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GENETIC EFFECTS OF COMBINING ABILITY ON FORAGE QUALITY TRAITS AND FORAGE YIELD IN DIALLEL CROSSES OF OATS (*Avena sativa* L.)

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ABSTRACT

Studies in oats (*Avena sativa* L.) were carried out to generate information on combining ability (general and specific), nature and magnitude of gene effects and heterosis for forage quality and yield. The experimental material comprised of 10 diverse parents and 45 F_1 crosses (excluding reciprocals) generated through a 10 x 10 diallel mating design. Significant interaction between combining ability effects were observed for all the quality traits and yield. The estimates of additive variance were higher in magnitude than their corresponding dominance variance estimates indicating the role of additive gene action, except green forage yield and dry matter yield. The parent SKO-213 had highly significant and desirable GCA effects for crude protein content, SKO-210 for neutral detergent fibre, SKO-204 for acid detergent fibre, SKO-208 for crude fibre parent, SKO-207 for ash content and SKO-212 for both green forage and dry matter yields. Cross combinations *viz.*, SKO-212 x SKO-213, SKO-204 x SKO-211, SKO-205 x Sabzaar, Sabzaar x SKO-212 and SKO-205 x SKO-211 exhibited high and desirable sca and heterobeltiosis effects simultaneously for all the quality traits, green forage yield and dry matter yield ha^{-1}.

Key words: *Avena sativa*, combining ability, forage quality, GCA, heterobeltiosis, SCA, yield

INTRODUCTION

Oats (*Avena sativa* L.) an important winter fodder/grain crop grown throughout world both for animal and human consumption. It is a quick growing, palatable, succulent and nutritious fodder crop which forms an excellent combination when fed along with other cool season legumes like berseem (*Trifolium alexandrinum*), alfalfa (*Medicago sativa*) Indian clover (*Melilotus indica*), Persian clover (*Trifolium resupinatum*), pea (*Pisum arvense*) and vetch (*Vicia sativa*). Inadequate supply of quality feed and fodder is the primary cause of lower productivity of milch animals in India (Patel *et al*., 2011). In Jammu and Kashmir state the fodder requirement is about 4.31 million tonnes against the available 3.26 million tonnes (Anonymous, 2008). Kashmir valley experiences a long lean period of winter, resulting in scarcity of green and quality fodder which results in drastic decrease in milk production. Therefore, to meet the need of animal products and to maintain good health of livestock in terms of milk, meat and wool, there is a great importance of fodder cultivation to compensate fodder scarcity during lean period. The best measure related to forage quality is animal productivity, which can be affected by nutrient intake, digestibility and utilization efficiency. Quality forage must have high intake, digestibility and efficient utilization. Oats genotypes that are low in neutral detergent fibre (NDF) and acid detergent fibre (ADF) have good forage quality because low NDF is associated with high forage intake and low ADF is associated with high digestibility. Protein content is an important feed factor *per se* with high quality feed having high protein content. The total mineral content (ash) is 3 to 12% dry matter. The minerals typically determined are calcium and phosphorus.

Combining ability plays a vital role in identifying the potential of lines for obtaining promising segregants. It should pave the way for bringing about a kind of plant type, which could enhance quality and productivity without sacrificing the consumer needs. Productivity and quality of forage oats can be improved through heterosis breeding. The estimation of heterosis for forage yield and its component characters would be useful to judge the best hybrid combination for exploitation of superior hybrids. However, the selection of promising parents to obtain superior hybrids primarily depends on the predominance of the genes for the additive effect due to heterosis and heterobeltiosis (Beche *et al.*, 2013). Hence, the present investigation was carried out with the objectives to study the combining ability, nature of gene action and magnitude of heterosis over better parent for quality and yield traits.

