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Heterosis Estimates for Yield and Yield Components in Sunflower (*Helianthus annus*)

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Abstract: The study was carried out to determine magnitude of heterosis for six heritable traits in sunflower. Study was conducted during 2000-2003 at NWFP Agricultural University, Peshawar on a 8x8 diallel cross of sunflower to find out the extent of heterosis for parameters like head size, achene yield/plant, achene number/plant, 100-achene weight, achene yield (kg ha^{-1}) and oil content. Heterosis was observed for all the parameters studied. The magnitude of heterosis for different characters varied for the parameters studied and it was the maximum (32.88%) for head size and minimum (1.29%) for achene yield ha^{-1}. No cross combination was consistent in heterosis for all characters studied. Maternal effects were significantly visible for traits like achene number/plant, achene yield ha^{-1} and oil content but not significantly visible for head size, achene yield/plant and 100-achene weight. For most of the characters except head size and achene number, heterosis was more in those cross combinations where parents were phenotypically at distance.

Key words: Sunflower, heterosis estimates, yield and yield components

INTRODUCTION

Heterosis (hybrid vigour) 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's major food crops and methods of hybrid seed production are critical for achieving this goal. Heterosis is significant for seed yield and is one of the driving forces behind the hybrid seed industry in cultivated sunflower (*Helianthus annuus)*. There are reports that cross 336A x MRHA2 exhibited highest heterosis and hetero-beltiosis for seed yield per plant and yield contributing characters like oil content, 100 seed weight and percentage of filled seeds[1]. Similarly Limbore[2] found that two hybrids viz., 2A x IB-222 (166.45%) and 2A x IBC-132/1 (161.32%) showed a high degree of heterosis for number of seeds per head followed by 2A x 132/1 (146.40%) and 2A x IB60 (114.79%) for seed yield per plant, respectively. On the other hand, the highest negative and significant heterotic values were noted in crosses 2A x BLC-183 (-72.50%) followed by 21A x IB-174/2-2 (-57.15%) and BLC-183 (-53.03%) for number of seeds per head and grain yield per plant, respectively. The primary aim of this study was to assess the magnitude of the heterosis for yield and yield components in sunflower (*Helianthus annuus* L).

MATERIALS AND METHODS

The present research work was carried out at Malakandher farm NWFP Agricultural University Peshawar for four years I-e., 2000-2003. Five different sunflower selections from Tarnab Fertile (TF) Lines viz., TF-1, TF-4, TF-7, TF-11 and TF-335 along with three hybrid cultivars viz., Gulshan-98, Aritar-93 and Peshawar-93 were taken. These TF-lines are the selection made from the crosses between sunflower materials brought from North Dakota State University Fargo, USA and local genotypes. The hybrid cultivars Gulshan-98, Peshawar-93 and Aritar-93 were evolved by Pakistan Oil Seed Development Board (PODB) Tarnab, Peshawar. These TF-lines and hybrid cultivars were selected for their agronomic characters i.e., head size, achene yield/plant, achene number/plant, 100-achene weight, achene yield (kg ha^{-1}) and oil content (g kg^{-1}).

The inbred lines were developed from all the genetic material (TF-lines and hybrid cv.) by selfing the material for four generations and selections were made in each generation for various parameters. The main purpose of the inbred line development was to bring homozygosity in these lines and cv. for these traits. These inbred lines were re-named as TF-1, TF-4, TF-7, TF-11, TF-335, GUL, ARI and PESH which made recognition of the genotypes easy.

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All the genetic materials (inbred lines) were crossed in 8x8 diallel fashion. To produce good enough F_0 seeds, the crossings were made for three consecutive years i.e. from 2000-2002. The F_0 seed was harvested separately from each cross at maturity.

Hybrid seeds (F_1) of 56 crosses along with their eight parents were tested in an experiment in a Randomized Complete Block design with three replications during 2004. Sowing was done by dibbling 3 seeds per hill that was thinned to one plant per hill. Each row was 4 m long. Plant to plant and row-to-row distance was kept at 25 and 60 cm, respectively. Normal cultural practices and plant protection measures were adopted during the crop season. The data on parameters like head size (cm^2), achene yield per plant (g), achene number per plant, 100-achene weight (g), achene yield (kg ha^{-1}) and oil content (g kg^{-1}) were recorded for each treatment on a plot size of 18 m^2 (4.5 x 4 m^2).

