Plant Archives Vol. 25, No. 1, 2025 pp. 2943-2954 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.1.423

ASSESSMENT OF COMBINING ABILITY AND HYBRID PERFORMANCE FOR MORPHOLOGICAL TRAITS IN OATS (*AVENA SATIVA*)

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(Date of Receiving-17-12-2024; Date of Acceptance-09-03-2025)

ABSTRACT

The field experiment was conducted in *Rabi* 2023-24 at Student Instructional Farm, C. S. Azad University of Agriculture and Technology, Kanpur (U.P.) to study morphological characterization of parents and F_1 hybrids and to estimate the combined capacity and hybrid performance in the circulating diallel in F_2 generation of oats. We obtained, highly significant variances for GCA and SCA in respect of all the traits in both the generations indicating the presence of both additive and non-additive genetic effect in the expression of all the characters but was predominant. The ratio of average degree of dominance ($\acute{o}^2s/\acute{o}^2g$) was observed less than the unity for all the traits in both generations of no cut and single cut. The parental line UPO 212 were considered as good general combiners for most of traits in both no and single cut. Diallel analysis of hybrids revealed that the best hybrid combiner is RO-19 x UPO 212 followed by JHO 99-2 x JHO 822, NDO 1 x Kent, JO-1 x UPO 94, JO-1 x JHO-851 in no cut and UPO 94 x UPO 212 followed by JHO 99-2 x JHO 822, JHO 822 x UPO 94, NDO 1 x JHO 822, NDO 1 x RO-19, NDO 1x Kent in single cut were found good specific combiners for grain yield per plant. Therefore, the implementation and use of diallel analysis were efficient in selecting superior parental genotypes and producing hybrids with high yield.

Key words : Additive gene effects, Combining ability, Diallel analysis, GCA, SCA.

Introduction

The common oat (*Avena sativa* L., 2n=6x=42), which belongs to the genus *Avena* and the family Poaceae, is among the most significant dual-purpose cereal crops grown globally for both grain and fodder. Oats are utilized as a green crop, hay, and silage for animal feed, either alone or mixed with other feeds for dairy cattle. In India, the demand for oats is rapidly increasing for products like oatmeal, granola, baby food and breakfast cereals. Oats are generally a low-fat, nutrient-rich food that includes essential components such as threonine, lysine, and methionine (Meydani, 2009). Whole oat grains are an excellent source of minerals, vitamins, fiber, and bioactive compounds, including phytic acid, carotenoids, phenolics, sterols, vitamin B5, and β-glucan (Shweta and Yadav, 2017). Additionally, oats have sufficient soluble carbohydrates, making them ideal for producing quality silage. Oat straw also serves as a good, palatable roughage and an excellent material for bedding. Selecting suitable parents for a hybridization program is essential for developing superior crosses. Relying solely on the parents' *per se* performance often fails to produce satisfactory results. Instead, selecting parents based on their general combining ability (GCA) estimates for economically important traits and genetic diversity has proven to be more effective. Over the past few decades, numerous studies have highlighted the effectiveness of diallel analysis as a method for understanding the genetic inheritance of traits and assessing parental prepotency. This approach is highly efficient for obtaining critical information on parental combinations, their combining ability and the nature and extent of gene action.

Materials and Methods

The present investigation was conducted at Student Instructional Farm, C. S. Azad University of Agriculture and Technology, Kanpur (U.P.) during *Rabi* 2023-24. The material for investigation comprised of 10 genotypes of Oats (*Avena sativa* L.) *viz.*, JHO-851, UPO 212, RO-19, UPO-94, JHO-822, JHO 99-2, Kent, JHO 2004, JO-1 and NDO1. These genotypes were crossed to develop 45 F_1 hybrids in 10 × 10 half diallel design. 100 treatments (10 parents, 45 F_1s and 45 F_2s) were grown in Randomized Block Design (RBD) with three replications. The data on 15 characters *viz.*, days to 50% flowering, days to maturity, plant height, number of tillers per plant, number of leaves per plant, spike length, leaf length, leaf width, leaf: stem ratio, green fodder yield per plant, dry matter yield, biological yield per plant, harvest index, 1000 seed weight, grain yield per plant for no cut and single cut were recorded. The general and specific combining ability variance and their effects will be done according to the procedure by (Griffing, 1956), method II and model I.

Results and Discussion

Analysis of variance for combining ability (Tables 1 and 2) revealed that gca and sca were highly significant for all the characters under study in both F_1 and F_2 generations in no cut and single cut. Thus, indicating difference among parents and their crosses regarding gca and sca effects in both no cut and single cut. This indicated the presence of both additive and non-additive genetic effect in the expression of all the characters but was predominant. The genetic control of traits can generally be inferred from the mean square estimates of gca and specific combining ability sca. In diallel analysis, gca primarily reflects additive genetic effects, though it may also include some dominance effects when gene frequencies deviate from one-half or when parents are included in the variance estimation. On the other hand, the sca is the function of non-additive genetic effects which include dominance and epistatic effects. The gca variance (σ^2g) arises from

Table 1 : Analysis of variance for combining ability in no cut.

Source of variation	df		Days to 50 % flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: Stem ratio	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
GCA	9	F_1	32.46**	12.04**	32.96**	5.39**	9.11**	1.40**	6.61**	0.01**	0.01**	22.58**	34.35**	21.82**	3.96**
		F_2	32.54**	30.04**	6.06**	2.23**	7.11**	3.21**	6.36**	0.01**	0.01**	27.70**	19.33**	27.96**	3.38**
SCA	45	F_1	37.12**	20.48**	14.34**	2.62**	7.15**	4.24**	5.87**	0.01**	0.01**	21.20**	37.07**	18.73**	2.39**
		F_2	25.95**	17.12**	18.91**	2.44**	6.31**	3.56**	4.30**	0.01**	0.01**	28.43**	37.73**	12.21**	3.79**
Error	108	F_1	1.37	0.42	4.01	0.03	0.34	0.62	2.06	0.01	0.01	0.56	0.97	1.23	0.07
		F_2	1.35	0.85	3.87	0.03	0.25	0.65	1.95	0.01	0.01	0.66	0.83	1.31	0.06
σ^2g		F_1	2.59	0.97	2.41	0.45	0.73	0.06	0.38	0.01	0.01	1.83	2.78	1.72	0.32
		F_2	2.60	2.43	0.18	0.18	0.57	0.21	0.37	0.01	0.01	2.25	1.54	2.22	0.28
σ^2s		F_1	35.75	20.06	10.33	2.59	6.82	3.62	3.81	0.01	0.01	20.64	36.11	17.51	2.32
		F_2	24.60	16.27	15.04	2.41	6.06	2.91	2.35	0.02	0.01	27.77	36.90	10.90	3.73
σ^2g/σ^2s		F_1	0.07	0.05	0.23	0.17	0.11	0.02	0.10	0.02	0.09	0.09	0.08	0.10	0.14
		F_2	0.11	0.15	0.01	0.08	0.09	0.07	0.16	0.09	0.10	0.08	0.04	0.20	0.07
(σ^2g/σ^2s)$^{0.5}$		F_1	3.71	4.55	2.07	2.41	3.05	7.47	3.17	6.24	1.13	3.35	3.60	3.19	2.68
		F_2	3.08	2.59	9.08	3.63	3.26	3.70	2.53	3.30	1.32	3.51	4.89	2.21	3.67

*** Significant at 5% probability level** Significant at 1% probability level**
gca = General combining ability; sca = Specific combining ability
δ^2g/δ^2s = Ratio of gca variance to sca variance, $(\delta^2 s/\delta^2 g)^{0.5}$ = Degree of dominance.

Table 2 : Analysis of variance for combining ability of single cut.

