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Short communication

Combining ability in African marigold (*Tagetes erecta* L.)

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ABSTRACT

A line x tester crossing programme was done using male sterile lines and a set of 11 genetically diverse pollinators as testers. F_1's along with parents were evaluated during winter and summer seasons. During the seasons, for plant height and flower size, additive gene action was higher compared to non-additive gene action, while for flowering days and stalk length, non-additive and non-additive gene actions played important role during both the seasons, indicating the usefulness of hybrids in marigold cultivation. Similarly, for flower number during winter and for plant spread during summer, both additive and non-additive gene action played significant role. For other traits, gene action was inconsistent during different seasons.

Key words: Additive, non-additive, gene action, GCA and SCA

African marigold (*Tagetes erecta* L.), a member of Asteraceae family, is grown for loose flower, cut flower, potting and bedding purposes, its insecticidal properties and as industrial use in poultry feed. The success of exploitation of hybrid vigour depends upon the combining ability of parental lines to be used in hybridization. Parents with high magnitude of combining ability are most suitable for heterosis breeding. Therefore, the main objective of this study was to select good combiners, which may produce most promising F_1 hybrids.

The present study was carried out at Experimental Farm of Division of Floriculture and Landscaping, IARI, New Delhi involving 3 male sterile lines, viz., ms_7 ms_8 and ms_{12} and a set of 11 genetically diverse pollinators numbered Sel. 7, Sel. 8, Sel. 14, Sel. 19, Sel. 21, Sel. 22, Sel. 27, Sel. 28, Sel. 29, Sel. 31 and Sel. 56 as testers. The total area covered under the experiment was 800 sq.m. The line x tester analysis, designed by Kempthorne (1957), was adopted to derive combining ability variance and the genic effect and test of significance was carried out using the model given by Singh (1979). The hybrids and their parental lines were evaluated during winter and summer seasons in a Randomized Block Design with three replications. Observations were recorded on nine characters. It may be mentioned here that during summer crop, Sel. 7 did not flower but its three hybrids flowered. No seed set was obtained in any of genotypes in summer. Since the environmental conditions during two seasons were strikingly diverse, the data were separately analysed for the two crops without pooling together.

The data presented in Table 1 & 2 are for winter and summer crops, respectively, indicated that during winter

Table 1. Analysis of variance for combining ability for nine characters during winter season

Source of variation	df	Days to flowering	Plant height (cm)	Number of flowers/plant	Flower size (cm)	Flower weight (g)	Flowering duration (days)	Flower yield (g)	Harvest index	No. of seeds/ head
Replication	2	36.20	0.73	887.47	0.50	173.81	27.75	12194.59	32.07	2063.83
Females	2	19.10	1139.35**	1628.18**	12.89**	24007.67**	25.30	166593.20**	67.96**	2674.28**
Males	10	160.21**	76.20**	622.08**	0.94**	1239.48**	362.74**	17889.93**	50.58**	352.96
Females x Males	20	80.89**	56.64**	326.53**	0.55**	431.14**	96.93**	26816.55**	68.23**	207.07
Error	64	12.47	7.30	161.20	0.15	159.82	31.14	1972.81	7.77	669.24

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

Table 2. Analysis of variance for combining ability for eight characters during summer season

Source of variation	df	Days to flowering	Plant height (cm)	Number of flowers / plant	Flower size (cm)	Flower weight (g)	Flowering duration (days)	Flower yield (g)	Harvest index
Replication	2	6.38	1.39	0.69	0.01	22.15	1.37	1182.49	1.44
Females	2	51.13**	1002.70**	1508.97**	6.82*	1511.08**	68.06**	137327.80**	93.31**
Males	9	259.79**	72.60**	210.82**	1.02	634.17**	89.06**	19103.49**	10.65**
Females x Males	20	74.82**	43.24**	23.31**	0.48**	329.89**	3.73	10809.84**	6.02**
Error	64	6.19	5.65	10.27	0.17	46.17	4.46	3065.76	3.05

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

Table 3. Estimate of gca effects of parents for nine characters during winter season

