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Studies on Heterosis in Oat

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A B S T R A C T

Nature and magnitude of heterosis was studied for ten quantitative characters in a diallel mating design in oat with eight parents in randomized block design with three replications at Crop Research Center of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, during *rabi* season 2015-16 and 2016-2017. Out of 28 F_1's, 15 cross combination expressed high heterotic response with significant and positive heterosis and among these four crosses *viz*., Kent x JHO851, Kent x UPO212, JHO-99-2 x JHO851 and UPO 212 x NDO612 showed heterosis per cent more than 27% over better and mid parents for 8-9 traits which suggested that these attributes were governed by additive genes. These crosses which showed very high level of heterosis can be exploited further in future breeding programme to develop high yielding genotypes in forage oat.

Introduction

Oat (*Avena sativa* L. 2n= 6x = 42) a constituent of family *Poaceae* ranks sixth in the world cereal production. It is cultivated for use as food, feed and fodder. The crop has been adopted well by the farmers because of its multicut nature and high yield of nutritious palatable fodder. Oat is a crop of Mediterranean origin, the domestication dates back to ancient times. Oat seeds are reportedly found in 4000 year old remains in Egypt. It is a descended form of member of diploid (14 chromosomes) and a tetraploid wild species. The genus *Avena* comprises about seventy species, a few are cultivated. Oat belong to genus *Avena* established by Tournefort, a French explorer and botanist classified it as, Phylum spermatophyta; Sub class Monocotyledons; Family- Poaceae (Gramineae); Tribe-Avenue and Genus-*Avena*. There are two divisions of the genus *Avena*; annual and perennial. Predominantly two species *i.e.*, *Avena sativa* L. and *Avena byzantina* C. Koch are under cultivated at global level. The *Avena sativa* L. is more important, contributing over 80 per cent of the total world acreage. The cultivated oats (*Avena sativa* L.) a natural allopolyploid, together with wild weedy hexaploid species like *Avena sterillis* and *Avena fatua* have evolved through repeated cycles of interspecific hybridization and polyploidization, combining three distinct diploid genomes. All the hexaploid species have genomic constitution of AACCDD. It is well established that the domesticated oats (*Avena sativa* L.) has evolved from the wild hexaploid species *Avena sterillis*, which is corroborated by the fact that the hybrids between two are fully fertile. The species with chromosome number 2n = 28 or 42, though apparently polyploidy do not normally from multivalent whose presence indicates auto-polyploidy or effective homology. Cultivated species of oats are mostly hexaploids, while the wild species, which could contribute valuable genes, are mostly diploid and tetraploid.

Materials and Methods

The experimental material for the present investigation was comprised of eight promising diverse parents namely Kent, OS6, JHO-99-2, JHO851, OS403, OL125, UPO212 and NDO612 and their all possible 28 F_1's, developed through crossing eight parental lines in diallel mating design (excluding reciprocals). All genotypes were evaluated in a complete randomized block design with three replications at Crop Research Center (Chirodi) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, during *rabi* season 2015-16 and 2016-2017. The observations were recorded on ten characters *viz*., days to 50% flowering, number of leaves per plant, leaf area, plant height, number of tillers per plant, stem girth, number of green pods per plant, length of spike, leaf stem ratio and green fodder yield per plant.

The data recorded on all these traits were subjected to various statistical and biometrical analyses *viz*., to work out analysis of variance, components of variance through numerical approaches, general and specific combining ability variances and effects. The experiment for raising parents and F_1's was conducted in a complete randomized block design with three replications. Seeds of eight parents and F_1's were sown by hand dibbling method and the length of each row was kept 3m with inter and intra row distances of 30cm and 10cm, respectively. The data were compiled and subjected to analysis for heterosis expressed as percentage increase or decrease of F_1's over better parent as well as mid parent was suggested by Fonesca and Patterson (1968).

