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HERITABILITY ANALYSIS FOR SEED YIELD AND YIELD RELATED COMPONENTS IN SUNFLOWER (*HELIANTHUS ANNUUS* L.) BASED ON GENETIC DIFFERENCE

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Abstract

The present study was conducted to develop sunflower hybrids with maximum yield potential. The genetically diverse sunflower (*Helianthus annuus L.*) inbred lines comprising 6 cytoplasmic male steriles (CMS) and 6 fertility restorers (R_f were crossed in line x tester mating design and 36F_1 hybrids were obtained. The hybrids were evaluated during spring of 2003-2004 and 2004-2005 years for seed yield and yield components. The yield components included in the study were head diameter, 1000-seed weight, yield per hectare, harvest index, moisture factor and leaf area. A low to high level of genetic variability existed among the hybrids for all characters as revealed by analysis of variance. For the years 2004-2005, the highest heterotic value for yield per hectare was observed for cross combination, CMS-H55-2-2-1 x C-206R. While for 2004-2005 year, it was recorded for CMS-303 x RHA-271. The yield performance of hybrids was evaluated on the basis of genetic distance between the two parental lines. For yield and yield components, the greatest genetic distance revealed by Euclidean dissimilarity co-efficient in the years 2003-2004 and 2004-2005 was observed for CMS-HAR-I x RHA-854 and CMS-64 x C-206R hybrids, respectivelly. This shows the existence of maximum genetic variability in these hybrids for seed yield and yield components. This study can be utilized in varietals improvement programme through heterosis breeding.

Introduction

Sunflower (*Helianthus annuus* L.) as a non-conventional oilseed crop, can play a vital role in Pakistan for oil production due to its high yield potential, drought resistance, salt tolerance and adjustment in the present cropping pattern. Unlike many other members of oilseed group, it is not strictly season-bound and hence can be gown twice a year. It is a short duration crop and can be grown as spring as well as autumn crop in major agro-ecological zones of irrigated and barani areas of Pakistan. (Samiullah, 2000).

Being an edible oilseed crop, sunflower seed can be eaten directly after frying or fed directly to cattle and poultry. The cake is a good protein supplement for livestock as it contains upto 25 % protein content. Its seed contains 40-50% oil which can directly be used for cooking purposes. Its oil is also used as salad oil and it contains high percentage of unsaturated fatty acids (80%) including oleic and linoleic acids. It also contains 20-25% protein, 30% carbohydrate and about 4% ash (Khalil & Jan, 2002). Its oil contains 20-25 % essential vitamins such as A,D,E and K (Satyabrata *et al*., 1988). It is also a good source of calcium, phosphorus and water soluble B-complex vitamins such as nicotinic acid, thiamine and riboflavin. Moreover, sunflower is an economically important raw material for industrial purposes (Pickett, 1936).

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Sunflower is the third major supplier of edible oil in the world after soybean and groundnut (Meric, 2003). Its production multiplied by approximately 1.8 times during the last 20 years (Pouzet & Delplancke, 2000). Keeping in view the future of edible oil requirements and to make up the deficiency of edible oil, sunflower research has been expanded and accelerated in Pakistan to produce sunflower genotypes which would be more productive with high genetic potential for seed yield.

Hybridization of inbred lines to produce improved high yielding hybrids or synthetics is the primary objective in sunflower breeding programmes that are designed to maximize heterosis. While breeding for hybrid vigor, considerable emphasis has been placed on oil concentration and fatty acid composition of oil. Sunflower hybrids show significant amount of heterosis and are more vigorous, self-fertile, high yielding and resistant to important foliar diseases (Seetharam, 1975). Hybrids have a uniform height at maturity which reduces losses during harvest. The hybrid seeds have a uniform moisture content making it suitable for storage. For breeding purpose, the inbred lines with greater genetic distance for a particular character may be crossed to create variations among the hybrids resulting in a hybrid vigor for that characteristic.

The knowledge of certain genetic parameter is essential for crop improvement. The main purpose of the present study was to evaluate the sunflower inbred lines and hybrids for high yield potential and their utilization in future breeding programme.

Material and Methods

The research was conducted under field conditions at National Agricultural Research Centre (NARC) Islamabad, Pakistan during the year 2003-2004, 2004-2005 in spring seasons. Among inbred (parental) lines, 6 cytoplasmic male sterile (CMS) lines and 6 fertility restorer (R_f) lines were obtained from NARC. The CMS lines were; CMS-H55-2-2-1 CMS-NDMTC, CMS-64, CMS-303, CMS-HAR-I and CMS-53. The fertility restorer lines were; C-206R, PAC-8712, RHA-295, SF-187R, RHA-271 and RHA-854. The inbred lines were evaluated before crossing for important quantitative characters such as protein, oil and fatty acids. The thirty six F_1 hybrids were obtained by crossing inbred lines in a Line x Tester design in spring 2004 at NARC. The experiment was laid down in randomized complete block design (RCBD). Each parental line and hybrid was planted in five meter long rows with plant to plant distance of 0.3m and row to tow distance of 0.75m in each plot. A basal fertilizer doze of 120kg per hectare (Urea) and 60kg per hectare of phosphorus (Diammonium phosphate) was applied. Full doze of Diammonium phosphate (DAP) and half doze of nitrogen was applied at the time of sowing; the remaining half doze of nitrogen was applied just before head initiation. The field was well irrigated after thirty days of germination and three more irrigations were applied to the experimental block at appropriate times. At the stage of physiological maturity when back of the heads turned yellow, the heads were cut with sickle and sun dried. Seeds of individual heads were threshed. Field data was recorded on various parameters including yield and its related traits; head diameter (cm), 1000-seed weight (g), yield per hectare (kg), harvest index (%), moisture factor and leaf area (cm^2).

