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MAGNITUDE OF HETEROSIS AND HERITABILITY IN SUNFLOWER OVER ENVIRONMENTS

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Abstract

This study was conducted using 5 cytoplasmic male sterile (CMS) lines and 5 restorers of sunflower, in a line x tester fashions at two locations to determine and quantify the magnitude of heterosis and heritability over environments. The traits studied were days to 50% flowering, days to maturity, 1000-seed weight, seeds head^{-1}, oil content and seed yield. Heterotic studies revealed that not a single cross combination showed consistent promising results for all traits. Best cross combinations at Peshawar were TS-18 x TR-13(-3.06) for early flowering, TS-18 x TR-6023(-37.91) for early maturity, TS-4 x TR-6(47.56) for 1000-seed weight, TS-11 x TR-5(80.70) for seeds head^{-1}, TS-11xTR-6023(98.25) for oil contents and T335xTR-5(117.97) for seed yield. At Mansehra the crosses identified for desirable heterosis were TS-4 x TR-6(-22.45) for days to flowering, T335xTR-13(-56.29) for days to maturity, TS-11xTR-6(30.71) for 1000-seed weight, TS-4 x TR-5(33.39) for seeds head^{-1}, Ts-4xTR-5(132.23) for oil contents and TS-11x TR-3(30.53) for seed yield Kg/h. Most of the crosses exhibited positive heterosis for all traits however, some of the crosses also depicted negative but desirable heterosis for traits like days to flowering and maturity. Very high heritability estimates were observed for 1000-seed weight, seeds head^{-1}, oil content and seed yield at both locations. On the basis of seed yield and oil contents the cross combinations TS-335xTR-5, TS-11x TR-3, TS-11xTR-6023 and TS-4xTR-5 are recommended for commercial and further use in plant breeding programs.

Introduction

Sunflower (*Helianthus annuus* L.) has been the main source of edible oil in Russia and other European countries for decades. In the last 25 to 30 years, production of sunflower has increased many fold due to the expansion of its cultivation in several parts of the world (Quresh *et al.,* 1992). Sunflower is a rich source of good quality edible oil and has a nice fit in our cropping pattern. It is visualized as the most potential crop to narrow the gap between the total requirements and the domestic production of edible oil in the country. This could help saving the huge amount of foreign exchange that is being incurred on import of edible oil.

Heterosis plays a major role in improving crop productivity and quality in order to feed the ever-increasing human population, particularly in developing countries. The development of hybrids in the world major food crops and methods of hybrid seed production are imperative for achieving this goal. Sunflower is also a crop in which heterosis could be exploited considerably for better seed and oil yield. Hybrids are more vigorous, uniform, self fertile and resistant to important foliar diseases. In a systematic breeding programme, it is essential to identify superior parents for hybridization and crosses to expand the genetic variability for selection of superior genotypes. Yilmaz & Emiroglu (1994) observed heterosis in the F_1 amounting 20-77% for number of seeds head^{-1}, 33-73% for seed weight, 7-16% for oil content, 30-73% for seed yield. Gill & Punia (1996) reported highest heterosis for early flowering and maturity.

Heritability, a measure of the phenotypic variance attributable to genetic causes, has predictive function breeding crops. It provides an estimate of genetic advance, a breeder can expect from selection applied to a population under certain environments. The higher the heritability estimates the simpler are the selection procedures. Gill *et al*., (1998) observed high estimates of heritability for 100-seed weight, oil content, while seed yield and number of seeds head^{-1} exhibited moderate values for these parameters. Ashok *et al*., (2000) observed a wide range of variability for yield and other component characters in sunflower. Jayalakshmi *et al.*, (2000) suggested the exploitation of heterosis in the hybrids recorded significant heterosis through cytoplasmic male sterility technology of large scale seed production.

The present study of line x tester analysis is an attempt to develop sunflower hybrids with diverse genetic background for their potential in varying cross combinations of different plant characters. Objectives of the study were to evaluate lines, tester and their crosses over two environments for wide adaptability and quantifying the magnitude of heterosis and heritability estimates for various growth and yield parameters over environments.