Parents	Days to flowering	Plant height	Number of flowers/plant(cm)	Flower size (cm)	Flower weight (g)	Flowering duration	Flower yield (g) (days)	Harvest index	No. of seeds/ head
					Females				
ms_7	0.62	2.46*	-1.15	-0.09	5.51	0.61	-21.78	-1.58*	-9.70
ms_8	0.23	4.25**	7.53*	0.67**	23.79**	0.39	79.39**	0.36*	8.09
ms_{12}	-0.85	-6.71**	-6.38	-0.57**	29.30**	-1.00	-57.61**	1.22	1.61
SE(gi)	0.42	0.32	1.51	0.05	1.51	0.66	5.29	0.33	3.08
					Males				
Sel. 7	-1.48	-0.18	11.14**	-0.35**	8.49*	7.57**	41.00**	-5.77**	4.97
Sel. 8	-0.62	0.97	2.04	0.07	10.28*	0.43	9.61	-0.71	3.41
Sel. 14	6.86**	3.42**	14.60**	0.11	-8.47*	-5.84**	-21.77	-3.42**	-6.92
Sel. 19	-3.48**	-1.88*	6.56	-0.35**	-14.87**	0.15	-15.93	0.30	3.64
Sel. 21	-8.68**	0.79	11.78**	0.39**	19.87**	13.51**	28.86*	0.12	9.08
Sel. 22	-0.79	-3.75**	-8.35*	-0.16	8.19*	-4.24*	-96.48**	-0.06	-11.59
Sel. 27	0.87	3.14**	-6.42	-0.09	2.33	-5.59**	40.67**	0.15	-1.81
Sel. 28	-2.32*	-0.76	-2.75	-0.28*	14.08**	-1.15	-56.44**	-0.71	-6.81
Sel. 29	-3.80**	-1.86*	-5.28	0.52**	2.05*	0.52	-19.60	-2.96**	0.53
Sel. 31	1.76	-5.89**	1.44	-0.29*	-9.52*	-8.33**	6.49	1.09	0.19
Sel. 56	4.07**	2.25*	4.43	0.42**	12.10**	2.96	43.99**	0.43	5.30
SE(gi)	0.94	0.72	3.38	0.11	3.37	1.49	11.83	0.74	6.89

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

Table 4. Estimate of gca effects of parents for eight characters during summer season

Parents	Days to flowering	Plant height	Number of flowers/plant (cm)	Flower size (cm)	Flower weight (g)	Flowering duration	Flower yield (g) (days)	Harvest index
				Females				
ms_7	1.50*	2.56*	-7.14**	0.22*	0.09	-0.95	-33.10*	0.14
ms_8	-0.86	4.06**	7.04**	0.33*	7.05*	1.74*	77.83**	1.83*
ms_{12}	-0.64	-6.62**	0.10	-0.55**	-7.14*	-0.78	-44.74*	-1.69*
SE(gi)	0.31	0.30	0.40	0.05	0.85	0.26	6.89	0.22
				Males				
Sel. 7	-	-	-	-	-	-	-	-
Sel. 8	-0.92	0.26	8.35**	0.52**	1.84	2.57**	49.61**	1.83**
Sel. 14	7.38**	3.36**	-1.87*	0.22	-12.46**	-2.00**	-71.32**	-0.70
Sel. 19	-1.94*	-1.35	-5.12**	0.31*	-14.17**	-4.95	-55.46**	-1.26*
Sel. 21	-12.54**	0.61	6.97**	0.56**	-3.79	4.81**	-4.66	0.63
Sel. 22	1.54*	-4.35*	-1.35	-0.22	9.64**	-1.59*	-28.44	-0.44
Sel. 27	1.43	2.16**	-4.02**	-0.16	6.82**	-2.30**	3.08	0.98
Sel. 28	-2.62**	-1.21	-3.71**	-0.43**	1.17	-1.15	-15.12	-0.70
Sel. 29	5.42**	1.43*	-4.23**	0.07	0.62	-1.57*	-30.44	-1.54**
Sel. 31	1.21	-5.29**	1.87	-0.17	10.90*	2.87**	78.66**	0.85
Sel. 56	1.04	1.97*	3.12**	-0.08	0.67	3.31**	17.21	0.35
SE(gi)	0.66	0.63	0.85	0.11	1.79	0.56	4.62	0.46

*Significant at 5% level
**Significant at 1% level
-No flowering

Table 5. Estimates of sca effects of hybrids for eight characters during winter season

