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Heterosis Studies for Seed Yield and its Components in Sunflower Hybrids Over Locations

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Seven cytoplasmic male sterile lines were crossed with six restorers in line x tester fashion to estimate the heterosis for seed yield and its component traits in sunflower. The result revealed that seed yield and its components showed highly significant differences for all the traits. The extent of heterosis in 42 hybrids over better parent (BP) ranged from 6.15 to 317.28% for seed yield and from -11.42 to 10.18% for oil content. The superiority of hybrids over standard check (PAC-1091) ranged from -58.41 to 24.63% and from -5.92 to 14.88% for seed yield and oil content respectively. The hybrids CMS 234A x RHA-6D-1R, CMS 852A x RHA-6D-1R and ARM 243A x 3376R were the best for seed yield, oil content and yield characters. These hybrids may be exploited for heterosis breeding and need to be screened for yield stability.

Key words: Sunflower, heterosis, yield components.

Sunflower (*Helianthus annuus* L.) has now become the oilseed crop of major economic importance world wide. Due to its cross pollinated nature, it offers considerable scope for commercial exploitation of heterosis utilizing cyto-restorer system (Madrap and Makne, 1993; Gangappa *et al*., 1997). A new era opened in sunflower breeding with the discovery of cytoplasmic male sterility by Leclercq (1969) in France and fertility restoration by Kinman (1970) in USA, which provided the required breakthrough in heterosis breeding. The area under sunflower in the country increased to around 2.4 m ha^{-1} (Loganathan and Gopalan, 2006) mainly due to the development of hybrids. Release of first sunflower hybrid BSH 1 (Seetharam, 1980) was considered as the turning point in the sunflower cultivation. In practice, heterosis can be useful only with marked superiority over commercial check. The present attempt has been taken to study the magnitude of heterosis in the form of heterobeltiosis and standard heterosis for seed yield and yield contributing characters.

Materials and Methods

Seven CMS lines (CMS 234A, CMS 17A, CMS 852A, CMS 89A, ARM 238A, ARM 243A and ARM 248A) were crossed with six restorers (RES-834-1, LTRR 341, RHA-6D-1R, 3376R, R-298 and R-649) during *Kharif*, 2008 at Directorate of Oilseeds Research, Rajendranagar, Hyderabad. Crosses were made in a line x tester fashion (Kempthorne, 1957) to synthesize 42 F_1 hybrids. During *rabi*, 2008-09 the parents and hybrids along with standard check (PAC-1091) were evaluated in a Randomized Block Design replicated thrice at three different locations *viz*., Directorate of Oilseeds Research, Hyderabad; Agricultural Research Station, Tandur; and Regional Agricultural Research Station, Jagtial. Each entry was grown in a two rows of 4 m length with a spacing of 60 cm between rows and 30 cm between plants with in a row was maintained. All the recommended agronomic practices were followed to raise a healthy crop. Observations were recorded on five randomly selected plants in each hybrid combination per replication for nine quantitative characters *i.e* ., days to 50 per cent flowering, days to maturity, plant height, head diameter, stem diameter, number of filled seeds per head, 100- seed weight, seed yield per plant and oil content. Oil content was determined through non-destructive method by utilizing Nuclear Magnetic Resonance (NMR) spectrometer available at Directorate of Oilseeds Research, Rajendranagar, Hyderabad and was expressed in percentage. Days to 50 per cent flowering and days to maturity were recorded on whole plot basis. Based on pooled values, heterobeltiosis, standard heterosis were calculated as per standard procedures.

Results and Discussion

The pooled Anova revealed that seed yield and its components showed highly significant differences for all the traits. The performance of 42 hybrids with respect to heterobeltiosis and standard heterosis for nine characters is presented in Table
1. The mean values of parents, hybrids and standard check on nine characters are presented in Table 2.

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Table 1. Estimates of heterobeltiosis and standard heterosis (Over PAC-1091) for days to 50% flowering, days to maturity and plant height