Source of variation	df		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: Stem ratio	Green fodder Yield per plamt	Dry matter yield	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
GCA	9	F_1	36.16**	4.07**	16.80*	1.63**	5.80**	5.92**	6.46**	0.01**	0.01**	102.73**	29.11**	15.01**	32.33**	21.68**	1.81**
		F_2	26.81**	11.55**	10.39***	2.00**	10.21**	4.40**	8.10**	0.01**	0.01**	101.33**	16.60**	24.02**	32.19**	27.82**	3.32**
SCA	45	F_1	30.10**	17.51**	23.14**	2.73**	6.32**	3.44**	7.79**	0.01**	0.01**	118.37**	23.45**	11.41**	26.86**	18.70*	2.43**
		F_2	22.77**	23.75**	14.50**	2.14**	5.14**	3.31**	5.15**	0.01**	0.01**	106.93**	20.18**	21.91**	48.94**	12.17**	3.75**
Error	108	F_1	1.36	0.52	3.80	0.05	0.22	0.80	1.67	0.01	0.01	21.30	3.17	0.48	0.85	0.92	0.04
		F_2	1.08	0.30	3.34	0.03	0.16	0.78	1.50	0.01	0.01	22.76	3.48	0.47	0.72	1.00	0.05
δ^2g		F_1	2.90	0.30	1.08	0.13	0.46	0.43	0.40	0.01	0.01	6.79	2.16	1.21	2.62	1.73	0.15
		F_2	2.14	0.94	0.59	0.16	0.84	0.30	0.55	0.01	0.01	6.55	1.09	1.96	2.62	2.24	0.27
δ^2s		F_1	28.74	16.99	19.34	2.67	6.10	2.64	6.12	0.01	0.01	97.06	20.29	10.93	26.01	17.78	2.38
		F_2	21.69	23.45	11.17	2.11	4.98	2.53	3.64	0.01	0.01	84.18	16.70	21.44	48.21	11.17	3.71
δ^2g/ δ^2s		F_1	0.10	0.02	0.06	0.05	0.08	0.16	0.07	0.03	0.08	0.07	0.11	0.11	0.10	0.10	0.06
		F_2	0.10	0.04	0.05	0.08	0.17	0.12	0.15	0.05	0.09	0.08	0.07	0.09	0.05	0.20	0.07
(δ^2g/ δ^2s)$^{0.5}$		F_1	3.15	7.58	4.23	4.52	3.62	2.49	3.91	5.66	1.13	3.78	3.06	3.00	3.15	3.21	4.03
		F_2	3.18	5.00	4.36	3.59	2.44	2.90	2.57	4.51	1.13	3.59	3.91	3.31	4.29	2.24	3.69

*** Significant at 5% probability level** Significant at 1% probability level**
gca = General combining ability; sca = Specific combining ability
δ^2g/δ^2s = Ratio of gca variance to sca variance, (δ^2s/δ^2g)$^{0.5}$ = Degree of dominance.

differences in the gca effects of parents while the sca variance (σ^2s) arises from differences in sca effects of crosses. The gca variance corresponds to the variance of the breeding value i.e. additive genetic variance (σ^2a) and sca variance corresponds to mainly dominance variance i.e. non-additive genetic variance (σ^2D). The ratio of σ^2g and σ^2s provides information regarding the relative importance of additive or non-additive genetic variances. If the value is equal to unity, it suggests the importance of both additive and non-additive genetic variances. The ratio of average degree of dominance (σ^2s/σ^2g) was observed less than the unity indicated a predominant role of non-additive gene action for all the traits in both F_1 and F_2 generation of no cut and single cut. Average degree of dominance (σ^2s/σ^2g)$^{0.5}$ revealed preponderance of over-dominance for all the traits in both F_1 and F_2 generations under no cut and single cut. The results were in general agreement with that of Bind *et al.* (2017), Kapoor and Singh (2017), Maying *et al.* (2018), Al-Juhaishi *et al.* (2020), Rana *et al.* (2022).

The magnitude and direction of combining ability effects provide guidelines for selecting parents and their utilization. An overall perusal of the parents for general combining ability effects (Tables 3 and 4) revealed UPO 212 was good general combiners for most of the traits under study in both no and single cut. However, none of the parents was a good combiner simultaneously for all the characters studied. For grain yield per plant, UPO 212, Kent and JHO 822 under no cut; JHO 822, NDO 1 and UPO 212 under single cut in both generations. NDO 1 and JHO 2004 were found best general combiner green fodder yield per plant. Similar findings of gca effect were also reported by Bind *et al.* (2017), Chauhan *et al.* (2019), Al-Juhaishi *et al.* (2020), Atar Singh *et al.* (2020), Rana *et al.* (2022).

The study of sca effects in no cut and single cut (Tables 5 & 6) revealed

Table 3 : Estimates of general combining ability effects in no cut for 13 traits in Oats (*Avena sativa*).

S. no.	Parents		Days to 50 % flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
1	NDO 1	F_1	-1.47**	-0.36*	3.31**	-0.20**	1.59**	0.10	0.08	-0.01	0.29	-0.26	0.44	-0.01
		F_2	-0.66*	1.54**	0.89	-0.42**	0.08	0.39	0.29	-0.04**	0.32	-1.71**	-1.86**	-0.45**
2	JO 1	F_1	1.11**	-1.03**	-0.90	-0.39**	-0.53**	-0.44*	1.08**	0.05**	-1.86**	0.69*	1.03**	-0.40**
		F_2	-1.47**	-0.35	-1.01	-0.27**	0.26	-0.57*	0.19	-0.01	-2.44 **	1.37 **	1.47 **	-0.26**
3	JHO 2004	F_1	-1.42**	1.86**	0.57	0.94**	-0.79**	-0.53*	-0.79*	0.01	1.93**	-0.63*	-1.62**	0.32**
		F_2	-2.74**	-0.04	0.44	0.28**	-0.94**	0.24	-0.25	-0.02*	1.03**	-0.96**	-0.12	0.01
4	Kent	F_1	3.64**	0.75**	1.05	0.72**	-0.27	0.31	0.44	-0.01	0.39	1.91**	0.76*	0.65**
		F_2	0.62	0.15	-0.06	0.04	-0.03	-0.05	0.31	0.04 **	0.50 *	0.23	0.79 *	0.25 **
5	JHO 99-2	F_1	-1.06**	-0.89**	-1.68**	-0.67**	0.57**	-0.10	-1.12**	-0.01	-0.18	-3.01**	-0.94**	-0.94**
		F_2	-0.11	-2.74**	-0.72	-0.46 **	0.71 **	-0.34	-1.10 **	0.03 **	-0.90**	-0.27	-2.25 **	-0.38 **
6	JHO 822	F_1	-0.03	0.33	1.62**	0.47**	-0.28	0.37	0.33	0.01	0.05	2.14**	-1.26**	0.64**
		F_2	2.23**	0.21	-0.01	0.38 **	-0.27 *	0.60 **	0.12	-0.01	-0.02	2.21 **	-1.32 **	0.56 **
7	UPO 94	F_1	-1.69**	-1.17**	-1.00	-0.23**	0.20	0.12	0.17	0.01	-1.76**	1.61**	-1.55**	-0.03
		F_2	0.01	0.26	0.66	-0.24 **	0.24	-0.98 **	0.20	0.01	0.85 **	-1.81 **	0.04	-0.30 **
8	RO-19	F_1	0.39	0.81**	-1.60**	-0.79**	1.18**	-0.36	-0.65	-0.03*	-0.54**	-2.21**	1.08**	-0.71**
		F_2	2.81**	0.32	-0.10	-0.35**	0.16	0.59 **	-0.71	0.02	-1.71 **	0.07 ns	2.36 **	-0.51 **
9	UPO 212	F_1	1.11**	-0.81**	0.19	0.81**	-0.61**	0.10	0.96*	0.01	2.37**	-0.09	2.40**	0.67**
		F_2	0.28	-2.13 **	-0.93	0.15 **	1.26 **	-0.15	1.54 **	0.02	-0.56 *	0.16	1.43 **	-0.09
10	JHO 851	F_1	-0.58	0.50**	-1.57**	-0.66**	-1.06**	0.41	-0.50	-0.02 *	-0.71**	-0.16	-0.36	-0.19*
		F_2	-0.97 **	2.79 **	0.84 ns	0.89 **	-1.46 **	0.27	-0.59	-0.05 **	2.93**	0.70 **	-0.54	1.18 **
	SE (gca)	F_{-1}	0.32	0.178	0.548	0.049	0.159	0.216	0.393	0.012	0.205	0.269	0.303	0.075
		F_2	0.318	0.252	0.539	0.047	0.136	0.221	0.383	0.012	0.222	0.250	0.313	0.067
	SE (g_i-g_j)	F_1	0.477	0.266	0.817	0.073	0.237	0.322	0.586	0.017	0.306	0.401	0.452	0.112
		F_2	0.474	0.376	0.803	0.070	0.203	0.329	0.571	0.017	0.331	0.372	0.467	0.100

* Significant at 5% probability level** Significant at 1% probability level.

Table 4 : Estimates of general combining ability effects in single cut for 15 traits in Oats (*Avena sativa*).

