HETEROSIS AND COMBINING ABILITY FOR QUALITY TRAITS IN INTERVARIETAL AND INTERSPECIFIC HYBRIDS IN OATS

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SUMMARY

Heterosis and combining ability studies were performed on 7 x 7 half diallel of intra-and inter-specific crosses involving six cultivars of *Avena sativa* and one accession of *A. sterilis* for crude protein, fat, total soluble sugars, reducing and non-reducing sugars in oat grain. The best crosses showing positive significant heterosis were identified as *A. sativa* cv. HJ 8 x *A. sativa* cv. UPO 212 and *A. sativa* cv. HJ 8 x *A. sativa* cv. OS 346 for protein content; *A. sativa* cv. HJ 8 x *A. sterilis* and *A. sativa* cv. HJ 8 x *A. sativa* cv. UPO 212 for fat content; *A. sativa* cv. HJ 8 x *A. sativa* cv. OS 6 for total soluble sugar; *A. sativa* cv. UPO 212 x *A. sterilis* and *A. sativa* cv. HJ 8 x *A. sterilis* for reducing sugar and *A. sativa* cv. HJ 8 x *A. sativa* cv. OS 6 for non-reducing sugars. Significant GCA effects revealed that parent *A. sterilis* for higher protein content; OS 6 (*A. sativa*) for higher fat; UPO 212 (*A. sativa*) for higher total soluble sugars while parent Kent (*A. sativa*) for high reducing sugar content whereas, parent OS 346 (*A. sativa*) for non-reducing sugar were identified as good general combiners. On the basis of significant SCA effects, hybrids Kent (*A. sativa*) x UPO 212 (*A. sativa*) and OS 6 (*A. sativa*) x OS 346 (*A. sativa*) for grain yield; HJ 8 (*A. sativa*) x OS 346 (*A. sativa*) and HJ 8 (*A. sativa*) x UPO 212 (*A. sativa*) for CP; HJ 8 (*A. sativa*) x *A. sterilis* and UPO 212 (*A. sativa*) x *A. sterilis* for high fat; HJ 8 (*A. sativa*) x OS 6 (*A. sativa*), HJ 8 (*A. sativa*) x UPO 212 (*A. sativa*) for total soluble sugars; HJ 8 (*A. sativa*) x *A. sterilis*, OL125 (*A. sativa*) x OS 346 (*A. sativa*) for reducing sugars and HJ 8 (*A. sativa*) x OS 6 (*A. sativa*) for non-reducing sugars were identified as best specific combiners.

Key words : Heterosis, combining ability, *Avena sativa*, A. *sterilis*, diallel

The oats are grown in several parts of India and abroad. It is mainly grown in *rabi* season mostly for fodder, however, of late, its grain is being used as baby food, breakfast food and animal feed. Zwer (2010) reported that oat are a versatile grain for food , animal feed and non-food products due to its unique grain qualities compared to other cereal grains. Heterosis exploitation has become an area of tremendous interest to boost up the production and productivity. For commercial exploitation of heterosis, the magnitude of heterosis provides criteria for selection of genetically diverse parents with better combining ability. Therefore, the concept of combining ability plays an important role in the identification of parents and development of superior lines or hybrids. Studies have indicated that the genotypes found good in performance might not necessarily produce desirable progenies when used in hybrid development. It is therefore, necessary to identify promising lines on the basis of combining ability in hybrid combinations using appropriate mating design. Keeping in mind the emerging importance of oats and its wild species, the present study was undertaken to estimate the heterotic response and combining ability effects for some biochemical parameters in oats involving intra- and inter-specific crosses between *A. sativa* x *A. sativa* and *A. sativa* x *A. sterilis*.

