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Research Article

Combining ability and gene action studies for seed yield and its components in Sunflower (*Helianthus annuus* L.)

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Abstract
Five CMS lines and six restorers were crossed in a line x tester fashion to elucidate the information on the combining ability for seed yield, yield components and oil content and also to know the nature of gene action involved in inheritance of important quantitative traits. A total of 30 crosses were evaluated for 13 different quantitative traits. Line CMS E002-92-2 and CMS-104A exhibited significant *gca* effects for most of the characters studied and were found to be the best combiners. Likewise, tester EC-623015 was the best combiner for seed filling per cent, seed yield per plant, harvest index, volume weight, kernel per cent, hull per cent, KH ratio and oil content. The estimates of variance components revealed predominance of non-additive gene action for all characters studied.

Key words
Sunflower, Combining ability, gene action, line x tester analysis

Introduction

Availability of cytoplasmic genetic male sterility and fertility restoring source and highly cross pollinated nature of sunflower has made the exploitation of heterosis possible on commercial scale. Hybrids using lines developed based on heterosis are preferred by farmers due to their high yielding performance, quality and uniformity. To develop sunflower hybrids with improved yield potential, the choice of parents through careful and critical evaluation is of paramount importance in order to improve productivity and total production. Combining ability studies elucidates the nature and magnitude of gene action involved in the inheritance of character by providing the information on the two components of variance *viz.,* additive genetic and dominance variance, which are important to decide upon the parents and crosses to be selected for eventual success.

The present investigation was undertaken to select parents with good *gca* and crosses with good *sca* effects through line x tester analysis. This study also gives an idea on the nature of gene action involved in inheritance of important quantitative traits. Such information is required to design efficient breeding programme for crop improvement.

Material and Methods

A set of five cytoplasmic male sterile lines *viz.*, CMS-127A, CMS-104A, CMS-103A, CMS E002-92-2, CMS-10A and six restorers *viz.*, GMU-490, EC-601800, EC-601807, EC-601923, EC-623009, EC-623015 were planted during *kharif* 2010-11 at Main Agriculture Research Station, University of Agricultural Sciences, Raichur. The seed material was obtained from the Principal Scientist and Head (Breeding), All India Co-ordinated Research Project on sunflower, Main Agricultural Research Station, Raichur. Crossing was performed in line x tester fashion and seeds were harvested separetely to study the combining ability analysis in next season.

During late *rabi* 2010-11, six selected germplasm lines as testers, five CMS lines, resultant 30 crosses and five check hybrids were sown in a simple Randomized Block Design with two replications for evaluation in line x tester fashion. Each entry was raised with two rows in a plot having 3 m x 0.6 m (1.8 m^2) by adopting a spacing of 60 cm between rows and 30 cm between plants. Observations were recorded on five randomly selected plants in each entry and in each replication for 13 quantitative characters *viz.*, days to 50 per cent flowering, days to maturity, plant height (cm), head diameter (cm), seed filling per cent, seed yield per plant (g), harvest index (%), 100 seed weight (g), volume weight (g/100 ml), kernel per cent, hull per cent, KH ratio and oil content (%). The analysis was carried out in computer using software INDOSTAT developed by Central Research Institute of Dry Land Agriculture, Hyderabad.

Results and Discussion

From the analysis of variance for combining ability (Table 1), it is quite evident that significant differences existed among both lines and testers in

respect of different characters studied thus justifying the selection of parents for combining ability analysis. The crosses between these lines and testers differed significantly from each other for all the characters studied. The variance due to interaction between female and male parents was significant for all the characters suggesting significant contribution of *sca* effects towards variation among the crosses. Interaction between lines and testers also exhibited significance difference for all the traits, showing the importance of non-additive gene action in the expression of the traits in the hybrids.

