APPLICATION OF HETEROSIS FOR YIELD AND YIELD ATTRIBUTING TRAITS IN BREEDING FOR DEVELOPMENT OF HIGH-YIELDING SUNFLOWER (*HELIANTHUS ANNUUS* L.) HYBRID

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ABSTRACT

A set of 56 hybrid combinations, developed by crossing 8 CMS lines and 7 diverse testers, was evaluated to identify potential parental genotypes for breeding new high yielding sunflower hybrids. The hybrid combinations were assessed for their *per se* performance and combining ability. Significant differences were recorded for parents versus hybrids for yield and its related traits, suggesting the presence of substantial heterotic responses. The inbred lines and their F_1hybrids differed significantly in their mean values of the traits under the present study. 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 considerable amount of heterosis for most of the traits except hull content(%), oil content and seed filling per cent. Most of the crosses exhibited high heterosis especially for 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. CMS-103A x EC-601878 and PET-89-1A x EC-601878 showed the negative heterosis for thin hull rate and high oil content. The evaluation of inbred lines based on different yield attributing 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. The male line EC-601878 and EC-601751 with regard to all measured traits, the female line CMS-852 A, CMS-103A and P-89-1A with regard to seed, oil yields and low hull rate could be used for increasing hybrid vigor in future sunflower breeding programs. Present study revealed that for improvement of oil content, the ranking of the female lines was CMS-103A, CMS-850-A and PET-89-1A and for restorer lines were EC-601718, EC-601751 and EC-601725 for regular heterosis. CMS 852A and CMS-853A and EC-623027 showed superiority for 100 seed weight and high volume weight, and, therefore, these parents can be considered as the good combiners for heterosis breeding programme for yield and yield attributing traits improvement in sunflower.

***Key words*: Sunflower, heterosis, heterobeltiosis, seed 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 programme is a continuous programme which started in our country early 1980s. Sunflower hybrid breeding was started economically in discovering **CMS** by Leclercq in 1960 and restorer genes by Kinman in 1970 (Miller and Fick, 1997).

Sunflower (*Helianthus annuus* L.; 2n=2x=34) is the second important source of vegetable oil in the world due to its low to moderate production requirements, high oil quality, protein content, and utilization of all plant parts and it is considered as good quality oil due to high concentration of poly unsaturated fatty acids . The importance of sunflower as an oilseed crop in India is of very recent origin and date backs to three decades. But its contribution towards attaining self-sufficiency in edible oil as well as to "yellow revolution" in the country is note worthy (Mangala Rai, 2002). In India, first ever sunflower hybrid developed by 1980s, gave a fillip and renewed the interest in crop because of well defined CMS system. Hybrids are preferred over varietal populations because of their high productivity in terms of seed and oil yield. At present the sunflower is grown on about 0.55 million ha (Anonymous 2017) in Indian sub continent.

Globally, the cytoplasmic male-sterility (CMS) systems have played a significant role in increasing the productivity in a number of economically important crops through its use in commercial exploitation of hybrid vigour. To reap the benefits of this technology, it is imperative that the hybrids, wherever they are grown, have full fertility restoration, high yield and broad adaptation. Efforts to exploit its natural out-crossing to break the yield plateau through hybrid breeding began with the discovery of a stable CMS system CMS by Leclercq in 1960 (Miller and Fick, 1997). First sunflower hybrids were produced in US in 1972 and reached 80% of production in five years (Miller and Fick, 1997). Single-cross hybrids quickly became dominantly in sunflower cultivars in the world. Hybrids were preferred by farmers due to its high yield and quality potential, homogeneity, same time maturing and easy possibility of cultural applications both in India and the world. Use of hybrids was reached over 95% in India sunflower production in last 10 years.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. The study of combining ability is useful in testing of hybrid combinations and in choice of the desirable parents for use in the heterosis breeding (Fick 1976).The hybrid technology in Sunflower has a potential to break the decades-old low yield plateau but it is still new and under the process of rooting. Therefore, to achieve a sustainable success in this endeavour in future, it is imperative that new high-yielding hybrids are produced at regular intervals; and therefore, new hybrid parental lines with high combining ability, disease resistance, high yield potential and wide adaptation are bred and made available to sunflower breeders. Hence as a backup strategy, it is important that a strong and vibrant hybrid parent breeding programme is established. In this context, the genetic characterization of advanced breeding inbred lines and diverse germplasm with respect to their *per se* performance, combining ability, and hybrid vigour is carried out. In the present study these parameters were estimated in 34 testers and three CMS lines and based on the results some potential parents for use in breeding high yielding hybrid and inbred cultivars were identified.

The selection of parent is one of the important aspect in developing the potential hybrid which is practiced after testing of parents for their combining ability effects. It is also useful in understanding the type of gene action controlling various traits. Line × Tester analysis (Kempthorne, 1957) has been widely used for genetic analysis as it is an efficient technique for evaluating large number of inbreds. Development of hybrids is the primary objective of most sunflower breeding programs in the world. National sunflower hybrid (development) breeding programme is continuous programme which started in our country in early 1980s.General combining ability effects and additive x additive gene action are theoretically fixable. On the other hand, specific combining ability attributed to non-additive gene action may be due to dominance or epitasis or both and is not fixable. The presence of non-additive genetic variance is primary justification for initiating the hybrid programme. The success of hybrid programme based on the results of combining ability depends on the extent of genetic parameters remaining stable over environments (Fick 1978).