The heterosis for individual crosses was calculated using following formula:

$$\text{Heterosis} = \frac{F_1 - MP}{MP} \times 100$$

Where, MP is the Mid-parent achieved as:

$$MP = \frac{P1 + P2}{2}$$

Tests of significance were performed on the differences between F_1 value and mid-parent. Differences among means were computed by Paschal and Wilcox[3].

RESULTS AND DISCUSSION

In the analysis of variance, the mean squares for genotypes were significant ($p<0.01$) for all the traits examined, indicating the presence of variability among the hybrids and their parents. Within the parental lines and hybrids, differences in all the characters studied were also significant ($p<0.01$). The response of F_1 generation in respect to heterosis for characters studied was as follows:

Table 1: Heterosis (%) of 28 direct and reciprocal crosses for head size (cm^2) in sunflower

	Direct crosses		Reciprocal crosses	
Genotypes	Size (cm^2)	Heterosis (%)	Size (cm^2)	Heterosis (%)
TF-1	507.33			
TF-4	440.67			
TF-7	381.67			
TF-11	599.00			
TF-335	402.67			
GUL	533.33			
ARI	450.67			
PESH	512.67			
TF-1xTF-4	856.33a	80.66**	808.33a	70.53**
TF-1xTF-7	533.33mn	19.99**	690.33b	55.31**
TF-1xTF-11	808.33b	46.13**	541.33f-I	-2.14**
TF-1xTF-335	741.00cd	62.86**	575.67d-f	26.52**
TF-1xGUL	806.33b	54.96**	511.33g-k	-1.73**
TF-1xARI	695.67ef	45.23**	546.67e-I	14.13**
TF-1xPESH	580.33i-k	13.79**	566.00d-g	10.98**
TF-4xTF-7	503.00n	22.33**	541.33f-j	31.66**
TF-4xTF-11	547.33lm	5.29**	598.33de	15.10**
TF-4xTF-335	569.00kl	34.94**	487.67j-m	15.65**
TF-4xGUL	807.67b	65.85**	446.67l-o	-8.28**
TF-4xARI	677.33e	51.98**	615.67cd	38.15**
TF-4xPESH	689.33f	44.62**	436.33m-o	-8.46**
TF-7xTF-11	547.33i-l	11.62**	500.33h-l	2.04**
TF-7xTF-335	723.67de	84.53**	495.00i-l	26.22**
TF-7xGUL	608.33hi	32.97**	429.00no	-6.23**
TF-7xARI	734.00d	76.37**	476.67k-n	14.54**
TF-7xPESH	503.33n	12.56**	553.00e-h	23.67**
TF-11 xTF-335	606.00ij	21.00**	575.67d-f	14.94**
TF-11xGUL	527.67mn	-6.80**	488.00j-m	-13.81**
TF-11xARI	593.67i-k	13.12**	502.00h-k	-4.35**
TF-11xPESH	639.00gh	14.96**	505.67h-k	-9.03**
TF-335xGUL	670.33fg	43.23**	477.67k-n	2.07**
TF-335 xARI	681.33f	59.69**	459.33k-n	7.66**
TF-335xPESH	780.67c	70.58**	653.67bc	42.83**
GULxARI	397.00o	-19.31**	439.33m-o	-10.70**
GULxPESH	400.67o	-23.39**	317.67p	-39.26**
ARIxPESH	575.67j-l	19.52**	394.67o	-18.06**
G/Means	635.00		522.62	Paschal value 5% 1.07
C/Variation	1%		1%	Paschal value 1% 1.40
LSD	32.31		32.31	
	% increase of F_1 over mid-parent 32.88		% increase of F_1 over mid-parent 9.23	

*, ** = Significant at 5 and 1% level of significance, respectively
ns = Non significant