MATERIALS AND METHODS

The basic material for the present study consisted of 10 diverse genotypes of oats (*Avena sativa* L.) *viz.*, SKO-204, SKO-205, SABZAAR, SKO-207, SKO-208, SKO-209, SKO-210, SKO-211, SKO-212 and SKO-213 selected from the germplasm maintained at the Division of Plant Breeding and Genetics, SKUAST-K, Shalimar. Forty five F_1 crosses (excluding reciprocals) generated through a diallel mating design were evaluated for forage quality and forage yield in a single environment at SKUAST-Kashmir, Shalimar, Srinagar, J&K (India) during *rabi* 2010-2011. The experiment was laid out in a completely randomized block design with three replications. The experimental plot comprised of two rows each of 1m length. Plant spacing was maintained at 30 cm x 10 cm. The forage quality was determined after the samples were dried and crushed to a fine powder. The forage quality parameters for which these genotypes were studied included, crude protein content (Jackson, 1973), neutral detergent fibre (Goering and Vansoest, 1970), acid detergent fibre (Goering and Vansoest, 1970), ash content (AOAC, 1984) and crude fibre (Maynard, 1970). Data was subjected to analysis of variance to find significant differences among genotypes for the recorded data. After obtaining the significant differences, Data recorded on parents and their F_1's were subjected to combining ability analysis following Griffing (1956) Method-II and Model-I. The increase or decrease of F_1 hybrids over better parent was calculated to estimate the possible heterotic effects for above mentioned parameters (Fonseca and Patterson, 1968).

Hbt (%) = (F_1-BP) /BP x100; where Hbt = Heterobeltiosis, & BP = mean value of better parent for trait

RESULTS AND DISCUSSION

Analysis of variance revealed significant mean squares for all parameters (Table 1). Significant differences were found among the parents and their crosses for all the traits indicating that the materials selected were diverse and resulted in the creation of substantial genetic variability in crosses. The contrast of parent's v/s hybrids was sizable and highly significant for all traits, pointing to the potential of heterotic effects in improving forage quality and yield traits. The mean sum of squares for general combining ability (gca) and specific combining ability (sca) were significant for all the traits. It indicated that additive and non additive genetic variance played a significant role in the expression of traits.

Table 1: Analysis of variance for combining ability and estimates of components of variance for forage quality, green forage yield and dry matter yield in oats (*Avena sativa*)

Source of variation	d.f.	Mean Square						
		Crude protein (%)	NDF (%)	ADF (%)	Crude fibre (%)	Ash (%)	Green fodder (q ha^{-1})	Dry matter yield (q ha^{-1})
Replication	2	0.014	0.008	0.238	0.026	0.216	0.209	0.011
Treatment	54	2.82**	47.53**	16.49**	23.60**	110.68**	603.69**	54.35**
Parents (P)	9	7.26 **	111.40**	12.08**	9.38**	1.44**	51.13**	79.34**
Hybrids (H)	44	1.73**	35.07**	16.25**	25.42**	19.19**	320.71**	35.99**
P vs H	1	10.94**	20.67**	66.67**	71.55**	25.06**	8028.05**	9672.89**
Error	108	0.01	9.83	0.11	0.12	0.32	0.313	0.440
Gca	9	108.79**	743.28**	11.30**	81.09**	18.98**	164.32**	324.57**
Sca	45	32.07**	704.22**	4.33**	43.74**	21.91**	208.61**	444.33**
σ^2A	-	0.71 ± 0.01	12.37 ± 1.22	4.30 ± 0.79	7.60 ± 1.31	0.67 ± 0.02	27.98 ± 2.67	43.23±3.78
σ^2D	-	0.35 ± 0.001	7.22 ± 1.11	1.88 ± 0.03	1.49 ± 0.31	0.48 ± 0.03	116.87± 3.07	98.21±4.22

*,**significant at 5 and 1% level, respectively.

