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STUDIES ON THE COMBINING ABILITY OF DWARF RESTORER LINES IN SUNFLOWER (*Helianthus annuus* L.)

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SUMMARY

The present investigation was undertaken to assess the combining ability for dwarfness among the given testers and also to estimate the extent of heterosis for ten different characters in 90 hybrids which were derived by crossing ten diverse *cms* lines with nine dwarf testers in a line × tester mating design during *rabi* 2008-09. The resultant hybrids and parents along with standard check RSFH-130 were evaluated for plant height and other yield contributing traits. CMS-107A among lines and R-411R among testers were found to be best general combiners for dwarfness and other yield contributing traits. The best cross combinations for seed yield per plant CMS-104A × RHA-288 and oil content CMS-131A × R-186-1 with high sca effect have been identified. The cross CMS-105A × R-186-1 recorded a significant heterosis over better parent (-10.65%) for plant height and seed yield and the cross CMS-X × R-4-2-Br recorded a significant heterosis over standard check (-37.30%) for plant height.

Key words: dwarf, gca effect, heterosis, sca effect

INTRODUCTION

The success of semi-dwarf genes in cereals has prompted scientists to consider height reduction in many other crops including sunflower (*Helianthus annuus* L.). In sunflower, semi-dwarf and dwarf phenotypes have been recently developed (Schneiter, 1992). Lodging and stalk breakage caused by excessive growth are known to be associated with yield reduction in sunflower. Therefore, development of dwarf and semi-dwarf varieties or hybrids is a major breeding objective. The use of dwarfing genes in several programs of genetic improvement has given important contribution to agriculture *via* the development of new short-stature varieties resistant to lodging. Many cereal grains actually cultivated around the world incorporate differ-

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ent dwarfing genes in their genetic background (Borlaug, 1983). However, the earlier attempts produced unsatisfactory results because of extreme/severe dwarf types with low yield (Jambhulkar, 2002; Cecconi *et al.*, 2002). In India, Morden (Cereni-anka-66) is the only dwarf (66-110 cm) and early maturing variety available for cultivation. Worldwide, only three sources of reduced plant height in sunflower, DDR (90.3 cm), Donsky (65.5 cm), and Donskoi 47 (79.8 cm), have been reported so far (Miller and Hammond, 1991). An attempt was made towards improving the yield of semi-dwarf/dwarf sunflower hybrids.

MATERIAL AND METHODS

The present field study was carried out at Main Agricultural Research Station, Raichur campus of the University of Agricultural Sciences, Raichur (Karnataka, India) in two seasons. The campus is being geographically situated in the North Eastern Dry Zone (Zone 2) of Karnataka State at 16°12' N latitude and 77°21' E longitude with an altitude of 389.37 meters above mean sea level. Crossing work was done in *rabi* 2008-09 and evaluation of parents and F_1's was taken up in *kharif* 2009. The materials used and methods followed during the course of the investigation are presented below.

The parent materials for the present study consisted of ten cytoplasmic male sterile lines which includes diversified *cms* lines *viz.*, CMS-E 002-91 (*Helianthus annuus*), CMS-E 002-92 (*Helianthus annuus*), CMS-AGR-2 (*Helianthus argophyllus*), CMS-X (*Helianthus annuus*), CMS-PHIR-27 (*Helianthus praecox* spp. *hirsutus*), CMS-104A (*Helianthus annuus*), CMS-105A (*Helianthus annuus*), CMS-106A (*Helianthus annuus*), CMS-107A (*Helianthus annuus*) and CMS-131A (*Helianthus annuus*) and nine diverse dwarf male parents, *viz.*, R-393, R-95C-2, R-83Br, R-4-2-Br, R-IT-2, R-411R, RHA-288, R-191-1, R-186-1, were used in the investigation. The seed materials were obtained from the Principal Scientist and Head (Breeding), All India Co-ordinated Research Project on Sunflower, Main Agricultural Research Station, UAS Raichur, India.