Cross	Days to 50% flowering		Days to maturity		Plant height	
	BP	SH	BP	SH	BP	SH
CMS-234A X RES-834-1	-3.09**	-3.84**	-0.71	-2.28**	17.98**	6.03**
CMS-234AX LTRR-341	1.61	-3.07**	0.72	-2.45**	19.39**	7.29**
CMS-234A X 3376R	-4.21**	-6.91**	-5.30**	-6.13**	21.65**	9.32**
CMS-234A X RHA-6D-1R	-2.87**	-4.86**	-1.59**	-2.28**	17.96**	10.94**
CMS-234A X R-298	-1.55	-2.56**	-0.88	-1.75**	23.23**	10.75**
CMS-234A X R-649	1.03	0	0	0.35	-7.01**	-16.43**
CMS-17A X RES-834-1	4.90**	4.09**	6.94**	5.25**	-1.31	2.27
CMS-17AX LTRR-341	-2.65**	-6.14**	-3.58**	-5.60**	-3.40**	0.1
CMS-17A X 3376R	4.21**	1.28	3.53**	2.63**	0.94	4.60**
CMS-17A X RHA-6D-1R	1.31	-0.77	0.53	-0.18	7.42**	11.32**
CMS-17A X R-298	2.33**	1.28	3.89**	2.98**	-0.83	2.77*
CMS-17A X R-649	4.91**	3.84**	4.71**	5.08**	-21.21**	-18.35**
CMS-852A X RES-834-1	-5.93**	-6.65**	-4.80**	-6.30**	20.73**	-6.75**
CMS-852AX LTRR-341	1.34	-3.07**	-0.18	-2.80**	16.32**	-1.65
CMS-852A X 3376R	6.05**	3.07**	6.18**	5.25**	40.30**	8.36**
CMS-852A X RHA-6D-1R	2.35**	0.26	2.29**	1.58**	9.16**	2.66*
CMS-852A X R-298	3.62**	2.56**	4.42**	3.50**	6.52**	-9.27**
CMS-852A X R-649	0.26	-0.77	1.22*	1.58**	12.21**	-0.61
CMS-89A X RES-834-1	-0.25	0.51	1.90**	3.50**	30.87**	0.2
CMS-89AX LTRR-341	-1.52	-0.77	0.69	2.28**	1.83	-13.90**
CMS-89A X 3376R	1.27	2.05*	1.55**	3.15**	18.45**	-10.26**
CMS-89A X RHA-6D-1R	-0.51	0.26	-0.69	0.88	9.66**	3.13*
CMS-89A X R-298	-4.31**	-3.58**	-5.69**	-4.20**	15.10**	-1.97
CMS-89A X R-649	-2.28**	-1.53	-1.55**	0	-0.31	-11.70**
ARM-238A X RES-834-1	-4.76**	-2.81	0.17**	1.58**	-1.04	6.54**
ARM-238AX LTRR-341	-7.02**	-5.12**	-4.84**	-3.50**	-3.55**	3.83**
ARM-238A X 3376R	-2.76**	-0.77	-0.17	1.23*	2.44*	10.28**
ARM-238A X RHA-6D-1R	-6.02**	-4.09**	-5.01**	-3.68**	11.16**	19.67**
ARM-238A X R-298	-3.01**	-1.02	0.35	1.75**	9.50**	17.88**
ARM-238A X R-649	-1.75*	0.26	2.94**	4.38**	5.46**	13.53**
ARM-243A X RES-834-1	-5.24**	-2.81**	-5.62**	-2.98**	-7.80**	2.11
ARM-243AX LTRR-341	-6.73**	-4.35**	-3.41**	-0.7	-3.44**	6.94**
ARM-243A X 3376R	-6.73**	-4.35**	-3.24**	-0.53	0.28	11.06**
ARM-243A X RHA-6D-1R	-7.98**	-5.63**	-6.81**	-4.20**	-0.96	9.69**
ARM-243A X R-298	-6.98**	-4.60**	-6.81**	-4.20**	-3.38**	7.00**
ARM-243A X R-649	-3.99**	-1.53	-3.75**	-1.05	-6.90**	3.10*
ARM-248A X RES-834-1	-5.81**	-4.60**	-7.91**	-4.20**	10.35**	16.09**
ARM-248AX LTRR-341	-6.31**	-5.12**	-7.24**	-3.50**	15.52**	21.54**
ARM-248A X 3376R	-2.78**	-1.53	-3.87**	0	0.96	6.22**
ARM-248A X RHA-6D-1R	-1.26	0	-2.86**	1.05	6.55**	12.09**
ARM-248A X R-298	-1.77	-0.51	-4.21**	-0.35	14.90**	20.88**
ARM-248A X R-649	-7.58**	-6.39**	-7.07**	-3.33**	-5.21**	-0.28
No.of hybrids with significant + ve value	7	5	12	15	24	27
No.of hybrids with significant - ve value	23	19	20	17	9	7
Range of heterosis	-7.98 to 6.05	-6.91 to 4.09	-7.91 to 6.94	-6.30 to 5.25	-21.21 to 40.30	-18.35 to 21.54

*: Significant at 5 % level; **: Significant at 1% level BP: Better Parent; SH: Standard Heterosis;