The estimates of variance due to additive genetic variance (σ^2A) were much higher than the corresponding dominance deviation (σ^2D) for all the quality traits, indicating preponderance of additive gene action as compared to dominance gene action except green forage yield and dry matter yield ha^{-1} that exhibited non additive gene action. Therefore, preponderance of additive gene action suggested that, methods based on direct selection in early generation such as pedigree method can be applied. Green forage and dry matter yield revealed preponderance of over-dominance indicating that the present set of materials was diverse and contained contrasting alleles which on combination through hybridization increased heterozygosity and could lead to hybrid vigour. The results are general agreement with earlier findings (Prajapati *et al.*, 2010; Akram *et al*, 2011; Ahmad *et al*., 2013a) for forge quality and green forage yield.

The estimates of gca effects showed difference of one individual parent to another and from trait to trait (Table 2).The gca effects represent the additive nature of gene action. A high general combiner is characterized by its better breeding value when crossed with a number of other parents. Knowledge of the relative importance of additive and non-additive gene action is essential to a plant breeder for the development of an efficient hybridization program. Combining ability analysis helps in the evaluation of pure lines in terms of their genetic value and in the selection of suitable parents for hybridization. Further, the gca variance (σ^2g) of parents and sca variance (σ^2s) of the crosses plays a significant role in the choice of parents.

In the present investigation, the gca effects of 10 lines were estimated to know their genetic worth for use in production of superior progenies. The estimates of gca effects of parents indicated that the parents SKO-213 (0.468**) and SKO-209 (0.402**) had highly significant positive gca effects for crude protein content (Table 2). For NDF, parents SKO-210 (-1.886**) and SABZAAR (-1.807**) had highly significant negative gca effects. For ADF, parents SKO-204 (-1.262**) and SKO-211 (-0.871**) were having highly significant negative gca effects. For crude fibre (CF), parents SKO-208 (-1.175**) and SKO-210 (-1.111**) showed highly significant negative gca effects. For ash content, parents SKO-207 (0.433**) and SKO-208 (0.424**) showed highly significant positive gca effects. For green forage yield, parents SKO-212 (6.883**) and SKO-205

Table 2: General combining ability (gca) effects for forage quality, green forage yield and dry matter yield in oats (*Avena sativa*)

Parents	Crude protein (%)	NDF (%)	ADF (%)	Crude fibre (%)	Ash (%)	Green fodder (q ha^{-1})	Dry matter yield (q ha^{-1})
SKO-204	-0.046**	-0.814	-1.262**	0.781**	0.045	1.577**	2.332**
SKO-205	-0.648**	-0.920	-0.821**	0.697**	0.284**	3.654**	1.356**
SABZAAR	-0.787**	-1.807**	0.713**	-0.106	-0.249**	-5.412**	-1.675**
SKO-207	0.100**	-1.669	-0.112*	-0.431**	0.433**	0.573**	2.389**
SKO-208	0.244**	-1.086**	1.641**	-1.175**	0.424**	-0.731**	-3.887**
SKO-209	0.402**	0.544	0.154**	1.408**	0.070	-3.267**	-1.554**
SKO-210	-0.078**	-1.886**	1.229**	-1.111**	-0.108*	-4.188**	-2.332**
SKO-211	0.110**	0.887	-0.871**	-0.492**	-0.316**	1.446**	0.776**
SKO-212	0.235**	-1.044*	-0.826**	-0.303**	0.364**	6.883**	4.221**
SKO-213	0.468**	-1.278*	0.154**	0.731**	0.067	-0.485**	-2.567**
S.E. (g i)	±0.013	±0.095	±0.051	±0.055	±0.050	±0.088	±0.024
SE(gi - gj)	0.020	0.104	0.077	0.082	0.074	0.131	0.213
Parents with desirable gca effects	6	5	5	5	4	5	5

*, **Significant at 5 and 1%t level, respectively

(3.654**) had highly significant positive gca effects. For dry matter yield, parents SKO-212 (4.221**) and SKO-207 (2.389**) had highly significant positive gca effects. Parents SKO-207 and SKO-212 with desirable gca for all traits could be utilised extensively in hybridisation program to accelerate the pace of genetic improvement of quality and forage yield. These genotypes could serve as a source for the isolation of new desirable lines. Parents presenting higher gca must be preferred to be part of crossing programme for the selection of promising homozygous lines (Ahmad *et al.,* 2013b). gca effects are attributable to additive and additive x additive gene effects, the above mentioned parents have good potential for improving the respective quality traits and may be used in a multiple crossing program to synthesize an improved population with most of the favourable genes for amelioration of quality and forage yield.