Head size: In direct crosses (Table 1) maximum heterosis (84.53%) over the mid-parent was shown by cross combination TF-7xTF-335, followed by TF-1xTF-4 with heterosis value of (80.66%) for head size (cm^2). In reciprocal crosses, maximum mean value 808.33 cm^2 was shown by cross combination TF-4xTF-1, with maximum heterosis of 70.53%, followed by cross combination TF-7xTF-1 with mean value of 690.33 cm and heterosis value of 55.31%. The overall mean percent increase of heterosis of F_1 over mid-parent was 9.23%. Maximum heterosis in head size was also reported by Gill *et al.*[4] who observed heterosis in all the yield related components of sunflower. Similarly 65 % heterosis over the better parent was also reported by Goksoy *et al.*[5]. The average percent increase of F_1 generation over mid-parent in direct crosses was more than that of reciprocal crosses. These findings were also confirmed by Alande *et al.*[1]. From these studies it was obvious that in majority of the crosses with positive heterosis for head size had parents that were phenotypically different for that character. But in direct crosses, the cross combination (TF-7xTF-335) showed the largest head size among the parents had the smallest head size among the derivatives. This showed that the recessive genes for

Table 2: Heterosis (%) of 28 direct and reciprocal crosses for achene yield (g/plant) in sunflower

Genotypes	Direct crosses Yield (g/plant)	Direct crosses Heterosis (%)	Reciprocal crosses Yield (g/plant)	Reciprocal crosses Heterosis (%)
TF-1	105.03		105.03	
TF-4	111.71		111.71	
TF-7	110.00		110.00	
TF-11	107.00		107.00	
TF-335	107.51		107.51	
GUL	112.36		112.36	
ARI	122.87		122.87	
PESH	121.70		121.70	
TF-1xTF-4	114.37ij	5.53**	117.15f-I	8.10**
TF-1xTF-7	114.23j	6.25**	116.74g-I	8.58**
TF-1xTF-11	104.17o	-1.75**	108.35j	2.20**
TF-1xTF-335	113.60jk	6.90**	119.87c-h	12.79**
TF-1xGUL	107.18mn	-1.40**	115.79hi	6.53**
TF-1xARI	137.18a	20.38**	123.69b-d	8.55**
TF-1XPESH	106.84m-o	-5.75**	121.30b-f	7.00**
TF-4xTF-7	105.51no	-4.82**	108.35j	-2.26**
TF-4xTF-11	117.21g-I	7.18**	121.83b-e	11.41**
TF-4xTF-335	106.22m-o	-3.09**	103.38k	-5.69**
TF-4xTGUL	126.40b	12.83**	122.13b-e	9.02**
TF-4xARI	135.84a	15.82**	130.12a	10.94**
TF-4xPESH	116.06h-j	-0.55ns	123.81bc	6.09**
TF-7xTF-11	115.89h-j	6.70**	107.51jk	-0.92ns
TF-7xTF-335	111.03kl	2.09**	120.84b-g	11.12**
TF-7xGUL	126.52b	13.80**	119.20d-h	7.22**
TF-7xARI	108.88lm	-6.49**	122.73b-d	5.41**
TF-7xPESH	115.23ij	-0.53ns	116.60g-I	0.65ns
TF-11xTF-335	136.69a	27.44**	107.83jk	0.54ns
TF-11xGUL	116.14h-j	5.89**	119.04d-h	8.53**
TF-11xARI	121.04d-f	5.31**	118.13e-I	2.78**
TF-11xPESH	122.78cd	7.38**	123.81b-d	8.27**
TF-335xGUL	118.54f-h	7.83**	123.30b-d	12.16**
TF-335xARI	125.00bc	8.52**	123.38b-d	7.11**
TF-335xPESH	121.09d-f	5.66**	124.94b	9.02**
GULxARI	123.26cd	4.80**	119.13d-h	1.29**
GULxPESH	121.97de	4.22**	121.89b-e	4.15**
ARIxPESH	119.72e-g	-1.89**	124.12bc	1.50**
G/Means	118.16		118.75	Paschal value 5% 1.07
C/Variation	1.53%		2.00%	Paschal value 1% 1.40
LSD	2.96		2.96	
	% increase of F_1 over mid-parent 5.25		% increase of F_1 over mid-parent 5.77	

*, ** = Significant at 5 and 1% level of significance, respectively
ns = Non-significant

Table 3: Heterosis (%) of 28 direct and reciprocal crosses for achene number/plant in sunflower