MATERIAL AND METHODS

Six genotypes namely Kent, OS 6, HJ 8, UPO 212, OL 125, OS 346 of *A. sativa*, the cultivated hexaploid species of oat and one genotype of *A. sterilis*,

[1]Part of M. Sc. Thesis

the wild hexaploid species of oat, were crossed in 7 x 7 half diallel fashion [n(n-1)/2] to obtain 21 F_1 hybrids. All the F_1 hybrids and their parents were grown in RBD with three replications. The crop was sown at the spacing of 45 cm between rows and 10 cm between plants. All the recommended package of practices was followed to grow a successful crop. Seeds from five competitive and random plants of each genotype were taken for estimation of quality parameters such as crude protein (%), fat (%), total soluble sugars and reducing and non-reducing sugars. Heterosis was worked out utilizing the overall mean of each hybrid for each trait. Relative heterosis (over mid-parent) was estimated as per cent deviation of the F_1 from its mid parental value (MP). Heterobeltiosis (over better parent) was estimated as per cent increase or decrease of F_1 over better parent (BP). Economic / Standard heterosis (over better check) for each character was expressed as per cent increase or decrease of F_1 value over the better check (BC). The significance of heterosis was tested against "t" value at error degree of freedom of ANOVA table at 5% or 1% level of probability. The combing ability analysis was estimated according to Method-2, Model-1 of Griffing (1956) in which parents and hybrids are included without reciprocals. The grain samples were subjected to biochemical analysis for estimating crude protein content by micro-Kjeldahl's method; fat content by Soxhlet method**;** total soluble sugar by the method of Dubois *et al*. (1956); reducing sugars by the method of Nelson Somogyi's (1944) and the concentration of non–reducing sugars was calculated by subtracting the reducing sugars from the total sugars.

RESULTS AND DISCUSSION

The range of heterosis for crude protein content was (-31.99 to 44.53; -32.15 to 26.65; -37.71 to -2.46%) over MP, BP and BC, respectively (Table 1). The maximum heterosis for CP was exhibited by HJ 8 x UPO 212 (44.53%, 26.55%) followed by HJ 8 x OS 346 (31.76 %, 6.23%) over MP and BP, respectively. In all ten crosses over mid-parent and five crosses over better parent showed significant desirable heterosis for CP. Sharma and Maloo (2009) showed significant positive mid-parent heterosis, heterobeltiosis and economic heterosis for protein content in soybean. The range of heterosis for fat content was (-35.73 to 22.54; -41.30 to 20.56; -45.82 to 28.31%) over MP, BP and BC, respectively (Table 1). Two crosses namely HJ 8 x *A. sterilis* (22.54%, 20.56%) and UPO 212 x *A. sterilis* (15.98%, 14.11%) showed heterosis over MP and BP whereas cross HJ 8 x UPO 212 (28.31%) showed heterosis over better check. In all four crosses over MP, two crosses over BP and one cross over better check showed significant desirable heterosis for fat content. Sharma and Maloo (2009) reported insignificant mid-parent heterosis and heterobeltiosis, but significant desirable economic heterosis for seed oil content in soybean.

The range of heterosis for TSS was (-56.29 to 26.85; -65.72 to 14.43; -85.44 to 12.16%) over MP, BP and BC, respectively (Table 1). The heterosis over MP and BP for TSS was recorded in two crosses namely; HJ 8 x OS 6 (26.85%, 7.76%) and Kent x HJ 8 (18.72%, 14.43%) however, a cross HJ 8 x UPO 212 (12.11%, 7.63%, 12.16%) exhibited heterosis for TSS over MP, BP and better check. In all four crosses over MP and 2 crosses over BP showed significant desirable heterosis for TSS. The range of heterosis for RS was (-48.34 to 72.54; -57.84 to 68.22; -59.81 to 23.98%) over MP, BP and BC, respectively (Table 1). For reducing sugar, heterosis over MP and BP was displayed by UPO 212 x *A. sterilis* (72.54%, 68 22%), HJ 8 x *A. sterilis* (65.81%, 61.67%), HJ 8 x OL 125 (59.43%, 43.43%), Kent x UPO 212 (45.92%, 23.40%), OL 125 x UPO 212 (30.17%, 21.33%), HJ 8 x UPO 212 (16.16%, 8.49%), Kent x OS 346 (13.17%, 10.27%), respectively. However, of these, three crosses namely; Kent x UPO 212(23.98%), Kent x OS 346 (10.78%) and HJ 8 x OL 125 (8.17%) showed heterosis over better check also. In all eleven crosses over MP, seven crosses over BP and three crosses over better check showed significant desirable heterosis for reducing sugars. The range of heterosis for NRS was (-86.68 to 72.26; -87.01 to 57.25; -87.01 to -9.50%) over MP, BP and BC, respectively (Table 1). For non-reducing sugars, two crosses namely, HJ 8 x OS 6 (72.26%, 57.25%) and HJ 8 x UPO 212 (9.24%, 18.49%) showed heterosis over MP and BP, respectively; however, none of the crosses displayed significant positive heterosis for this trait over better check. In all five crosses over MP and 2 crosses over BP showed significant desirable heterosis for non-reducing sugars.

