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Original article

Evaluation of Combining Ability and Heterosis for Yield and Oil content in Sunflower Hybrids: Line × Tester Approach

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Abstract

Sunflower is a vital oilseed crop, and enhancing its yield and oil content through heterosis breeding is crucial for food security and agricultural sustainability. The present study entitled, "Evaluation of Combining Ability and Heterosis for Yield and Oil content in Sunflower hybrids: Line x Tester Approach was aimed to study combining ability and heterosis.The experiment was conducted in a Randomized Block Design (RBD) with two replications. Using a Line × Tester mating design, four female lines were crossed with five male lines, resulting in 20 hybrids. The combining ability analysis indicated that CMS 10 A and CMS 112 A were good general combiners for seed yield per plant (g). CMS 234 A and PET 2-7-1-A showed good general combining ability for oil content (%). Among the restorer lines, EC 601924 exhibited good general combining ability for all traits except seed yield per plant (g) and volume weight (g/100ml). Out of the 20 hybrids, three hybrids CMS 234 A x EC 279309-1, CMS 112 A x RHA 138-2 and PET 2-7-1 A x EC 601924 were identified as particularly significant in terms of seed yield/plant(g), as well as other yield- related traits, recorded in a desirable direction, indicating that the crosses had high performance. The hybrids CMS 10 A x RHA 138-2, CMS 10 A x EC 399600, CMS 112 A x EC 75717, and CMS 112 A x RHA 138-2 exhibited significant heterosis for all measured traits, excluding plant height, in comparison to both checks LSFH 171 and KBSH 44. It was concluded that CMS 10 A, CMS 112 A, and their tester line RHA 138-2 were regarded as effective combiners in terms of seed yield and associated yield-contributing traits.

Keywords: Combining Ability, GCA, Heterosis, SCA, Yield

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INTRODUCTION

Sunflower (*Helianthus annuus* L., 2n=34) belongs to the Asteraceae family and is commonly grown as an annual oilseed crop. Its botanical name, 'Suryaphul' in Marathi and 'Surajmukhi' in Hindi, is derived from the Greek words 'Helios' (sun) and 'anthos' (flower). The species is thought to have originated in the Southern United States and Mexico (Pilorge, 2020). Globally, sunflower is the second most significant oilseed crop after soybean, appreciated for its high-quality edible oil rich in polyunsaturated fatty acids (40-45%), linoleic acid (55-60%), and oleic acid (25-30%). This desirable fatty acid composition improves cardiovascular health by lowering blood plasma cholesterol levels (Zhang *et al*., 2023).It has grown in agricultural importance in India in recent decades, despite the fact that its adoption as a significant oilseed crop is relatively new in comparison to other traditional oilseeds. According to Helia, sunflower breeding projects around the world have increasingly concentrated on improving production potential, oil quality, and stress adaptation through systematic genetic improvement (Pilorge, 2020). To boost crop resilience, hybrid cultivars with cytoplasmic male sterility (CMS) and fertility restorer (Rf) systems are being developed (Fernández-Martínez *et al*., 2021).Given the increasing demand for vegetable oils and the need for climate-resilient oilseed varieties, knowing the genetic architecture of yield and oil-related characteristics is critical. The line × tester mating design evaluates both general and specialized combining abilities, identifying superior parental lines and hybrid combinations (Kempthorne, 1957). The purpose of this study is to evaluate combining ability and heterosis for yield and oil content in sunflower hybrids, thereby contributing to the development of high-performing genotypes suitable for a wide range of agro-climatic situations.

It is one of the important oilseed crop in India, leading global producers being Russia, Ukraine, Argentina, China, France, USA, Spain. The area under sunflower cultivation in India is 150.86 ha, with the production of 172.53 tones and productivity of 1247 kg/ha in 2023-24. In India, Karnataka is the largest producer of sunflower with 72.42 MT of production followed by Haryana and Odisha with the production of 28.66 and 22.87 MT, respectively (Indiastat,2024). In Maharashtra, sunflower is grown in 61,400 ha area with a production *of* 23,800 tones and a productivity of 1,346 kg/ha.

Sunflower hybrids have repeatedly shown increased agronomic performance, such as yield stability, disease resistance, and fertilizer responsiveness (Seetharam *et al.,* 1980). Single-cross hybrids dominate commercial production because of exploitable heterosis. Line × tester analysis (Kempthorne, 1957) identifies superior parental lines and hybrid combinations in sunflower by partitioning genetic variance into General combining ability and Specific combining ability (Jondhale *et al*., 2012; Bhoite *et al*., 2018). Heterosis breeding remains critical for sunflower improvement, with well-documented increases in yield and oil-related traits (Labroo *et al.,* 2021). This study uses the line × tester design to assess combining ability and heterosis, aiming to generate high-performance sunflower hybrids.