Genotypes	Direct crosses Achene No.	Direct crosses Heterosis (%)	Reciprocal crosses Achene No.	Reciprocal crosses Heterosis (%)
TF-1	1018.00		1018.00	
TF-4	2118.67		2118.67	
TF-7	1407.67		1407.67	
TF-11	1448.33		1448.33	
TF-335	1742.00		1742.00	
GUL	1563.00		1563.00	
ARI	1756.00		1756.00	
PESH	1543.33		1543.33	
TF-1xTF-4	1707.33c	8.86**	1696.67b	8.18**
TF-1xTF-7	1450.00ij	19.55**	1381.33w	13.89**
TF-1xTF-11	1329.67mn	7.83**	1601.67h	29.88**
TF-1xTF-335	1521.33h	10.24**	1502.00q	8.84**
TF-1xGUL	1377.33l	6.73**	1423.00u	10.27**
TF-1xARI	1607.00f	15.86**	1532.67m	10.50**
TF-1xPESH	1282.67o	0.16**	1508.00p	17.75**
TF-4xTF-7	1738.67h	-1.39**	1601.67h	-9.16**
TF-4xTF-11	1739.33h	-2.48**	1682.00d	-5.69**
TF-4xTF-335	1945.33a	0.78**	1522.67o	-21.12**
TF-4xGUL	1732.00bc	-5.91**	1544.00l	-16.12**
TF-4xARI	1733.33b	-10.53**	1556.67j	-19.65**
TF-4xPESH	1344.33lm	-26.58**	1532.67m	-16.29**
TF-7xTF-11	1739.33b	21.80**	1349.00x	-5.53**
TF-7xTF-335	1628.00ef	3.38**	1525.67no	-3.12**
TF-7xGUL	1739.33b	17.10**	1474.00s	-0.76**
TF-7xARI	1318.33h	-16.66**	1671.00e	5.64**
TF-7xPESH	1488.33I	0.87**	1460.33t	-1.03**
TF-11xTF-335	1733.00b	8.64**	1693.00c	6.13**
TF-11xGUL	1633.33e	8.48**	1557.67j	3.45**
TF-11xARI	1461.67j	-8.77**	1615.00g	0.80**
TF-11xPESH	1576.33g	5.38**	1625.67f	8.68**
TF-335xGUL	1464.00d	-11.41**	1526.33n	-7.63**
TF-335xARI	1576.67g	-9.85**	1497.00r	-14.41**
TF-335xPESH	1413.67k	-13.94**	1550.33k	-5.62**
GULxARI	1618.00ef	-2.50**	1916.33a	15.48**
GULxPESH	1498.00hi	-3.55**	1578.00i	1.60**
ARIxPESH	1481.67ij	-10.18**	1557.33j	-5.60**
G/Means	1567.07		1560.06	Paschalvalue 5% 1.07
C/Variation	1%		1%	Paschalvalue 1% 1.40
LSD	25.61		25.61	
	% increase of F_1 over mid-parent -0.48		% increase of F_1 over mid-parent -0.92	

*, ** = Significant at 5 and 1% level of significance, respectively
ns = Non-significant

the head size in both parents complemented each other in F_1 generation. These findings were however different from Nehru *et al*.[6] which may be due to different genetic materials used and the environmental impact.

Achene yield/plant: In direct crosses (Table 2), the maximum heterosis (27.44%) was shown by cross TF-11xTF-335 followed by TF-1xARI with the heterosis value of 20.38%. In reciprocal crosses, the maximum heterosis (12.79%) over mid-parent was shown by TF-335xTF-1 followed by GULxTF-335 with heterosis value of 12.16%, showing that these crosses can successfully be used for hybrid seed production in sunflower. The more the difference between the parents, the higher was the hybrid vigour in the F_1s for the character. The overall mean of heterosis increase for the character in both direct and reciprocal crosses was nearly the same i.e., 5.25 and 5.77%, respectively. Gill and Punia[7] also found hybrids superior for seed yield/plant in single cross hybrids.