Based upon mean values, parent *A. sterilis* for CP (14.23%) and non-reducing sugar (6.31%); OS 6 for fat content (10.83%) and reducing sugar (4.97%);

and OS346 was found superior for total soluble sugar. For the quality parameters the best crosses identified were; HJ 8 x UPO 212 and HJ 8 x OS 346 for protein content. HJ 8 x *A. sterilis* and HJ 8 x UPO 212, for fat content; HJ 8 x OS 6 for total soluble sugar; HJ 8 x *A. sterilis*, UPO212 x *A. sterilis*, for reducing sugar and HJ 8 x OS 6, for non reducing sugars all these crosses showed positive significant heterosis over mid parent and/or better parent and/or best check variety.

The mean square due to gca and sca were highly significant for all the characters indicated importance of both additive and non-additive gene effects in the expression of the characters. The estimates of general combining ability effects of parents and specific combining ability effects of F_1 hybrids are presented in Table 2 and 3, respectively. The gca component of variance were higher than sca component of variance for all the quality traits. The significant gca value in desirable direction was estimated in the parents and showed them as the better combiner parents namely; *A. sterilis* (0.63) followed by Kent (0.45) and OL125 (0.44) for higher protein content; OS 6 (1.01) followed by OS

TABLE 1

Estimates of heterosis (%) over mid parent, better parent and better check for quality traits in oats