The average data were subjected to standard techniques for analysis of variance according to Steel & Torrie (1980) to test the significance level of variations among the genotypes for yield and its related components. Mid-and high parent heterosis were computed for each trait according to the method described by Sharma & Singh (1978). Euclidean dissimilarity co-efficient among parents for the characters was calculated with the help of computer software “Statistica” for windows XP 2006 (Sneath & Sokal, 1973).

Results and Discussion

The genotypes exhibited significant variations for head diameter, 1000-seed weight, yield per hectare, harvest index and leaf area as revealed by their mean values and the analysis of variance (Tables 1-3). All the genotypes including parents and hybrids were evaluated for seed yield and related components on the basis of their genetic distance. Euclidean dissimilarity co-efficient as a measure of genetic distance was calculated for parents including 6 females and 6 males for the characters under study. A low to high level of genetic variability for all characters existed among the inbred lines as indicated by the euclidean dissimilarity matrix (Table 5). The heterotic value of F_1 hybrids for same characters was calculated and compared with the genetic distance exhibited by their parents (Table 4).

For the year 2003-2004, maximum positive heterosis for head diameter was observed by CMS-H55-2-2-1 x RHA-295 (53.41) hybrid showing that this hybrid out performed mid- parent (Table 3). A high value for euclidean dissimilarity co-efficient (338.839) was observed for this hybrid indicating sufficient genetic variability for the character. For 2004-2005, maximum positive heterotic percentage for head diameter was observed in CMS-H55-2-2-1 x C-206R (40.50) hybrid, indicating the out-performance of hybrid over mid-parent (Table 3). The euclidean dissimilarity co-efficient for this hybrid was 186.313 indicating a moderate level of genetic variability for the character. Our findings are supported by Gangappa *et al*., (1997). Venice & Arslan (1997) observed 11.49% heterosis in synthetic varieties of sunflower. Head diameter is influenced greatly by environmental effects especially by plant population, soil moisture and soil fertility. Therefore, the total variation in head size is more due to certain agronomic traits rather than genetic effects (Fick, 1978).

Breeding for higher values of 1000-seed weight increases the seed yield. Therefore this character is regarded as one of the most important yield components in sunflower. In our research studies genotypes exhibited a low level of genetic variability for 1000-seed weight. The co-efficients of variation for the character in years 2003-2004 and 2004-2005 were 6.19 and 8.78%, respectively (Table 3).

For 2003-2004, maximum positive heterotic value for 1000-seed weight was observed for cross CMS-64 x RHA-271 (35.88). The euclidean dissimilarity co-efficient for the hybrid was 23.864. For 2004-2005, the maximum positive heterosis was recorded for the cross CMS-64 x SF-187R (136.05%). The hybrid vigor was due to the greater genetic distance for the cross (855.060) which confirmed high differences among the parents. Out results are in accordance with the previous findings (Morozov, 1970; Shabana, 1974; Sassikumar *et al*., 1999).

Seed yield of sunflower is a complex character which depends on many traits and varies with the environment. Because of environmental effects, heritability of the seed is relatively low when compared with other agronomic traits (Pathak, 1974). In our studies, a low to high level of genetic variability existed among the genotypes for the character. For the year 2003-2004, the co-efficients of variation among the genotypes were 1.86 while for 2004-2005 it was 18.47 % which indicates the involvement of factors other than genetic. The maximum heterosis for the character was observed for CMS-H55-2-2-1 x C-206R (294.41%) hybrid. The euclidean dissimilarity co-efficient for this cross was 96.305 showing a low level of variability for yield per hectare. For 2004-2005, a cross CMS-303 x RHA-271 exhibited maximum positive heterosis (488.2%). The genetic distance for this hybrid was 91.985 showing a moderate level of genetic variability. Our results are in accordance with the findings of Gangappa et al, (1997), Shrinivasa (1982); Giriraj *et al*., (1986); and Goksoy (2002) who observed significant heterosis for seed yield per hectare.

Breeding for increased harvest index usually results in an increase in seed yield. In our study, sufficient genetic variability existed among the genotypes for harvest index as revealed by analysis for variance (Table 4). For the year 2003-2004, maximum positive heterosis was observed for CMS-303 x RHA-854 (322.00%) hybrid. This hybrid exhibited a high level of genetic variability as indicated by euclidean dissimilarity co-efficient (310.004) (Table 5). For 2004-2005, the cross CMS-303 x RHA-271 exhibited maximum heterosis (247.32%) for the character. The genetic distance for this hybrid was 159.036 showing sufficient genetic variability for the character. Our results are in accordance with other findings of Madrap *et al.,* (1994); Alone *et al.,* (2003) and Khan *et al.,* (2004)).