Since heterosis breeding demands extensive hybrid development and evaluation to exploit hybrid vigour, which is resource-intensive, identifying a correlation between yield heterosis and genetic diversity can help optimize the selection of parents and enhance breeding efficiency.

MATERIALS AND METHODS

The current study on heterosis in sunflower (*Helianthus annuus* L.) was carried out during *Rabi*-2022 at Oilseeds Research Station, Latur. The experimental material involved four female lines (CMS 234 A, CMS 10 A, PET 2-7-1-A, CMS 112 A) and five restorer lines (EC 279309-1, EC 601924, EC 623008, RHA 138-2, EC 399600), crossed in a Line × Tester mating to generate 20 hybrids, along with the 9 parental lines and two standard checks (LSFH-171 and LSFH-35), were evaluated during Kharif 2023 at the Oilseeds Research Station, Latur, using a randomized block design with two replications. Each plot comprised two rows of 3.0 meters in length, with row-to-row spacing of 60 cm and plant-to-plant spacing of 30 cm. A fertilizer dose of 60:30:30 kg NPK per hectare was applied, and standard agronomic and plant protection practices were followed.The morphological observations *viz.,* days to 50% flowering, days to maturity, plant height (cm), head diameter (cm), 100 seed weight(g), volume weight (g/100 m l), hull content (%), oil content (%), seed yield per plant (g) were recorded by selecting randomly 3 competitive plants per each entry and replication. The details of parental lines, and checks evaluated in *Kharif*-2023 are given in Table 1.1

The standard error and critical difference at 1 and 5 per cent levels of significance were calculated using the appropriate statistical formula (Panse and Sukhatme,1967). Heterosis is defined as superiority of the F_1 hybrid over both the parents. However, an increase over the inferior parent may not hold much practical significance. On the other hand, an improvement of the F_1 over established standard check hybrids, known as standard heterosis, is of commercial relevance (Labroo *et al*., 2021). Therefore, standard heterosis was assessed using two popular check hybrids, LSFH-171 (Check-1) and KBSH-44 (Check-2). Heterosis was estimated following the procedure outlined by Fonseca and Patterson (1968).

RESULTS AND DISCUSSION

ANOVA found considerable genetic diversity among genotypes for all nine traits tested. Plant height and seed yield per plant exhibited the greatest phenotypic variance, while days to 50% flowering, days to maturity, and oil content showed comparably less variability (Fig. 1).Days to 50% flowering ranged from 50 to 58, with an average of 52.8 days. CMS 10 A and PET 2-7-1-A were early flowering (51 days), followed by the hybrids CMS-10A × EC-601924 and CMS-112A × EC-601924 (50 days). Days to maturity varied from 78.5 to 84 days (mean = 82.87 days). The restorer line EC 279309-1 matured the first (79.5 days), whereas hybrids such as PET-2-7-1-A × EC-75717 also matured early (78.5 days), making them suitable for short-season conditions. Head diameter varied from 6.7 cm to 18.2 cm (mean 13.7 cm). Among parents, CMS-112 A had the largest head diameter (14 cm), while the hybrid CMS-112A × EC-75717 recorded the maximum value (18.2 cm). Hundred-seed weight ranged from 3.5 g to 7.9 g (mean 6.32 g). The restorer PET 2-7-1-A showed the highest test weight (6.5 g), and hybrids such as PET 2-7-1-A × EC 601924 (7.92 g) exhibited superior seed size. Seed yield per plant varied from 9.8 g to 77 g (mean 49.76 g). CMS 112 A was the highest-yielding parent (19.95 g), whereas CMS-112A × RHA 138-2 yielded the highest among hybrids (77 g). Oil content ranged from 22.1% to 40.3% (mean 34.19%). High oil content was observed in parents CMS 234 A, PET 2-7-1-A, and CMS 10 A, with hybrids CMS 234 A × EC 623008 (41.72%) and PET 2-7-1-A × EC 601924 (40.3%) recording the highest oil percentages.

The large genetic variability revealed in this study is consistent with earlier results in sunflower, which have demonstrated significant variation in yield and oil-related variables (Karande *et al.,* 2020; Telangre *et al*., 2019). Such variation is required for successful selection and hybrid formation. The increased yield and early maturity of selected hybrids demonstrate the promise of heterosis breeding in sunflower improvement.