The following observations of ten different characters *viz*. were recorded: plant height, days to 50 percent flowering, days to maturity, head diameter, KH ratio, 100 seed weight, volume weight, hull percent, oil content and seed yield per plant. The data were analysed by L × T.

RESULTS AND DISCUSSION

The analysis of variance indicated that the parents exhibited significant variances for all the characters studied, indicating that the parents chosen were highly variable for all the characters. The analysis of variance revealed higher magnitude of SCA variance than GCA variance and also GCA to SCA ratio was less than unity for all the characters, indicating the prevalence of non additive gene action in the inheritance of all the characters studied.

Table 1: Estimates of general combining ability (gca) effects of male and female parents for 10 different characters in sunflower

Parents	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	KH ratio	100 seed weight (g)	Volume weight (g/100 ml)	Hull per cent	Oil content (%)	Seed yield/ plant (g)
Lines										
CMS E 002-91	-0.27	-0.79**	-11.75**	-0.65**	-0.33**	-0.13**	2.70**	2.00**	1.00**	-3.63**
CMS E 002-92	-0.16	-1.29**	-15.69**	-0.54**	0.44**	-0.04*	-1.05**	-2.87**	-0.63**	-3.23**
CMS-AGR-2	-0.38*	0.21	-14.60**	-0.71**	0.09	-0.18**	1.08**	-0.69**	0.81**	-4.01**
CMS-X	-0.88**	-1.41**	-4.08**	-0.05	0.05	-0.02	-1.28**	0.65**	-0.43**	-2.25**
CMS-PHIR-27	-0.38*	-0.74**	-5.05**	-0.23*	-0.03	-0.39**	-0.50**	0.16	-0.98**	-2.27**
CMS-104A	1.12**	0.82**	19.02**	0.06	0.06	0.07**	-0.03	-0.47**	1.57**	2.67**
CMS-105A	1.34**	1.98**	22.86**	0.72**	-0.12*	0.53**	0.81**	0.43*	0.26**	4.89**
CMS-106A	-1.66**	1.04**	17.14**	0.22	0.21**	0.34**	-0.23**	-1.42**	1.98**	3.03**
CMS-107A	-0.49**	0.26	-9.86**	0.85**	-0.13*	-0.17**	0.48**	0.71**	-1.66**	4.85**
CMS-131A	1.73**	-0.07	2.02**	0.34**	-0.26**	-0.02	-1.97**	1.49**	-1.93**	-0.04
CD at 5%	0.4254	0.3898	1.2373	0.3192	0.1370	0.0516	0.2143	0.4872	0.1701	1.4047
CD at 1%	0.5651	0.5178	1.6434	0.424	0.1820	0.0686	0.2846	0.6472	0.2259	1.8659
Testers										
R-393	1.54**	0.70**	0.93*	0.18	0.17**	0.46**	-0.39**	-1.01**	-0.11	-1.53**
R-95C-2	1.54**	0.80**	-3.80**	-0.11	0.08	0.32**	0.29**	-0.58**	0.59**	-0.52
R-83Br	-1.56**	-1.75**	1.24**	0.10	-0.03	-0.06**	-3.57**	0.06	-0.97**	0.60
R-4-2-Br	-1.21**	-0.85**	-8.49**	-0.64**	-0.20**	0.00	-1.05**	0.52**	0.44**	-2.23**
R-IT-2	1.39**	1.10**	3.19**	0.10	-0.25**	-0.57**	-0.16*	1.57**	0.17**	1.79**
R-411R	-2.71**	-0.35**	-6.09**	-0.16	0.05	0.05**	3.85**	-0.33*	0.46**	3.01**
RHA-288	-0.86**	-1.55**	3.48**	-0.42**	0.09*	-0.29**	0.14	-0.50**	0.04	-1.35**
R-191-1	0.54**	0.80**	4.41**	0.24*	-0.10*	0.37**	0.16*	1.16**	-0.62**	-1.71**
R-186-1	1.34**	1.10**	5.16**	0.70**	0.18**	-0.25**	0.72**	-0.89*	0.00	1.92**
CD at 5%	0.4036	0.3698	1.1738	0.3028	0.1300	0.0490	0.2033	0.4622	0.1614	1.3327
CD at 1%	0.5361	0.4912	1.5591	0.4023	0.1726	0.0651	0.2700	0.6140	0.2143	1.7701