High seed moisture is favorable for getting high seed yield (Robelin, 1967). A low level of genetic variability for moisture factor was observed among the genotypes for the years 2003-2004 and 2004-2005 (Table 3) For the year 2003-2004 maximum positive heterosis (63.79%) for the character was observed for CMS-NDMTC x SF-187R hybrid. The euclidean distance for the hybrid was 293.739 showing sufficient amount of genetic variability (Table 5). For 2004-2005, maximum heterosis was observed for cross combination CMS-H55-2-2-1 x RHA-295 (64.15%) whereas the genetic distance for this hybrid was 431.729 indicating greater difference among the parents.

Total leaf area per plant may be influenced by environmental factors although genetic variations exist (Gundaev, 1971). According to Vrebalov (1975) total leaf area per plant varies widely among the genotypes. The co-efficient of variation for leaf area showed a moderate level of genetic variability among the genotypes for the year 2004 and 2005 (Table 4). For 2004, maximum heterosis for leaf area was observed for CMS-NDMTC x RHA-854 (60.88%) hybrid while the euclidean dissimilarity co-efficient for this hybrid was 313.797 indicating sufficient genetic differences between their parents. For 2005, maximum positive heterosis was expressed by the cross CMS-NDMTC x C-206R (54.74%) whereas the euclidean dissimilarity co-efficient for this hybrid was 258.947 showing the existence of enough genetic differences among their parental lines (Table 5).

The two years research study has led to the conclusion that there is a positive relationship between the genetic distance of parental lines and heterotic value of F_1 hybrids for a particular character. The greater the genetic distance between two parents, the more is the dissimilarity between them. As genetic distance is a measure of genotypic variations, therefore a cross between genetically dissimilar parents usually give rise to a hybrid vigor. This knowledge provides information about genetic variations among parental lines and F_1 hybrids. Inbred lines with greater genetic distance may be utilized for varietal improvement through heterosis breeding.

Table 1. Seed yield and yield related characteristics in sunflower genotypes.

Genotypes	Head Diameter(cm)		1000-seed weight (g)		Yield per hectare (kg)	
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
	2004	2005	2004	2005	2004	2005
Females						
CMS-H55-2-2-1	14.33 ± 1.200	16.00 ± 1.15	37.30 ± 3.350	18.81 ± 2.43	394.20 ± 26.200	719.90 ± 93.6
CMS-NDMTC	14.00 ± 1.150	15.33 ± 1.33	51.93 ± 5.400	12.03 ± 2.87	411.04 ± 1.020	284.40 ± 85.1
CMS-64	19.00 ± 0.577	17.33 ± 0.88	47.07 ± 3.440	13.32 ± 0.73	395.20 ± 42.700	265.70 ± 0.90
CMS-303	20.67 ± 4.060	19.67 ± 1.86	51.46 ±0.882	13.60 ± 1.50	586.60 ± 0.640	326.20 ± 4.81
CMS-HAR-I	21.00 ± 2.650	23.00 ± 2.65	64.40 ± 6.850	27.47 ± 3.68	482.20 ± 12.800	290.00 ± 25.00
CMS-53	18.33 ± 1.760	20.00 ± 0.57	56.63 ± 3.210	24.57 ± 1.78	351.03 ± 2.310	829.20 ± 29.30
Males						
C-206R	10.00 ± 0.577	10.67 ± 0.88	49.97 ± 2.430	41.07 ± 0.60	338.22 ± 1.230	504.00 ± 117.00
PAC-8712	10.33 ± 1.760	13.00 ± 1.15	48.00 ± 1.150	38.20 ± 2.96	431.10 ± 6.080	575.00 ± 157.00
RHA-295	10.00 ± 1.000	10.33 ± 1.20	51.93 ± 1.100	38.35 ± 2.90	522.70 ± 11.400	471.10 ± 11.70
SF-187R	11.33 ± 0.667	10.66 ± 0.33	49.33 ± 0.984	52.20 ± 1.14	537.80 ± 21.800	564.40 ± 54.60
RHA-271	13.00 ± 0.577	13.00 ± 1.00	45.17 ± 0.917	42.28 ± 3.53	409.77 ± 3.910	502.70 ± 19.70
RHA-854	13.33 ± 1.200	14.00 ± 0.57	62.33 ± 1.150	35.22 ± 1.69	526.20 ± 20.900	473.77 ± 40.60
Mean	**14.61**	**15.25**	**51.32**	**29.76**	**448.84**	**483.86**
Crosses						
CMS-H55-2-2-1 x C-206R	17.00 ± 1.530	18.66 ± 0.66	41.33 ± 0.882	41.16 ± 0.57	1444.33 ± 1.200	1209.80 ± 5.10
CMS-H55-2-2-1 x PAC-8712	18.33 ± 0.333	16.00 ± 0.00	50.66 ± 0.882	49.06 ± 0.54	695.33 ± 0.880	802.66 ± 2.04
CMS-H55-2-2-1 x RHA-295	18.67 ± 0.333	18.33 ± 0.88	53.67 ± 1.200	53.16 ± 0.31	591.67 ± 0.880	653.00 ± 167.0
CMS-H55-2-2-1 x SF187R	14.66 ± 0.882	12.33 ± 1.20	42.66 ± 0.882	33.47 ± 3.32	518.33 ± 0.670	573.30 ± 40.0
CMS-H55-2-2-1 x RHA-271	16.66 ± 0.882	15.66 ± 0.88	41.33 ± 0.882	45.70 ± 3.29	751.67 ± 0.880	986.70 ± 88.7
CMS-H55-2-2-1 x RHA-854	15.00 ± 0.577	16.66 ± 0.88	53.33 ± 0.882	56.27 ± 2.32	1011.00 ± 0.600	1072.00 ± 3.5
CMS-NDMTC x C-206R	13.33 ± 0.882	16.33 ± 1.20	40.00 ± 0.577	40.10 ± 0.88	835.33 ± 0.880	774.20 ± 54.7
CMS-NDMTC x PAC-8712	16.66 ± 0.882	17.33 ± 1.76	46.66 ± 0.333	47.50 ± 1.16	683.33 ± 0.880	679.00 ± 122.0
CMS-NDMTC x RHA-295	16.00 ± 0.577	13.33 ± 0.88	44.00 ± 0.577	43.16 ± 0.54	587.33 ± 1.200	716.00 ± 97.1
CMS-NDMTC x SF-187R	16.00 ± 0.577	13.66 ± 0.88	53.33 ± 0.882	49.23 ± 0.67	666.67 ± 0.880	543.99 ± 7.05
CMS-NDMTC x RHA-271	18.67 ± 0.333	17.66 ± 0.33	54.00 ± 1.150	61.03 ± 0.02	900.33 ± 0.330	781.00 ± 326.0

