RESEARCH PAPER

Genetic analysis of heterosis for seed yield and its components in sunflower (*Helianthus annuus* L.)

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A study was undertaken to assess the magnitude of heterosis involving seventeen inbred lines of sunflower. The inbred comprised of five new male sterile lines and twelve diverse restorer lines (six branching and six non-branching) which were crossed in all possible combinations. The resulting 60 F_1 hybrids along with their parents were studied for the extent of heterosis during summer 2006 for nine characters by adopting line x tester analysis, considerable average heterosis was observed for all characters studied. Highest magnitude of average heterosis was observed for seed yield per plot (150.34) followed by seed yield per plant (118.86), head diameter (26.79), plant height (15.32), thousand seed weight (7.49) and oil content (2.13) for the characters days to 50 per cent flowering, the hybrids recorded negative average heterosis. Percentage contribution of component characters, *viz*., thousand seed weight, plant height and head diameter towards expression of heterotic effect for seed yield was to the extent of 15.06, 30.82 and 53.86 per cent, respectively.

Key words **:** Heterosis, Sunflower, Inbred lines, Line x tester analysis

How to cite this paper **:** Athoni, B.K. and Nandini, C. (2012). Genetic analysis of heterosis for seed yield and its components in sunflower (*Helianthus annuus* L.). *Asian J. Bio. Sci.*, **7** (1) : 77 - 83.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the important oilseed crops of major economic importance. The introduction of this crop to India in 1969 has helped a great deal increasing oilseed production and the area under cultivation due to its day neutrality, wide adaptability, short duration, high yielding potential, remunerative market price and good quality oil. Due to its cross pollinated it offers considerable scope for commercial exploitation of heterosis utilizing cyto-restorer system (Madrap and Makane, 1993; Sugoor *et al.,* 1996; Gangappa *et al.,* 1997). The discovery of cytoplasm is male sterility (Leclereq, 1969) and subsequent identification of restorers (Ennis *et al.,* 1970) had significantly contributed in genetic improvement of the crop as well as in exploitation, of heterosis, leading to development and release of several hybrids for commercial cultivation. However, favourable characters of the hybrids like production stability, suitability to high input agriculture, high self fertility and uniform growth and maturity shifted the focus towards heterosis breeding leading to the release of the first ever sunflower hybrid in India, BSH-1 by Seetharam (1981). The crop is gaining rapid popularity in India, but the productivity levels of sunflower still continue to be as low as 0.68 tonnes per ha against the world productivity of 1.22 tonnes per ha (Annonymous, 2005). To develop sunflower hybrids with improved yield potential, the choice of parents through careful and critical evaluation is of indicative of the crosses, which are likely to throw productive transgressive segregants. Hence, there is an urgent need to collect basic information about these traits in order to conceptualize breeding strategies suited to specific conditions. The present attempt has been taken to study heterosis for seed yield, oil content and the yield components in sunflower using 5 CMS line and 12 restorer lines among which 6 were branching types and 6 were non-branching types.

RESEARCH METHODOLOGY

Present experimental material consisted of five

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cytoplasmic male sterile lines, DSF-15A,VRF X NDOL-2, 4546A X NDOL-2, 4546A X NDOL-3, 234A X NDOL-2 and restorer lines V-20 (Br), RHA-857 (Br), R-8297 (Br), VI-46 (Br), VI-66 (Br), 6D-1 (Br), RHA-265 (NB), RHA-298 (NB), IV-57 (NB), IX-79 (NB), R-274 (NB) and IV-41 (NB), for crossing at the time of flowering all heads in lines and testers covered with cloth bags to prevent open pollination. Pollens from 12 restorers collected in Petriplates with the help of camel hair brunch, during morning hours and pollinated to each of the male sterile lines separately during *Kharif* 2005.

All the resultant 60 hybrids with 12 restorer 5 maintainer and 2 cheeks were planted in randomized complete block design with three replication at G-Block, MARS, University of Agricultural Sciences, Dharwad during Summer-2006. Each entry was sown in two rows of 4m length per replication with spacing of 60 cm x 30 cm. Observations were recorded on five randomly chosen plants per replication. Data were recorded on days to fifty per cent flowering, days to 100 per cent flowering, days to maturity, seed yield per plant (g), seed yield per plot (g), seed yield per plot per meter row, thousand seed weight (g), Head diameter (cm), plant height (cm), oil content (%).

Heterosis was calculated as a percentage increase or decrease in the F_1 mean over its better parent and mid-parents. Means and heterotic effects were tested by the least significant differences (LSD) test at the 0.05 and 0.01 levels.