In India, the sunflower is grown on about 0.55 million ha (Anonymous, 2018) and mostly grown in the states of Karnataka, Maharastra, AP and Tamil Nadu with potential scope of growing in the non-traditional areas like West Bengal (Dutta, 2011). In West Bengal, Sunflower is second important oilseed crop after rapeseed-mustard during *rabi*-summer season and it was grown on about 21,000 ha in *rabi* season,2016-17. Due to short winter spell and delayed and heavy rainfall during rainy season, the sowing of mustard was delayed which ultimate 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 wide scope to replace the rapeseed-mustard cultivation with high yield potentiality.

MATERIALS AND METHODS:

The present experiment was started in 2014-15 with aimed to breeding and evaluate the performance of the sunflower hybrids in 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 to study the Heterosis and Heterobeltiosis to identify the good heterotic combinations/ the superior sunflower hybrids suitable for growing in *rabi-summer* season in variable agro-climatic conditions in West Bengal.

The experiment was carried out during December 2014-15 and 2015-16 under AICRP Sunflower, Nimpith Centre of RAKVK Research Farm, South 24 Parganas, West Bengal. The soil texture was clay loam in "On station" plots. Three irrigations were provided during the cropping period. With a view to identify the lines with good combining ability and to identify the good specific cross combination for further exploitation, the present investigation was undertaken in the 2014-15 and 2015-16 at AICRP on Sunflower(ICAR-IIOR) Research Farm, Nimpith centre, Ramkrishna Ashram Krishi Vigyan Kendra, Nimpith, South 24 Parganas, West Bengal-743338,India to study the Heterosis and Heterobeltiosis for seed yield and certain yield attributing components in sunflower (*Helianthus annuuas L.*) involving 7 restorer and 8 CMS. The crossing was affected in the 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 where in each replications were represented by five rows of three meter length. A total of 56 sunflower hybrids developed (2014 and 2015 Off season / *Kharif* season) at AICRP-Sunflower, Nimpith along with parents were evaluated .Three irrigations were provided during the cropping period. One foliar spray was given with Boron (@ 2g/lit. of water in 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. Uniform dose of fertilizer @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/hull content (%), No. of filled grain and unfilled grain per head, volume weight (g/100cc) and the seed yield/ plant. The seed yield (kg/ha), oil percentage and oil yield (kg/ha) were estimated on plot basis. The mean values were subjected to statistical analysis. The data pertaining to seed yield and other yield attributing traits for these test hybrids along with the checks are presented in **Table 3**.

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	Seed Filling %	100 seed Wt.(g)	100 kernel Wt.(g)	Hull Cont. %	Vol. Wt. (g/100cc)	Oil cont. %	Seed yield/ (Kg/ha)	Oil Yield (Kg/ha)
Location	1	212.46	2978.5**	28.01	14545.1**	176.9	1.182	0.250	26.22	39.01	10.58	441289.2**	35704.6**
Repl./Loc	2	27.14	540.8	9.03	6907.4	26.21	2.887	1.870	5.93	19.17	18.21	143396.6*	47090.2
Line	7	194.04**	9449.0**	25.2**	21097.7**	36.11**	3.522	1.641**	57.04**	35.63**	9.49**	1965372.0**	229786.2**
Tester	6	74.85**	4816.9**	20.23**	17476.8**	17.35**	0.640	0.547**	55.80**	14.16**	6.49*	958346.7**	108418.7**
Line X Tester	42	31.86**	510.12**	21.50**	27690.3**	10.51**	0.654	0.394**	16.30**	13.60**	2.38	176794.2**	21047.8**
Line X LC	7	0.382	6.92	0.031	286.2	0.216	0.004	0.0009	0.034	0.028	0.007	1501.09	116.0
Tes X LC	6	0.360	4.27	0.036	69.14	0.199	0.003	0.001	0.009	0.033	0.004	1278.4	114.6
L X T X LC	42	0.290	2.37	0.026	80.30	0.015	0.002	0.0008	0.054	0.010	0.005	752.3	80.27
Error	110	0.002	0.261	0.002	155.21	0.029	0.003	0.001	0.008	0.006	0.002	98.22	28.83

- ***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 seeds/Hd.**	**Seed. Filling %**	**Vol. Wt. (g/100cc)**	**Oil %**	**Oil Yield (kg/ha)**
CMS Line(L)												
CMS-853A	67.9	118.6	11.5	1385.0	5.7	3.98	30.2	298.0	83.3	42.8	36.2	774.9
CMS-852A	65.6	123.5	11.8	1140.0	5.0	3.40	32.1	280.0	86.8	42.2	35.6	791.8
CMS-850A	66.0	116.0	12.8	1090.0	4.9	3.48	28.9	286.0	90.2	42.0	35.4	605.2
CMS-103A	65.0	129.3	12.3	1035.0	5.3	3.90	26.5	321.0	87.8	45.4	36.2	516.4
PET-2-7-1A	70.4	131.8	13.2	1150.0	5.5	3.68	33.1	364.0	86.9	43.7	35.2	740.5
CMS-207A	68.8	136.0	12.6	1100.5	4.6	3.14	31.8	478.0	88.0	40.4	35.4	677.8
PET-89-1A	71.0	107.8	10.5	1210.0	4.9	3.46	29.3	408.0	84.0	45.4	35.2	704.6
CMS-10A	69.4	141.9	12.4	1225.0	5.3	3.64	31.4	340.0	87.1	42.1	34.0	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**	**43.00**	**35.40**	**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	1020.0	5.6	4.14	26.0	393	77.5	45.3	38.9	718.1
EC-623023	71.3	95.8	7.5	825.0	5.3	3.76	29.1	283	85.2	43.0	38.2	706.4
EC-623021	64.0	87.4	8.6	780.0	5.0	3.53	29.5	262	87.5	42.0	42.5	671.6
EC-601978	66.3	87.4	11.6	770.0	4.9	3.45	29.6	286	87.9	42.9	42.5	727.8