*, ** – Significant at 5% and 1% levels, respectively

The information on the general combining ability of parents for plant height, yield and its component characters is very much essential as it facilitates the selection of best parents for medium and dwarf hybrids in breeding programmes. The importance of combining ability in selection of parents for hybridization has been emphasized by many sunflower researchers (Putt, 1966) and Giriraj *et al.* (1987). The estimates of general combining ability effects of 19 parents (Table 1) revealed that the line CMS-E 002-92 reported the significant highest negative gca effect for plant height and hull percent in desirable direction but it is undesirable for yield and its attributing characters. It is interesting to note that the line CMS-106A was a good combiner for seed yield and its attributing characters *viz.*, KH ratio hundred seed weight, hull percent, oil content but however it was undesirable for dwarfness. In the present study the line CMS-107A was best general combiner for plant height and seed yield as it recorded significant gca effects for plant height as well as seed yield. The line CMS-107A may be included in further breeding programme to exploit dwarfness along with desirable yield. Among testers R-4-2-Br recoded highest negative gca effects for plant height but it was undesirable for yield and its attributing characters. However, it is interesting to note that the same tester R-4-2-Br was found to be a good general combiner for oil content which is also akin with results of Jagadeesan *et al.* (2008) indicating dwarfness and oil content positively correlated. Other two testers R-95C-2 and R-411R were also good general combiners for dwarfness. The tester R-411R was the best restorer to be included in future breeding programme to exploit dwarfness and yield and its attributing characters. The specific combining ability (sca) effects of 90 crosses were presented in Table 2. For plant height, 35 hybrids exhibited significant negative sca effects. Among these CMS-105A × R-186-1 (-26.21) had the highest negative *sca* effect followed by the crosses CMS-105A × R-IT-2 (-23.24), CMS-131A × R-393 (-21.04), CMS-X × R-83-Br (-20.85), and CMS-X × R-4-2-Br (-18.12), which had the highest negative *sca* effects. However, none of these top dwarf crosses recorded significant sca effects for seed yield but the crosses *viz.*, CMS-E002-91 × RHA-288, CMS-PHIR-27 × R-411R, CMS-106A × R-4-2-Br and CMS-131A × R191-1 exhibited significant sca effects for dwarfness also exhibited significant sca effects for seed yield hence these crosses consider to be best cross combinations for exploitation of dwarfness.

The range of heterosis over mid parent, better parent and standard check (RSFH-130) for 10 quantitative characters are presented in Table 3. For the plant height the range of heterosis over mid parent, better parent and standard check ranged from 14.04 percent to 121.85 percent, -10.65 percent to 108.07 percent and -37.30 to 8.04, respectively. For this trait the highest negative heterosis over standard check was recorded in the cross CMS-X × R-4-2-Br (-37.30%). Out of 90 crosses, 74 hybrids exhibited highly significant negative heterosis over RSFH-130. Rajanna *et al.* (2001) noticed that the hybrids 265A × Morden and 274A × 398 were also significantly shorter than the checks MSFH-17 and KBSH-1. As regards seed yield per plant the range of heterosis over mid parent, better parent and stand-

Table 2a: Specific combining ability (sca) effects for 10 different characters in sunflower (Part I)