Results and Discussion

The result of manifestation of heterosis was found in both positive and negative direction (Table 1) for days to 50% flowering. The heterosis over better parent ranged from -13.17 (JHO851 x OS403) to 15.85 (UPO212 x NDO612). Out of 28 F_1 hybrids, seven crosses observed highly significant and positive heterobeltiosis values *viz*., Kent x JHO851, Kent x UPO212, JHO-99-2 x UPO212, OS403 x UPO212, OS403 x NDO612, OL125 x UPO212 and UPO212 x NDO612 for late flowering while, one cross combination JHO851 x OS403 exhibited highly significant negative heterosis over better parent for early flowering. Similar results on the importance of positive heterosis for days to 50% flowering have been reported by Mishra *et al.,* (2014).

Number of leaves per plant magnitude of heterosis varied from -13.56 (JHO-99-2 x OL125) to 32.51 (UPO212 x NDO612). Eleven crosses *i.e.* Kent x JHO-99-2, Kent x JHO851, Kent x OS403, Kent x UPO212, OS6 x JHO-99-2, JHO-99-2 x JHO851, JHO851 x OL125, JHO851 x UPO212, OS403 x OL125, OL125 x NDO612 and UPO212 x NDO612 noted positive and significant heterosis over better parent for more number of leaves per plant and hybrid JHO-99-2 x OL125 recorded negative significant heterosis over better parent for this character. Estimates of positive heterosis for this character were earlier reported by Dumlupinar *et al.,* (2015). Heterobeltiosis for leaf area was found in the ranged -17.48 (JHO851 x OS403) to 24.04 (JHO-99-2 x OL125) of heterobeltiosis was recorded among all the F_1's for stem girth.

Table.1 Estimates of heterosis (%) over better parent (Heterobeltiosis) and mid parent (Relative heterosis) of yield and its components in oats (*Avena sativa* L.)

Hybrids	Days to 50% flowering		No. of leaves per plant		Leaf area (cm²)		Plant height (cm)		No. of tillers per plant	
	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
Kent x OS6	3.40	2.45	-6.12	-6.51	-1.05	-5.11	4.88	2.57	-13.46**	**-12.48****
Kent x JHO-99-2	5.56	3.64	17.43**	16.76**	5.24	4.79	0.66	0.67	15.38**	**14.76****