RESEARCH FINDINGS AND ANALYSIS

The variance due to treatments was highly significant for all the characters expect for head diameter (Table 1). Female parents showed highly significant variation for all the characters except days to 50 per cent flowering and days to 100 per cent flowering. Male parents showed highly significant variation for all the characters expect days to 50 per cent flowering. For the hybrids/crosses, there was a highly significant variation for all the characters.

The estimate of heterosis for days to 50 per cent flowering, days to 100 per cent flowering and days to maturity over the mid parent, better parent and check hybrids, all the hybrids showed highly significant negative heterosis. Majority of hybrids recorded significant negative heterosis over both the check hybrids DSH-1 and MSFH-17, which indicate the earliness of the hybrids compare of parents. These results are in agreement with earlier findings of Voskobionik (1978), Shankara (1983) and Giriraj *et al.* (1986). The estimates of heterosis (%) over mid parent (MP), better parent (BP) and popular check hybrids, DSH-1 and MSFH-17 are presented in Table 2.

For head diameter, a total of 52 hybrids showed significant positive heterosis. The heterosis ranged from -35.48 per cent (4546A#NDOL-2 x VI-46 (Br)) to 76.00 per cent (DSF-15A x R-274 (NB)). Positive heterotic effect for this trait was also reported by Yilmaz and Emiroglu (1994).

For thousand seed weight, a total of 49 hybrids showed in positive direction and 11 hybrids had shown heterosis in negative direction. The magnitude of heterosis for the characters over mid parent and checks ranged from -55.41 per cent (4546A#NDOL-2 x VI-46 (Br)) to 114.22 per cent (DSF-15A x RHA-265 (NB)). Similar results were reported by Radhika *et al.* (2001), Seetharam *et al.* (2001) and Gill and Sheoran (2002).

The mid parent heterosis for plant height ranged from -22.66 per cent (VRF#NDOL-2 x IV-57 (NB)) to 43.61 (4546A#NDOL-2 x VI-46 (Br)). A total of 52 out of 60 hybrids recorded positive heterosis were 48 of them showing a significant positive heterosis over mid parent. Many authors have also reported marked heterosis for plant height *viz.*, Seetharam *et al.* (1977) and Shirinivasa (1980).

For seed yield (g/plant); magnitude of heterosis over mid parent ranged from -56.67 per cent (4546A#NDOL-2 x VI-46 (Br)) to 193.06 per cent (DSF-15A x R-274 (NB)). Majority of hybrids exhibited highly significant heterosis in positive direction.

The magnitude of heterobeltoisis was from -65.18 per cent (4546A#NDOL-2 x VI-46 (Br)) to 151.65 per cent (4546A#NDOL-2 x R-298 (NB)). 37 hybrids exhibited significant positive heterosis over better parent.

Table 1 : Analysis of variance of nine quantitative traits recorded in parents and hybrids

Sources	Degree of freedom (df)	DFF	DHF	DM	SYP	SYPT	TSW	HD	PH	OC
Replications	2	0.32	0.24	1.21	8.16	22222.13*	1.89	0.96	101.12**	139.32**
Treatments	76	15.03**	17.47**	10.15**	1424.45**	800917.49**	528.59**	18.47**	673.82**	71.41**
Parents	16	0.97**	2.23**	8.87**	620.12**	183880.90**	545.55**	15.54	894.92**	97.55**
Crosses	59	3.02**	14.18**	4.02**	1176.01**	620676.60**	415.67**	12.22**	495.64**	65.17**
Lines	4	1.01*	0.81	9.96**	367.07**	183123.90**	194.43**	2.90**	349.26**	24.10**
Testers	11	0.82*	1.99**	2.49**	415.23**	128040.20**	614.89**	16.63**	1087.94**	132.62**
Lines x testers	1	2.42*	10.64**	114.13**	3886.10**	801156.00**	1187.20**	54.13**	954.40**	5.51*
Error	152	0.37	0.48	0.67	8.77	5360.97	2.12	0.40	4.51	0.88

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 2 : Heterosis over mid parent (MP), better parent (BP) and standard checks (DSH-1 & MSFH-17) for different characters

