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Heterosis Study in Sunflower (*Helianthus annuus* L.) Hybrids for Yield Attributing Traits in High Salinity Condition for Identification of Superior Sunflower Hybrids for Coastal Saline Belts

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Abstract

Heterosis is the increase or decrease in the vigor of F1 over its mid or better parental value. One of the objectives of the present study was to estimate the extent of heterosis for various characters and to isolate promising hybrids over standard check hybrids for seed yield and oil content for commercial exploitation. The development of new high yielding and stable sunflower hybrids were based on hybridization which requires information on the heterotic effects for agronomically important traits in the F1 generation. Heterotic effects for seed yield and it's attributing traits viz., plant height and head diameter, number of seeds per head, seed filling%, 100 seed weight (g), 100 seed kernel weight (g), volume weight (g/100cc), hull content (%), oil content (%) and oil yield (kg/ha) were studied in the sunflower hybrids developed by the line x tester method. There are significant differences among the sunflower genotypes (inbred lines and F1 hybrids) we tested with regard to the mean values of all the traits involved indicating a considerable amount of heterosis for most of the traits except hull content (%), oil content and seed filling percent. Most of the crosses exhibited high heterosis especially for the number of seeds per head seed yield (kg/ha) and oil yield (kg/ha). However, mean heterosis was comparatively low for hull and oil contents. The study on heterosis in sunflower showed that the crosses with favorable characteristics such as oil and seed yields, oil and hull contents could be bred from correctly selected parents. The cross CMS-853A X EC-623027 reached the breeding aim mentioned above, especially for high vigor in seed and oil yields.

Under present study, the genotypes, EC-601878 and EC-601751 with regard to all measured traits, CMS-852A, CMS-103A and P-89-1A for seed yield, oil content and low hull rate could be used for increasing hybrid vigor in future sunflower breeding programs as well as the sunflower genotypes, viz., CMS-852A, CMS-853A, and EC-623027, EC-623023 appeared to possess high concentration of additive genes for seed yield and component traits and, therefore, these parents can be considered as the good combiners for heterosis breeding program for seed and oil yield improvement in sunflower.

Keywords: Sunflower; Heterosis; Seed yield; Oil yield; Yield components

Introduction

The main objectives of sunflower breeding programs are the development of productive F1 hybrids with high seed and oil yield. Sunflower oil yield is determined as the product of seed yield per unit area and the oil percentage in grains. Therefore, consideration of both components is important when breeding for high oil yield. National sunflower hybrid (development of new hybrid) breeding program is a continuous program that started in our country in the early 1980s. Sunflower hybrid breeding was started economically in discovering by Leclercq [1] and restorer genes by Kinman [2], Miller and Fick [3].

Heterosis of these crops has been exploited only over the past few decades. Hybrid sunflower became a reality with the discovery of cytoplasmic male sterility and an effective male fertility restoration system during 1970. Hybrid vigor has been the main driving force for the acceptance of this oilseed crop. Utilization of heterosis has allowed sunflowers to become one of the major oilseed in many countries of Eastern and Western Europe, Russia and South America and is an important crop in the USA, Australia, South Africa, China, India and Turkey. Sunflower hybrid breeding has thus played a vital role in the improvement of this crop. Increasing seed and oil yields is the top priority of most sunflower breeding programs. Getting benefits from the use of heterosis is the main purpose of sunflower hybrid breeding. In this study, an effort has been made to discuss the various approaches for hybrid breeding in sunflower and present status for the development of high yielding hybrids in sunflower with high seed and oil yield. The present study has been carried out to with the specific objectives to determine performance of sunflower varieties and to measure the vigor of sunflower hybrids in different location and year to identify one/few high yielding Sunflower hybrids with at least 10-12 higher seed and oil yield over best national check and suitable for cultivation in Rabi season. In India, the sunflower is grown on about 0.7 million ha [4] and mostly grown in the states of Karnataka, Maharastra, Andhra Pradesh and Tamil Nadu with potential scope of growing in the non-traditional areas like West Bengal [5]. In West Bengal, Sunflower is the second important oilseed crop after rapeseed-mustard during Rabi-summer season and it was grown on about 21,000 ha in the last Rabi season (2016-17). Due to short winter spell and delayed and heavy rainfall during the rainy season, the sowing of mustard was delayed which ultimately reduced the production of rapeseed-mustard. The delayed sowing also invites the insect pests in most of the years. Sunflower being a photoperiod natural crop has a wide scope to replace the rapeseed-mustard cultivation with high yield potentiality. In addition to ascertaining overall specific combining ability status of cross combinations, it is also equally important to ascertain the overall heterotic status of the cross combinations across the traits. The overall heterotic status of the cross combinations is estimated as the same method followed for overall specific combining ability status based on the rank sum of hybrid (mid-parent heterosis) across the traits compared with the final norm for the heterosis.

Methods

The present experiment was started in 2014-15 with aimed to breed and evaluates the performance of the sunflower hybrids with respect to yield and yield component and to identify the superior sunflower hybrids suitable for Rabi-summer season in West Bengal agro-climatic condition. The objective(s) of the present study identified the good heterotic combinations, and to study the Heterosis and Heterobeltiosis. The crossing was affected in line X tester fashion and the resultant hybrids were subjected to combining ability studies. The genotypes were raised in Randomized Block Design with two replications wherein each replication was represented by three rows of three-meter length. The soil texture was clay loam in "On station" plots. Three irrigations were provided during the cropping period. One foliar spray was given with Boron at 2 g/l of water in the ray floret stage. The row per plot were five in number with a row spacing of 60 cm and plant to plant spacing was 30 cm. The uniform dose of fertilizer at 80 kg N, 40 Kg P_2O_5 and 40 kg K_2O per ha was applied. The germinated seed of sunflower used as the planting materials and one per hill were maintained throughout the cropping period. The data was recorded in ten randomly selected plants from each plot of all replications on the following characters viz., days to 50% flowering, days to maturity, plant height at harvest (cm), head diameter per plant (cm), seed weight per head (g), 100-seed weight (g), husk (or hull) content (%), volume weight (g/100 cc). The seed yield (kg/ha), oil percentage and oil yield (kg/ha) were estimated on plot basis **(Table 1)**. The mean values were subjected to statistical analysis. In the very first year (2014-15), 56 of hybrids (developed from line X tester matting design) were evaluated and next year, 2015-16 and 2016-17, 56 superior hybrids were tested along with the two national checks LSFH-171 and DRSH-1 were evaluated for performance (seed/Oil yield) higher at research farm under AICRP Sunflower, Nimpith Centre in Randomized complete block design with three replications. The data pertaining to seed yield and other yield attributing traits for these test hybrids **(Table 2)**.

The seed yield (kg/ha), oil percentage and oil yield (kg/ha) were estimated on a plot basis. The mean values were subjected to statistical analysis Singh and Chaudhary [6], Singh and Kakar [7]. The differences in mean were tested by Tukey's test using MSTAT statistical software (MSTAT-C 1991, Michigan State University, East Lansing, MI).

Heterosis

Percent increase or decrease of F1 over the mid parent has been referred as heterosis and percent superiority of F1 over better parent and standard check as heterobeltiosis and economic heterosis, respectively.

Heterosis, Heterobeltiosis and economic heterosis will be estimated as per the methods suggested by Fonesca and Patterson [8] for the individual as well as over the environments.