For days to 50 per cent flowering, negative values of heterosis imply early flowering in hybrids over better parent or standard check, as the case may be. Hence, heterosis in the negative direction is desirable for this trait. In pooled analysis, out of 42 crosses, 23 cross combinations depicted significant negative heterobeltiosis for days to 50 per cent flowering. The spectrum of variation was from –7.98 (ARM 243A x RHA-6D-1R) to 6.05 per cent (CMS 852A x 3376R). Nineteen hybrids exhibited significant negative standard heterosis and matured earlier than the standard check PAC -1091.The highest negative standard heterosis of –6.91 per cent was recorded by CMS 234A x 3376R. Early maturing hybrids are desirable as they produce more yield per day and fit well in multiple cropping systems. In the present study, the hybrid ARM 248A x RES 834-1 (-7.91%) recorded the maximum heterobeltiosis and two hybrids CMS 852A x RES-834-1 (-6.30%) and CMS 234A x 3376R (-6.13%) recorded high significant negative standard heterosis for days to maturity. The present findings are in agreement with the earlier investigations by Phad *et al.* (2002), Bharathi *et al.* (2007), Dudhe *et al.* (2009) and Gijli *et al.* (2011) While, positive

Table 1 (Contd..). Estimates of heterobeltiosis and standard heterosis (Over PAC-1091) for head diameter, stem diameter and no. of filled seeds/head

Cross	Head diameter		Stem diameter		No. of filled seeds/head	
	BP	SH	BP	SH	BP	SH
CMS-234A X RES-834-1	9.34*	-13.00**	23.53**	6.98**	26.06**	-35.75**
CMS-234AX LTRR-341	18.88**	-16.00**	28.23**	16.13**	45.01**	-40.41**
CMS-234A X 3376R	22.47**	2.71	9.12**	16.23**	44.30**	-27.39**
CMS-234A X RHA-6D-1R	42.12**	0.42	13.77**	13.77**	163.73**	8.38**
CMS-234A X R-298	56.13**	10.32**	10.61**	11.13**	88.01**	-8.22**
CMS-234A X R-649	20.60**	-12.32**	19.62**	0.09	-3.38	-32.27**
CMS-17A X RES-834-1	9.84**	-3.47	-1.53	-3.11**	72.20**	-6.54*
CMS-17AX LTRR-341	5.34	-7.42*	-18.12**	-19.43**	93.71**	5.13
CMS-17A X 3376R	9.99**	-3.34	-17.98**	-12.64**	82.45**	-0.98
CMS-17A X RHA-6D-1R	27.19**	11.78**	-13.11**	-13.11**	95.78**	6.26*
CMS-17A X R-298	7.20*	-5.79	-8.64**	-8.21**	46.79**	-20.33**
CMS-17A X R-649	1.47	-10.82**	8.05**	6.32**	6.51	-25.34**
CMS-852A X RES-834-1	-2.72	-20.08**	41.54**	24.72**	57.89**	-19.53**
CMS-852AX LTRR-341	4.41	-14.23**	-5.83**	-14.72**	109.46**	-12.72**
CMS-852A X 3376R	6.66	-10.55**	-20.90**	-15.75**	59.14**	-19.92**
CMS-852A X RHA-6D-1R	33.54**	9.71**	-0.66	-0.66	151.94**	4.98
CMS-852A X R-298	3.75	-14.77**	-5.35**	-4.91**	58.38**	-22.69**
CMS-852A X R-649	8.22*	-11.10**	21.09**	6.70**	13.71**	-20.29**
CMS-89A X RES-834-1	16.36**	-7.42*	7.19**	-7.17**	79.04**	-8.75**
CMS-89AX LTRR-341	7.58	-22.67**	6.15**	-3.87**	43.34**	-44.34**
CMS-89A X 3376R	5.84	-11.23**	-10.01**	-4.15**	51.82**	-23.60**
CMS-89A X RHA-6D-1R	27.84**	-8.10**	-11.23**	-11.23**	163.38**	2.27
CMS-89A X R-298	32.20**	-4.97	-11.27**	-10.85**	35.50**	-33.85**
CMS-89A X R-649	32.21**	-3.88	0.11	-17.26**	29.01**	-9.57**
ARM-238A X RES-834-1	7.60*	-4.42	4.53**	0.19	133.95**	32.83**
ARM-238AX LTRR-341	18.18**	4.97	18.11**	13.21**	61.65**	-8.21**
ARM-238A X 3376R	13.73**	1.02	11.43**	18.68**	100.93**	14.09**
ARM-238A X RHA-6D-1R	13.43**	0.75	12.64**	12.64**	19.39**	-32.21**
ARM-238A X R-298	8.22*	-3.88	6.48**	6.98**	57.74**	-10.43**
ARM-238A X R-649	17.72**	4.56	7.09**	2.64**	-9.37*	-36.47**
ARM-243A X RES-834-1	3.37	-5.65	6.93**	13.58**	72.79**	-11.93**
ARM-243AX LTRR-341	12.62**	2.79	10.83**	17.74**	67.52**	-29.23**
ARM-243A X 3376R	13.51**	3.61	11.07**	18.30**	100.16**	0.73
ARM-243A X RHA-6D-1R	23.81**	13.00**	1.33	7.64**	104.17**	-13.75**
ARM-243A X R-298	19.48**	9.05**	4.53**	11.04**	103.37**	-0.72
ARM-243A X R-649	17.69**	7.42*	11.10**	18.02**	-7.06	-34.85**
ARM-248A X RES-834-1	9.22**	-4.83	38.69**	23.77**	43.36**	-26.93**
ARM-248AX LTRR-341	16.87**	1.84	8.96**	-1.32	42.71**	-30.03**
ARM-248A X 3376R	21.72**	6.06*	-2.39*	3.96**	91.45**	-3.66
ARM-248A X RHA-6D-1R	18.59**	3.34	8.58**	8.58**	101.24**	-1.34
ARM-248A X R-298	11.09**	-3.20	3.38**	3.87**	43.21**	-29.79**
ARM-248A X R-649	23.59**	7.69*	22.41**	9.25**	10.29*	-22.69**
No.of hybrids with significant + ve value	33	8	27	24	38	4
No.of hybrids with significant - ve value	0	14	11	14	1	30
Range of heterosis	-2.72 to 56.13	-22.67 to 13.00	-20.90 to 41.54	-19.43 to 24.72	-9.37 to 163.73	-44.34 to 32.85

