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Inheritance of Some Quantitative Characters in Barley (*Hordeum vulgare* L.) under Normal and Saline Sodic Soils

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ABSTRACT

Six populations viz., P1, P2, F1, F2, B1 and B2 of four crosses involving eight parents were evaluated following compact family block design during kharif season in 2008 to 2011 to study the mode of inheritance by using simple (A, B, C and D) and joint scaling tests. The nature and magnitude of gene effects for yield and its components in Barley was also studied using six parameters model of generation mean analysis. The presence of epistasis was detected in 64 cases by simple as well as joint sealing test and inadequacy of additive-dominance model was established. Additive (d), dominance (h) gene effects along with one or more type of non-allelic interaction (i, j, l) contributed significantly towards the inheritance of all the quantitative characters in majority of the crosses. Duplicate type of epistasis was also prevalent in most of the cases with few exceptions. Thus, biparental mating may be suggested for improvement of Barley populations.

Key Words: Barley, Epistasis, Gene action, Generation mean. analysis,

INTRODUCTION

Barley (*Hordeum vulgare* L., 2n = 14), a member of sub-family Poaceae is considered as crop of winter cereal in India and grown in Northerns Hills, plains and Central India for food, feed forage and industrial purposes. The crop is inherited with better tolerance to problematic soils, like salinity, alkalinity. It requires less water and fertilizers than the wheat. Thus, in most breeding programme, major emphasis is placed on the improvement of yield and related component traits of polygenetic nature. An understanding of the mode of inheritance of complex quantitative traits in different cropping seasons is essential for formulation of an effective breeding program for improvement of a particular trait. Epistasis is a universal phenomenon in the inheritance of yield and components in crop plants. Detection of epistasis becomes essential not only for obtaining unbiased estimates of additive and dominance gene effects but it also facilitates the breeders to decide about the specific breeding methods to bring about improvement in the crop. Thus, present investigation was undertaken to detect the epistasis and adequacy of additive dominance/ non-allelic model by using simple (A, B, C and D) scaling test (Mather 1949, Hayman and Mather 1955), as well as by Joint Scaling Test (Cavalli 1952) and to estimate the nature and magnitude of gene effects for yield and its components during rabi in four crosses of barley.

MATERIALS AND METHODS

Eight genetically diverse and homozygous varieties of barley namely NDB 943, NDB 1173, DL 88, K 890, DWR 57, PL 762, Azad and K 750 were selected for building up the experimental material. These barley genotypes were crossed to produce four F1's i.e. NDB 943 x NDB 1173 (cross I), DL88 x K 890 (cross II), DWR 57 x PL 762 (cross III), Azad x K 750 (cross IV). These F1's were backcrossed to their respective parents (P1 and P2) to produce B1's and B2's as well as selfed to produce F2 seeds. Thus, six genetic populations namely, P1, P2, F1, F2, B1 and B2 were raised in a

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compact family block design with three replications during rabi 2008 under normal and saline sodic soils at the Genetics and Plant Breeding Research Farm, N.D. University of Agriculture and Technology, Kumarganj, Faizabad. The F1's and parents were sown in a single row plot of each whereas, back cross and F2 populations were sown in a three and six rows plot, respectively in five meter length at a row spacing of 22.5 cm. The present investigation was undertaken to test the adequacy of 'additive-dominance model' using simple scaling test and joint scaling test , work out nature and magnitude of gene effects for yield quality and its component traits , study heterosis and inbreeding depression for yield quality and its component traits and work out heritability and genetic advance in per cent of mean. Sixteen quantitative characters namely, initial seed germination, plant height, number of effective tillers, peduncle length, spike length, chlorophyll content, number of grains/spike, grains weight/spike, days to maturity, harvest index, grain yield/plant, grain size, 1000-grain weight, protein content, grain hardness and amylose content were studied in both experiments.

The data on sixteen metric traits from two environments were subjected to analysis of variance of Compact Family Block Design, separately, simple and joint scaling tests and six parameter models of generation mean were used to study the nature and magnitude of gene effects for sixteen traits of four crosses in normal and saline sodic soils.

Heterosis was estimated over standard variety (Azad), better parent and inbreeding depression was studied for understanding the manifestation of heterosis in different crosses. Heritability in broad sense, narrow sense and expected genetic advance in per cent were computed to assess the efficiency of selection in improving the characters.

RESULTS AND DISCUSSION

The mean sum of squares due to differences among generations or progenies within each cross family were significant or highly significant in all the characters under both conditions (normal and

Table -1: Simple scaling tests, gene effects and type of epistasis for 16 metric traits under normal soil.

Crosses	Gene effects						Scales				Type of epistasis
	m	d	h	i	j	l	A	B	C	D	
Initial seed germination (%) in field											
NDB-943xNDB1173	82.220** ±0.20	2.220** ±0.53	14.440** ±1.64	4.440** ±1.33	2.220* ±0.94	15.560** ±2.96	-7.780** ±1.00	-12.220** ±1.81	-24.440** ±2.08	-2.220** ±0.67	C
DL-88 x K-890	85.553** ±0.54	-3.330** ±0.53	-0.562 ±2.62	-6.673** ±2.41	-0.552 ±0.85	14.457** ±3.65	-4.443** ±1.42	-3.340* ±1.43	-1.110 ±2.97	3.337** ±1.20	--
DWR-57 x PL-762	85.553** ±0.74	1.110** ±0.95	-5.558 ±3.63	-11.113** ±3.51	-2.225 ±1.23	15.557** ±5.15	-4.447* ±2.05	0.003 ±1.54	6.670 ±3.50	5.557** ±1.75	--
Azad x K-750	85.550** ±0.20	1.110* ±0.47	8.893** ±1.59	6.673** ±1.25	0.000 ±0.92	-4.453 ±2.85	-1.110 ±1.34	-1.110 ±1.50	-8.893** ±2.12	-3.337** ±0.63	--
Plant height (cm)											
NDB-943xNDB1173	77.680** ±0.14	-0.437** ±0.26	-5.657** ±0.81	-7.860** ±0.77	- 0.613** ±0.35	6.433** ±1.29	0.100 ±0.37	1.327* ±0.61	9.287** ±0.76	3.930** ±0.39	D