Table 1: Analysis of variance parents and hybrids (Mean squares) for combining ability.

Source of variation	d.f.	Days to 50% flowering	Plant height	Head Dia.	No. of Filled Seeds/hd	Gr. Filling %	100 seed weight	Hull Cont. %	Vol. Wt. (g/100 cc)	Oil cont.%	Seed Yield /Pl	Seed yield/ (Kg/ha)	Oil Yield (Kg/ha)	100 kernel Wt. (g)
Location	1	212.46	2978.5**	28.01	14545.1**	176.9	1.182	26.22	39.01	10.58	147.1**	441289.2**	35704.6**	0.25
Repl/Loc	2	27.14	540.8	9.03	6907.4	26.21	2.887	5.93	19.17	18.21	47.34**	143396.6*	47090.2	1.87

Line	7	194.04**	9449.0**	25.2**	21097.7**	36.11**	3.522	57.04**	35.63**	9.49**	650.2**	1965372.0**	229786.2**	1.641**
Tester	6	74.85**	4816.9**	20.23**	17476.8**	17.35**	0.64	55.80**	14.16**	6.49*	317.1**	958346.7**	108418.7**	0.547**
Line X Tester	42	31.86**	510.12**	21.50**	27690.3**	10.51**	0.654	16.30**	13.60**	2.38	58.32	176794.2**	21047.8**	0.394**
Line X LC	7	0.382	6.92	0.031	286.2	0.216	0.004	0.034	0.028	0.007	0.482**	1501.09	116	0.0009
Test X LC	6	0.36	4.27	0.036	69.14	0.199	0.003	0.009	0.033	0.004	0.453	1278.4	114.6	0.001
L X T X LC	42	0.29	2.37	0.026	80.3	0.015	0.002	0.054	0.01	0.005	0.247	752.3	80.27	0.0008
Error	110	0.002	0.261	0.002	155.21	0.029	0.003	0.008	0.006	0.002	0.034	98.22	28.83	0.001

*Significant at 5% level; ** Significant at 5% level

Table 2: Parental mean for yield and yield attributing characters.

Name of the parent	Days to 50% Flow.	Pl. Ht. (cm)	Hd. Dia. (cm)	Seed Yield (kg/ha)	100 seed Wt. (g)	100 kernel weight	Hull. Cont. (%)	No. of filled grains/Hd.	Gr. Filling (%)	Vol. Wt. (g/100 cc)	Oil (%)	Oil Yield (kg/ha)
CMS Line (L)												
CMS-853A	67.9	118.6	11.5	1385	5.7	3.98	30.2	298	83.3	42.8	36.2	774.9
CMS-852A	65.6	123.5	11.8	1140	5	3.4	32.1	280	86.8	42.2	35.6	791.8
CMS-850A	66	116	12.8	1090	4.9	3.48	28.9	286	90.2	42	35.4	605.2
CMS-103A	65	129.3	12.3	1035	5.3	3.9	26.5	321	87.8	45.4	36.2	516.4
PET-2-7-1A	70.4	131.8	13.2	1150	5.5	3.68	33.1	364	86.9	43.7	35.2	740.5
CMS-207A	68.8	136	12.6	1100.5	4.6	3.14	31.8	478	88	40.4	35.4	677.8
PET-89-1A	71	107.8	10.5	1210	4.9	3.46	29.3	408	84	45.4	35.2	704.6
CMS-10A	69.4	141.9	12.4	1225	5.3	3.64	31.4	340	87.1	42.1	34	647.4
Range	65.0-71.0	107.8-141.9	10.5-13.2	1035.0-1385.0	4.6-5.7	3.14-3.98	26.5-33.1	340.0-478.0	83.3-90.2	40.4-45.4	34.0-36.2	516.4-774.9
G.M	68.01	125.61	12.14	1166.9	5.15	3.58	30.41	346.88	86.76	43	35.4	682.34
SEM (±)	1.1	2.2	0.3	36	0.17	0.08	0.9	18	1.6	0.8	-	12.6
C.D. (p=0.005)	3.2	6.2	0.8	108	0.52	0.21	2.8	54	4.8	2.4	NS	36
C.V. (%)	7.7	8.4	6.8	9.4	6.2	7.6	7.1	9.2	6.1	5.4	-	8.8
R line (T)												
EC-623027 (M)	71.5	104.8	9.9	1020	5.6	4.14	26	393	77.5	45.3	38.9	718.1
EC-623023	71.3	95.8	7.5	825	5.3	3.76	29.1	283	85.2	43	38.2	706.4
EC-623021	64	87.4	8.6	780	5	3.53	29.5	262	87.5	42	42.5	671.6
EC-601978	66.3	87.4	11.6	770	4.9	3.45	29.6	286	87.9	42.9	42.5	727.8
EC-601751	62	91.2	9	720	5.4	3.78	30	256	85.5	43	42	563.8
EC-601725	70.5	84.2	9.8	880	5.2	3.5	32.7	308	83	44.6	41.8	731.9
EC-623016	69.8	86.2	6.4	690.5	5.1	3.62	29	235	86.3	41.5	41.5	656.8

Range	62.0-71.5	84.2-104.8	6.5-11.6	690-1020	4.9-5.6	3.53-4.14	26.0-32.7	256-393	77.5-87.9	42.0-45.3	38.2-42.5	563.3-773.9
G.M	67.91	91	8.97	812.2	5.21	3.68	29.41	289	84.7	43.19	41.1	682.35
SEM (±)	1.4	2.8	0.4	41.5	0.14	0.05	1.1	16.2	1.58	0.82	0.94	14.2
C.D. (p=0.005)	4.2	8.6	1.1	120	0.42	0.17	3.4	48	4.6	2.4	2.8	41.6
C.V. (%)	5.8	7.2	6.1	8.8	5.5	6.8	6.4	8.2	6.6	5.8	8.5	8.6

Table 3: Sunflower hybrids (F1s) mean for different yield and yield attributing characters.

