Pak. J. Agri. Sci., Vol. 43(3-4), 2006

HETEROSIS STUDIES IN SUNFLOWER (*HELIANTHUS ANNUUS* L.) CROSSES FOR AGRONOMIC TRAITS AND OIL YIELD UNDER FAISALABAD CONDITIONS

Habibullah Habib[1], Syed Sadaqat Mehdi[2], Abdul Rashid[3], Saeed Iqbal[3] and Muhammad Ashfaq Anjum[4]
[1]Department of Agriculture, Govt. of the Punjab, Pakistan.
[2]Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan.
[3]Oilseed Research Institute, AARI, Faisalabad, Pakistan
[4]Soil Bacteriology Section, Ayub Agricultural Research Institute, Faisalabad, Pakistan

Fourteen cytoplasmic male sterile lines and 6 testers were crossed in a line x tester fashion to develop 84 sunflower hybrids during Spring, 2000 at Oilseeds Research Institute, AARI, Faisalabad, Pakistan. The hybrids and parents were evaluated during Spring 2001. Highly significant differences existed among genotypes for all the studied plant traits. The highest heterosis and heterobeltiosis for stem girth was showed by crosses ORI-3 x RL-77 and ORI-3 x RL-84, respectively in the positive direction. The cross combination ORI-3 x RL-84 exhibited maximum increase over mid and better parents for 100-achene weight. The highest positive heterosis and heterobeltiosis for oil content was exhibited by crosses ORI-6 x RL-27 and ORI-47 x RL-69, respectively. Crosses ORI-29 x RL-84 and ORI-3 x RL-77 showed the maximum increase over mid and better parents, respectively for head diameter. The hybrid ORI-20 x RL-77 showed highest positive heterosis and heterobeltiosis values for plant height. The cross ORI-3 x RL-77 showed the highest positive heterosis over mid and better parents for both number of seeds per head and oil yield.
Key words: Sunflower, Heterosis, Heterobeltiosis, Stem girth, Head diameter, Plant height, Seed yield.

INTRODUCTION

Sunflower is one of the most important oilseed crop grown for edible purposes in the world. Per capita consumption and requirements for edible oil is increasing day by day in Pakistan. The country has to spend a huge amount of foreign exchange earning on the import of edible oil every year. It is short duration crop and matures in 90 to 110 days. It has a nice fit in the existing cropping pattern in Pakistan. It has the potential to narrow the gap between the requirements and domestic production. So the local production of hybrid seed with increased oil yield is one of basic step to achieve the goal.

The discovery of cytoplasmic male sterility (Lecklereq, 1969) in France and fertility restoration (Kinman, 1970) in America has provided the desired means for the development of hybrids through heterosis breeding. Gill *et al.* (1998) reported that high heterosis could be utilized for earliness, seed yield and head diameter in sunflower. Yenice and Arslan (1997) reported 92.62, 77.90, 8.87 and 5.51% hybrid vigor for oil yield, seed yield, 1000-achene weight and oil content percentage, respectively. Sunflower hybrids exhibit varied magnitude and direction of heterosis for different characteristics (Gangappa *et al.* 1997). Sessikumar, and Gopalan (1999) studied a considerable degree of heterosis for yield per plant, head diameter, stem girth and 100-achene weight. The main objective of this study was to observe the heterosis over mid and better parents for oil yield in the sunflower hybrids developed form Russian blood lines and European blood testers. Heterosis is significant for oil and seed yield and is one of driving forces behind the hybrid seed industry in cultivated sunflower *Helianthus annuus* L. (Cheres *et al.* 2000).