EC-601751	62.0	91.2	9.0	720.0	5.4	3.78	30.0	256	85.5	43.0	42.0	563.8
EC-601725	70.5	84.2	9.8	880.0	5.2	3.50	32.7	308	83.0	44.6	41.8	731.9
EC-623016	69.8	86.2	6.4	690.5	5.1	3.62	29.0	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**	**91.00**	**8.97**	**812.2**	**5.21**	**3.68**	**29.41**	**289.00**	**84.70**	**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 -2A . Performance of the parents for yield and yield contributing characters.

Name of the parent	Plant height	Head Diameter	Days. to 50% flowering	Seed yield/plant	100 seed weight	No. of Filled seeds/head	Autogamy % (Gr. Filling%)	Hull Cont.(%)	Vol. Wt. (g/100cc)	Oil Cont. %
CMS-850A	-6.25**	-0.22*	-1.82**	- 6.08*	-1.28*	3.25	0.35	-0.56*	-0.55*	-0.55*
CMS-852A	8.65**	0.66**	-0.61*	13.27**	1.22*	16.25**	0.32	0.45*	0.57*	-0.58*
CMS-10A	11.45**	0.45**	-0.55*	5.42	-1.08*	11.65**	0.41	0.45*	-0.48*	-0.65*
CMS-853A	14.45**	0.81**	0.41**	14.42**	1.62*	18.75**	0.32	0.41*	0.71*	-0.71*
P-89-1A	9.56**	0.52**	-0.35	10.55**	-1.16*	12.65**	0.71*	0.49*	0.35*	-0.55*
CMS-103A	-9.87**	-0.26*	-2.31**	-7.42*	-1.56*	3.45*	0.83*	-0.78*	-0.38*	-0.48*
P-2-7-1A	9.02**	0.46**	-0.29	10.51**	-1.02*	14.81**	0.65	0.41*	0.47	-0.56*
CMS-207A	7.12*	0.36**	-0.31	8.28*	-1.16*	12.58**	0.37	0.41*	-0.41*	-0.55*
S.Em(±)	**2.62**	**0.14**	**0.12**	**3.48**	**0.05**	**4.67**	**0.25**	**0.27**	**0.31**	**0.31**
EC-601878	3.41*	0.81 **	-0.72*	5.08*	-1.18*	11.51**	0.73*	-0.25*	-0.47*	0.39*
EC-623023	8.85**	0.89**	1.17**	10.08**	-1.18*	13.18**	-0.25	0.32*	0.55*	-0.37*
EC-623016	8.25**	0.49**	-1.14*	6.27**	-1.42**	7.68	0.65*	-0.35*	-1.06**	-1.25**
EC-623027	11.25**	1.58**	1.54**	14.27**	1.22**	17.44**	0.35	0.25*	1.21**	-0.38**
EC-601751	8.21**	1.17**	-0.72*	10.08**	0.75*	12.25*	-0.38	0.36*	-0.55*	-0.55*
EC-601725	6.28**	1.09**	-0.55*	14.55**	-1.28*	10.61**	-0.27	0.25*	0.57*	-1.26**
EC-623021	12.25**	1.60**	0.64*	11.23**	-1.02*	11.86**	-0.45	-0.40	-1.05**	-1.05**
S.Em(±)	**4.28**	**0.21**	**0.38**	**1.28**	**0.07**	**3.28**	**0.36**	**0.56**	**0.41**	**0.36**