Sl. No	Hybrid combination	50% Flow.	Pl. Ht. (cm)	Hd Dia. (cm)	Seed Yield (kg/ha)	No. of Filled Grain/Hd	Autogamy%	100 seed Wt. (g)	100 Kernel Wt. (kg)	Hull Cont. %	Vol. Wt. (g/100 cc)	Oil %	Oil Yield (Kg/ha)
1	CMS-853A X EC-623027 (M)	75	184.5	16.2	2462	731.5	87	6.1	4.1	32.1	42.8	35.7	879
2	CMS-853A X EC-623023	74.5	176.5	15.9	2428	746	87.5	5.9	4.1	29.8	43	35.6	864.5
3	CMS-853A X 623021	73.5	170	15.7	2292	792.5	87	5.6	4	27.8	43.7	36.4	834.5
4	CMS-853A X EC601751	69	158	15.4	1861	660	91.5	5.3	3.9	27.3	42.6	36.8	685
5	CMS-853A X EC601978	68.5	145	15.5	1575.5	543.5	86.5	5.4	4	24.8	45.3	37.4	589
6	CMS-853A X EC601725	75.5	182.5	16.1	2278	805	87	5.5	3.7	33.1	40	35.2	802
7	CMS-853A X 623016	72	160.5	15	2072	682.5	87.5	5.5	3.8	31.9	43.8	37.2	770.5
8	CMS-852A X EC-623027 (M)	76	175	15.1	2270	855.5	92	4.9	3.4	29.8	40	35.8	813
9	CMS-852A X EC-623023	76	170	15.4	2328	935	88.5	4.6	3	34.6	43.2	36.1	840.5
10	CMS-852A X EC-623021	77.5	174	15.4	2272	839	91	5	3.5	29.8	40	35.8	813.5
11	CMS-852A X EC-601751	72.5	160.1	15.4	2284	879	90	4.8	3.3	31.1	41.6	36.4	831.5
12	CMS-852A X EC-601978	66	153	15	1761	637.5	91.5	5.1	3.7	27.3	42.6	36.8	648
13	CMS-852A X EC-601725	70.5	155	16.7	2072	682.5	87.5	5.5	3.8	31.9	43.8	37.2	770.5
14	CMS-852A X EC-623016	73	175.5	15.3	2306	720.5	88.5	5.8	4.3	25.2	42.7	35.8	825.5
15	CMS-850A X EC-623027 (M)	69	133	15.2	1861	673.5	91.5	5.1	3.7	27.3	42.6	36.8	685
16	CMS-850A X EC-623023	64	122.5	13.8	1472	605	91	4.5	3.1	30.9	43.6	38.4	565
17	CMS-850A X EC-623021	63	112	13.2	1340	516	90	4.8	3.4	29	42.2	37.2	498.5
18	CMS-850A X EC-601751	69	133	15.4	1861	673.5	91.5	5.1	3.7	27.3	42.6	36.8	685

19	CMS-850A X EC-601978	65	92.5	9.6	1500	553.5	94	5	3.6	27.8	39.7	37	555
20	CMS-850A X EC-601725	69	112	13.7	1836	664.5	91.5	5.1	3.7	27.3	42.6	37.2	683
21	CMS-850 X EC-623016	68	122.5	13.3	1472	605	91	4.5	3.1	30.9	43.6	38.4	565
22	CMS-103A X EC-623027 (M)	67.5	138.5	13.5	1350	476	89	5.1	3.3	34.4	43.2	38.7	518.5
23	CMS-103A X EC-623023	67	135	12.7	1340	516	90	4.8	3.4	29	42.2	37.2	498.5
24	CMS-103A X EC-623021	66	132	12.7	1348	516	90	4.8	3.4	29	42.2	37.2	499.5
25	CMS-103A X EC-601751	67	130.1	13.4	1472	533	91.5	5.1	3.5	30.3	42.6	36.8	541.5
26	CMS-103A X EC-601978	66	124.5	12.8	1533	487.5	90.5	5.7	4.4	23.6	48.5	38.4	589
27	CMS-103A X EC-601725	62.5	120.5	12.2	1232	484.5	91	4.7	3.3	29.8	43.4	38.1	469.5
28	CMS-103A X EC-623016	64	124	12.7	1340	485	90	5.1	3.5	31	42.2	37.2	498.5
29	P-2-7-1A X EC-623027	73	184	16.4	2094	743	89	5.1	3.3	34.4	43.2	37	775
30	P-2-7-1A X EC-623023	68	145.5	15.7	2192	735.5	88.5	5.4	3.7	32.5	43.5	37.6	824.5
31	P-2-7-1A X EC-623021	70	168.5	14.9	1872	514.5	90	6.6	4.4	33.6	42.4	37.8	707.5
32	CP-2-7-1A X EC-601751	76	177.5	15.8	2340	770.5	87.5	5.5	3.8	31.9	42.6	35.2	824
33	P-2-7-1A X EC-601978	64.5	137.5	11.5	1340	457.5	90	5.3	3.6	30.8	45.6	38.7	518.5
34	P-2-7-1A X EC-601725	68	145.5	15.7	2192	735.5	88.5	5.4	3.7	32.5	43.5	37.6	824
35	P-2-7-1A X EC-623016	70	155.5	14.9	1878	501	90	6.8	4.5	33.6	42.4	37.8	710
36	207A X EC-623027	63.5	142.5	14	1567	616	92	4.7	3.1	32.6	39.6	39	611.5
37	207A X EC-623023	73	142.5	14.7	2194	922	88	4.4	3.1	29.3	39.9	36.4	799
38	CMS-207A X EC-623021	70.5	167	14.4	1886	696.5	90	5	3.3	33.8	38	37.5	707.5
39	CMS-207A X EC-601751	68	145.5	15.7	1962	658	88.5	5.4	3.7	32.5	43.5	37.6	737.5
40	CMS-207A X EC-601978	67	115	13.5	1431	498	90.5	5.2	3.5	31.9	39.2	38.5	551
41	CMS-207A X EC-601725	71.5	172.5	14.8	2017	776	86	4.8	3.2	33.1	40	36.8	742.5
42	CMS-207A X EC-623016	68.5	153	14	1547	665.5	92	4.3	2.9	32.4	40.2	38.5	596
43	P-89-1A X EC-623027 (M)	73.5	180	15.6	2218	911	88	4.5	3.1	30.9	45.1	37.6	834
44	P-89-1A X EC-623023	73	168.5	15	1974	793	89	4.6	3.1	31.6	39.7	36.8	726.5

45	P-89-1AA X EC-623021	71	148.5	14.2	1856	714	89	4.8	3.3	31.6	39.7	36.8	683
46	P-89-1AA X EC-601751	71	154	15.1	2144	761	85.5	5.1	3.5	30.6	45.5	37.4	802
47	P-89-1AA X EC-601978	68.5	123	12	1445	533.5	91.5	5	3.7	25.8	45.2	38.8	561
48	P-89-1A X EC-601725	73	148.5	15	1960	787.5	89	4.6	3.1	31.6	39.7	36.8	721.5
49	P-89-1A X EC-623016	67	136.5	13.9	1611	583	90	5.1	3.4	33.1	41	37.5	604.5
50	10A X EC-623027	72.5	167.5	15.4	1722	577.5	88	5.4	3.7	30.6	40.8	36.5	628.5
51	10A X EC-623023	64	154	14.6	1380	531	92	4.8	3.4	29	42.2	38.6	532.5
52	10AA X EC-623021	71.5	162.5	15.2	1722	577.5	88	5.4	3.7	30.7	40.8	36.5	628.5
53	10A X EC-601751	73.5	142.5	14.7	1967	826.5	87	4.4	3	31.6	39.6	36.4	716
54	10A X EC-601978	64.5	119	12.8	1306	482.5	92	5	3.5	29.8	40.3	38.2	499
55	10A X EC-601725	70.5	156.5	15.4	2240	795	86	5.1	3.4	32.5	44.6	37.6	842.5
56	10A X EC-623016	68	145.5	15	1792	601	87.5	5.4	3.7	32.5	41.5	38.2	685
	G. Mean	69.6	148.8	14.5	1840.5	661.8	89.4	5.1	3.6	30.6	42.2	37.2	682.3
	Range	64-76	112.0-184.5	9.6-16.4	1232-2462	476 -935	87.0-94.0	4.4-6.8	3.1- 4.4	24.8-34.6	38.0-48.5	35.2-38.5	498.5-879.5
	LSFH-171 (Ch-1)	80	194	15.6	2256	634	85.5	5.24	3.24	38.1	38.78	33.7	760
	DRSH-1 (CH-2)	75	168.7	14.8	1978	557	87.2	5.68	3.76	34.5	41.36	38	751
	SEM (±)	1.1	6.3	0.34	30.1	20.3	0.5	0.2	0.15	0.5	0.9	0.7	23.2
	C.D. (p=0.005)	3.1	6.8	1	90.2	60.4	1.5	0.6	0.45	1.4	2.7	2.1	68.6
	C.V. (%)	6.8	9.2	6.1	9.6	9.2	7.5	5.8	6.5	8.2	7.1	8.2	9.4

Table 4: Heterobeltiosis and Heterosis of sunflower hybrids for yield and yield attributing characters.

