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Studies on heterosis and heterobeltiosis for seed yield and yield attributing traits of sunflower (*Helianthus annuus* L.) in high saline soil of West Bengal

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ABSTRACT

Increasing seed and oil yields is the top priority of most sunflower breeding programs. Getting benefit from use of heterosis is the main purpose in sunflower hybrid breeding. The objectives of this study were to determine performance of sunflower varieties and to measure the vigor of sunflower hybrids. In 2014-15 and 2015-16, sunflower hybrids were evaluated for four important yield components, yield performance, standard and regular heterosis, and heterobeltiosis, in West Bengal agro climatic conditions. Based on observations in this research, Heterobeltiosis for seed yield ranged between 36.0 and 94per cent in 2015-16 and 40.2-104per cent in the year-2014-15 respectively. The standard heterosis for seed yield range from -8.8 to 25.9per cent. Based on observations in this research, seed yield of hybrids, the maximum hybrid vigor (heterobeltiosis) was measured in the PET-2-7-1A X EC-601751, CMS-103A X EC-623023, respectively as heterosis 94.5 and 89 per cent in 2015-16 and 104 and 102 per cent, respectively in the 2014-15 growing season. Negative heterotic values for hull rate are preferred by sunflower breeders. Maximum negative values of standard heterosis for hull rate, both in 2014-15 and in 2015-16 (-12.9% and -11.9%, respectively), were registered in 852A X EC-623016(-16%) and PET-89-1A X EC-601878 (-15.7) in 2015-16. Lower hull rate in the aforementioned crosses was accompanied by higher heterobeltiosis and regular heterosis values for this trait too. Standard heterotic values measured in the hybrids for low hull content were recorded in the hybrids CMS-103 A X EC-601878(-26%) and PET-89-1A X EC-601878(-19%), respectively. Heterosis for oil yield was as high as this for seed yield, especially in 2014-15. The values of heterobeltiosis for seed yield was changed between 40 and 105 per cent, The values of heterobeltiosis and standard heterosis changed between 36 and 94 per cent, and -8.8 to 25.9 per cent.respectively in the year 2015-16. Maximum values of 86.55 and 85 per cent for heterobeltiosis were recorded for oil yield in PET-2-7-1A XEC-601751 in 2015-16. The maximum standard heterosis (31.2%) was registered in the cross CMS-853 A X EC-623027 (M) followed by PET-2-7-1A XEC-601751(29.6%) and CMS-853 AX EC 623023(23.9%) respectively in the growing season of 2015-16.Among inbred lines, the female 853A,CMS-852-A and the male EC-623027 and EC-601878 exhibited higher hybrid vigor than the others.

Keywords: Coastal saline belts, heterosis, heterobeltiosis, oil, seed, sunflower, yield

Sunflower (*Helianthus annuus* L.) is grown worldwide, mostly as a source of vegetable oil and proteins. In India, sunflower is cultivated in an area of 0.7 million ha with a total productivity of 0.50 million tones (Padmaiah *et.al.*,2015) and with an average productivity of 713kg ha^{-1} (Anonymous, 2016) and in West Bengal the sunflower has enormous potentiality to grown in *rabi* season by replacing mustard (Dutta,2015). 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 (Fick and Miller, 1997).

Seed oil and hull content are the main characteristics determining oil yield in sunflower. Oil content is a quantitatively inherited trait and it varies considerably depending on cultivar and also environmental effects (Miller, 1987). There is a negative correlation between hull and oil contents of seed. Miller and Fick (1997) indicated that most of the increase in seed oil from past sunflower breeding and selection resulted from decreases in hull percentage of seed.