S. No	Parents		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf : Stem ratio	Green fodder yield per plant	Dry matter yield	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
1	NDO 1	F_1	-1.30**	0.37	1.62**	0.11	0.54 **	0.73 **	0.38	0.01	-0.01**	3.68**	0.72	-0.26	0.17	0.45	0.38 **
		F_2	-1.30**	0.37	1.62**	0.11	0.54 **	0.73 **	0.38	0.01	0.01**	3.68**	0.72	-0.26	0.17	0.45	0.38 **
2	JO 1	F_1	1.28**	-0.38	-0.59	-0.43 **	-1.01 **	-0.33	0.10	0.03 **	0.01**	-0.77	1.43**	-0.09	-0.77 **	1.03**	-0.18 **
		F_2	1.28**	-0.38	-0.59	-0.43 **	-1.01 **	-0.33	0.10	0.03 **	-0.01**	-0.77	1.43**	-0.09	-0.77 **	1.03**	-0.18 **
3	JHO 2004	F_1	-1.24**	0.54**	-0.44	-0.22 **	-0.05	-0.29	-0.61	0.01	0.01**	3.05 *	2.29**	1.09 **	0.17	-1.61**	0.01
		F_2	-1.24**	0.54**	-0.44	-0.22 **	-0.05	-0.29	-0.61	0.01	0.01	3.05 *	2.29**	1.09 **	0.17	-1.61**	0.01
4	Kent	F_1	3.81**	-0.46*	-0.58	0.30 **	0.75 **	0.07	-0.54	0.02*	0.01	-2.41	1.31**	0.65 **	1.01 **	0.77**	-0.08
		F_2	3.81**	-0.46*	-0.58	0.30 **	0.75 **	0.07	-0.54	0.02*	0.01	-2.41	1.31**	0.65 **	1.01 **	0.77**	-0.08
5	JHO 99-2	F_1	-0.88**	-0.63**	-2.13**	-0.52 **	-0.69 **	-0.27	0.20	-0.02	0.01**	-1.61	0.21	-0.14	-3.76 **	-0.94**	-0.67**
		F_2	-0.88**	-0.63**	-2.13**	-0.52 **	-0.69 **	-0.27	0.20	-0.02	-0.01**	-1.61	0.21	-0.14	-3.76 **	-0.94**	-0.67**
6	JHO 822	F_1	-1.58**	-0.07	1.69**	0.36**	0.41 **	1.66 **	0.63	0.00	-0.04**	-5.89 **	0.22	-0.61 **	2.39 **	-1.25**	0.69**
		F_2	-1.58**	-0.07	1.69**	0.36**	0.41 **	1.66 **	0.63	0.00	0.06**	-5.89 **	0.22	-0.61 **	2.39 **	-1.25**	0.69**
7	UPO 94	F_1	-1.52**	0.34	0.18	0.07	-1.04 **	-0.07	0.37	0.01	-0.04**	2.33	-0.58	-0.50 **	0.91**	-1.55**	-0.04
		F_2	-1.52**	0.34	0.18	0.07	-1.04 **	-0.07	0.37	0.01	-0.02	2.33	-0.58	-0.50 **	0.91**	-1.55**	-0.04
8	RO-19	F_1	0.56	0.26	-0.94	-0.42**	0.18	-0.72 **	-1.40**	-0.02*	-0.01	0.64	-2.40**	-1.38 **	-0.89 **	1.09**	-0.41**
		F_2	0.56	0.26	-0.94	-0.42**	0.18	-0.72 **	-1.40**	-0.02*	-0.01**	0.64	-2.40**	-1.38 **	-0.89 **	1.09**	-0.41**
9	UPO 212	F_1	1.28**	-0.91**	0.76	0.30**	0.85 **	-0.58 *	1.18**	-0.02	0.01	-0.97	-2.33**	2.39 **	-0.24	2.38 **	0.25**
		F_2	1.28**	-0.91**	0.76	0.30**	0.85 **	-0.58 *	1.18**	-0.02	0.01**	-0.97	-2.33**	2.39 **	-0.24	2.38 **	0.25**
10	JHO 851	F_1	-0.41	0.93**	0.44	0.46**	0.07	-0.20	-0.32	-0.01	-0.01	1.94	-0.87	-1.16 **	1.03 **	-0.36	0.05
		F_2	-0.41	0.93**	0.44	0.46**	0.07	-0.20	-0.32	-0.01	0.01**	1.94	-0.87	-1.16 **	1.03 **	-0.36	0.05
	SE (gca)	F_{-1}	0.32	0.20	0.53	0.06	0.13	0.25	0.35	0.01	0.03	1.26	0.49	0.19	0.25	0.26	0.06
		F_2	0.32	0.20	0.53	0.06	0.13	0.25	0.35	0.01	0.01	1.26	0.49	0.19	0.25	0.26	0.06
	SE (g_i-g_j)	F_1	0.48	0.29	0.80	0.09	0.19	0.37	0.53	0.02	0.01	1.88	0.73	0.28	0.38	0.39	0.08
		F_2	0.42	0.22	0.75	0.08	0.16	0.36	0.50	0.02	0.02	1.95	0.76	0.28	0.35	0.41	0.09

* Significant at 5% probability level** Significant at 1% probability level.

Table 5 : Estimates of specific combining ability effects in no cut for 13 traits in Oats (*Avena sativa*).

S. no.	Hybrids	Days to 50% flowering		Days to maturity		Plant height		No. of tillers per plant	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
1.	NDO 1 x JO-1	2.79 **	-2.84 **	-5.34 **	4.46 **	-3.45 **	-1.72*	0.71 **	0.57 **
2.	NDO 1 x JHO 2004	-0.02	3.11 **	0.44	-0.18	-1.62 *	-2.71**	1.29 **	0.92 **
3.	NDO 1 x Kent	-0.74	-3.59 **	-3.45 **	-5.71 **	2.74 **	-6.96**	1.81 **	-1.94 **
4.	NDO 1 x JHO 99-2	-4.71 **	7.14 **	3.52 **	1.52 **	-3.42 **	1.18	-0.70 **	1.66 **
5.	NDO 1 x JHO 822	-2.08 **	-3.86 **	0.97 **	0.90 **	5.97 **	-3.52**	2.35 **	-0.08
6.	NDO 1 x UPO 94	-4.74 **	-7.97 **	-3.20 **	4.52 **	-5.21 **	-0.52	-1.05 **	0.33 **
7.	NDO 1 x RO-19	-0.83	2.22 **	-2.51 **	-1.54 **	-6.15 **	4.26 **	-1.68 **	2.14 **
8.	NDO 1 x UPO 212	3.45 **	2.75 **	4.11 **	2.24 **	-4.29 **	-6.99**	-1.28 **	-1.05 **
9.	NDO 1 x JHO 851	1.48 **	4.33 **	-3.20 **	-4.01 **	-0.62	-6.24**	1.49 **	-1.59 **
10.	JO-1 x JHO 2004	1.06 *	-6.42 **	-0.56 *	5.38 **	1.07	1.70 *	0.50 **	-0.33 **
11.	JO-1 x Kent	5.34 **	3.55 **	-3.12 **	-2.82 **	0.67	1.14	0.79 **	1.51 **
12.	JO-1 x JHO 99-2	6.04 **	-1.72 **	1.19 **	0.40	-1.19	0.37	-0.82 **	0.61 **
13.	JO-1 x JHO822	-2.33 **	-9.06 **	8.63 **	-5.54 **	-1.57 *	-1.06	-1.53 **	-0.83 **
14.	JO-1 x UPO94	-9.33 **	8.16 **	-1.53 **	-0.60	2.84 **	3.17 **	1.67 **	2.18 **
15.	JO-1 x RO-19	-3.74 **	4.36 **	-1.84 **	0.35	2.43 **	1.49 *	0.31 **	-1.01 **
16.	JO-1 x UPO 212	0.20	0.89 *	-1.56 **	-0.54	-2.23 **	-4.92 **	-0.29 **	-1.70 **
17.	JO-1 x JHO-851	-2.44 **	-6.20 **	0.80 **	1.54 **	3.52 **	4.03 **	1.87 **	1.56 **
18.	JHO 2004 x Kent	-1.80 **	2.50 **	-5.34 **	-2.12 **	0.58	-5.55 **	0.76 **	-2.84 **
19.	JHO 2004 x JHO 99-2	0.23	1.89 **	-0.37	4.10 **	0.11	1.00	0.35 **	1.36 **
20.	JHO 2004 x JHO 822	-7.13 **	-1.45 **	-3.59 **	-1.85 **	-0.14	-3.89 **	1.11 **	-0.68 **
21.	JHO 2004 x UPO 94	1.87 **	-5.89 **	9.24 **	-5.57 **	-2.75 **	0.65	-0.69 **	0.33 **
22.	JHO 2004 x RO-19	4.79 **	4.64 **	-2.06 **	-3.96 **	0.43	-4.48 **	2.08 **	-1.86 **
23.	JHO 2004 x UPO 212	-5.60 **	1.16 **	0.55 *	-1.51 **	-4.87 **	4.44 **	-3.42 **	0.75 **
24.	JHO 2004 x JHO-851	5.42 **	-2.59 **	-4.76 **	-5.10 **	5.19 **	8.81 **	1.74 **	2.31 **
25.	Kent x JHO 99-2	-4.16 **	-2.81 **	-3.26 **	-4.10 **	-0.81	-2.65 **	-0.33 **	-1.00 **
26.	Kent x JHO 822	-11.19 **	-3.47 **	-2.14 **	1.29 **	-2.43 **	1.12	-1.37 **	-0.04
27.	Kent x UPO 94	-1.52 **	0.41	7.36 **	2.90 **	-0.90	6.00 **	1.03 **	1.58 **
28.	Kent x RO-19	-6.27 **	-11.39 **	-1.95 **	-4.15 **	-1.96 **	-0.12	-1.20 **	0.98 **
29.	Kent x UPO 212	10.01 **	0.47	0.99 **	-5.37 **	5.69 **	4.47 **	2.40 **	-1.51 **
30.	Kent x JHO-851	0.70	-3.95 **	-6.64 **	3.38 **	0.34	4.55 **	-1.64 **	1.65 **
31.	JHO 99-2 x JHO-822	0.84	0.25	-0.17	4.85 **	5.79 **	-1.17	2.42 **	-2.34 **
32.	JHO 99-2 x UPO 94	-4.49 **	1.47 **	1.99 **	-2.21 **	-0.61	-1.48 *	1.22 **	-1.62 **
33.	JHO 99-2 x RO-19	-0.58	-4.67 **	8.69 **	-1.60 **	-6.10 **	2.60 **	-1.21 **	2.18 **
34.	JHO 99-2 x UPO 212	8.37 **	1.53 **	-2.37 **	-0.82 *	0.83	-3.50 **	-0.41 **	-2.11 **
35.	JHO 99-2 x JHO-851	-1.94 **	3.78 **	-0.67 **	2.27 **	-3.08 **	1.52 *	-1.24 **	0.25 **
36.	JHO-822 x UPO 94	6.15 **	-2.20 **	-2.89 **	3.18 **	-1.78 *	-1.69 *	1.27 **	0.73 **
37.	JHO-822 x RO-19	-11.27 **	3.33 **	-2.87 **	-2.87 **	-4.31 **	-4.41 **	-1.36 **	-2.16 **
38.	JHO-822 x UPO 212	-4.33 **	-7.81 **	-3.26 **	0.90 **	-4.70 **	4.36 **	-2.16 **	2.05 **
39.	JHO-822 x JHO-851	-6.30 **	-0.89 *	-2.56 **	-6.01 **	-4.03 **	-0.94	-2.09 **	0.51 **
40.	UPO 94 x RO-19	-1.60 **	0.89 *	-1.03 **	6.07 **	-1.55 *	-0.32	-0.96 **	0.76 **
41.	UPO 94 x UPO 212	-6.33 **	3.75 **	-4.09 **	4.52 **	2.66 **	-0.12	0.74 **	-1.13 **
42.	UPO 94 x JHO-851	9.70 **	1.33 **	-5.73 **	-3.73 **	3.49 **	-0.37	0.01	-1.07 **
43.	RO-19 x UPO 212	6.59 **	-1.06 *	0.61 *	-0.87 *	3.99 **	-5.96**	3.31 **	-1.42 **
44.	RO-19 x JHO-851	2.29 **	4.19 **	-0.37	6.54 **	-2.27 **	-0.01	-1.12 **	-0.77 **
45.	UPO 212 x JHO-851	-6.10 **	4.72 **	-0.09	-5.68 **	-0.13	3.21 **	-1.12 **	0.14 *
	S_{ij}	1.08	1.07	0.60	0.85	1.84	1.81	0.16	0.16
	$S_{ij}-S_{ik}$	0.43	0.43	0.24	0.34	0.74	0.73	0.07	0.06
	$S_{ij}-S_{kl}$	1.58	1.57	0.88	1.25	2.71	2.66	0.24	0.23