Sr. No.	Hybrids	Seed yield per plant				Seed yield per plot				1000 seed weight			
		MP	BP	DSH-1	MSFH-17	MP	BP	DSH-1	MSFH-17	MP	BP	DSH-1	MSFH-17
1.	CMS234 A//INDOL 2 x V 20 (Br)	0.14	40.68**	21.31**	50.26**	20.70**	21.91**	28.65**	55.07**	16.61**	3.07	33.16**	17.06**
2.	CMS234 A//INDOL 2 x R 857 (Br)	38.22**	17.74**	9.13	31.62**	42.15**	15.24**	22.56**	51.23**	2.13	15.34**	41.62**	27.56**
3.	CMS234 A//INDOL 2 x R 8297 (Br)	121.16**	42.14**	88.57**	19.20**	102.86**	42.85**	30.25**	17.98**	18.96*	1.84	32.32**	16.02**
4.	CMS234 A//INDOL 2 x VI 46 (Br)	9.82*	17.74**	9.13	31.02**	35.54**	50.38**	54.84**	71.56**	7.80**	6.45**	35.40**	20.20**
5.	CMS234 A//INDOL 2 x VI 66 (Br)	46.15**	33.18**	46.68**	11.69**	43.09**	28.50**	17.41**	26.06**	19.35**	13.50**	21.74**	2.88
6.	CMS234 A//INDOL 2 x R 274 (NB)	20.17**	27.81**	4.23	39.46**	33.20**	14.48**	21.86**	50.79**	8.94**	21.47**	45.85**	32.80**
7.	CMS234 A//INDOL 2 x RHA 265 (NB)	5.20	30.05**	7.19	41.33**	0.16	17.58**	24.69**	62.58**	19.85**	1.84	32.32**	16.02**
8.	CMS234 A//INDOL 2 x R 298 (NB)	26.01**	8.49**	21.00**	23.51**	17.71**	10.88**	18.57**	48.72**	0.53	11.63**	19.63**	0.27
9.	CMS234 A//INDOL 2 x R 6D 1 (Br)	18.23**	45.16**	27.24**	54.01**	7.20	35.37**	40.91**	62.81**	7.63**	22.09**	46.28**	33.34**
10.	CMS234 A//INDOL 2 x IV 57 (NB)	158.70**	68.44**	123.45**	41.25**	139.67**	70.50**	55.79**	1.90	37.32**	31.90**	9.05**	12.87**
11.	CMS234 A//INDOL 2 x XI 79 (NB)	42.81**	19.75**	58.86**	0.42	85.31**	20.93**	10.49**	30.42**	13.41**	12.43**	21.32**	2.36
12.	CMS234 A//INDOL 2 x IV 41 (NB)	49.37**	3.53	37.35**	13.18**	16.98**	25.29**	31.74**	57.01**	4.65**	0.55	23.86**	5.51**
13.	VRF//INDOL 2 x V 20 (Br)	120.36**	37.31**	36.59**	13.66	145.28**	85.16**	2.47	38.58**	26.39**	1.11	23.01**	4.46*
14.	VRF//INDOL 2 x R 857 (Br)	70.24**	6.72	6.17	32.89**	235.87**	124.02**	18.00**	25.69**	24.41**	3.33	21.32**	2.36
15.	VRF//INDOL 2 x R 8297 (Br)	114.05**	47.76**	46.99**	7.08	99.37**	69.78**	10.57*	43.68**	34.97**	7.22	18.36**	1.31
16.	VRF//INDOL 2 x VI 46 (Br)	96.41**	63.63**	62.58**	2.77	143.56**	134.52**	23.53**	22.21**	23.75**	2.78	21.74**	2.88