MATERIALS AND METHODS

The experiment was conducted at Oilseeds Research Institute, AARI, Faisalabad, Pakistan. Fourteen cytoplasmic male sterile lines namely ORI-1, ORI-3, ORI-4, ORI-6, ORI-10, ORI-20, ORI-22, ORI-27, ORI-29, ORI-37, ORI-41, ORI-47, ORI-48 and ORI-49 and 6 testers namely RL-27, RL-46, RL-55, RL-69, RL-77 and RL-84 were crossed in a line x tester fashion to obtain 84 cross combinations in Spring 2000. The seed was harvested separately from each cross at maturity. The seed of 84 cross combinations along with their 20 parents were planted in a randomized complete block design in Spring 2001. In lieu of male sterile lines (line A), their maintainer lines (line B) were used to eliminate the effect of male sterility for seed yield. The experimental unit consisted of a single row plot of 4.6-meter length with plant-to-plant and row-to-row distances of 23 and 60 cm, respectively.

All other standard practices were applied to the crop to both replications of the experiment. The data were recorded on ten randomly selected plants of each entry of each replication for stem girth, head diameter, 100-achene weight, number of seeds per head, oil content, oil yield. The data thus recorded were analyzed according to the analysis of variance technique as outlined by Steel and Torrie, (1980) for the plant traits in order to determine significance of differences among the sunflower genotypes, parents, parents vs crosses, crosses, lines, testers and line x tester interaction. difference of F_1 means form the respective mid parent and better parent values was evaluated by using t-test according to Wynne *et al.* (1970).

RESULTS AND DISCUSSION

The analysis of variance for six sunflower traits is presented in Table I. The table depicts highly significant differences among sunflower genotypes for stem girth, head diameter, 100-achene weight, number of seeds per head, oil content and oil yield.

Table I. Analysis of variance for agronomic traits, oil content and oil yield of sunflower (*Helianthus annuus* L.)

Sources of variation	df	Mean squares					
		Stem girth	Head diameter	100-achene weight	No. of seeds per head	Oil content	Oil yield
Replications	1	6.473**	1.525 ^{ns}	1.70**	112605**	4.69 ^{ns}	353236*
Genotypes	103	1.148**	12.50**	1.31**	104192**	9.99**	243271**
Error	103	0.264	1.77	0.167	15647	3.81	54711

*, ** significant at 5% and 1% probability levels, respectively; ns = non-significant.

The increase (+) or decrease (-) of F_1 hybrid over mid parent as well as better parent was calculated to observe the heterotic effects for all the studied plant traits. The estimates of heterosis over mid parent and better parent (heterobeltiosis) were calculated using the procedure of Matzingar *et al.* (1962). The highly significant differences among sunflower genotypes indicate the diverse nature of experimental material used in the studies. The estimates of heterosis and heterobeltiosis for indicated sunflower traits are presented in Table II.

Table II. Estimates of heterosis and heterobeltiosis for indicated plant traits of 84 sunflower hybrids.