Hybrids	Days to flowering	Plant height	Number of flowers/plant (cm)	Flower size (cm)	Flower weight (g)	Flowering duration	Flower yield (g) (days)	Harvest index
ms_7 x Sel. 7	8.58**	2.12*	-16.16**	0.51**	-24.72*	-3.31	-105.78**	-5.10**
ms_7 x Sel. 8	4.98**	-4.54**	-12.99*	0.28	-10.71*	-8.73	-124.33**	-5.85**
ms_7 x Sel. 14	0.97	3.52**	-2.49	0.17	12.00*	4.13*	22.55	-2.47*
ms_7 x Sel. 19	1.02	-2.15*	7.72	0.06	7.07	7.71**	77.71**	-1.53
ms_7 x Sel. 21	-6.72**	1.32	6.79	0.21	-5.50	0.59	27.72	1.22
ms_7 x Sel. 22	-1.44	-4.35**	-3.44	0.16	0.03	-8.40**	-74.24**	-1.17
ms_7 x Sel. 27	1.06	2.39*	-3.74	0.04	7.54	2.79	-41.59*	0.12
ms_7 x Sel. 28	-2.78*	-0.74	-7.51	0.04	6.42	0.21	-95.12**	-0.89
ms_7 x Sel. 29	-1.43	2.88**	17.56**	0.04	10.66*	5.38*	157.12**	-6.59**
ms_7 x Sel. 31	0.14	0.79	5.84	0.17	-5.24	-0.34	52.10**	2.38*
ms_7 x Sel. 56	-4.37**	-1.25	8.42	0.19	2.44	-0.03	103.80**	5.90**
ms_8 x Sel. 7	-8.37**	-5.07**	4.23	0.30*	5.23	4.51**	6.88	-1.61
ms_8 x Sel. 8	-6.27**	-6.98**	14.89**	-0.01	12.44**	10.06**	77.86**	6.04**
ms_8 x Sel. 14	4.46**	2.87**	-5.21	0.31*	-1.25	-0.81	-17.12	-3.52**
ms_8 x Sel. 19	-1.80	2.80**	-9.19*	-0.27	-4.85	-5.60*	-44.04*	-0.74
ms_8 x Sel. 21	-1.13	-4.43*	-3.25	-0.73**	-12.85*	1.64	-66.26**	2.34*
Ms_8 x Sel. 22	0.94	-0.17	-7.15	0.34*	8.04	2.32	-57.91**	-1.78
ms_8 x Sel. 27	-1.82	-1.59	7.25	-0.56**	2.48	1.88	53.93**	-1.23
ms_8 x Sel. 28	-0.50	-4.42**	3.72	-0.40*	7.97	-0.83	104.18**	2.44*
ms_8 x Sel. 29	4.39	-3.10**	-2.72	-0.27	1.81	-9.17**	-20.59	2.55*
ms_8 x Sel. 31	1.86	3.88**	-0.87	-0.47**	0.57	-3.52	-18.71	-2.66
ms_8 x Sel. 56	8.24**	2.27*	-1.69	0.23	-4.25	-0.48	-18.21	-1.84
ms_{12} x Sel. 7	-0.22	2.95**	11.93*	0.21	19.49**	-1.20	98.91**	6.70**
ms_{12} x Sel. 8	1.28	-2.44*	-1.90	-0.27	-1.73	-1.32	46.46**	0.19
ms_{12} x Sel. 14	-5.43**	-6.38**	7.70	-0.48**	-10.76*	-3.32	-5.43	5.99**
ms_{12} x Sel. 19	0.78	-0.65	1.48	0.21	-2.22	-2.11	-33.67	2.27*
ms_{12} x Sel. 21	7.85**	3.12**	-3.54	-0.53**	17.74**	-2.23	38.54*	-3.55**
ms_{12} x Sel. 22	0.50	4.51**	10.59*	-0.18	-8.07	6.08**	132.15**	2.96**
ms_{12} x Sel. 27	0.76	-0.81	-3.51	0.52**	-10.02*	-4.67*	-12.34	-1.11
ms_{12} x Sel. 28	3.28*	5.16**	3.79	0.44**	1.56	0.62	-9.06	-2.35*
ms_{12} x Sel. 29	-2.96	0.22	-14.84**	0.27	-12.47*	3.79	-136.59**	-9.14**
ms_{12} x Sel. 31	-1.99	-4.67**	-4.97	0.25	4.67	3.87	-33.38	0.28
ms_{12} x Sel. 56	-3.87**	-1.02	-6.72	-0.43**	1.81	0.51	-85.58**	-4.07**
$SE(S_{ij})$	1.33	1.02	4.78	0.15	4.76	2.10	16.73	1.07