*: Significant at 5 % level; **: Significant at 1% level BP: Better Parent; SH: Standard Heterosis;

heterosis for this trait has also been reported by Gill and Sheoran (2002)

For plant height, heterosis in negative direction is considered suggesting that dwarfness is always desirable in sunflower hybrids as it reduces the problems of stem breaking, neck breaking and difficulty at the time of harvesting. The heterobeltiosis ranged from -21.21 per cent (CMS 17A x R-649) to 40.30 (CMS 852A x 3376R) per cent. Nine and seven crosses recorded desirable heterobeltiosis and standard heterosis respectively. The range of standard heterosis observed from –18.35 (CMS 17A x R 649) to 21.54 per cent (ARM 248A x LTRR 341). Gijli *et al.* (2011) reported that lodging and stalk breakage caused by excessive growth are known to be associated with yield reduction in sunflower. Both positive and negative heterosis for plant height was reported by Sawant *et al.* (2007), while negative heterosis by Phad *et al.* (2002), Bharathi *et al.* (2007) and Savangaonkar and Ghodke (2008). In case of CMS 17A x R 649 it was medium x short combination of plant height. Hence, dominance and the genetic diversity existing between these two parents might have played a role in the expression of heterosis in the hybrid. These parental lines are of promise in the production of hybrids with reduced plant height.

Table 1. (Contd..). Estimates of heterobeltiosis and standard heterosis (Over PAC-1091) for 100-seed weight, seed yield/plant and oil content