Table 5 continued....

S. no.	Hybrids	No. of leaves per plant		Spike length		Leaf length		Leaf width	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
1.	NDO 1 x JO-1	1.09 **	-2.18 **	-0.77**	2.10**	-1.07 *	-0.15	0.08 **	-0.07 **
2.	NDO 1 x JHO 2004	1.95 **	0.25	3.29 **	0.53	-0.86	1.93 **	0.22 **	0.11 **
3.	NDO 1 x Kent	0.66 **	2.51 **	-4.08**	-2.55 **	-3.49 **	-2.00 **	-0.08 **	-0.02
4.	NDO 1 x JHO 99-2	-2.81 **	-2.83 **	-1.13 **	1.41 **	3.73**	3.77 **	-0.02	-0.09 **
5.	NDO 1 x JHO 822	2.64 **	-1.25 **	2.58**	1.30**	-0.35	-1.31 *	0.06 **	0.09 **
6.	NDO 1 x UPO 94	-3.68 **	-0.43 *	1.03 **	-0.62 *	-2.22 **	-3.69 **	0.22 **	0.12 **
7.	NDO 1 x RO-19	0.42	-1.35 **	-0.94 **	0.94 **	4.10 **	2.59 **	-0.11 **	0.03
8.	NDO 1 x UPO 212	0.00	0.76 **	0.85 **	-1.28 **	1.43 **	-3.29 **	-0.12 **	-0.05 **
9.	NDO 1 x JHO 851	2.59 **	-1.43 **	-1.28 **	-0.90 **	-0.68	0.44	0.01	-0.03 *
10.	JO-1 x JHO 2004	1.54 **	0.63 **	0.81 **	-4.35 **	-1.19*	-3.18 **	-0.06 **	0.04 **
11.	JO-1 x Kent	1.96 **	-0.58 **	2.32 **	-2.16 **	2.01 **	0.79	0.05 **	-0.15 **
12.	JO-1 x JHO 99-2	-2.65 **	-0.45 *	0.27	0.23	0.37	2.46**	-0.14**	-0.02
13.	JO-1 x JHO822	4.47 **	2.76 **	-1.18 **	0.82 **	1.52 **	-2.15**	0.12**	-0.04 **
14.	JO-1 x UPO94	0.32	-2.55 **	2.35 **	-0.81 **	1.14 *	1.93**	-0.09**	0.07 **
15.	JO-1 x RO-19	-5.46 **	2.13 **	0.92**	3.89 **	5.57**	-0.42	-0.17 **	-0.07 **
16.	JO-1 x UPO 212	0.33	2.16 **	-2.90 **	-0.16	-1.57 **	-0.30	0.04*	-0.19 **
17.	JO-1 x JHO-851	-1.19 **	-1.05 **	-1.04 **	0.95 **	-5.05**	-3.94 **	-0.01	0.03
18.	JHO 2004 x Kent	2.71 **	3.06 **	0.98 **	2.50 **	-0.75	-0.53	-0.07 **	0.20 **
19.	JHO 2004 x JHO 99-2	-0.46 *	-1.45 **	0.59 *	-1.08 **	1.77 **	-2.42 **	-0.08**	-0.16 **
20.	JHO 2004 x JHO 822	-3.54 **	-2.17 **	-0.84 **	0.38	2.29 **	3.24 **	0.09**	-0.08 **
21.	JHO 2004 x UPO 94	0.48 *	0.06	-1.20 **	1.06 **	1.02	0.18	-0.05 **	-0.07 **
22.	JHO 2004 x RO-19	3.80 **	-1.97 **	-3.25 **	-0.88 **	-1.76 **	-2.11 **	-0.04 **	-0.02
23.	JHO 2004 x UPO 212	1.48 **	3.04 **	-2.31 **	-0.07	-0.40	0.88	0.05 **	-0.05 **
24.	JHO 2004 x JHO-851	-1.07 **	2.09 **	-1.84 **	1.42 **	-0.61	0.51	0.05 **	-0.05 **
25.	Kent x JHO 99-2	-2.14 **	-1.12 **	2.47 **	1.38 **	-0.73	-1.81 **	-0.12 **	0.03 *
26.	Kent x JHO 822	2.24 **	-0.54 **	-2.84 **	-2.60 **	1.03	1.00	0.01	-0.04 *
27.	Kent x UPO 94	-1.04 **	0.28	-3.47 **	0.78 **	-1.05 *	-0.08	0.07 **	-0.13 **
28.	Kent x RO-19	4.88 **	-0.55 **	1.34 **	1.45 **	-1.76 **	-0.24	-0.09 **	-0.03
29.	Kent x UPO 212	-0.74 **	2.70 **	-1.68 **	-0.87 **	-0.06	1.25 *	0.01	0.04 **
30.	Kent x JHO-851	-2.38 **	-1.41 **	1.94 **	-2.19 **	4.62 **	-2.19 **	0.00	0.03 *
31.	JHO 99-2 x JHO-822	2.43 **	1.45 **	-1.50 **	-1.44 **	2.25 **	-1.79 **	0.00	0.00
32.	JHO 99-2 x UPO 94	-1.48 **	-1.02 **	0.91 **	-0.83 **	1.84 **	0.55	-0.09 **	-0.07 **
33.	JHO 99-2 x RO-19	-0.16	-3.62 **	-0.85 **	-3.23 **	1.10 *	1.94 **	0.22 **	0.10 **
34.	JHO 99-2 x UPO 212	1.23 **	2.73 **	0.93 **	0.21	-2.11 **	1.49 **	-0.03 *	-0.05 **
35.	JHO 99-2 x JHO-851	0.38	-1.52 **	-1.39 **	2.90 **	-2.05 **	-1.11 *	0.07 **	0.19 **
36.	JHO-822 x UPO 94	0.67 **	-3.45 **	0.44	-2.31 **	1.49 **	1.04 *	-0.04 *	0.20 **
37.	JHO-822 x RO-19	0.72 **	-0.61 **	-0.32	1.33 **	-2.82 **	-0.75	-0.04 *	-0.04 *
38.	JHO-822 x UPO 212	-0.71 **	3.57 **	-2.43 **	1.57 **	-2.46 **	0.77	-0.15 **	0.09 **
39.	JHO-822 x JHO-851	-1.67 **	4.79 **	3.44 **	-0.55	2.26 **	1.14 *	0.19 **	-0.04 *
40.	UPO 94 x RO-19	-3.76 **	0.65 **	3.14 **	0.50	0.11	1.04 *	0.04 *	-0.02
41.	UPO 94 x UPO 212	3.35 **	-2.24 **	1.81 **	-0.05	2.53 **	-3.48 **	-0.13 **	-0.08 **
42.	UPO 94 x JHO-851	-1.39 **	-0.42 *	-1.37 **	1.73 **	-1.84 **	2.52 **	0.08 **	-0.04 *
43.	RO-19 x UPO 212	-1.38 **	1.64 **	-2.07 **	-2.32 **	-1.87 **	-0.57	-0.06 **	-0.14 **
44.	RO-19 x JHO-851	3.27 **	-0.78 **	-0.68 *	-0.34	3.88 **	1.70 **	-0.04 *	0.05 **
45.	UPO 212 x JHO-851	3.65 **	-2.44 **	1.82 **	-3.79 **	0.28	-1.78 **	-0.08 **	0.01
	S_{ij}	0.54	0.46	0.73	0.74	1.32	1.29	0.04	0.04
	$S_{ij}-S_{ik}$	0.22	0.18	0.29	0.30	0.53	0.52	0.02	0.02
	$S_{ij}-S_{kl}$	0.79	0.67	1.07	1.09	1.94	1.89	0.06	0.06

