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Combining Ability Studies for Morphological Traits in Sunflower (*Helianthus annuus* L.)

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ABSTRACT: The present investigation used four CMS lines and nine testers as a parental material and crossing was made in line × tester mating design to obtained 36 hybrids to estimate general combining ability effects of parents and specific combining ability effects of hybrids. 36 hybrids and 13 parents were evaluated with randomized block design in three replications during year *Kharif*-2019 at Agriculture Research Station, Amravati. The observations were recorded yield and yield contributing traits. Among the parents, AKSF-10-1-1A and GP_4 2902 considered best general combiner for yield and its contributing traits. Out of 36 hybrids top most three hybrids *i.e* CMS- 17 A × PKV-106 R, CMS - 302 A × AK- 1R, AKSF -10-1-1A × $Gp_6$389 displayed highest significant positive sca effects for yield and major yield contributing components and found to be promising results for yield and yield contributing traits, hence it may be use in future breeding programs.

Keywords: Combining ability, GCA, SCA, hybrids, sunflower.

INTRODUCTION

Sunflower (*Helianthus annuus* L. 2n=2x=34) is an important oilseed crop, belongs to the family Compositae (Karande *et al*., 2020). Suited to different agro-climatic zones of India due to its agronomic merits *viz*., wider adaptability, photothermo-insensitivity, high yield potential, high oil content, drought tolerance, short duration, easy cultivation, responsiveness to better management practices, suitability to fit in to different cropping systems and patterns and remunerative market price (Rathi *et al*., 2019; Debaeke *et al*., 2017). Sunflower contains 38-42 per cent oil and it is considered as good quality oil due to high concentration of linoleic (55-60%) and oleic acid (25-30%) (poly unsaturated fatty acids) (Lakshman *et al*., 2020).

Poor seed set and high percentage of empty seeds are the major constrains in sunflower. Discovery of cytoplasmic male sterility by Leclercq (1969) and fertility restoration system by Kinnman (1970) makes possible to breeders to overcome these constrains by focusing their attention towards production of hybrids through heterosis breeding. In India, the first sunflower hybrid (by using cytoplasmic genetic male sterility) BSH-1 was released in 1980 for commercial cultivation. (Seetharam, 1984).

The selection of parents is one of the important aspects in developing the potential hybrid. The study of combining ability is useful in testing of hybrid combinations and in choice of the desirable parents for use in the heterosis breeding. Line × tester (L × T) mating design by Kempthorne (1957), which was widely used to extract the Information about the potentiality of the parental lines and the gene action governing the inheritance of traits.

MATERIAL AND METHOD

The experimental material consist of four CMS lines (AKSF -10 – 1 – 1 A, CMS – 302, CMS – 17A, ARM – 250 and nine testers ($GP_6$961, $GP_6$1075, $GP_6$1075, $GP_6$2902, AK – 1R, 856R, PKV – 103, R298 – 1R and PKV – 106R) crossing was made using line × tester mating design to obtained 36 hybrids at Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *Rabi*-2019 season. The resultant 36 hybrids and 13 parents were evaluated in randomized block design with three replications at Agriculture Research Station, Amravati during *kharif*-2019 seasons. Each hybrid and parental lines consist of three rows of 3.0m length with a spacing of 60cm between rows and 30cm between plant. All the package of practices was followed for good crop growth. The observations were recorded on five randomly selected plants from each genotype in each replication on seven characters *viz.,* days to maturity, plant height (cm), head diameter (cm), 100 seed weight (g), 100 volume weight (g/ml), seed filling, and seed yield (g).

RESULTS AND DISCUSSION

The variances due to parents and hybrids noted significant differences for all the characters presented in Table 1 indicating presence of the sufficient variability in the genetic material. The variances due to lines vs testers were significant for all the traits studied summarised in Table 2. Significant variance indicated the presence of substantial amount of genetic variability among the parents and hybrids for all characters.

Table 1: Analysis of variance for seed yield and yield contributing components.