Sr. #	Crosses	Stem girth		Head diameter		100-achene weight		# seeds per head		Oil content		Oil yield	
		Het.	Hetbel.	Het.	Hetbel.	Het.	Hetbel.	Het.	Hetbel.	Het.	Hetbel.	Het.	Hetbel.
1	ORI-1 RL-27	24.7*	-3.0	21.5**	-6.2	21.1**	-14.2**	103.0**	93.4**	10.0**	6.0	92.6**	172.2
2	ORI-1 RL-46	-0.4	-7.7	-1.3	-3.9	3.1	-5.9	48.6**	11.2	16.2**	10.6**	52.0	84.8
3	ORI-1 RL-55	66.0**	26.3**	45.3**	5.7	58.0**	14.3**	121.4**	95.2**	6.1	5.1	133.1**	249.6
4	ORI-1 RL-69	42.8**	6.5	39.0**	1.3	28.5**	-2.6	193.0**	150.7**	17.6**	11.4**	170.4**	308.8
5	ORI-1 RL-77	55.9**	11.2	37.4**	3.1	29.2**	1.8	159.1**	117.0**	11.7**	4.0	126.2**	239.4
6	ORI-1 RL-84	68.2**	23.3**	50.4**	8.8	53.7**	8.6	184.8**	153.6**	10.6**	5.2	189.9**	349.7
7	ORI-3 RL-27	77.3**	76.0**	58.0**	38.9**	50.0**	26.4**	120.6**	108.5**	16.3**	8.6*	270.4**	296.4**
8	ORI-3 RL-46	45.9**	7.0	36.8**	14.8**	10.6	-3.8	109.9**	56.3**	11.5**	5.3	58.1**	139.8**
9	ORI-3 RL-55	91.9**	87.4**	76.2**	43.9**	79.2**	55.3**	148.4**	120.6**	11.5**	1.4	327.7**	403.8**
10	ORI-3 RL-69	86.7**	77.2**	80.7**	48.0**	63.7**	51.0**	169.4**	132.1**	14.7**	9.0*	326.8**	409.4**
11	ORI-3 RL-77	131.9**	106.3**	74.6**	48.2**	63.1**	58.5**	230.3**	178.4**	17.8**	13.9**	440.8**	537.5**
12	ORI-3 RL-84	131.5**	114.2**	79.3**	45.4**	102.4**	69.6**	145.7**	120.4**	15.1**	8.8*	361.3**	474.7**
13	ORI-4 RL-27	26.1*	-4.4	14.4*	-11.9*	29.6**	-1.3	46.8**	12.5	9.3**	5.5	19.6	90.8**
14	ORI-4 RL-46	17.6*	12.9	15.1**	12.5*	-6.8	-8.3	42.9**	40.7**	10.9**	5.7	41.3**	47.5**
15	ORI-4 RL-55	7.8	-20.0*	24.9**	-9.4	43.3**	11.8*	26.8	-13.3	0.0	-0.8	-3.2	60.9*
16	ORI-4 RL-69	45.1**	5.6	51.0**	9.8	22.9**	1.1	105.4**	37.9**	3.8	-1.6	38.0*	130.5**
17	ORI-4 RL-77	51.9**	6.0	48.3**	11.0*	19.6**	2.8	113.3**	41.4**	7.5*	0.2	44.9**	140.7**
18	ORI-4 RL-84	48.0**	6.0	44.0**	3.9	45.5**	10.3	70.0**	17.0	10.1**	4.8	35.5*	130.3**
19	ORI-6 RL-27	36.0**	12.8	38.7**	14.3*	58.7**	40.9**	92.2**	72.6**	25.0**	14.5**	234.4**	288.1**