The comparative estimates of variance due to general combining ability (GCA) and specific combining ability (SCA) revealed the predominance of SCA variance in relation to GCA variance for all the traits which implies that all the characters were predominantly under the control of non-additive gene action (Table 2). The results corroborates with the findings of Singh *et al.* (1999) and Madhavi Latha *et al.* (2004). The degree of dominance was more than unity for all the traits studied suggesting the earlier inference drawn. The magnitude of average degree of dominance (more than unity) revealed over-dominance for all the traits, confirming the earlier inference drawn about the preponderance of non-additive genetic variance in the material, which is in agreement with the report of Madhavi Latha *et al.* (2004).

Among the lines, the line CMS-10A was found to posses genes for earliness as evident from its significant negative highest general combining ability (*gca*) effects in desirable direction for days to 50 per cent flowering. The same line also had highest negative *gca* effects for days to maturity. Whereas, the line CMS E002-92-2 recorded the significant highest negative *gca* effects for plant height and significant positive *gca* effects for seed yield per plant, harvest index and 100 seed weight. Line CMS-104A was found to be best combiner for seed filling per cent, volume weight, kernel per cent, hull per cent, KH ratio and oil content in desirable direction (Table 3).

Among testers, EC-601807 was found with highest negative *gca* effects for days to 50 per cent flowering whereas, EC-623009 exhibited highest negative *gca* effects for days to maturity and plant height. The highest positive *gca* effects for head diameter and 100 seed weight were found in tester GMU-490. The tester EC-623015 was the best combiner with highest *gca* effects for remaining eight characters *viz.*, seed filling per cent, seed yield per plant, harvest index, volume weight, kernel per cent, hull per cent, KH ratio and oil content.

It is evident from the data presented in Table 4 that no single line or tester was a good combiner for all the characters studied. However for improving a specific character, the parent showing high *gca* effect in desirable direction can be used as good donors for improvement of that character. Many workers *viz.*, Halaswamy *et al.* (2004), Reddy and Madhavi Latha (2005), Manivannan *et al.* (2005) and Tavade *et al.* (2009) reported good general combiners for most of the characters under study.

The cross CMS E002-92-2 x GMU-490 indicated the highest specific combining ability (*sca*) effects for kernel per cent (6.03), hull per cent (-6.03) and KH ratio (0.66), while CMS E002-92-2 x EC-601800 for days to 50 per cent flowering (-3.92) and days to maturity (-7.40) showed significant *sca* effects.

The significant positive *sca* effects were noticed in nine hybrids for seed yield per plant. Among these CMS-127A x EC-623015 (4.79), CMS A2 x EC-601923 (6.02) and CMS-10A x EC-601800 (5.76) recorded highest positive *sca* effects.

The hybrid CMS-10A x GMU-490 recorded highest *sca* effect for plant height (-18.55) and harvest index (7.47). However, the crosses CMS-127A x GMU-490, CMS-127A x EC-601800, CMS-127A x EC-623015, CMS 104A x EC-623015 and CMS 103A x EC-601807 showed significantly more *sca* effect for 100 seed weight (1.30), volume weight (3.45), oil content (4.36), seed filling per cent (9.68) and head diameter (2.80) respectively. The tester EC-623015 was the best combiner with highest *gca* effects for remaining eight characters *viz.*, seed filling per cent, seed yield per plant, harvest index, volume weight, kernel per cent, hull per cent, KH ratio and oil content. Sharma *et al.* (2003), Patil *et al.* (2007) and Tavade *et al.* (2009) reported significant *sca* effects in desirable direction for yields and contributing characters.

Therefore it can be concluded in the present investigation that almost all the characters studied were governed by non-additive gene action. The cross combinations showing high *sca* effects for yield and its related traits with one or both parents having good general combining ability can be utilized in the hybrid development programme for exploitation of hybrid vigour through diversified restorer systems to raise the yield levels of sunflower.