Hybrids	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	KH ratio	100seed weight (g)	Volume weight (g/100 ml)	Hull per cent	Oil content (%)	Seed yield/plant (g)
CMS E 002-91 × R-393	-0.48	0.24	4.13**	1.62**	-0.28	0.48**	-2.45**	0.98	0.09	3.86*
CMS E 002-91 × R-95C-2	0.02	0.14	-2.14	0.11	0.02	-0.18**	-1.58**	-0.24	0.34	-2.45
CMS E 002-91 × R-83Br	0.12	-1.81**	-0.18	0.30	0.23	-0.10	0.28	-1.68**	-1.40**	4.03**
CMS E 002-91 × R-4-2-Br	0.27	1.29**	5.55**	-0.66	-0.23	-0.06	1.61**	2.33**	0.63**	3.46*
CMS E 002-91 × R-IT-2	0.17	-0.16	7.37**	0.10	0.05	0.36**	3.77**	-0.44	0.66**	-0.46
CMS E 002-91 × R-411R	0.77	2.79**	6.65**	-0.34	-0.21	0.04	-2.54**	0.99	-0.49**	-6.07**
CMS E 002-91 × RHA-288	-2.58**	-1.51**	-9.42**	-0.58	-0.3*	0.13*	-1.98**	1.40**	0.84**	2.98*
CMS E 002-91 × R-191-1	0.52	-0.86*	0.65	0.46	-0.28	-0.53**	1.45**	1.03*	-1.31**	5.74**
CMS E 002-91 × R-186-1	1.22**	-0.16	-12.60**	-1.00**	1.00**	-0.16**	1.44**	-4.35**	0.63**	-11.09**
CMS E 002-92 × R-393	-1.09*	0.24	2.07	0.50	0.08	0.09	1.84**	0.05	2.82**	0.66
CMS E 002-92 × R-95C-2	-0.59	0.64	2.30	0.10	0.00	-0.17**	2.46**	0.39	1.57**	4.65**
CMS E 002-92 × R-83Br	1.51**	0.69	-7.24**	-0.51	0.71**	-0.39**	-1.43**	-2.36**	-0.57**	-3.67*
CMS E 002-92 × R-4-2-Br	0.16	-2.21**	16.49**	-0.57	-0.22	0.00	-1.65**	-2.8**	-0.63**	-0.24
CMS E 002-92 × R-IT-2	-1.94**	-0.16	1.31	0.38	0.62**	0.22**	-2.74**	-3.02**	-3.51**	3.94*
CMS E 002-92 × R-411R	2.66**	1.29**	-0.41	0.15	0.42**	0.45**	-1.04**	-1.46**	-0.50**	-5.27**
CMS E 002-92 × RHA-288	-1.69**	-1.01*	-10.48**	-1.49**	-0.54**	-0.81**	0.47*	4.01**	-1.23**	-4.12**
CMS E 002-92 × R-191-1	0.91*	0.64	-7.91**	0.34	-0.5**	1.03**	3.64**	2.23**	2.48**	1.24
CMS E 002-92 × R-186-1	0.11	-0.16	3.84**	1.09**	-0.56**	-0.45**	-1.57**	2.96**	-0.44*	2.81
CMS-AGR-2 × R-393	1.63**	2.24**	-1.52	-0.43	-0.46**	0.13*	2.22**	1.46**	-2.07**	1.64
CMS-AGR-2 × R-95C-2	1.13*	0.14	-7.79**	-1.43**	0.35*	0.12*	1.19**	-0.69	0.03	-5.17**
CMS-AGR-2 × R-83Br	0.73	-0.31	9.17**	0.26	0.01	-0.30**	0.55*	-0.02	2.04**	3.81*
CMS-AGR-2 × R-4-2-Br	-1.12*	-1.21**	-4.10**	0.10	0.36*	0.04	-2.27**	-1.65**	-0.92**	0.04
CMS-AGR-2 × R-IT-2	1.28**	0.34	0.52	0.65	0.04	0.66**	-2.91**	-0.57	-0.90**	3.32*
CMS-AGR-2 × R-411R	-1.12*	-0.21	4.00**	0.42	-0.74**	0.14*	0.93**	4.42**	1.76**	0.60