Achene number/plant: In direct crosses (Table 3), maximum heterosis was shown by cross combination TF-7xTF-11 and TF-1xTF-7 with heterosis value of 21.80 and 19.55%, respectively. In reciprocal crosses, the maximum heterosis (29.88%) over mid-parent was shown by cross TF-11xTF-1 followed by cross PESHxTF-1 with 17.75% heterosis. overall increase in heterosis of -0.48 and -0.92% by F_1 over mid-parent was received in direct and

Table 4: Heterosis (%) of 28 direct and reciprocal crosses for 100-achene's weight (g) in sunflower

Genotypes	Direct crosses 100 achene wt. (g)	Direct crosses Heterosis (%)	Reciprocal crosses 100 achene wt. (g)	Reciprocal crosses Heterosis (%)
TF-1	9.53		9.53	
TF-4	5.25		5.25	
TF-7	7.70		7.70	
TF-11	7.22		7.22	
TF-335	6.03		6.03	
GUL	7.17		7.17	
ARI	6.74		6.74	
PESH	7.78		7.78	
TF-1xTF-4	6.72n	-9.00ns	7.05l	-4.53ns
TF-1xTF-7	7.83e-g	-9.15ns	8.55a	-0.72ns
TF-1xTF-11	7.60I	-9.21ns	6.70m	-19.96**
TF-1xTF-335	7.41j	-4.71ns	8.02b-d	3.13ns
TF-1xGUL	7.46j	-10.70ns	8.08b	-3.19ns
TF-1xARI	8.46a	4.00ns	8.04bc	-1.13ns
TF-1xPESH	8.32b	-3.91ns	7.98b-d	-7.80ns
TF-4xTF-7	5.87o	-9.42ns	6.70m	3.50ns
TF-4xTF-11	6.72n	7.75ns	7.18kl	15.07ns
TF-4xTF-335	5.52p	-2.04ns	6.56m	16.29ns
TF-4xTGUL	7.10l	14.25ns	7.80ef	25.52**
TF-4xARI	7.74gh	29.09**	7.88c-e	31.42**
TF-4xPESH	8.55a	31.15**	8.02b-d	23.07**
TF-7xTF-11	6.72m	-9.96ns	7.72e-g	3.39ns
TF-7xTF-335	6.73n	-1.97ns	7.78ef	13.28ns
TF-7xGUL	7.27k	-2.31ns	7.98b-d	7.33ns
TF-7xARI	8.16c	12.97ns	7.31jk	1.20ns
TF-7xPESH	7.72h	-0.34ns	7.64f-h	-1.29ns
TF-11xTF-335	7.86ef	18.69**	6.30n	-4.86ns
TF-11xGUL	7.03lm	-2.34ns	7.41ij	2.89ns
TF-11xARI	8.17c	17.05**	7.48hi	7.21ns
TF-11xPESH	7.76f-h	3.42ns	7.57g-I	0.84ns
TF-335xGUL	8.08cd	22.37**	7.98b-d	20.91*
TF-335xARI	7.87e	23.27**	7.27jk	13.87ns
TF-335xPESH	8.49a	22.95**	8.08b	17.02*
GULxARI	7.40j	6.45ns	6.19n	-11.05ns
GULxPESH	8.04d	7.51ns	7.72e-g	3.23ns
ARIxPESH	8.04d	10.70ns	7.86de	8.26ns
G/Means	7.52		7.53	Paschal value 5% 1.07
C/Variation	1%		1%	Paschal value 1% 1.40
LSD	0.104		0.104	
	% increase of F_1 over mid-parent 4.79		% increase of F_1 over mid-parent 4.89	

*, ** = Significant at 5 and 1 % level of significance, respectively
ns = Non-significant

Table 5: Heterosis (%) of 28 direct and reciprocal crosses for achene's yield (kg ha^{-1}) in sunflower