DL-88 x K-890	83.640** ±0.07	-4.873** ±0.24	-11.478** ±0.64	-14.920** ±0.57	-2.698** ±0.32	16.850** ±1.18	-3.663** ±0.47	1.733** ±0.54	12.990** ±0.68	7.460** ±0.28	D
DWR-57 x PL-762	62.747** ±0.14	-0.287** ±0.17	-4.807** ±0.74	-6.333** ±0.65	0.153** ±0.30	6.387** ±1.13	0.127 ±0.48	-0.180 ±0.50	6.280** ±0.90	3.167** ±0.32	D
Azad x K-750	73.173** ±0.14	-4.460** ±0.19	-9.217** ±0.77	-12.653** ±0.68	-1.850** ±0.29	15.713** ±1.20	-3.380** ±0.41	0.320 ±0.59	9.593** ±0.93	6.327** ±0.34	D
Number of effective tillers											
NDB-943xNDB1173	10.267** ±0.06	-0.980** ±0.11	-4.870** ±0.35	-6.467** ±0.32	0.057 ±0.12	15.047** ±0.58	-4.233** ±0.23	-4.347** ±0.197	-2.113** ±0.37	3.233** ±0.16	D
DL-88 x K-890	11.540** ±0.04	-0.280** ±0.08	-11.727** ±0.24	-14.453** ±0.23	0.427** ±0.10	25.827** ±0.40	-5.260** ±0.18	-6.113** ±0.12	3.080** ±0.23	7.227** ±0.11	D
DWR-57 x PL-762	10.847** ±0.03	-1.153** ±0.13	-4.853** ±0.30	-5.800** ±0.27	-0.853** ±0.15	14.720** ±0.58	-5.313** ±0.21	-3.607** ±0.26	-3.120** ±0.28	2.900** ±0.14	D
Azad x K-750	9.867** ±0.08	-0.767** ±0.08	9.587** ±0.38	8.333** ±0.36	-0.687** ±0.13	-10.960** ±0.51	0.627** ±0.20	2.000** ±0.18	-5.707** ±0.39	-4.167** ±0.18	D
Peduncle length (cm)											
NDB-943xNDB1173	9.333** ±0.11	-3.367** ±0.09	-10.617** ±0.52	-9.667** ±.47	-1.083** ±0.13	7.900** ±0.71	-0.200 ±0.26	1.967** ±0.29	11.433** ±0.63	4.833** ±0.24	D
DL-88 x K-890	5.500** ±0.03	0.333** ±0.08	-0.670** ±0.25	1.600** ±0.21	1.430** ±0.12	-5.327** ±0.45	3.293** ±0.20	0.433* ±0.18	2.127** ±0.30	-0.800** ±0.12	C
DWR-57 x PL-762	4.900** ±0.06	-2.967** ±0.09	1.100** ±0.32	0.333 ±0.30	-2.533** ±0.12	2.467** ±0.48	-3.933** ±0.16	1.133** ±0.21	-3.133** ±0.31	-0.167 ±0.15	C
Azad x K-750	5.733** ±0.03	3.600** ±0.05	6.440** ±0.18	4.800** ±0.15	4.733** ±0.08	13.280** ±0.31	-4.307** ±0.15	-13.773** ±0.13	-22.880** ±0.23	-2.400** ±0.07	C
Spike length (cm)											
NDB-943xNDB1173	8.900** ±0.04	-0.467** ±0.11	1.475** ±0.28	1.467** ±0.27	0.075 ±0.12	-3.617** ±0.49	1.150** ±0.20	1.000** ±0.14	0.683** ±0.19	-0.733** ±0.13	D
DL-88 x K-890	8.867** ±0.04	0.600** ±0.08	-0.667** ±0.23	-1.600** ±0.22	0.567** ±0.10	1.067** ±0.38	0.833** ±0.09	-0.300 ±0.19	2.133** ±0.21	0.800** ±0.11	D
DWR-57 x PL-762	10.600** ±0.06	0.600** ±0.04	-8.050** ±0.25	-9.067** ±0.24	0.117** ±0.06	19.033** ±0.32	-4.867** ±0.12	-5.100** ±0.10	-0.900** ±0.27	4.533** ±0.12	D
Azad x K-750	10.100** ±0.04	-0.233** ±0.08	-4.123** ±0.23	-5.667** ±0.25	0.177 ±0.12	14.913** ±0.50	-4.447** ±0.19	-4.800** ±0.25	-3.580** ±0.38	2.833** ±0.12	D
Chlorophyll content (mg/100g)											
NDB-943xNDB1173	2.267** ±0.00	0.077** ±0.00	-0.570** ±0.01	-0.700** ±0.02	0.033** ±0.01	1.140** ±0.03	-0.187** ±0.01	-0.253** ±0.01	0.260** ±0.02	0.350** ±0.01	D