Sources of variation	d.f.	Days to maturity	Plant height	Head diameter	100 seed weight	Volume weight	Seed filling	Seed yield plant per plant
		1	2	3	4	5	6	7
Replications	2	3.476	29.390	0.092	0.113	1.378	7.786	12.956
Treatments (Genotypes)	48	18.79**	824.33**	15.07 **	3.74**	9.52**	144.56**	176.20**
Parents	12	25.63**	987.37**	14.98 **	5.61**	4.87**	156.44**	156.30**
Hybrids	35	15.70**	672.43**	15.39 **	2.37**	10.81**	138.17**	161.75**
Parents vs Hybrids	1	44.82**	4184.51**	5.07 **	28.94**	19.97**	225.29**	921.04**
Error	96	1.664	18.76	0.617	0.04	0.65	3.8	5.73

Note: * and ** indicates significant at 5% and 1% respectively

Table 2: Analysis of variance for combining ability.

Sources of variation	d.f.	Days to maturity	Plant height	Head diameter	100 seed weight	Volume weight	Seed filling	Seed yield $plant^{-1}$
		1	2	3	4	5	6	7
Replications	2	1.815	7.950	0.014	0.102	0.469	8.101	9.170
Hybrids	35	15.704***	672.427***	15.390***	2.373***	10.808***	138.174***	161.745***
Lines (Females)	3	34.691	1171.561	18.567	4.952	45.143**	84.433	32.460
Testers (Male)	8	12.141	780.350	11.372	3.065	5.210	129.825	173.286
Lines Vs Testers (Female Vs Male)	24	14.518***	574.061***	16.332***	1.820***	8.382***	147.674***	174.059***
Error	70	1.824	21.957	0.667	0.051	0.439	4.454	6.828

Note: * and ** indicates significant at 5% and 1% respectively

General combining ability effects results of 13 parents for seed yield and yield contributing traits were presented in Table 3 for characters days to 50% flowering, days to maturity and plant height the parents possessing negative and significant gca are desirable as they contribute to dwarf and early maturity. Thus, among the female parents CMS-17A (-0.963 and -8.822) recorded highly significant and negative gca effects while among male parents, 298-1R (-1.519), AK- 1R (-1.185) and $GP_4$2902(-0.769) found to be good general combiners for early maturity and the parents, $GP_6$961(-9.911), $GP_6$1075(--6.995) and $GP_6$389(-9.895) recorded good general combiner for plant height. Thus these are the parents may be useful for development of early and dwarf hybrids. Significant negative gca effects for plant height and days to maturity were also noted by Hilli *et al*. (2020); Karande *et al*. (2020); Dake *et al*. (2021).

Female parent, ARM-250A were found to be good general combiner for 100 seed weight, volume weight and seed filling percentage, while male parents GP_4 2902 (1.614), and PKV-103R(0.750) showed significant and positive gca effects for head diameters and parent 856 R (1.278 and 2.704) were found to be best general combiner for head diameters and seed filling percentage. Parent $GP_6$961 (0.335) were found to best general combiner for 100 seed weight.

Among the parents, AKSF-10-1-1A (1.128) and $GP_4$2902(8.355) exhibited positive and significant gca effects for seed yield and most of yield contributing traits *i.e*., days to maturity, head diameter, 100 seed weight, volume weight and seed filling percentage). Hence it concluded that the parent with high gca effects for yield also reported high gca effects for other yield contributing characters. Similar results also reported by Lakshman *et al.* (2019); Habib (2021); Andarkhor *et al*. (2012); Asif *et al.* (2013); Saleem *et al.* (2014) for yield and yield contributing traits *i.e.* head diameter, 100 seed weight, volume weight and seed filling percentage.

Table 3: General combining ability effects of the parents for different yield and yield contributing characters.