Materials and Methods

The material used were 5 cytoplasmic male sterile lines of sunflower (*Helianthus annuus* L.) viz., TS-4, TS-11, TS-17, TS-18 and TS-335, five testers/restorers viz., TR-3, TR-5, TR-6, TR-13 and TR-6023, and their 25 crosses, Parents of the developed CMS lines and restorers were selected on the basis of early maturity, head size, high yield and oil content. The CMS lines were crossed with the restorers/testers in a line x tester fashion. The 25 crosses along with 10 parents were field evaluated at two locations (ARI Tarnab, Peshawar and ARS Baffa) for two consecutive seasons of spring 2002 and 2003.

Randomized Complete Block design with 3 replications was used at each location. The plot consisted of 5 meter long two rows with row to row and plant to plant distances of 0.75 m and 0.25 m, respectively. Approved cultural practices were used at each location during both years. Harvesting and threshing was done manually.

Data were taken on 10 randomly selected plants of each entry of all the replications. For days to flowering, numbers of days were counted from planting to the day when last row (central whorl) of disc flowers opened on 50% of the plants in a plot. Days to maturity were determined as the number of days from planting to the day when 50% of the plants in a plot reached physiological maturity i.e., R9 stage as explained by Schneiter & Miller (1981). The head diameter of 10 randomly selected plants in each plot was measured at maturity with a measuring tap.

A sample of 1000-filled seeds (at 8% moisture content) was drawn at random from the bulked seed of 10 random plants and weighed with an electronic balance. Seed yield per head were determined and converted to yield in kg /ha. Oil content was determined by Nuclear Magnetic Resonance (NMR). Seeds head^{-1} were calculated using the formula adopted from Hussain & Schneiter (1990) as follows:

$$\text{Seeds head}^{-1} = \frac{\text{Seed weight from 10 plants x 1000}}{\text{1000-Seed weight x 10}}$$

Data were analyzed for each trait according to Steel & Torrie (1980). The magnitude of heterosis for all the traits was estimated separately at each location. Heterosis was expressed as deviation of cross mean from the mid parent value using the procedure of Matzingar *et al.*, (1963), whereas heritability estimates (broad sense) across two years for each location were analysed using the Snedecore & Cochran (1980) procedure.

Results and Discussions

The locations chosen have significant differences in soil type, temperature and rainfall. ARI, Tarnab is 358 m above sea level having clay-loam soil with pH of 8.4 while ARS Baffa is 950 m above sea level with clay-loam soil having pH of 7.2. Soil organic matter at Baffa was 0.5% while at Tarnab 0.8%. Air temperature at Peshawar during March to July of 2002 and 2003 ranged from 10.0 to 39.0 and 11.2 to 40.4°C respectively, with annual rainfall of 135 and 74mm. In contrast air temperature at Baffa ranged from 2.5 to 32.0 and 3.9 to 35.0°C with annual rainfall of 490 and 540mm during March to July of 2002 and 2003, respectively.

Combined analysis of variance indicated significant differences ($p \leq 0.01$) among the entries for all the traits evaluated at two locations. Sunflower parental line TS-18 was the best for early flowering and maturity, seeds head^{-1} and % oil content whereas TS-335 was found the best for seed weight and seed yield at both locations (Table 1). Among the superior restorer included TR-6023 and TR-5 for early flowering at Peshawar and Mansehra, respectively. For early maturity the desirable male parents at Peshawar was TR-6023 and at Mansehra wasTR-3 while TR-13 was found best for seeds head^{-1} and seed yield at both locations (Table 2).