17.	VRF//INDOL 2 x VI 66 (Br)	82.21**	74.15**	90.04**	20.13**	136.75**	104.10**	48.46**	6.51**	35.78**	23.33**	6.09**	16.54**
18.	VRF//INDOL 2 x R 274 (NB)	138.82**	51.49**	50.71**	4.73	90.38**	42.09**	25.15**	52.87**	70.63**	19.44**	9.05**	12.87**
19.	VRF//INDOL 2 x RHA 265 (NB)	119.18**	79.10**	78.17**	12.63**	192.35**	176.68**	63.25**	2.80	48.59**	17.22**	10.75**	10.76**
20.	VRF//INDOL 2 x R 298 (NB)	46.73**	17.16**	16.55**	26.33**	56.70**	48.24**	21.91**	50.83**	18.99**	9.30**	0.60	23.35**
21.	VRF//INDOL 2 x 6D 1 (Br)	50.77**	9.70	9.13	31.02**	106.45**	73.18**	8.56	42.42**	69.96**	19.44**	9.05**	12.87**
22.	VRF//INDOL 2 x IV 57 (NB)	178.22**	95.52**	94.50**	22.95**	249.24**	202.69**	59.44**	0.40	43.47**	31.11**	0.16	23.85**
23.	VRF//INDOL 2 x IX 79 (NB)	97.65**	88.06**	87.08**	18.26**	132.76**	77.97**	6.25*	40.96**	5.51**	1.11	23.01**	4.46*
24.	VRF//INDOL 2 x IV 41 (NB)	35.96**	2.99	2.45	35.24**	154.67**	88.57**	0.69	37.46**	25.21**	26.00**	42.89**	23.13**
25.	4546A//INDOL 3 x V 20 (Br)	38.92**	13.43**	13.88**	45.56**	109.90**	58.45**	16.54**	47.44**	7.64**	13.87**	34.43**	18.17**
26.	4546A//INDOL 3 x R 857 (Br)	23.81**	22.39**	22.78**	51.19**	55.64**	3.81	45.32**	65.57**	11.71**	26.67**	44.16**	30.71**
27.	4546A//INDOL 3 x R 8297 (Br)	107.57**	43.28**	42.54**	9.90**	210.38**	164.31**	39.22**	2.33**	47.55**	17.22**	10.75**	10.76**
28.	4546A//INDOL 3 x VI 46 (Br)	164.57**	120.15**	119.00**	38.43**	291.13**	276.61**	98.38**	24.93**	19.73**	0.56	24.28**	6.03**
29.	4546A//INDOL 3 x VI 66 (Br)	7.47	12.99	3.50	39.00**	0.66	13.22*	36.88**	60.25**	8.26**	16.67**	36.55**	21.26**
30.	4546A//INDOL 3 x R 274 (NB)	110.59**	33.58**	32.90**	15.99**	308.83**	205.13**	66.73**	1.21*	35.54**	7.22**	29.35**	12.33**
31.	4546A//INDOL 3 x RHA 265 (NB)	15.98**	5.22	5.72**	40.41**	35.15**	27.90**	24.54**	52.48**	4.23	24.44**	42.47**	28.61**
32.	4546A//INDOL 3 x R 298 (NB)	13.08*	30.60**	30.96**	56.36**	43.07**	35.35**	28.70**	55.10**	15.95**	22.78**	29.78**	12.87**
33.	4546A//INDOL 3 x 6D 1 (Br)	4.62	23.88**	24.28**	52.13**	92.22**	61.62**	14.87**	46.39**	20.16**	15.56**	35.40**	20.20**