After the discovery of the cytoplasamic male sterility (CMS) lines (Leclercq in 1969) and fertility restorer genes by Kinman in 1970 which shifted the interest from population breeding to heterosis breeding. Heterosis of sunflower has been exploited only over the past few decades. Hybrid sunflower became a reality with the discovery of cytoplasmic male sterility and effective male fertility restoration system during 1970. Pathak *et al*. (1983) detected negative increases in oil content of sunflower hybrids and they concluded that the reasons for that were possibly overdominance effects of the genes conferring low oil content and the same frequencies of these genes in hybrids and their parents. Heterosis, defined as the unusual growth and yield of heterozygous hybrids from two less vigorous homozygous parents, has been explored during last 70 years. Heterosis can be

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considered as one of the most important contributions of the genetics to agriculture, with large consequences on agricultural yields. Farmers generally prefer hybrids developed by utilizing heterosis to cultivars and grow them on large areas. Sunflower hybrids predominate the sunflower productions in Turkey and rest in the world (Kaya, 2004). Although the hybrid vigor can be generally defined as the superiority of individuals from the F1 generation in relation to their parents, it can also be considered as the superiority of new hybrids over currently grown commercial hybrids. This phenomenon has been analyzed for many different traits of sunflower. Researchers have observed considerable increases of heterosis for seed and oil yield and oil content in sunflower. Reddy *et al*. (2009) measured heterosis rates higher than 100% and heterobeltiosis rates higher than 10% in sunflower hybrids. Giriraj and Virupakshappa (1992) and Virupakshappa *et. al.* (1997) observed that the hybrid vigor for sunflower seed yield remained at the same level in different environments. This study was conducted to determine sunflower parents and hybrids with the highest potential and hybrid vigor for seed and oil yields and hull and oil contents.

MATERIALS AND METHODS

The present experiment was started in 2014-15 with aimed to (i) Breeding and Evaluate the performance of the sunflower hybrids in respect to yield and yield component and (ii) To identify the superior sunflower hybrids suitable for the *rabi-summer* season in West Bengal agro-climatic condition. The objective(s) of the present study was identify the Standard (economic) heterotic combinations, and not to concentrate the study the Heterobeltiosis.

The present experiment which was carried out during *rabi* season, 2015-16 and 2016-17 at research farm under AICRP Sunflower, Nimpith Centre. A total of 18 sunflower hybrids were evaluated including the three National check hybrids, KBSH-44, LSFH-171 and DRSH-1 in a Randomized complete block design with three replications. The plot size was 4.5 x 3.0 m. The area representing the medium to high soil salinity (EC 2.0-3.0dS/m) throughout the sunflower growing season. The soil texture was clay loam in “On station” and “MLT” plots. Three irrigations were provided during the cropping period. One foliar spray was given with Boron (@ 2g lit^{-1}. of water in ray floret stage. The row plot^{-1} were five in number with a row spacing of 60 cm and plant to the plant was 30 cm. A uniform dose of fertilizer @80 kg N,40 Kg P_2O_5 and 40 kg K_2O ha^{-1} 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 plant^{-1} (cm), seed weight head^{-1} (g), 100-seed weight (g), husk weight(g) and hull content (%),volume weight (seed weight in gram per 100 ml) and oil content(%). The seed yield (kg ha^{-1}), oil percentage and oil yield (kg ha^{-1}) were estimated on a plot basis. The mean values were subjected to statistical analysis.

The magnitude of relative heterosis, heterobeltiosis and standard heterosis were estimated to facilitate the exploitation of hybrid vigor through heterosis breeding. The % heterosis was calculated from the formula:

% heterosis (HTS)=100 × (F1-MP) / MP, where F1 is the hybrid progeny and MP is the “mid-parent” or the average of the parents (P1+P2) / 2.

The % heterobeltiosis was calculated from the formula: % heterobeltiosis (HTB) = 100 × (F1-HP) / HP, where heterobeltiosis is the parent with highest phenotypic expression.

The standard heterosis was calculated from the formula: % standard heterosis (SHS) =100 ×(F1-SA) / SA,

where SA is the average of commercial standard hybrids *viz*. of LSFH-171 or KBSH-53 or DRSH-1

Commercial standard checks were LSFH-171 or DRSH-1 as registered National check sunflower hybrids in India by ICAR-IIOR, Hyderabad.

RESULTS AND DISCUSSION

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.