Table 2b: Specific combining ability (sca) effects for 10 different characters in sunflower (Part II)

Hybrids	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	KH ratio	100seed weight (g)	Volume weight (g/100 ml)	Hull per cent	Oil content (%)	Seed yield/plant (g)
CMS-AGR-2 × RHA-288	-2.47**	-1.01*	-8.07**	0.98**	-0.16	0.13*	-1.66**	0.57	-0.82**	-5.24**
CMS-AGR-2 × R-191-1	-0.87	-2.36**	1.50	-0.59	0.80**	-0.63**	-0.48*	-4.20**	-0.36*	-1.88
CMS-AGR-2 × R-186-1	0.83	2.34**	6.25**	0.06	-0.20	-0.31**	2.46**	0.68	1.22**	2.89
CMS-X × R-393	0.63	0.36	5.96**	-0.78*	-0.52**	-0.08	-3.07**	1.62**	0.42*	-3.22*
CMS-X × R-95C-2	-1.37**	-1.74**	-3.31*	-0.49	-0.70**	-0.24**	-2.35**	3.04**	-1.68**	2.17
CMS-X × R-83Br	-1.27**	-1.19**	-20.85**	0.00	-0.64**	-0.66**	-1.74**	2.78**	-0.82**	-2.65
CMS-X × R-4-2-Br	-0.62	-1.59**	-18.12**	-0.76*	0.32*	-0.37**	3.74**	-1.64**	-0.44*	-3.92*
CMS-X × R-IT-2	2.28**	1.96**	-6.80**	0.55	0.76**	0.40**	3.05**	-5.14**	-0.26	1.26
CMS-X × R-411R	-1.12*	-0.09	0.48	0.76*	0.83**	-0.07	2.59**	-4.94**	1.99**	1.39
CMS-X × RHA-288	-0.97*	-0.89*	-9.09**	-0.38	-0.05	-0.28**	0.40	-0.67	1.32**	1.50
CMS-X × R-191-1	-0.37	3.26**	39.48**	1.91**	0.27	0.31**	-0.02	4.16**	1.77**	6.55**
CMS-X × R-186-1	2.83**	-0.04	12.23**	-0.80*	-0.27	0.98**	-2.58**	0.79	-2.29**	-3.07*
CMS-PHIR-27 × R-393	1.13*	-0.81	-7.47**	-0.45	0.64**	-0.01	1.20**	-3.04**	3.17**	1.40
CMS-PHIR-27 × R-95C-2	1.13*	0.59	-7.34**	-0.11	0.13	-0.37**	0.32	-0.93	0.92**	-1.41
CMS-PHIR-27 × R-83Br	-2.77**	-2.36**	6.12**	-0.12	-0.21	1.36**	1.33**	1.10*	-0.97**	5.27**
CMS-PHIR-27 × R-4-2-Br	-4.12**	0.74	3.85**	1.12**	-0.20	0.45**	0.51*	1.61**	1.66**	2.00
CMS-PHIR-27 × R-IT-2	1.28**	0.79	-11.83**	0.58	-0.37*	-0.18**	3.52**	2.14**	0.59**	-5.82**
CMS-PHIR-27 × R-411R	4.38**	1.74**	-3.55**	0.14	-0.33*	-0.50**	-4.49**	1.49**	-2.41**	4.87**
CMS-PHIR-27 × RHA-288	-1.47**	-2.56**	23.58**	-0.70*	-0.38*	0.04	0.37	2.07**	-0.73**	0.52
CMS-PHIR-27 × R-191-1	-0.87	1.59**	-3.05*	0.64	0.09	-0.37**	-0.40	-2.10**	-1.38**	-1.81
CMS-PHIR-27 × R-186-1	1.33**	0.29	-0.30	-1.12**	0.63**	-0.45**	-2.36**	-2.34**	-0.84**	-5.05**
CMS-104A × R-393	2.13**	1.63**	0.86	0.30	-0.13	-0.06	-0.82**	0.65	-1.48**	1.06
CMS-104A × R-95C-2	-0.37	1.53**	-0.51	1.80**	-0.17	0.28**	4.05**	0.74	0.87**	-3.45*
CMS-104A × R-83Br	-0.27	-0.42	-6.45**	-1.11**	-0.04	-0.20**	1.96**	-0.01	1.63**	-0.57