The results of the heterotic studies are presented in Table 3. Early flowering provide sufficient time for seed formation process and if flowering is delayed the duration of seed formation (seed filling period) is altered resulting in poor seed formation especially loss of seed weight. Hence for early flowering negative heterosis is desirable. At the experimental site Peshawar four crosses for days to flowering revealed significant and negative heterosis. Maximum negative heterosis over mid parent value for days to 50% flowering was observed in cross-combination TS-18xTR-13 (-3.06) followed by TS-11xTR-6023 (-1.98) at Peshawar while at Mansehra TS-4xTR-6 (-22.45) and TS-11xTR-13 (-19.93) showed negative heterosis for flowering. These results are in confirmation with Ashok *et al*., (2000).

Genotypes with early maturing habit are desirable, therefore, negative heterosis for days to maturity is considered useful. At Peshawar maximum negative heterosis for days to maturity, demonstrated by TS-18 xTR-6023 (-37.91), TS-18 x TR-5 (-34.07) and TS-17 x TR-5 (-32.59) while at Mansehra maximum negative heterosis for maturity was displayed by the crosses TS-335xTR-13 (-56.29), TS-18xTR-13 (-52.04) and TS-17xTR-5(-46.0). Similar findings of heterosis in early flowering and days to maturity were also mentioned by Gill *et al*., (1998).

Most of the cross combinations (Table 3) manifested highly significant and positive heterosis over the mind parent value for 1000-seed weight at Peshawar and Mansehra. Cross combination TS-4 x TR-6 showed maximum positive heterosis (47.56) followed by TS-4 x TR-3 (37.40) and TS-4 x TR-5 (35.52) at Peshawar. Fifteen crosses at Peshawar and 16 crosses at Mansehra exhibited positive heterosis for 1000-seed weight. At Mansehra maximum increase of 30.71 was recorded for cross combination TS-11 x TR-6 followed by TS-11 x TR-13 (29.63) and TS-11 x TR-3 (27.34) for 1000-seed weight.

Table 1. Mean values for 5 lines of seed parents of sunflower, evaluated at two locations through the Line x Tester analysis.

Female parents	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra
	Days to flowering		Days to maturity		1000 seed weight (g)		Seeds head^{-1}		Oil content (%)		Yield (kg ha^{-1})	
TS-4	71.7	78.0	90.67	101.67	42.50	40.33	939.67	819.33	33.07	36.03	2129.00	1762.30
TS-11	68.0	79.0	89.67	102.00	39.17	37.17	926.00	796.00	41.50	39.49	1934.00	1576.70
TS-17	72.7	79.0	90.33	99.33	46.00	42.50	840.00	599.67	40.47	40.35	2061.33	1359.00
TS-18	66.7	78.0	88.00	100.33	38.83	37.50	971.33	875.67	42.30	43.96	2009.33	1751.00
TS-335	68.3	79.0	90.00	100.00	46.67	44.33	905.33	794.67	39.97	39.17	2254.67	1878.70
Mean	69.47	78.60	89.73	100.67	42.63	40.37	916.47	777.07	39.46	39.80	2077.67	1665.53
LSD 5%	0.95	0.002	0.69	0.80	0.78	1.48	36.67	47.38	0.06	0.42	81.32	90.14

Table 2. Mean values for 5 lines of pollinators, evaluated at two locations through the Line x Tester analysis.

Male parents	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra
	Days to flowering		Days to maturity		1000 seed weight (g)		Seeds head^{-1}		Oil content (%)		Yield (kg ha^{-1})	
TR-3	70.0	80.0	91.67	99.33	40.67	38.17	722.33	642.00	27.53	29.44	1569.33	1306.70
TR-5	72.3	78.3	93.67	99.67	45.67	42.33	569.33	570.67	33.00	32.17	1386.33	1287.00
TR-6	74.3	79.0	94.00	101.00	41.67	38.17	697.33	648.67	30.50	33.51	1551.33	1318.30
TR-13	73.0	80.3	93.33	102.00	39.00	36.83	829.00	691.67	30.10	30.89	1723.33	1357.70
TR-6023	66.7	80.0	89.67	100.00	45.67	40.67	645.67	591.67	28.43	29.84	1574.33	1282.00
Mean	71.3	79.5	92.47	100.40	42.53	39.23	692.73	628.93	29.91	31.17	1560.93	1310.33
LSD 5%	0.91	0.73	1.06	0.65	0.80	2.19	32.60	24.78	0.10	0.27	52.11	75.14

Table 3. Heterosis expressed as %age of mid parent of 25 crosses derived from CMS and tester lines of sunflower evaluated at Peshawar and Mansehra.