Maximum hybrid vigor (heterobeltiosis) was measured in the PET-2-7-1A XEC-601751 , CMS-103A X EC-623023, CMS-10A X EC-623023 and CMS-103 A X EC-601878 respectively as heterosis 94.5, 89, 88.7 and 87.7 per cent in 2015-16 and 104,102, 95 and 94 per cent respectively in the 2014-15 growing season. The lowest heterobeltiosis for seed yield was 36.7 and 40.5 per cent respectively were observed in the CMS-

207A X EC-623016 and 853A XEC-601725 in the 2015-16 growing season. (Table 1). The evaluation of hybrids for heterosis breeding based on standard heterosis led to the identification of different sets of hybrids. Therefore, the evaluation of hybrids based on all three criteria would be more meaningful. Viewed from this angle, the following hybrids were considered as best: Heterobeltiosis for seed yield ranged between 36.0 and 94% coupled with significant from 36.6-94.9% (2015-16) and 40.2-104% in the year-2014-15 respectively. The standard heterosis for seed yield range -8.8 to 25.9%.

Based on the average values of the two years, 853A crosses among the female lines, followed by CMS-852-A, CMS-103-A, PET-2-7-1A, PET-89-1A and CMS-207-A were best female parents regarding the regular heterosis for seed yield. The lines EC-623027 followed by EC-601878, EC-623023 and EC-601751, were best restorers. Regarding heterobeltiosis, 853A,CMS-852-A, CMS-103-A,PET-2-7-1A, PET-89-1A were best female parents and EC-623027, EC-601878, EC-623023 and EC-601751were best male parents. The values of heterosis in sunflower are highly variable for the different agronomic traits, especially for seed yield. Positive heterosis for this trait has been maintained from -20.9 to 21.2 per cent. High heterosis values for sunflower seed yield, similar to those obtained in this research, were reported by Giriraj and Virupakshappa (1992). Heterosis for oil yield was as high as this for seed yield, especially in 2014-15. The values of heterobeltiosis for seed yield was changed between 40 and 105 per cent. The values of heterobeltiosis and standard heterosis changed between 36 and 94, and -8.8 to 25.9 per cent respectively in the year 2015-16 (Table 2). Maximum values of 86.55 and 85 per cent for heterobeltiosis were recorded for oil yield in PET-2-7-1A XEC-601751, 10A XEC-623023 followed by CMS-103 A X EC-601878(76.5%), CMS-207A X EC-601878(73.2%) and PET-2-7-1A X EC-601878(73.1%) in 2015-16. The maximum standard heterosis (31.2%) was registered in the cross CMS-853 A X EC-623027 (M) followed by PET-2-7-1A XEC-601751(29.6%), CMS-853 AX EC 623023(23.9%), CMS-207A X EC-601878(22.8%) CMS-103 A X EC-601878 (22.1%), CMS-852AX EC-601751(20.4%) and PET-2-7-1A X EC-601878 (20.1%) respectively in the growing season of 2015-16. Recently high heterotic hybrids for seed yield were also reported by Chandra *et al*. (2013), Thombare *et al*. (2007)

Based on the calculated values for 2015-16, maximum heterobeltiosis values were found in the crosses of 853A-A crosses among the female lines, followed by CMS-852-A, CMS-103-A,PET-2-7-1A, PET-89-1A and CMS-207-A crosses. The crosses of EC-623027 exhibited highest positive heterotic values over better parent, followed by EC-601878, EC-623023, EC-601751, EC-601725, EC-623021and EC-623016 crosses.Among the restorer lines, the maximum regular heterosis in 2015-16 was determined in EC-601878 hybrids followed by EC-623027, EC-623021, EC-601751 and EC-601725. The maximum heterobeltiosis for oil yield was registered in EC-601878 cross hybrids (100%), followed by EC-623027 EC-601751, EC-601725 and EC-623023 respectively. Based on the values for the two years, the crosses 853-A × EC-623027, PET-2-7-1A XEC-601751, 853-A × EC-623023, CMS-207A X EC-601878, PET-2-7-1A X EC-601878, CMS-852AX EC-601751 and CMS-103A X EC-623023 respectively from the females 853-A and 852-A and the males EC-601778,EC-623023 and Ec-601751 respectively showed higher standard heterosis for oil yield than the other crosses.