DL-88 x K-890	1.727** ±0.00	0.147** ±0.01	-0.647** ±0.03	-0.693** ±0.02	0.167** ±0.01	1.000** ±0.05	0.013 ±0.01	-0.320** ±0.02	0.387** ±0.02	0.347** ±0.01	D
DWR-57 x PL-762	2.553** ±0.00	-0.107** ±0.00	-0.567** ±0.01	-0.693** ±0.02	-0.047** ±0.01	1.253** ±0.03	-0.327** ±0.01	-0.233** ±0.01	0.133** ±0.02	0.347** ±0.01	D
Azad x K-750	2.160** ±0.00	-0.123** ±0.00	-0.503** ±0.02	-0.687** ±0.02	-0.057** ±0.01	0.940** ±0.03	-0.183** ±0.01	-0.070** ±0.01	0.433** ±0.02	0.343** ±0.01	D
Number of grains/spike											
NDB-943xNDB1173	52.000** ±0.21	-5.78** ±0.56	57.667** ±1.08	50.667** ±1.00	-3.000** ±0.45	-63.333** ±1.57	3.333** ±0.60	9.333** ±0.71	-38.000** ±1.16	25.333** ±0.50	D
DL-88 x K-890	45.000** ±0.21	-3.333** ±0.45	17.167** ±1.34	18.667** ±1.24	-3.833** ±0.65	-25.000** ±2.23	-0.667 ±0.76	7.000** ±1.09	-12.333** ±1.32	-9.333** ±0.62	D
DWR-57 x PL-762	31.667** ±0.27	-35.000** ±0.35	20.000** ±1.38	35.333** ±1.28	-26.000** ±0.42	-8.000** ±2.04	-39.667** ±0.64	12.333** ±0.50	-62.667** ±2.24	-17.667** ±0.41	D
Azad x K-750	62.000** ±0.21	-1.000** ±0.35	-52.833** ±1.15	-42.000** ±1.10	-0.500** ±0.38	72.333** ±1.78	-15.667** ±0.62	-14.667** ±0.62	11.667** ±1.10	21.000** ±0.55	D
Grains weight/spike (g)											
NDB-943xNDB1173	3.007** ±0.00	0.002** ±0.00	-2.529** ±0.01	-2.647** ±0.01	-0.198** ±0.01	2.403** ±0.02	-0.076** ±0.02	0.320** ±0.01	2.891** ±0.02	1.323** ±0.01	D
DL-88 x K-890	1.804** ±0.00	-0.555** ±0.01	0.956** ±0.03	1.393** ±0.03	-0.468** ±0.01	-0.962** ±0.04	-0.684** ±0.01	0.253** ±0.02	-1.824** ±0.03	-0.696** ±0.01	D
DWR-57 x PL-762	1.908** ±0.01	-1.172** ±0.02	-2.484** ±0.05	-1.056** ±0.05	-0.659** ±0.02	2.865** ±0.08	-1.564** ±0.02	-0.245** ±0.04	-0.753** ±0.05	0.528** ±0.02	D
Azad x K-750	2.811** ±0.00	-0.435** ±0.01	-2.342** ±0.03	-2.407** ±0.03	-0.230** ±0.01	3.903** ±0.05	-0.978** ±0.01	-0.518** ±0.03	0.911** ±0.03	1.204** ±0.01	D
Days to maturity											
NDB-943xNDB1173	136.000** ±0.12	1.000** ±0.17	1.667** ±0.58	6.000** ±0.55	1.333** ±0.21	-7.333** ±0.91	2.000** ±0.36	-0.667* ±0.31	-4.667** ±0.58	-3.000** ±0.27	D
DL-88 x K-890	138.333** ±0.16	0.333** ±0.26	11.000** ±0.85	6.000** ±0.83	2.333** ±0.30	-23.333** ±1.29	11.000** ±0.56	6.333** ±0.30	11.333** ±0.78	-3.000** ±0.41	D
DWR-57 x PL-762	139.333** ±0.12	5.000** ±0.27	-3.000** ±0.78	-6.000** ±0.72	3.333** ±0.36	0.667 ±1.30	6.000** ±0.53	-0.667** ±0.53	11.333** ±0.75	3.000** ±0.36	--
Azad x K-750	133.000** ±0.10	1.667** ±0.22	12.333** ±0.65	15.333** ±0.62	0.667** ±0.27	-28.667** ±1.08	7.333** ±0.46	6.000** ±0.36	-2.000** ±0.61	-7.667** ±0.31	D
Harvest index (%)											
NDB-943xNDB1173	35.383** ±0.20	-1.760** ±0.34	-6.293** ±1.11	-7.467** ±1.07	-5.280** ±0.40	14.760** ±1.70	-8.927** ±0.69	1.633** ±0.52	0.173 ±1.01	3.733** ±0.53	D

DL-88 x K-890	47.910** ±0.15	-5.320** ±0.27	-29.947** ±0.86	-37.013** ±0.81	-5.587** ±0.36	56.920** ±1.36	-15.540** ±0.67	-4.367** ±0.36	17.107** ±0.83	18.507** ±0.41	D
DWR-57 x PL-762	36.183** ±0.14	-2.433** ±0.27	1.707** ±0.83	-3.867** ±0.77	-3.723** ±0.39	1.520 ±1.36	-2.550** ±0.65	4.897** ±0.46	6.213** ±0.80	1.933** ±0.39	--
Azad x K-750	43.080** ±0.10	4.947** ±0.29	-0.035 ±0.75	-1.200 ±0.72	7.788** ±0.34	9.310** ±1.32	3.733** ±0.39	-11.843** ±0.59	-6.910** ±0.60	0.600 ±0.36	D
Grain yield/plant (g)											
NDB-943xNDB1173	23.000** ±0.13	-0.857** ±0.23	-8.260** ±0.73	-11.953** ±0.49	-0.450** ±0.07	25.133** ±3.21	-7.040** ±0.41	-6.140** ±0.40	-1.227 ±0.66	5.977** ±0.35	D
DL-88 x K-890	16.767** ±0.05	-3.927** ±0.10	-7.135** ±0.32	-8.813** ±0.29	-5.048** ±0.14	22.137** ±0.53	-11.710** ±0.27	-1.613** ±0.16	-4.510** ±0.35	4.407** ±0.14	D
DWR-57 x PL-762	12.667** ±0.05	-6.067** ±0.08	-3.028** ±0.28	-4.533** ±0.25	-5.775** ±0.15	15.257** ±0.46	-11.137** ±0.23	0.413* ±0.20	-6.190** ±0.33	2.267** ±0.12	D
Azad x K-750	21.540** ±0.05	0.247 ±0.14	-3.510** ±0.37	-5.187** ±0.36	0.937** ±0.16	18.940** ±0.64	-5.940** ±0.15	-7.813** ±0.29	-8.567** ±0.28	2.593** ±0.18	D
Grain size (L:B ratio)											
NDB-943xNDB1173	3.325** ±0.00	-0.639** ±0.01	-2.814** ±0.03	-3.281** ±0.02	-0.318** ±0.01	3.450** ±0.04	-0.402** ±0.01	0.233** ±0.02	3.112** ±0.03	1.641** ±0.01	D
DL-88 x K-890	3.633** ±0.00	0.651** ±0.00	-1.287** ±0.01	-1.503** ±0.00	0.774** ±0.00	2.097** ±0.01	0.477** ±0.01	-1.071** ±0.00	0.909** ±0.01	0.751** ±0.00	D
DWR-57 x PL-762	3.308** ±0.00	-1.031** ±0.00	-0.255** ±0.00	-0.413** ±0.00	-1.169** ±0.00	3.209** ±0.00	-2.567** ±0.00	-0.229** ±0.00	-2.383** ±0.00	0.207** ±0.00	D
Azad x K-750	3.903** ±0.00	-0.447** ±0.00	-2.356** ±0.00	-2.495** ±0.00	-0.129** ±0.00	2.365** ±0.01	-0.064** ±0.01	0.193** ±0.00	2.624** ±0.01	1.247** ±0.00	D
1000-grain weight (g)											
NDB-943xNDB1173	42.007** ±0.01	1.147** ±0.05	-7.732** ±0.24	-10.347** ±0.12	-0.012 ±0.18	12.837** ±0.48	-1.257** ±0.14	-1.233** ±0.38	7.857** ±0.43	5.173** ±0.05	D
DL-88 x K-890	40.113** ±0.09	-8.293** ±0.27	5.542** ±0.80	12.600** ±0.65	-5.978** ±0.47	3.730* ±1.47	-14.143** ±0.63	-2.187** ±0.79	-28.930** ±1.01	-6.300** ±0.33	C
DWR-57 x PL-762	60.357** ±0.22	9.043** ±0.54	-74.553** ±1.41	-74.953** ±1.36	6.927** ±0.55	100.667** ±2.39	-5.930** ±0.89	-19.783** ±0.75	49.240** ±1.06	37.477** ±0.69	D
Azad x K-750	45.357** ±0.08	-8.293** ±0.44	-5.732** ±0.95	-13.840** ±0.94	-6.555** ±0.45	25.077** ±1.82	-12.173** ±0.84	0.937* ±0.37	2.603** ±0.45	6.920** ±0.47	D
Protein content (%)											
NDB-943xNDB1173	9.750** ±0.00	-1.067** ±0.01	2.183** ±0.04	1.467** ±0.03	-1.217** ±0.03	-2.300** ±0.07	-0.800** ±0.03	1.633** ±0.05	-0.633** ±0.06	-0.733** ±0.07	D