20	ORI-6 RL-46	22.7**	5.5	25.3**	12.5*	5.6	-12.7*	83.6**	55.2**	22.8**	13.7**	54.2**	123.0**
21	ORI-6 RL-55	34.4**	8.7	42.0**	9.4	72.7**	58.1**	94.3**	50.6**	22.2**	9.1**	232.1**	320.1**
22	ORI-6 RL-69	40.0**	10.7	45.5**	12.4	69.5**	65.9**	125.3**	70.4**	22.4**	14.0**	269.8**	373.3**
23	ORI-6 RL-77	65.4**	24.5*	53.6**	22.6**	57.0**	52.0**	146.4**	83.1**	21.6**	15.2**	288.7**	392.0**
24	ORI-6 RL-84	52.6**	18.4	58.3**	21.3**	91.2**	68.8**	124.8**	75.7**	25.0**	15.9**	302.0**	434.5**
25	ORI-10 RL-27	82.0**	76.6**	38.4**	16.0*	60.1**	34.4**	69.3**	58.5**	15.8**	15.3**	146.7**	213.3**
26	ORI-10 RL-46	19.8*	-9.9	7.8	-5.0	10.4	-3.6	42.4**	16.0	16.9**	15.0**	31.7	77.8**
27	ORI-10 RL-55	96.9**	85.4**	62.4**	27.0**	72.7**	49.2**	100.7**	60.7**	9.3**	6.7	170.0**	269.4**
28	ORI-10 RL-69	70.5**	56.2**	55.0**	21.5**	46.8**	34.9**	114.1**	67.2**	19.5**	16.9**	164.5**	265.6**
29	ORI-10xRL-77	70.3**	46.7**	47.7**	19.8**	33.3**	29.0**	117.6**	66.7**	14.4**	9.9**	137.5**	225.1**
30	ORI-10xRL-84	86.1**	66.4**	55.9**	21.2**	55.4**	29.8**	127.3**	83.7**	11.9**	10.0**	162.8**	275.3**
31	ORI-20 RL-27	62.4**	37.8**	37.3**	10.1	53.1**	28.9**	75.3**	45.0**	8.2*	8.0*	97.5**	176.5**
32	ORI-20 RL-28	29.5**	8.8	19.8**	11.1*	-14.8*	-25.9**	64.3**	51.2**	8.8*	7.3*	23.4	49.9*
33	ORI-20 RL-29	43.8**	18.9	42.4**	7.1	49.2**	29.1**	76.4**	28.0*	8.9*	6.1	82.9**	172.1**
34	ORI-20 RL-69	60.5**	29.7**	55.1**	16.9**	27.4**	17.4*	106.2**	46.5**	10.3**	8.2*	84.8**	177.2**
35	ORI-20 RL-77	100.0**	53.5**	71.2**	33.1**	37.3**	33.1**	197.2**	107.9**	12.0**	7.8*	195.1**	339.3**
36	ORI-20 RL-84	94.5**	54.1**	73.9**	30.0**	52.2**	27.4**	132.7**	70.0**	10.6**	8.9*	132.5**	258.1**
37	ORI-22 RL-27	65.1**	36.4**	48.9**	16.7**	74.5**	47.0**	73.6**	33.2**	15.9**	15.7**	125.2**	232.7**
38	ORI-22 RL-46	30.2**	12.5	10.4	5.3	-1.6	-14.4**	55.0**	53.0**	10.4**	9.0*	51.2**	69.8**
39	ORI-22 RL-55	55.5**	25.3*	43.8**	6.0	52.1**	31.8**	56.6**	7.2	7.5*	4.7	55.0*	141.4**
40	ORI-22 RL-69	45.5**	14.7	37.5**	1.6	41.6**	30.7**	54.2**	3.6	10.7**	8.6*	45.0*	127.3**
41	ORI-22 RL-77	65.0**	23.7*	44.4**	9.9	24.5**	20.9**	110.6**	39.7**	13.1**	9.0*	83.6**	186.0**
42	ORI-22 RL-84	54.9**	19.7	54.9**	13.5*	58.6**	33.0**	99.0**	37.1**	18.0**	16.3**	110.6**	237.8**
43	ORI-27 RL-27	40.4**	13.3	30.2**	5.4	21.2*	6.3	87.3**	50.6**	-1.5	-2.6	58.7*	118.1**
44	ORI-27 RL-46	6.6	-5.5	11.3*	2.0	-0.1	-16.5**	37.2**	30.6**	12.2**	12.1**	22.0	51.8*
45	ORI-27 RL-55	101.2**	58.6**	55.5**	17.9**	64.8**	48.9**	94.6**	38.1**	7.3*	3.2	127.2**	232.7**
46	ORI-27 RL-69	48.8**	14.8	61.9**	23.1**	43.5**	38.5**	111.9**	47.4**	17.2**	16.4**	137.4**	250.7**
47	ORI-27 RL-77	76.1**	29.5**	69.1**	32.7**	43.3**	40.7**	143.6**	67.1**	17.3**	14.4**	178.0**	307.4**
48	ORI-27 RL-84	73.6**	31.4**	60.6**	21.0**	58.1**	37.9**	140.7**	72.1**	9.6*	9.4*	157.8**	291.4**
49	ORI-29 RL-27	56.1**	31.1**	48.8**	21.9**	40.4**	29.9**	107.2**	66.9**	12.5**	6.9	158.2**	230.1**
50	ORI-29 RL-46	58.0**	34.2**	34.7**	21.7**	2.0	-18.6**	104.9**	94.5**	12.5**	8.2*	68.9**	126.7**
51	ORI-29 RL-55	42.1**	16.3	50.0**	15.0*	66.1**	58.7**	74.9**	24.4*	11.3**	2.9	139.5**	229.6**
52	ORI-29 RL-69	84.9**	47.9**	76.6**	35.7**	36.8**	33.6**	139.4**	66.8**	14.1**	10.3**	178.4**	287.0**
53	ORI-29 RL-77	84.8**	40.5**	70.5**	35.3**	37.1**	27.1**	130.1**	58.0**	10.0*	8.3*	172.3**	274.9**
54	ORI-29 RL-84	79.9**	41.1**	84.2**	40.4**	77.6**	63.4**	136.6**	69.4**	10.7**	6.5	225.5**	367.3**
55	ORI-37 RL-27	34.0**	11.3	33.1**	9.9	20.8*	7.1	68.7**	32.8**	6.8	4.0	56.3*	114.4**
56	ORI-37 RL-46	22.9**	5.5	13.3*	1.5	-8.8	-24.6**	38.3**	35.3**	10.4**	8.7*	11.0	38.4
57	ORI-37 RL-55	15.8	-6.2	28.8**	-0.6	41.6**	29.5**	30.2	-9	2.7	-2.8	27.9	86.9*
58	ORI-37 RL-69	72.2**	36.4**	62.6**	25.8**	41.7**	38.5**	110.0**	43.8**	14.3**	13.2**	135.1**	246.7**
59	ORI-37 RL-77	81.0**	36.4**	73.9**	39.0**	47.0**	42.6**	128.8**	54.6**	11.8**	10.9**	167.5**	291.2**
60	ORI-37 RL-84	68.3**	30.8**	68.0**	28.9**	69.9**	49.8**	89.2**	33.0**	8.1*	6.5	120.0**	233.6**
61	ORI-41 RL-27	-5.2	-34.3**	8.6	-21.4**	11.8	-14.7**	52.8**	20.9	6.5	5.9	9.9	69.7*
62	ORI-41 RL-46	2.1	-7.5	-2.8	-9.2*	-20.8**	-22.3**	52.0**	47.7**	6.2	4.3	25.4	29.6
63	ORI-41 RL-55	-4.8	-35.2**	-1.0	-32.0**	14.8*	-10.3	17.7	-17.5	3.9	1.6	-13.8	39.2
64	ORI-41 RL-69	26.5**	-15.2*	36.4**	-6.1	15.7*	-4.6	84.7**	27.0*	10.2**	7.7*	29.4	110.4**
65	ORI-41 RL-77	27.2**	-17.6**	26.2**	-10.9*	27.6**	9.9	105.0**	39.0**	7.6*	3.2	62.8**	163.1**
66	ORI-41 RL-84	31.4**	-13.1*	33.1**	-9.1*	41.2**	7.3	97.1**	39.1**	7.4*	5.3	58.5**	162.7**
67	ORI-47 RL-27	20.6	-9.1	25.8**	-2.6	13.8	-6.5	52.3**	18.6	10.4**	8.8*	24.8	83.4*
68	ORI-47 RL-46	8.4	4.8	1.4	-1.7	-10.1	-19.7**	14	13.2	7.7*	7.4*	-1.6	11.3
69	ORI-47 RL-55	29.6**	-4.3	46.6**	6.9	54.1**	30.2**	41.4**	-2.1	8.1*	3.6	44.1	123.5**