Table 2c: Specific combining ability (sca) effects for 10 different characters in sunflower (Part III)

Hybrids	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	KH ratio	100seed weight (g)	Volume weight (g/100 ml)	Hull per cent	Oil content (%)	Seed yield/plant (g)
CMS-104A × R-4-2-Br	0.38	-1.82**	-5.72**	-0.07	0.03	0.10	2.84**	0.04	0.76**	0.56
CMS-104A × R-IT-2	-0.22	-0.77	14.60**	-0.42	-0.32*	-0.13*	-4.05**	1.66**	0.24	0.84
CMS-104A × R-411R	-1.62**	-0.32	-8.62**	-0.45	-0.17	-0.11	1.54**	0.63	1.69**	-5.47**
CMS-104A × RHA-288	1.53**	1.38**	3.31*	0.31	0.89**	-0.01	-4.10**	-3.55**	-1.78**	9.88**
CMS-104A × R-191-1	-3.37**	-0.97*	-9.12**	-0.56	-0.40**	-0.42**	-3.32**	1.61**	-0.93**	-7.96**
CMS-104A × R-186-1	1.83**	-0.27	11.63**	0.19	0.31*	0.55**	1.92**	-1.77**	-0.99**	5.11**
CMS-105A × R-393	0.41	-1.03*	7.52**	-0.65	0.19	-0.48**	0.39	-0.95	0.38*	0.74
CMS-105A × R-95C-2	-0.59	-1.13**	10.75**	1.34**	-0.56**	0.61**	-1.84**	3.14**	-2.12**	9.53**
CMS-105A × R-83Br	5.01**	4.42**	15.21**	-0.17	-0.13	0.69**	0.12	0.66	0.19	-6.99**
CMS-105A × R-4-2-Br	7.16**	4.52**	13.94**	0.87*	0.20	-0.17**	2.55**	-0.79	-0.83**	-2.76
CMS-105A × R-IT-2	-1.94**	0.57	-23.24**	-1.57**	-0.16	-0.85**	-0.94**	1.36*	0.65**	-12.58**
CMS-105A × R-411R	-3.34**	-0.98*	7.54**	0.19	0.05	0.53**	1.65**	-0.53	0.10	7.80**
CMS-105A × RHA-288	3.31**	0.72	-8.03**	-0.05	0.21	0.62**	0.36	-1.28*	-0.57**	1.96
CMS-105A × R-191-1	-2.59**	-2.13**	2.54	-0.21	0.23	-0.19**	0.29	-2.15**	2.43**	3.42*
CMS-105A × R-186-1	-7.39**	-4.93**	-26.21**	0.23	-0.04	-0.77**	-2.57**	0.54	-0.23	-1.11
CMS-106A × R-393	-1.59**	-0.59	10.74**	-0.25	0.61**	1.06**	3.97**	-2.58**	2.16**	3.80*
CMS-106A × R-95C-2	1.41**	-0.69	14.47**	-0.46	-0.06	-0.15**	-1.36**	0.30	1.46**	2.99*
CMS-106A × R-83Br	-1.49**	-1.64**	-5.57**	0.03	0.06	-0.42**	0.65**	-0.45	1.17**	-4.23**
CMS-106A × R-4-2-Br	-1.34**	0.96*	-8.34**	0.77*	0.02	-0.03	-5.62**	0.19	0.46*	6.70**
CMS-106A × R-IT-2	0.06	-0.99*	6.98**	0.23	-0.08	-0.51**	-2.36**	0.27	-1.27**	4.48**
CMS-106A × R-411R	-2.34**	-2.54**	-18.24**	-0.81*	-0.28	0.07	1.14**	1.32*	-0.36*	-2.63
CMS-106A × RHA-288	-2.19**	0.16	-11.31**	0.75*	0.18	-0.24**	1.00**	-0.65	-0.99**	-3.68*
CMS-106A × R-191-1	7.91**	1.81**	4.76**	-0.11	0.13	0.25**	2.52**	-1.27*	-0.63**	-2.41
CMS-106A × R-186-1	-0.39	3.51**	6.51**	-0.17	-0.57**	-0.03	0.06	2.86**	-2.00**	-5.05**