Table 1. (Cont'd.).

Genotypes	Head Diameter(cm)		1000-seed weight (g)		Yield per hectare (kg)	
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
	2004	2005	2004	2005	2004	2005
CMS-NDMTC x RHA-854	16.00 ± 1.530	14.33 ± 1.20	57.33 ± 0.882	59.30 ± 0.85	1008.70 ± 0.900	998.70 ± 72.7
CMS-64 x C-206R	16.00 ± 0.577	14.66 ± 0.66	52.33 ± 0.882	52.02 ± 5.01	599.67 ± 0.880	1003.10 ± 68.3
CMS-64 x PAC-8712	14.66 ± 0.882	13.33 ± 1.33	46.66 ± 0.882	46.69 ± 0.69	590.00 ± 1.150	863.10 ± 37.2
CMS-64 x RHA-295	16.00 ± 0.577	17.33 ± 1.76	56.66 ± 0.667	55.33 ± 0.66	1015.70 ± 0.900	1028.40 ± 47.9
CMS-64 x SF-187R	14.33 ± 0.333	15.67 ± 1.20	60.00 ± 1.530	77.33 ± 0.66	1163.30 ± 0.900	1028.48 ± 74.9
CMS-64 x RHA-271	16.00 ± 1.530	16.33 ± 2.73	62.67 ± 0.882	63.33 ± 6.77	990.67 ± 1.200	667.00 ± 175.0
CMS-64 x RHA-854	13.00 ± 0.882	12.66 ± 0.88	39.33 ± 1.20	39.66 ± 0.88	976.33 ± 0.880	712.00 ± 64.7
CMS-303 x C-206R	16.00 ± 0.577	17.67 ± 1.45	41.66 ± 0.882	41.66 ± 0.66	1031.70 ± 0.900	826.70 ± 15.4
CMS-303 x PAC-8712	14.66 ± 0.882	14.00 ± 0.00	36.67 ± 0.882	38.80 ± 2.43	1000.30 ± 0.300	1267.10 ± 38.9
CMS-303 x RHA-295	17.33 ± 1.200	17.00 ± 2.65	59.00 ± 0.577	58.96 ± 0.60	846.67 ± 0.330	1201.80 ± 29.5
CMS-303 x SF-187R	17.33 ± 1.200	14.33 ± 0.33	62.67 ± 0.333	40.33 ± 0.88	1010.00 ± 0.600	822.20 ± 22.2
CMS-303 x RHA-271	17.33 ± 1.200	15.00 ± 0.57	59.33 ± 0.882	63.47 ± 3.27	1068.00 ± 1.200	2437.80 ± 48.8
CMS-303 x RHA-854	14.00 ± 1.150	15.33 ± 0.33	54.66 ± 0.882	57.00 ± 4.93	1330.00 ± 1.200	1857.80 ± 8.9
CMS-HAR-I x C-206R	16.00 ± 0.577	15.66 ± 0.66	40.00 ± 0.577	40.06 ± 0.03	862.33 ± 0.880	977.80 ± 44.4
CMS-HAR-I x PAC-8712	17.33 ± 0.882	15.66 ± 0.33	51.66 ± 0.882	53.07 ± 2.92	680.67 ± 0.330	1073.80 ± 3.5
CMS-HAR-I x RHA-295	16.00 ± 0.577	14.66 ± 0.66	43.33 ± 0.882	41.83 ± 1.39	1030.00 ± 0.600	1351.50 ± 55.0
CMS-HAR-I x SF-187R	13.33 ± 0.882	15.33 ± 0.33	44.00 ± 1.150	49.30 ± 0.45	1530.00 ± 0.600	1421.70 ± 21.1
CMS-HAR-I x RHA-271	16.00 ± 0.577	14.66 ± 0.33	41.33 ± 0.882	44.40 ± 1.33	696.67 ± 0.880	793.80 ± 23.7
CMS-HAR-I x RHA-854	16.33 ± 0.882	15.33 ± 0.66	43.33 ± 0.333	46.27 ± 2.79	1220.00 ± 0600	1382.20 ± 84.4
CMS-53 x C-206R	16.66 ± 0.882	16.66 ± 0.33	45.66 ± 0.667	45.86 ± 0.96	999.00 ± 0.580	1111.10 ± 8.9
CMS-53 x PAC-8712	16.00 ± 0.577	16.00 ± 0.00	43.00 ± 1.150	43.17 ± 1.31	1006.70 ± 0.900	952.00 ± 129.0
CMS-53 x RHA-295	18.66 ± 0.333	18.33 ± 0.33	51.66 ± 0.882	50.13 ± 0.54	1230.70 ± 0.330	1252.40 ± 66.2
CMS-53 x SF-187R	15.33 ± 0.333	14.66 ± 0.33	46.66 ± 0.882	48.90 ± 0.79	996.67 ± 0.330	1378.70 ± 44.0
CMS-53 x RHA-271	15.66 ± 0.882	15.00 ± 0.57	46.66 ± 0.882	47.80 ± 0.80	903.33 ± 0.880	800.38 ± 0.48
CMS-53 x RHA-854	19.00 ± 0.577	14.33 ± 0.33	40.66 ± 0.882	43.90 ± 0.62	963.33 ± 0.330	604.90 ± 31.7
Mean	**15.19**	**15.55**	**48.54**	**49.04**	**928.77**	**1017.33**
LSD %	**3.042**	**3.044**	**4.942**	**0.295**	**24.42**	**301.1**