DL-88 x K-890	9.167** ±0.02	0.433** ±0.01	2.042** ±0.07	2.267** ±0.07	-0.192** ±0.02	-6.750** ±0.09	2.050** ±0.03	2.433** ±0.03	2.217** ±0.08	-1.133** ±0.03	D
DWR-57 x PL-762	11.150** ±0.00	0.400** ±0.01	-2.200** ±0.03	-2.800** ±0.03	0.750** ±0.01	5.800** ±0.05	-0.750** ±0.02	-2.250** ±0.02	-0.200** ±0.04	1.400** ±0.01	D
Azad x K-750	9.550** ±0.00	1.767** ±0.01	-2.558** ±0.03	-0.333** ±0.03	1.042** ±0.01	4.717** ±0.06	-1.150** ±0.03	-3.233** ±0.02	-4.050** ±0.03	0.167** ±0.01	D
Grain hardness (kg pressure)											
NDB-943xNDB1173	11.600** ±0.02	-0.800** ±0.03	4.900** ±0.12	4.800** ±0.11	-0.100** ±0.05	-5.800** ±0.18	0.400** ±0.07	0.600** ±0.07	-3.800** ±0.12	-2.400** ±0.05	D
DL-88 x K-890	13.600** ±0.02	-2.533** ±0.06	-10.767** ±0.15	-10.667** ±0.14	-3.033** ±0.06	15.933** ±0.26	-5.667** ±0.11	0.400** ±0.07	5.400** ±0.12	5.333** ±0.07	D
DWR-57 x PL-762	10.600** ±0.02	-1.000** ±0.03	9.700** ±0.12	8.400** ±0.11	-0.900** ±0.05	-16.200** ±0.18	3.000** ±0.07	4.800** ±0.07	-0.600** ±0.12	-4.200** ±0.06	D
Azad x K-750	12.000** ±0.02	2.000** ±0.03	-6.600** ±0.12	-7.200** ±0.11	2.400** ±0.05	6.000** ±0.18	3.000** ±0.07	-1.800** ±0.07	8.400** ±0.12	3.600** ±0.05	D
Amylose content (%)											
NDB-943xNDB1173	10.250** ±0.00	0.217** ±0.01	1.025** ±0.04	0.833** ±0.031	0.125 ±0.02	-8.450** ±0.07	3.933** ±0.03	3.683** ±0.04	6.783** ±0.05	-0.417** ±0.01	D
DL-88 x K-890	9.750** ±0.00	1.433** ±0.01	3.720** ±0.03	2.467** ±0.03	1.587** ±0.01	-5.040** ±0.05	2.873** ±0.02	-0.300** ±0.02	0.107** ±0.03	-1.233** ±0.01	D
DWR-57 x PL-762	9.487** ±0.01	-0.220** ±0.01	4.547** ±0.03	3.480** ±0.03	-0.163** ±0.01	-8.373** ±0.05	2.283** ±0.02	2.610** ±0.02	1.413** ±0.04	-1.740** ±0.01	D
Azad x K-750	10.613** ±0.01	-0.173** ±0.01	1.530** ±0.03	0.827** ±0.03	0.330** ±0.01	-6.580** ±0.04	3.207** ±0.02	2.547** ±0.02	4.927** ±0.03	-0.413** ±0.01	D

Table -2: Simple scaling tests, gene effects and type of epistasis for 16 metric traits under saline sodic soil