Kent x JHO 851	14.06**	13.30**	18.97**	18.33**	14.22**	10.43**	0.63	0.91	24.18**	**23.81****
Kent x OS 403	5.86	2.54	23.54**	22.39**	4.50	3.49	3.54	1.66	-2.33	**-1.40**
Kent x OL 125	4.01	1.66	-5.80	-4.46	-1.60	-2.03	0.94	0.13	-14.36**	**-10.02****
Kent x UPO 212	7.07**	6.41**	24.38**	23.90**	12.44**	12.27**	15.00**	14.29**	17.38**	**16.88****
Kent x NDO 612	4.01	4.01	6.78	5.37	2.60	1.17	3.56	2.83	-11.64**	**-10.15****
OS 6 x JHO-99-2	1.82	0.90	26.31**	20.38**	2.05	1.96	5.60	5.85	3.87	**4.90**
OS-6 x JHO 851	-4.13	-1.71	-2.37	-2.11	-0.08	-0.94	2.00	1.61	-3.06	**-3.47**
OS 6 x OS 403	3.64	1.33	1.08	1.02	-3.17	-1.37	2.05	1.57	1.15	**1.97**
OS 6 x OL 125	-1.82	-0.45	1.03	1.01	1.25	1.94	3.56	1.01	14.01**	**13.62****
OS 6 x UPO 212	4.74	3.07	-3.97	-3.16	-0.82	-0.81	-1.50*	-1.91	-18.96**	**-17.18****
OS 6 x NDO 612	1.85	0.92	-1.58	28.00**	0.91	0.17	-1.76	3.72	1.50	**1.29**
JHO-99-2 x JHO 851	1.62	1.15	19.05**	18.63**	16.36**	16.12**	14.72**	13.36**	24.96**	**23.08****
JHO-99-2 x OS 403	-1.79	-0.44	-10.86**	-10.11**	-4.42	-3.14	15.08**	13.31**	3.14	**3.90**
JHO-99-2 x OL 125	2.08	1.63	-13.56**	-13.49**	24.04**	23.44**	3.74	2.51	-2.40	**-4.26**
JHO-99-2 x UPO 212	12.45**	11.53**	-2.84	1.97	6.83	2.31	-18.77**	-17.09**	4.82	**3.81**
JHO-99-2 x NDO 612	4.01	2.12	-3.32	-2.66	-0.66	-0.10	1.74	1.66	18.78**	**17.72****
JHO 851 x OS 403	-13.17**	-12.52**	-1.54	1.06	-17.48**	-17.11**	5.07	4.85	-2.95	**-1.05**
JHO 851 x OL 125	3.49	-0.31	18.26**	17.13**	-4.45	-2.98	4.32	3.04	5.62	**4.50**
JHO 851 x UPO 212	1.38	1.29	22.60**	22.00**	-1.77	-1.87	5.12	4.06	4.18	**2.27**
JHO 851 x NDO 612	1.59	0.16	3.12	3.01	-1.53	-1.42	1.95	0.53	-14.02**	**-13.52****
OS 403 x OL 125	2.06	1.17	20.58**	19.71**	-14.30**	-13.49**	4.14	3.05	1.54	**2.11**
OS 403 x UPO 212	14.47**	13.92**	7.55	6.85	-2.40	-2.29	-17.95**	-16.44**	-1.40	**-2.84**
OS403 x NDO 612	7.41**	7.04**	-2.80	-2.34	2.25	1.74	2.70	1.59	-1.99	**-1.49**
OL 125 x UPO 212	12.12**	11.72**	3.61	3.01	1.28	1.75	2.77	1.69	5.46	**4.63**
OL 125 x NDO 612	4.94	2.56	18.36**	17.28**	3.08	2.88	0.92	0.86	6.57	**5.73**