Table 2. Moisture factor and leaf area characteristics in sunflower genotypes.

Genotypes	Harvest Index (%)		Moisture factor		Leaf area (cm2)	
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
	2004	2005	2004	2005	2004	2005
Females						
CMS-H55-2-2-1	3.06 ± 0.968	5.83 ± 1.18	0.66 ± 0.021	0.62 ± 0.002	133.60 ± 18.2	128.20 ± 13.3
CMS-NDMTC	2.00 ± 0.577	4.53 ± 0.60	0.51 ± 0.008	0.59 ± 0.001	122.20 ± 15.0	124.67 ± 8.11
CMS-64	2.00 ± 0.000	0.25 ± 0.14	0.52 ± 0.013	0.52 ± 0.002	156.40 ± 3.49	155.03 ± 7.52
CMS-303	1.00 ± 0.000	0.75 ± 0.43	0.47 ± 0.013	0.52 ± 0.002	172.30 ± 15.3	171.70 ± 17.6
CMS-HAR-I	4.00 ± 0.577	1.52 ± 0.88	0.79 ± 0.046	0.83 ± 0.002	149.10 ± 11.0	145.60 ± 14.1
CMS-53	5.66 ± 1.200	0.47 ± 0.27	0.74 ± 0.084	0.60 ± 0.001	149.20 ± 15.0	158.00 ± 14.0
Males						
C-206R	3.33 ± 1.200	3.30 ± 1.91	0.71 ± 0.019	0.66 ± 0.000	124.90 ± 12.3	121.57 ± 5.75
PAC-8712	3.66 ± 1.200	1.55 ± 0.89	0.63 ± 0.081	0.62 ± 0.002	135.57 ± 3.02	137.37 ± 2.66
RHA-295	3.00 ± 0.333	0.25 ± 0.14	0.48 ± 0.027	0.42 ± 0.011	138.67 ± 1.20	136.00 ± 6.43
SF-187R	2.66 ± 0.333	0.20 ± 0.11	0.63 ± 0.009	0.63 ± 0.001	120.00 ± 0.58	122.12 ± 3.12
RHA-271	2.00 ± 0.000	0.61 ± 0.35	0.59 ± 0.034	0.66 ± 0.001	153.57 ± 8.85	151.80 ± 8.46
RHA-854	2.00 ± 0.000	3.33 ± 1.92	0.67 ± 0.014	0.70 ± 0.002	132.30 ± 13.1	132.70 ± 14.0
Mean	**2.81**	**4.76**	**0.62**	**0.62**	**140.65**	**140.39**
Crosses						
CMS-H55-2-2-1 x C-206R	2.33 ± 0.882	11.33 ± 0.33	0.943 ± 0.001	0.913 ± 0.001	170.50 ± 18.1	173.33 ± 8.82
CMS-H55-2-2-1 x PAC-8712	5.00 ± 0.577	7.67 ± 0.84	0.566 ± 0.002	0.620 ± 0.011	170.30 ± 21.4	169.70 ± 18.5
CMS-H55-2-2-1 x RHA-295	4.66 ± 0.33	6.30 ± 1.19	0.673 ± 0.001	0.866 ± 0.002	199.43 ± 9.53	173.35 ± 2.53
CMS-H55-2-2-1 x SF187R	5.00 ± 1.530	5.56 ± 0.29	0.773 ± 0.000	0.840 ± 0.005	176.20 ± 16.0	169.30 ± 21.2
CMS-H55-2-2-1 x RHA-271	7.66 ± 0.667	7.46 ± 0.26	0.426 ± 0.002	0.480 ± 0.017	161.73 ± 2.55	149.10 ± 15.2
CMS-H55-2-2-1 x RHA-854	7.33 ± 0.333	9.56 ± 0.03	0.966± 0.001	0.833 ± 0.002	161.60 ± 1.74	154.85 ± 9.48
CMS-NDMTC x C-206R	4.66 ± 0.882	6.76 ± 0.42	0.693 ± 0.000	0.686 ± 0.001	186.03 ± 8.77	173.15 ± 4.70
CMS-NDMTC x PAC-8712	3.66 ± 0.333	5.56 ± 0.86	0.500 ± 0.115	0.693 ± 0.001	144.20 ± 12.9	141.23 ± 0.62
CMS-NDMTC x RHA-295	4.33 ± 0.667	5.23 ± 0.53	0.680 ± 0.011	0.433 ± 0.001	151.80 ± 15.5	143.22 ± 5.58
CMS-NDMTC x SF-187R	3.33 ± 0.882	7.10 ± 0.20	0.946 ± 0.001	0.933 ± 0.001	185.23 ± 9.51	165.81 ± 7.60
CMS-NDMTC x RHA-271	3.66 ± 0.882	5.16 ± 0.06	0.453 ± 0.000	0.463 ± 0.001	174.00 ± 12.8	159.01 ± 0.58