Hybrids	CP (%)			Fat (%)			TSS (%)			RS (%)			NRS (%)		
	MP	BP	MP	BP	BC	MP	BP	BC	MP	BP	BC	BC	MP	BP	BC
Kent x HJ8	12.36**	-12.55**	18.72**	14.43**	-29.86**	21.00**	-3.00*	-2.55	14.61**	-26.09**	-59.61**	-13.96**	-2.02	-2.83	-28.25**
Kent x OS6	1.00	-3.83	-3.17	-17.85**	-32.95**	-4.55*	-5.00*	-4.55*	0.29	-36.06**	-63.20**	-5.39**	-13.98**	-25.23**	-25.23**
Kent x OL125	-8.02**	-9.62**	6.86**	-5.73**	-29.86**	-12.03**	-23.00**	-22.64**	41.92**	-11.72**	-42.71**	-11.08**	-11.41**	-18.53**	-28.31**
Kent x UPO212	10.65**	-2.67	-0.32	-18.85**	-26.54**	45.92**	23.40**	23.98**	-55.45**	-74.04**	-74.97**	-4.24**	-8.94**	-11.11**	-31.08**
Kent x OS346	0.95	-2.43	-19.44**	-36.81**	-36.81**	13.17**	10.27**	10.78**	-66.11**	-80.84**	-81.73**	-4.01	-1.93	-10.13**	-20.31**
Kent x *A.sterilis*	-10.06**	-10.99**	-4.64**	-21.10**	-31.47**	15.07**	-9.67**	-9.24**	-25.80**	-57.02**	-57.02**	-10.99**	-15.16**	-16.53**	-36.31**
HJ8 x OS6	26.40**	3.13	26.85**	7.63**	12.16**	-10.91**	-28.60**	-28.60**	72.26**	57.25**	-9.50**	-8.25**	1.24	-12.00**	-12.00**
HJ8 x OL125	29.01**	2.69	-4.69**	-15.92**	-87.44**	59.43**	43.43**	8.17**	-65.71**	-70.30**	-80.73**	-2.48	-20.53**	-26.92**	-35.69**
HJ8 x UPO212	44.53**	26.65**	12.11**	-8.73**	-17.38**	16.16**	8.49*	-24.65**	9.24**	18.49**	-21.33**	-5.39**	-5.28**	-7.54**	28.31**
HJ8 x OS346	31.76**	6.23**	-56.29**	-65.72**	-65.72**	-48.34**	-57.84**	-59.81**	-63.29**	-72.16**	-74.39**	-3.48	-10.64**	-18.11**	-27.38**
HJ8 x *A.sterilis*	17.53**	-8.20**	-2.26	-19.13**	-29.76**	65.81**	61.67**	-2.55	-45.03**	-59.45**	-59.45**	-8.20**	22.54**	20.56**	-8.00**
OS6 x OL125	4.70**	2.71	-1.29	-7.59**	-21.17**	12.95**	-1.13	-0.67	-16.84**	-17.82**	-46.67**	-2.46	3.57**	-10.00**	-8.62**
OS6 x UPO212	7.12**	-2.64	-14.90**	-17.35**	-25.18**	12.42**	-4.93*	-4.49*	-37.78**	-48.47**	-50.26**	-11.06**	-19.35**	-28.88**	-27.78**
OS6 x OS346	-31.99**	-32.15**	-12.19**	-18.64**	-18.64**	-27.27**	-29.13**	-28.80**	2.79	-13.20**	-20.17**	-37.71**	-4.89**	-10.91**	-9.54**
OS6 x *A.sterilis*	-7.04**	-11.06**	-38.81**	-39.36**	-47.33**	-18.56**	-36.07**	-35.77**	-54.23**	-62.62**	-62.62**	-11.06**	10.07**	-3.61*	-2.12
OL125 x UPO212	-6.27**	-17.55**	0.02	-8.10**	-16.81**	30.17**	21.33**	-2.48	-22.26**	-35.61**	-37.86**	-18.88**	-18.84**	-25.33**	-31.08**
OL125 x OS346	-3.53	-6.76**	-4.58**	-16.11**	-16.11**	-25.66**	-31.48**	-34.70**	13.87**	-3.85	-11.56**	-8.27**	-11.59**	-13.33**	-20.00**
OL125 x *A.sterilis*	-3.48	-4.26**	-26.01**	-30.70**	-39.81**	-16.98**	-28.92**	-42.87**	-32.00**	-44.46**	-44.46**	-4.26**	-35.73**	-41.30**	-45.82**
UPO212 x OS346	-4.92**	-12.43**	-13.38**	-15.64**	-15.64**	10.20**	-10.05**	-14.27**	-21.51**	-22.78**	-26.61**	-19.61**	7.91**	-1.11	-12.31**
UPO212 x *A.sterilis*	6.70**	-5.41**	-38.77**	-41.33**	-44.39**	72.54**	68.22**	1.41	-86.68**	-87.01**	-87.01**	-5.41**	15.98**	14.11**	-12.92**
OS346 x *A.sterilis*	-0.99	-5.27**	-17.94**	-24.79**	-21.58**	-7.01**	-27.00**	-26.66**	-25.07**	-26.93**	-26.93**	-5.27**	-7.30**	-15.33**	-21.85**
SE(+)	1.82	2.11	1.78	2.06	2.06	1.18	1.37	1.37	1.99	2.30	2.30	2.11	1.45	1.67	1.67
CD (5%)	3.57	4.14	3.49	4.04	4.04	2.32	2.68	2.68	3.90	4.50	4.50	4.14	2.84	3.27	3.27
Range	-31.99 to 44.53	-32.15 to 26.65	-56.29 to 26.85	-65.72 to 14.43	-87.44 to 12.16	-48.34 to 72.54	-57.84 to 68.22	-59.81 to 23.98	-86.68 to 72.26	-87.01 to 57.25	-87.01 to -9.50	-37.71 to -2.46	-35.73 to 22.54	-41.30 to 20.56	-45.82 to 28.31
Number of crosses showing desirable heterosis	10	5	4	2	0	11	7	3	5	2	0	0	4	2	1

MP=mid parent; BP=Better parent; BC=Better Check.

