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Original Research Article

Combining Ability and Gene Action Studies for Yield and Its Component in Sunflower (*Helianthus annuus* L.)

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ABSTRACT

Field experiments were carried out during 2015-2016 in order to study the genetic structure of a hybrid sunflower population, to identify the parents and crosses showing superior general and specific combining ability and finally to evaluate F1 hybrid vigour. Fifty four hybrids were created using 6 CMS and 9 restorer lines in sunflower (*Helianthus annus* L.) The resultant 54 hybrids were evaluated along with their parents with three standard checks at two locations during *Rabi* at *viz*., Akola and Amravati. The ratio of GCA to SCA variance were found lower than unity which indicated the preponderance of non-additive gene actions for the characters viz. Days to 50% flowering, Days to maturity, plant height, head diameter, seed filling percentage, 100 seed weight, volume weight, hull content, seed yield per plant and oil content. The *gca* effects of the parents in Rabi pooled analysis revealed that among the, lines AKSF-10-1-1A, CMS-234A and among the testers RHA-138-2R, 856-R AK-1R and GMU--830 were found to be promising general combiners for seed yield and yield component characters. Based on significant *sca* effects in pooled analysis, five hybrids *viz.*, CMS-302A X 856-R, CMS-234A X RHA-138-2R, CMS-607A X RHA-138-2R, CMS-607A X 856-R and CMS 302A X AK-1R were identified as promising for seed yield and other yield contributing characters.

Keywords

Combining ability, Line x Tester, Pooled analysis, Gene action, Sunflower

Introduction

Sunflower is one of the most important oilseed crop grown for edible purposes in the world. Per capita consumption and requirements for edible oil is increasing. So the local production of hybrid seed with increased seed and oil yield is one of basic step to achieve the goal. An important direction of research work on sunflower is heterosis breeding. It became possible after the discovery of the first CMS source in sunflower by Leclerq (1969) and the finding out of efficient fertility restorers (Kinman, 1970 and Leclerq, 1971).Utilization of heterosis has allowed sunflower to become one of the major oil seed in many countries.

The importance of hybrid cultivars in sunflower has increased recently because of their higher seed yield compared with cross-pollinated varieties in many countries in the world. Hybrids of sunflower are more stable, highly self-fertile, with high yield performance, and more uniform at maturity (Seetharam, 1979; Kaya and Atakisi, 2004). Resistance to diseases has also increased the importance of hybrid varieties. The heterotic performance of a hybrid combination depends upon the combining abilities of its parents (Allard, 1960; Kadkol *et al.*, 1984). Kaya and Atakisi (2004) reported that superior hybrids have been obtained by crossing inbred CMS female and restorer lines with high GCA (General Combining Ability) and SCA (Specific Combining Ability) values. Recently, line x tester analysis has widely been used for combining ability tests, suggested by Singh and Chaudhary (1977). Kempthorne (1957) reported that line x tester analysis is an extension of top cross method in which several testers are used. Virupakshappa *et al.,* (1997) stated that two testers were enough to efficiently test GCA of inbred lines. In addition, the use of two testers due to additional costs of using several testers was suggested by Skoric (1992) and Fick and Miller (1997). High heterosis for yield and its components in sunflower, being cross-pollinated crops has been reported bymany previous researchers (Chaudhary and Anand, 1984; Goksoy *et al.,* 2000; Khan *et al.,* 2004; Kaya, 2005). However, heterosis does not appear in all hybrid combinations of the F1 generation (Hladni *et al.,* 2007). Therefore to achieve the success in hybrid breeding is quite difficult and it takes some time. Hladni *et al.,* (2007) reported that the occurrence of heterosis in sunflower hybrids is highly correlated with genetic distance between the parental lines. The aim of this study was to estimate the amount of heterosis in fifty-four hybrids obtained from six CMS and nine restorer lines and to select parental lines having good combining abilities and superior high level of heterosis.