Table 2. (Cont'd.).

Genotypes	Harvest Index (%)		Moisture factor		Leaf area (cm2)	
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
	2004	2005	2004	2005	2004	2005
CMS-NDMTC x RHA-854	4.33 ± 0.333	4.83 ± 0.12	0.893 ± 0.001	0.900 ± 0.005	204.73 ± 0.70	176.67 ± 2.40
CMS-64 x C-206R	4.33 ± 0.333	5.63 ± 0.08	0.613 ± 0.001	0.620 ± 0.011	204.73 ± 0.70	167.40 ± 7.96
CMS-64 x PAC-8712	5.00 ± 0.000	6.83 ± 0.33	0.666 ± 0.001	0.726 ± 0.001	174.31 ± 3.00	173.43 ± 0.62
CMS-64 x RHA-295	5.00 ± 0.577	5.50 ± 0.25	0.743 ± 0.000	0.776 ± 0.001	190.17 ± 6.90	172.50 ± 2.34
CMS-64 x SF-187R	7.00 ± 0.577	6.06 ± 0.52	0.813 ± 0.000	0.866 ± 0.002	161.70 ± 12.0	180.47 ± 1.16
CMS-64 x RHA-271	4.00 ± 0.577	6.33 ± 0.24	0.513 ± 0.000	0.493 ± 0.001	184.90 ± 12.2	168.67 ± 2.95
CMS-64 x RHA-854	5.00 ± 0.577	5.60 ± 0.45	0.666 ± 0.001	0.700 ± 0.057	133.97 ± 7.16	137.87 ± 1.80
CMS-303 x C-206R	4.33 ± 0.667	5.86 ± 0.46	0.680 ± 0.011	0.693 ± 0.001	184.50 ± 10.9	141.10 ± 1.05
CMS-303 x PAC-8712	7.00 ± 0.577	9.50 ± 1.32	0.500 ± 0.057	0.486 ± 0.001	161.70 ± 15.9	174.67 ± 3.33
CMS-303 x RHA-295	5.00 ± 1.530	10.50 ± 1.04	0.706 ± 0.003	0.660 ± 0.005	187.70 ± 8.06	180.63 ± 4.63
CMS-303 x SF-187R	7.00 ± 0.577	8.73 ± 0.65	0.880 ± 0.005	0.886 ± 0.001	173.67 ± 5.67	167.50 ± 0.65
CMS-303 x RHA-271	5.66 ± 1.200	12.33 ± 1.33	0.673 ± 0.001	0.733 ± 0.001	165.80 ± 11.5	170.90 ± 4.08
CMS-303 x RHA-854	6.33 ± 1.760	15.00 ± 1.00	0.686 ± 0.000	0.680 ± 0.005	154.67 ± 8.97	157.33 ± 7.69
CMS-HAR-I x C-206R	7.33 ± 0.882	9.53 ± 0.23	0.760 ± 0.015	0.740 ± 0.005	151.00 ± 12.3	159.67 ± 1.86
CMS-HAR-I x PAC-8712	6.33 ± 0.667	8.00 ± 0.68	0.533 ± 0.000	0.560 ± 0.005	144.00 ± 18.3	154.40 ± 7.11
CMS-HAR-I x RHA-295	9.33 ± 0.667	9.83 ± 0.16	0.683 ± 0.000	0.716 ± 0.001	165.30 ± 17.7	150.50 ± 1.78
CMS-HAR-I x SF-187R	7.66 ± 0.667	11.66 ± 0.33	0.880 ± 0.005	0.813 ± 0.001	130.40 ± 25.6	148.07 ± 0.12
CMS-HAR-I x RHA-271	4.66 ± 0.333	8.26 ± 0.76	0.666 ± 0.000	0.746 ± 0.002	172.73 ± 6.91	150.57 ± 4.65
CMS-HAR-I x RHA-854	4.66 ± 0.333	9.13 ± 0.20	0.800 ± 0.057	0.803 ± 0.001	172.53 ± 7.10	160.90 ± 3.97
CMS-53 x C-206R	6.00 ± 1.000	5.86 ± 0.69	0.690 ± 0.005	0.700 ± 0.115	183.37 ± 7.60	168.20 ± 7.51
CMS-53 x PAC-8712	4.00 ± 0.577	6.86 ± 0.32	0.513 ± 0.000	0.520 ± 0.005	183.37 ± 11.4	174.83 ± 5.49
CMS-53 x RHA-295	3.33 ± 0.333	7.76 ± 0.50	0.693 ± 0.000	0.700 ± 0.115	200.40 ± 10.4	177.80 ± 1.88
CMS-53 x SF-187R	3.66 ± 0.333	9.26 ± 0.54	0.933 ± 0.000	0.946 ± 0.001	210.73 ± 8.58	192.60 ± 6.11
CMS-53 x RHA-271	3.00 ± 0.000	4.96 ± 0.80	0.626 ± 0.000	0.606 ± 0.001	212.17 ± 6.69	184.33 ± 4.97
CMS-53 x RHA-854	5.33 ± 0.333	4.80 ± 0.20	0.786 ± 0.000	0.793 ± 0.001	187.70 ± 16.5	173.67 ± 5.76
Mean	**5.19**	**7.76**	**0.70**	**0.71**	**167.53**	**158.78**
LSD %	**2.760**	**2.038**	**0.0725**	**0.0725**	**33.49**	**21.47**

