Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2020; 9(1): 1732-1734
Received: 01-11-2019
Accepted: 03-12-2019

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Stability analysis in marigold

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Abstract
The present investigation was carried out at the Experimental Farm of the Department of Horticulture, Assam Agricultural University, Jorhat during 2015-16 to identify a suitable and stable genotype for higher flower yield across the environments. The stability analysis was done over six environments created by three dates of planting and two spacing's. Twelve marigold varieties were studied over the six environments for eleven growth and flower characters including flower yield. There was significant genotype-environment (GE) interaction for all the characters except for plant height and number of ray florets. Both linear and non linear components contributed towards GE interaction except disc floret. Seracole followed by Pusa Narangi Gainda and Pusa Basanti Gainda were found to be the best for flower yield and possess considerable average stability making them appropriate varieties for recommendation in Assam.

Keywords: Phenotypic stability, marigold, spacing, environment

Introduction
Marigold (*Tagetes erecta*) is one of the most commonly grown commercial flower crops in India. In India, it ranks first among loose flowers followed by chrysanthemum, Jasmine, tuberose and crossandra. (Kavitha and Anburani, 2009) [2]. Increased flower production, quality of flowers and perfection in the form of plants are important objectives to be reckoned in commercial flower production. Marigold is extensively used as loose flower, potted plant as well as bedding plant. Loose flowers are in great demand for making garlands as well as in social and religious functions. Varietal adaptability to environmental fluctuations is important for the stabilization of crop production enabling enhancement of commercial production. Yield is a complex quantitative trait and is greatly influenced by environmental fluctuations; hence these election for superior genotypes based on yield *perse*at a single environment may not be very effective. Thus, study of genotype-environment (GE) interaction and evaluation of genotypes for stability of performance under varying environmental conditions for yield and yield attributes has become an essential part of any breeding programme. Development of marigold hybrids and improved varieties with high yield and desirable flower quality consistent over variable environments is a much needed research programme for commercialization of the crop. Keeping all these points in view, the present investigation was carried out with an objective to study GE interaction for identifying suitable, stable and higher flower yielding genotypes across the environments.

Materials and Methods
The present investigation was carried at the Experimental Farm of the Department of Horticulture, Assam Agricultural University, Jorhat during 2015-16 and 2016-17.The experimental site is situated approximately 86.6 meters above mean sea level, 26° 47' N latitude, and 94° 12' E longitude, having sub-tropical climate, *i.e.* hot and humid during summer and cool and dry in the winter season. The experimental material compromised of 12 marigold varieties Seracole (T_1), Pusa Narangi Gainda (T_2), Pusa Basanti Gainda (T_3), Pusa Arpita (T_4), Hawaii Orange(T_5), Hajo Yellow(T_6), Hajo Orange (T_7), Calcutta Orange (T_8), Calcutta Yellow (T_9), Yellow Babuda (T_{10}), Sunrise Orange (T_{11}),Mumbai Orange (T_{12}) which were collected from IARI, New Delhi and different nurseries of Jorhat and Kolkata. The field **e**xperiments were conducted in six environments created by planting at three different dates and two spacings as mentioned below:

The field experiments were conducted in six environments created by planting at three different dates and two spacings as mentioned below:

Environment	Date of Planting	Spacing
E_1	1st Oct. 2015	45cm×45cm
E_2	1st Oct. 2015	60cm×45cm
E_3	1st Nov. 2015	45cm×45cm
E_4	1st Nov. 2015	60cm×45cm
E_5	1st Dec. 2015	45cm×45cm
E_6	1st Dec. 2015	60cm×45cm

The data were recorded for growth characters viz plant height, number of branches per plant and flower characters vizdays to bud visibility, days to full bloom, number of flowers per plant, flower diameter, fresh weight of flower, self-life, number of ray florets, number of disc florets and yield per sq.m. The mean data of each of the varieties in each environment were subjected to genotype-environment interaction and phenotypic stability studies following the stability model proposed by Eberhart and Russell (1966) [1]. The model involves the estimation of stability parameters, vizmean, regression coefficient and deviation from regression. In order to easily assess means of the varieties, a parameter known as phenotypic index (P_i) proposed by Ram (1970) [7] was considered which the direction of mean of each variety is over environments from population mean.