Sl. No	Hybrid combination	Days to 50% Flowering		Pl. Ht. (cm)		Hd. Dia.(cm)		Seed Yield (kg/ha)		No. of Filled Grain/Hd		Gr. Fil.%	
		h^2 BP	h^2 MP	h^2 BP	h^2 MP	h^2 BP	h^2 MP	h^2 BP	h^2 MP	h^2 BP	h^2 MP	h^2 BP	h^2 MP
1	CMS-853A X EC623027 (M)	3.91	6.91**	72.30**	123.28**	53.27**	68.02**	101.74**	170.1**	90.00**	140.5**	3.86	8.84*
2	CMS-853A X Ec623023	9.42*	12.58**	52.09**	78.74**	61.98**	74.30**	119.73**	192.03**	106.65**	164.2**	1.87	7.68*
3	CMS-853A X 623021	10.37**	13.60**	37.11**	66.73**	56.22**	66.53**	111.73**	182.0**	119.38**	172.7**	6.89**	7.32*
4	CMS-853A X EC601751	6.15*	6.00**	31.74**	48.50**	33.33**	55.44**	72.71**	136.1**	82.19**	180.1**	2.49	40.77**
5	CMS-853A X EC601778	6.72*	10.27**	27.30**	38.96**	51.22**	75.33**	49.69**	92.4**	59.50**	73.06**	4.63	3.47

6	CMS-853A X EC601725	11.03**	14.24**	57.76**	87.39**	53.99**	67.54**	101.15**	175.0**	115.67**	214.4**	3.18	35.24**
7	CMS-853A X 623016	5.49*	8.55**	35.04**	51.08**	46.60**	64.79**	99.71**	148.1**	99.27**	192.8**	11.99**	34.30**
8	CMS-852A X EC-623027 (M)	10.14**	13.31**	38.31**	65.07**	32.17**	43.66**	110.19**	175.4**	130.44**	188.5**	2.91	12.61**
9	CMS-852A X EC-623023	12.18**	15.43**	46.38**	66.00**	54.17**	65.29**	136.95**	212.8**	169.26**	240.5**	4.42	6.57*
10	CMS-852A X EC-623021	16.98**	20.39**	60.61**	76.57**	50.98**	61.07**	136.67**	213.2**	141.44**	205.2**	3.03	9.84**
11	CMS-852A X EC-601751	13.73**	13.50**	39.52**	60.06**	31.62**	53.45**	139.16**	225.8**	152.22**	292.8**	6.21**	34.77**
12	CMS-852A X EC601878	0.38	3.77	40.98**	57.71**	44.23**	67.38**	89.35**	140.7**	94.95**	109.8**	3.06	7.19*
13	CMS-852A X EC-601725	5.62*	8.68*	47.62**	51.12**	54.63**	68.48**	105.15**	179.5**	89.85**	184.8**	2.25	32.35**
14	CMS-852A X EC-623016	8.96*	12.14**	45.57**	65.44**	46.13**	65.83**	152.02**	208.4**	119.16**	221.2**	9.12**	32.23**
15	CMS-850A X EC-623027	-0.36	7.17**	19.15**	38.16**	33.92**	64.72**	76.40**	119.2**	82.89**	91.3**	3.76	11.96**
16	CMS-850A X EC-623023	-5.88*	1.35	14.41**	32.24**	35.63**	71.88**	53.73**	91.4**	75.74**	83.2**	1.29	9.58*
17	CMS-850A X EC-623021	-5.26*	2.16	8.92*	26.68**	23.36**	59.69**	43.32**	78.6**	49.78**	56.1**	2.75	8.59*
18	CMS-850A X EC-601751	7.81*	12.77**	29.35**	47.07**	26.23**	75.95**	100.11**	156.4 **	94.93**	141.2**	7.00 *	36.98**
19	CMS-850A X EC-601878	-1.52	6.68*	-11.69**	13.88**	-11.93**	24.87**	65.75 **	98.4 **	54.83**	74.1**	5.66 *	10.05**
20	CMS-850A X EC-601725	2.99	10.98**	10.64**	29.08**	21.24**	58.46**	86.40**	139.8**	86.40**	124.3**	3.12	38.37**
21	CMS-850 X EC-623016	1.12	8.92*	19.83**	35.68**	38.54**	67.42**	65.39**	90.5**	85.73**	115.4**	7.68*	35.95**
22	CMS-103A X EC-623027	-1.82	0.99	17.05**	20.23**	21.62**	25.24**	30.41**	70.3**	39.41**	73.3**	4.05	8.23*
23	CMS- 103A X EC-623023	-0.74	2.11	18.66**	21.03**	27.96**	32.98**	44.09**	89.6**	62.52**	103.1**	2.68	7.74*
24	CMS-103A X EC-623021	0	2.91	16.52**	22.98**	21.53**	29.67**	47.66**	94.8**	62.39**	102.8**	4.15	7.97*
25	CMS-103A X EC-601751	-5.51 *	5.26	10.74**	18.91**	12.13**	30.17**	63.10**	121.8**	67.22**	162.4**	4.44	36.01**
26	CMS-103A X EC-601978	0.76	4.14	11.71**	24.34**	20.19**	38.80**	74.70 **	120.9**	64.00**	72.9**	6.56 *	5.38**
27	103A X EC-601725	-6.02*	-3.3	11.65**	14.02**	10.41**	19.90**	28.67**	75.1**	46.93**	120.2**	3.39	36.62**
28	CMS-103A X EC-623016	-4.12	-1.35	7.84**	13.53	25.83**	34.05**	55.36**	88.7**	62.21**	137.0**	8.27*	33.48**
29	P-2-7-1A X EC-623016	2.1	8.11*	53.85**	82.18	41.99**	74.86**	93.00**	145.9**	109.89**	168.7**	2.85	12.66**
30	P-2-7-1A X EC-623023	-3.2	2.54	26.47**	49.43**	51.33**	91.85**	121.97**	184.2**	122.88**	188.5**	3.21	10.19**
31	P-2-7-1A X EC-623021	1.82	11.13**	52.08**	86.95**	36.70**	83.87**	93.99**	161.1**	55.79**	105.3**	0.11	12.67**