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Table 2 contd....

Sr. No.	Hybrids	Seed yield per plant				Seed yield per plot				1000 seed weight			
		MP	BP	DSH 1	M.SFH 17	MP	BP	DSH 1	M.SFH 17	MP	BP	DSH 1	M.SFH 17
34.	4546A//NDOL 3 x IV 57 (NB)	22.34**	14.18**	14.63**	46.04**	114.93**	86.28**	1.88	38.21**	7.60**	15.56**	35.82**	20.36**
35.	4546A//NDOL 3 x IX 79 (NB)	81.96**	73.13**	72.23**	8.87**	260.66**	175.78**	45.27**	8.52**	13.62**	8.89**	17.09**	2.88
36.	4546A//NDOL 3 x IV 41 (NB)	20.20**	8.96	9.42	42.74**	85.03**	37.01**	27.83**	54.55**	24.65**	24.31**	4.82**	18.11**
37.	4546A//NDOL 2 x V 20 (Br)	106.68**	42.86**	3.50	39.00**	151.86**	108.41**	14.56**	46.19**	1.76**	7.32**	35.70**	20.20**
38.	4546A//NDOL 2 x R 857 (Br)	191.20**	100.00**	35.12**	14.59**	349.60**	221.27**	31.71**	17.06**	27.92**	10.37**	23.44**	4.99**
39.	4546A//NDOL 2 x R 8297 (Br)	70.42**	32.97**	10.18	43.22**	132.76**	121.52**	9.18*	42.81**	22.96**	1.22	29.78**	12.87**
40.	4546A//NDOL 2 x VI 46 (Br)	56.67**	65.18**	71.05**	81.70**	34.56**	39.36*	70.63**	81.50**	55.41**	47.06**	73.35**	16.93**
41.	4546A//NDOL 2 x VI 66 (Br)	50.42**	21.77**	32.90**	15.99**	117.59**	70.12**	23.74**	22.08**	4.82**	0.01	31.05**	14.44**
42.	4546A//NDOL 2 x R 274 (NB)	117.32**	51.65**	2.45	35.24**	137.42**	93.85**	20.52**	49.95**	38.98**	0.00	3.62**	13.91**
43.	4546A//NDOL 2 x RHA 265 (NB)	36.36**	31.87**	10.91*	43.69**	63.84**	38.89**	18.13**	48.45**	13.43**	7.32**	35.70**	20.20**
44.	4546A//NDOL 2 x R 298 (NB)	167.84**	151.65**	70.00**	7.46*	253.05**	230.54**	55.32**	2.19	19.25**	5.12**	4.40**	18.63**
45.	4546A//NDOL 2 x 6D 1 (Br)	59.21**	32.97**	10.18	43.22**	147.63**	132.25**	4.78	40.04**	2.11	26.22**	48.82**	36.49**
46.	4546A//NDOL 2 x IV 57 (NB)	33.79**	47.75	64.37**	77.47**	30.30**	38.16*	72.25**	82.52**	12.46**	18.05**	42.04**	28.08**
47.	4546A//NDOL 2 x IX 79 (NB)	145.28**	114.88**	93.03**	22.02**	128.01**	91.53**	21.48**	50.55**	36.17**	35.76**	5.24**	17.59**
48.	4546A//NDOL 2 x IV 41 (NB)	86.25**	63.74**	10.62*	30.07**	102.71**	63.99**	32.77**	57.66**	5.51**	0.55	23.01**	4.46**
49.	DSF 15A x V 20 (Br)	71.63**	12.04	10.18	43.22**	81.77**	30.77**	19.98**	49.61**	57.21**	48.76**	23.86**	5.51**
50.	DSF 15A x R 857 (Br)	157.75**	69.44**	35.86**	14.22**	168.36**	72.76**	5.71	33.43**	110.83**	108.09**	7.02**	32.80**
51.	DSF 15A x R 8297 (Br)	88.68**	38.89**	11.36*	29.61**	60.36**	28.71**	21.24**	50.40**	73.57**	60.81**	16.66**	3.42
52.	DSF 15A x VI 46 (Br)	146.70**	125.00**	80.40**	14.04**	89.43**	70.20**	4.14	34.42**	50.83**	49.57**	23.44**	4.99**
53.	DSF 15A x VI 66 (Br)	69.41**	46.94**	60.36**	1.37	82.75**	68.25**	22.38**	22.93**	58.21**	44.22**	10.32**	11.29**
54.	DSF 15A x R 274 (NB)	193.06**	95.37**	56.64**	0.99	177.74**	97.77**	21.01**	23.79**	86.53**	48.76**	23.86**	5.51**
55.	DSF 15A x RHA 265 (NB)	156.99**	129.63**	84.12**	16.39**	132.10**	127.95**	39.48**	12.66v	114.22**	90.17**	1.94	26.50**
56.	DSF 15A x R 298 (NB)	96.81**	71.30**	37.35**	13.18**	60.82**	42.16**	13.01**	45.22**	4.17*	21.12**	32.74**	15.48**
57.	DSF 15A x 6D 1 (Br)	13.61	11.11	28.73**	54.95	48.66**	17.95**	27.83**	54.55**	70.10**	36.36**	30.20**	13.39**
58.	DSF 15A x IV 57 (NB)	155.56**	91.67**	53.67**	2.86	148.13**	102.40**	23.84**	22.01**	0.74	10.07**	43.31**	29.65**
59.	DSF 15A x IX 79 (NB)	86.90**	76.86**	53.86**	0.42	217.18**	130.85**	41.26**	11.05**	35.66**	17.58**	17.93**	1.84
60.	DSF 15A x IV 41 (NB)	123.73**	83.33**	46.99**	7.08*	185.67**	101.98	23.59**	22.17**	28.48**	7.18**	17.93**	1.84

Contd... ...Table 2

Table 2 contd....