Characters	Gene effects						Scales				Type of epistasis
	m	d	h	i	j	l	A	B	C	D	
Initial seed germination (%) in field											
NDB-943xNDB1173	78.887** ±0.20	2.223** ±0.47	13.887** ±1.45	8.887** ±1.25	3.890** ±0.67	3.333 ±2.52	-2.220* ±1.00	-10.000** ±1.21	-21.107** ±1.66	-4.443** ±0.63	--
DL-88 x K-890	83.330** ±0.71	-4.447** ±0.33	-12.222** ±3.03	-13.333** ±2.91	-3.335** ±0.74	24.443** ±3.55	-8.890** ±1.31	-2.220* ±1.00	2.223 ±3.29	6.667** ±1.46	D
DWR-57 x PL-762	82.220** ±0.74	-4.443** ±0.74	-3.893 ±3.36	-4.447 ±3.31	-6.110** ±0.91	21.107** ±4.37	-14.440** ±1.48	-2.220 ±1.13	-12.213** ±3.18	2.223 ±1.65	--
Azad x K-750	83.330** ±0.35	1.110* ±0.47	6.110** ±1.87	2.220 ±1.70	-1.557* ±0.70	-3.327 ±2.83	-0.003 ±1.04	1.110 ±1.24	-1.113 ±2.10	-1.110* ±0.55	--
Plant height (cm)											
NDB-943xNDB1173	74.093** ±0.15	0.437 ±0.29	-4.825** ±0.92	-5.167** ±0.85	0.498 ±0.41	-3.017* ±1.48	4.590** ±0.51	3.593** ±0.69	13.350** ±0.92	2.583** ±0.43	C
DL-88 x K-890	82.000** ±0.13	-4.773** ±0.20	-18.152** ±0.71	-17.040** ±0.67	-1.445** ±0.28	5.503** ±1.07	4.323** ±0.33	7.213** ±0.45	28.577** ±0.70	8.520** ±0.34	D
DWR-57 x PL-762	70.000** ±1.18	-0.233 ±0.26	-31.683** ±4.75	-31.533** ±4.75	0.183 ±0.36	27.233** ±4.86	2.333** ±0.62	1.967** ±0.36	35.833** ±4.74	15.767** ±2.37	D
Azad x K-750	71.967** ±0.18	-3.973** ±0.24	-6.767** ±0.95	-10.187** ±0.87	-1.193** ±0.34	12.227** ±1.44	-2.213** ±0.49	0.173 ±0.64	8.147** ±1.06	5.093** ±0.44	D
Number of effective tillers											
NDB-943xNDB1173	9.267** ±0.06	-1.003** ±0.11	-1.457** ±0.34	-2.940** ±0.32	0.133 ±0.13	9.127** ±0.54	-2.960** ±0.20	-3.227** ±0.20	-3.247** ±0.33	1.470** ±0.16	D
DL-88 x K-890	9.753** ±0.04	-0.100 ±0.08	-6.057** ±0.26	-6.467** ±0.23	0.930** ±0.11	9.660** ±0.43	-0.667** ±0.20	-2.527** ±0.16	3.273** ±0.29	3.233** ±0.12	D
DWR-57 x PL-762	10.933** ±0.03	-0.993** ±0.12	-4.243** ±0.27	-5.347** ±0.24	-0.577** ±0.13	13.900** ±0.51	-4.853** ±0.18	-3.700** ±0.24	-3.207** ±0.26	2.673** ±0.12	D
Azad x K-750	9.733** ±0.07	-0.667** ±0.06	8.983** ±0.32	7.733** ±0.30	-0.417** ±0.12	-11.033** ±0.44	1.233** ±0.23	2.067** ±0.13	-4.433** ±0.37	-3.867** ±0.15	D
Peduncle length (cm)											
NDB-943xNDB1173	9.000** ±0.05	-3.533** ±0.06	-10.983** ±0.29	-9.733** ±0.24	-1.450** ±0.12	7.300** ±0.44	-0.233 ±0.17	2.667** ±0.23	12.167** ±0.37	4.867** ±0.12	D
DL-88 x K-890	5.433** ±0.02	0.167 ±0.11	0.083 ±0.28	1.933** ±0.24	1.017** ±0.15	-4.567** ±0.55	2.333** ±0.24	0.300 ±0.24	0.700* ±0.32	-0.967** ±0.12	D

DWR-57 x PL-762	5.333** ±0.04	-3.233** ±0.07	1.950** ±0.25	1.133** ±0.22	-2.883** ±0.11	-0.700 ±0.39	-3.100** ±0.15	2.667** ±0.18	-1.567** ±0.27	-0.567** ±0.11	--
Azad x K-750	5.667** ±0.03	3.167** ±0.05	8.817** ±0.19	6.733** ±0.16	4.217** ±0.09	10.233** ±0.33	-4.267** ±0.16	-12.700** ±0.15	-23.700** ±0.26	-3.367** ±0.08	C
Spike length (cm)											
NDB-943xNDB1173	8.800** ±0.03	-0.167** ±0.06	1.733** ±0.17	1.667** ±0.16	0.433** ±0.08	-4.000** ±0.29	1.600** ±0.12	0.733** ±0.10	0.667** ±0.16	-0.833** ±0.08	D
DL-88 x K-890	8.900** ±0.04	0.767** ±0.06	-0.950** ±0.21	-1.533** ±0.20	0.650** ±0.09	1.100** ±0.33	0.867** ±0.10	-0.433** ±0.15	1.967** ±0.21	0.767** ±0.10	D
DWR-57 x PL-762	10.533** ±0.05	0.900** ±0.06	-7.050** ±0.25	-8.067** ±0.24	0.483** ±0.07	18.367** ±0.33	-4.667** ±0.11	-5.633** ±0.07	-2.233** ±0.22	4.033** ±0.12	D
Azad x K-750	10.367** ±0.07	-0.367** ±0.09	-4.708** ±0.39	-6.600** ±0.36	0.125 ±0.12	15.283** ±0.59	-4.217** ±0.18	-4.467** ±0.25	-2.083** ±0.44	3.300** ±0.18	D
Chlorophyll content (mg/100g)											
NDB-943xNDB1173	2.247** ±0.00	0.070** ±0.00	-0.597** ±0.02	-0.713** ±0.02	0.027 ±0.01	1.140** ±0.03	-0.187** ±0.01	-0.240** ±0.01	0.287** ±0.02	0.357** ±0.01	D
DL-88 x K-890	1.733** ±0.00	0.160** ±0.00	-0.710** ±0.02	-0.773** ±0.02	0.203** ±0.01	1.127** ±0.03	0.027** ±0.01	-0.380** ±0.01	0.420** ±0.02	0.387** ±0.01	D
DWR-57 x PL-762	2.543** ±0.00	-0.140** ±0.01	-0.563** ±0.02	-0.693** ±0.02	-0.070** ±0.01	1.273** ±0.05	-0.360** ±0.02	-0.220** ±0.01	0.113** ±0.01	0.347** ±0.01	D
Azad x K-750	2.110** ±0.01	-0.107** ±0.01	-0.303** ±0.03	-0.453** ±0.03	-0.057** ±0.01	0.567** ±0.05	-0.113** ±0.02	0.71** ±0.21	0.340** ±0.03	0.227** ±0.02	D
Number of grains/spike											
NDB-943xNDB1173	51.000** ±0.21	2.667** ±0.22	51.333** ±1.03	45.333** ±0.96	0.052 ±0.04	-53.333** ±1.43	4.000** ±0.62	4.000** ±0.47	-37.333** ±1.11	-22.667** ±0.48	D
DL-88 x K-890	44.333** ±0.16	-2.000** ±0.47	20.833** ±1.23	20.000** ±1.14	-3.167** ±0.59	-19.000** ±2.20	-3.667** ±1.01	2.667** ±0.74	-21.000** ±1.13	-10.000** ±0.57	D
DWR-57 x PL-762	32.667** ±0.27	-35.000** ±0.36	19.500** ±1.33	34.000** ±1.29	-26.833** ±0.41	-8.333** ±1.90	-39.667** ±0.74	14.000** ±0.49	-59.667** ±1.23	-17.000** ±0.65	D
Azad x K-750	61.000** ±0.11	1.000** ±0.27	-52.500** ±0.88	-42.000** ±0.70	1.833** ±0.36	78.333** ±1.60	-16.333** ±0.70	-20.000** ±0.70	5.667** ±1.15	21.000** ±0.35	D
Grains weight/spike (g)											
NDB-943xNDB1173	2.969** ±0.01	-0.001** ±0.00	-2.763** ±0.03	-2.876** ±0.03	-0.124** ±0.00	2.646** ±0.03	-0.009* ±0.00	0.239** ±0.00	3.106** ±0.03	1.438** ±0.01	D
DL-88 x K-890	1.759** ±0.01	-0.567** ±0.00	1.062** ±0.06	1.476** ±0.06	-0.479** ±0.01	-0.945** ±0.06	-0.745** ±0.01	0.213** ±0.01	-2.007** ±0.06	-0.738** ±0.03	D