Results and Discussion

It was observed (Table 1) that the varieties differed significantly for all the growth and flower characters except for plant height and number of ray florets. There was significant GE interaction for all characters studied. Further both linear and non linear components contributed towards GE interaction for number of branches per plant and flower characters *viz* days to bud visibility, days to full bloom, number of flowers per plant, flower diameter, fresh weight of flower, self life, number of ray florets, and yield per sq.m. except for plant height and number of disc florets as evident from significant GE (linear) and pooled deviation.

Owing to the performance of significant GE interaction, the varieties were further assessed for phenotypic stability. Eberhart and Russell (1966) [1] provided three stability parameters to identify phenotypically stable genotypes. They considered mean performance of the i^{th} variety over environments (m_i), regression of varietal mean on environmental indices (b_i) and deviation from linear regression (S^2_{di}) as the three parameters. Based on these they classified stability into average stable (high m_i, b_i=1 and lowS^2_{di}), below average stable (high m_i, b_i>1 and lowS^2_{di}) and above average stable (high m_i, b_i<1 and lowS^2_{di}). According to them average stable varieties perform uniformly over environments, below average stable varieties perform much higher than its actual potentiality in high yielding favourable environment but much lower performance in unfavourable environment and above average stable varieties express their potentiality in low yielding stress environment. In order to easily assess means of the varieties, a parameter known as phenotypic index (P_i) proposed by Ram (1970) [7] was considered. A positive P_i indicated high mean performance.

Among the two growth characters, it was observed (Table 2) that Hawaii Orange with highest mean (mi) and the phenotypic index (Pi), regression coefficient (bi) not significantly deviating from unity and non-significant deviation mean square (S^2di) exhibited average stability for taller plants followed by Mumbai Orange, Pusa Narangi Gainda and Pusa Basanti Gainda. On the other hand Calcutta Orange followed by Yellow Babuda with low mi and negative Pi, bi not significantly deviating from unity and non-significantS^2di exhibited average stability for shorter plant height.

Table 1: Pooled analysis of variance for genotype-environment (GE) interaction with respect to different growth and flower characters

Source	Degree of freedom	Mean squares										
		Plant height (cm)	Number of branches per plant	Days to bud visibility	Days to full bloom	Number of flowers per plant	Flower diameter (cm)	Fresh weight of flower (g)	Self life (days)	Number of ray florets	Number of disc florets	Yield per sq.m (kg)
Variety	11	1412.26*	1807.65*	411.91*	439.95*	2662.92*	6.00*	7.18*	338.10*	9515.99*	1699.23*	1.31*
Env+ (VxE)	60	60.01	4.10*	196.82*	386.95*	52.60*	0.20*	4.79*	280.05*	11.82	4.09	0.11*
Env (Lin)	1	720.53*	15.48*	9859.92*	15639.74*	2062.94*	5.83*	2.90*	14580.02*	234.91*	49.53	3.76*
VxE (Lin)	11	9.83	16.42*	164.61*	541.79*	74.59*	0.35*	1.11*	140.27*	9.42	10.76*	0.11*
Pooled deviation	48	67.75	1.04*	2.89*	33.70*	5.68*	0.05*	0.08*	14.17*	7.73	1.61	0.03*
Pooled error	144	53.83	0.28	0.59	0.26	0.71	0.005	0.005	0.20	14.84	2.73	0.003

*Significant at 5% probability levels respectively

Table 2: stability performance of the twelve marigold varieties for different characters