Table 3. Analysis of variance for seed yield and yield related traits in sunflower genotypes for the years 2004 and 2005.

Source	df	Head diameter		1000-seed weight		Yield per hectare		Harvest index		Moisture factor		Moisture factor	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Replication	2	25.528*	10.333^{ns}	13.189^{ns}	10.194^{ns}	744.370**	3214.900^{ns}	3.197^{ns}	0.340^{ns}	0.004^{ns}	0.005^{ns}	228.441**	1195.171**
Genotypes	47	18.330**	17.573**	163.120**	517.686**	270097.465**	502048.663**	10.502**	20.278**	0.058^{ns}	0.057^{ns}	1806.967**	927.499**
Error	94	3.521	3.525	9.291	15.079	226.958	26655.537	2.098	1.581	0.002	0.002	426.845	175.400
Total	143												
Coefficient of variations (CV%)		11.92	12.13	6.19	8.78	1.86	18.47	31.4	18.09	7.3	6.27	12.43	8.34

** Significant at 1% Probability level
* Significant at 5% Probability level
ns = non-significant

Table 4. Heterosis for seed yield and yield related characteristics in sunflower genotypes for years 2004 and 2005.

Hybrids	Heterosis(%)											
	Head Diameter(cm)		1000-seed weight(gm)		Yield per hectare(kg)		Harvest Index(%)		Moisture Factor		Leaf area(cm2)	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
CMS-H55-2-2-1 x C-206R	39.69*	40.50*	-5.29	37.49*	294.41**	97.69*	-27.07	88.41*	34.29**	41.54**	31.90*	38.79*
CMS-H55-2-2-1 x PAC-8712	48.66*	10.34	18.80*	72.13**	68.51**	23.97	48.50	46.55*	-12.31*	-1.59	26.50	27.80*
CMS-H55-2-2-1 x RHA-295	53.41*	39.25*	20.28*	86.02**	28.99**	9.65	62.78	34.08	15.52*	64.15**	46.49*	31.22*
CMS-H55-2-2-1 x SF-187R	14.34	-7.52	-1.50	-5.73	11.23*	-10.72	74.39	26.09	16.67*	31.25**	36.95	32.26*
CMS-H55-2-2-1 x RHA-271	21.95	8.04	0.22	49.61*	86.99**	61.41*	202.68*	75.75*	-31.75**	-26.15*	12.63	6.50
CMS-H55-2-2-1 x RHA-854	8.46	11.11	7.05	108.29**	119.69**	79.73*	189.45*	32.59*	44.78**	23.88*	1.54	18.70*
CMS-NDMTC x C-206R	11.08	25.62	-21.49*	51.03*	122.97**	96.39*	75.05	26.09	11.29	9.52	50.50*	40.63*
CMS-NDMTC x PAC-8712	36.98*	22.34	-6.60	89.16**	62.28**	62.20	29.43	21.47	-13.79*	11.29	11.88	7.79
CMS-NDMTC x RHA-295	33.33*	3.92	-15.27*	71.36**	25.81**	89.54	73.20	29.20	36.00*	-15.69*	16.37	9.88
CMS-NDMTC x SF-187R	26.28	5.14	5.33	53.3**	40.57**	28.17	42.86	88.50*	63.79**	50.00**	52.95*	34.37*
CMS-NDMTC x RHA-271	38.30*	24.72*	11.23*	124.74**	119.37**	98.45*	83.35	43.51	-19.64*	-28.13*	26.19	15.02
CMS-NDMTC x RHA-854	17.04	-2.28	0.35	155.05**	115.24**	163.72*	116.65	-26.39	48.33**	38.46**	60.88*	37.28*
CMS-64 x C-206R	10.34	-4.76	7.85	91.28**	63.53**	160.60*	62.52	27.55	-3.17	3.33	45.55*	21.04*
CMS-64 x PAC-8712	0.00	-12.10	-1.83	81.26**	42.81**	105.32*	76.49	88.08*	15.52*	25.86*	19.40	18.62*
CMS-64 x RHA-295	10.34	25.29*	14.48*	114.17**	121.32**	179.15*	100.00	77.41*	45.10**	52.08**	28.89*	18.54*
CMS-64 x SF-187R	-5.54	11.92	24.48*	136.05**	149.39**	147.77*	200.42*	85.16*	37.29**	47.46**	17.00	30.23*
CMS-64 x RHA-271	0.00	7.67	35.88**	127.80**	146.15**	73.60	100.00	138.98*	-8.93	-18.33*	19.30	9.94

Table 4. Heterosis for seed yield and yield related characteristics in sunflower genotypes for years 2004 and 2005.