Table-3: Sunflower hybrids (F_1s) 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 seed/Hd.	Autogamy %	100 seed wt(g)	100 seed Kernel Wt (g)	Hull Cont. %	Vol. Wt. (g/100cc)	Oil %	Oil Yield (Kg/ha)
1.	CMS-853 A X EC-623027(mono)	75.0	184.5	16.2	2462.0	731.5	87.0	6.1	4.1	32.1	42.8	35.7	879.0
2.	CMS-853 A X EC-623023	74.5	176.5	15.9	2428.0	746.0	87.5	5.9	4.1	29.8	43.0	35.6	864.5
3.	CMS-853 A X623021	73.5	170.0	15.7	2292.0	792.5	87.0	5.6	4.0	27.8	43.7	36.4	834.5
4.	CMS-853 A X EC601751	69.0	158.0	15.4	1861.0	660.0	91.5	5.3	3.9	27.3	42.6	36.8	685.0
5.	CMS-853 A X EC601978	68.5	145.0	15.5	1575.5	543.5	86.5	5.4	4.0	24.8	45.3	37.4	589.0
6.	CMS-853 A XEC601725	75.5	182.5	16.1	2278.0	805.0	87.0	5.5	3.7	33.1	40.0	35.2	802.0
7.	CMS-853 A X623016	72.0	160.5	15.0	2072.0	682.5	87.5	5.5	3.8	31.9	43.8	37.2	770.5
8.	CMS-852A X EC-623027(M)	76.0	175.0	15.1	2270.0	855.5	92.0	4.9	3.4	29.8	40.0	35.8	813.0
9.	CMS-852A X EC-623023	76.0	170.0	15.4	2328.0	935.0	88.5	4.6	3.0	34.6	43.2	36.1	840.5
10	CMS-852A X EC-623021	77.5	174.0	15.4	2272.0	839.0	91.0	5.0	3.5	29.8	40.0	35.8	813.5
11.	CMS-852A X EC-601751	72.5	160.1	15.4	2284.0	879.0	90.0	4.8	3.3	31.1	41.6	36.4	831.5
12.	CMS-852A X EC-601978	66.0	153.0	15.0	1761.0	637.5	91.5	5.1	3.7	27.3	42.6	36.8	648.0
13.	CMS-852A X EC-601725	70.5	155.0	16.7	2072.0	682.5	87.5	5.5	3.8	31.9	43.8	37.2	770.5
14.	CMS-852A X EC-623016	73.0	175.5	15.3	2306.0	720.5	88.5	5.8	4.3	25.2	42.7	35.8	825.5
15.	CMS-850AX EC-623027 (M)	69.0	133.0	15.2	1861.0	673.5	91.5	5.1	3.7	27.3	42.6	36.8	685.0
16.	CMS-850A X EC-623023	64.0	122.5	13.8	1472.0	605.0	91.0	4.5	3.1	30.9	43.6	38.4	565.0
17.	CMS-850AX EC-623021	63.0	112.0	13.2	1340.0	516.0	90.0	4.8	3.4	29.0	42.2	37.2	498.5
18.	CMS-850A X EC-601751	69.0	133.0	15.4	1861.0	673.5	91.5	5.1	3.7	27.3	42.6	36.8	685.0
19.	CMS-850A X EC-601978	65.0	92.5	9.6	1500.0	553.5	94.0	5.0	3.6	27.8	39.7	37.0	555.0
20.	CMS-850A XEC-601725	69.0	112.0	13.7	1836.0	664.5	91.5	5.1	3.7	27.3	42.6	37.2	683.0
21.	CMS-850X EC-623016	68.0	122.5	13.3	1472.0	605.0	91.0	4.5	3.1	30.9	43.6	38.4	565.0
22.	CMS-103AX EC-	67.5	138.5	13.5	1350.0	476.0	89.0	5.1	3.3	34.4	43.2	38.7	518.5