Table 2d: Specific combining ability (sca) effects for 10 different characters in sunflower (Part IV)

Hybrids	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	KH ratio	100seed weight (g)	Volume weight (g/100 ml)	Hull per cent	Oil content (%)	Seed yield/plant (g)
CMS-107A × R-393	0.24	0.19	-1.26	-0.08	0.50**	-0.53**	-4.93**	-2.16**	-1.40**	-2.72
CMS-107A × R-95C-2	1.24**	0.09	2.47	-0.19	0.42**	0.06	-0.21	-2.55**	-1.95**	-4.33**
CMS-107A × R-83Br	1.34**	2.64**	5.43**	-0.50	0.39**	-0.16**	-0.05	-2.41**	-2.10**	3.65*
CMS-107A × R-4-2-Br	-1.51**	-1.26**	7.16**	-1.86**	-0.29*	-0.22**	-2.62**	2.52**	1.64**	0.78
CMS-107A × R-IT-2	0.89	-0.21	1.48	1.00**	-0.60**	-0.20**	-1.56**	4.43**	2.06**	1.86
CMS-107A × R-411R	-0.51	-1.76**	11.26**	0.76*	-0.14	0.38**	6.48**	0.38	0.72**	3.75*
CMS-107A × RHA-288	-1.36**	-0.56	-4.31**	0.52	0.09	0.32**	1.14**	-0.93	0.80**	-1.00
CMS-107A × R-191-1	-1.76**	0.09	-19.74**	-0.94**	0.02	-0.34**	2.12**	-1.17*	-0.45*	-7.84**
CMS-107A × R-186-1	1.44**	0.79	-2.49	1.30**	-0.40**	0.68**	-0.34	1.89**	0.68**	5.83**
CMS-131A × R-393	-2.98**	-2.48**	-21.04**	0.23	-0.64**	-0.62**	1.67**	3.97**	-4.08**	-7.23**
CMS-131A × R-95C-2	-1.98**	0.42	-8.91**	-0.68*	0.57**	0.02	-0.66**	-3.19**	0.57**	-2.54
CMS-131A × R-83Br	-2.88**	-0.03	4.35**	1.81**	-0.38*	0.19**	-1.65**	2.39**	0.83**	1.34
CMS-131A × R-4-2-Br	0.77	0.57	-10.72**	1.05**	0.02	0.24**	0.93**	0.20	-2.34**	-6.63**
CMS-131A × R-IT-2	-1.83**	-1.38**	9.60**	-1.49**	0.05	0.21**	4.24**	-0.70	1.74**	3.15*
CMS-131A × R-411R	2.27**	0.07	0.88	-0.83*	0.57**	-0.92**	-6.27**	-2.31**	-2.51**	1.04
CMS-131A × RHA-288	7.92**	5.27**	33.81**	0.63	0.06	0.08	3.99**	-0.96	3.17**	-2.81
CMS-131A × R-191-1	0.52	-1.08*	-9.12**	-0.93**	-0.36*	0.87**	-5.78**	1.85**	-1.63**	4.95**
CMS-131A × R-186-1	-1.78**	-1.38**	1.13	0.21	0.10	-0.06	3.56**	-1.25*	4.26**	8.72**
CD at 5%	1.2763	1.1695	3.7118	0.9577	0.4110	0.1549	0.6429	1.4617	0.5102	4.2142
CD at 1%	1.6952	1.5534	4.9303	1.2720	0.5460	0.2058	0.8539	1.9416	0.6778	5.5977