70	ORI-47 RL-69	57.1**	13.8	55.7**	13.7*	38.7**	24.5**	107.8**	41.2**	17.5**	17.1**	112.1**	231.3**
71	ORI-47 RL-77	48.4**	3.2	50.1**	12.9*	42.0**	34.0**	64.3**	10.1	11.0**	8.6*	78.5**	177.0**
72	ORI-47 RL-84	68.5**	20.1*	58.7**	15.0**	83.9**	50.4**	66.4**	15.9	12.6**	12.5**	96.8**	214.5**
73	ORI-48 RL-27	27.2*	-4	21.6**	-8.1	54.3**	27.7**	44.0**	11.4	11.2**	10.2**	56.4*	131.8**
74	ORI-48 RL-46	-1.3	-4.8	-4.9	-5.2	-5.1	-15.9**	3.6	3.4	6.6	6.3	-7.1	3.8
75	ORI-48 RL-55	29.4**	-4.4	25.3**	-10.6*	57.2**	33.7**	24.9	-14.0	8.4*	4.4	26.2	97.1**
76	ORI-48 RL-69	36.8**	-0.8	32.7**	-5.1	28.2**	15.9*	75.4**	18.6	13.2**	12.3**	51.7*	138.4**
77	ORI-48 RL-77	73.3**	20.6*	52.1**	11.8*	52.5**	44.9**	106.7**	37.9**	12.2**	9.3*	116.1**	237.5**
78	ORI-48 RL-84	84.5**	31.6**	62.9**	15.7**	67.4**	37.8**	109.1**	44.9**	7.8*	7.4*	110.4**	238.4**
79	ORI-49 RL-27	54.2**	25.1*	47.4**	16.2**	73.7**	49.6**	91.9**	50.9**	10.0**	6.3	163.9**	266.7**
80	ORI-49 RL-46	17.8*	3.7	26.0**	19.2**	15.8*	-1.5	66.9**	63.6**	17.8**	15.2**	84.7**	126.7**
81	ORI-49 RL-55	37.8**	9.2	45.4**	7.7	73.4**	53.8**	61.1**	12.4	0.4	-5.5	90.0**	180.8**
82	ORI-49 RL-69	69.5**	31.4**	76.7**	31.3**	58.8**	50.2**	148.0**	69.7**	17.1**	15.2**	209.4**	361.1**
83	ORI-49 RL-77	81.7**	34.3**	72.0**	31.7**	39.4**	39.0**	140.2**	62.1**	5.3	5.1	141.2**	256.8**
84	ORI-49 RL-84	68.3**	28.0**	67.7**	23.5**	96.5**	68.3**	93.5**	35.8**	10.2**	8.0*	160.4**	298.8**