Sr. No.	Hybrids	Head diameter MP	Head diameter BP	Head diameter DSH 1	Head diameter MSFH 17	Plant height MP	Plant height BP	Plant height DSH 1	Plant height MSFH 17	Oil content MP	Oil content BP	Oil content DSH 1	Oil content MSFH 17
1.	CMS234A/INDOL 2 x V 20 (Br)	31.03**	0.00	0.24	13.22**	4.55**	16.44**	27.41**	34.55**	5.71**	8.92**	17.07**	23.43**
2.	CMS234A/INDOL 2 x R 857 (Br)	50.88**	13.16**	12.83**	1.85	8.53**	4.33**	9.69**	18.58**	9.31**	2.55**	4.74*	10.43**
3.	CMS234A/INDOL 2 x R 8297 (Br)	61.40**	21.05**	20.71**	5.00	27.03**	19.10**	17.78**	6.19**	9.49**	8.33**	1.45	3.90
4.	CMS234A/INDOL 2 x VI 46 (Br)	5.71	13.16**	13.39**	24.66**	22.19**	20.47**	4.27**	5.99**	34.24**	82.18**	14.22**	20.43**
5.	CMS234A/INDOL 2 x VI 66 (Br)	10.53**	10.53**	10.21*	4.11	10.47**	0.51	6.12**	4.32**	19.27**	13.82**	7.36**	2.33
6.	CMS234A/INDOL 2 x R 274 (NB)	21.43**	10.53**	10.79**	22.40**	18.37**	17.13**	3.55**	6.64**	18.21**	50.45**	4.64	10.33**
7.	CMS234A/INDOL 2 x RHA 265 (NB)	0.00	7.89**	8.11*	20.07**	18.48**	14.13**	6.62**	3.87**	15.32**	17.79**	21.40**	28.00**
8.	CMS234A/INDOL 2 x R 298 (NB)	27.54**	15.79**	15.51**	0.48	35.80**	33.11**	15.21**	3.87**	19.29**	36.76**	13.72**	19.90**
9.	CMS234A/INDOL 2 x R 6D 1 (Br)	6.67	15.79**	15.98**	26.92**	30.63**	29.41**	14.12**	2.89**	7.27**	17.94**	26.77**	33.66**
10.	CMS234A/INDOL 2 x IV 57 (NB)	70.00**	34.21**	33.86**	16.24**	7.88**	6.01**	9.56**	1.22	8.68**	15.73**	10.11**	16.10**
11.	CMS234A/INDOL 2 x XI 79 (NB)	13.89**	7.89**	7.64	6.37	18.93**	16.50**	5.13**	5.21**	10.75**	10.62**	4.20	1.00
12.	CMS234A/INDOL 2 x IV 41 (NB)	14.71*	2.63	2.36	10.96**	10.87**	10.15**	3.41**	12.92**	5.89**	13.15**	6.95**	12.76**
13.	VRF/INDOL 2 x V 20 (Br)	47.17**	18.18	2.36	10.96**	29.17**	13.54**	1.83	11.49**	18.23**	22.95**	29.84**	36.90**
14.	VRF/INDOL 2 x R 857 (Br)	26.92**	0.00	13.39**	29.66**	17.07**	12.60**	2.64*	12.22**	5.89**	2.10**	7.80**	13.66**
15.	VRF/INDOL 2 x R 8297 (Br)	53.85**	21.21	4.96	8.70	6.85**	10.16**	13.67**	22.17**	5.27**	3.19**	2.21	7.76**
16.	VRF/INDOL 2 x VI 46 (Br)	35.38**	33.33	15.51**	0.48	14.63**	13.07**	2.24	11.86**	5.57**	26.72**	20.55**	16.23**
17.	VRF/INDOL 2 x VI 66 (Br)	21.13**	13.16	12.83**	1.85*	1.01	8.13**	3.00*	12.55**	29.62**	24.25**	20.01**	16.21**
18.	VRF/INDOL 2 x R 274 (NB)	52.94**	18.18	2.36	10.96**	17.55**	16.26**	2.78*	7.33**	13.36**	42.73**	0.72	4.66
19.	VRF/INDOL 2 x RHA 265 (NB)	35.38**	33.33	15.51**	0.48	10.65**	6.53**	0.47	10.27**	11.82**	10.74**	7.99**	3.00
20.	VRF/INDOL 2 x R 298 (NB)	12.50**	9.09	5.51	17.81**	12.10*	9.93**	5.02**	14.36**	14.01**	29.40**	7.58**	13.40**
21.	VRF/INDOL 2 x 6D 1 (Br)	23.64**	3.03	10.79**	22.40**	11.40**	10.35**	2.69*	12.27**	2.02**	13.27**	19.60**	26.10**
22.	VRF/INDOL 2 x IV 57 (NB)	60.00**	33.33	15.51**	0.48	22.66**	9.20**	21.49**	29.22**	12.97**	19.16**	13.40**	19.56**
23.	VRF/INDOL 2 x IX 79 (NB)	7.46	5.88	5.51	17.81**	18.38**	15.90**	4.59**	5.70**	7.28**	6.59**	1.35	4.00
24.	VRF/INDOL 2 x IV 41 (NB)	11.11**	6.06	8.11*	20.17**	10.93**	10.15**	3.41**	12.92**	19.75**	26.76**	19.82**	26.33**
25.	4546A/INDOL 3 x V 20 (Br)	24.53**	0.00	13.39**	24.66**	22.27**	7.48**	7.07**	16.22**	8.43**	7.13**	2.97	8.56**
26.	4546A/INDOL 3 x R 857 (Br)	23.08**	3.03	15.98**	26.92**	9.29**	5.12**	9.11**	18.05**	21.94**	17.49**	8.53**	3.56
27.	4546A/INDOL 3 x R 8297 (Br)	50.00**	18.18	2.36	10.96**	4.75**	1.83	2.92*	12.47**	0.76	1.05	11.38**	17.43**
28.	4546A/INDOL 3 x VI 46 (Br)	56.92**	54.55	33.86**	16.44**	15.37**	13.80**	1.61	11.29**	29.45**	2.35**	38.76**	35.43**
29.	4546A/INDOL 3 x VI 66 (Br)	12.68**	5.26	4.96	8.70*	2.99**	11.77**	6.85**	16.01**	10.29**	5.89**	4.33	10.00**
30.	4546A/INDOL 3 x R 274 (NB)	56.86**	21.21	4.96	8.70*	17.39**	16.10**	2.64*	7.46**	31.43**	70.45**	18.50**	25.00**
31.	4546A/INDOL 3 x RHA 265 (NB)	4.62	3.03	10.79**	22.40**	0.30	3.43**	9.78**	18.66**	29.06**	33.95**	38.06**	45.56**