32	P-2-7-1A X EC-601751	14.72**	18.14**	60.20**	86.53**	27.42**	77.52**	143.75**	221.4**	132.60**	277.3**	4.41	36.61**
33	P-2-7-1A X EC-601978	-5.49*	0.65	21.98**	59.99**	8.6	46.64**	43.32**	76.6**	47.70**	61.2**	4.18	8.89**
34	P-2-7-1A X EC-601725	-1.81	4.08	33.24**	59.02**	36.52**	78.43**	115.96**	185.4**	114.90**	232.6**	3.93	39.60**
35	P-2-7-1A X EC-623016	0.72	6.79*	41.11**	63.65**	52.04**	83.86**	104.13**	42.3 **	60.83**	143.3**	13.93**	40.20**
36	207A X EC-623027	-11.50**	-7.33*	12.59**	22.15**	17.25**	28.47**	47.80**	84.6**	67.28**	93.5**	4.02	11.78**
37	207A X EC-623023	3.55	8.50*	18.45**	26.09**	42.88**	51.85**	127.89**	185.3**	167.83**	211.1**	4.96	5.22
38	207-1A X EC-623021	2.17	7.11*	39.24**	53.50**	30.79**	45.03**	52.58**	95.40**	102.18**	134.8**	2.97	7.84*
39	207A X EC-601751	2.26	4.08	23.45**	31.27**	42.08**	50.74**	143.75**	170.3**	90.45**	169.3**	3.86	31.31**
40	207A X EC-601978	-2.19	2.98	8.3	13.1**	38.41**	44.31**	43.32**	89.2**	53.65**	105.7**	0.68	5.26
41	207A X EC-601725	2.88	7.80*	46.70**	60.97**	31.45**	43.53**	115.96**	163.3**	93.40**	195.6**	5.85*	28.92**
42	207A X EC-623016	-1.79	2.92	26.00**	38.24**	32.68**	45.60**	74.13**	100.2 **	117.67**	169.4**	3.61	36.28**
43	P-89-1A X EC-623027	4.26	11.35**	47.87**	91.70**	38.67**	72.24**	47.80**	174.4**	104.30**	207.3**	6.60*	10.02**
44	P-89-1A X EC-623023	5.42*	12.69**	43.80**	86.70**	48.88**	91.18**	127.89**	170.9**	125.91**	188.8**	9.46*	13.55**
45	P-89-1AA X EC-623021	4.8	12.14**	31.50**	72.64**	33.96**	75.59**	100.58**	161.5**	109.10**	159.8**	4.46	9.70*
46	P-89-1AA X EC-601751	8.81*	13.02**	36.37**	74.87**	24.79**	76.35**	109.78**	212.8**	88.14**	242.4**	1.71	31.44**
47	P-89-1AA X EC-601978	1.86	9.49*	27.10*	56.03**	11.11**	60.00**	57.21**	101.8**	75.70**	100.7**	-2.73	9.40*
48	P-89-1A X EC-601725	6.96*	14.41**	33.39**	76.00**	33.93**	77.27**	103.69**	170.2**	68.61**	227.3**	7.02*	38.22**
49	P-89-1A X EC-623016	-2.19	4.59	21.52**	55.29**	46.32**	78.88**	72.80**	120.1**	101.15**	158.9**	7.23*	38.06**
50	CMS-10A X EC-623027	5.45 *	12.81**	34.32**	79.48**	38.12**	76.47**	98.92**	132.9**	61.61**	108.3**	4.29	8.68*
51	CMS-10A X EC-623023	-5.19*	1.53	28.17**	71.70**	46.37**	94.54**	94.00**	109.2**	54.31**	106.8**	13.55**	18.83**
52	CMS-10A A X EC-623021	8.33*	16.11**	40.21**	90.16**	44.76**	96.03**	86.53**	168.8**	51.61**	125.8**	7.18*	7.98 *
53	CMS-10A X EC-601751	15.75**	20.37**	22.95**	62.87**	22.50**	78.82**	116.57**	219.12**	64.76**	201.7**	0.57	31.78**
54	CMS-10A X EC-601978	-1.53	6.05**	10	52.04	19.63**	78.53**	49.74**	101.8**	135.14**	68.8**	-1.02	8.73*
55	CMS-10A X EC-601725	6.02*	13.59**	36.92**	86.72**	38.74**	89.27**	87.56**	241.30**	46.21**	258.7**	7.60*	31.58**
56	CMS-10A X EC-623016	1.87	9.12**	26.19**	66.56**	59.57**	101.72**	69.58**	170.3**	119.31**	191.3**	3.61	32.23**
	Lowest	-11.5	-7.33	-11.69	13.1	-11.94	24.87	43.32	42.3	39.41	56.1	-2.73	3.47
	Highest	16.98	20.39	72.26	123.2	61.98	101.72	152.02	225.8	169.26	277.3	13.93	40.77

	Crosses with positive and significant heterosis	19	38	54	56	54	56	56	56	56	56	18	53
	Crosses with negative and significant heterosis	6	1	1	0	0	0	0	0	0	0	0	0
	SEm (±)	0.03	0.02	0.62	0.53	0.07	0.06	11.4	9.87	8.3	7.2	0.2	0.17

Table 5: Heterobeltiosis and Heterosis of sunflower hybrids for yield and yield attributing characters.

Sl. No	Hybrid combination	100 seed Wt. (g)		100 kernel weight		Hull Cont.%		Vol. Wt. (g/100 cc)		Oil%		Oil Yield (Kg/ha)	
		h^2 BP	h^2 MP	h^2 BP	h^2 MP	h^2 BP	h^2 MP	h^2 BP	h^2 MP	h^2 BP	h^2 MP	h^2 BP	h^2 MP
1	CMS-853A X EC-623027 (M)	5.49*	7.96*	1.8	3.5	8.37*	10.14**	-2.84	0.23	-4.93	-2.28	95.77**	152.1**
2	CMS-853A X EC-623023	5.22*	7.27 *	5.74*	6.84 *	-1.34	0.51	0.23	2.21	-4.30 *	-2.39	111.89**	171.6**
3	CMS-853A X 623021	1.63	3.74	5.51*	6.23 *	-9.12*	-6.87 *	3.07	4.81	-7.56 *	-3.49	100.36**	161.4**
4	CMS-853A X EC601751	0	2.2	-36.4**	3.49	-18.78**	-8.70 *	-0.58	2.5	-15.60**	-6.54 *	65.36 **	122.6**
5	CMS-853A X EC601778	-3.6	11.70**	22.8**	3.21	-22.91**	17.61**	5.59 *	18.06**	-4.35 **	2.63	46.61**	76.9**
6	CMS-853A X EC601725	0	6.20*	-67.2**	-2.67	-5.53*	5.09 *	-8.47 *	-3.84	-19.68 **	-9.74 *	84.69**	149.9**
7	CMS-853 A X623016	1.85	8.27*	-63.4**	-1.32	-2.63	7.60 **	3.91	5.61 *	-4.25	-14.92**	95.68**	139.5**
8	CMS-852A X EC-623027 (M)	-10.07*	-8.49 *	-9.53**	-7.97 *	-2.56	-0.83	-8.57 *	-5.80*	-3.89	-1.57	102.49**	160.4**
9	CMS-852A X EC-623023	-12.83*	11.65**	-17.4**	16.64**	11.04**	12.91**	1.41	3.25	-2.17	-0.58	133.15**	198.2**
10	CMS-852A X EC-623021	-2.74	-1	-0.65**	0	-5.31*	-3.25 **	-4.99	-3.55	-8.38 *	-4.67	120.46**	187.7**
11	CMS-852A X EC-601751	-1.31	-4.04	-68.0**	-4.38	-9.97*	0.65	-2.23	0.63	-16.20**	-6.85 *	126.72**	206.6**
12	CMS-852A X EC601878	-2.88	14.37**	1.94	23.3**	-17.33**	12.08**	0	11.72**	-5.15 *	1.37	82.92**	118.5**
13	CMS-852A X EC-601725	7.84*	15.20**	8.70 *	65.4**	-11.36**	-1.7	0.92	5.92 *	- 14.77 **	-3.88	99.22**	171.0**
14	CMS-852A X EC-623016	14.85**	22.91**	24.00**	56.4**	-9.37*	17.51**	2.03	3.51	-17.86**	-7.13 *	138.41**	189.3**
15	CMS-850A X EC-623027	-3.35	-4.46	-1.48	7.63*	0.7	-4.04	-2.41	1.27	-2.37	-0.94	74.97**	114.0**
16	CMS-850A X EC-623023	-4.09	12.32**	-5.58*	14.58**	-6.57*	6.38*	2.59	5.19*	2.15	4.35	61.20**	95.2**
17	CMS-850A X EC-623021	-3.35	4.92	-3.57	7.31*	-19.82**	-0.68	0.48	2.74	-4.55	-4.25	38.86**	71.5**
18	CMS-850A X EC-601751	3.58	18.81**	6.38 *	62.8**	-14.60**	-6.67 *	0.35	4.08	-5.58 *	-1.65	92.01**	145.4**