UPO 212 x NDO 612	15.05**	14.48**	32.51**	31.84**	15.35**	14.36**	16.66**	14.35**	19.03**	18.48**
SE	2.15	1.61	1.00	0.74	0.68	0.51	2.91	2.06	0.29	0.25

Hybrids	Stem girth (mm)		No. of green pods per spike		Length of spike (cm)		Leaf stem ratio (w/w)		Green fodder yield per plant (g)	
	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
Kent x OS6	-0.24	-0.93	0.70	0.71	-4.14	-1.70	-3.35	-3.38	5.36	4.53
Kent x JHO-99-2	5.00	4.49	0.29	0.19	-1.24	-0.32	0.68	0.50	19.03**	18.24**
Kent x JHO 851	7.67**	6.76**	17.48**	17.14**	7.00**	6.00**	20.53**	20.50**	29.98*	29.70**
Kent x OS 403	-2.86	-2.78	-12.59**	-11.50**	-1.84	1.72	11.05**	10.62**	13.76**	13.39**
Kent x OL 125	4.48	3.83	-23.13**	-20.03**	-4.35	-3.14	-2.15	-1.92	11.21**	11.00**
Kent x UPO 212	20.19**	19.16**	36.51**	35.71**	21.14**	20.03**	0.56	0.96	39.99**	38.94**
Kent x NDO 612	4.22	4.56	-3.56	-1.14	0.60	0.20	-12.73**	-11.08**	17.08**	16.98**
OS 6 x JHO-99-2	-19.28**	-18.45**	-6.39	-5.25	5.56	4.58	3.18	2.78	1.85	1.75
OS-6 x JHO 851	-2.24	-1.28	5.16	2.76	0.52	0.42	14.31**	13.91**	-0.91	-0.69
OS 6 x OS 403	2.03	1.33	-0.30	-0.26	1.29	1.96	23.34**	22.44**	5.80	5.72
OS 6 x OL 125	-5.61	-4.31	-27.93**	-26.76**	1.85	3.89	-2.87	-1.41	-1.83	1.74
OS 6 x UPO 212	-4.65	-5.01	-2.48	-1.81	5.01	5.70	-1.12	-1.92	14.46**	13.50**
OS 6 x NDO 612	-18.64**	-18.39**	-0.51	-0.37	4.70	3.65	16.85**	15.21**	3.06	2.76
JHO-99-2 x JHO 851	14.87**	14.59**	26.39**	25.80**	24.17**	23.79**	38.91**	34.93**	27.71**	27.53**
JHO-99-2 x OS 403	-5.35	-4.64	-17.02**	-17.00**	-16.45**	-15.46**	13.45**	12.55**	18.58**	17.55**
JHO-99-2 x OL 125	-1.21	-1.14	-14.01**	-13.96**	-4.62	-3.85	0.52	0.17	5.19	4.34
JHO-99-2 x UPO 212	3.44	3.30	-4.28	-3.46	-3.42	-1.85	1.22	1.07	3.24	2.77
JHO-99-2 x NDO 612	17.12**	16.08**	-3.87	-2.06	1.60	1.06	1.28	1.86	-17.82**	-16.14**
JHO 851 x OS 403	2.71	1.91	13.69**	12.73**	1.08	1.34	5.04	4.15	15.25**	14.30**
JHO 851 x OL 125	-1.04	-0.67	3.42	1.13	-1.04	1.46	2.96	1.45	2.84	1.38
JHO 851 x UPO 212	-4.55	-3.02	-20.11**	-19.18**	-4.45	-1.39	-4.02	-3.00	7.05	6.24
JHO 851 x NDO 612	-3.07	2.95	-3.91	-2.16	1.50	0.90	4.61	3.49	15.50**	11.37**
OS 403 x OL 125	0.04	0.21	-4.52	-3.19	-1.22	-0.93	23.86**	22.64**	12.75**	12.34**
OS 403 x UPO 212	-4.27	-2.66	-17.48**	-16.41**	-11.21**	-10.57**	18.24**	16.39**	11.99**	11.89**
OS403 x NDO 612	3.41	2.74	2.77	1.12	5.47	4.60	30.98**	29.40**	1.98	1.63
OL 125 x UPO 212	1.84	1.67	4.82	2.57	-3.75	-2.46	3.95	2.80	1.08	1.40
OL 125 x NDO 612	4.28	3.30	5.16	3.32	22.36**	20.15**	-4.27	-3.41	14.60**	16.69**
UPO 212 x NDO 612	19.83**	18.36**	24.74**	23.31**	15.40**	16.50**	14.55**	13.47**	38.40**	37.85**
SE	0.15	0.12	1.28	0.92	0.68	0.51	0.01	0.01	3.02	2.89