Table 5 continued....

Table 5 continued....

S. no.	Hybrids	Biological yield per plant		Harvest Index		1000 seed weight		Grain yield per plant	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
1.	NDO 1 x JO-1	-2.31 **	-1.22 **	5.33 **	-1.41 **	1.51 **	1.67 **	0.56 **	-0.60 **
2.	NDO 1 x JHO 2004	5.63 **	-5.67 **	-1.84 **	9.54 **	2.17 **	-2.90 **	1.46 **	0.84 **
3.	NDO 1 x Kent	3.11 **	-4.93 **	3.61 **	-1.83 **	7.04 **	3.46 **	2.37 **	-1.70 **
4.	NDO 1 x JHO 99-2	-7.81 **	9.66 **	11.54 **	-0.22	2.14 **	0.02	0.09	2.73 **
5.	NDO 1 x JHO 822	2.98 **	3.16 **	3.01 **	-3.56 **	-2.65 **	6.91 **	2.07 **	0.08
6.	NDO 1 x UPO 94	-0.98 **	5.25 **	-1.29 **	-5.46 **	-1.70 **	-2.11 **	-0.66 **	-0.26 **
7.	NDO 1 x RO-19	5.39 **	0.30	-7.85 **	9.79 **	4.27 **	-2.63 **	-0.70 **	2.75 **
8.	NDO 1 x UPO 212	-7.58 **	-7.16 **	4.15 **	5.22 **	3.83 **	0.54	-1.34 **	-0.86 **
9.	NDO 1 x JHO 851	-0.03	-0.64 *	1.31 **	-8.49 **	-2.11 **	-0.24	0.42 **	-2.63 **
10.	JO-1 x JHO 2004	-5.21 **	1.67 **	6.48 **	-3.54 **	3.88 **	3.76 **	-0.11	-0.45 **
11.	JO-1 x Kent	-1.98 **	-1.27 **	6.88 **	6.96 **	2.12 **	-3.17 **	0.88 **	1.11 **
12.	JO-1 x JHO 99-2	-1.32 **	1.51 **	-0.04	2.64 **	-4.96 **	-4.08 **	-0.18	1.14 **
13.	JO-1 x JHO822	-1.29 **	-2.29 **	0.44	-2.78 **	-6.49 **	-6.13 **	-0.33 **	-1.41 **
14.	JO-1 x UPO94	3.57 **	6.72 **	4.48 **	3.67 **	1.45 **	4.62 **	2.34 **	3.16 **
15.	JO-1 x RO-19	2.26 **	-4.84 **	1.51 **	2.98 **	0.62	-0.64	1.16 **	-0.94 **
16.	JO-1 x UPO 212	8.29 **	-4.98 **	-11.70 **	2.85 **	-6.43 **	-5.37 **	-1.13 **	-1.05 **
17.	JO-1 x JHO-851	1.70 **	6.33 **	6.63 **	2.79 **	-1.70 **	0.54	2.20 **	2.80 **
18.	JHO 2004 x Kent	-0.56 *	-5.77 **	2.94 **	-4.42 **	0.78	-1.60 **	0.94 **	-2.55 **
19.	JHO 2004 x JHO 99-2	4.47 **	-3.94 **	-5.12 **	8.67 **	8.12 **	0.57	-0.05	1.08 **
20.	JHO 2004 x JHO 822	-5.38 **	4.89 **	8.28 **	-10.82 **	-1.20 **	1.61 **	0.27 **	-1.87 **
21.	JHO 2004 x UPO 94	-0.84 **	-2.86 **	-2.07 **	1.92 **	-0.85 *	-0.76	-0.66 **	-0.14
22.	JHO 2004 x RO-19	2.57 **	-1.75 **	2.18 **	-8.11 **	-6.59 **	6.08 **	1.60 **	-2.30 **
23.	JHO 2004 x UPO 212	-8.11 **	-2.37 **	2.91 **	11.06 **	-1.84 **	-2.67 **	-1.61 **	2.19 **
24.	JHO 2004 x JHO-851	-0.95 **	4.08 **	5.75 **	5.32 **	-4.94 **	0.88 *	1.44 **	3.01 **
25.	Kent x JHO 99-2	-2.28 **	1.66 **	2.17 **	-4.74 **	4.14 **	3.27 **	0.00	-0.87 **
26.	Kent x JHO 822	3.56 **	-2.51 **	-8.88 **	1.37 **	-5.46 **	1.71 **	-1.30 **	-0.31 **
27.	Kent x UPO 94	1.45 **	7.06 **	0.56	2.14 **	-0.36	-3.71 **	0.62 **	2.74 **
28.	Kent x RO-19	-5.67 **	8.07 **	1.91 **	-6.71 **	-9.20 **	-1.95 **	-1.42 **	0.18 *
29.	Kent x UPO 212	11.35 **	-1.40 **	-6.09 **	-5.69 **	2.04 **	2.63 **	1.77 **	-1.83 **
30.	Kent x JHO-851	-3.09 **	5.66 **	2.34 **	3.02 **	-1.27 **	-1.27 **	-0.62 **	2.70 **
31.	JHO 99-2 x JHO-822	9.25 **	-8.56 **	-0.98 **	0.68 *	0.12	2.73 **	2.81 **	-2.45 **
32.	JHO 99-2 x UPO 94	-3.10 **	-6.26 **	5.38 **	3.28 **	3.20 **	6.54 **	0.31 **	-0.92 **
33.	JHO 99-2 x RO-19	-0.62 *	3.80 **	-3.39 **	8.21 **	-1.35 **	-1.03 *	-0.84 **	3.51 **
34.	JHO 99-2 x UPO 212	-5.47 **	-5.95 **	6.27 **	-6.64 **	1.08 **	-5.03 **	0.02	-2.93 **
35.	JHO 99-2 x JHO-851	-2.59 **	-4.01 **	-0.98 **	5.32 **	0.27	3.99 **	-0.83 **	0.10
36.	JHO-822 x UPO 94	1.69 **	7.57 **	6.26 **	-3.67 **	6.56 **	0.53	2.18 **	1.13 **
37.	JHO-822 x RO-19	-0.38	-0.97 **	-5.09 **	-3.10 **	5.99 **	2.31 **	-1.42 **	-0.96 **
38.	JHO-822 x UPO 212	-4.54 **	3.56 **	-2.03 **	6.30 **	3.15 **	-2.85 **	-1.93 **	3.03 **
39.	JHO-822 x JHO-851	-1.36 **	-0.33	-5.04 **	3.20 **	4.53 **	-3.07 **	-1.75 **	0.85 **
40.	UPO 94 x RO-19	-5.19 **	-6.34 **	6.86 **	8.89 **	-3.61 **	-2.21 **	-0.42 **	0.20 *
41.	UPO 94 x UPO 212	2.14 **	5.82 **	3.53 **	-9.62 **	-4.97 **	2.11 **	1.90 **	-1.41 **
42.	UPO 94 x JHO-851	3.67 **	-3.86 **	-4.69 **	-4.38 **	-1.84 **	-1.29 **	-0.17	-2.29 **
43.	RO-19 x UPO 212	0.48	-5.61 **	9.28 **	-2.06 **	-0.51	2.32 **	2.96 **	-2.01 **
44.	RO-19 x JHO-851	0.85 **	2.61 **	-4.13 **	-8.10 **	2.61 **	-5.49 **	-0.82 **	-1.68 **
45.	UPO 212 x JHO-851	-4.71 **	-1.55 **	2.30 **	-0.37	-0.93 *	-0.68	-0.89 **	-0.59 **
	Sij	0.69	0.75	0.91	0.84	1.02	1.05	0.25	0.23
	Sij-Sik	0.28	0.30	0.36	0.34	0.41	0.42	0.10	0.09
	Sij-Skl	1.01	1.10	1.33	1.23	1.50	1.55	0.37	0.33