Contd... ... Table 2

Table 2 contd....

32.	4546A/INDOL 3 x R 298 (NB)	3.12	0.00	18.66**	29.25**	0.11	2.04	15.30**	23.64**	18.41**	38.15**	14.85**	21.10**
33.	4546A/INDOL 3 x 6D 1 (B+)	16.36**	3.03	15.98**	26.92**	0.57	0.91	12.18**	20.83**	12.97**	5.89**	4.33	10.00**
34.	4546A/INDOL 3 x IV 57 (NB)	27.27**	6.06	8.11*	20.07**	10.95**	22.45**	9.61	18.50**	9.05**	18.05**	12.33**	18.43**
35.	4546A/INDOL 3 x IX 79 (NB)	25.37**	23.53**	10.23*	4.11	9.99**	7.69**	2.83*	12.39**	1.21	2.95**	10.33**	16.33**
36.	4546A/INDOL 3 x IV 41 (NB)	11.11**	6.06	8.11*	20.07**	8.95**	8.20**	5.13**	14.47**	16.88**	9.70**	14.63**	10.00
37.	4546A/INDOL 2 x V 20 (B+)	48.00**	23.33**	2.91	15.55**	37.69**	32.67**	6.22**	15.46**	0.53	3.60**	9.07**	15.00**
38.	4546A/INDOL 2 x R 857 (B+)	75.51**	43.33**	12.83**	1.85	28.73**	21.34**	3.10**	12.63**	4.65**	13.71**	19.69**	26.23**
39.	4546A/INDOL 2 x R 8297 (B+)	34.59**	10.00*	13.39**	24.66**	8.32**	7.13**	8.16**	17.19**	8.56**	11.11**	16.97**	23.33**
40.	4546A/INDOL 2 x VI 46 (B+)	35.48**	37.33**	47.48**	54.32**	43.61**	32.19**	4.19**	0.24	40.53**	88.24**	18.02**	24.33**
41.	4546A/INDOL 2 x VI 66 (B+)	23.53**	10.53*	10.24*	4.11	18.56**	1.03	4.49**	5.79**	6.78**	15.12**	20.18**	27.76**
42.	4546A/INDOL 2 x R 274 (NB)	50.00**	20.00**	5.51	17.81**	33.18**	19.84**	5.95**	4.48**	2.23**	22.88**	14.54**	9.90**
43.	4546A/INDOL 2 x RHA 265 (NB)	16.13**	12.50*	5.51	17.81**	15.06**	1.06	5.58**	14.87**	4.30**	3.27**	0.31	5.10*
44.	4546A/INDOL 2 x R 298 (NB)	50.82**	48.39**	20.71**	5.00	29.89**	20.17**	0.12	9.94**	20.58**	36.63**	13.59**	19.76**
45.	4546A/INDOL 2 x 6D 1 (B+)	30.77**	13.33*	10.79**	22.40**	0.65**	9.33**	20.15**	27.92**	13.68**	26.43**	33.10**	40.33**
46.	4546A/INDOL 2 x IV 57 (NB)	23.08**	33.33**	47.48**	54.32**	9.39**	27.22**	15.17**	23.51**	30.28**	26.58**	30.12**	26.33**
47.	4546A/INDOL 2 x IX 79 (NB)	46.88**	38.24**	23.39**	7.33*	18.13**	5.33**	4.95**	14.30**	4.66**	5.61**	11.19**	17.23**
48.	4546A/INDOL 2 x IV 41 (NB)	36.67**	36.67**	7.64	6.37	22.60**	10.72**	2.92**	12.47**	36.60**	44.37**	36.48**	43.90**
49.	DSF 15A x V 20 (B+)	38.46**	12.50*	5.51	17.81**	26.79**	10.44**	2.46*	12.06**	3.03**	11.39**	2.08**	3.23
50.	DSF 15A x R 857 (B+)	56.86**	25.00**	4.96	8.70*	4.22**	0.77	12.36**	20.98**	12.26**	35.01**	18.65**	25.10**
51.	DSF 15A x R 8297 (B+)	33.33**	6.25	10.79	22.40**	9.56**	3.70**	2.56*	7.54**	8.30**	22.06**	7.27**	13.10**
52.	DSF 15A x VI 46 (B+)	43.75**	43.75**	20.71	5.00	7.42**	4.86**	7.39**	16.50**	36.32**	63.70**	2.65	8.23
53.	DSF 15A x VI 66 (B+)	20.00**	10.53*	10.24	4.11	7.60**	15.16**	10.42**	19.24**	6.39**	11.63**	1.89	3.43
54.	DSF 15A x R 274 (NB)	76.00**	37.50**	15.51	0.48	18.82**	18.76**	5.00**	5.34**	32.13**	49.55**	4.01	9.66
55.	DSF 15A x RHA 265 (NB)	46.88**	46.88**	23.39	7.33*	11.56**	8.51**	1.38	8.60**	18.43**	28.66**	13.08**	19.23**
56.	DSF 15A x R 298 (NB)	26.98**	25.00**	4.96	8.70*	25.60**	21.90**	7.66**	2.93**	21.45**	25.22**	4.11	9.46**
57.	DSF 15A x 6D 1 (B+)	18.52**	0.05	15.98	26.92**	15.80**	15.71**	2.19	7.87**	11.81**	37.89**	21.18**	27.76**
58.	DSF 15A x IV 57 (NB)	55.56**	31.25**	10.24	4.11	10.21**	21.09**	8.06**	17.07**	17.21**	22.06**	7.27**	13.10**
59.	DSF 15A x IX 79 (NB)	27.27**	23.53**	10.24	4.11	15.12**	13.90**	2.72*	7.33**	2.65**	13.91**	0.12	5.56*
60.	DSF 15A x IV 41 (NB)	35.48**	31.25**	10.24	4.11	10.02**	9.62**	3.19**	12.71**	26.63**	31.41**	15.49**	21.76**