	623027(M)												
23.	CMS-103A X EC-623023	67.0	135.0	12.7	1340.0	516.0	90.0	4.8	3.4	29.0	42.2	37.2	498.5
24.	CMS-103AX EC-623021	66.0	132.0	12.7	1348.0	516.0	90.0	4.8	3.4	29.0	42.2	37.2	499.5
25.	CMS-103A X EC-601751	67.0	130.1	13.4	1472.0	533.0	91.5	5.1	3.5	30.3	42.6	36.8	541.5
26.	CMS-103A x EC-601978	66.0	124.5	12.8	1533.0	487.5	90.5	5.7	4.4	23.6	48.5	38.4	589.0
27.	CMS-103A X EC-601725	62.5	120.5	12.2	1232.0	484.5	91.0	4.7	3.3	29.8	43.4	38.1	469.5
28.	CMS-103AX EC-623016	64.0	124.0	12.7	1340.0	485.0	90.0	5.1	3.5	31.0	42.2	37.2	498.5
29.	P-2-7-1A X EC-623027	73.0	184.0	16.4	2094.0	743.0	89.0	5.1	3.3	34.4	43.2	37.0	775.0
30.	P-2-7-1A X EC-623023	68.0	145.5	15.7	2192.0	735.5	88.5	5.4	3.7	32.5	43.5	37.6	824.5
31	P-2-7-1A X EC-623021	70.0	168.5	14.9	1872.0	514.5	90.0	6.6	4.4	33.6	42.4	37.8	707.5
32	CP-2-7-1AX EC-601751	76.0	177.5	15.8	2340.0	770.5	87.5	5.5	3.8	31.9	42.6	35.2	824.0
33	P-2-7-1AX EC-601978	64.5	137.5	11.5	1340	457.5	90.0	5.3	3.6	30.8	45.6	38.7	518.5
34	P-2-7-1AX EC-601725	68.0	145.5	15.7	2192.0	735.5	88.5	5.4	3.7	32.5	43.5	37.6	824.0
35	P-2-7-1AX EC-623016	70.0	155.5	14.9	1878.0	501.0	90.0	6.8	4.5	33.6	42.4	37.8	710.0
36	CMS-207AX EC-623016	63.5	142.5	14.0	1567.0	616.0	92.0	4.7	3.1	32.6	39.6	39.0	611.5
37	CMS-207A X EC-623023	73.0	142.5	14.7	2194.0	922.0	88.0	4.4	3.1	29.3	39.9	36.4	799.0
38	CMS-207-1A X EC-623021	70.5	167.0	14.4	1886.0	696.5	90.0	5.0	3.3	33.8	38.0	37.5	707.5
39	CMS-207AX EC-601751	68.0	145.5	15.7	1962.0	658.0	88.5	5.4	3.7	32.5	43.5	37.6	737.5
40	CMS-207AX EC-601978	67.0	115.0	13.5	1431.0	498.0	90.5	5.2	3.5	31.9	39.2	38.5	551.0
41	CMS-207AX EC-601725	71.5	172.5	14.8	2017.0	776.0	86.0	4.8	3.2	33.1	40.0	36.8	742.5
42	CMS-207AX EC-623027	68.5	153.0	14.0	1547.0	665.5	92.0	4.3	2.9	32.4	40.2	38.5	596.0
43	P-89-1AX EC-623027(M)	73.5	180.0	15.6	2218.0	911.0	88.0	4.5	3.1	30.9	45.1	37.6	834.0
44	P-89-1A X EC-623023	73.0	168.5	15.0	1974.0	793.0	89.0	4.6	3.1	31.6	39.7	36.8	726.5
45	P-89-1A A X EC-623021	71.0	148.5	14.2	1856.0	714.0	89.0	4.8	3.3	31.6	39.7	36.8	683.0
46	P-89-1A AX EC-601751	71.0	154.0	15.1	2144.0	761.0	85.5	5.1	3.5	30.6	45.5	37.4	802.0
47	P-89-1A AX EC-601978	68.5	123.0	12.0	1445.0	533.5	91.5	5.0	3.7	25.8	45.2	38.8	561.0
48	P-89-1A X EC-601725	73.0	148.5	15.0	1960.0	787.5	89.0	4.6	3.1	31.6	39.7	36.8	721.5
49	P-89-1AX EC-623016	67.0	136.5	13.9	1611.0	583.0	90.0	5.1	3.4	33.1	41.0	37.5	604.5
50	CMS-10AX EC-623027	72.5	167.5	15.4	1722.0	577.5	88.0	5.4	3.7	30.6	40.8	36.5	628.5
51	CMS-10A X EC-623023	64.0	154.0	14.6	1380.0	531.0	92.0	4.8	3.4	29.0	42.2	38.6	532.5
52	CMS-10A A X EC-623021	71.5	162.5	15.2	1722.0	577.5	88.0	5.4	3.7	30.7	40.8	36.5	628.5
53	CMS-10AX EC-601751	73.5	142.5	14.7	1967.0	826.5	87.0	4.4	3.0	31.6	39.6	36.4	716.0
54	CMS-10AX EC-601978	64.5	119.0	12.8	1306.0	482.5	92.0	5.0	3.5	29.8	40.3	38.2	499.0
55	CMS-10AX EC-601725	70.5	156.5	15.4	2240.0	795.0	86.0	5.1	3.4	32.5	44.6	37.6	842.5
56	CMS-10AX EC-623016	68.0	145.5	15.0	1792.0	601.0	87.5	5.4	3.7	32.5	41.5	38.2	685.0
	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)	80.0	194.0	15.6	2256	634	85.5	5.24	3.24	38.1	38.78	33.7	760
	DRSH-1(CH-2)	75.0	168.7	14.8	1978	557	87.2	5.68	3.76	34.5	41.36	38.0	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**	**1.0**	**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

	Hybrid combination	**Days to 50% Flow.**		**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-853 A x EC623027(mono)	**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-853 A 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-853 A 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-853 A 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-853 A 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-853 A x	**11.03**	14.24*	57.76	87.39**	53.99	67.54*	101.15	175.0	115.67	214.4*	3.18	35.24**

	EC601725	**	*	**		**	*	**	**	**	*		
7.	CMS-853 A 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-850AX 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 xEC-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-850x 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 EC623023	-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	0.00	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 EC601751	-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 xEC-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.	CMS-103A x EC-601725	-6.02 *	-3.30	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	2.10	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	-3.20	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**	8.60	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	CMS-207A x EC-623016	-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	CMS-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	CMS-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	CMS-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	CMS-207A x EC-601978	-2.19	2.98	8.30	13.1**	38.41**	44.31**	43.32**	89.2 **	53.65**	105.7**	0.68	5.26
41	CMS-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	CMS-207Ax EC-623027	-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-89-1Ax 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-89-1A A x EC-623021	4.80	12.14**	31.50 **	72.64**	33.96 **	75.59**	100.58 **	161.5**	109.10 **	159.8**	4.46	9.70*
46	P-89-1A 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-89-1A 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 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**	10.00	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	-11.50	-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 nagetive and significant heterosis	**6**	**01**	**01**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	SEm (±)	**0.03**	**0.02**	**0.62**	**0.53**	**0.07**	**0.06**	**11.40**	**9.87**	**8.30**	**7.20**	**0.20**	**0.17**

Continue:Table:4: Heterobeltiosis and heterosis of sunflower hybrids for yield attributing characters