Materials and Methods

Six CMS lines *viz*., CMS 302A, CMS 6071A, CMS 234A, CMS 21, AKSF-6-1A, and AKSF-10-1-1A and nine restorers *viz*., PKV-105, AKSF-6R, AKSF-12R, AK-1R, GMU-830, RHA-138-2R, 298-R, 856-R and 189-1R were planted during *Rabi*, 2014 at Oilseeds Research Unit, Dr. PDKV, Akola and crossing was performed in line x tester fashion to produce 54 hybrids. During *Rabi* 2015 -16, the 54 hybrids along with their parents and three standard checks *viz*., DRSH-1, PKVSH-952 and SH-3322 were evaluated in a Randomized Block Design replicated thrice at two different locations *viz*., Oilseeds Research Unit, Dr. PDKV, Akola; and Regional Research Center, Amravati. Observations were recorded on five randomly selected plants in each hybrid combination per replication for ten quantitative characters. Data obtained were subjected to line x tester analysis (Singh and Chaudhary1977) to estimate general and specific combining ability effects and their respective variances. The result of pooled analysis over locations is presented.

Results and Discussion

The pooled analysis of variance revealed significant differences due to environments for all the characters except plant height, 100 seed weight, volume weight and hull content indicating the sufficient diversity among the environments (Table 1). The differences among the parents, parents and crosses were observed to be significant for all the characters studied indicating the existence of wider genetic differences among parents and crosses. Partitioning of crosses into lines, testers and lines x testers revealed that the variance due to lines were significant for all the characters except head diameter, seed filling percentage, hull content seed yield per plant and oil content, whereas for testers days to 50% flowering was found significant, indicates wide variability existing among the genotypes. The interaction due to lines x testers were significant for all the traits studied, suggesting that significant contribution of *sca* effects towards the variation among the crosses. The results are in accordance with the earlier studies Madhavilatha *et al.,* (2004). Interaction effects of environments x crosses were significant for all the characters, except plant height, seed filling %, 100 seed weight and volume weight. Further partitioning of the interaction of females x environments only for 100 seed weight showed significant differences, while males x environments was significant only for head diameter, suggesting the sensitivity of *gca* effects of parents to environmental fluctuations for these characters. Interaction effects of environments x females x males were significant for all the characters studied except plant height, seed filling %,100 seed weight and volume weight, indicates the *sca* effects of hybrids interacted with the environments for all the characters studied. The comparative estimates of variances 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 implied that all the characters were predominantly under the control of non-additive gene action (Table 2). The results corroborates with the findings of Satyanarayana (2000) and Madhavilatha *et al.,* (2004). The *gca* effects of the parents revealed that the lines AKSF -10-1-1A, CMS-234A and CMS-302A were good general combiners for seed yield per plant and other most of the traits like plant height, head diameter, 100 seed weight, by exhibiting significant positive *gca* effects (Table 3). These lines also showed negative significant *gca* effects for the traits like days to 50 per cent flowering and days to maturity indicating their usefulness in breeding for early maturing hybrids (Table 3). Among the testers, RHA-138-2R was best general combiner for majority of the important yield components, *i.e*., head diameter, seed filling percentage, 100 seed weight, volume weight and seed yield per plant. The tester 856-R possessed favourable genes for early flowering, maturity and dwarf plant type by recording significant negative *gca* effects. Favourable genes for oil content were predominantly contributed by PKV -105, RHA-138-2R and 189-1Rby recording significant positive *gca* effects. Hence, among the lines AKSF-10-1-1A, CMS-234A and CMS-302A and among the testers RHA-138-2R,856-R, PKV-105and AK-1R were proved to be good combiners for seed yield and its most of the related characters and need to be exploited in future breeding programme. The parents which are good general combiners for yield possessed *gca* effects in the desired direction for yield components was also reported earlier by Madrap and Makane (1993), Radhika (1994), Kandhola (1995).

Twenty-two crosses exhibited positive and significant sca effects for the characters seed yield per plant the cross CMS-302A X 856-R exhibited highest significant sca effects for seed yield per plant and other traits viz., head diameter, see filling percentage 100 seed weight, volume weight, hull and also oil content. Twenty-two crosses were identified as good specific combinations for seed yield per plant. Among these crosses the positive *sca* effect for seed yield also exhibited significant positive *sca* effects for other yield contributing traits. The cross combination CMS-302A X 856-R showed significant positive *sca* effects for seed yield per plant along with head diameter, seed filling percentage, 100 seed weight, volume weight, hull content and oil content along with negative significant *sca* effect for hull content indicating its suitability for commercial exploitation hybrids (Table 4). In the other cross *viz.*, CMS-234A X RHA-138-2R showed significant positive sca effects for seed yield per plant along with head diameter, seed filling percentage, volume weight and oil content along with negative significant *sca* effect for days to 50% flowering and hull content indicating its suitability for commercial exploitation for high yielder and early maturing hybrids.