Combining ability

Combining ability analysis was used to determine the roles of general combining ability (GCA) and specific combining ability (SCA) in sunflower hybrids. GCA represents the additive genetic effects contributed by the parents, whereas SCA represents non-additive genetic effects including dominance and epistasis. The combining ability analysis revealed significant variation across all traits, indicating the presence of considerable genetic diversity among the parents and their resulting hybrids (Table 3.1). CMS 10 A and CMS 112 A were found to be good general combiner for 100 seed weight, head diameter and seed yield per plant (g). The lines CMS 234 A and PET 2 7-1- A were found to be good general combiner for hull content (%) and oil content (%) in desirable direction. Among the restorer lines, EC 601924 and EC 623008 had positive GCA for oil content and seed yield, indicating that they might be used in breeding. PET-2-7-1-A × EC 601924 outperformed other hybrids in terms of seed yield and oil content, making it the most promising for commercial use (Table 3.3). Other hybrids with high SCA effects for many traits included CMS-112A × RHA 138-2 and CMS-234 × EC-623008 (Table 3.4). Among all the restorer lines, EC 601924 emerged as a good general combiner for all the traits except seed yield per plant (g), head diameter (cm) and oil content (%), High GCA values in this line indicate the presence of positive additive gene effects, which are crucial for effective hybrid breeding (Singh *et al*., 2015). However, for yield-related traits, hybrids as PET-2-7-1-A × EC 601924 and CMS-112A × RHA 138-2 showed the largest specific combining ability (SCA) effects (Table 3.3), indicating that non-additive gene activity plays a part in their inheritance (Telangre *et al*., 2019).

Heterosis

Heterosis estimation helped in identifying hybrids that performed significantly better than their mid-parents and standard checks for various traits. In sunflower breeding, the expression of hybrid vigour is indicated by both positive and negative heterosis.

Mid parent heterosis

The assessment of mid-parent heterosis across several traits revealed significant genetic improvements in numerous hybrids. For days to 50% flowering, most hybrids exhibited considerable negative heterosis, indicating earliness, a desirable trait in sunflower breeding. CMS 112 A × EC 601924 had the most negative heterosis (-10.6%), followed by CMS 10 A × EC 601924 (-7.76%) and PET 2-7-1-A × EC 601924 (-7.34%). Crosses with negative mid-parent heterosis values, such as CMS 112 A × EC 75717 (-5.26%), PET 2-7-1-A × EC 75717 (-4.85%), and PET 2-7-1-A × EC 601924 (-4.50%), suggest the possibility of early-maturing hybrids. Plant height showed both positive and negative heterosis, with PET 2-7-1-A × EC 75717 exhibiting the most favorable negative heterosis (-22.53%), effective for minimizing lodging where as some hybrids, including CMS 112 A × EC 75717 (91.56%), demonstrated positive heterosis. PET 2-7-1-A × EC 623008 (97.71%), PET 2-7-1-A × EC 399600 (91.70%), and PET 2-7-1-A × EC 75717 (90.34%) all showed substantial positive mid-parent heterosis for head diameter, indicating improved sink capacity. Hybrids such as CMS 112 A × RHA 138-2 (88.95%), CMS 234 A × EC 601924 (75.06%), and CMS 10 A × RHA 138-2 (63.96%) showed high positive heterosis, indicating larger seeds in terms of 100 seed weight. The crosses with the highest volume weight were CMS 234 A × EC 399600 (29.91%), CMS 10 A × EC 399600 (25.00%), and CMS 234 A × EC 601924 (22.83%). The hull content of PET 2-7-1-A × EC 75717 (-45.06%) and CMS 234 A × EC 601924 (-39.30%) demonstrated extremely desirable negative heterosis, leading to higher oil recovery. Crosses with high oil content (%) include CMS 112 A × EC 601924 (27.28%), CMS 112 A × RHA 138-2 (25.53%), and CMS 234 A × EC 399600 (23.91%) (Table 3.4).

Standard Heterosis

Several hybrids exhibited significant standard heterosis over the check LSFH 171, indicating potential for early and high-yielding sunflower varieties. Early flowering was observed in CMS 10 A × EC 601924 and PET 2-7-1-A × EC 601924 (–8.18%), while PET 2-7-1-A × EC 75717 (–16.04%), CMS 112 A × EC 75717 (–11.68%), and CMS 112 A × RHA 138-2 (–9.09%) showed early maturity. Dwarfness was notable in CMS 10 A × EC 601924 (–19.08%). Significant heterosis for head diameter were recorded in CMS 112 A × EC 75717 (29.08%), CMS 10 A × EC 623008 (20.57%), and PET 2-7-1-A × EC 623008 (22.70%). PET 2-7-1-A × EC 601924 (26.80%) and PET 2-7-1-A × EC 623008 (24.08%) showed superior 100-seed weight. For volume weight, CMS 234 A × EC 601924 (16.42%), CMS 234 A × EC 623008 (13.43%), and CMS 10 A × EC 399600 (11.94%) exhibited significant heterosis. Desirable negative heterosis in hull content was noted in PET 2-7-1-A × EC 75717 (–46.88%) and CMS 234 A × EC 601924 (–39.30%). For oil content, significant heterosis was exhibited by CMS 234 A × EC 623008 (38.19%) and CMS 10 A × EC 399600 (30.69%). The highest seed yield per plant was recorded in CMS 112 A × RHA 138-2 (26.23%), CMS 10 A × EC 601924 (27.27%), and PET 2-7-1-A × EC 601924 (26.36%), exploiting their commercial purpose (Table 3.5).