* and ** indicate significance of values at P 0.05 and 0.01, respectively

The range in standard heterosis over the DSH-1 was from -71.05 per cent (4546A#NDOL-2 x VI-46 (Br) to 123.45 per cent (CMS-234A#NDOL-2 x IV-57 (NB)). Totally 16 hybrids recorded positive heterosis and 44 hybrids that showed negative heterosis. The results were in agreement with that of Ashok *et al.* (2000) and Ahmed *et al.* (2005).

In case of seed yield per plot, the mid-parent heterosis for seed yield ranged from -35.54 per cent (CMS-234A#NDOL-2 x IV-46 (Br)) to 349.60 per cent (4546A#NDOL-2 x R-857 (Br)). Expect one hybrid (CMS-234A#NDOL-2 x VI-46 (Br)), all the hybrids showed significant positive heterosis over mid-parent for this economic trait.

The heterosis over better parent ranged from -50.38 per cent (CMS-234A#NDOL-2 x VI-46 (Br)) to 276.61 per cent (4546A#NDOL-3 x VI-46 (Br)). A total of 48 hybrids out of 60 showed significant positive heterosis over the better parent.

The standard heterosis over the DSH-1 ranged from -72.25 per cent (4546A#NDOL-2 x IV-57 (NB)) to 98.38 per cent (4546A#NDOL-2 x IV-46 (Br)). A total of 24 hybrids showed positive and 36 hybrids recorded negative heterosis. Indicating that MSFH-17 was high yielder than most of the crosses under study as compared to DSH-1.

Significant heterotic effect for seed yield has also been reported earlier by Reddy *et al.* (1985) and Madrap and Makn (1993).

For oil content, 36 out of 60 hybrids recorded highly significant positive heterosis. The maximum heterotic effect was exhibited in the cross (4546A#NDOL-2 x IV-46 (Br)) to an extent of 40.53 per cent. The average heterotic effect of F1 over mid parent was 6.13%. Similar positive heterosis for oil content% was also observed by several workers *viz.*, Rather *et al.* (1999) and Nehru *et al.* (2000).

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Received : *20.01.2012;* **Revised :** *15.02.2012;* **Accepted :** *04.03.2012*