The estimates of specific combining ability effects of 45 crosses for quality traits revealed that 26 cross combinations had desirable significant sca effect for crude protein content (Table 3). For NDF, 21 crosses exhibited desirable negative sca effect. For ADF, only 23 crosses exhibited desirable significant negative sca effect. Only 18 and 15 crosses exhibited desirable and significant sca effect for crude fibre and ash content, respectively. For dry matter yield, 23 crosses exhibited desirable significant positive sca effect. For green fodder yield, 24 cross possessed desirable and significant sca effect. Five crosses *viz*., SKO-204 x SKO-211, SKO-205 x SABZAAR, SKO-205 x SKO-211, SABZAAR x SKO-212 and SKO-212 x SKO-213 possessed desirable and significant sca for forage quality, green forage and dry matter yield. The crosses having high sca for forage quality and yield with other agronomic features need to be evaluated vigorously for the isolation of desirable transgressive segregants. Parents with positive significant gca effects involved additive type of gene action that would be easily fixable. These desirable cross combinations which involve high x low (Table 4) gca effects in this situation could be utilized in recombination breeding. It is noteworthy that crosses which exhibited consistently positive sca effects, it is, therefore, suggested that sca performance may be considered as a criterion for selecting the best crosses. It may be worthwhile to attempt bi-parental mating among selected crosses in advanced generation to permit superior recombination. Parents which have been identified with desirable forage quality parameters could be used in hybridization programmes to improve the quality characteristics in adopted cultivars and desirable cross combinations need to be evaluated vigorously in advanced generation. Crosses which had one good general combiner in their parentage indicated the involve-ment of additive x dominance type of interaction and they may be advanced for deriving desirable transgressive segregants and homozygous lines in subsequent generations (Ahmad *et al*., 2013a).

Table 3: Estimates of specific combining ability (sca) effects for forage quality, green forage yield and dry matter yield of promising crosses of oats (*Avena sativa*)