Crosses	Days to flowering		Days to maturity		1000 seed weight (g)		Seeds head^{-1}		Oil content (%)		Seed yield (kg ha^{-1})	
	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra	Peshawar	Mansehra
TS-4xTR-3	4.04**	-5.61**	-23.22**	32.07**	37.40**	6.61**	43.31**	25.19**	58.53**	94.07**	95.63**	7.85**
TS-4xTR-5	4.17**	66.20**	-8.67*	46.71**	35.52**	5.10**	71.63**	33.39**	15.46**	132.23**	52.54**	10.89**
TS-4xTR-6	0.41^{NS}	-22.45**	6.32**	24.70**	47.56**	19.60**	49.44**	26.21**	23.92**	118.96**	55.52**	24.84**
TS-4xTR-13	1.89**	-10.90**	30.51**	29.95**	10.92**	-1.43^{NS}	56.46**	21.38**	46.90**	72.27**	76.12**	4.98**
TS-4xTR-6023	4.09**	30.88**	12.20**	30.96**	35.39**	3.97**	59.01**	30.76**	39.87**	112.73**	80.42**	11.53**
TS-11xTR-3	1.88**	-4.55**	-9.09**	36.47**	-2.27^{NS}	27.34**	65.92**	7.53**	20.71**	58.84**	28.09**	30.53**
TS-11xTR-5	-1.66**	42.29**	0.80^{NS}	62.76**	-0.31^{NS}	11.19**	80.70**	2.28^{NS}	76.86**	76.78**	79.04**	15.30**
TS-11xTR-6	-1.64**	2.31^{NS}	-10.94**	15.84**	23.24**	30.71**	43.63**	21.44**	11.80**	74.23**	35.24**	9.29**
TS-11xTR-13	4.96**	-19.93**	-9.84**	42.34**	-0.28^{NS}	29.63**	59.70**	22.15**	52.42**	57.73**	84.91**	22.97**
TS-11xTR-6023	-1.98**	-0.73^{NS}	13.29**	56.03**	6.01**	0.58^{NS}	75.66**	10.55**	98.25**	82.51**	115.87**	6.63**
TS-17xTR-3	-0.05^{NS}	15.91**	-5.71**	-30.03**	10.79**	-7.70**	-10.25**	12.71**	46.88**	-3.10^{NS}	65.49**	-5.79**
TS-17xTR-5	0.69*	-7.21**	-32.59**	-46.00**	-5.72**	-12.37**	3.82^{NS}	-13.04**	45.12**	-3.82^{NS}	25.53**	-11.99**
TS-17xTR-6	2.99**	-4.85**	20.00**	40.09**	-10.94**	-3.05**	38.90**	10.67**	52.94**	21.05**	69.38**	2.47**
TS-17xTR-13	2.97**	19.93**	-5.35**	8.49*	-2.88^{NS}	7.45**	17.65**	17.04**	30.87**	12.80**	53.31**	8.84**
TS-17xTR-6023	1.91**	15.79**	-19.51**	-27.82**	2.56^{NS}	-10.91**	-9.54**	13.93**	12.96**	-9.41**	28.52**	-6.62**
TS-18xTR-3	2.88**	42.30**	-14.69**	-40.02**	-3.29^{NS}	3.56**	-7.43**	-1.00^{NS}	-19.09**	-12.87**	-22.18**	4.85**
TS-18xTR-5	8.92**	78.97**	-34.07**	51.98**	-11.82**	19.53**	45.11**	-5.56**	38.82**	24.84**	28.07**	16.92**
TS-18xTR-6	1.70**	-8.35**	-24.00**	-2.56^{NS}	-4.49**	-3.11**	3.69^{NS}	-6.16**	-6.62**	-3.10^{NS}	-14.05**	-3.98**
TS-18xTR-13	-3.06**	17.35**	-22.88**	-52.04**	-20.26**	2.79**	-32.86**	-2.03^{NS}	8.45**	-46.90**	3.95*	-4.02**
TS-18xTR-6023	12.04**	58.77**	-37.91**	-36.77**	8.67**	0.99^{NS}	-7.58**	-2.90^{NS}	6.98**	-1.93^{NS}	0.82^{NS}	2.34**
TS-335xTR-3	8.87**	58.40**	-28.49**	40.58**	16.64**	14.88**	51.87**	0.88^{NS}	60.88**	71.61**	58.30**	19.59**
TS-335xTR-5	0.53^{NS}	73.67**	-20.09**	35.19**	14.76**	-2.53*	63.09**	24.84**	77.84**	83.16**	117.97**	3.46**
TS-335xTR-6	-0.46^{NS}	24.28**	5.05**	2.24^{NS}	19.01**	-12.08**	4.99*	25.22**	18.65**	22.07**	46.40**	-1.41*
TS-335xTR-13	6.13**	27.96**	-10.89**	-56.29**	21.41**	-6.23**	34.96**	18.07**	-2.92^{NS}	60.86**	12.47**	-0.62^{NS}
TS-335xTR-6023	10.67**	17.24**	-1.05^{NS}	15.20**	1.17^{NS}	7.21**	51.95**	10.45**	60.77**	49.44**	73.25**	19.60**