Genotypes	Direct crosses Yield (kg ha^{-1})	Direct crosses Heterosis (%)	Reciprocal crosses Yield (kg ha^{-1})	Reciprocal crosses Heterosis (%)
TF-1	2117.62		2117.62	
TF-4	2201.83		2201.83	
TF-7	2114.67		2114.67	
TF-11	2152.00		2152.00	
TF-335	2103.33		2103.33	
GUL	2216.33		2216.33	
ARI	2312.00		2312.00	
PESH	2293.67		2293.67	
TF-1xTF-4	2208.49m	2.26**	2281.03j	5.62**
TF-1xF-7	2225.39l	5.16**	2254.00n	6.51**
TF-1xTF-11	2101.40u	-1.57**	2168.00q	1.55**
TF-1xTF-335	2198.22n	4.16**	2295.33i	8.76**
TF-1XGUL	2122.30s	-2.06**	2245.33o	3.62**
TF-1XARIi	2454.33a	10.81**	2325.00c	4.98**
TF-1xPESH	2157.00q	-2.21**	2301.67h	4.35**
TF-4xTF-7	2114.73t	-2.02**	2168.00q	0.45**
TF-4xTF-11	2265.70h	4.08**	2252.00n	3.45**
TF-4xTF-335	2137.03r	-0.72**	2096.00t	-2.63**
TF-4xTGUL	2351.37d	6.44**	2303.00h	4.25**
TF-4xARI	2434.33b	7.86**	2317.89e	2.70**
TF-4xPESH	2247.11ij	-0.03ns	2317.22e	3.09**
TF-7xTF-11	2265.70h	6.20**	2140.33s	0.33**
TF-7xTF-335	2192.00o	3.94**	2294.00I	8.77**
TF-7xGUL	2389.00c	10.32**	2271.67l	4.90**
TF-7xARI	2165.33p	-2.17**	2312.00f	4.46**
TF-7xPESH	2243.00j	1.76**	2258.78m	2.48**
TF-11xTF-335	2251.67I	5.83**	2164.00r	1.71**
TF-11xGUL	2232.00k	2.19**	2275.00k	4.16**
TF-11xARI	2286.33g	2.43**	2308.78g	3.44**
TF-11xPESH	1219.00v	-45.16**	2325.67c	4.63**
TF-335xGUL	2303.33f	6.64**	2316.00e	7.23**
TF-335xARI	2303.33f	4.33**	2328.00b	5.45**
TF-335xPESH	2307.00f	4.94**	2346.00a	6.71**
GULxARI	2318.00e	2.38**	2281.33j	0.76**
GULxPESH	2305.67f	2.25**	2308.56g	2.38**
ARIxPESH	2284.67g	-0.79**	2320.67d	0.77**
G/Means	2217.27		2270.55	Paschal value 5% 1.07
C/Variation	1.3%		0.13	Paschal value 1% 1.04
LSD	4.68		4.68	
	% increase of F_1 over mid-parent 1.29		% increase of F_1 over mid-parent 3.73	

*, ** = Significant at 5 and 1 % level of significance, respectively
ns = Non-significant

reciprocal crosses, respectively. Yilmaz and Emiroglu[8] also reported 20-77% heterosis for number of achenes per head while significant positive heterosis for achene number/plant over mid-parent. Here one cross combination (TF-1xTF-7) with the 2nd highest heterosis for the character involved parents with the least number of achenes/plant, which showed complementary behaviour of recessive genes in the cross combination.

100-achene weight: In direct crosses (Table 4), the cross combination TF-4xPESH and TF-335xPESH exhibited the highest heterosis (31.15 and 22.95%, respectively). reciprocal crosses, the cross combination ARIxTF-4 and GULxTF-4 exhibited the highest significant heterosis (31.42 and 25.52%, respectively). The amount of heterosis for the character over the better parent was observed 93% by Goksoy *et al.*[5]. Similarly Alande *et al.*[1] noted highest heterosis for yield contributing characters like oil content, 100 seed weight and percentage of filled seeds. Overall average of F_1 in direct and reciprocal crosses showed 4.79 and 4.89% increase for the trait over the mid-parent, respectively. Heterosis was achieved in many crosses involved parents that were genetic different. This showed that genetically biodiversity is utmost necessary for heterosis.