Previous research has demonstrated positive heterosis for yield traits, which is attributed to the synergistic interaction of advantageous alleles from the parental lines (Ramaraju *et al*., 2021). CMS-10A × EC-601924 also showed negative heterosis for plant height, which is beneficial for mechanical harvesting and lodging resistance (Yamgar *et al*., 2015). According to the Bhoite *et al*. (2018) study, the hybrid PET-2-7-1-A × EC 623008 had the highest positive heterosis for head diameter, which is associated with increased seed filling and ultimately higher yield potential. notable heterotic response in oil content across hybrids, specifically CMS 234 A × EC 623008, indicates that hybrid breeding may be able to enhance the yield of sunflower oil. The necessity for a breeding strategy that combines selection for superior parental lines with successful hybrid combinations is highlighted by the existence of both additive and non-additive gene action for oil content (Karande *et al*., 2020). A wide range of significant heterosis was observed in four hybrids *viz.,* CMS 10 A × RHA 138-2, CMS 10 A × EC 399600, CMS 112 A × EC 75717, CMS 112 A × RHA 138-2 exhibited desired significant heterosis for all the traits except plant height either or over both the checks LSFH 171 and KBSH 44 (Fig. 1&2).The beneficial effects of heterosis, which have been extensively reported in sunflower, are demonstrated by the existence of high-yielding hybrids (Bhoite *et al*., 2018).

CONCLUSION

It is concluded that CMS 10 A, CMS 112 A and its tester line RHA 138-2 were considered good combiners in terms of seed yield and its yield-related traits, and may be prioritized in the breeding program. The hybrid PET 2-7-1-A x EC 601924 exhibited significant SCA effects for the traits viz., seed yield per plant (g) and oil content. The hybrids CMS 10 A × RHA 138-2 and CMS 10 A × EC 399600 exhibited significant standard heterosis for multiple traits, including days to 50% flowering, days to maturity, 100-grain weight (g), volume weight (g/100ml), hull content (%), oil content (%), and seed yield per plant (g). Similarly, the hybrid CMS 112 A × EC 75717 showed significant standard heterosis for days to 50% flowering, days to maturity, 100-grain weight (g), hull content (%), oil content (%), and seed yield per plant (g). These hybrids and their parental lines are expected to produce promising segregants in future generations.

The current study shows how hybridization can increase seed yield and oil content, underscoring the importance of genetic diversity and heterosis in sunflower breeding. There is sufficient genetic diversity for selection, as evidenced by the analysis of variance, which verified large genotype differences. Superior hybrids like CMS-112A × RHA 138-2 and PET-2-7-1-A × EC 601924 have been identified, demonstrating the value of heterosis breeding in sunflower improvement. Overall, the study reinforces the potential of the line × tester mating design in developing superior sunflower hybrids with desirable agronomic traits. The findings of this study provide a strong foundation for future genetic improvement efforts, combining conventional and modern breeding approaches to enhance sunflower productivity and sustainability.

Table 1. Description of sunflower parental lines (CMS and restorers) along with check hybrids

CMS lines	Restorer lines	Checks
1)CMS 234 A	1)EC 279309-1	LSFH 171
2) CMS 10 A	2)EC 601924	KBSH 44
3) PET -2-7-1-A	3) EC 623008	
4) CMS 112 A	4)RHA 138-2	
	5)EC 399600	

Table 2. Analysis of variance for different traits in sunflower.

Sr. No.	Character	Source of variation		
		Replication MSS 1 (d.f)	Treatment MSS 30 (d.f)	Error MSS 30 (d.f)
1	**Days to 50% flowering**	0.403	9.318**	2.969
2	**Days to maturity**	0.258	27.73**	3.358
3	**Plant Height**	152.25	2111.61**	343.958
4	**Head diameter**	1.88	18.98**	1.215
5	**100-seed weight**	0.441	3.031**	0.462
6	**Volume-weight**	2.725	18.93**	3.492
7	**Hull content**	2.658	140.92**	14.203
8	**Oil content**	0.948	35.756**	0.554
9	**Seed yield/plant**	52.45	1128.40**	18.41

*Significant at 5% level, **significant at 1 % level

Table 3. Assessment of the general combining ability (GCA) effects of parental lines and testers for nine traits in sunflower.