The cross combinations *viz*., Kent x JHO851, Kent x UPO212, JHO-99-2 x JHO851, JHO -99-2 x OL 125 and UPO212 x NDO612 showed positive significant heterosis over better parent for leaf area and two crosses JHO851 x OS403 and OS403 x OL125 revealed negative significant heterosis over better parent for this character. The present study is in agreement with Kapoor and Bajaj (2013). A range for plant height per plant was -18.77 (JHO-99-2 x UPO212) to 16.66 (UPO212 x NDO612). The best crosses *i.e.* Kent x UPO212, JHO-99-2 x JHO851, JHO-99-2 x OS 403 and UPO212 x NDO612 exhibited positive and significant heterosis over better parent, suggested that good performance for this character and two hybrids JHO-99-2 x UPO212 and OS403 x UPO212 revealed negative and significant heterosis over better parent, indicated poor performance for plant height. These results are somewhat in accordance with the findings of Dumlupinar *et al.,* (2015). Heterobeltiosis for number of tillers per plant over the better parent ranged from -18.96 (OS6 x UPO212) to 24.96 (JHO-99-2 x JHO851). Out of twenty eight F_1's hybrid, only seven crosses namely, Kent x JHO-99-2, Kent x JHO851, Kent x UPO212, OS6 x OL 125, JHO-99-2 x JHO851, JHO-99-2 x NDO612 and UPO212 x NDO612 showed positive and significant heterosis in order to merit over better parent and five crosses revealed negative significant heterosis over better parent for this trait. Such types of findings were reported by Vishwakarma *et al.,* (2010). Magnitude of heterosis for stem girth varied from -19.28 (OS6 x JHO-99-2) to 20.19 (Kent x UPO212). Hybrids *viz.*, Kent x JHO851, Kent x UPO212, JHO-99-2 x JHO851, JHO-99-2 x NDO612 and UPO212 x NDO612 exhibited positive significant heterosis over better parent for stem girth and only two F_1's OS6 x JHO-99-2 and OS6 x NDO612 showed negative significant heterosis over better parent, emerged as poor performance for this character. Positive heterosis for stem girth studied has also been reported earlier Mishra *et al.*, (2014) and Dumlupinar *et al.*, (2015). Heterobeltiosis for number of green pods per spike ranged from -27.93 (OS6 x OL125) to 36.51 (Kent x UPO212). Five F_1's hybrid noted highly significant and positive heterosis over better parent values in Kent x JHO851, Kent x UPO212, JHO-99-2 x JHO851, JHO851 x OS403 and UPO212 x NDO612. Seven crosses recorded significant negative heterosis over better parent for number of green pods per plant. Similar results were found by Verma and Singh (2010). The degree of heterosis over better parent for length of spike varied from -16.45 (JHO-99-2 x OS403) to 24.17 (JHO-99-2 x JHO851). Highly significant and positive heterosis values over better parent were recorded in five F_1 hybrids *viz*., Kent x JHO851, Kent x UPO212, JHO-99-2 x JHO851, OL125 x UPO212 and UPO212 x NDO612 for length of spike and two crosses JHO-99-2 x OS403 and OS403 x UPO212 noted negative and significant heterosis over better parent for this character. Heterosis of similar magnitude has been reported by Vishwakarma *et al.,* (2010). Estimates of heterosis for leaf stem ratio ranged from -12.73 (Kent x NDO612) to 38.91 (JHO-99-2 x JHO851). A total of 11 F_1 hybrids revealed positive and highly significant heterosis over better parent, these were Kent x JHO851, Kent x OS403, OS6 x JHO851, OS6 x OS403, OS6 x NDO612, JHO-99-2 x JHO851, JHO-99-2 x OS403, OS403 x OL125, OS403 x UPO212, OS403 x NDO612 and UPO212 x NDO612. Only one cross Kent x NDO612 had significant and negative heterosis over better parent for leaf stem ratio. These results are in conformity with the findings of Dumlupinar *et al.*, (2015). Expression of heterosis over better parent for green fodder yield per plant varied from - 17.82 (JHO-99-2 x NDO612) to 39.99 (Kent x UPO212). Out of 28 F_1's, 15 crosses showed highly significant and positive heterobeltiosis values, *viz*., Kent x JHO-99-2, Kent x JHO851, Kent x OS403, Kent x OL125, Kent x UPO212, Kent x NDO612, OS6 x UPO212, JHO-99-2 x JHO851, JHO-99-2 x OS403, JHO851 x OS403, JHO851 x NDO612, OS403 x OL125, OS403 x UPO212, OL 125 x NDO612 and UPO 212 x NDO612 for green fodder yield per plant, whereas, only one cross combination JHO-99-2 x NDO612 exhibited negative significant heterosis over better parent for this character. The expression of heterosis of similar magnitude for this attribute has also been reported by Kapoor and Bajaj (2013), Mishra *et al.*, (2014) and Dumlupinar *et al.*, (2015). As above cross combinations may be exploited for heterosis breeding programme. Since these hybrids involve high x high or high x average or average x average or average x low or low x low gca value of parent and significant sca effect for involved of non-additive gene action and response of dominance and dominance x dominance type of gene effect. A high heterosis result for yield might be obtained by exploiting these individual cross for developing hybrids through heterosis breeding programme.

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