19	CMS-850A X EC-601878	-3.41	29.14**	-1.38	36.4**	-23.11**	-5.60*	-6.59*	5.21*	-17.27**	-4.39	61.22**	82.3**
20	CMS-850A X EC-601725	0.5	20.97**	5.61*	65.0**	-6.97*	-11.36**	-1.62	3.99	-14.40**	-3.63	81.29**	133.7**
21	CMS-850 X EC-623016	8.31*	10.55**	12.77**	67.9**	6.56*	24.16**	4.43	6.76*	-0.13	5.70*	68.03**	92.8**
22	CMS-103A X EC-623027	-8.43*	-6.42*	-16.6**	15.32**	2.14	26.06**	-4.74	-1.47	3.06	1.73	34.33**	79.5**
23	CMS-103A X EC-623023	-11.53**	10.38*	-12.6**	11.76**	1.06	4.32	-4.52	-2.43	-1.61	0	44.49**	92.9**
24	CMS-103A X EC-623021	-8.96*	-7.77*	-10.0**	-9.40*	-4.55	3.57	-3.43	-1.56	-15.81**	-5.52*	41.30**	92.4**
25	CMS-103A X EC-601751	-0.98	1.27	-66.4**	-4.08	-22.15**	7.84*	-3.51	-0.29	-6.54*	5.10*	54.16**	118.6**
26	103A X EC-601978	6.54*	24.44	13.12**	34.9**	-10.04**	-16.46**	9.73*	22.73**	-13.21**	-1.79	73.87**	115.6**
27	CMS-103A X EC-601725	-4.91	11.43*	-70.6**	11.76**	0.41	0.68	-3.56	1.53	-15.14**	-2.31	26.46**	80.0**
28	CMS-103A X EC-623016	-2.88	3.92	-65.8**	-7.07*	5.58*	11.53**	-2.88	-1.04	-4.25	3.87	50.72**	90.3**
29	P-2-7-1A X EC-623016	-14.65**	-8.11*	-13.8**	13.12**	-2.28	12.44**	-2.92	10.51**	-0.13	5.8	93.27**	155.6**
30	P-2-7-1A X EC-623023	-7.22*	0	-2.17	-2.01	2.64	4.34	0.35	13.02**	2.45	2.3	129.03**	202.2**
31	P-2-7-1A X EC-623021	19.10**	25.71**	21.10**	24.7**	-12.80**	7.19*	-1.05	10.06**	-17.51**	-2.77	91.99**	170.1**
32	CP-2-7-1A X EC-601751	1.65	5.77*	-63.8**	4.9	-11.91**	1.59	-1.62	12.19**	-9.45*	8.99*	124.98**	214.2**
33	P-2-7-1A X EC-601978	-2.75	6.12*	18.4**	-2.27*	-14.61**	-2.22	5.19*	31.10**	-12.34**	0.26	46.57**	80.3**
34	P-2-7-1A X EC-601725	0.93	1.19	-66.7**	1.39	-6.02*	-1.37*	-1.47	14.49**	-11.70**	-2.34	113.33**	199.3**
35	P-2-7-1A X EC-623016	19.16**	28.30**	-55.1**	23.84**	7.15*	8.05*	-0.47	11.89**	-1.43	6.98*	105.35**	157.1**
36	CMS-207A X EC-623027	-10.46**	11.43**	-13.7**	15.84**	-5.55*	13.61**	4.45	-12.68**	-0.07	5.26	55.90**	97.5**
37	CMS-207A X EC-623023	-13.35**	14.71**	-18.00**	-11.7**	7.92*	0.34	-9.73*	-2.3	-0.82	-0.4	127.47**	186.3**
38	CMS-207-1A X EC-623021	0	1.3	-7.61*	-2.7	-5.52*	14.80**	-6.03**	13.04**	-13.62**	-3.54	96.66**	152.7**
39	CMS-207A X EC-601751	10.20**	16.16	-63.9**	5.80*	-2.93	10.19**	-1.47	7.95**	-3.28	5.84*	111.89**	174.8**
40	CMS-207A X EC-601978	0.97	23.49	-6.71*	24.4**	-7.52*	6.17**	5.64*	11.31**	-15.96**	-0.26	59.71**	87.6**
41	CMS-207A X EC-601725	-5.94*	4.74	-70.3**	-9.14*	-3.47	1.07	-0.86	11.11**	-11.81**	-4.42	96.69**	163.7**
42	CMS-207A X EC-623016	-5.35*	15.00**	-70.7**	-20.14**	0.29	11.55**	-7.48*	-0.09	0.39	3.24	76.85**	110.8**
43	P-89-1A X EC-623027	-15.98**	12.75**	-23.12**	-13.6**	0.6	10.18**	5.25*	15.5**	1.16	1.21	102.06**	182.5**
44	P-89-1A X EC-623023	-11.11**	-8.08*	-16.93**	-8.66*	-0.52	8.42**	-4.8	3.35	-2.18	0.00	95.43**	174.4**