Sl. No	Hybrid combination	100 seed wt(g)		100 kernel weight		Hull Cont.%		Vol. Wt. (g/100cc)		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-853 A X EC-623027(mono)	5.49 *	7.96*	1.80	3.50	8.37*	10.14 **	-2.84	0.23	-4.93	-2.28	95.77**	152.1**
2.	CMS-853 A 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-853 A X623021	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-853 A X EC601751	0.00	2.20	-36.4**	3.49	-18.78**	-8.70 *	-0.58	2.50	-15.60 **	-6.54 *	65.36 **	122.6**
5.	CMS-853 A XEC601778	-3.60	11.70**	22.8**	3.21	-22.91**	17.61 **	5.59 *	18.06**	-4.35 **	2.63	46.61 **	76.9**
6.	CMS-853 A X EC601725	0.00	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 X EC-623016	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(mono)	-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	-1.00	-0.65**	0.00	-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 **	0.00	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**	-1.70	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- 850AX EC-623027	-3.35	-4.46	-1.48	7.63*	0.70	-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-850AX 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 XEC-601725	0.50	20.97**	5.61 *	65.0**	-6.97*	-11.36**	-1.62	3.99	-14.40**	-3.63	81.29**	133.7**
21.	CMS-850X 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-103AX 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	0.00	44.49**	92.9**
24.	CMS-103AX 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.	CMS-103A XEC-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-103AX 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	5.80	93.27**	155.6**
30.	P-2-7-1A X EC-623023	-7.22*	0.00	-2.17	-2.01	2.64	4.34	0.35	13.02**	2.45	2.30	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	P-2-7-1A X EC-601751	1.65	5.77 *	-63.8**	4.90	-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-2-7-1AX 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-207AX EC-623016	-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 *	-2.30	-0.82	-0.40	127.47**	186.3**
38	CMS-207-1A x EC-623021	0.00	1.30	-7.61 *	-2.70	-5.52*	14.80 **	-6.03**	13.04**	-13.62**	-3.54	96.66**	152.7**
39	CMS-207AX 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-207AX 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-207AX 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-207AX EC-623027	-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-89-1AX EC-623027	-15.98**	12.75**	-23.12**	-13.6**	0.60	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 **	-4.80	3.35	-2.18	0.00	95.43**	174.4**
45	P-89-1A A X EC-623021	-4.33	-1.04	-1.30	-8.31 *	-11.91**	6.95 *	-3.64	4.39	-5.58 *	-13.98	79.62**	157.1**

											**		
46	P-89-1A AX 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-89-1A AX EC-601978	-1.00	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 *	4.70	-14.04**	-4.66	81.28**	169.9**
49	P-89-1AX 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-10AX 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*	2.30	**-5.35***	-0.34	-0.82	**8.43****	-3.67	6.93 *	45.59**	120.0**
52	CMS-10A A X EC-623021	4.85	11.29**	5.49 *	7.6***	**-10.75****	3.90	-2.97	**5.84****	-16.84**	-4.64	67.94**	158.7**
53	CMS-10AX EC-601751	-4.71	14.71**	-70.0**	**-13.77***	**-12.06****	6.59 *	**-6.82***	3.16	-4.90	4.38	92.47**	209.3**
54	CMS-10AX 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-10AX 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	**31.10**	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**	**06**	**36**	**12**	**33**	**06**	**9**	**2**	**12**	**7**	**0**	**0**
	SEm(±)	**0.11**	**0.09**	**0.05**	**0.04**	**0.263**	**0.227**	**0.162**	**0.140**	**0.147**	**0.127**	**6.35**	**5.50**

RESULTS AND DISCUSSION:

Significant genotypic differences were 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 combination of parents can give superior hybrids (Table-3). Among the sunflower hybrids, for days to 50% flowering, the heterosis was observed from -7.33 per cent (CMS-207A x EC-623016) to 20.37 per cent (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 per cent (CMS-853 A x EC-623027(Mono), for head diameter , the heterosis was ranged from 19.90 per cent (CMS-103A x EC-601725) to 101.02 per cent (CMS-10A x EC-623016), for seed yield(kg/ha), heterotic variation was observed from 42.3 per cent (P-2-7-1AX EC-623016) to 241.3 per cent (CMS 10AX EC-601725), for number of filled seed/head, the heterotic variation was observed from 56.1 per cent (CMS-850A x EC-623021) to 277.3 per cent (P-2-7-1A x EC-601751), for seed filling %, the heterosis was ranged from -3.47 per cent (CMS-853A x EC601978) to 40.77 per cent (CMS-853 A x EC601751), for 100 seed weight(g) the heterosis was ranged from -8.49 per cent (CMS-852A x EC-623027(mono) to 29.14 per cent (CMS-850A x EC-601978), for 100 seed kernel weight(g) the heterotic variation was observed from -20.14 per cent (CMS-207A x EC-623016) to 67.9 per cent (CMS-850A x EC-623016), for hull content, the heterosis was ranged from -14.46 per cent (CMS-103A x EC-601978) to 26.06 per cent (CMS-103A x EC-623027); for volume weight(g/100 cc) the heterotic variation was observed from -12.68 per cent (CMS-207A x EC-623027) to 31.10 per cent (P-2-7-1A x EC-601978); for oil content %, the heterotic variation was observed from -14.92 per cent (CMS-853 A X623016) to 8.98 per cent (P-2-7-1A x EC-601751); for oil yield (kg/ha), heterotic variation was observed from 71.5 per cent (CMS-850A x EC-623021) to 223.8 per cent (CMS-10A x EC-601725) respectively. Significantly less heterosis was recorded in the case of oil content (%) relative to parental mean. A total of 6 crosses exhibited significant 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 with Janjal *et al.* (2016), Chandirakala *et al.* (2016), Manivannan *et al.* (2015).