The crosses had higher heterosis values for seed and oil yields in 2014-15 than in 2015-16. The main reason for the low yields in 2014-15 was a long drought (including high salinity throughout the growing season) that continued for a better part of the sunflower vegetation period. The heterosis values for the measured traits were higher in 2014-15, indicating that the climatic conditions in 2014-15 acted in a positive way, allowing a better expression of the potentials of the hybrids with regards to plant development. These highly heterotic crosses from 2014-15, involving highly significant x highly significant combiners, exhibited considerable additive genetic variance, which can be exploited for developing high yielding pure lines through progeny selection. The similar type of findings also reported by Patil *et al.* (2012), Jondhale, *et al.*(2012).

Negative heterotic values for hull rate are preferred by sunflower breeders. Maximum negative values of standard heterosis for hull rate, both in 2014-15 and in 2015-16 (-12.9% and -11.9%, respectively), were registered in 852A X EC-623016(-16%) and PET-89-1A X EC-601878 (-15.7) followed 103A × EC-601718 (-14.5%) for the year 2015-16 (Table 3). Lower hull rate in the aforementioned crosses was accompanied by higher heterobeltiosis and regular heterosis values for this trait too. Usefulness of crosses in heterosis breeding depends on their mean performance, SCA effects and magnitude of heterosis. Regarding the value of regular heterosis for hull rate, the most favorable performance among the females was shown by 850A crosses among the female lines, followed by CMS-103 A and PET-89-1A crosses. The crosses of EC-601878 followed by EC-

Table 1: Specific cross combination for Heterobeltiosis and Standard/Economic Heterosis : 2014-15 and 2015-16 for seed and oil yield and hull content(%)

Hybrid combination	2015-16			2014-15			2015-16			2014-15			
	Seed Yield Pl^{-1}(g)	Seed yield ($kg.ha^{-1}$)	h^2 for seed yield (%)	h^2/ SD -Ch-1 (%)	h^2 for seed yield (%)	Oil 2015-16 %	Oil Yield. ($Kg.ha^{-1}$)	h^2 for Oil yield (%) ($kg.ha^{-1}$)	h^2 for Oil yield ($kg.ha^{-1}$)/ (%) SD-Ch-2 DRSH-1	h^2 for Oil yield (%) ($Kg.ha^{-1}$)	h^2 for Hull Cont. (%)	h^2 for Hull Cont. / SD-Ch-1 (%)	h^2 for Hull Cont. SD-Ch-2 (%)
853 A X EC-623027 (M)	21.2	1168	58.7	25.9	60.4	32.6	381	53.6	31.8	56.2	18.9	-7.8	0.6
852A X EC-601751	19.7	1082	60.3	16.6	66.5	31.9	345	46.2	19.4	50.8	9.8	-0.8	8.2
89-1A X EC601878	17.4	956	63.4	3.0	61.6	34.2	327	63.5	13.1	60.2	-15.7	-25.8	-19.0
103 A X EC601878	18.9	1040	87.7	12.1	91.2	33.9	353	76.5	22.1	80.2	-14.0	-32.1	-26.0
850 A X EC601878	17.9	982	69.3	5.8	72.5	34.6	340	68.3	17.6	70.5	-7.4	-20.2	-13.0
853 AX EC 623023	20.3	1116	51.6	20.3	57.2	32.1	358	44.4	23.9	47.2	-8.0	-20.2	-13.0
207A X EC-601878	19.0	1045	68.0	12.6	71.5	34.0	355	73.2	22.8	74.5	4.1	-8.3	0.0
850A X EC-623016	15.4	846	45.9	-8.8	41.6	33.9	287	42.1	-0.7	38.2	2.6	-11.4	-3.3
853 A X EC623023	19.9	1096	48.9	18.1	54.5	31.4	344	38.7	19.0	47.6	-2.8	-14.4	-6.6
P-2-7-1A X EC601878	18.5	1018	75.5	9.7	86.2	34.1	347	73.5	20.1	84.2	0.6	-11.4	-3.3
207A X EC-623023	17.9	984	58.2	6.0	63.5	32.1	316	54.1	9.3	65.8	-4.4	-15.8	-8.2
853A X EC623021	18.6	1022	38.9	10.1	46.5	33.0	337	35.9	16.6	43.2	2.0	-28.5	-22.1
852A X EC623016	15.5	852	26.2	-8.2	35.2	31.6	269	18.0	-6.9	27.6	-16.0	-27.4	-20.8
850A X EC-601751	19.0	1046	80.3	12.7	98.6	32.4	339	67.8	17.3	86.5	-13.2	-21.6	-14.5
P-2-7-1A X EC-601751	17.6	968	66.9	4.3	75.2	31.1	301	50.5	4.2	64.2	1.5	-8.3	0.0
P-89-1A X EC-601916	18.0	992	69.6	6.9	78.6	31.4	311	55.5	7.6	65.1	2.6	-11.4	-3.3
852AX EC-601751	19.7	1085	60.7	16.9	72.0	32.1	348	47.5	20.4	60.7	-1.2	-10.8	-2.7
P-89-1A X EC-601751	17.9	984	68.2	6.0	84.5	32.8	323	61.5	11.8	63.4	-2.8	-12.2	-4.2
P-2-7-1A X EC-623016	15.6	857	47.8	-7.7	55.2	33.3	285	45.4	-1.4	56.2	11.5	-3.6	5.1
P-2-7-1A XEC-601751	20.5	1128	94.5	21.6	102	33.1	373	86.5	29.1	96.5	3.4	-6.6	1.8
10A X EC-623023	18.8	1036	88.7	11.6	104	32.1	333	85.0	15.2	98.2	3.1	-9.1	-0.9