Table 6 : Estimates of specific combining ability effects in single cut for 15 traits in Oats (*Avena sativa*).

S. no.	Hybrids	Days to 50% flowering		Days to maturity		Plant height		No. of tillers per plant	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
1.	NDO 1 x JO-1	2.63 **	-2.98 **	-1.32 **	3.96 **	-0.52	0.97	-1.28 **	-1.01 **
2.	NDO 1 x JHO 2004	-0.18	3.02 **	-2.57 **	-4.37 **	1.61 *	2.79 **	0.68 **	0.35 **
3.	NDO 1 x Kent	-0.90 *	-2.23 **	-0.23	5.27 **	4.81 **	1.03	2.39 **	1.17 **
4.	NDO 1 x JHO 99-2	-4.87 **	6.90 **	0.93 **	-0.73 **	-3.74 **	-5.02 **	-1.82 **	-1.38 **
5.	NDO 1 x JHO 822	-0.51	-2.35 **	1.71 **	-2.48 **	6.77 **	-1.20	2.82 **	0.41 **
6.	NDO 1 x UPO 94	-4.90 **	-9.32 **	-0.04	0.10	-4.01 **	-0.97	-2.28 **	-0.15 *
7.	NDO 1 x RO-19	-0.98 *	2.04 **	-3.95 **	-4.59 **	3.61 **	6.82 **	1.34 **	1.73 **
8.	NDO 1 x UPO 212	3.30 **	2.54 **	2.88 **	-1.26 **	-3.58 **	-2.18 **	-0.78 **	-0.52 **
9.	NDO 1 x JHO 851	1.32 **	4.13 **	-1.29 **	-1.84 **	-3.73 **	-4.78 **	0.23 **	-1.39 **
10.	JO-1 x JHO 2004	0.91 *	-7.10 **	-1.82 **	1.63 **	-3.32 **	0.03	0.45 **	0.32 **
11.	JO-1 x Kent	5.18 **	3.32 **	0.52	-8.06 **	3.02 **	1.13	0.96 **	1.13 **
12.	JO-1 x JHO 99-2	5.88 **	-1.87 **	1.02 **	0.27	1.19	2.35 **	-0.88 **	0.69 **
13.	JO-1 x JHO822	-0.76	-7.46 **	7.13 **	0.19	-3.27 **	-2.18 **	-0.44 **	-0.12
14.	JO-1 x UPO94	-9.48 **	8.24 **	-0.62 *	5.10 **	0.47	6.48 **	2.56 **	1.02 **
15.	JO-1 x RO-19	-3.90 **	4.27 **	-0.54 *	-3.92 **	-0.45	-3.47 **	0.95 **	-0.53 **
16.	JO-1 x UPO 212	0.05	0.77 *	-6.04 **	-4.26 **	-1.56 *	5.88 **	-1.30 **	2.42 **
17.	JO-1 x JHO-851	-2.59 **	-6.32 **	-3.20 **	-2.84 **	5.68 **	-4.67 **	1.47 **	-1.62 **
18.	JHO 2004 x Kent	-1.95 **	2.32 **	-4.07 **	-8.06 **	-0.08	-7.52 **	0.75 **	-1.98 **
19.	JHO 2004 x JHO 99-2	0.07	2.13 **	4.43 **	6.60 **	-0.06	3.67 **	-0.32 **	0.98 **
20.	JHO 2004 x JHO 822	-5.57 **	0.21	-3.12 **	-5.48 **	-1.38	-3.70 **	0.86 **	-1.63 **
21.	JHO 2004 x UPO 94	1.71 **	-6.76 **	7.13 **	-2.90 **	-2.94 **	1.23	0.92 **	0.24 **
22.	JHO 2004 x RO-19	4.63 **	4.60 **	-2.12 **	5.08 **	3.34 **	1.54 *	2.82 **	1.52 **
23.	JHO 2004 x UPO 212	-5.76 **	1.10 **	-0.29	4.08 **	-4.85 **	-8.26 **	-1.44 **	-1.46 **
24.	JHO 2004 x JHO-851	5.27 **	-2.65 **	-3.45 **	-9.17 **	-6.90 **	5.46 **	-2.34 **	2.50 **
25.	Kent x JHO 99-2	-4.32 **	-3.12 **	0.10	0.91 **	-0.03	-0.52	1.39 **	0.29 **
26.	Kent x JHO 822	-9.62 **	-2.04 **	-2.45 **	-2.84 **	-3.28 **	3.15 **	-0.06	2.95 **
27.	Kent x UPO 94	-1.68 **	0.32	-0.87 **	-3.26 **	-5.48 **	3.65 **	-1.67 **	0.69 **
28.	Kent x RO-19	-6.43 **	-11.98 **	-7.45 **	-4.95 **	-2.92 **	-2.54 **	-0.75 **	-1.43 **
29.	Kent x UPO 212	9.85 **	0.18	0.71 **	7.71 **	-7.81 **	-4.94 **	-1.50 **	-2.31 **
30.	Kent x JHO-851	0.55	-4.23 **	-2.79 **	-0.54 **	-3.63 **	-1.13	-0.93 **	-0.52 **
31.	JHO 99-2 x JHO-822	2.41 **	1.77 **	0.05	-0.84 **	3.31 **	-2.41 **	3.36 **	-1.96 **
32.	JHO 99-2 x UPO 94	-4.65 **	1.46 **	-6.37 **	-3.26 **	2.31 **	-0.04	-0.92 **	0.54 **
33.	JHO 99-2 x RO-19	-0.73	-4.85 **	7.71 **	2.05 **	-7.33 **	-4.03 **	-1.69 **	-1.24 **
34.	JHO 99-2 x UPO 212	8.21 **	1.32 **	0.21	-2.95 **	-8.29 **	3.24 **	-1.47 **	0.81 **
35.	JHO 99-2 x JHO-851	-2.09 **	3.57 **	1.38 **	1.46 **	4.80 **	1.32	1.66 **	0.64 **
36.	JHO-822 x UPO 94	7.71 **	-0.46	-1.59 **	1.33 **	4.40 **	-0.03	1.77 **	0.84 **
37.	JHO-822 x RO-19	-9.70 **	4.90 **	-1.18 **	-3.04 **	-5.44 **	-0.15	-1.85 **	1.32 **
38.	JHO-822 x UPO 212	-2.76 **	-6.26 **	-2.34 **	-2.70 **	-2.36 **	1.76 **	-0.86 **	1.07 **
39.	JHO-822 x JHO-851	-4.73 **	0.65	-8.51 **	-0.95 **	-2.19 **	0.69	-0.20 *	1.03 **
40.	UPO 94 x RO-19	-1.76 **	0.93 *	-3.26 **	1.88 **	-0.21	1.49 *	-0.85 **	0.59 **
41.	UPO 94 x UPO 212	-6.48 **	3.77 **	-0.76 **	-1.12 **	8.72 **	-1.58 *	2.34 **	-1.76 **
42.	UPO 94 x JHO-851	9.55 **	1.35 **	1.07 **	-7.04 **	-0.05	-3.01 **	0.54 **	-0.83 **
43.	RO-19 x UPO 212	6.43 **	-1.21 **	5.32 **	-6.15 **	5.29 **	-4.37 **	1.79 **	-2.07 **
44.	RO-19 x JHO-851	2.13 **	4.04 **	3.82 **	4.60 **	-3.03 **	0.27	-1.01 **	-1.98 **
45.	UPO 212 x JHO-851	-6.26 **	4.54 **	-3.34 **	0.27	-3.63 **	-1.54 *	-0.99 **	-0.93 **
	S_{ij}	1.07	0.96	0.66	0.50	1.80	1.68	0.21	0.17
	$S_{ij}-S_{ik}$	0.43	0.38	0.27	0.20	0.72	0.67	0.08	0.07
	$S_{ij}-S_{kl}$	1.58	1.41	0.98	0.74	2.64	2.47	0.31	0.25

Table 5 continued....

