangi Gainda	57.07	1.06	-12.28	21.62	0.61	-0.86	57.42	1.03	-5.08	6.75	0.60	0.01
Summer Sugat	65.58	1.25	-10.91	20.80	0.62	-0.19	55.29	1.71	-4.95	7.83	1.37	0.22
Namdhari African Orange	57.89	0.96	-18.56	26.40	0.94	74.77 **	56.42	0.53	-4.85	6.60	0.23	-0.03
Hawaii Orange	58.73	1.34	303.38 **	17.80	0.14	11.72 **	48.38	-0.38	31.06 **	6.21	0.44	-0.07
Swati Orange	74.78	1.21	89.02 *	32.07	1.14	8.22 *	54.02	1.75	31.53 **	7.46	0.70	-0.14
Indus Orange Bunch	60.93	1.04	-18.51	31.78	1.52	0.29	57.56	-0.02	-3.90	7.24	0.92	-0.10
Local Selection 1	71.89	1.22	-16.96	35.20	1.13	-0.58	57.58	2.28	-2.84	10.81	0.83	11.82 **
Suvarna Orange	48.00	-0.18*	-18.59	35.40	1.74*	-1.44	57.58	1.92	16.10 *	6.69	0.34	0.36
F_1 White Dwarf	28.07	0.22	0.88	14.82	0.61	-0.96	45.82	0.33	0.00	5.58	0.15	0.02
Local Selection 2	64.56	0.91	-13.01	31.29	1.26	1.47	55.93	1.07	-3.24	10.00	1.84	3.42 **
Local Selection 3	67.13	1.31	-17.07	36.96	1.28*	-1.37	59.31	2.64	-4.27	9.10	2.44	0.38
Local Selection 4	71.98	1.37	-12.93	32.16	1.20	22.27 **	53.67	1.87	30.85 **	10.70	2.69	6.69 **
Local Selection 5	76.58	1.74	-5.26	31.60	1.39	1.97	75.47	-2.78	240.33 **	11.51	1.85	4.73 **
Local Selection 6	70.23	0.96	5.33	32.67	1.04	3.46	62.47	2.76	-4.60	11.08	2.43	0.14
Local Selection 7	72.42	1.44	10.46	27.40	0.62	2.28	62.62	2.00	-2.09	12.59	1.78	8.0 **
Local Selection 8	69.89	1.30	-8.47	34.42	1.40	-0.98	54.09	-0.36	3.71	11.75	0.67	4.11 **
Local Selection 9	66.82	1.20	-16.39	30.78	1.10	1.85	61.33	0.34	-4.54	12.10	0.44	-0.16
Inca Gold	30.27	0.32*	-18.51	19.82	0.82	10.15 **	43.36	-0.17	25.48 *	9.95	1.31	3.46 **
Local Selection 10	62.53	1.33	5.68	37.22	0.61	1.04	64.87	1.03	-4.92	6.29	0.47	0.11
Local Selection 11	73.84	1.40	-17.31	29.64	0.94	0.33	61.78	3.15	-4.19	8.74	1.49	0.29
Local Selection 12	64.91	1.02	40.75	32.71	0.95	-1.36	56.42	-0.67	17.60 *	7.73	0.16*	-0.22
Local Selection 13	64.38	1.04	-13.82	32.96	1.11	3.22	56.49	3.14	0.32	9.84	0.60	0.43
Inca Yellow	32.91	0.33*	-18.32	19.42	0.82	3.52	53.98	1.36	-1.06	12.27	0.07	0.32
Local Selection 14	70.11	1.01	-9.33	33.98	1.13	-0.69	60.73	-1.13	-4.10	10.58	0.41	0.04
Sonata Orange	32.51	0.13	7.08	20.16	0.69*	-1.45	45.62	1.82	5.55	8.47	2.14	1.36 *
Local Selection 15	70.29	1.07	-5.36	35.33	1.21	0.66	52.24	0.82	22.15 *	12.82	-0.34	-0.07
Population Mean	60.93			29.02			56.56			9.26		

The genotype F_1 White Dwarf found superior over other genotypes for earliness with desirable b_i value almost unity and desirable S^2di values. But, Local Selection 2 and Namdhari African Orange also showed earliness with b_i values near unity and less than unity and desirable S^2di values. In case of flower diameter, Local Selection 15 and Local Selection 2 registered higher mean value with low S^2di values with bi values near unity.