45	P-89-1AA X EC-623021	-4.33	-1.04	-1.3	-8.31 *	-11.91**	6.95 *	-3.64	4.39	-5.58 *	-13.98**	79.62**	157.1**
46	P-89-1AA X EC-601751	7.07 *	7.87 *	-64.7**	2.61	-22.44**	3.21	9.24 *	20.0**	-4.04	6.80*	112.17**	215.5**
47	P-89-1AA X EC-601978	-1	14.71**	-3.42	32.2**	-12.73**	14.00**	8.39 *	30.2**	-15.86**	0.26	53.49**	100.6**
48	P-89-1A X EC-601725	-1.91	-7.14*	-70.7**	-11.00**	-2.35	-3.52	-6.59*	4.7	-14.04**	-4.66	81.28**	169.9**
49	P-89-1A X EC-623016	4.12	9.64	-65.4**	-6.11 *	-2.69	13.97**	0.12	8.41**	-2.47	-0.58	69.09**	125.3**
50	CMS-10A X EC-623027	-0.92	4.18	-6.37*	8.57*	-9.74*	9.46*	-6.64*	3.19	0.14	5.43*	54.52**	130.7**
51	CMS-10A X EC-623023	-4.33	10.38**	-10.00*	2.3	-5.35*	-0.34	-0.82	8.43**	-3.67	6.93*	45.59**	120.0**
52	CMS-10AA X EC-623021	4.85	11.29**	5.49*	7.6***	-10.75**	3.9	-2.97	5.84**	-16.84**	-4.64	67.94**	158.7**
53	CMS-10A X EC-601751	-4.71	14.71**	-70.0**	-13.77*	-12.06**	6.59*	-6.82*	3.16	-4.9	4.38	92.47**	209.3**
54	CMS-10A X EC-601978	-7.48 *	18.90**	-8.55 *	30.5**	-11.81**	-0.67	-5.29*	14.49**	-14.52**	0.53	38.80**	94.2**
55	CMS-10A X EC-601725	-2.86	13.24**	-67.3**	-1.57	-6.18*	-0.76	2.88	16.07**	-12.94**	-0.79	114.92**	244.4**
56	CMS-10A X EC-623016	3.85	20.80**	-62.2**	1.39	7.65*	11.90**	-0.72	8.27**	-14.40**	1.19	94.88**	178.9**
	Lowest	-15.98	-8.49	-70.7	-20.14	-23.11	-16.46	-9.73	-12.68	-19.67	-14.92	26.46	71.5
	Highest	19.16	29.14	24.05	67.9	11.04	26.06	9.73	31.1	3.06	8.98	138.4	244.4
	Crosses with positive and significant heterosis	10	25	12	22	7	26	7	27	0	7	56	56
	Crosses with negative and significant heterosis	10	6	36	12	33	6	9	2	12	7	0	0
	S. Em (±)	0.11	0.09	0.05	0.04	0.263	0.227	0.162	0.14	0.147	0.127	6.35	5.5

Results and Discussion

Significant genotypic differences existed for all the agronomic traits among the lines, testers and hybrids. The analysis of variance shows significant differences among the genotypes for all the above said characters studied. Hybridization helps to augment the desirable genes of various parents in one combination. Irrespective of general combining ability of the parents, certain combinations of parents can give superior hybrids **(Table 3).** Among the sunflower hybrids, for days to 50% flowering the heterosis was observed from -7.33% (CMS-207A X EC-623027 (M) to 20.37% (CMS-10A X EC-601751), for plant height the heterosis was ranged from 13.10 per cent (CMS-207A X EC-601978) to 123.2% (CMS-853 A X EC-623027 (Mono), for head diameter the heterosis was ranged from 19.90% (CMS-103A X EC-601725) to 101.02% (CMS-10A X EC-623016), for seed yield (kg/ha) heterotic variation was observed from 42.3% (P-2-7-1A X EC-623016) to 241.3% (CMS-10A X EC-601725), for number of filled seed/ head the heterotic variation was observed from 56.1% (CMS-850A X EC-623021) to 277.3% (P-2-7-1A X EC-601751), for seed filling% the heterosis was ranged from -3.47% (CMS-853A X EC601978) to 40.77% (CMS-853A X EC601751), for 100 seed weight (g) the heterosis was ranged from -8.49% (CMS-852A X EC-623027 (M) to 29.14% (CMS-850A X EC-601978), for 100 seed kernel weight (g) the heterotic variation was observed from -20.14% (CMS-207A X EC-623016) to 67.9% (CMS-850A X EC-623016), for hull content, the heterosis was ranged from -14.46% (CMS-103A X EC-601978) to 26.06% (CMS-103A X EC-623027); for volume weight (g/100 cc) the heterotic variation was observed from -12.68% (CMS-207A X EC-623027) to 31.10% (P-2-7-1A X EC-601978); for oil content%, the heterotic variation was observed from -14.92% (CMS-853A X 623016) to 8.98% (P-2-7-1A X EC-601751); for oil yield (kg/ha), heterotic variation was observed from 71.5% (CMS- EC-623021) to 223.8% (CMS-10A X EC-601725) respectively. Significantly less heterosis was recorded in the case of oil content (%) relative to the parental mean. A total of 6 crosses exhibited significantly better parent heterosis (Heterobeltiosis), for days to 50% flowering for earliness. The significant contribution in the induction of earliness in the above crosses is from CMS-850A, CMS-103A and CMS-10A. The findings have close proximity to Janjal et al. [9], Chandirakala et al. [10], Manivannan et al. [11].

In the sunflower dwarf to medium-tall plant is required because tall plants are prone to lodging therefore, negative heterosis, in this case, is desirable. A perusal of **Table 4** revealed that only a single cross (CMS-207A X EC-623027 showed significant negative mid parent heterosis for days to 50% flowering. The sunflower hybrids CMS-207A X EC-623027 (63.5 days), CMS-10A X EC-623023 (64 days), CMS-10A X EC-601978 (64 days) and CMS-103A X EC-623016 (65days) recorded significantly lower days to 50% flowering.

From our experiment, over the years of study, it was observed that the sunflower hybrids viz. CMS-103A X EC-601725 took minimum 92 days to mature followed by CMS-207A X EC-623027 (94 days), CMS-10A X EC-623023 (95 days) and CMS-10A X EC-601978 (95 days) and CMS-103A X EC-623016 (95 days) respectively. Therefore, these hybrids may be considered as the early maturing hybrids. Head diameter is one of the most important characters related to yield. Large heads accommodate more seeds which help to increase production. A perusal of **Table 3** revealed that many of the hybrids showed significant and positive mid parent heterosis viz. CMS852A X EC-623016 followed by CMS-853A X EC-623027, CMS-852A X EC-623023, PET-89-1A X EC-601916 and CMS-852A X EC-623021 respectively for the said trait under study.

The hybrids, viz. CMS-852A X EC-623023 (935), P-89-1A X EC-623027 (911) CMS-852A X EC-601751 (879), CMS-852A X EC-623027 (M) (856) and CMS-852A X EC-623021 (839) showed significant and positive mid parent heterosis for number of filled grain per head. The % performance of most of these hybrids was significantly superior to the highest yielding check LSFH 171. Gangappa et al. [12] and many other workers also observed a higher magnitude of heterosis for a number of filled seeds in a sunflower. The F1s viz. CMS-852A X EC-623027 (M) (92%), CMS-853A X EC601751 (92%) and CMS-852A X EC601878 (92%), followed by CMS-852A X EC-623021 (91%), CMS-852A X EC-621951 (90%) showed significant and positive mid parent heterosis for seed filling percentage. The % performance of most of these hybrids was significantly superior to the highest yielding check LSFH 171 for grain filling (%). Rathi et al. [13] also observed a higher magnitude of heterosis for higher seed filling (%), 100 seed weight, and head diameter in sunflower.

Oil yield is the important criterion in sunflower which depends on the oil content of the genotype. For oil content, the range of heterosis was -14.98 to 8.98%. Only 2 sunflower hybrids, viz., CMS-10A X EC-623023, and CMS 10A X EC-623027 showed significant positive mid parent heterosis for the oil content (%). For oil yield (kg/ha), as performance per se, most of the hybrids were showed significant positive mid parent heterosis for the same trait PET-89-1A X EC-601916 followed by CMS-852A X EC-601751, CMS-853A X EC623023, CMS-850A X EC-601878, P-2-7-1A X EC-601751, CMS 852A X EC-623021, CMS-10A X EC-601725 and CMS-852A X EC-601725 respectively were found superior ones.