Table 5 continued....

S. no.	Hybrids	No. of leaves per plant		Spike length		Leaf length		Leaf width	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
1.	NDO 1 x JO-1	2.16 **	-0.60 **	-1.44 **	-1.01 **	0.65	-0.07	0.01	-0.11 **
2.	NDO 1 x JHO 2004	2.00 **	2.63 **	1.81 **	0.77 *	-0.30	0.87	0.16 **	0.13 **
3.	NDO 1 x Kent	0.80 **	1.55 **	2.12 **	0.52	-5.47 **	-1.91 **	-0.02	0.00
4.	NDO 1 x JHO 99-2	-0.66 **	-0.77 **	-1.53 **	-2.95 **	2.45 **	2.05 **	0.00	-0.08 **
5.	NDO 1 x JHO 822	2.64 **	0.01	1.89 **	0.77 *	-0.61	-0.93 *	0.08 **	0.10 **
6.	NDO 1 x UPO 94	-1.31 **	-0.05	-1.64 **	-0.19	-2.38 **	-3.16 **	0.11 **	0.11 **
7.	NDO 1 x RO-19	1.67 **	4.45 **	2.07 **	2.57 **	4.89 **	3.46 **	-0.02	0.04 *
8.	NDO 1 x UPO 212	-0.50 **	-1.76 **	-1.30 **	0.00	1.24 **	-2.84 **	-0.12 **	-0.03 *
9.	NDO 1 x JHO 851	2.38 **	-3.33 **	-1.24 **	-1.11 **	-0.33	0.82	-0.02	-0.05 **
10.	JO-1 x JHO 2004	1.35 **	-0.16	0.52	-0.59	0.24	-1.16 *	-0.06 **	0.04 *
11.	JO-1 x Kent	1.35 **	-0.17	1.34 **	1.56 **	4.62 **	3.95 **	0.00	-0.15 **
12.	JO-1 x JHO 99-2	-0.82 **	1.40 **	0.39	0.95 **	0.57	2.32 **	-0.13 **	-0.03
13.	JO-1 x JHO822	4.49 **	-1.02 **	-1.31 **	-0.19	1.54 **	-1.70 **	0.10 **	-0.04 *
14.	JO-1 x UPO94	2.64 **	3.73 **	1.50 **	2.45 **	1.26 **	2.54 **	-0.10 **	0.06 **
15.	JO-1 x RO-19	-3.38 **	-0.28	-0.23	-1.22 **	4.63 **	0.52	-0.13 **	-0.07 **
16.	JO-1 x UPO 212	-0.85 **	3.81 **	-2.28 **	2.38 **	0.22	0.22	0.05 **	-0.09 **
17.	JO-1 x JHO-851	-1.77 **	-2.66 **	3.24 **	-1.64 **	-3.21 **	-3.48 **	-0.03	0.00
18.	JHO 2004 x Kent	1.09 **	-3.84 **	1.03 **	-1.76 **	1.28 **	1.00 *	0.03	0.13 **
19.	JHO 2004 x JHO 99-2	0.13	3.83 **	-0.63	0.37	1.51 **	-2.70 **	-0.07 **	-0.02
20.	JHO 2004 x JHO 822	-4.87 **	-3.28 **	-0.03	-2.47 **	2.45 **	3.56 **	0.08 **	-0.07 **
21.	JHO 2004 x UPO 94	1.78 **	-0.54 **	-1.19 **	0.60	1.27 **	0.66	-0.07 **	-0.09 **
22.	JHO 2004 x RO-19	2.96 **	0.95 **	0.89 **	0.83 *	-0.56	-1.29 **	0.02	-0.02
23.	JHO 2004 x UPO 212	-0.61 **	-4.46 **	-1.81 **	-3.14 **	-0.17	1.27 **	0.05 **	-0.04 *
24.	JHO 2004 x JHO-851	-2.83 **	3.58 **	-3.52 **	4.24 **	-0.34	1.34 **	0.02	-0.06 **
25.	Kent x JHO 99-2	-1.77 **	-0.45 **	-2.78 **	0.01	-1.23 *	-3.86 **	-0.01	0.04 *
26.	Kent x JHO 822	0.63 **	2.84 **	-0.75 *	0.84 *	1.54 **	-0.44	-0.03	-0.02
27.	Kent x UPO 94	-0.72 **	2.58 **	-0.22	1.71 **	-0.43	-1.37 **	0.02	-0.14 **
28.	Kent x RO-19	3.16 **	-0.93 **	-0.94 **	-0.76 *	-3.49 **	-1.19 **	-0.10 **	-0.01
29.	Kent x UPO 212	-2.41 **	-2.74 **	-2.24 **	-2.33 **	0.53	2.78 **	-0.03	0.06 **
30.	Kent x JHO-851	-3.73 **	-0.40 **	-0.82 *	-0.48	5.26 **	-0.72	0.07 **	0.01
31.	JHO 99-2 x JHO-822	2.77 **	-1.99 **	1.72 **	-2.27 **	1.26 **	-2.74 **	0.01	0.01
32.	JHO 99-2 x UPO 94	1.11 **	-0.85 **	-0.69 *	-1.66 **	0.96 *	-0.24	-0.09 **	-0.10 **
33.	JHO 99-2 x RO-19	2.19 **	-0.75 **	-3.09 **	-3.60 **	1.16 *	1.49 **	0.17 **	0.10 **
34.	JHO 99-2 x UPO 212	1.13 **	0.84 **	-1.45 **	3.23 **	-2.41 **	0.61	-0.06 **	-0.05 **
35.	JHO 99-2 x JHO-851	0.61 **	0.07	2.73 **	1.51 **	-5.92 **	-4.35 **	0.05 **	0.17 **
36.	JHO-822 x UPO 94	0.42 *	1.94 **	1.20 **	0.16	1.42 **	0.85	-0.05 **	0.14 **
37.	JHO-822 x RO-19	0.50 **	-1.17 **	-2.86 **	-0.14	-3.34 **	-0.60	-0.05 **	-0.03
38.	JHO-822 x UPO 212	-3.07 **	2.02 **	-0.27	1.59 **	-2.35 **	0.50	-0.01	0.10 **
39.	JHO-822 x JHO-851	-3.68 **	0.45 **	0.53	0.40	2.41 **	0.80	0.12 **	-0.06 **
40.	UPO 94 x RO-19	-1.45 **	-0.13	-0.40	1.03 **	1.09 *	1.64 **	0.02	-0.03
41.	UPO 94 x UPO 212	3.28 **	-1.84 **	3.60 **	-0.54	2.55 **	-3.60 **	-0.09 **	-0.09 **
42.	UPO 94 x JHO-851	-1.10 **	-0.60 **	0.00	-2.22 **	-1.79 **	2.34 **	0.02	-0.08 **
43.	RO-19 x UPO 212	-1.74 **	-1.95 **	2.28 **	-2.26 **	-0.92	-0.05	-0.06 **	-0.14 **
44.	RO-19 x JHO-851	3.24 **	-0.71 **	-1.36 **	-0.69 *	4.88 **	2.16 **	-0.07 **	0.03
45.	UPO 212 x JHO-851	1.17 **	-0.62 **	0.20	-0.71 *	0.30	-1.75 **	-0.10 **	-0.01
	S_{ij}	0.43	0.37	0.82	0.82	1.19	1.13	0.04	0.04
	S_{ij}-S_{ik}	0.17	0.15	0.33	0.33	0.48	0.45	0.02	0.02
	S_{ij}-S_{kl}	0.63	0.54	1.21	1.20	1.75	1.66	0.06	0.06

Table 5 continued....

Table 5 continued....