Sr. No.	Characters	Days to 50% Flowering	Days to Maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Volume weight (g/100ml)	Hull content (%)	Oil content (%)	Seed yield/ plant (g)
		1	2	3	4	5	6	7	8	9
	CMS Lines									
1	**CMS 234 A**	-0.675**	0.000	-3.045	-0.402**	-0.317**	1.050**	-0.746	1.915**	-2.555
2	**CMS 10 A**	0.425	-0.200	-14.195**	0.307**	0.175**	-1.050**	1.295**	-1.348**	3.355*
3	**PET 2-7-1 A**	-0.775**	-0.500	-3.770	-0.223	0.462*	0.550	-2.636**	0.931**	-2.045
4	**CMS 112 A**	1.025**	0.700*	21.010**	0.3180**	-0.319**	-0.550	2.087**	-1.499	1.246*
	SE ±	0.5585	0.5931	6.0576	0.3553	0.2219	0.5654	0.7385	0.2431	1.3949
	CD at 5%	1.1690	1.2413	12.6786	0.7436	0.4645	1.1834	1.5456	0.5087	2.9196
	Testers									
5	**EC 279309-1**	0.950**	1.200**	-0.286	-0.188	-0.306**	-1.750**	-1.116	-0.343	-2.462
6	**EC 601924**	-1.300**	-1.425**	-5.318**	-1.063**	0.149**	1.125	-1.766**	0.994*	-0.685
7	**EC 623008**	0.450**	0.075	8.633**	1.325**	0.253**	-0.375	-0.703	1.749**	1.040
8	**RHA 138-2**	0.200**	0.325	2.458**	0.425	0.031	-0.375	1.060	-1.334**	3.152**
9	**EC 399600**	-0.300**	-0.175	-5.486**	-0.500	-0.127**	1.375**	2.525**	-1.065**	-1.045
	SE ±	0.6244	0.6631	6.7726	0.3972	0.2481	0.6322	0.8256	0.2717	1.5596
	CD at 5%	1.3070	1.3878	14.1751	0.8313	0.5194	1.3231	1.7281	0.5688	3.2643

** and * indicates 1 % and 5 % significant, respectively.

Table 4. Assessment of specific combining ability (SCA) effects for nine characters in sunflower.

Sr. No.	Characters	Days to 50% flowering	Days to Maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Volume weight (g/100ml)	Hull content (%)	Oil content (%)	Seed yield/ plant
	Crosses	**1**	**2**	**3**	**4**	**6**	**7**	**8**	**9**	**5**
1	CMS-234 x EC-279309-1	-0.950	-2.000	-4.199	1.928 *	0.320	-0.550	0.396	0.420	9.132 **
2	CMS-234 x EC 601924	1.800	2.625	1.232	-0.498	0.420	1.075	-1.105	-1.486*	-6.345
3	CMS-234 x EC-623008	-0.950	-0.875	-11.068	-1.735 *	0.236	1.575	-1.267	1.924**	1.480
4	CMS-234 x RHA-138-2	-0.200	-0.125	8.108	-0.535	-0.546*	-1.925	6.371 **	-1.399*	-2.982
5	CMS-234 x EC-399600	0.300	0.375	5.926	0.840	-0.429	-0.175	-4.395 *	0.542	-1.285
6	CMS-10A x EC-279309-1	-1.050	0.200	-5.124	-0.433	-0.057	3.550 *	5.606 **	1.608**	-4.778
7	CMS-10A x EC-601924	-0.800	-0.675	-12.968	-0.407	-0.307	-2.325	3.556 *	-0.884	2.445
8	CMS-10A x EC-623008	2.950 *	0.325	7.533	-0.095	-0.521*	-3.825 **	-6.057 **	-0.609	-4.930
9	CMS-10A x RHA-138-2	-0.300	1.075	6.058	-0.045	0.411	1.175	-2.320	0.674	2.758
10	CMS-10A x EC-399600	-0.800	-0.925	4.501	0.980	0.474*	1.425	-0.784	-0.790	4.505
11	PET-2-7-1-Ax EC-502036	0.650	1.500	3.576	0.098	0.331	-0.550	-2.314	0.184	6.321
12	PET-2-7-1-Ax EC-601924	0.400	-0.375	2.908	0.123	0.266	0.075	2.986	2.302**	7.345 *
13	PET-2-7-1-Ax EC-623008	0.650	2.125	3.657	0.735	-0.008	0.575	6.173 **	-0.447	-2.380
14	PET-2-7-1-A x EC-75717	-1.100	-3.125 *	-18.718	-0.365	-0.456	0.575	-7.740**	-1.075	-7.492 *
15	PET-2-7-1-Ax EC-399600	-0.600	-0.125	8.576	-0.590	-0.133	-0.675	0.896	-0.964	-3.795
16	CMS 112A x EC279309-1	1.350	0.300	5.746	-1.593*	-0.593*	-2.450	-3.687 *	-2.211**	-10.675**
17	CMS 112A x EC-601924	-1.400	-1.575	8.828	0.782	-0.378	1.175	-5.437**	0.068	-3.446
18	CMS 112A x EC-75717	-2.650 *	-1.575	-0.123	1.095	0.293	1.675	1.151	-0.867	5.829
19	CMS 112A x RHA-138-2	1.600	2.175	4.552	0.945	0.591*	0.175	3.689 *	1.800**	7.717 *
20	CMS 112A x EC-399600	1.100	0.675	-19.004	-1.230	0.088	-0.575	4.284 *	1.211*	0.574
	SE	1.2489	1.3261	13.5452	0.7944	0.4963	1.2643	1.6513	0.5435	3.1192
	CD at 5%	2.6140	2.7756	28.3502	1.6627	1.0387	2.6463	3.4561	1.1375	6.5285