Table.1 Analysis of variance for combining ability (Pooled Rabi seasons)

Genotype	d. f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed filling (%)	100 seed weight (g)	Volume weight (g/100ml)	Hull content (%)	Seed yield/plant (g)	Oil content (%)
Environments	**1**	38.72**	7.41**	19.30	65.40**	22.30**	0.02	0.20	0.30	27.80**	147.29**
Crosses	**53**	98.17**	78.55**	852.47**	58.21**	34.22**	5.77**	136.18**	108.07**	575.46**	33.21**
Females	**5**	280.30**	405.69**	2254.37*	90.53	47.19	14.59*	367.43**	76.07	1170.40	25.09
Males	**8**	171.73*	30.74	635.15	60.23	64.67*	6.99	162.47	92.01	618.11	25.58
Males x Females	**40**	60.69**	47.22**	720.70**	53.76**	26.51**	4.42**	102.02**	115.29**	492.56**	35.74**
Env. x Crosses	**53**	1.27*	13.03**	100.56	3.26**	3.10	0.06	0.61	9.20**	23.93**	10.51**
Env. x Females	**5**	1.98	7.52	172.60	5.35	1.06	0.14*	1.30	11.12	27.42	17.34
Env. x Males	**8**	0.72	17.88	131.54	5.56*	3.51	0.08	0.33	9.32	27.74	9.82
Env. x Malesx Females	**40**	1.29*	12.74**	85.36	2.54**	3.27	0.05	0.58	8.94**	22.73**	9.80**
Error	**212**	0.88	0.52	81.21	1.37	2.51	0.08	1.53	1.53	3.97	0.90

Table.2 Analysis of variance of combining ability for different characters (Pooled Rabi seasons)

Source of variations	Mean of Squares									
	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed filling (%)	100 seed weight (g)	Volume weight (g/100ml)	Hull content (%)	Seed yield/ plant (g)	Oil content (%)
GCA	3.672**	3.800**	14.607	0.415	0.675*	0.140*	3.615*	-0.722	8.818	-0.315
SCA	9.900**	5.745**	105.890***	8.536**	3.872**	0.728**	16.906**	17.724**	78.304**	4.324**
GCA/SCA	0.370	0.661	0.137	0.048	0.174	0.192	0.213	0.040	0.112	0.072

Table.3GCA effects of promising parents in desirable direction for seed yield and other yield contributing characters (Pooled Rabi seasons)

Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed filling percentage	100 seed weight (g)	Volume weight (g/100ml)	Hull content (%)	Seed yield /plant (g)	oil content (%)
	1	2	3	4	5	6	7	8	9	10
Lines (Females)										
CMS-302A	-1.76**	-	-2.674**	0.87**	-	-	3.81 **	-	-	-
CMS-607A	-	-	-	0.62**	-	-	1.92**	-	-	1.22**
CMS-234A	-	-	-	-	-	0.82**	-	-0.39**	2.30**	-
CMS-21A	-	-	-5.748**	-	-	-	-	-1.16**	-	-
AKSF-6-1A	-2.89**	-5.00**	-5.357**	-	0.97**	-	-	-1.20**	-	-
AKSF-10-1-1A	-0.74**	-1.12**	-2.07**	1.12**	1.13**	0.46**	-	-	8.08**	-
Tester(males)										
Pkv-105	-	-	-	2.31**	1.11**	-	1.70**	-	-	1.03**
AKSF-6R	-	-	-	-	-	0.21**	-	-	-	-
AKSF-12R	-1.74**	-	-	-	-	-	-	-	-	-
AK-1R	-1.94**	-0.67**	-	0.98**	-	-	3.248**	-1.66**	1.81**	-
GMU-830R	-	-	-7.65**	-	0.72**	-	-	-2.97**	0.80*	-
RHA-138-2R	-	-	-	0.92**	2.27**	0.57**	1.97**	-	6.74**	1.34**
298-R	-	-1.20**	-	-	-	-	-	-0.95**	-	-
856-R	-2.08**	-1.20**	-4.37**	0.80**	-	0.14**	1.33**	-	5.72**	-
189-1R	-2.69**	-	-	-	-	0.44**	-	-	-	0.65**

Table.4 SCA effects of promising crosses in desirable direction for seed yield and other yield contributing characters (Pooled Rabi seasons)