The studies revealed that the best cross combination for semi-dwarf plant height coupled with good seed yield per plant and high oil content were P-2-7-1A X EC-623023 (98 days maturity and seed yield of 2192 kg/ha), CMS-207A X EC-601751 (98 days maturity and seed yield of 1962 kg/ha), P-2-7-1A X EC-601751 (100 days maturity and seed yield of 1872 kg/ha) and P-89-1AA X EC-601751 (101 days maturity and seed yield of 2144 kg/ha) respectively.

Seed yield is an exceedingly complex quantitative trait in sunflower, whose control involves a series of genes, because practically all traits have some influence, to a large or small measure, on the seed yield. However, heterosis occurred practically for all traits with different magnitudes. The highest positive heterosis observed for seed yield was explained by the sum of favorable values of heterosis for the different traits correlated with seed yield. A similar type of report was found by Suresha et al. [14] and Patil et al. [15] and Raghavendra et al. [16].

Among the 56 sunflower hybrids under study, CMS-853A X EC-623027 (2462 kg/ha, 77 days to flower, and oil yield of 881 kg/ha, 100 seed weight 6.2 g), CMS-853A X EC-623023 (seed yield 2428 kg/ha, 75 days to flower, oil yield of 861 kg/ha, 100 seed weight 6.2 g), CMS-852A X EC-623016 (2306 kg/ha, 75 days to flower, oil yield of 840 kg/ha and 100 seed weight 5.9 g) possessed superiority for seed yield, oil yield as well as high 100 seed weight and high volume weight. As per the performance per se and heterosis study, it was revealed that the best cross combination for semi-dwarf plant height coupled with good seed yield per plant and high oil content are P-2-7-1A X EC-623023 (98 days maturity, seed yield of 2192 kg/ha), CMS 207A X EC-601751 (98 days maturity, seed yield of 1962 kg/ha), CMS-850A X EC-601751 (99 days maturity and seed yield of 1861 Kg/ha), CMS 852A X EC-601725 (100 days maturity, seed yield of 2072 kg/ha), and CMS-10A X EC-601725 (100 days maturity and seed yield 2240 kg/ha and oil yield 842 kg/ha), P-89-1A X EC-601751 (100 days maturity and seed yield 2245 kg/ha, oil yield 835 kg/ha) and P-2-7-1A X EC-601725 (100 days maturity and seed yield 2192 kg/ha, oil yield 824 kg/ha) respectively. Among 56 hybrids studied, the desirable negative significant mid parent heterosis was manifested by F1 viz., CMS-103A X EC-601978 (23.6%) followed by P-89-1AA X EC-601978 (25.8%), CMS-853A X EC601978 (24.8%), CMS-853A X EC-601751, CMS-852A X EC601978 (27.3%), CMS-10A X EC-623023 (29%), CMS-207A X EC-623016 (29.5%), PET-89-1A X EC-601916 (30.2%) and CMS-852A X EC-601751 (30.5%) respectively. The parental lines viz. CMS-852A, CMS-103 A, PET-89-1A and Rf line viz. EC-601978, EC-601751 and EC-623016 for hull content have contributed to desirable significant negative heterosis in the above hybrids for low hull content in a desirable negative direction. The high volume weight is having a direct relation with the weight of seed yield and high oil percentage and therefore, high oil yield per unit area. The desirable positive significant mid parent heterosis for the same traits was observed in F1s viz., CMS-103A X EC-601978 (48.5 g) followed by P-2-7-1A X EC-601978 (45.6 g), CMS-853A X EC601978 (45.3 g), P-89-1AA X EC-601751 (45.3 g), P-89-1AA X EC-601978 (45.2 g), CMS-852A X EC-601725 (43.8 g), CMS-853A X EC-623016 (43.6 g), CMS-850A X EC-623023 (43.6 g), 207A X EC-601751 (43.5 g) respectively. All the three sunflower hybrids were high oil percentage and significantly superior over the LSFH-171 **(Tables 3-5)**. The parental lines viz. CMS-852A, CMS-853A, CMS-103A, PET-89-1A and Rf line viz. EC-601978, EC-601725, EC-623023 and EC-623016 with might have significant positive GCA effects for volume weight which might be contributed for desirable significant positive heterosis in the above hybrids for high volume weight in a positive desirable direction.

In sunflower, 100 seed weight is having a direct relation with the weight of seed yield. The desirable positive significant mid parent heterosis for the same traits were observed in F1s viz., Pet-2-7-1A X EC-623016 (6.8 g) followed by P-2-7-1A X EC-623021 (6.6 g), CMS-853A X EC-623027 (M) (6.1 g), CMS-853A X EC-623023 (5.9 g), CMS-103A X EC-601978 (5.7 g), CMS-207A X EC-601878 and CMS-10A X EC-623021, CMS-10A X EC-623016 respectively. The parental lines viz. P-2-7-1A, CMS-853A and CMS-207A, EC-623027 (M), EC-623023, EC-623023 and EC-601978 have contributed to desirable significant positive heterosis among the above hybrids for high 100 seed weight.

Hybridization helps to augment the desirable genes of various parents in one combination. Irrespective of the general combining ability of the parents, a certain combination of parents can give superior hybrids **(Table 3)**. Higher seed volume weight in sunflower is often associated with higher seed yield as well as oil content. CMS 852A and CMS-853A testers recorded significant values; therefore, these parents can be considered as the good combiners for high oil content as well as for high seed yield. The studies revealed that the best cross combinations for high 100 seed weight and high volume weight were CMS-852A X EC-601725, P-2-7-1A X EC-623016, CMS-207A X EC-601751 and CMS-207A X EC-601978. Recently high heterotic hybrids for seed yield were also reported by Tyagi et al. [17], Chandra et al. [18], Parameshwarappa et al. [19], Gaurishankar et al. [20].

These crosses involved at least one parent with high GCA effects and had high seed yield and other yield attributing traits at performance per se. The results revealed that it is desirable to involve parents contrasting for GCA effects to realize a high frequency of hybrids with high overall performance per se and heterotic status. Thus, the present study clearly established the superiority of L × H/H × L type of crosses followed by H × H category of crosses. This type of observation was also brought out in the studies by Tyagi et al. [21], Supriya et al. [22] and Sahane et al. [23].

Conclusion

Most of the crosses exhibited high heterosis, especially for seed and oil yields. However, mean heterosis was comparatively low for hull and oil contents. The study on heterosis in sunflower showed that the crosses with favorable characteristics such as oil and seed yields, oil and hull contents could be bred from correctly selected parents. The cross CMS-853A X EC-623027 reached the breeding aim mentioned above, especially for high vigor in seed and oil yields. CMS-103A X EC-601878 and PET-89-1A X EC-601878 showed the negative heterosis for the hull rate. The evaluation of inbred lines based on all three criteria of heterosis showed that the crosses of the female line 853-A and the male line EC-623027 revealed higher hybrid vigor in cross combination than the other lines and testers for yield attributing traits.

Under present study, the genotypes, EC-601878 and EC-601751 with regard to all measured traits, CMS-852A, CMS-103A and P-89-1A for seed yield, oil content and low hull rate could be used for increasing hybrid vigor in future sunflower breeding programs as well as the sunflower genotypes, viz., CMS 852A, CMS-853A, and EC-623027, EC-623023 appeared to possess high concentration of additive genes for seed yield and component traits and, therefore, these parents can be considered as the good combiners for heterosis breeding program for seed and oil yield improvement in sunflower.

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