** and * indicates 1 % and 5 % significant respectively.

Table 5. Mid Parent Heterosis Estimation for nine Traits in Sunflower

S.no	Hybrids	DFF	DM	PH	HD	HGW	VW	HC	OC	SYPP
1	CMS-234 x EC-279309-1	-1.9	0	52.91**	59.62**	54.44**	0	-28.46**	9.07**	343.02**
2	CMS-234 x EC 601924	-5.45	1.22	51.70**	35.34**	75.06**	22.83**	-39.30**	14.01**	328.68**
3	CMS-234 x EC-623008	-1.92	-4.14*	54.81**	41.20**	50.65**	10.14*	-28.29**	19.79**	325.25**
4	CMS-234 x RHA-138-2	-2.37	0.92	45.16**	45.50**	54.51**	9.52	-18.15**	7.48**	340.92**
5	CMS-234 x EC-399600	-3.74	0.61	59.96**	62.53**	28.05*	29.91**	-30.65**	23.91**	392.81**
6	CMS-10A x EC-279309-1	0.48	1.84	45.49**	33.48**	36.65**	3.55	-13.72**	13.18**	268.02**
7	CMS-10A x EC-601924	-7.76*	-3.64	31.83	32.41**	46.50**	3.08	-26.87**	16.95**	403.60**
8	CMS-10A x EC-623008	8.21*	-3.53	66.02**	51.79**	27.73*	-13.48**	-35.27**	13.24**	296.00**
9	CMS-10A x RHA-138-2	0	1.53	37.62*	45.50**	63.96**	10.08*	-32.09**	14.68**	388.63**
10	CMS-10A x EC-399600	-3.29	-1.83	52.13**	57.77**	38.26**	25.00**	-19.27**	21.15**	444.21**
11	PET-2-7-1-Ax EC-502036	1.92	2.13	58.83**	70.22**	39.86**	3.03	-31.77**	6.12**	342.45**
12	PET-2-7-1-Ax EC-601924	-7.34*	-4.50*	51.99**	71.26**	52.70**	23.97**	-28.66**	23.20**	460.48**
13	PET-2-7-1-Ax EC-623008	1.94	-2.62	67.14**	97.71**	33.42**	10.61*	-6.22	10.73**	316.95**
14	PET-2-7-1-A x EC-75717	-3.35	-4.85*	22.53	76.88**	40.51**	21.67**	-45.06**	6.05**	327.79**
15	PET-2-7-1-Ax EC-399600	-4.72	-2.11	61.14**	80.25**	24.09*	33.33**	-14.91**	16.38**	396.79**
16	CMS 112A x EC279309-1	2.78	2.44	88.67**	22.81*	37.66*	-10.79*	-27.14**	6.73**	201.97**
17	CMS 112A x EC-601924	-10.62**	-4.22*	84.85**	42.86**	60.99**	17.19**	-39.20**	27.28**	316.81**
18	CMS 112A x EC-75717	-4.67	-5.26*	91.56**	61.78**	56.12**	5.04	-11.32*	18.66**	323.80**
19	CMS 112A x RHA-138-2	1.38	3.34	64.92**	53.81**	88.95**	10.24*	-13.46**	25.53**	376.78**
20	CMS 112A x EC-399600	-1.82	0.61-	62.85**	35.75**	42.64**	22.03**	-0.03	37.00**	364.03**