DWR-57 x PL-762	1.909** ±0.01	-1.223** ±0.01	-2.258** ±0.05	-0.875** ±0.04	-0.748** ±0.01	2.447** ±0.06	-1.534** ±0.02	-0.039* ±0.02	-0.698** ±0.04	0.437** ±0.02	D
Azad x K-750	2.804** ±0.00	-0.425** ±0.01	-2.053** ±0.03	-2.420** ±0.02	-0.424** ±0.01	3.361** ±0.05	-0.895** ±0.01	-0.047* ±0.02	1.479** ±0.02	1.210** ±0.01	D
Days to maturity											
NDB-943xNDB1173	134.000** ±0.11	-2.000** ±0.17	5.667** ±0.58	12.000** ±0.55	-1.667** ±0.21	-15.333** ±0.91	0.171 ±0.10	3.333** ±0.31	-8.667** ±0.58	-6.000** ±0.27	D
DL-88 x K-890	139.000** ±0.10	-0.333* ±0.14	3.833** ±0.57	0.667 ±0.51	1.833** ±0.24	-11.667** ±0.87	7.333** ±0.44	3.667** ±0.30	10.333** ±0.66	-0.333 ±0.26	D
DWR-57 x PL-762	137.000** ±0.12	6.000** ±0.17	1.500* ±0.59	1.89* ±0.90	3.500** ±0.23	-7.000** ±0.92	7.000** ±0.36	3.23** ±0.50	7.000** ±0.61	5.30** ±0.79	D
Azad x K-750	135.000** ±0.12	2.000** ±0.17	4.500** ±0.59	8.000** ±0.55	0.500** ±0.23	-25.000** ±0.92	9.000** ±0.36	8.000** ±0.36	9.000** ±0.61	-4.000** ±0.27	D
Harvest index (%)											
NDB-943xNDB1173	32.620** ±0.13	-6.387** ±0.26	13.620** ±0.80	3.840** ±0.74	-8.940** ±0.30	2.267 ±1.32	-11.993** ±0.58	5.887** ±0.41	-9.947** ±0.81	-1.920** ±0.37	--
DL-88 x K-890	32.867** ±0.17	0.053 ±0.31	5.332** ±0.97	6.507** ±0.92	1.992** ±0.42	5.523** ±1.54	-4.023** ±0.61	-8.007** ±0.59	-18.537** ±0.92	-3.253** ±0.46	C
DWR-57 x PL-762	32.630** ±0.09	-2.360** ±0.35	-3.727** ±0.84	6.187** ±0.80	-1.113** ±0.41	4.493** ±1.55	-6.453** ±0.72	-4.227** ±0.45	-16.867** ±0.65	-3.093** ±0.40	D
Azad x K-750	38.973** ±0.09	-5.163** ±0.13	-5.152** ±0.49	-10.953** ±0.45	-4.858** ±0.17	39.850** ±0.77	-19.307** ±0.27	-9.590** ±0.30	-17.943** ±0.51	5.477** ±0.23	D
Grain yield/plant (g)											
NDB-943xNDB1173	21.207** ±0.08	-3.833** ±0.16	-0.857** ±0.49	-4.227** ±0.46	-3.163** ±0.18	5.153** ±0.80	-3.627** ±0.34	2.700** ±0.25	3.300** ±0.49	2.113** ±0.23	D
DL-88 x K-890	16.433** ±0.08	-3.513** ±0.22	-2.355** ±0.61	-1.160* ±0.56	-0.725** ±0.29	11.323** ±1.07	-5.807** ±0.47	-4.357** ±0.42	-9.003** ±0.60	0.580** ±0.28	D
DWR-57 x PL-762	18.507** ±0.15	-10.227** ±0.24	-22.112** ±0.79	-14.773** ±0.77	-8.905** ±0.26	35.357** ±1.19	-19.197** ±0.36	-1.387** ±0.43	-5.810** ±0.70	7.387** ±0.38	D
Azad x K-750	23.387** ±0.06	-5.040** ±0.08	-1.463** ±0.030	-2.693** ±0.28	-4.790** ±0.12	11.380** ±0.46	-9.133** ±0.18	0.447* ±0.18	-5.993** ±0.32	1.347** ±0.14	D
Grain size (L:B ratio)											
NDB-943xNDB1173	3.343** ±0.00	-0.599** ±0.01	-2.871** ±0.02	-3.339** ±0.02	-0.276** ±0.01	3.483** ±0.04	-0.348** ±0.01	0.204** ±0.02	3.195** ±0.03	1.670** ±0.01	D
DL-88 x K-890	3.559** ±0.00	0.639** ±0.00	-1.163** ±0.02	-1.216** ±0.01	0.723** ±0.01	1.337** ±0.03	0.663** ±0.01	-0.783** ±0.03	1.095** ±0.03	0.608** ±0.00	D