346 (0.42) for higher fat content; UPO 212 (0.62) followed by OS 346 (0.51) and OS 6 (0.28) for higher total soluble sugars; Kent (0.60) followed by UPO 212 (0.26), OS 6(0.14) for high reducing sugar content; OS 346 (0.70) followed by UPO 212 (0.36), OL125 (0.16), OS 6 (0.14) and *A. sterilis* (0.13) for non-reducing sugar for breeding oat in Table 2 . The common parents selected on the basis of high gca and high *per se*, it was concluded that parent OS 6 was best for fat (%) and reducing sugars; OS 346 for fat (%), total soluble sugars and non-reducing sugars; Kent for CP (%) and reducing sugars, while parent *A. sterilis* and OL 125 were found best for CP (%). They could be used to breed for better nutritional quality in oat. The gca effect of parent is primarily a function of additive and additive x additive gene effect and it determines the breeding value of the parent. Besides, gca effects are more stable due to polygenic fixable components of genetic variation and therefore, it is of more use for breeders (Griffing, 1956).

The estimates of sca effects of 21 F_1 hybrids obtained through cross combination of *A. sativa x A. sativa* and *A. sativa x A. sterilis* are given in Table 3. In all, ten crosses showed positive and significant sca effects for CP (%), however, maximum sca effects was shown by cross HJ 8 x OS 346 (poor x poor). Some other crosses viz., HJ 8 x UPO 212, HJ 8 x OL 125, HJ 8 x OS 6, were also found to be good specific combiners for high protein content. For high fat, cross combination HJ 8 x *A. sterilis*, showed highest positive significant sca effects which happened to be a combination of poor x poor general combining parents. Some other crosses like UPO 212 x *A. sterilis* (poor x poor), OS 6 x *A. sterilis*, (good x poor), UPO 212 x OS 346 (poor x good) also showed significant positive sca effects for higher fat content. Significant positive sca effects were recorded for total soluble sugars in ten hybrids. Most prominent among these crosses were HJ 8 x OS 6 (poor x good), HJ 8 x UPO 212 (poor x poor), Kent x HJ 8 (poor x poor). Other important crosses showing positive and significant sca effects were HJ 8 x *A. sterilis*, OL 125 x OS 346, Kent x *A. sterilis* and OS 6 x OL 125. Ten crosses showed significant positive sca effects for reducing sugars. Crosses with high significance were HJ 8 x OL 125 (poor x poor), HJ 8 x *A. sterilis* (poor x poor), Kent x UPO 212 (good x good), UPO 212 x *A. sterilis* (good x poor), Kent x OS 346, OS 6 x OL 125 and OL 125 x UPO 212 and depicting tendency for high reducing sugar for these crosses. Eight crosses showed positive significant sca effect for non- reducing sugar. The cross which registered maximum sca effect was HJ 8 x OS 6 (good x poor), followed by HJ 8 x UPO 212 (poor x good), OL 125 x OS 346 (good x good), Kent x OL 125 (poor x good) and OS 6 x OS 346 (good x good) indicating these crosses to be good for higher non-reducing sugar. It was reflected that the hybrids superior in F_1 involved both or at least one parent of

TABLE 2
Estimates of general combining ability effects for quality characters in oats

Characters/ Parents	CP (%)	Fat (%)	Total soluble sugars	Reducing sugars	Non-reducing sugars
Kent	0.45*	-0.54*	-0.63*	0.60*	-1.23*
HJ 8	-0.72*	-0.30*	-0.60*	-0.33*	-0.27*
OS 6	-0.20*	1.01*	0.28*	0.14*	0.14*
OL 125	0.44*	-0.29*	0.07*	-0.08*	0.16*
UPO 212	-0.47*	-0.23*	0.62*	0.26*	0.36*
OS 346	-0.13*	0.42*	0.51*	-0.18*	0.70*
A. sterilis	0.63*	-0.06	-0.26*	-0.40*	0.13*
SE (g_i)	0.01	0.05	0.01	0.02	0.03

TABLE 3
Estimates of specific combining ability effects for quality characters in a 7 x 7 diallel in oats