DFF: Days to 50% flowering, DM: Days to maturity, PH: Plant height(cm), HD: Head diameter(cm), HGW:100 Grain weight(g), VW:Volume weight(g/100ml), HC: Hull content(g), OC: Oil Content(%), SYPP: Seed yield per plant(g)

Table 6. Standard Heterosis Estimation for nine Traits in Sunflower

S.no	Hybrids	DFF	DM	PH	HD	HGW	VW	HC	OC	SYPP
1	CMS-234 x EC-279309-1	-6.36	-13.37 **	-4.65	19.15 *	7.92	2.99	-30.31 **	26.28 **	13.11
2	CMS-234 x EC 601924	-5.45	-11.23 **	-4.42	-4.26	16.8	16.42 **	-34.85 **	24.39 **	-9.34
3	CMS-234 x EC-623008	-7.27*	-13.37 **	-3.47	3.9	15.52	13.43 *	-32.95 **	38.19 **	6.31
4	CMS-234 x RHA-138-2	-6.36	-12.30 **	4.05	6.03	-0.56	2.99	-13.09 *	16.97 **	2.46
5	CMS-234 x EC-399600	-6.36	-12.30 **	-1.81	9.22	-1.2	13.43 *	-32.73 **	24.29 **	-1.64
6	CMS-10A x EC-279309-1	-4.55	-11.23 **	-11.63	7.45	9.76	8.96	-14.99 **	19.41 **	0
7	CMS-10A x EC-601924	-8.81*	-14.97 **	-19.08	1.42	13.04	0	-20.70 **	15.58 **	14.75
8	CMS-10A x EC-623008	1.82	-12.30 **	0.84	20.57 *	11.28	-8.96	-38.75 **	18.99 **	5.49
9	CMS-10A x RHA-138-2	-4.55	-11.23 **	-3.58	14.54	22.64	5.97	-27.14 **	13.03 **	21.56 **
10	CMS-10A x EC-399600	-6.36	-13.90 *	-9.08	15.25	21.12	11.94 *	-20.80 **	9.07 **	17.54 *
11	PET-2-7-1-Ax EC-502036	-3.64	-10.16 **	-0.58	7.45	20.56	1.49	-40.02 **	22.24 **	9.34
12	PET-2-7-1-Ax EC-601924	-8.18 *	-14.97 **	-3.87	1.42	26.80 *	11.94 *	-30.20 **	33.68 **	13.93
13	PET-2-7-1-Ax EC-623008	-4.55	-10.70 **	4.62	22.70 *	24.08 *	8.96	-21.22 **	27.07 **	0.82
14	PET-2-7-1-A x EC-75717	-8.18 *	-16.04 **	-11.88	8.51	13.36	8.96	-46.88 **	14.79 **	-4.1
15	PET-2-7-1-Ax EC-399600	-8.18 *	-13.37 **	-0.69	0.35	16	10.45	-25.55 **	16.05 **	-4.92
16	CMS 112A x EC279309-1	0.91	-10.16 **	15	-0.71	-6.72	-7.46	-32.95 **	6.26 *	-13.12
17	CMS 112A x EC-601924	-8.18 *	-14.97 **	13.87	9.93	4	11.94 *	-38.01 **	18.23 **	1.64
18	CMS 112A x EC-75717	-7.27 *	-13.37 **	16.76	29.08 **	16.4	8.96	-21.86 **	17.64 **	19.67 *
19	CMS 112A x RHA-138-2	0	-9.09 **	15.9	21.63 *	17.6	4.48	-12.78 *	16.26 **	26.23 **
20	CMS 112A x EC-399600	-1.82	-11.23 **	-2.31	-0.35	7.04	7.46	-8.43	15.20 **	7.64

DFF:Days to 50% flowering, DM:Days to maturity, PH:Plant height(cm), HD: Head diameter(cm), HGW:100 Grain weight(g), VW:Volume weight(g/100ml), HC:Hull content(g), OC: Oil Content(%), SYPP : Seed yield per plant(g)