Sr. No.	Parents	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Volume weight (g/100ml)	Seed filling percentage (%)	Seed yield per plant (g)
	Females							
1.	**AKSF-10-1-1A**	-0.704**	5.969**	1.103**	0.307**	1.302**	1.490**	1.128*
2.	**CMS-302A**	0.111	-1.088	-0.080	-0.633**	-0.896**	-0.694	-0.515
3.	**CMS-17A**	-0.963**	-8.822**	-0.909**	0.133**	-1.306**	-2.182**	-1.276**
4.	**ARM-250A**	1.556**	3.940**	-0.114	0.193**	0.901**	1.386**	0.663
	SE (gi)+	**0.248**	**0.834**	**0.151**	**0.038**	**0.155**	**0.375**	**0.461**
	SE (Gi – Gj)+	**0.351**	**1.179**	**0.214**	**0.054**	**0.219**	**0.531**	**0.651**
	C.D.5%	**0.495**	**1.663**	**0.302**	**0.075**	**0.308**	**0.749**	**0.918**
	C.D.1%	**0.657**	**2.207**	**0.400**	**0.100**	**0.410**	**0.994**	**1.219**
	Testers							
5.	**GP_6961**	1.148**	-9.911**	-0.549*	0.335**	0.731**	-0.051	-2.073**
6.	**GP_61075**	0.065	-6.995**	-1.066**	-0.372**	-0.513*	-5.890**	-6.077**
7.	**GP_6389**	1.481**	-9.895**	-0.480*	0.157**	-0.131	-1.284*	0.266
8.	**GP_42902**	-0.769*	6.422**	1.614**	1.018**	-1.089**	6.041**	8.355**
9.	**AK- 1R**	-1.185**	-1.579	-0.451	0.106	0.837**	-1.882**	-0.969
10.	**856 R**	0.148	5.866**	1.278**	0.064	0.005	2.704**	0.819
11.	**PKV-103R**	0.148	6.220**	0.750**	-0.328**	0.574*	1.097	0.343
12.	**298-1R**	-1.519**	-2.467	-0.941**	-0.237**	0.215	-1.201*	-1.445*
13.	**PKV- 106R**	0.481	12.339**	-0.154	-0.743**	-0.630**	0.465	0.781
	SE (gj)+	**0.372**	**1.25**	**0.227**	**0.057**	**0.232**	**0.563**	**0.691**
	SE (Gi – Gj)+	**0.527**	**1.77**	**0.321**	**0.080**	**0.328**	**0.796**	**0.977**
	C.D.5%	**0.743**	**2.494**	**0.452**	**0.113**	**0.463**	**1.123**	**1.378**
	C.D.1%	**0.986**	**3.311**	**0.600**	**0.150**	**0.614**	**1.491**	**1.829**

Note: * and ** indicates significant at 5% and 1% respectively

Table 4: Specific combining ability (sca) for yield and yield contributing components in 36 hybrids.