In 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 single cross (CMS-CMS-207A X EC-623016 showed significant negative mid parent heterosis for days to 50% flowering. The sunflower hybrids CMS-207A x EC-623016(63.5days), 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 the present 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-623016(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 considerd as the early maturing hybrids. Head diameter is one of the most important character related to yield. Large heads accommodate more seeds which help to increase the production. A perusal of Table 3 revealed that many of the hybrids showed significant and positive mid parent heterosis *viz*. CMS-852A x EC-623016 followed by 853A x EC-623027, 852A x EC-623023, PET-89-1A x EC-601916 and CMS-852 A 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 *per se* performance of most of these hybrids was significantly superior to highest yielding check LSFH 171. Gangappa *et al.* (1994) and many other workers like also observed higher magnitude of heterosis for number of filled seeds in sunflower. The F1,*viz.* CMS-852A x EC-623027(M) (92.%), CMS-853 A 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. Rathi *et al.* (2016) also observed higher magnitude of heterosis for higher seed filling %, 100 seed weight, head diameter in sunflower. Oil yield is the important criteria in sunflower which depends on 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), *per se* performance of most of these hybrids were showed significant positive mid parent heterosis for the same trait among them PET-89-1A x EC-601916 followed by CMS-852A x EC-601751, CMS-853 A 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 2192kg/ha), CMS-207A x EC-601751 (98 days maturity and seed yield of 1962kg/ha), P-2-7-1A x EC-601751(100days maturity and seed yield of 1872 kg/ha) and P-89-1A x EC-601751(101days maturity and seed yield of 2144kg/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. Similar type of report was found by Suresha *et al.* (2016) and Patil *et al.* (2016) and Raghavendra *et al*. (2004). 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 6.2g), CMS-853A x EC-623023 (seed yield 2428kg/ha,75 days to flower, oil yield of 861 kg /ha,100 seed weight 6.2g), CMS-852A x EC-623016 (2306kg/ha,75 days to flower, oil yield of 840 kg /ha and 100 seed weight 5.9g) 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 2192kg/ha), CMS 207A x EC-601751 (98 days maturity, seed yield of 1962kg/ha), CMS-850A x EC-601751(99 days maturity and seed yield of 1861Kg/ha), CMS 852A x EC-601725 (100 days maturity, seed yield of 2072kg/ha), and CMS-10A x EC-601725(100days maturity and seed yield 2240kg /ha and oil yield 842 kg/ha), P-89-1A x EC-601751(100days maturity and seed yield 2245 kg /ha, oil yield 835 kg /ha) and P-2-7-1A x EC-601725(100days 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-89-1A 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%) and 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 for desirable significant negative heterosis in the above hybrids for low hull content in desirable negative direction. High volume weight is having direct relation with 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 F_1s *viz.*,CMS-103A x EC-601978 (48.5g) followed by P-2-7-1A x EC-601978(45.6g), CMS-853 A x EC601978(45.3g), P-89-1A x EC-601751(45.3g), P-89-1A x EC-601978(45.2g), CMS-852A x EC-601725(43.8g),CMS-853 A x EC-623016(43.6g), CMS-850A x EC-623023(43.6g), CMS-207Ax EC-601751(43.5g) respectively (Table-3 and Table-4). The parental lines *viz.* CMS-852A, CMS-853A CMS-103 A, 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 positive desirable direction.

In sunflower, 100 seed weight is having direct relation with 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(6.8g) followed by P-2-7-1A x EC-623021(6.6g), CMS-853 A x EC-623027(M) (6.1g),CMS-853 A x EC-623023(5.9g),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(table-4).The parental lines *viz.* P-2-7-1A ,CMS-853A and CMS-207 A and EC-623027(M), EC-623023, EC-623023 and EC-601978 has contributed for 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 general combining ability of the parents, 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-2-7-1Ax EC-623016, CMS-207A x EC-601751 and CMS-207A xEC-601978.

Recently high heterotic hybrids for seed yield were also reported by Chandra *et al*. (2013), Parameshwarappa *et al*.(2008), Gaurishankar *et al*.(2007) and Thombare *et al*. (2007).

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 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 observations was also brought out in the studies by Tyagi *et al.* (2017), Sahane *et al.* (2016) and Supriya *et al.* (2017).

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. Based on average heterotic values of inbred lines, negative results were obtained in almost all of them for oil content. 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 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. The male line EC-601878 and EC-601751 with regard to all measured traits, the female line CMS-852 A, CMS-103A and P-89-1A with regard to seed, oil yields and low hull rate could be used for increasing hybrid vigor in future sunflower breeding programs.

Present study revealed that for improvement of oil content, the ranking of the female lines was CMS-103A, CMS-850-A and PET-89-1A and for restorer lines were EC-601718, EC-601751 and EC-601725 for regular heterosis. CMS 852A and CMS-853A and EC-623027 showed superiority for 100 seed weight and high volume weight, therefore, therefore, these genotypes 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 programme for yield and yield attributing traits improvement in sunflower.

References:

Allard R W 1960. Principles of plant breeding. John Wiley and sons Inc. New York. Anonymous (2018-19). https://www.sunflowernsa.com/stats/worldsupply. Ann. Report, Directors report, Dept. of Ag., GOWB-2016-17:25-26.