*, **: Significant at 5% and 1% probability levels, respectively.

Larger stem girth is desirable in sunflower plants and therefore positive heterosis for stem girth is useful. Eighty out of 84 crosses showed positive heterosis for this trait but 74 crosses have significant values. Maximum increase over mid parent (131.9 followed by 131.5 and 101.2 %) was recoded in hybrid ORI-3 x RL-77 fallowed by ORI-3 x RL-84 and ORI-27 x RL-55, respectively. Significant positive heterobeltiosis was observed in 38 crosses where maximum values (114.2, 106.3 and 87.4%) were displayed by the crosses ORI-3 x RL-84, ORI-3 x RL-77 and ORI-3 x RL-55, respectively for stem girth. Sassikumar and Gopalan, (1999) reported positive heterosis for stem girth. However, Gangappa *et al.* (1997) found highest positive heterotic effects for stem girth.

Larger head size is a desired trait to effect more yield in sunflower crop. Regarding head diameter, 80 out of 84 crosses exhibited positive heterosis whereas 76 crosses had significant values. The maximum heterosis percentage (84.2, 80.7 and 79.3%) for head diameter was displayed by the crosses ORI-29 x RL-84, ORI-3 x RL-69 and ORI-3 x RL-84, respectively. The positive and significant heterobeltiosis was manifested by 46 cross combinations for head diameter. The hybrids viz. ORI-3 x RL-77, ORI-3 x RL-69 and ORI-3 x RL-84 showed the highest positive heterobeltiosis with the values of 48.2, 48.0 and 45.4%, respectively for head diameter. Gangappa *et al.* (1997), Gill *et al.* (1998), and Sassikumar and Gopalan, (1999) also found high positive heterosis for head diameter.