*, ** – Significant at 5% and 1% levels, respectively

ard check was from -35.69 to 149.54 percent, -37.23 to 134.30 percent and -64.78 to 20.30 percent, respectively. The cross CMS-105A × R-411R (149.54%) had the highest heterosis over mid parent for seed yield per plant. The cross CMS-105A × R-186-1 recorded a significant heterosis over better parent (-10.65%) for plant height and seed yield (61.17%) indicating this cross was the best to exploit dwarfness and seed yield.

Table 3: The range of heterosis over mid parent, better parent and standard check (RSFH-130) for 10 different characters in sunflower

Characters	Mid parent	Better parent	Standard check
Days to 50% flowering	-11.67 – 20.91	-19.70 – 18.75	-12.82 – 13.68
Days to maturity	-5.85– 11.50	-10.58– 11.18	-6.63 – 4.42
Plant height (cm)	14.04 – 121.85	-10.65 – 108.07	-37.30 – 8.04
Head diameter (cm)	55.43 – 153.66	17.242 – 122.86	-18.49 –17.81
KH ratio	-44.00 – 45.87	-56.56 – 36.48	-34.48 – 25.72
100 seed weight (g)	13.85 – 152.69	-22.35 – 116.07	-31.46 – 35.96
Volume weight (g/100 ml)	-8.25 – 28.67	-18.46 – 20.69	-22.45–21.26
Hull per cent	-26.94 – 50.03	-33.76 – 30.79	15.88 – 37.07
Oil content (%)	-7.47 – 43.29	-22.95 – 38.94	-21.33 –3.70
Seed yield per plant (g)	-35.69 – 149.54	-37.23-134.30	-64.78 – 20.30

From the above facts it can be concluded that evaluation of cytoplasmic sources with various nuclear genotypes is also necessary in hybrid sunflower breeding. The top crosses exhibiting maximum sca effects were frequently observed for all the characters indicating pre-dominance of additive gene action and very low non additive gene action. They can be very well utilized in breeding programme for additive gene action as well as non-additive gene action since these crosses also have high sca effects. Parents exhibiting the favourable additive effects with high gca lead to the favourable interaction effects present in the crosses, which could finally result in higher sca effects. The cross CMS-105A × R-186-1 indicated the highest sca effect for plant height, days to 50 percent flowering and days to maturity.

CONCLUSIONS

Lodging and stalk breakage caused by excessive growth are known to be associated with yield reduction in sunflower. Therefore, development of dwarf and semi-dwarf varieties or hybrids is a major breeding objective. In this respect the present study was carried out to identify dwarf restorer to exploit dwarfness along with other yield and its attributing traits. It is worth mentioning here that the majority of the crosses which exhibited dwarfness were poor in seed yield. However, the crosses *viz.*, CMS-E002-91 × RHA-288, CMS-PHIR-27 × R-411R, CMS-106A × R-4-2-Br and CMS-131A × R191-1 exhibited significant sca effects for dwarfness and also significant sca effects for seed yield. Hence these crosses are considered the best cross combinations for exploitation of dwarfness. Exploitation of heterosis for seed yield and its attributing characters is common and it was successfully done by several researchers in the past, but exploitation of dwarfness in sunflower has started recently. In the present study the cross CMS-105A × R-186-1 had a significant heterosis over better parent (-10.65%) for plant height and seed yield (61.17%) indicating that this cross was the best to exploit dwarfness and seed yield.

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