Cross	100-seed weight		Seed yield/plant		Oil content	
	BP	SH	BP	SH	BP	SH
CMS-234A X RES-834-1	33.95**	11.07**	67.81**	-29.41**	1.36	8.25**
CMS-234AX LTRR-341	25.50**	1.93	84.88**	-39.83**	2.00	-0.98
CMS-234A X 3376R	44.63**	17.47**	150.69**	-15.10**	3.45	6.88**
CMS-234A X RHA-6D-1R	22.55**	-0.46	235.66**	9.24**	-6.80**	7.71**
CMS-234A X R-298	16.71**	-5.21**	166.60**	-13.24**	-3.39	3.25
CMS-234A X R-649	0.71	-18.20**	28.70**	-44.79**	10.18**	8.55**
CMS-17A X RES-834-1	9.47**	0.35	86.48**	-6.07*	-6.53**	-0.17
CMS-17AX LTRR-341	13.84**	4.36**	119.34**	10.49**	-3.89*	-5.92**
CMS-17A X 3376R	9.84**	0.69	92.42**	-3.07	-5.24**	-2.09
CMS-17A X RHA-6D-1R	28.86**	18.13**	147.42**	24.63**	-11.42**	2.37
CMS-17A X R-298	10.27**	1.08	57.76**	-20.53**	-4.14*	2.44
CMS-17A X R-649	-20.15**	-26.80**	6.15	-46.53**	0.91	-0.58
CMS-852A X RES-834-1	-32.52**	-22.37**	33.16**	-37.58**	-3.24	7.97**
CMS-852AX LTRR-341	-19.85**	-7.79**	72.57**	-19.11**	-6.31**	4.55*
CMS-852A X 3376R	-24.47**	-13.11**	48.85**	-30.23**	-6.77**	4.03*
CMS-852A X RHA-6D-1R	-11.23**	2.12	130.61**	8.10**	-3.78*	11.21**
CMS-852A X R-298	-28.49**	-17.74**	34.81**	-36.81**	-6.27**	4.60*
CMS-852A X R-649	-18.10**	-5.78**	60.82**	-24.62**	2.17	14.01**
CMS-89A X RES-834-1	40.28**	16.31**	140.39**	1.12	7.56**	14.88**
CMS-89AX LTRR-341	-3.30*	-24.33**	46.76**	-58.41**	3.86*	10.52**
CMS-89A X 3376R	2.71	-28.31**	61.31**	-45.37**	-0.34	6.05**
CMS-89A X RHA-6D-1R	52.68**	2.16	317.28**	2.55	-5.22**	9.54**
CMS-89A X R-298	16.66**	-21.94**	58.73**	-51.57**	6.34**	13.64**
CMS-89A X R-649	14.41**	-23.45**	61.61**	-30.67**	2.90	9.50**
ARM-238A X RES-834-1	-5.83**	-21.48**	127.59**	5.12	5.75**	12.95**
ARM-238AX LTRR-341	-1.43	-17.82**	64.32**	-24.10**	-1.19	0.46
ARM-238A X 3376R	11.10**	-7.37**	131.70**	7.01**	0.75	4.10*
ARM-238A X RHA-6D-1R	21.37**	1.20	47.17**	-32.03**	-3.65*	11.36**
ARM-238A X R-298	12.72**	-6.02**	82.10**	-15.89**	6.57**	13.88**
ARM-238A X R-649	32.84	10.76**	49.31**	-31.04**	8.36**	10.16**
ARM-243A X RES-834-1	-31.23	-3.36**	46.77**	-14.71**	3.60*	13.31**
ARM-243AX LTRR-341	-28.79**	0.08	19.57**	-30.51**	-5.11**	3.78*
ARM-243A X 3376R	-24.59**	5.98**	84.51**	7.22**	-2.08	7.10**
ARM-243A X RHA-6D-1R	-18.06**	15.16**	70.00**	-1.20	-2.84	12.30**
ARM-243A X R-298	-23.96**	6.86**	77.63**	3.23	2.35	11.95**
ARM-243A X R-649	-21.13**	10.84**	23.20**	-28.40**	1.83	11.38**
ARM-248A X RES-834-1	-7.86**	0.85	38.01**	-27.16**	4.28*	11.37**
ARM-248AX LTRR-341	3.70**	13.50**	49.17**	-21.27**	-4.40*	1.42
ARM-248A X 3376R	-16.07**	-8.14**	67.61**	-11.53**	1.87	8.07**
ARM-248A X RHA-6D-1R	-1.90	7.37**	100.13**	5.63*	-3.16*	11.92**
ARM-248A X R-298	4.26**	14.11**	48.60**	-21.57**	2.51	9.54**
ARM-248A X R-649	1.97	11.61**	60.94**	-15.05**	3.78*	10.09**
No.of hybrids with significant + ve value	19	14	41	7	10	32
No.of hybrids with significant - ve value	16	18	0	29	15	1
Range of heterosis	-32.52 to 52.68	-28.31 to 18.13	6.15 to 317.28	-58.41 to 24.63	-11.42 to 10.18	-5.92 to 14.88

*: Significant at 5 % level; **: Significant at 1% level BP: Better Parent; SH: Standard Heterosis;

Head diameter is an important yield component in sunflower which signifies the amount of sink area. Larger the diameter, larger will be the sink area paving the way for higher yields accompanied by complete filling. Heterosis in the positive direction indicates increase in head diameter. Many hybrids exhibited significant heterobeltiosis in the desired direction in the present study varied from –2.72 to 56.13 per cent. Thirty three hybrids exhibited positive and significant heterobeltiosis and eight hybrids over standard heterosis for this trait. The hybrids ARM 243A x RHA-6D-1R and CMS 17A x RHA-6D-1R recorded the maximum heterosis over better parent and standard check PAC 1091. In majority of the crosses, the heterosis for head diameter was reflected in the heterosis for seed yield. Skoric (1992) suggested that to achieve high seed yield per unit area, it is essential to develop a genotype capable of producing more than 1500 seeds per head even when grown at a high density of population. These findings are in accordance with Singh and Singh (2003), Bharathi *et al.* (2007), Patil *et al.* (2008), Savangaonkar and Ghodke (2008), Dudhe *et al.* (2009) and Gijli *et al.* (2011) who reported positive heterosis for this trait.