Variety	Stability Parameters	Plant Height (Cm)	Number of branches per plant	Days to bud visibility	Days to full bloom	Number of flowers per plant	Flower diameter (cm)	Fresh Weight of flower (g)	Self life (days)	Number of ray florets	Number of disc florets	Yield per Sq.m. (kg)
Seracole	m_i	44.92	76.12	71.18	77.62	99.82	5.43	4.72	16.89	143.77	53.48	2.05
	p_i	-5.97	52.14	-0.32	0.94	45.49	0.38	-0.12	3.8	-15.02	-1.4	0.80
	b_i	1.58	9.79*	0.30	0.26	1.98	2.62	1.49*	0.56	2.01*	1.64**	1.18
	S^2_{di}	-35.29	4.38*	2.63*	2.36*	5.74*	0.03*	0.16*	25.86*	44.43*	1.96	0.003
Pusa Narangi Gainda	m_i	66.80	19.94	69.12	75.92	57.25	6.23	6.85	13.27	196.13	72.19	1.83
	p_i	15.91	-4.04	-2.38	-0.76	2.92	1.18	2.01	-0.3	37.34	17.31	0.58
	b_i	1.98	3.68**	0.47	0.35	1.73	2.17	1.50*	0.34	1.46	1.09	1.17
	S^2_{di}	-16.40	0.13	1.04	1.44*	1.05	0.04*	0.09	1.44*	-11.32	-2.44	0.01
Pusa Basanti Gainda	m_i	65.23	24.95	64.55	71.53	45.16	6.74	6.60	15.85	182.22	69.36	1.45
	p_i	14.34	0.97	-6.95	-5.15	-9.17	1.69	1.76	-0.64	23.43	14.18	0.20
	b_i	0.73	5.37	0.54	0.42	0.87	1.35	1.91*	0.79	1.78*	0.71	1.10
	S^2_{di}	-49.26	1.85*	-0.33	1.68*	1.01	0.003	0.02	54.25*	-10.42	-1.50	0.004
Pusa	m_i	47.58	31.26	96.34	101.71	83.62	4.75	4.49	13.66	142.08	59.74	1.76

Arpita	p_i	-3.31	7.28	24.84	25.03	29.29	-0.3	-0.35	20.13	-16.71	4.86	0.51
	b_i	0.80	-1.83	1.65	1.03	0.94	0.53	1.22	1.27	1.52	0.88	1.39*
	S^2_{di}	-49.89	1.08*	0.58	14.00*	5.59*	0.07*	0.19*	8.78*	-13.36	-2.58	0.04*
Hawaii Orange	m_i	72.33	20.16	67.31	72.21	53.68	5.07	4.41	8.75	132.52	56.46	1.35
	p_i	21.44	-3.82	-4.19	-4.47	-0.65	0.02	-0.43	-7.39	-26.27	1.58	0.10
	b_i	0.90	0.02	1.23	0.86	-0.72	0.78	-0.90	1.04	0.67	0.53	0.67
	S^2_{di}	-52.16	0.29	2.98*	11.49*	6.91*	0.005	0.10*	3.93*	-13.24	0.98	0.24*
Hajo Yellow	m_i	46.16	24.87	68.87	77.77	74.55	5.44	4.08	13.45	235.26	82.22	1.30
	p_i	-4.73	0.89	-2.63	1.09	20.22	0.39	-0.76	-0.86	76.44	27.34	0.05
	b_i	1.08	0.83	0.80	0.63	1.76	1.71	0.55	0.89	1.29	1.07	0.73
	S^2_{di}	-39.98	0.36	3.93*	17.04*	2.85	0.10*	0.01	1.58*	-7.25	0.66	0.0006
Hajo Orange	m_i	54.64	20.14	66.13	69.23	40.94	3.65	3.60	13.86	120.33	40.62	0.66
	p_i	3.75	-3.84	-5.37	-7.45	-13.39	-1.41	-1.24	-10.63	-38.46	-14.26	-0.59
	b_i	0.90	-0.72	1.57	1.23	1.13	0.58	-0.33	1.40	0.06	0.87	0.55
	S^2_{di}	-43.36	-0.09	5.77*	25.65*	25.87*	0.03*	0.07*	33.68*	-11.99	-2.50	-0.001
Calcutta Orange	m_i	22.48	14.70	72.20	79.63	39.50	3.64	3.63	15.66	151.11	41.23	0.68
	p_i	-28.41	-9.28	0.7	2.95	-14.83	-1.43	-1.21	-0.92	-7.68	-13.65	-0.57
	b_i	0.86	-0.64	0.92	0.80	1.19	0.06	-0.33	0.95	0.65	-0.97	0.56
	S^2_{di}	-49.34	0.27	0.75	9.44*	4.04*	0.009*	0.07*	0.28*	-10.53	-1.17	-0.002
Calcutta Yellow	m_i	33.12	14.25	73.02	77.90	38.56	3.58	3.66	17.33	141.37	38.25	0.70
	p_i	-17.77	-9.73	1.52	1.22	-15.77	-1.47	-1.18	-0.19	-17.42	-16.63	-0.55
	b_i	1.50	-0.18*	0.70	0.70	1.06	0.16	-0.27*	0.83	0.26*	-0.08*	0.74
	S^2_{di}	651.13*	0.06	4.96*	3.08*	-0.38	0.004	0.03*	1.15*	-14.20	-1.07	-0.001
Yellow Babuda	m_i	42.60	12.63	68.26	74.26	48.24	5.25	5.17	13.60	219.47	74.60	1.26
	p_i	-8.29	-11.35	-3.24	-2.42	-6.09	0.2	0.33	-5.28	60.68	19.72	0.01
	b_i	0.41	-2.21*	1.38	1.08	0.94	1.33	1.12	1.22	1.62	0.34	0.51
	S^2_{di}	-53.15	0.20	2.03*	15.18*	3.71*	0.22*	0.06*	2.60*	-10.90	-2.26	0.03
Sunrise Orange	m_i	43.06	14.90	67.75	70.95	39.93	5.42	5.38	11.66	123.77	36.03	1.07
	p_i	-7.83	-9.08	-3.75	-5.73	-14.4	0.37	0.54	1.37	-35.02	-18.85	-0.18
	b_i	0.80	-0.13	1.08	2.25	1.05	0.04	-0.08	1.46	0.64	1.75	0.60
	S^2_{di}	-50.05	-0.19	1.99	144.15*	1.37*	0.06*	0.03*	32.30*	-12.41	-1.25	0.005
Mumbai Orange	m_i	70.66	13.83	73.35	71.51	30.65	5.32	5.43	17.80	117.44	34.38	0.94
	p_i	19.77	-10.15	1.85	-5.17	-23.68	0.27	0.59	0.97	-41.35	-20.5	-0.31
	b_i	0.96	-1.97	1.37	2.11	0.61	0.61	-0.61	1.26	0.05	0.15	0.88
	S^2_{di}	-45.14	0.73*	1.29*	155.72*	2.89*	0.003	0.06*	1.85*	-14.14	-2.29	0.002