Achene yield: In direct crosses (Table 5), maximum heterosis (10.81 and 10.32%,) was shown by cross combination TF-1xARI and TF-7xGUL, respectively. In reciprocal crosses, maximum heterosis (8.77%) was

Table 6: Heterosis (%) of 28 direct and reciprocal crosses for oil content ($g\ kg^{-1}$) in sunflower

Genotypes	Direct crosses Oil ($g\ kg^{-1}$)	Direct crosses Heterosis (%)	Reciprocal crosses Oil ($g\ kg^{-1}$)	Reciprocal crosses Heterosis (%)
TF-1	32.20		32.20	
TF-4	31.83		31.82	
TF-7	32.58		32.58	
TF-11	35.51		35.51	
TF-335	34.56		35.28	
GUL	27.25		27.25	
ARI	37.93		37.93	
PESH	38.29		38.29	
TF-1xTF-4	43.87a	37.03**	33.79e-I	5.55**
TF-1xTF-7	30.69l-n	-5.25**	34.84c-I	7.55**
TF-1xTF-11	33.33g-m	-1.57ns	39.53ab	16.74**
TF-1xTF-335	35.28e-k	5.68**	36.01b-h	6.72**
TF-1xGUL	26.83n	-9.73**	40.62a	36.66**
TF-1xARI	30.99k-n	-11.62**	32.68f-k	-6.82**
TF-1xPESH	31.23k-m	-11.40**	39.11a-c	10.96**
TF-4xTF-7	31.16k-m	-3.23ns	39.53ab	22.73**
TF-4xF-11	39.61a-d	17.64**	36.76a-f	9.18**
TF-4xTF-335	37.21b-h	12.09**	31.41i-k	-6.38**
TF-4xTGUL	37.83b-f	28.07**	38.53a-d	30.45**
TF-4xARI	32.00j-m	-8.27**	33.55e-j	-3.81*
TF-4xPESH	40.12a-c	14.44**	39.19a-c	11.79**
TF-7xTF-11	39.61a-d	16.33**	33.41e-j	-1.88ns
TF-7xTF-335	36.77c-j	9.52**	31.61h-k	-6.84**
TF-7xGUL	35.80d-j	19.67**	33.70e-j	12.64**
TF-7xARI	37.60b-g	6.64**	36.74a-f	4.19**
TF-7xPESH	39.34b-e	11.01**	34.34d-I	-3.11*
TF-11xTF-335	33.35g-m	-4.82**	34.41d-I	-2.78ns
TF-11xGUL	41.18ab	31.24**	38.51a-d	22.71**
TF-11xARI	31.64j-m	-13.84**	29.27jk	-20.30**
TF-11xPESH	32.22j-m	-12.69**	32.22g-k	-12.68**
TF-335xGUL	34.60f-l	11.95**	37.38a-e	19.57**
TF-335xARI	32.56i-m	-10.16**	36.92a-f	0.86ns
TF-335xPESH	37.63b-g	3.29*	32.74f-k	-10.99**
GULxARI	33.13h-m	1.65ns	39.55ab	21.36**
GULxPESH	29.50mn	-9.99**	39.35ab	20.07**
ARIxPESH	30.62l-n	-19.66**	36.50a-h	-4.22**
G/Means	34.85		35.79	Paschal value 5% 1.07
C/Variation	7.56		7.56	Paschal value 1% 1.40
LSD	4.31		4.31	
	% increase of F_1 over mid-parent 31.19		% increase of F_1 over mid-parent 5.71	

*, ** = Significant at 5 and 1 % level of significance, respectively
ns = Non-significant

recorded by cross combination TF-335xTF-7, followed by TF-335xTF-1 with 8.76% heterosis for the trait. These results showed crosses involving at least one parent with high showed that maximum heterosis potential for the trait. Goksoy *et al.*[5] reported more than 16% heterosis for the trait, while Reddy *et al.*[9]. The value of heterosis for the trait was 70% overall average of F_1 hybrids showed 3.73% increase in achene yield over mid-parents.

Oil content: In direct crosses of F_1 generation (Table 6), cross combination TF-1xTF-4 gave the highest heterosis (37.03%), followed by TF-11xGUL with heterotic value of 31.24%. In reciprocal crosses, combination GULxTF-1 gave the highest heterosis (36.66%) followed by GULxTF-4 with heterotic value of 30.45 %. Overall average of F_1 showed 5.71 % increase in oil content over mid-parent value. Ali *et al.*[10] reported 13.48% heterosis for oil content in their experiments. In reciprocal crosses, cross combination (GULxTF-4) with the 2nd highest heterosis for the character involved parents with the least amount of oil content, which showed complementary nature of recessive genes for the character in F_1 generation.

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