Contd.

Table 1 Contd.

Hybrid combination	2015-16			2014-15			2015-16			2014-15			
	Seed Yield Pl^{-1}(g)	**Seed yield ($kg.ha^{-1}$)**	**h^2 for seed yield (%)**	**h^2/ SD - Ch-1 (%)**	**h^2 for seed yield (%)**	**Oil 2015-16 %**	**Oil Yield. ($Kg.ha^{-1}$)**	**h^2 for Oil yield (%) ($kg.ha^{-1}$)**	**h^2 for Oil yield ($kg.ha^{-1}$)/ (%) SD-Ch-2 DRSH-1**	**h^2 for Oil yield (%) ($Kg.ha^{-1}$)**	**h^2 for Hull Cont. (%)**	**h^2 for Hull Cont. / SD-Ch-1 (%)**	**h^2 for Hull Cont. SD-Ch-2 (%)**
207AX EC-623016	15.5	851	36.8	-8.3	47.5	34.0	289	41.0	0.0	44.1	7.7	-6.9	1.5
P-2-7-1A X EC-601878)	19.0	1045	80.2	12.6	92.7	32.6	341	70.5	18.0	82.5	11.9	-1.4	7.6
852 AX EC-623021	17.9	986	46.1	6.3	57.2	31.6	312	32.2	8.0	45.8	-2.5	-14.4	-6.6
10A X EC-601725	17.5	962	75.2	3.7	84.5	33.1	318	47.2	10.0	49.6	-0.3	-6.6	1.8
853A X EC-601725	18.8	1036	40.8	11.6	47.2	31.1	322	29.8	11.4	34.5	1.5	-5.0	3.6
852 A X EC-601725	19.2	1056	56.4	13.8	61.4	32.8	346	46.6	19.7	52.6	-3.2	-8.3	0.0
10 AX EC-601878	17.2	948	72.7	2.2	77.5	33.7	319	59.5	10.4	56.8	-2.8	-14.4	-6.6
207A X EC-601878	17.7	974	56.6	5.0	51.2	33.1	322	57.1	11.4	50.5	7.9	-5.0	3.6
103A X EC-623023	19.1	1048	89.2	12.9	95.1	32.8	344	84.0	19.0	86.2	-3.8	-16.6	-9.1
10A X EC-623021	17.4	956	65.4	3.0	61.5	32.2	308	57.1	6.6	58.5	0.3	-11.9	-3.9
207A X EC-601725	17.7	974	56.6	5.0	49.2	32.4	316	54.1	9.3	57.2	0.3	-5.0	3.6
207A X EC-623021	17.9	985	58.4	6.1	67.5	33.1	326	59.0	12.8	68.5	10.4	-3.0	5.7
207A X EC-623027	17.2	948	52.4	2.2	59.6	34.4	326	50.9	12.8	52.6	20.7	-6.4	2.1
10 AX EC-623023	16.7	921	59.3	-0.8	66.3	34.0	313	70.2	8.3	78.6	-3.8	-16.6	-9.1
10 AX EC-623016	15.3	841	45.5	-9.4	58.2	33.7	283	44.4	-2.1	61.5	8.0	-6.6	1.8
KBSH-44	15.9	875	-	-	-	25.2	221	-	-	-			
LSFH-171(Sd.Ch-2)	16.9	928	-	-	-	27.3	253	-	-	-			
DRSH-1 (Sd.CH-1)	15.2	835	-	-	-	34.6	289	-	-	-			
G. Mean	**19.6**	**1075**	-	-	-	**33.2**	**412.2**	-	-	-			
SEm(±)	**0.8**	**30.1**	-	-	-	**0.7**	**23.2**	-	-	-			
LSD.(0.05)	**2.2**	**90.2**	-	-	—	**2.1**	**68.6**	-	-	-			
C.V.(%)	**8.8**	**9.6**	-	-	-	**8.2**	**9.4**	-	-	-			