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Table 1. ANOVA for combining ability for different characters in sunflower

Source of variation	Degrees of freedom	Mean sum of squares												
		Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed filling per cent	Seed yield/ plant (g)	Harvest index (%)	100 seed weight (g)	Volume weight (g/100 ml)	Kernel per cent	Hull per cent	KH ratio	Oil content (%)
Replication	1	0.07	0.42	12.70	0.45	1.97	1.33	0.38	0.02	0.29	3.25	2.73	0.04	1.55
Lines	4	39.18*	75.23	913.16**	1.53	52.15	53.60	93.86	1.31	119.94**	51.32	51.33	0.76	126.42**
Testers	5	30.15*	94.19	351.65	8.68	79.64	55.40	53.93	5.52**	46.88*	27.92	27.92	0.40	8.80
Lines x Testers	20	10.91**	54.42**	184.58**	106.83**	55.41**	36.98**	35.25**	0.86**	14.81**	493.06**	493.17**	6.42**	13.67**
Error	29	0.83	0.93	46.33	1.35	0.79	1.23	6.33	0.03	1.61	1.62	1.04	0.02	0.73

*, ** – Significant at 5% and 1% levels, respectively

Table 2. Estimates of combining ability variance and degree of dominance for yield and yield components

Characters	Variance due to GCA	Variance due to SCA	GCA / SCA proportion	Degree of dominance
Days to 50 per cent flowering	0.2372	5.0440	0.0470	3.2607
Days to maturity	0.3199	26.7405	0.0120	6.4649
Plant height (cm)	4.2513	69.1295	0.0615	2.8514
Head diameter (cm)	0.0016	1.9965	0.0008	24.9781
Seed filling per cent	0.1226	27.3106	0.0045	10.5537
Seed yield per plant (g)	0.1797	17.8777	0.0101	7.0529
Harvest index (%)	0.3717	14.4597	0.0257	4.4103
Hundred seed weight (g)	0.0284	0.4169	0.0681	2.7092
Volume weight (g/100 ml)	0.6586	6.6006	0.0998	2.2385
Kernel per cent	0.1395	11.5186	0.0121	6.4254
Hull per cent	0.1394	11.8111	0.0118	6.5088
KH ratio	0.0024	0.1514	0.0159	5.6162
Oil content (%)	0.4838	6.4663	0.0748	2.5851

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Table 3. Estimates of general combining ability (*gca*) effects of male and female parents for different characters in sunflower

Sl. No.	Parents	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed filling per cent	Seed yield/ plant (g)	Harvest index	100 seed weight (g)	Volume weight (g/100 ml)	Kernel per cent	Hull per cent	KH ratio	Oil content (%)
Lines														
1.	CMS-127A	-1.18**	1.32**	1.03	0.09	0.85**	0.21	-0.25	0.32**	1.73**	1.22**	-1.22**	0.14**	1.85**
2.	CMS-104A	2.40**	1.57**	14.71**	-0.46	1.69**	1.11**	1.29	0.00	3.32**	2.87**	-2.87**	0.35**	4.55**
3.	CMS-103A	1.48**	-0.68*	-4.11*	-0.18	-0.29	-2.12**	-2.99**	-0.39**	1.71**	-0.26	0.26	-0.03	-0.73**
4.	CMS E002-92-2	-1.18**	1.90**	-6.92**	0.04	1.24**	2.83**	4.04**	0.33**	-3.09**	-1.77**	1.77**	-0.23**	-2.01**
5.	CMS-10A	-1.52**	-4.1**	-4.71*	0.51	-3.49**	-2.02**	-2.09**	-0.26**	-3.67**	-2.06**	2.06**	-0.23**	-3.66**
CD at 5%		**0.7603**	**0.8080**	**5.6962**	**0.9719**	**0.7415**	**0.9273**	**2.1060**	**0.1368**	**1.0629**	**1.0638**	**0.8520**	**0.1127**	**0.7174**
CD at 1%		**1.0236**	**1.0889**	**7.6690**	**1.3085**	**0.9984**	**1.2485**	**2.8354**	**0.1842**	**1.4311**	**1.4322**	**1.1471**	**0.1518**	**0.9658**
Testers														
6	GMU-490	2.47**	1.95**	3.34	1.32**	2.26**	1.28**	-1.34	1.25**	-2.37**	-2.68**	2.68**	-0.29**	-1.04**
7	EC-601800	1.17**	5.15**	6.04**	0.56	3.08**	3.36**	3.56**	0.53**	3.40**	1.42**	-1.42**	0.24**	1.37**
8	EC-601807	-2.13**	-1.15**	5.24*	0.42	-1.56**	0.49	1.89*	-0.27**	-0.50	0.08	-0.08	0.03	0.65*
9	EC-601923	-0.03	-3.35**	-5.78*	-0.32	-4.73**	-3.56**	-2.19*	-0.61**	-0.80	0.32	-0.32	-0.01	0.03
10	EC-623009	-1.73**	-1.95**	-8.18**	-1.14**	0.37	-1.36**	-2.02*	-0.65**	1.78**	1.90**	-1.90**	0.19**	-1.01**
11	EC-623015	0.27	-0.65*	-0.64	-0.84*	0.58*	-0.21	0.09	-0.25**	-1.49**	-1.04*	1.04**	-0.15**	0.00
CD at 5%		**0.8329**	**0.8860**	**6.2399**	**1.0647**	**0.8123**	**1.0158**	**2.3070**	**0.1499**	**1.1644**	**1.1653**	**0.9333**	**0.1235**	**0.7858**
CD at 1%		**1.1213**	**1.1928**	**8.4010**	**1.4334**	**1.0936**	**1.3677**	**3.1060**	**0.2018**	**1.5677**	**1.5689**	**1.2566**	**0.1663**	**1.0580**