Chandra, B.S., Ranganatha A.R.G. and Kumar S.,(2013). Heterosis studies for yield and it's components in sunflower hybrids over locations. *Madras Agric. J.,* 100 (**13**):23-29.

Chandirakala, R., Premnath, A. and Manivannan, N. 2015. Meteroglyph analysis on genetic diversity in germplasm accessions of sunflower (*Helianthus annuus* L.). *Journal of Oilseeds Research* 32(2): 170-173.

Gangappa, E. and Virupakshappa, K., 1994, Interrelationship of yield and yield components in sunflower (*Helianthus annuus* L.). *Mysore. J. Agric. Sci.* **28**(1): 1-4. Gaurishankar, V., Ganesh M., Ranganatha, A. R. G., Suman A. and Shridhar, V. (2007). Combining ability studies in diverse CMS sources in sunflower *(Helianthus annuus* L). *Ind. J Agric. Res*., **41**(3): 171-176.

Jondhale, A.S., Goud, I.S. and Praveenkumar, B. (2012). Combining Ability and Gene Action Studies in Diverse CMS Sources in Sunflower (*Helianthus annuus* L.) *International Journal of Science and Research,* **3**(12): 2183-2187. Kmpthorne O. 1957**.** An Introduction of Genetics Statistics. The Lowa University Press.

Kinman, M.L., 1970.New development in the USDA and State Experiment Station, Sunflower breeding programme. In: *Proc. of the Fourth Int. Sunflower Conference,* Memphis, Tennessa, pp.181-183.

Leclercq, P., 1969.Line sterile cytoplasmic quechezktournesol. *Ann. Amelior Planta,* **12**: 99-106.

Makanda, I., Matamela, T., Mashingaidze, K., Chigeza, G., Musanya, J., and Muungani, D. (2012). Breeding investigations into the gene action an agronomic performance of sunflower (*Helianthus annus* L.) traits based on F1 Top-Cros hybrids. *Helia*., **35**(56): 31-40.

Janjal, S.M., Vaidya, E.R., Nichal, S.S., Ratnaparkhi, R.D. and Rathi, S.R. 2016. Combining ability studies in sunflower (*Helianthus annuus*L.). *Advances in Life Sciences* 5(21): pp.10043-10048.

Rathi, S.R., Nichal, S.S., Vaidya, E.R., Ratnaparkhi, R.D. and Janjal, S.M. 2016. Combining ability for yield contributing traits and oil content in sunflower (*Helianthus annuus*L.). *International Journal of Tropical Agriculture*. Vol. 34(4): pp.1043-1049.

Manivannan, N., Chandirakala, R. and Abirami, S. 2015. Evaluation of new CMS lines for heterosis breeding in sunflower (*Helianthus annuus* L.). *Advances in life sciences* 5(5): 1909-1912.

Patil,R., Gouds., Kulkarni, V. and Bankar, C. (2012). Combining ability and gene action studies for seed yield and it's components in sunflower (*Helianthus annus* L.). *E.J. Plant Breeding*, **3**(3):861-867.

Patil T.R., P.G.,Vikas Kulkarni, Shankergoud, I., **Kenganal M. and Diwan. J. R.** (2017) Combining ability studies in restorer lines of sunflower (*Helianthus annuus* L.) *Journal of applied and natural sciences*, **9** (1), 603-608

Parameshwarappa, K. G., Jalandhar Ram and Lingaraju, B. S. (2008). Heterosis and combining ability for seed yield, oil content and other agronomic traits involving mutant restorer lines in sunflower (*Helianthus annuus* L.). *J. Oilseeds Res.,* **25** (1): 8-12.

Raghavendra, R. (2004). Heterosis and combining ability studies in sunflower (*Helianthus annuus* L.) using mutant restorer lines. *M. Sc* (*Agri*.) *Thesis*, Univ. Agric. Sci. Dharwad (India).

Sahane, G.S., Nichal, S.S., Vaidya, E.R. and Girnare, V.B. (2017). Heterotic studies in Sunflower (*Helianthus annuus L.*) through Line x Tester analysis. *Trends in Bio-Science,* **10**(42): 8778-8788.

Suresha, P.G., **Vikas Kulkarni, Shankergoud, I., Govindappa,M.R. and Lokesha,R.** 2016. Combining ability analysis for seed yield, component traits and powdery mildew tolerance in sunflower (*Helianthus annuus* L.). *Ecology, Environment and Conservation* 22:209-214.

SM Supriya, VV Kulkarni, CN Ranganatha, PG Suresha (2017): Quantitative Analysis of Oil Yield and Its Components in Newly Developed Hybrids of Sunflower (*Helianthus annuus* L.):*Int. J. Curr. Microbiol. App. Sci.*:**6** (8), 3088-3098.

Tyagi, N., Dhillon, S. K. and Bajaj, R. K., 2013, Estimates of heterosis for oil content in sunflower (*Helianthus annuus* L.). *16th Punjab Science Congress. bfuhs, faridkot*, 72.

Vikrant Tyagi, S. K. Dhillon and Prashant Kaushik : 2018. Stability Analysis of Some Novel Cytoplasmic Male Sterile Sources of Sunflower and Their Hybrids. *HELIA:* 41(73):1-48.