Table 2 : Values of specific sunflower cross combination /hybrids for yield and yield attributing characters -2015-16

Sl. No.	Hybrid combination	Pl. Ht (cm)	Hd. Dia. (cm)	50% Flow.	Seed yield ($kg.ha^{-1}$)	100 seed wt.(g)	Hull Cont. (%)	No. of Filled grain/Hd	Gr. Fill. %	Vol. Wt (g/100 cc)	Oil %	Oil Yld. ($Kg.ha^{-1}$)
1.	CMS-853 A X EC-623027 (M)	129	11.5	65.5	1276	5.6	33.3	414	90.0	39.6	32.2	411
2.	CMS-852A X EC-601751	120	12.0	66.5	1208	4.1	35.8	536	91.6	40.0	32.5	393
3.	PET-89-1A X EC-601878	110	10.2	66.3	1045	4.5	26.8	422	90.7	41.8	34.9	365
4.	CMS-103 A X EC-601878	116	11.2	63.8	1156	5.3	24.5	397	93.7	44.9	34.6	400
5.	CMS-850 A X EC-601878	98	9.6	63.3	1128	4.5	28.8	456	91.3	36.7	35.3	398
6.	CMS-853 AX EC 623023	128	11.0	65.5	1240	4.5	28.8	501	90.0	40.4	32.8	407
7.	CMS-207A X EC-601878	116	10.6	68.2	1132	4.8	33.1	429	88.7	36.3	34.7	393
8.	CMS-850A X EC-623016	96	9.3	61.9	917	4.1	32.0	407	91.2	40.3	34.6	317
9.	CMS -853 A X EC623023	135	11.2	66.5	1178	5.4	30.9	397	90.6	39.8	32.0	377
10	PET-2-7-1A X EC-601878	112	9.8	65.8	1125	4.1	32.0	499	91.2	42.2	34.8	392
11.	CMS -207A X EC-623023	125	10.3	66.5	1016	4.0	30.4	462	91.1	36.9	32.8	333
12.	CMS-853A X EC623021	121	10.9	64.0	1136	5.0	25.8	413	89.5	41.9	33.7	383
13.	852A X EC-623016	123	9.1	65.5	908	5.3	26.2	311	88.6	39.5	32.2	292
14.	CMS-850A X EC-601751	93	10.6	62.5	1162	4.6	28.3	459	92.7	39.4	33.1	385
15.	P-2-7-1A X EC-601751	124	11.1	68.5	1075	5.0	33.1	391	90.6	39.4	31.7	341
16.	PET-89-1A X EC-601916	127	10.3	67.5	932	4.1	32.0	413	87.1	41.7	32.0	298
17.	CMS-852AX EC-601751	119	11.1	65.5	1175	4.3	32.2	497	91.2	38.5	32.8	385
18.	PET-89-1A X EC-601751	108	11.3	68.8	1108	4.7	31.7	429	88.5	42.5	33.5	371
19.	PET-2-7-1A X EC-623016	109	10.4	67.7	952	6.2	34.8	279	88.2	39.2	34.0	324
20.	PET-2-7-1A XEC-601751	114	11.0	66.0	1065	5.0	33.7	387	90.6	40.2	33.8	360
21.	CMS-10A X EC-623023	125	11.8	65.0	1080	4.0	32.8	491	90.0	36.6	32.8	354
22.	CMS-207AX EC-623016	120	9.8	64.9	945	3.9	33.6	441	91.2	37.2	34.7	328
23.	P-2-7-1A X EC-601878	127	11.5	68.5	1161	4.7	35.6	449	92.1	40.0	33.3	387
24.	CMS 852 AX EC-623021	131	10.8	67.5	1132	4.5	30.9	457	91.2	37.0	32.2	365