Heterotic studies for seeds head^{-1} at Peshawar showed that 17 crosses out of 25 expressed highly significant heterosis in the desired direction. Maximum positive heterosis over mid parent value was demonstrated by cross combination TS-11 x TR-5 (80.70) followed by TS-11 x TR-6023 (75.56) and TS-4 x TR-5 (71.63). Five crosses exhibited negative heterosis ranging from -32.86 (TS-18 x TR-13) to -7.43 (TS-18 x TR-3) while at the sub-mountainous location Mansehra, 19 crosses out of 25 depicted highly significant and positive heterosis for seeds head^{-1}. Maximum increase of 33.39% over mid parent value was recorded in cross combination TS-4 x TR-5 followed by TS-4 x TR-6023 (30.76%) and TS-4 x TR-6 (26.21%) for number of seeds head^{-1}. Deokar & Patil (1979) also reported significant and positive heterosis for seeds head$^{-1.}$ Similarly Yilmaz & Emiroglu (1994) recorded heterosis for 1000-seed weight and seeds head^{-1} in sunflower.

Sunflower cultivars with higher percentage of oil are needed for higher oil yield per unit area, therefore, highly significant and positive heterosis is desirable. At the experimental site Peshawar, 22 crosses out of 25 exhibited positive and highly significant heterosis for % oil content. Cross combination TS-11 x TR-6023 gave maximum increase of 98.25% over mid parent, followed by TS-335 x TR-5 (77.84%) and TS-11 x TR-5 (76.86%). At the experimental location Mansehra 18 crosses showed increase in the percent oil content over their mid parent values. Maximum increase of 132.23% was found in cross combination TS-4 x TR-5 followed by TS-4 x TR-6 (118.96%) and TS-4 x TR-6023 (112.73%), over their mid parent for oil content (%). These results have the support of Jaya Lakshmi *et al*., (2000), who reported wide range of heterosis for oil content in their study.

Twenty-three out of 25 crosses expressed positive heterosis for seed yield at Peshawar. Cross combination TS-335 x TR-5 revealed highest positive heterosis of 117.97% followed by TS-11 x TR-6023 (115.87%) and TS-4 x TR-3 (95.63%) for seed yield. At Mansehra 18 crosses expressed highly significant and positive heterosis for seed yield. Maximum increase of 3053% in seed yield over mid parent was given by TS-11 x TR-3 followed by TS-4 x TR-6 (24.84%) and TS-11 x TR-13 (22.97%). Negative heterosis for seed yield was exhibited by 2 crosses at Peshawar and 7 crosses at Mansehra (Table 3). Yilmaz & Emiroglu (1994) and Jaya Lakshmi *et al.*, (2000) reported a wide range heterosis for seed yield.