Sr. No.	Hybrids	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Volume weight (g/100ml)	Seed filling percentage (%)	Seed yield per plant
1.	AKSF -10-1-1A × Gp_6961	-1.963*	2.281	-0.496	-0.748**	-0.345	-3.670**	-2.285
2.	AKSF -10-1-1A × Gp_61075	-2.213**	5.697*	2.522**	0.052	-0.811	4.755**	3.096*
3.	AKSF -10-1-1A × Gp_6389	-1.963*	8.997**	3.212**	0.367**	0.817	6.319**	12.023**
4.	AKSF -10-1-1A × Gp_42902	0.954	2.614	-3.548**	-0.691**	-2.215**	-10.422**	-12.002**
5.	AKSF -10-1-1A × AK- 1R	1.037	0.391	-1.927**	0.185	0.266	-3.229**	-3.811**
6.	AKSF -10-1-1A × 856R	0.704	-17.830**	-0.806	-0.613**	-1.398**	-5.542**	-4.396**
7.	AKSF -10-1-1A × PKV- 103 R	1.370	-2.518	0.705	0.426**	2.079**	5.685**	8.803**
8.	AKSF -10-1-1A × 298 – 1 R	0.037	20.170**	0.897	0.727**	1.194*	2.940*	0.104
9.	AKSF -10-1-1A × PKV 106 R	2.037**	-19.803**	-0.558	0.294*	0.413	3.163**	-1.531
10.	CMS - 302 A × Gp_6961	-0.111	16.671**	1.424**	0.496**	0.353	7.928**	4.025**
11.	CMS - 302 A × Gp_61075	-0.028	-7.246**	0.539	1.106**	1.007*	1.352	1.249
12.	CMS - 302 A × Gp_6389	-1.111	-18.012**	-2.255**	-0.859**	-1.075*	-4.077**	-3.701**
13.	CMS - 302 A × Gp_42902	-1.861*	2.338	0.802	0.036	-0.567	3.225**	1.611
14..	CMS - 302 A × AK- 1R	1.889*	19.559**	3.367**	1.025**	2.770**	11.405**	12.545**
15.	CMS - 302 A × 856R	2.222**	10.227**	0.111	-0.827**	-0.011	-2.854*	-2.573
16.	CMS - 302 A ×PKV – 103R	-1.444	-0.684	0.822	0.282*	-0.183	-0.201	-0.321
17.	CMS - 302 A × PKV – 298-1R	0.889	-17.106**	-2.586**	-1.106**	-1.211*	-8.216**	-6.319**
18.	CMS – 302 A × PKV-106 R	-0.444	-5.746*	-2.224**	-0.153	-1.083*	-8.563**	-6.515**
19.	CMS - 17 A × Gp_6961	4.963**	-13.261**	-1.984**	-0.258*	1.063*	-7.752**	-4.500**
20.	CMS - 17 A × Gp_61075	0.713	-15.178**	-2.300**	-1.298**	1.211*	-2.967*	-2.989*
21.	CMS - 17 A × Gp_6389	1.963*	0.055	-1.720**	-0.033	-1.044*	-5.006**	-6.653**
22.	CMS - 17 A × Gp_42902	-0.787	3.739	2.020**	0.342**	0.696	5.889**	8.362**
23.	CMS - 17 A × AK- 1R	-0.037	0.073	0.602	0.402**	0.291	-2.538*	-2.397
24.	CMS - 17 A × 856R	-1.370	13.738**	0.466	0.983**	0.566	4.963**	-0.079
25.	CMS - 17 A × PKV – 103R	-2.704**	2.274	-1.783**	-0.188	-2.606**	-4.510**	-5.836**
26.	CMS - 17 A × PKV – 298- 1R	-2.037**	-1.262	-0.425	0.031	-1.524**	-1.248	-2.048
27.	CMS- 17 A × PKV-106 R	-0.704	9.822**	5.121**	0.017	1.347**	13.168**	16.140**
28.	ARM – 250 A × Gp_61075	-2.889**	-5.690*	1.055*	0.509**	-1.071*	3.494**	2.760*
29.	ARM – 250 A × Gp_6961	1.528*	16.726**	-0.761	0.139	-1.407**	-3.141**	-1.356
30.	ARM – 250 A × Gp_6389	1.111	8.960**	0.763	0.524**	1.302**	2.763*	-1.669
31.	ARM – 250 A × Gp_42902	1.694*	-8.690**	0.726	0.313**	2.086**	1.308	2.029
32.	ARM – 250 A × AK- 1R	-2.889**	-20.023**	-2.042**	-1.611**	-3.327**	-5.638**	-6.337**
33.	ARM – 250 A × 856R	-1.556*	-6.135*	0.229	0.457**	0.842	3.433**	7.048**
34.	ARM – 250 A × PKV- 103 R	2.778**	0.928	0.256	-0.521**	0.710	-0.974	-2.646
35.	ARM – 250 A × 298 – 1 R	1.111	-1.801	2.114**	0.348**	1.542**	6.524**	8.263**
36.	ARM – 250 A × PKV 106 R	-0.889	15.726**	-2.340**	-0.159	-0.677	-7.769**	-8.093**
	SE(Sij)±	0.745	2.501	0.454	0.113	0.464	1.126	1.386
	SE(Sij-Skl)±	1.053	3.537	0.641	0.160	0.656	1.592	1.954
	CD (5%)	1.485	4.987	0.905	0.226	0.925	2.246	2.755
	CD (1%)	1.972	6.622	1.201	0.300	1.229	2.981	3.658