Crosses	Crude protein (%)	NDF (%)	ADF (%)	Crude fibre (%)	Ash (%)	Green fodder (q ha^{-1})	Dry matter yield (q ha^{-1})
SKO-204 x SKO-205	-1.124**	0.401*	-0.849**	2.186**	-0.292	0.632**	0.363**
SKO-204 x SABZAR	-1.425**	0.278	-2.782**	2.389**	0.141	0.143**	0.243**
SKO-204 x SKO-207	0.488**	-0.988**	-0.057	2.114**	-0.375**	2.285**	1.267**
SKO-204 x SKO-208	0.494**	-1.019**	-0.010	-3.342**	0.461**	4.765**	3.457**
SKO-204 x SKO-209	0.385**	-3.363**	3.676*	3.375**	-0.822**	4.213**	-0.577**
SKO-204 x SKO-210	-0.824**	1.595**	3.701*	-3.906**	-2.400**	-3.899**	-4.897**
SKO-204 x SKO-211	0.387**	-4.503**	-2.799**	-3.525**	4.208**	4.432**	3.556**
SKO-204 x SKO-212	-0.543**	-4.437**	-1.243**	2.453**	4.561**	-1.123**	-2.976**
SKO-204 x SKO-213	0.037	-1.041**	-5.724**	-1.547**	0.225	-0.334**	-0.556**
SKO-205 x SABZAR	1.563**	-4.193**	-4.776*	-3.128**	5.198**	1.568**	0.987**
SKO-205 x SKO-207	-0.610**	-5.383**	-5.299*	1.497**	0.086	1.044**	2.056**
SKO-205 x SKO-208	0.506**	0.053	0.548*	-1.659**	-1.623**	2.324**	3.982**
SKO-205 x SKO-209	0.788**	2.342**	-1.265**	2.958**	0.283	-0.432**	-0.221**
SKO-205 x SKO-210	1.379**	0.901**	1.260**	0.178	4.061**	1.543**	2.445**
SKO-205 x SKO-211	2.340**	-2.391**	-2.540**	-4.742**	5.031**	3.345**	2.045**
SKO-205 x SKO-212	0.955**	0.642**	0.885**	1.931**	1.489**	-0.554**	-1.007**
SKO-205 x SKO-213	0.832**	-2.372**	0.435*	1.036**	-0.114	0.224**	1.788**
SABZAR x SKO-207	0.969**	2.404**	-4.632**	1.733**	-1.181**	2.987**	3.112**
SABZAR x SKO-208	0.125**	0.973**	-0.985**	-0.856**	-1.089**	-3.445**	-2.455**
SABZAR x SKO-209	0.926**	3.229**	-3.199**	-3.649**	-0.583**	1.224**	2.114**
SABZAR x SKO-210	1.317**	4.487**	0.526*	-1.720**	0.694**	1.376**	1.665**
SABZAR x SKO-211	1.135**	-0.305	0.626**	-3.639**	0.602**	-1.234**	-0.556**
SABZAR x SKO-212	1.004**	-3.329**	-2.582**	-0.472**	4.522**	1.879**	2.768**
SABZAR x SKO-213	0.161**	-3.851**	3.401**	1.239**	0.319*	0.980**	1.098**
SKO-207 x SKO-208	-0.942**	-3.498**	1.740**	-0.331	-0.206	3.443**	3.116**
SKO-207 x SKO-209	0.039	0.753**	-0.074	1.186**	0.100	-1.342**	-0.987**
SKO –207 x SKO-210	0.780**	-1.588**	-1.049**	-6.495**	0.777**	1.234**	1.449**
SKO-207 x SKO-211	0.331**	1.120**	-1.102**	-0.114	0.386*	2.231**	2.443**
SKO-207 x SKO-212	-0.753**	1.953**	-3.413**	-7.803**	-0.294	-0.321**	-0.435**
SKO-207 x SKO-213	-0.466**	3.376**	-0.027	1.364**	-0.098	-2.345**	-2.776**
SKO-208 x SKO-209	-0.365**	0.923**	0.773**	-1.670**	-0.108	3.786**	2.980**
SKO-208 x SKO-210	-0.414**	-0.519*	-0.498*	-0.050	3.269**	0.986**	0.994**
SKO-208 x SKO-211	0.187**	-2.011**	-1.102**	1.370**	0.377*	-0.124**	-0.866**
SKO-208 x SKO-212	0.213**	-2.277**	-3.413**	0.941**	-0.697**	-0.008	-0.303**
SKO-208 x SKO-213	-0.430**	0.845**	-0.627**	2.108**	0.094	-1.237**	-2.342**
SKO-209 x SKO-210	-0.572**	-1.263**	-2.115**	-2.634**	-0.425*	0.447**	-1.005**
SKO-209 x SKO-211	0.199**	-2.655**	1.385**	3.278**	0.517**	-0.990**	-1.021**
SKO-209 x SKO-212	-0.796**	1.978**	0.040	2.011**	0.133	-0.248**	-1.225**
SKO-209 x SKO-213	-0.079	0.501*	-0.040	2.658**	-0.100	-0.345**	-1.768**
SKO-210 x SKO-211	-0.280**	0.597**	-1.290**	-5.825**	-2.039**	-4.020**	-3.986**
SKO-210 x SKO-212	0.125*	5.163**	-1.035**	-0.164	-0.719**	-0.704**	-0.342**
SKO-210 x SKO-213	3.412**	0.740**	-2.915**	-3.197**	1.077**	-0.258**	-1.552**
SKO-211 x SKO-212	-0.924**	0.645**	-1.035**	0.369	-0.211	-0.495**	-1.993**
SKO-211 x SKO-213	-0.037	0.367	-0.015	1.425**	-0.114	-0.331**	-1.886**
SKO-212 x SKO-213	4.099**	-3.101**	-0.860**	-3.303**	4.298**	6.469**	4.776**
S. E (sij)	±0.046	±0.197	±0.174	±0.186	±0.151	±0.024	±0.012
S. E (sij –sik)	±0.068	±0.292	±0.255	±0.274	±0.248	±0.041	±0.032
Crosses with desirable SCA effects (No.)	26	21	23	18	15	24	23