Contd.

Table 2 Contd.

Sl. No.	Hybrid combination	Pl. Ht (cm)	Hd. Dia. (cm)	50% Flow.	Seed yield (kg.ha^{-1})	100 seed wt.(g)	Hull Cont. (%)	No. of Filled grain/Hd	Gr. Fill. %	Vol. Wt (g/100 cc)	Oil %	Oil Yld. (Kg.ha^{-1})
25.	CMS-10A X EC-601725	120	12.2	66.5	1106	4.7	33.7	428	89.0	41.3	33.8	374
26.	CMS-853A XEC-601725	135	12.8	66.5	1152	4.3	34.3	487	90.0	37.0	31.7	365
27.	CMS-852 A X EC-601725	117	11.7	62.0	1176	5.0	33.1	428	90.6	40.5	33.5	394
28.	CMS-10 AX EC-601878	124	10.8	63.8	1045	4.5	30.9	422	90.2	37.3	34.4	359
29.	CMS-207A X EC-601878	112	10.1	66.1	1082	4.6	34.3	428	91.2	37.9	33.8	366
30.	CMS-103A X EC-623023	122	10.4	63.1	1086	4.3	30.1	459	90.5	39.0	33.5	364
31	CMS -10A X EC-623021	130	10.4	68.0	1018	5.0	31.8	370	91.1	37.7	32.9	335
32	CMS207AX EC-601725	121	10.1	68.0	1082	4.3	34.3	458	89.0	37.0	33.1	358
33	CMS207AX EC-623021	128	10.4	67.0	1028	4.5	35.0	415	92.2	35.2	33.8	347
34	CMS-207AX EC-623027	122	9.5	66.1	992	4.2	33.8	429	90.2	36.6	35.1	348
35	CMS-10 AX EC-623023	132	10.3	65.5	1056	4.3	30.1	447	91.2	39.0	34.7	366
36	CMS-10 AX EC-623016	116	10.5	67.2	932	5.0	33.7	339	90.6	38.4	34.4	321
	KBSH-44	**130**	**10.9**	**70.5**	**972**	**4.6**	**37.6**	**384**	**89.5**	**33.3**	**25.7**	**250**
	DRSH-1	**123**	**10.6**	**68.5**	**928**	**5.0**	**33.0**	**337**	**92.2**	**37.5**	**35.3**	**328**
	LSFH-171	**127**	**11.0**	**70.5**	**1032**	**4.6**	**36.1**	**408**	**90.6**	**33.8**	**27.9**	**288**
	G. Mean	**120.1**	**10.7**	**66.2**	**1075**	**4.6**	**32.0**	**425.**	**90.5**	**38.8**	**33.2**	**412.2**
	SEm(±)	**2.3**	**0.34**	**1.1**	**30.1**	**0.2**	**0.5**	**20.3**	**0.5**	**0.9**	**0.7**	**23.2**
	LSD(0.05)	**6.8**	**1.0**	**3.1**	**90.2**	**0.6**	**1.4**	**60.4**	**1.5**	**2.7**	**2.1**	**68.6**
	C.V.(%)	**9.2**	**5.1**	**6.8**	**9.6**	**5.8**	**8.2**	**9.2**	**7.5**	**7.1**	**8.2**	**9.4**