Hybrids	Heterosis(%)											
	Head Diameter(cm)		1000-seed weight(gm)		Yield per hectare(kg)		Harvest Index(%)		Moisture Factor		Leaf area(cm2)	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
CMS-64 x RHA-854	-17.56	-19.14	-28.10**	63.44*	111.92**	92.77	150.00*	9.58	11.67*	12.90*	-7.19	-4.16
CMS-303 x C-206R	4.30	16.49	-18.12*	52.43*	123.10**	99.15*	84.75	10.35	13.33*	15.00*	24.15	-3.77
CMS-303 x PAC-8712	-5.42	-14.29	-26.51**	42.08*	96.58**	181.20**	200.42*	109.57*	-16.66*	-15.52*	5.09	13.02
CMS-303 x RHA-295	12.97	13.33	13.75*	127.01**	54.65**	202.98**	172.77*	162.50**	47.92**	37.50*	20.71	17.40*
CMS-303 x SF-187R	8.31	-5.50	23.93*	22.59*	79.65**	84.63*	281.88*	134.97*	57.14**	50.85**	18.82	14.02
CMS-303 x RHA-271	2.91	-8.17	22.36*	127.16**	114.37**	488.2**	277.80*	247.32**	26.42*	21.67*	1.75	16.32
CMS-303 x RHA-854	-17.65	-8.92	-4.21	133.51**	139.02**	364.91**	322.20*	130.18**	21.05*	9.68	1.55	-2.70
CMS-HAR-I x C-206R	3.23	-6.92	-30.06**	16.91	110.29**	146.29*	100.02*	52.12*	0.00	-1.33	10.21	19.52*
CMS-HAR-I x PAC-8712	10.59	-12.96	-8.06	61.62**	49.05**	148.28*	65.22	45.90*	-25.35*	-23.29*	1.16	9.12
CMS-HAR-I x RHA-295	3.23	-13.62	-25.51**	27.10*	104.99**	255.14**	166.57*	98.64*	6.25	14.29*	14.88	6.88
CMS-HAR-I x SF-187R	-17.56	-8.91	-22.63*	23.76*	200.00**	232.80**	130.03*	150.00**	22.22*	9.46	-3.08	10.61
CMS-HAR-I x RHA-271	-5.88	-18.51	-24.57**	27.31*	56.21**	100.27*	55.33	83.71*	-4.29	0.00	14.13	1.25
CMS-HAR-I x RHA-854	-4.89	-17.10	-31.62**	47.61*	141.96**	262.30*	55.33	22.30	9.59	3.90	22.62	15.63
CMS-53 x C-206R	17.64	8.69	-14.32*	39.75*	189.86**	66.68*	44.05	6.99	-5.48	11.11	33.79*	20.32*
CMS-53 x PAC-8712	11.65	-3.05	-17.81*	37.54*	157.39**	35.59	-7.62	46.10	-26.09*	-16.13*	40.74*	18.38*
CMS-53 x RHA-295	31.76	20.89	-4.81	59.35**	181.70**	92.63*	-16.75	86.39*	13.11*	37.25**	35.40*	20.95*
CMS-53 x SF-187R	3.37	-4.34	-11.91*	27.39*	124.25**	97.86*	-4.43	138.62**	34.78**	53.23**	56.56*	37.51*
CMS-53 x RHA-271	0.00	-9.09	-8.31*	43.00*	137.44**	20.18	-14.28	33.62	-5.97	-4.69	40.41*	18.99*
CMS-53 x RHA-854	20.03	-15.68	-31.62**	46.84*	119.61**	-7.09	52.28	-28.18	11.27*	21.54*	35.35*	19.48*

* ** Heterosis significant at 5 and 1% probability levels, respectively

Table 5. Euclidean distance (dissimilarity matrix) in sunflower genotypes (parents) seed yield and yield related characters for years 2004 and 2005.

Females / Males	CMS H55-2-2-1		CMS-NDMTC		CMS-64		CMS-303		CMS-HAR-I		CMS-53	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
C-206R	96.305	186.313	294.118	258.947	151.757	865.709	290.097	221.735	360.166	251.665	191.526	295.314
PAC-8712	130.872	223.487	255.411	217.766	108.245	837.497	248.741	178.670	318.738	209.602	149.800	332.683
RHA-295	338.839	431.729	53.083	45.204	110.783	806.714	53.134	60.665	114.152	26.095	67.361	540.856
SF-187R	94.411	186.391	293.739	258.567	149.743	855.060	289.711	222.265	358.439	251.179	189.952	295.861
RHA-271	218.878	312.159	170.850	134.538	23.864	809.832	159.036	91.985	229.656	121.664	61.417	419.911
RHA-854	69.372	161.948	316.797	277.744	168.107	852.031	310.004	238.846	379.501	270.440	210.408	271.487

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