More the weight of hundred achenes, more will be the seed yield. So heavier weight of 100 seeds is a desirable plant trait for a successful hybrid seed development programme. Heterosis studies for 100-achene weight (Table II) revealed that 76 cross combinations showed positive increase over the mid parent value. However, significant positive heterosis was indicated in 70 of the crosses. The cross combinations ORI-3 x RL-84, ORI-49 x RL-84 and ORI-6 x RL-84 displayed the highest heterosis percentages (102.4, 96.5 and 91.2%) for 100-achene weight. Heterobeltiosis was positive and significant for only 54 crosses for this trait. The maximum positive and significant heterobeltiosis %ages (69.6, 68.8 and 68.3 %) were observed in the crosses, ORI-3 x RL-84, ORI-6 x RL-84 and ORI-49 x RL-84, respectively. High mid parent heterosis was also recorded by Gangappa *et al.* (1997), and Sassikumar and Gopalan, (1999). The results are in line with the findings of Kandhola *et al.* (1995) regarding heterobeltiosis.

Number of seeds per head is also an effective trait for seed yield and thus positive heterosis for this trait is desirable. Significant and positive heterosis was showed in seventy-eight cross combinations for number of seeds per head. Maximum increase over mid parent was recorded in crosses ORI-3 x RL-77, ORI-20 x RL-77, ORI-1 x RL-69 for number of seeds per head with the value of 230.3, 197.2 and 193.0%, respectively. Significantly positive heterobeltiosis for number of seeds per head was recorded in 64 cross combinations while 5 crosses showed negative heterobeltiosis for this trait. The maximum increase over better parent (178.4, 153.6 and 150.7%) was observed in ORI-3 x RL-77, ORI-1 x RL-84, ORI-1 x RL-69, accordingly. Limbore *et al.* (1999) also reported positive heterosis for number of seeds per head.

Seed yield followed by oil content had the highest direct positive influence on oil yield and it also had a positive direct effect for seed yield per plant (Teklewold *et al.* 2000). Thus higher oil content is a useful trait in sunflower and thus positive heterosis is important. Positive and significant heterosis was indicated in 72 cross combinations for oil content. Highest oil content heterosis was indicated in ORI-6 x RL-27, ORI-6 x RL-46, ORI-6x RL-69, ORI-6 x RL-55, ORI-6 x RL-77 and ORI-10 x RL-69 hybrids with a value of 25.0, 22.8, 22.4, 22.2, 21.6, 19.5%, respectively. Prominent heterobeltiosis was observed in ORI-47 x RL-69, ORI-10 x RL-69, ORI-27 x RL-69, ORI-22 x RL-84, ORI-6 x RL-84 and ORI-22 x RL-27 for oil content in descending order. The results get support from the earlier findings of Kandhola *et al.* (1995), Rather and Sandha (1999) and Nehru (2000).

Positive heterosis for oil yield was displayed in 80 crosses (Table II). Sixty-eight cross combinations showed significant heterosis for oil yield. Maximum heterosis was recorded in ORI-3 x RL-77, ORI-3 x RL-84, ORI-3 x RL-55, ORI-3 x RL-69 and ORI-6 x RL-84 with a value of 440.8, 361.3, 327.7, 326.8 and 302.0%, respectively for oil yield. Yenice and Arslan (1997) found 92.57% hybrid vigor for oil yield.

Positive heterobeltiosis for oil yield was recorded in all the 84 crosses. Positive and significant increase over better parent was observed in 79 hybrids for sunflower oil yield. Maximum heterobeltiosis for this trait was recorded in ORI-3 x RL-77, followed by ORI-3 x RL-84, ORI-6 x RL-84, ORI-3 x RL-69, ORI-3 x RL-55, ORI-6 x RL-77, ORI-6 x RL-69, ORI-29 x RL-84, ORI-49 x RL-69 and ORI-1 x RL-84 with the value of 537.5, 474.7, 434.5, 409.4, 403.8,392.0, 373.3, 367.3, 361.1 and 349.7%, respectively. Rather and Sandha (1999) observed a wide range heterosis and heterobeltiosis in their respective studies.