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

both male and female lines showed significant variation for plant height, plant spread, flower number, flower weight, flower size, stalk length, flower yield, harvest index and 1000-seed weight, providing the evidence of appreciable diversity present in the parental lines for these traits. For flowering days and flowering duration only males, and, for seed number per head only females showed the presence of significant diversity. However, significant variances for all the traits, except for seed number per head, proved that there were significant genic interactions among parental lines for all the characters providing appreciable heterosis for all the traits under study.

During summer (Table 2), both female and male parents showed significant variances for all the traits, except for flower size in males and for stalk length in females, indicating the presence of appreciable diversity among parents for all the traits during this crop season also. Significant variances for all the traits, except for flowering duration, proved the presence of significant genic interactions among male and female lines, giving appreciable heterosis for these traits during summer also.

A perusal of data presented in Table 3 & 4 indicated that three male sterile lines involved in hybrid production, showed varying degrees of general combining ability (gca) effects for different traits. Male sterile line ms-12 showed significant gca for four traits during winter but the effect was in negative direction. During summer also, this female line showed significant gca for five traits but in this season too the effect was in negative direction. Line ms-7 showed significant gca effects for three traits during winter, the effect

Table 6. Estimates of gca effects of hybrids for ten characters during summer season

Hybrids	Days to flowering	Plant height	Number of flowers/plant (cm)	Flower size (cm)	Flower weight (g)	Flowering duration	Flower yield (g) (days)	Harvest index
ms_7 x Sel. 8	6.06**	-3.36**	-2.87*	0.29	5.93	-0.89	7.80	0.89
ms_7 x Sel. 14	1.16	2.61**	0.74	0.59**	-1.43	-0.98	-7.17	-0.45
ms_7 x Sel. 19	2.51*	-2.82**	1.43	-0.21	0.38	0.06	68.58**	1.42
ms_7 x Sel. 21	-4.52**	1.79	0.48	-0.17	-0.67	-0.36	24.18	0.89
ms_7 x Sel. 22	0.09	-4.45**	1.26	-0.16	13.53**	-0.59	-53.44*	-1.27
ms_7 x Sel. 27	-1.53	2.04*	1.10	-0.26	6.29**	-0.78	17.93	1.10
ms_7 x Sel. 28	-3.14**	3.66**	3.59**	-0.02	-10.83**	1.26	34.87	-2.12**
ms_7 x Sel. 29	-0.09	1.14	0.11	0.02	-1.21	2.35**	-9.75	0.29
ms_7 x Sel. 31	-1.21	0.43	-4.62**	0.35*	-4.89	0.11	-82.15**	-1.23
ms_7 x Sel. 56	0.66	-1.04	-1.21	-0.44**	-7.10**	-0.19	-38.00	0.47
ms_8 x Sel. 8	-8.15**	5.48**	-0.99	0.28	-3.56	-0.48	-21.63	-1.37*
ms_8 x Sel. 14	2.35*	3.08**	1.03	-0.55**	-2.60	0.43	-17.10	0.02
ms_8 x Sel. 19	-3.33**	1.39	-2.22	-0.29	-5.12	0.04	-81.66**	0.25
ms_8 x Sel. 21	-4.27**	-4.50**	-0.27	-0.22	-0.60	-0.01	25.31**	-0.44
Ms_8 x Sel. 22	-0.82	-0.05	-0.19	-0.07	-19.03**	1.35	-88.96**	-1.11
ms_8 x Sel. 27	0.82	-1.89*	-2.25	0.53**	8.96**	0.73	21.90	0.24
ms_8 x Sel. 28	-0.65	-5.67**	-3.33**	-0.16	18.07**	-0.09	55.30*	2.48**
ms_8 x Sel. 29	2.53*	-2.06*	3.46**	0.14	5.14	-0.67	-11.18	0.99
ms_8 x Sel. 31	4.15**	2.60**	4.49**	0.04	11.65**	-0.51	122.05**	1.04
ms_8 x Sel. 56	7.38**	1.53	0.27	0.28	-2.63	-0.78	-11.23	-1.10
ms_{12} x Sel. 8	2.10*	-2.11*	3.85**	-0.58**	-2.37	1.37	13.84	0.48
ms_{12} x Sel. 14	-3.50**	-5.68**	-1.77	-0.08	4.03	0.55	24.27	0.44
ms_{12} x Sel. 19	0.82	1.43	0.79	0.49**	4.74	-0.11	13.08	-1.66*
ms_{12} x Sel. 21	8.78**	2.71**	-0.20	0.39*	1.26	0.37	-49.49*	-0.45
ms_{12} x Sel. 22	0.73	4.40**	-1.08	0.24	5.50*	-0.76	35.51	2.38**
ms_{12} x Sel. 27	0.71	-0.15	1.15	-0.26	-15.25**	0.05	-47.03*	-1.24
ms_{12} x Sel. 28	3.80**	2.01*	-0.26	0.18	-7.24**	-1.17	-20.43	-0.36
ms_{12} x Sel. 29	-2.45*	0.92	-3.57**	-0.15	6.33*	-1.68*	20.92	-0.39
ms_{12} x Sel. 31	-2.94**	-3.03**	0.13	-0.39	-6.76*	0.41	-39.91	0.10
ms_{12} x Sel. 56	-8.04**	-0.49	0.94	0.16	9.73*	0.97	-49.24*	0.62
SI (S_{ij})	0.93	0.89	1.20	0.15	2.54	0.79	20.68	0.65