*, ** – Significant at 5% and 1% levels, respectively

Table 4. Estimates of specific combining ability (*sca*) effects for different characters in sunflower

Hybrids	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed filling per cent	Seed yield/ plant (g)	Harvest index (%)	100 seed weight (g)	Volume weight (g/100 ml)	Kernel per cent	Hull per cent	KH ratio	Oil content (%)
CMS-127A x GMU-490	-0.72	2.38**	2.91	0.93	1.92**	1.50	-0.66	1.30**	-0.16	-3.63**	3.63**	-0.42**	-4.75**
CMS-127A x EC-601800	1.58*	-1.82*	15.61**	-0.61	3.70**	0.53	-0.19	-0.74**	3.45**	3.20**	-3.20**	0.44**	1.99**
CMS-127A x EC-601807	-1.62*	-0.02	-13.49**	-1.07	0.55	-0.41	-2.08	0.02	-0.55	1.63	-1.63*	0.16	-1.44*
CMS-127A x EC-601923	0.78	1.68*	-1.67	-1.43	-4.52**	-5.46**	-0.24	0.40**	-1.71	-0.30	0.30	-0.03	-2.72**
CMS-127A x EC-623009	-0.02	-2.72**	-2.17	-0.21	-3.28**	-0.95	-3.43	-0.41**	-3.38**	-2.09*	2.09**	-0.27**	2.57**
CMS-127A x EC-623015	-0.02	0.48	-1.21	2.39**	1.63*	4.79**	6.60**	-0.55**	2.34*	1.19	-1.19	0.12	4.36**
CMS-104A x GMU-490	1.70*	7.13**	10.93*	0.28	-3.19**	1.51	-0.97	-0.18	-1.23	2.20*	-2.20**	0.22*	-1.60*
CMS-104A x EC-601800	0.50	-0.07	-0.87	-0.46	3.92**	1.93*	1.26	0.63**	-0.04	2.23*	-2.23**	0.36**	-1.01
CMS-104A x EC-601807	3.30**	-0.77	-6.57	-2.32**	-6.93**	-5.90**	-3.52	-0.26*	0.01	-0.34	0.34	-0.09	-1.69**
CMS-104A x EC-601923	-1.30	4.93**	3.85	0.92	-1.49*	-0.75	-0.62	-0.18	-1.29	-3.59**	3.59**	-0.45**	0.88
CMS-104A x EC-623009	-2.10**	-3.97**	0.15	1.84*	-1.99**	-0.35	1.53	0.31*	1.26	-1.14	1.14	-0.11	2.52**
CMS-104A x EC-623015	-2.10**	-7.27**	-7.49	-0.26	9.68**	3.56**	2.33	-0.33**	1.30	0.64	-0.64	0.06	0.91
CMS-103A x GMU-490	-2.38**	-0.12	-3.05	-0.70	5.08**	-1.40	0.36	-0.14	-1.47	-1.88*	1.88*	-0.22*	2.63**
CMS-103A x EC-601800	1.92**	3.68**	-13.25*	-1.64	-7.10**	-6.04**	0.30	-0.73**	1.82	-2.02*	2.02**	-0.36**	-0.03
CMS-103A x EC-601807	-0.78	1.48*	11.55*	2.80**	4.10**	3.51**	6.09**	0.83**	-0.28	4.50**	-4.50**	0.57**	0.89
CMS-103A x EC-601923	0.62	-4.32**	3.67	0.34	3.32**	3.42**	1.59	-0.14	0.96	1.66	-1.66*	0.20*	0.71