DWR-57 x PL-762	3.305** ±0.00	-1.031** ±0.00	-0.249** ±0.00	-0.414** ±0.00	-1.178** ±0.00	3.201** ±0.00	-2.571** ±0.00	-0.216** ±0.00	-2.373** ±0.00	0.207** ±0.00	D
Azad x K-750	3.909** ±0.00	-0.452** ±0.00	-2.385** ±0.00	-2.531** ±0.00	-0.127** ±0.00	2.391** ±0.01	-0.057** ±0.00	0.197** ±0.00	2.670** ±0.01	1.265** ±0.00	D
1000-grain weight (g)											
NDB-943xNDB1173	42.137** ±0.03	1.473** ±0.13	-7.272** ±0.45	-7.787** ±0.29	-0.105 ±0.31	-7.603** ±0.89	7.590** ±0.37	7.800** ±0.58	23.177** ±0.71	3.893** ±0.15	C
DL-88 x K-890	38.373** ±0.16	-8.260** ±0.24	8.383** ±0.84	13.373** ±0.80	-6.570** ±0.27	-10.980** ±1.26	-7.767** ±0.55	5.373** ±0.30	-15.767** ±0.83	-6.687** ±0.40	D
DWR-57 x PL-762	47.087** ±0.09	6.633** ±0.27	-33.537** ±0.67	-22.413** ±0.66	5.817** ±0.29	16.567** ±1.18	8.740** ±0.50	-2.893** ±0.31	28.260** ±0.44	11.207** ±0.33	D
Azad x K-750	45.300** ±0.03	-2.073** ±0.10	-13.187** ±0.27	-17.800** ±0.25	-1.327** ±0.12	23.280** ±0.49	-4.067** ±0.11	-1.413** ±0.25	12.320** ±0.24	8.900** ±0.13	D
Protein content (%)											
NDB-943xNDB1173	9.640** ±0.01	-1.063** ±0.01	2.053** ±0.04	1.367** ±0.03	-1.197** ±0.02	-1.947** ±0.07	-0.907** ±0.03	1.487** ±0.04	-0.787** ±0.06	-0.683** ±0.01	D
DL-88 x K-890	9.283** ±0.01	0.217** ±0.05	2.318** ±0.12	2.633** ±0.10	-0.335** ±0.05	-7.423** ±0.20	2.060** ±0.04	2.730** ±0.09	2.157** ±0.06	-1.317** ±0.05	D
DWR-57 x PL-762	11.050** ±0.00	0.433** ±0.01	-2.317** ±0.03	-2.867** ±0.03	0.783** ±0.01	5.833** ±0.05	-0.700** ±0.02	-2.267** ±0.02	-0.100** ±0.03	1.433** ±0.01	D
Azad x K-750	9.500** ±0.00	1.750** ±0.01	-2.777** ±0.04	-0.500** ±0.03	1.110** ±0.02	4.553** ±0.07	-0.917** ±0.04	-3.137** ±0.03	-3.553** ±0.05	0.250** ±0.02	D
Grain hardness (kg pressure)											
NDB-943xNDB1173	11.400** ±0.02	-0.333** ±0.04	4.233** ±0.14	3.867** ±0.12	0.167** ±0.06	-4.200** ±0.23	0.333** ±0.08	0.220 ±0.10	-3.533** ±0.14	-1.933** ±0.06	D
DL-88 x K-890	13.800** ±0.02	-1.600** ±0.03	-10.500** ±0.12	-10.400** ±0.11	-2.100** ±0.05	15.400** ±0.18	-4.600** ±0.07	-0.400** ±0.07	5.400** ±0.12	5.200** ±0.05	D
DWR-57 x PL-762	10.200** ±0.02	-1.000** ±0.03	9.767** ±0.11	8.400** ±0.11	-0.800** ±0.05	-14.867** ±0.18	2.433** ±0.07	4.033** ±0.07	-1.933** ±0.11	-4.200** ±0.05	D
Azad x K-750	11.800** ±0.02	1.633** ±0.03	-6.033** ±0.12	-6.467** ±0.10	1.867** ±0.05	4.867** ±0.18	2.667** ±0.09	-1.067** ±0.06	8.067** ±0.13	3.233** ±0.05	D
Amylose content (%)											
NDB-943xNDB1173	10.200** ±0.02	0.117** ±0.02	0.742** ±0.10	0.633** ±0.09	0.025 ±0.03	-8.683** ±0.14	4.050** ±0.06	4.000** ±0.06	7.417** ±0.12	-0.317** ±0.05	D
DL-88 x K-890	9.900** ±0.01	1.400** ±0.02	3.275** ±0.06	2.200** ±0.05	1.575** ±0.02	-4.550** ±0.09	2.750** ±0.05	-0.400** ±0.03	0.150* ±0.06	-1.100** ±0.03	D

DWR-57 x PL-762	9.500** ±0.01	-0.183** ±0.01	3.192** ±0.05	3.167** ±0.05	-0.158** ±0.02	-10.383** ±0.08	3.450** ±0.03	3.767** ±0.03	4.050** ±0.05	-1.583** ±0.03	D
Azad x K-750	10.550** ±0.05	-0.200** ±0.02	1.343** ±0.05	0.547** ±0.04	0.330** ±0.02	-5.873** ±0.09	2.993** ±0.03	2.333** ±0.04	4.780** ±0.05	-0.273** ±0.02	D

*, ** Significant at 5% and 1% level of probability, respectively; C = complementary epistasis and D = Duplicate epistasis.