Note: * and ** indicates significant at 5% and 1% respectively

Specific combining ability effects for yield and its contributing traits are summarized in Table 4. The minimum SCA effects are considered to be desirable for days to maturity and plant height. The hybrids which recorded significant negative sca effects for days to maturity and plant height contribute for earliness and dwarf plant height.

Out of 36 hybrids 9 and 12 hybrids exhibited negative and significant sca effects for days to maturity and plant height respectively. The hybrid ARM – 250 A × AK- 1R (-2.889 and -20.023) recorded highest negative significant sca effect for days to maturity and plant height respectively. The hybrids ARM – 250 A × $Gp_6$1075 (-2.889) and CMS - 17 A × PKV – 103R (-2.704) exhibited highest significant and negative sca effects for days to maturity, while the hybrids AKSF -10-1-1A × PKV 106 R (-19.803) and CMS - 302 A × $Gp_6$389(-18.012) showed significantly highest negative sca effects for plant height. Memon *et al*. (2015); Kale *et al.* (2019) also observed the significant negative sca effects for maturity and plant height.

Larger head diameter has a greater number of seed and also contributes towards more yield. Among the 36 hybrids, 8 hybrids exhibited significant positive sca effects for head diameter. Highest magnitude of significant and positive sca effects was found in hybrids CMS- 17 A × PKV-106 R(5.121), CMS - 302 A × AK-1R(3.367), AKSF -10-1-1A × $Gp_6$389(3.212).

Highest 100 seed weight is an also important yield contributing trait. Hence maximum weight of 100 seed, more will be the yield. Out of 36 hybrids 16 hybrids displayed significant positive sca effects. The hybrid CMS - 302 A × $Gp_6$1075(1.106) displayed highest significant sca effects for 100 seed weight, followed by hybrids CMS - 302 A × AK- 1R (1.025) and CMS - 17 A × 856R (0.983).

Seed filling percentage is an important character for obtaining higher seed yield per head in sunflower. Hence positive SCA effects are considered to be desirable. The positive and significant sca effects for seed filling percentage was observed in 15 hybrids. The best three hybrids combinations CMS- 17 A × PKV-106 R(13.168), CMS - 302 A × AK- 1R(11.405) and CMS - 302 A × $Gp_6$961(7.928) exhibited highest significant sca effects for seed filling percentage.

Highest seed yield is an ultimate objective in any crop breeding programme hence the best three hybrids combination along with highest magnitude of significant positive sca effects were observed in CMS-17 A × PKV-106 R(16.140), CMS - 302 A × AK-1R(12.45) AKSF -10-1-1A × $Gp_6$389(12.023). Among the 36 hybrids 10 hybrids noticed significant positive sca effects for seed yield. The positive significant sca effects for seed yield and yield contributing component reported by Devi *et al.* (2005); Andarkhor (2012); Din *et al.* (2014); Memon *et al.* (2015); Karande *et al.* (2020); Habib *et al.* (2021).

CONCLUSION

Overall results showed that among the parents, AKSF-10-1-1A and $GP_4$2902 noted to be best general combiners for yield and most of the yield contributing traits. The hybrids CMS- 17 A × PKV-106 R, CMS - 302 A × AK- 1R and AKSF -10-1-1A × $Gp_6$389 were best specific combination for seed yield and its related traits. Hence above the parents and hybrids may be useful for hybridization and selection programme for hybrid developments.

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Conflicts of Interest. None.

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