Sr. No.	Genotype	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed filling (%)	100 seed weight (g)	Volume weight (g)	Hull content (%)	Seed yield/plant (g)	Oil content (%)
1	CMS-302A X 856-R	-	-	-	2.65**	3.80**	1.75**	1.56**	-2.20**	15.73**	3.53**
2	CMS-234A X RHA-138-2R	-1.45**	-	-	2.80**	1.53*	-	2.33**	-1.35**	7.20**	0.93*
3	CMS-607A X RHA-138-2R	-1.79**	-	-	2.53**	-	1.41**	2.81**	-6.58**	9.48**	1.17**
4	CMS-607A X 856-R	-	-	-	1.69**	2.75**	-	2.00**	-3.38**	10.34**	-
5	CMS 302A X AK-1R	-1.76**	-1.95**	-	1.37**	3.38**	0.41**	-	-1.02*	17.26**	1.88**

Table.5 Promising crosses on the basis of mean performance, heterosis, GCA and SCA effects for seed yield and other yield contributing characters (Pooled Rabi seasons)

Sr. No.	Crosses	Seed yield per plant (g)	Oil content (%)	Heterosis (%)			SCA effects for Seed yield per plant	GCA effects of parents for seed yield	Significance SCA effects for other characters in desirable direction	Significance GCA effects for other characters in desirable direction
				H_1	H_2	H_3				
1	CMS-302A X 856-R	67.20	37.54	67.68**	59.04**	25.46**	15.73**	-3.45** X 5.72** L x H	4,5,6,7,8, 10	P1:1,3,4,7, P2:1,2,3,4,6,7,
2	CMS-234A X RHA-138-2R	65.46	36.69	13.64**	8.37**	22.14**	7.20**	2.30** X 6.74** H x H	1,4,5,7,8,10	P1:6,8 P2:4,5,6,7,10
3	CMS-607A X RHA-138-2R	65.35	38.55	17.76**	17.50**	8.20**	9.48**	0.09 X 6.74** L x H	1,4,6,7,8, 10	P1:4,7 P2:4,5,6,7,10
4	CMS-607A X 856-R	65.18	34.87	40.04**	28.23**	21.63**	10.34**	0.09 X 5.72** L x H	4,5, 7,8,10	P1:4,7,10 P2:1,2,3,4,6,7,
5	CMS-302A X AK-1R	64.83	36.61	45.72**	26.91**	20.98**	17.26**	-3.45 X 1.81 L x H	1,2,4,5,6,8, 10	P1:1,3,4,7 P2:1,2,4,7,8

*, **- significant at 5% and 1% level respectively
*, **- significant at 5% and 1% level respectively
Note:-1: Days to 50 % flowering 2: Days to maturity 3: Plant height (cm) 4: Head diameter (cm) 5: Seed filling (%) 6: 100 seed weight (g) 7: Volume weight (g/100ml) 8: Hull content (%) 9: Seed yield per plant (g) 10: Oil content (%)
H_1-average heterosis, H_2-heterobeltiosis H_3-useful heterosis

Similar findings as observed in present study were also reported by Binodh *et al.,* (2008), Khan *et al.,* (2009), Asif *et al.,* (2013) and Rizwana *et al.,* (2015) involved parents with high x high, high x low *gca* parental combination, indicating a genetic interaction of the additive and non-additive types. High *gca* effects indicating the involvement of additive x dominance genetic interaction. Virmani (1990) also reported about the possibility of interaction between positive alleles from good combiner and negative alleles from poor combiners in high x low crosses in sunflower. Based on significant high *sca* effects, five hybrids *viz*.,CMS-302A X 856-R, CMS-234A X RHA-138-2R, CMS-607A X RHA-138-2R, CMS-607A X 856-R, and CMS-302A X AK-1R (Table 5) were identified as promising for seed yield and other yield contributing characters. The performance of these crosses needs to be critically evaluated over different locations to confirm their superiority and stability.

Considering to combining ability analysis, when the GCA: SCA variance ratio is greater than 1 it means that additive genes have higher effect than non-additive genes on inheritance of character observed whereas, when the GCA:SCA variance ratio is lower than 1 indicates that non-additive effects (dominant or epistatic) are more effective in the inheritance of studied characters. As a results, lines AKSF -10-1-1A, CMS-234A and CMS-302A and restorers RHA-138-2R, 856-R and AK-1R were good combiners with the highest positive GCA effect involved in the best-yielding crosses.

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