Table- 3: joint scaling test for 16 characters of four crosses under Normal and saline sodic soil

Characters	Chi-square values							
	Normal soil				Saline sodic soil			
	Cross I	Cross II	Cross III	Cross IV	Cross I	Cross II	Cross III	Cross IV
Initial seed germination (%) in field	0.075	0.422	3.267	2.523	1.751	2.805	1.805	2.043
Plant height (cm)	3.385	69.220**	0.268	40.758**	2.964	25.696**	3.737	12.520**
Number of effective tillers	0.238	16.869**	12.679**	0.613	1.023	69.447**	19.008**	5.431*
Peduncle length (cm)	70.325**	60.526**	1.240	263.512**	154.509**	36.916**	3.257	9.262**
Spike length (cm)	0.396	0.264	3.523	2.042	31.740**	3.649	53.827**	1.106
Chlorophyll content (mg/100g)	27.348**	17.998**	53.184**	68.353**	17.957**	34.794**	34.306**	26.288**
Number of grains/spike	44.630**	1.125	15.308**	1.724	0.000	11.065**	19.187**	13.462**
Grains weight/spike (g)	521.332**	172.820**	465.870**	260.326**	2407.624**	249.771**	385.923**	7.509**
Days to maturity	6.995**	52.581**	0.263	5.981*	6.995**	1.699	0.000	4.620*
Harvest index (%)	49.053**	1.280	0.008	2.767	2.938	0.006	10.794**	6.471*
Grain yield/plant (g)	2.896	118.102**	5.170*	35.335**	25.003**	4.293*	205.781**	8.656**
Grain size (L:B ratio)	540.761**	1400.493**	7018.194**	1425.036**	528.376**	37.151**	255720.375**	2346.878**
1000-grain weight (g)	0.004	0.725	159.070**	126.702**	0.142	76.390**	66.432**	113.549**
Protein content (%)	37.799**	80.991**	2054.500**	115.961**	30.760**	45.145**	2061.345**	206.686**
Grain hardness (kg pressure)	4.621*	262.518**	10.500**	168.006**	9.344**	262.500**	41.998**	34.297**
Amylose content (%)	17.290	477.487**	32.628**	774.986**	0.506	93.560**	4.201*	172.709**

*, ** Significant at 5% and 1% level of probability, respectively.

saline sodic soil). Thus, these characters in different cross combinations as stated above were utilized for further statistical analyses.

Significance of epistasis was detected by either one or both type of scaling tests in four crosses for all the characters under both (normal and saline sodic soil) condition (Table 1, 2 &3).Out of 64 cases (4 crosses, 16 characters in both condition, all cases showed significance of epistasis which was detected by either one or both type of scaling tests in normal and saline sodic soil for all the characters. Both tests, simple and joint scaling tests led to similar inferences in respect of presence or absence of epistasis in majority of cases for sixteen characters in four crosses in normal and saline sodic soils. Out of 128 comparisons, forty results of two type of tests differed across the sixteen characters in four crosses under both conditions. Presence of epistasis by simple scaling test with absence by joint scaling test was observed in 40 cases, while, its opposite case i.e. absence of epistasis by simple scaling test with presence of epistasis by joint scaling test was not found. Importance of epistasis in inheritance of yield and yield components in barley has been reported by Singh *et al* (1988) and Jezowski et al (2000).

The generation mean analysis revealed importance of additive (d) and or dominance (h) gene effects as well as one or more of the epistatic interactions (i, j, l) for all the sixteen traits of four crosses in normal and saline sodic soils. However, nature and magnitude of gene effects and epistatic interactions for a character exhibited considerable variation across the four crosses under two soil situations.

The significance of additive gene effects for most of the traits in four crosses under both soil situations suggested that substantial improvement in yield status can still be achieved in barley by using breeding procedures exploiting fixable components of genetic variance leading to development of pure line varieties in barley under both soil situations. Significance of dominance gene effects and epistatic interactions for most of the traits in four crosses under both soil situations indicated that exploitation of heterosis through hybrid varieties may be explored as potential alternative in future. Lone (1985), Prakash *et al* (2005) and Singh *et al* (1988) recorded importance of additive as well as non-additive gene effects for plant height. In absence of exploitation of heterosis through commercial hybrids, non-additive gene effects may be utilized for facilitating development of pure line cultivars by involving population improvement methods.

Duplicate type of epistasis was detected for plant height, number of effective tillers, peduncle length, spike length, chlorophyll content, number of grains/spike, grains weight/spike, days to maturity, harvest index, grain yield/plant, grain size, 1000-grain weight, protein content, grain hardness and amylose content in cross NDB 943 x NDB 1173, plant height, number of effective tillers, spike length, chlorophyll content, number of grains/ spike, grains weight/spike, days to maturity, harvest index, grain yield/plant, grain size, protein content, grain hardness and amylose content in cross DL 88 x K 890, plant height, number of effective tillers, spike length, chlorophyll content, number of grains/ spike, grains weight/spike, grain yield/plant, grain size, 1000 grain weight, protein content, grain hardness and amylose content in cross DWR 57 x PL 762, for plant height, number of effective tillers, spike length, chlorophyll content, number of grains/ spike, grains weight/spike, days to maturity, grain yield/plant, grain size, 1000-grain weight, protein content, grain hardness and amylose content in cross Azad x K 750 under normal soil.

In saline sodic soils, duplicate type of epistasis was detected for number of effective tillers, peduncle length, spike length, chlorophyll content, number of grains/spike, grains weight/spike, days to maturity, grain yield/plant, grain size, protein content, grain hardness and amylose content in cross NDB 943 x NDB 1173, initial seed germination, plant height, number of effective tillers, peduncle length, spike length, chlorophyll content, number of grains/

spike, grains weight/spike, days to maturity, grain yield/plant, grain size, protein content, grain hardness and amylose content in cross DL 88 x K 890, plant height, number of effective tillers, spike length, chlorophyll content, number of grains/ spike, grains weight/spike, grain yield/plant, grain size, 1000-grain weight, protein content, grain hardness and amylose content in cross DWR 57 x PL 762, for plant height, number of effective tillers, spike length, chlorophyll content, number of grains/ spike, grains weight/spike, days to maturity, grain yield/plant, grain size, 1000-grain weight, protein content, grain hardness and amylose content in cross Azad x K 750 .

Further, Out of 128 , all the crosses showing epistasis for different traits revealed manifestation of duplicate type of epistasis in 108 cases while, 09 cases showed complementary type of epistasis over the both soil conditions. Thus, presence of duplicate epistasis slows down the selection procedure of additive and or non-additive genetic variance (Gupta, 2005).

CONCLUSION

It may be suggested that the normal breeding methods would not solely work. Some forms of recurrent selection namely diallel selective mating or bi parental mating in early segregating generations might prove to be effective approaches. The restricted recurrent selection of desirable segregates followed by selection might also be a useful breeding strategy for exploitation of both additive as well as non-additive type of gene action (Chakraborty et al, 2010). It is apparent that information obtained will help in improving the existing barley varieties for its yield and quality traits.

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