It is, therefore, concluded that ten hybrids viz., ORI-3 x RL-77, ORI-3 x RL-84, ORI-6 x RL-84, ORI-3 x RL-69, ORI-3 x RL-55, ORI-6 x RL-77, ORI-6 x RL-69, ORI-29 x RL-84, ORI-49 x RL-69 and ORI-1 x RL-84 can be exploited for better oil yield on commercial basis.

REFERENCES

Cheres, M.T., J.F. Miller, J.M. Crane and S.J. Knapp. 2000. Genetic distance as a predictor of heterosis and hybrid performance within and between heterotic groups in sunflower. Theoretical and Applied Genetics, 100(6): 889-894.

Gangappa, E.K.M. Channakrishnaiah, S. Ramesh and M.S. Hariri. 1997. Exploitation of heterosis in sunflower (*Helianthus annuus* L.). Crop Res. 13(2): 339-348 [Pl. Br. Abst. 68(2): 2036; 1998].

Gill, H.S., S.R. Khurana, T.P. Yadava and R.K. Sheoran. 1998. Expression of heterosis for different characters in sunflower over environments. Haryana Agric. Univ. J. Res. 28(2-3): 95-100 [Pl. Br. Abst. 69(9): 9044; 1999].

Kandhola, S.S., R.K. Behl and M.S. Punia. 1995. Heterosis in sunflower. Annals Biology (Ludhiana) 11(½): 98-102 [Pl. Br. Abst. 66(8): 87254; 1996].

Kinman, M.L. 1970. New developments in the UDSA and state experiment station, sunflower breeding programme. Proc. 4th Int. Sunflower Conf. Memphis. Tennessee pp. 181-183.

Leclereq, P. 1969. An utilizable male sterile line for the production of hybrid sunflower. Ann. Amelior. Planata., 76: 135-139.

Limbore, A.R., D.G. Weginwar, S.S. Lande, B.D. Gite, Manjusha- Ghodke and M. Ghodke. 1999. Heterosis in sunflower (*Helianthus annuus* L.). Annals of Pl. Physiology, 13(1): 11-15.

Matingar, D.F., T.J. Mann and C.C. Cockerham. 1962. Diallel crosses in *Nicotiana tobaccum*. Crop Sci. 2: 383-386.

Nehru, S.D., A. Manjunath and D. Basavarajaiah. 2000. Extent of heterosis for seed yield and oil content in sunflower. Karnataka J. Agri. Sci. 13(3): 718-720.

Rather, A.G. and G.S. Sandha. 1999. Heterosis in sunflower. Advances in Plant Sci. 12(1): 53-56.

Sessikumar, D. and A. Gopalan. 1999. Heterosis for seed yield and its components in sunflower (*Helianthus annuus* L.) Madras Agric. J. 86(10-12): 565-567.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. McGraw Hill Book Co. Inc., New York, USA.

Teklewold, A, H. Jayaramaiah and B.N. Jagadeesh. 2000. Correlation and path analysis of physio-marphological characters of sunflower (*Helianthus annuus* L.) as related to breeding method. Helia, 23(32): 105-114.

Wynne, J.C., D.A. Emery and P.M. Rice. 1970. Combining ability estimates in *Arachis hypogaea* L. II. Field performance of F_1 hybrids. Crop Sci. 10(6): 713-715.

Yenice, N. and O.I. Arslan. 1997. Heterosis reported for a synthetic variety obtained from selfed sunflower (*Helianthus annuus* L.) lines. Turkish J. Agric. and Forestry. 21(3): 307-307.