Broad-sense heritability for sunflower genotypes over two years estimated at each location separately is presented in Fig. 1. Broad-sense heritability estimates for days to 50% flowering at Peshawar were 0.88±0.22 whereas at Mansehra heritability estimates for days to 50% flowering were 0.67±0.19. Days to physiological maturity are often closely correlated with days to flowering, although genetic differences in the time acquired from flowering to maturity exist (Fick, 1978). Heritability estimates for days to maturity at Peshawar were 0.22±0.14 while at Mansehra heritability estimates for days to maturity were 0.81±0. Heritability estimates of 0.93±0.23 and 0.89±0.22 were observed for 1000-seed weight at Peshawar and Mansehra respectively.

Heritability estimates for seeds head^{-1} at Peshawar and Mansehra were 0.86±0.23 and 0.78±0.21, respectively. At Peshawar heritability estimates of 0.93±0.23 were observed for oil content, while heritability estimates of 0.85±0.24 were found for oil content at Mansehra. Heritability estimates for seed yield at Peshawar were 0.89±0.22, whereas at Mansehra estimates of heritability for seed yield were 0.86±0.22. Heritability values for most of the characters were very high. The dominant nature of inheritance was reflected by high heritability estimates for these traits (Tariq *et al*., 1992).

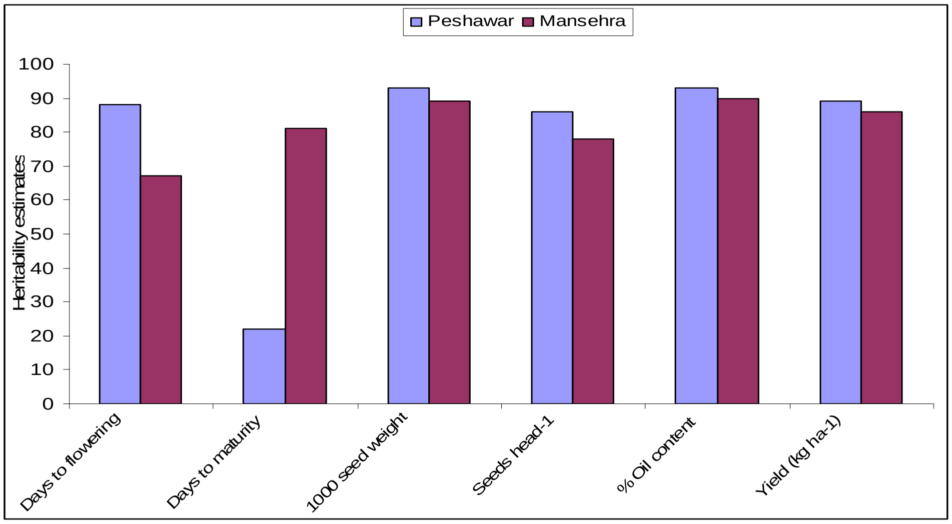

Fig. 1. Heritability estimates (broad sense) for selected sunflower traits evaluated for two years at the environmental conditions of Peshawar and Mansehra.

The cross combinations TS-335xTR-5 and TS-11x TR-3 were the best for seed yield and also performed well for oil contents and 1000 seed weight. The cross combinations TS-11xTR-6023 and TS-4xTR-5 having high oil contents, also performed well for number of seeds per head and 1000 seed weight. Heritability estimates for most of the traits were very high; hence selection for these traits would be effective. The cross combinations TS-335xTR-5, TS-11xTR-3, TS11xTR-6023 and TS-4xTR-5 are recommended for commercial and further use in plant breeding programmes.

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