For stem diameter, 27 hybrids have recorded significant positive heterobeltiosis and 24 hybrids

Table 2. Mean performance of parents and hybrids for nine characters in sunflower (Pooled mean values)

	DFF	DM	PH (cm)	HD (cm)	SD(cm)	NFS	TW (g)	SY (g)	OC (%)
LINES									
CMS-234A	60.67	92.17	125.92	8.65	1.48	17.67	3.51	11.21	34.25
CMS-17A	62.83	93.17	145.19	10.76	1.74	23.63	3.96	17.35	34.53
CMS-852A	62.33	92.67	108.22	10.06	1.56	23.52	4.97	16.15	39.37
CMS-89A	65.67	96.67	106.03	8.80	1.45	20.90	2.89	8.47	37.54
ARM-238A	66.50	96.50	150.83	10.87	1.69	25.97	3.60	15.91	35.87
ARM-243A	66.83	97.83	155.17	11.17	1.88	28.27	6.07	20.02	38.59
ARM-248A	66.00	99.00	147.40	10.67	1.58	24.43	4.73	18.18	37.42
Mean	64.40	95.43	134.11	10.14	1.62	23.48	4.25	15.33	36.79
TESTERS									
RES-834-1	64.67	93.67	107.27	9.74	1.53	22.20	3.58	14.49	37.68
LTRR-341	62.17	89.83	118.47	7.43	1.60	23.90	3.38	9.76	32.75
3376R	63.33	94.33	106.15	10.27	1.88	21.07	3.02	11.67	36.45
RHA-6D-1R	63.83	94.50	131.77	8.00	1.77	20.67	2.81	8.33	40.77
R-298	64.50	94.33	119.33	7.90	1.78	22.20	2.80	10.51	37.70
R-649	64.50	95.50	124.10	8.90	1.46	21.37	2.66	14.78	34.76
Mean	63.83	93.69	117.85	8.71	1.67	21.90	3.04	11.59	36.68
Parental mean	64.14	94.63	126.60	9.48	1.64	22.75	3.69	13.60	36.74
CROSSES									
CMS-234A X RES-834-1	62.67	93.00	148.55	10.65	1.89	25.60	4.80	24.32	38.19
CMS-234A X LTRR-341	63.17	92.83	150.33	10.28	2.05	27.30	4.41	20.73	34.93
CMS-234A X 3376R	60.67	89.33	153.17	12.57	2.05	26.02	5.08	29.25	37.71
CMS-234A X RHA-6D-1R	62.00	93.00	155.43	12.29	2.01	28.30	4.30	37.63	38.00
CMS-234A X R-298	63.50	93.50	155.17	13.51	1.96	28.32	4.10	29.89	36.42
CMS-234A X R-649	65.17	95.50	117.09	10.73	1.77	27.45	3.54	19.02	38.30
CMS-17A X RES-834-1	67.83	100.17	143.29	11.82	1.71	26.47	4.34	32.36	35.22
CMS-17A X LTRR-341	61.17	89.83	140.25	11.33	1.42	27.23	4.51	38.06	33.19
CMS-17A X 3376R	66.00	97.67	146.55	11.83	1.54	25.72	4.35	33.39	34.54
CMS-17A X RHA-6D-1R	64.67	95.00	155.97	13.68	1.54	24.10	5.11	42.94	36.12
CMS-17A X R-298	66.00	98.00	143.98	11.53	1.62	25.80	4.37	27.38	36.14
CMS-17A X R-649	67.67	100.00	132.18	10.92	1.88	21.77	3.16	18.42	35.08
CMS-852A X RES-834-1	60.83	89.50	130.65	9.78	2.20	29.37	3.36	21.50	38.09
CMS-852A X LTRR-341	63.17	92.50	137.80	10.50	1.51	29.55	3.99	27.87	36.88
CMS-852A X 3376R	67.17	100.17	151.83	10.95	1.49	29.00	3.76	24.04	36.70
CMS-852A X RHA-6D-1R	65.33	96.67	143.83	13.43	1.76	27.52	4.41	37.24	39.23
CMS-852A X R-298	66.83	98.50	127.12	10.43	1.68	27.77	3.56	21.77	36.90
CMS-852A X R-649	64.67	96.67	139.25	10.88	1.89	28.12	4.07	25.97	40.22
CMS-89A X RES-834-1	65.50	98.50	140.38	11.33	1.64	27.90	5.03	34.84	40.53
CMS-89A X LTRR-341	64.67	97.33	122.63	9.47	1.70	22.17	3.27	14.33	38.99
CMS-89A X 3376R	66.50	98.17	125.73	10.87	1.69	22.87	3.10	18.82	37.41
CMS-89A X RHA-6D-1R	65.33	96.00	144.50	11.25	1.57	23.37	4.42	35.33	38.64
CMS-89A X R-298	62.83	91.17	137.35	11.63	1.58	26.23	3.37	16.69	40.09
CMS-89A X R-649	64.17	95.17	123.72	11.77	1.46	25.33	3.31	23.88	38.63
ARM-238A X RES-834-1	63.33	96.67	149.27	11.70	1.77	25.63	3.39	36.21	39.85
ARM-238A X LTRR-341	61.83	91.83	145.47	12.85	2.00	25.07	3.55	26.15	35.44
ARM-238A X 3376R	64.67	96.33	154.52	12.37	2.10	27.40	4.00	36.87	36.72
ARM-238A X RHA-6D-1R	62.50	91.67	167.67	12.33	1.99	25.77	4.37	23.42	39.29
ARM-238A X R-298	64.50	96.83	165.17	11.77	1.89	28.00	4.06	28.98	40.18
ARM-238A X R-649	65.33	99.33	159.07	12.80	1.81	27.42	4.79	23.76	38.86
ARM-243A X RES-834-1	63.33	92.33	143.07	11.55	2.01	25.57	4.18	29.38	39.98
ARM-243A X LTRR-341	62.33	94.50	149.83	12.58	2.08	24.73	4.33	23.94	36.61
ARM-243A X 3376R	62.33	94.67	155.60	12.68	2.09	25.73	4.58	36.94	37.78
ARM-243A X RHA-6D-1R	61.50	91.17	153.68	13.83	1.90	26.55	4.98	34.04	39.62
ARM-243A X R-298	62.17	91.17	149.92	13.35	1.96	26.70	4.62	35.56	39.49
ARM-243A X R-649	64.17	94.17	144.46	13.15	2.09	25.77	4.79	24.67	39.29
ARM-248A X RES-834-1	62.17	91.17	162.65	11.65	2.19	25.53	4.36	25.10	39.29
ARM-248A X LTRR-341	61.83	91.83	170.28	12.47	1.74	29.27	4.91	27.12	35.78
ARM-248A X 3376R	64.17	95.17	148.82	12.98	1.84	28.37	3.97	30.48	38.13