623016, EC-601751,EC-601751 had the lowest heterotic values among the restorer lines. Standard heterotic/ Economic heterotic values measured in the hybrids for low hullcontent were recorded in the hybrids CMS-103 A X EC-601878(-26%), PET-89-1A X EC-601878(-19%), 852A X EC-623016(-16%) and CMS-850A X EC-601751(-13%) respectively. Lowest heterobeltiosis values for hull rate were demonstrated followed by CMS-103 A and PET-89-1A crosses. The crosses of EC-601718 exhibited highest negative heterotic values over better parent, followed by EC-623016, EC-601751, EC-601751 crosses. 850A, 103A and PET-89-1A crosses had more favorable values of standard heterosis for hull rate than the other crosses in the research study.

Heterosis values for oil content were low. The average standard heterosis ranged between 1.5 and 11.5 per cent in the experiment (Table 4). Low heterotic values were also observed for heterobeltiosis (between -15.3 and -0.8%). Low heterosis results similar to these were obtained by Pathak *et. al*. (1993) for sunflower oil content. Heterotic values measured in the hybrids for oil content were mostly negative and there was no superiority of parents of crosses or standards. Highest values of heterobeltiosis was recorded by in the cross CMS-207AX EC-623027, CMS-207AX EC-623023,CMS-207AX EC-623016,PET-2-7-1A X EC-601878 respectively. The higher values for standard heterosis were observed in CMS-850 A X EC-601878(11.5%), CMS-10 AX EC-623023(11.1%) PET-89-1A X EC-601878(10.5%), PET-2-7-1A X EC-601878(10.2%), CMS-207A X EC-601878(9.9%) and CMS-850A X EC-623016(9.5%), CMS-10 AX EC-623023(9.9%) and CMS-10 AX EC-623016 (8.9%) respectively against the best national check hybrids LSFH-171(27.3% oil), KBSH-44(25.3% oil) and DRSH-1 (33.4% oil) respectively.

Based on average heterotic values of inbred lines, negative results were obtained in almost all of them for oil content. The ranking of the female lines was CMS-103A, CMS-850-A, and PET-89-1A for regular heterosis and as well as for heterobeltiosis. The ranking of the restorer lines was EC-601718,Ec-601751 and Ec-601725 for regular heterosis and for heterobeltiosis. Due to a drought and salinity (Ec-2.0-3.0ds/m) that occurred in 2014-15 and 2015-16, low oil content values were measured in the sunflower crosses in the research. 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 most favorable performance was shown for seed yield (105 % in 2014-15 and 94 % in 2015-16).

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 853A X EC-623027 reached the breeding aim mentioned above, especially for high vigor in seed and oil yields. The following crosses demonstrated high hybrid vigor and superior performance over standard hybrids in the studied characteristics: the cross 853-A × EC-623023, CMS-207A X EC-601878, PET-2-7-1A X EC-601878, CMS-852AX EC-601751for seed and oil yields, the crosses CMS-103 A X EC-601878 and PET-89-1A X EC-601878 for thin hull rate and high oil content. 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 than the other lines regarding the characteristics examined in this research. The male line EC-601878and EC-601751 with regard to all measured traits, the female line 852 A,103A and P-89-1A with regard to seed and oil yields and the female lines CMS103A and CMS-852A with regard to high oil content and low hull rate could be used for increasing hybrid vigor in future sunflower breeding programs.

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