Table 4: Best parents and crosses identified on the basis of gca and sca effects for forage quality, green forage yield and dry matter yield in oats (*Avena sativa* L.)

Characters	Parents	Gca	Crosses	sca	gca effect of parents
Crude protein (%)	SKO-213	0.468**	SKO-212 x SKO-213	4.099**	High x High
	SKO-209	0.402**	SKO-210 x SKO-213	3.412**	Average x High
	SKO-208	0.244**	SKO-205 x SKO-211	2.340**	Average x High
NDF (%)	SKO-210	-1.886**	SKO-205 x SKO-207	-0.583**	Low x Low
	SABZAR	-1.807**	SKO-204 x SKO-211	-4.503**	Low x Low
	SKO-208	-0.086**	SKO-204 x SKO-212	-4.437**	Low x High
ADF (%)	SKO-204	-1.262**	SKO-204 x SKO-213	-5.724**	High x Average
	SKO-211	-0.871**	SKO-205 x SABZAR	-4.776**	High x Average
	SKO-212	-0.826**	SABZAR x SKO-207	-4.632**	Average x High
Crude fibre (%)	SKO-208	-1.175**	SKO-207 x SKO-210	-6.495**	High x High
	SKO-210	-1.111**	SKO-205 x SKO-211	-4.742**	Average x High
	SKO-211	-0.492**	SKO-204 x SKO-210	-3.696**	Average x High
Ash content (%)	SKO-207	0.433**	SKO-205 x SABZAR	5.198**	High x Average
	SKO-208	0.424**	SKO-211 x SABZAR	5.031**	Average x Average
	SKO-212	0.364**	SKO-204 x SKO-212	4.561**	Low x High
Green fodder yield	SKO-212	6.883**	SKO-212 x SKO-213	6.469**	High x Average
(q ha^{-1})	SKO-205	3.654**	SKO-204 x SKO-208	4.765**	High x Average
	SKO-204	1.557**	SKO-204 x SKO-211	4.432**	High x High
Dry matter yield	SKO-212	4.221**	SKO-212 x SKO-213	4.776**	High x Average
(q ha^{-1})	SKO-207	2.389**	SKO-205 x SKO-208	3.982**	High x Average
	SKO-204	2.332**	SKO-204 x SKO-211	3.566**	High x High