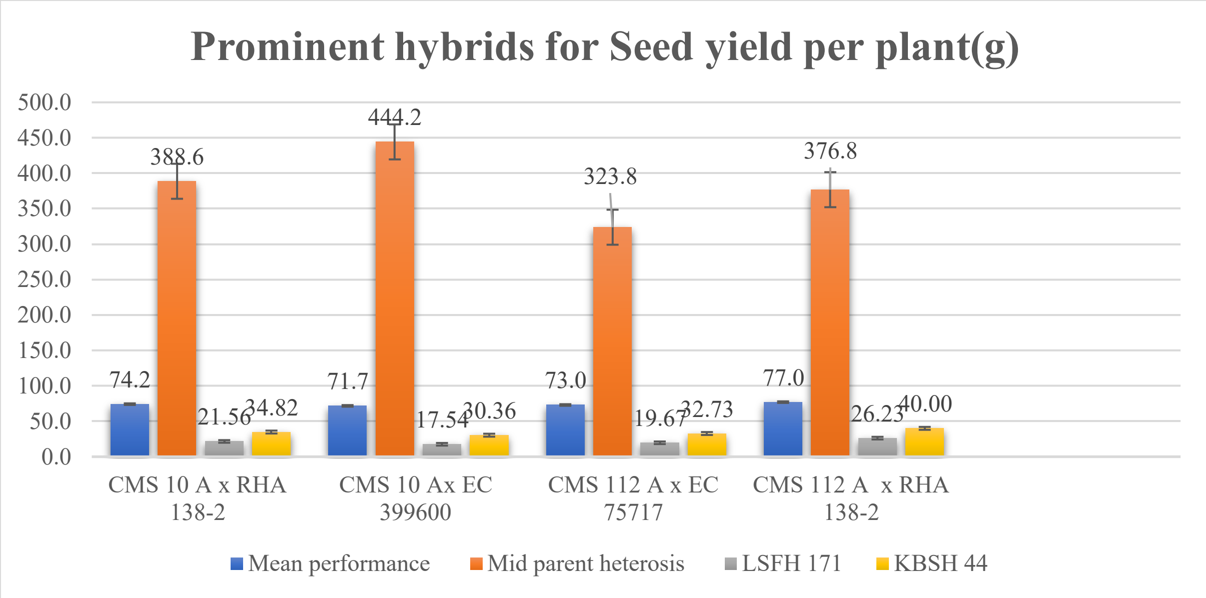

Figure 1. Mean performance, Mid Parent Heterosis and Standard heterosis of prominent hybrids for seed yield per plant(g).

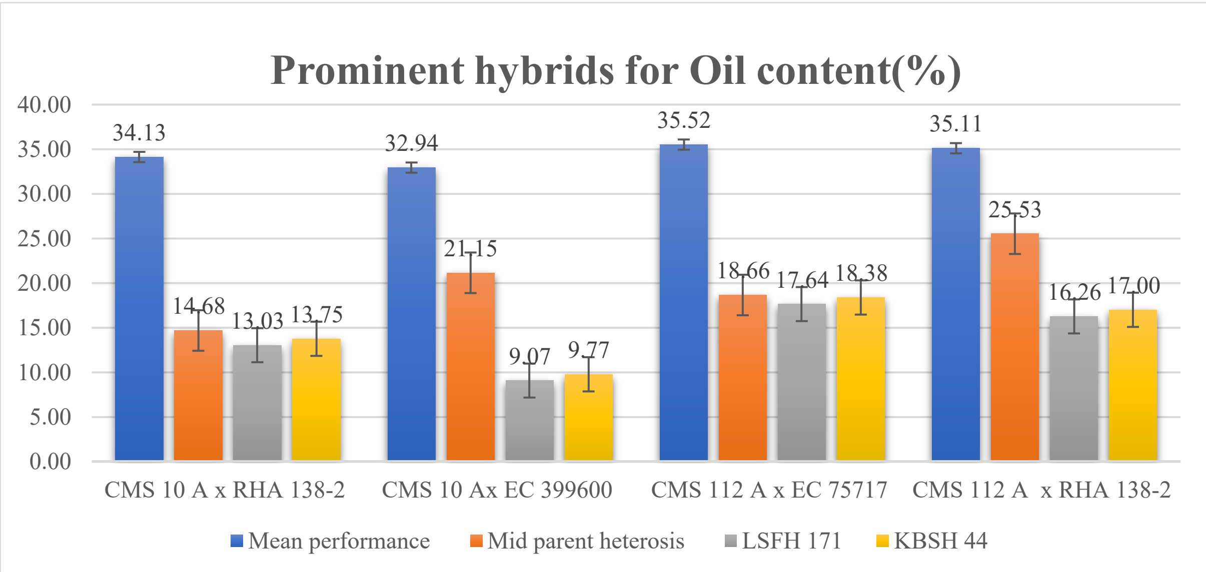

Figure 2. Mean performance, Mid Parent Heterosis and Standard heterosis of prominent hybrids for Oil content(%).

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