S. no.	Hybrids	Harvest Index		1000 seed weight		Grain yield per plant	
		F_1	F_2	F_1	F_2	F_1	F_2
1.	NDO 1 x JO-1	0.64	2.88 **	1.49 **	1.66 **	0.09	-0.51 **
2.	NDO 1 x JHO 2004	2.13 **	-2.96 **	2.16 **	-2.90 **	1.40 **	1.15 **
3.	NDO 1 x Kent	4.14 **	5.76 **	7.03 **	3.45 **	1.95 **	1.79 **
4.	NDO 1 x JHO 99-2	3.97 **	4.89 **	2.13 **	0.02	-0.72 **	-1.25 **
5.	NDO 1 x JHO 822	2.41 **	0.96 **	-2.66 **	6.90 **	2.31 **	0.06
6.	NDO 1 x UPO 94	1.58 **	-2.44 **	-1.71 **	-2.12 **	-0.85 **	-0.54 **
7.	NDO 1 x RO-19	-7.54 **	4.66 **	4.26 **	-2.64 **	2.19 **	2.81 **
8.	NDO 1 x UPO 212	5.61 **	-0.86 **	3.84 **	0.55	-0.88 **	-1.36 **
9.	NDO 1 x JHO 851	2.37 **	-7.85 **	-2.12 **	-0.25	-0.14	-1.85 **
10.	JO-1 x JHO 2004	3.58 **	-6.33 **	3.88 **	3.76 **	0.17 *	-0.51 **
11.	JO-1 x Kent	4.80 **	5.10 **	2.12 **	-3.16 **	1.55 **	0.54 **
12.	JO-1 x JHO 99-2	5.48 **	7.76 **	-4.97 **	-4.08 **	0.34 **	1.33 **
13.	JO-1 x JHO822	-0.19	4.44 **	-6.50 **	-6.13 **	-0.42 **	-1.14 **
14.	JO-1 x UPO94	7.95 **	11.13 **	1.45 **	4.62 **	2.31 **	3.30 **
15.	JO-1 x RO-19	5.68 **	-6.57 **	0.61	-0.64	0.89 **	-1.15 **
16.	JO-1 x UPO 212	-9.40 **	7.63 **	-6.41 **	-5.35 **	-1.18 **	3.57 **
17.	JO-1 x JHO-851	0.47	-11.26 **	-1.70 **	0.54	1.93 **	-1.91 **
18.	JHO 2004 x Kent	-7.16 **	-9.36 **	0.77 *	-1.60 **	0.96 **	-2.90 **
19.	JHO 2004 x JHO 99-2	-2.12 **	8.69 **	8.12 **	0.56	0.15 *	2.55 **
20.	JHO 2004 x JHO 822	3.52 **	-10.10 **	-1.20 **	1.60 **	0.52 **	-2.01 **
21.	JHO 2004 x UPO 94	3.19 **	6.18 **	-0.85 *	-0.76 *	0.03	-0.08
22.	JHO 2004 x RO-19	4.30 **	12.40 **	-6.59 **	6.08 **	1.70 **	1.51 **
23.	JHO 2004 x UPO 212	2.51 **	-3.63 **	-1.82 **	-2.65 **	-1.16 **	-3.27 **
24.	JHO 2004 x JHO-851	6.84 **	4.40 **	-4.93 **	0.88 *	-2.14 **	3.65 **
25.	Kent x JHO 99-2	-6.07 **	-9.08 **	4.14 **	3.27 **	-0.75 **	0.00
26.	Kent x JHO 822	-4.88 **	3.21 **	-5.46 **	1.71 **	-0.73 **	2.90 **
27.	Kent x UPO 94	4.02 **	12.52 **	-0.36	-3.71 **	-0.99 **	2.50 **
28.	Kent x RO-19	-0.37	-3.59 **	-9.20 **	-1.95 **	-0.62 **	-1.28 **
29.	Kent x UPO 212	-1.05 **	-5.33 **	2.06 **	2.65 **	-1.59 **	-2.52 **
30.	Kent x JHO-851	2.54 **	-7.55 **	-1.27 **	-1.27 **	0.12	-0.51 **
31.	JHO 99-2 x JHO-822	3.93 **	-4.34 **	0.12	2.73 **	2.53 **	-2.37 **
32.	JHO 99-2 x UPO 94	-0.46	-6.58 **	3.20 **	6.54 **	0.10	-0.83 **
33.	JHO 99-2 x RO-19	1.21 **	-7.86 **	-1.36 **	-1.03 **	-1.63 **	-1.98 **
34.	JHO 99-2 x UPO 212	7.21 **	7.43 **	1.10 **	-5.00 **	0.30 **	2.34 **
35.	JHO 99-2 x JHO-851	-5.51 **	10.22 **	0.26	3.99**	1.63 **	0.90 **
36.	JHO-822 x UPO 94	3.56 **	-4.24 **	6.56 **	0.52	2.36 **	0.97 **
37.	JHO-822 x RO-19	-1.96 **	-3.29 **	5.99 **	2.31 **	-1.59 **	-0.69 **
38.	JHO-822 x UPO 212	-2.32 **	5.26 **	3.17 **	-2.83 **	-1.36 **	2.44 **
39.	JHO-822 x JHO-851	-5.02 **	3.83 **	4.54 **	-3.06 **	0.10	1.65 **
40.	UPO 94 x RO-19	-0.56	1.74 **	-3.61 **	-2.21 **	-0.66 **	0.52 **
41.	UPO 94 x UPO 212	2.33 **	-10.13 **	-4.95 **	2.13 **	2.78 **	-1.95 **
42.	UPO 94 x JHO-851	0.16	-2.71 **	-1.84 **	-1.29 **	-0.22 **	-1.64 **
43.	RO-19 x UPO 212	4.65 **	2.19 **	-0.49	2.35 **	1.73 **	-2.11 **
44.	RO-19 x JHO-851	-5.15 **	-5.85 **	2.60 **	-5.49 **	-1.24 **	-0.59 **
45.	UPO 212 x JHO-851	0.19	2.53 **	-0.90 *	-0.66	-0.61 **	-0.37 **
	S_{ij}	0.85	0.78	0.88	0.92	0.19	0.20
	S_{ij}-S_{ik}	0.34	0.31	0.35	0.37	0.08	0.08
	S_{ij}-S_{kl}	1.25	1.15	1.30	1.35	0.28	0.29

* Significant at 5% probability level** Significant at 1% probability level

that none of the crosses was a desirable specific combiner for all the traits under study. The cross RO-19 x UPO 212 in no cut UPO 94 x UPO 212 in single cut showed the highest significant sca effects for grain yield per plant. For green fodder yield per plant JHO 99-2 x JHO-85,1 Kent x UPO 94, NDO 1 x JHO 99-2 in F_1 generation and JO-1 x UPO 212 followed by JHO 2004 x UPO 121, JHO 99-2 x JHO-822 in F_2 generation showed the highest significant sca effects. With respect to early flowering in no cut, the best crosses were JHO 822 x RO-19, Kent x JHO 822, JO 1 x UPO 94 in F_1 generation and Kent x RO-19, JO-1 x JHO-822, NDO-1 x UPO 94 in F_2 generation; in single cut JHO 822 x RO-19, Kent x JHO 822, JO 1 x UPO 94 94 in F_1 generation and Kent x RO-19 followed by ND 01 x UPO 94, JO-1 x JHO 822 in F_2 generation. For early maturity type, the best crosses which show negative and significant sca effects in no cut were Kent x JHO 851 followed by UPO 94 x JHO-851, NDO 1 x JO-1 in F_1 generation and JHO 822 x JHO 851 followed by NDO-1 x Kent, UPO 212 x JHO-851 in F_2 generation; in single cut JHO 822 x JHO-851, Kent x RO-19, JHO 99-2 x UPO 94 in F_1 generation and JHO 822 x JHO-851, JO-1 x Kent, JHO 2004 x Kent in F_2 generation. The desirable cross having negative and significant sca effects for plant height in no cut were NDO 1 x RO-19, JHO 99-2 x RO-19, JHO 2004 x UPO 212 in F_1 generation and NDO-1 x UPO 212, NDO-1 x Kent, NDO-1 x JHO-851 in F_2 generation; in single cut JHO 99-2 x UPO 212, Kent x UPO 212, JHO 2004 x JHO-851 in F_1 generation and JHO 2004 x UPO 121, JHO 2004 x Kent, ND 01 x JHO 99-2 in F_2 generation. The sca of 28 heterotic crosses for yield and its component traits indicated that most of the good specific cross combinations for different characters involved parents with either one or both good gca effects. This was in accordance with the findings of Prakash *et al.* (2013), Bind *et al.* (2017), Chauhan *et al.* (2019), Al-Juhaishi *et al.* (2020), Atar Singh *et al.* (2020), Rana *et al.* (2022).

Conclusion

It is revealed from the experimental findings that there is importance of both additive and non-additive gene effects for grain yield and yield contributing characters studied. Thus, it may be suggested that there is a considerable scope for improving oat grain and fodder yield of through heterosis breeding. The sca effects of the crosses for yield and its contributing characters indicated that most of the good specific cross combinations for different characters involved parents with either one or both good gca effects.

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