Heterosis expression

The estimation of heterosis for quality and forage yield would be useful to judge the best hybrid combination for exploitation of superior hybrids. In the present investigation, the magnitude of heterobeltiosis effects (%) for forage quality, green forage yield and dry matter yield varied (Table 5). For crude protein content, crosses SKO-212 x SKO-213, SKO-210 x SKO-213 and SKO-209 x SKO-210 exhibited highly significant positive heterobelitosis values. For NDF, hybrids SKO-205 x SKO-207, SKO-204 x SKO-212 and SKO-205 x SABZAAR showed the highest and desirable values over better parent. For ADF, the crosses SKO-204 x SKO-213, SKO-205 x SKO-207 and SABZAAR x SKO-207 showed significant heterosis over better parent. For crude fibre, the crosses SKO-207 x SKO-210, SKO-212 x SKO-213 and SKO-210 x SKO-211 exhibited highly significant and negative heterobelitosis values. For ash percentage, heterobelitosis was positive for most of the crosses. The crosses SKO-205 x SKO-211, SKO-205 x SABZAAR and SKO-212 x SKO-213 showed highly significant and positive heterosis over better parent. For green fodder and dry matter yield ha^{-1}, the respective ranges for over better parent heterosis were: -17.906% to and SKO-204 x SKO-208 exhibited significantly positive heterobelitosis for green fodder and dry matter yield. It is interesting to note that the majority of crosses showing heterobelitosis and SCA effects for some traits were also among the best performing for the same traits; hence, utilizing heterosis in improving such traits might be rewarding. Furthermore, although quality traits and forage yield are usually reported to be adversely associated (Mohammed and Talib, 2008) some crosses in this study depicted a non adverse association between yield and some quality traits 23.908% and -15.667% to 21.333%. The crosses SKO-212 x SKO-213, SKO-204 x SKO-2011 pointing to the possibility of developing crosses with better yield and quality or these cross combinations need further evaluation in segregating generations to identify desirable transgressive segregants. The results from this study indicate that, by using the correct breeding parents and selection procedures, forage quality and yield can be improved.

Conclusions: Variances due to gca were higher in magnitude than sca for forage quality traits which could be exploited for the improvement of these traits by selection. Preponderance of additive type of gene effects suggested directional selection for isolating better homozygous lines

Table 5: Magnitude of heterosis over better parent (% heterobeltiosis) for forage quality, green forage yield and dry matter yield in oats (*Avena sativa*)