Table 2. contd.,

	DFF	DM	PH (cm)	HD (cm)	SD(cm)	NFS	TW (g)	SY (g)	OC (%)
ARM-248A X RHA-6D-1R	65.17	96.17	157.05	12.65	1.92	23.12	4.64	36.39	39.48
ARM-248A X R-298	64.83	94.83	169.37	11.85	1.84	24.57	4.93	27.02	38.65
ARM-248A X R-649	61.00	92.00	139.72	13.18	1.93	24.40	4.82	29.27	38.84
Crosses mean	63.92	94.76	146.64	11.89	1.83	26.26	4.21	28.36	37.84
General mean	64.01	94.80	142.36	11.41	1.79	25.40	4.11	25.34	37.51
Check									
PAC-1091	65.17	95.17	140.11	12.24	1.77	25.17	4.32	34.45	35.28
SEm±	0.61	0.63	2.49	0.46	2.02	0.95	6.07	1.02	0.77
CD (5%)	1.73	1.78	7.06	1.30	0.06	2.68	0.17	2.87	2.18
CV (%)	1.36	0.94	2.49	5.75	1.58	5.18	2.10	10.71	2.90

DFF : Days to 50% flowering; DM : Days to maturity; PH : Plant height; HD : Head diameter; SD : Stem diameter; NFS : No. of filled seeds/head; TW : 100-seed wt.; SY : Seed yield/plant; OC : Oil content

have recorded significant positive standard heterosis over PAC-1091. Similar results were observed in the studies of Sasikumar and Gopalan (2000). Number of filled seeds per head is one of the important yield components and directly related to yield. More the number of filled seeds more will be the yield and *vice versa*. Hence, heterosis over better parent and standard checks in the positive direction is desirable in sunflower for this trait. For heterobeltiosis, it varied from –9.37 to 163.73 per cent. As many as 38 hybrids registered significant positive heterobeltiosis ranging from 10.29 (ARM 248A x R 649) to 163.73 per cent (CMS 234A x RHA-6D-1R) over the better parents. With respect to standard heterosis, the highest heterosis of 32.83 per cent (ARM 238A x RES-834-1) was observed. Earlier workers Gill and Sheoron (2002) and Bharathi *et al.* (2007) have been reported similar results on standard heterosis for this character. The hybrid ARM 238A x RES-834-1 was a high x high combination suggesting additive gene action operating for this trait.

Table 3. Performance of six top ranking sunflower hybrids in comparison with *per se*, higher *sca, gca* effects of parents, heterosis over PAC-1091 and significant desirable heterosis for other yield traits.