For branch number none of the varieties exhibited average stability except Hajo Yellow which exhibited moderately high mean and positive Pi, bi not significantly deviating from unity and non-significantS^2di.

.For earliness to bud visibility Pusa Basanti Gainda followed by Sunrise Orange and Pusa Narangi Gaindaexhibited average stability. On the contrary, Pusa Arpita could be considered as average stable for lateness.

None of the varieties exhibited stability for days to full bloom. However Hajo Orange exhibited linear stability for earliness to full bloom.

With respect to flower diameter Pusa Basanti Gainda exhibited average stability for flower diameter and for fresh weight while Pusa Narangi Gaindaexhibited below average stability for fresh weight. Forself-life none of the varieties exhibited stability.

For both ray florets Hajo Yellow, Yellow Babuda and Pusa Narangi Gainda and exhibited average stability. In addition, Hajo Yellow, Yellow Babudaand Pusa Narangi Gainda, exhibited average stability for number of disc florets.

For yield per sq.m, Seracole followed by Pusa Narangi Gainda and Pusa Basanti Gainda exhibited average stability.

Naik *et al.* (2005) [6] reported that the variety African Marigold Orange out of 15 genotypes was considered to be superior with higher mean values and stability across the three environments.

In the present investigation the variety Seracole followed by Pusa Narangi Gainda and Pusa Basanti Gainda were found to be best for flower production and stable across the environments with respect to most of the characters studied but flexible for characters like number of branches per plant, days to full bloom,self-life, fresh weight and number of ray florets (except Pusa Narangi Gainda). The stability of these variety for plant height, days to bud visibility, number of flowers per plant and number of disc florets (except Seracole) and flexibility for other characters compensated leading to genetic homeostasis (Learner 1954) [3] resulting in stability of these varieties for flower yield.A similar finding was reported by Naik *et al.* (2005) [6] in marigold and Mishra (2002) [4] in carnation.

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