Crosses	Crude protein (%)	NDF (%)	ADF (%)	Crude fibre (%)	Ash content (%)	Green fodder (q ha^{-1})	Dry matter yield (q ha^{-1})
SKO-204 x SKO-205	-2.334**	2.321*	-2.765**	5.33**	-3.004**	5.098**	5.446**
SKO-204 x SABZAR	-5.556**	2.578**	-4.443**	5.57**	0.007	6.880**	5.334**
SKO-204 x SKO-207	3.567**	-2.989**	-0.341	6.44**	-3.889**	11.233**	9.007**
SKO-204 x SKO-208	3.998**	-3.008**	-0.112	-7.22**	4.807**	17.899**	15.678**
SKO-204 x SKO-209	2.978**	-3.045**	5.775**	8.55**	-03.090**	16.775**	-9.002**
SKO-204 x SKO-210	-3.775**	3.678**	5.332**	-7.66**	-6.001**	-14.643**	-13.089**
SKO-204 x SKO-211	3.008**	-6.556**	-4.577**	-8.21**	9.078**	18.467**	14.342**
SKO-204 x SKO-212	-4.908**	-6.867**	-3.221**	5.34**	8.988**	-8.046**	-12.333**
SKO-204 x SKO-213	1.876**	-3.443**	-7.553**	-4.59**	0.045	-8.870**	-6.774**
SKO-205 x SABZAR	6.776**	-6.774**	-6.332*	-7.89**	13.034**	9.003**	6.773**
SKO-205 x SKO-207	-3.089**	-7.443**	-7.367*	4.58**	0.001	10.886**	11.233**
SKO-205 x SKO-208	4.076**	1.236**	2.362**	-4.88**	-5.445**	12.446**	12.332*
SKO-205 x SKO-209	5.664**	4.455**	-3.876**	5.65**	0.020	-6.776**	-7.001**
SKO-205 x SKO-210	5.334**	2.116**	3.559**	0.13	9.040**	9.880**	10.989**
SKO-205 x SKO-211	7.453**	-4.393**	-4.576**	-8.78**	13.980**	14.080**	13.132**
SKO-205 x SKO-212	1.221**	2.665**	2.788**	4.22**	4.556**	-5.556**	-4.908**
SKO-205 x SKO-213	2.643**	-4.255**	2.576**	4.56**	-0.030	6.673**	4.553**
SABZAR x SKO-207	3.997**	4.587**	-6.787**	4.01**	-4.087**	11.212**	10.989**
SABZAR x SKO-208	5.977**	2.006**	-2.344**	-3.91**	-5.067**	-14.334**	-13.432**
SABZAR x SKO-209	3.334**	5.789**	-5.221**	-7.88**	-3.332**	8.009**	9.998**
SABZAR x SKO-210	6.667**	6.543**	2.322*	-4.77**	4.221**	9.012**	8.908**
SABZAR x SKO-211	7.445**	-2.334**	2.978**	-7.85**	3.007**	-10.880**	-9.008**
SABZAR x SKO-212	3.443**	-5.312**	-4.445**	-3.07**	9.889**	9.030**	7.887**
SABZAR x SKO-213	1.997**	-5.745**	5.887**	4.76**	4.005*	5.001**	3.332**
SKO-207 x SKO-208	-3.233**	-5.887**	3.443**	-0.004	-0.304	14.231**	12.890**
SKO-207 x SKO-209	1.001**	2.643**	-0.221	8.347**	0.004	-15.887**	-14.143**
SKO-207 x SKO-210	2.221**	-3.221**	-1.049**	-14.56**	3.114**	8.900**	7.664**
SKO-207 x SKO-211	1.556**	3.665**	-3.775**	-0.22	4.223*	11.070**	9.003**
SKO-207 x SKO-212	-5.665**	3.451**	-5.769**	-10.80**	-0.090	-5.676**	-4.444**
SKO-207 x SKO-213	-3.883**	5.424**	-1.002	4.021**	-0.098	-11.898**	-10.122**
SKO-208 x SKO-209	-0.365**	2.774**	2.331**	-4.44**	-3.009**	4.445**	5.344**
SKO-208 x SKO-210	-7.665**	-2.089**	-2.557**	-0.009	8.885**	5.989**	4.332**
SKO-208 x SKO-211	2.113**	-4.464**	-3.115**	4.08**	3.060*	-6.778**	-5.554**
SKO-208 x SKO-212	1.231**	-4.806**	-5.881**	3.91**	-4.505**	-0.010	-0.033
SKO-208 x SKO-213	-3.332**	2.327**	-2.115**	5.07**	0.102	8.777**	-8.889**
SKO-209 x SKO-210	-6.789**	-3.007**	-4.221**	-5.09**	-3.065**	5.006**	-6.443**
SKO-209 x SKO-211	1.087**	-4.440**	3.334**	7.99**	4.557**	-6.770**	-5.443**
SKO-209 x SKO-212	-3.345**	3.009**	0.002	5.77**	0.990*	-5.225**	-3.324**
SKO-209 x SKO-213	-1.876**	2.655**	-0.223*	5.60**	-0.050	-6.664**	-7.876**
SKO-210 x SKO-211	-3.112**	2.703**	-3.229**	-11.99**	-6.774**	-17.906**	-15.667**
SKO-210 x SKO-212	2.434*	8.060**	-3.677**	-3.01**	-4.558**	-5.778**	-2.334**
SKO-210 x SKO-213	9.341**	2.670**	-4.553**	-7.88**	6.080**	-6.993**	-7.080**
SKO-211 x SKO-212	-3.467**	2.909**	-3.332**	0.006	-0.012	-5.552**	-2.098**
SKO-211 x SKO-213	-1.589**	2.507**	-0.115	4.06**	1.033*	-6.996**	-5.554**
SKO-212 x SKO-213	10.569**	-5.967**	-2.235**	-12.90**	9.998**	23.908**	21.333**
S.E.	0.0981	0.0572	0.0411	0.089	0.0465	0.0778	0.0557
$CD_{0.05}$	0.5476	0.2671	0.3013	0.203	0.1041	0.3445	0.3687

from segregating population for these traits. Exploiting heterosis in forage oats to improve quality traits might be promising. Hybrids low in NDF, ADF and CF percentages appears to be attainable without sacrificing high yield levels.

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