Characters/Crosses	CP (%)	Fat (%)	TSS (%)	RS (%)	NRS (%)
Kent x HJ8	-0.19*	0.07	0.96*	0.39*	0.56*
Kent x OS6	0.49*	-0.91*	-0.24*	-0.17*	-0.07
Kent x OL125	-0.95*	0.05	0.29*	-0.84*	1.19*
Kent x UPO212	0.93*	-0.30*	0.08	1.12*	-1.04*
Kent x OS346	0.62*	0.20	-0.88*	0.91*	-1.80*
Kent x *A.sterilis*	-1.13*	-1.03*	0.45*	0.13	0.31*
HJ8 x OS6	1.27*	0.28*	1.91*	-0.43*	2.35*
HJ8 x OL125	1.45*	-0.97*	-0.53*	1.62*	-2.16*
HJ8 x UPO212	1.94*	-0.24	1.02*	-0.35*	1.37*
HJ8 x OS346	2.02*	-0.79*	-3.96*	-1.65*	-2.30*
HJ8 x *A.sterilis*	0.44*	1.79*	0.60*	1.40*	-0.80*
OS6 x OL125	0.92*	0.64*	0.29*	0.71*	-0.42*
OS6 x UPO212	0.61*	-1.49*	-0.68*	0.17*	-0.86*
OS6 x OS346	-3.51*	-0.17	0.11*	-0.58*	0.70*
OS6 x *A.sterilis*	-0.49*	1.11*	-2.13*	-0.72*	-1.41*
OL125 x UPO212	-1.13*	-0.55*	0.40*	0.50*	-0.09
OL125 x OS346	0.03	-0.01	0.59*	-0.65*	1.22*
OL125 x *A.sterilis*	-0.16*	-2.31*	-1.13*	-0.84*	-0.28*
UPO212 x OS346	-0.66*	0.76*	0.08	0.01	0.07
UPO212 x *A.sterilis*	0.58*	1.18*	-2.17*	1.01*	-3.17*
OS346 x *A.sterilis*	0.26*	-0.43*	0.34*	-0.52*	0.28*
S.E(s_{ij})	0.04	0.13	0.04	0.07	0.08
C.D(s_{ij})	0.08	0.26	0.08	0.14	0.16

high/poor per se performance. Although the parent HJ 8 was not found good general combiner for any of the quality traits estimated from oat grain, since this cultivar has been bred chiefly for multi-cut fodder, yet it has produced very good cross combinations for quality traits. Based on various estimates viz., mean performance, heterosis and combining ability the best parents and crosses for quality traits in oats were identified. Crosses HJ 8 x OS 346 and HJ 8 x OL 125 for CP (%); HJ 8 x *A. sterilis* and OS 6 x *A. sterilis* for fat (%); HJ 8 x OS 6 for total soluble sugars and non-reducing sugars, while HJ 8 x OL 125 and Kent x UPO 212 for reducing sugars can be exploited further for attaining improvement in such traits.

To conclude, combining ability mean squares revealed that all the quality traits displayed preponderance of non-additive gene effects which might be due to dominance or epistasis. Although heterosis breeding makes maximal use of the non-additive genetic effects appears to be difficult for improving oat in view of the non-availability of mass pollination systems/male sterility systems needed for hybrid seed production. Accordingly, the feasible alternative is to consider simultaneous exploitation of both additive and non-additive gene action by adopting recurrent selection procedures. Further, the results of present study suggested that heterosis coupled with high sca effects might be considered as criteria for selecting cross for improvement with respect to quality traits.

REFERENCES

Dubois, M., K. A. Gilles, J. J. Hamilton, P. A. Rubress, and F. Smith 1956: Colorimetric method for determination of sugar and related substances. *Anal. Chem.* **28** : 350-356.

Griffing, B. 1956: Concept of general and specific combining ability in relation to diallel crossing systems. *Aust. J. Biol. Sci*. **9** : 463-493.

Nelson Somogyi, 1944: A photometric adaptation of the Somogyi method for determination of glucose. *J. Biol. Chem*., **153** : 375-380.

Sharma, S. C., and S. R. Maloo, 2009: Heterosis and combining ability studies for oil and protein content in soybean. *Indian J. Plant Genet. Resour*. **22** : 253-259.

Zwer, P. 2010: Oats: characteristics and quality requirements. In: *Cereal grains : assessing and managing quality*. pp. 163-182.