Hybrid	Seed yield Mean	Heterosis over PAC 1091	*sca* effect	*gca* female	*gca* male	Desirable heterosis for other yield contributing traits
CMS-17A x RHA-6D-1R	42.94	24.63**	3.92**	3.74**	6.93**	HD, NFS,TW
CMS-17A x LTRR-341	38.06	10.49**	8.87**	3.74**	-2.90**	DFF, DM, NFS, TW
CMS-234A x RHA-6D-1R	37.63	9.24*	3.90**	-1.55**	6.93**	DFF, DM, NFS, TW, OC
CMS-852A x RHA-6D-1R	37.24	8.10*	3.91**	-1.96**	6.93**	DFF, TW, OC
ARM-243A x 3376R	36.94	7.22*	4.57**	2.40**	1.61**	DFF, TW, OC
ARM-238A x 3376R	36.87	7.01*	6.02**	0.87**	1.61**	NFS, OC

DFF: Days to 50% Flowering; DM: Days to Maturity; HD: Head Diameter; NFS; No.of filled seeds/head; TW: Test Weight; OC: Oil Content

Hundred seed weight is an important yield component as it influences volume weight property and is positively related to yield. For this trait the heterobeltiosis range from –32.52 to 52.68 per cent. The hybrids CMS 17A x RHA-6D-1R, CMS 234A x 3376R and CMS 89A x RES- 834-1 recorded significant positive heterosis over better parent and standard check PAC 1091 for this character. Similar results were reported by Phad *et al.* (2002), Bharathi *et al.* (2007) and Savangaonkar and Ghodke (2008).

All breeding programmes invariably aim at achieving higher yields and hence, seed yield per plant is such an important character that decides the direction of the breeding programmes. Though yield is a complex character directly or indirectly influenced by yield component traits, the trait itself holds great importance and studied along with other characters. The heterobeltiosis and standard heterosis for this trait ranged from 6.15 per cent to 317.28 per cent and from -58.41 per cent to 24.63 per cent, respectively. High heterosis over PAC 1091 manifested by the crosses CMS 17A x RHA-6D-1R (24.63%), CMS 17A x LTRR 341 (10.49%), CMS 234A x RHA-6D-1R (9.24%), CMS 852A x RHA-6D-1R (8.10%) and ARM 238A x 3376R (7.01%). These findings are in agreement with Singh and Singh (2003), Bharathi *et al.* (2007), Dudhe *et al.* (2009) and Gijli *et al.* (2011). From the *per se* performance it can be noted that the hybrid CMS 17A x RHA-6D-1R involved a high x low combination of parents resulting in high heterosis which may be due to dominance of the female parent and the diversity among the parents.

Oil content is also an equally important character along with seed yield per plant in sunflower. Heterosis in positive direction over better parent and standard check is highly desirable. In pooled analysis, the observed heterobeltiosis range of the hybrids was from-11.42 to 10.18 per cent and from –5.92 to 14.88 per cent for standard heterosis. The hybrids CMS 89A x RES-834-1 (14.88%), CMS 852A x R 649 (14.01%) and ARM 238A x R 298 (13.88%) recorded significant positive heterosis over standard check for oil content. Superiority of this trait was reported by Bharathi *et al.* (2007), Parameshwarappa *et al.* (2008) and Gijli *et al.* (2011).

Based on the *per se* performance, significant *sca* effects and extent of heterosis, three hybrids *viz.,* CMS 234A x RHA-6D-1R, CMS 852A x RHA-6D-1R and ARM 243A x 3376R were best for seed yield,oil content and other related yield contributing characters over the better check, PAC 1091 and could be exploited through heterosis breeding programme (Table 3). All the cross combinations with significant *sca* effects for seed yield did not possess significant and desirable *sca* effects for all the component traits which suggested that at least significant and desirable *sca* effects of two to three compound traits resulted in significant *sca* effect for seed yield. Similar results have been reported by Loganathan and Gopalan (2006) and Bharathi *et al.* (2007). Further, crosses namely CMS 17A x LTRR 341, CMS 234A x RHA-6D - 1R also exhibited desirable heterosis over the mid parent, better parent and standard check PAC 1091, for earliness and its related traits (days to 50% flowering and days to maturity). Hence, these crosses need to be studied over locations and years and if found suitable may be released.

The overall results of heterosis indicated that the parents involved in the crossing programme should have at least one parent with high *per se* performance. Similar results were also ascribed from the specific combining ability studies. High *sca* resulted either due to high × low or low × low *gca* effects of parents in majority of crosses. Further, results revealed that over dominance may be the cause of heterosis for seed yield per plant. The main reason ascribed is diversified parents involved in the cross combinations or uncommon gene(s) for trait(s) is the cause to exploit the maximum level of heterosis. Breeder can exploit the non-additive gene action through heterosis breeding programme for the desirable cross combinations involving high × low *gca* effects of parents.

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