Table 4 contd..

Hybrids	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed filling per cent	Seed yield/ plant (g)	Harvest index (%)	100 seed weight (g)	Volume weight (g/100 ml)	Kernel per cent	Hull per cent	KH ratio	Oil content (%)
CMS-103A x EC-623009	-1.18	-6.22**	-5.03	-0.54	0.64	-0.42	-3.22	-0.05	2.06*	1.25	-1.25	0.17	-3.40**
CMS-103A x EC-623015	1.82**	5.48**	6.13	-0.24	-6.04**	0.93	-5.11**	0.21	-3.09**	-3.51**	3.51**	-0.36**	-0.81
CMS E002-92-2 x GMU-490	3.78**	-3.20**	7.76	-0.52	-3.41**	-2.64**	-6.19**	-0.01	3.44**	6.03**	-6.03**	0.66**	3.71**
CMS E002-92-2 x EC-601800	-3.92**	-7.40**	-11.74*	0.04	-6.91**	-2.19**	-2.84	-0.40**	-7.58**	-6.96**	6.96**	-0.76**	-1.45*
CMS E002-92-2 x EC-601807	-3.12**	0.40	0.46	2.18*	0.99	2.38**	1.33	-0.29*	0.67	-0.11	0.11	-0.06	2.37**
CMS E002-92-2 x EC-601923	1.78**	0.10	-0.72	1.02	3.14**	6.02**	3.59	-0.36**	0.52	0.64	-0.64	0.09	0.69
CMS E002-92-2 x EC-623009	1.98**	11.20**	4.48	-1.76*	4.16**	-2.67**	2.07	0.43**	1.19	0.52	-0.52	0.06	-2.57**
CMS E002-92-2 x EC-623015	-0.52	-1.10	-0.26	-0.96	2.04**	-0.90	2.03	0.64**	1.76	-0.13	0.13	0.00	-2.73**
CMS-10A x GMU-490	-2.38**	-6.20**	-18.55**	0.01	-0.40	1.03	7.47**	-0.97**	-0.58	-2.72**	2.72**	-0.24*	0.01
CMS-10A x EC-601800	-0.08	5.60**	10.25*	2.67**	6.39**	5.76**	1.47	1.24**	2.35*	3.55**	-3.56**	0.33**	0.51
CMS-10A x EC-601807	2.22**	-1.10	8.05	-1.59	1.30*	0.43	-1.81	-0.30*	0.15	-5.68**	5.69**	-0.58**	-0.13
CMS-10A x EC-601923	-1.88**	-2.40**	-5.13	-0.85	-0.45	-3.23**	-4.32*	0.28*	1.52	1.59	-1.59*	0.17	0.44
CMS-10A x EC-623009	1.32	1.70*	2.57	0.67	0.46	4.38**	3.05	-0.28*	-1.13	1.45	-1.46	0.14	0.89
CMS-10A x EC-623015	0.82	2.40**	2.83	-0.93	-7.30**	-8.38**	-5.85**	0.03	-2.31*	1.80	-1.80*	0.18	-1.72**

*, ** – Significant at 5% and 1% levels, respectively