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

being negative for two traits. During summer, this female line showed significant gca effects for six traits but the effect was negative for three traits. Line ms-8 showed significant gca effects for eight traits during both the seasons, of which only one was in negative direction. For flower yield, ms-8 gave the highest positive gca effect during both the seasons, while for other two female lines it was in negative direction.

Among the 11 male lines selected for F_1 hybrid production, Sel. 7 did not flower in summer, while in winter it showed positive gca effects for five traits and negative gca effects for three traits. Sel. 8 showed significant negative effect for five traits during summer, while during winter significant negative effect was for three traits. Sel. 14 showed significant positive gca effects for three traits during both the seasons. Sel. 19 showed significant negative effect for four traits during winter and for eight traits during summer. Sel. 21 showed significant positive gca effects for three traits during summer and for six traits during winter including flower yield. Sel. 22 showed significant negative effect for six traits during winter and for three traits during summer. Sel. 27 produced significant positive gca effect for three traits including yield during winter. In Sel. 28, almost all significant effects observed were in negative direction during both the seasons. Sel. 29 showed significant positive gca effects for two traits only during winter and summer. Sel. 31 showed significant negative effect for five traits during winter but positive effect for three traits during summer. Sel. 56 showed significant positive effect for three traits during summer, while during winter it showed significant positive effect for six traits including flower yield.

Above discussion clearly indicates that among females, ms-8 and among pollinators, Sel. 7 (during winter only), Sel. 21, Sel. 27 and Sel. 56 were the best general combiners in both the seasons.

An understanding of magnitude of additive and non-additive gene actions controlling various traits in the breeding population is essential for the purposeful management of genetic variability in any crop. During both the crop seasons, for plant height and flower size, additive gene action was more important in addition to non-additive gene action in production of hybrids in marigold. It was supported by earlier finding of Reddy *et al* (1989). In case of flowering days and stalk length, non-additive gene action played a major role in both the seasons. Singh and Swarup (1971) also reported the role on non-additive gene action in controlling flowering days in marigold. For other traits, gene action was inconsistent over the seasons.

Estimates of gca effects for 10 characters (Table 5 & 6) indicate that for flower yields and for two of its most important components, i.e., flower number and flower weight, out of 33 F_1 hybrids evaluated, ms-7 x Sel. 29, ms-7 x Sel. 56, ms-8 x Sel. 8, ms-12 x Sel. 22 and ms-12 x Sel. 7 were suitable for cultivation during winter, and three hybrids, ms_{7-} x Sel. 19, ms-8 x Sel. 28 and ms-8 x Sel. 31 for cultivation during summer. Hybrid, ms-8 x Sel. 28 showed adaptation for cultivation over both the seasons. Thus, for flower production, desirable performance of only 8 F_1 hybrids out of 33 F_1 hybrids advocates that a large number of hybrids combinations should be attempted and the hybrids should be the best performance for commercial cultivation.

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