Local Selection 6 registered higher mean value for flower weight with desirable b_i value above unity along with low S^2di value, while Local Selection 9, Local Selection 14 and Local Selection 13 registered higher mean values with bi values below unity and lower S^2di values. Whereas, Pusa Narangi Gainda registered higher mean value with b_i value less than one and low S^2di value.

In the present investigation, only one genotype Local Selection 13 possessed high *per se* performance (over general mean) for flower yield per plant (414.40 g/plant) and b_i value (1.16) approaching unity together with comparatively low S^2di (-589.50) value. Therefore, Local Selection 13 may be considered superior over the remaining genotypes under varying environments. Whereas, Local Selection 15 exhibited high mean flower yield (575.40 g/plant) with b_i value (0.97) nearer to unity but, it had significant value of S^2di (16431.2*). This genotype although, unstable according to the model of Eberhart and Russel (1966) however it is of economic interest due to their specific suitability for favourable environments. This genotype can be considered as less adoptive and can be further evaluated for their yield performance over more locations and years.

The present study revealed that the local genotypes as a group had slightly higher mean value for flower yield per plant.

Table 3. Stability parameters of individual genotype for different characters

Genotype	Number of flowers per plant			Flower yield/plant (g)		
	Mean	b_i	S^2di	Mean	b_i	S^2di
Pusa Narangi Gainda	39.87	0.57	5.24	222.20	0.34	2456.9 *
Summer Sugat	34.73	1.32	16.42 **	294.20	1.35	-527.80
Namdhari A.Orange	33.89	1.49	4.93	212.20	0.68	-463.20
Hawaii Orange	24.20	0.212*	-2.40	144.90	0.17*	-677.70
Swati Orange	36.58	1.39	-1.13	273.60	0.93	565.90
Indus Orange Bunch	30.51	1.38*	-2.17	229.30	0.99	-169.60
Local Selection 1	44.42	1.53	19.22 **	488.00	1.59	15713.6 **
Suvarna Orange	30.11	0.59	-1.09	196.60	0.35	144.40
F_1 White Dwarf	21.02	0.86	3.47	115.50	0.30*	-629.20
Local Selection 2	44.20	1.17	189.32 **	453.00	1.59	19400.9 **
Local Selection 3	37.69	1.67	151.97 **	410.80	2.32	5123.8 **
Local Selection 4	35.60	1.24	32.04 **	427.30	2.00	7512.9 **
Local Selection 5	27.07	0.52*	-2.29	306.00	0.88	3239.4 *
Local Selection 6	50.67	1.34	234.71 **	567.70	2.31	5598.3 **
Local Selection 7	37.44	1.29	67.67 **	480.60	1.84	25774.0 **
Local Selection 8	29.87	0.80	115.73 **	359.90	0.86	17791.4 **
Local Selection 9	36.96	0.72	24.11 **	433.50	0.67	4765.5 **
Inca Gold	25.71	0.53	3.61	267.30	0.78	2332.9 *
Local Selection 10	33.00	0.76	-1.74	199.40	0.50*	-613.90
Local Selection 11	37.36	1.45	31.29 **	348.50	1.52	1846.00
Local Selection 12	39.00	1.32	12.33 *	267.30	0.61	-363.30
Local Selection 13	44.33	1.39	16.28 **	414.40	1.16	-589.50
Inca Yellow	19.22	0.36	-0.62	232.20	0.23	96.70
Local Selection 14	25.89	0.23	22.18 **	263.10	0.28	762.60
Sonata Orange	24.96	0.37	0.26	211.60	0.80	-688.80
Local Selection 15	47.27	1.52	7.91 *	575.40	0.97	16431.2 **
Population Mean	34.29			322.87		

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