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Inheritance studies of metric traits in three barley populations under normal and saline-alkali soils*

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Summary. The weighted least square estimates of gene effects (Hayman 1958) were estimated using 7 generations of the cross 'BG 25'×'NP 21' and 'BH 15'×'RD 103', and 11 generations of the cross 'C 164'×'EB 1556'. The joint scaling test of Cavalli (1952) indicated the failure of a simple additive – dominance model in majority of the cases. The variability of the characters studied could not be explained by the 6-parameter model in cross 'C 164'×'EB 1556', but it could explain the majority of characters in the crosses 'BG 25'×'NP 21' and 'BH 15'×'RD 103'. The grains per ear in 'BG 25'×'NP 21' exhibited differential response of generation means to a change in the environment due, perhaps. to the more pronounced expression of additive gene action in saline-alkali soil. Among the components of epistasis, additive×additive and dominance×dominance types of epistasis were important in 'BG 25'×'NP 21', while dominance×dominance type of epistasis was important in the crosses 'C 164'×'EB 1556' and 'BH 15'×'RD 103'. The cross 'BH 15'×'RD 103' appeared to be the least sensitive to a saline-alkali soil condition.

Key words: *Hordeum vulgare* L. – Gene effects – Saline-alkaline soil-salt tolerance

Introduction

Reclamation of saline and alkaline soils through desalinization is not only expensive but also laborious and time-consuming. This alone warrants efforts towards developing suitable cultivars which can adapt to these adverse soil conditions.

Barley has its own merits, being comparatively well adapted to drought, cold and adverse soil conditions. Among field crops, it ranks as the most tolerant with soil salinity levels of ECe up to 17.5 m mhos/cm (Bernstein 1964). The success in developing such high yielding cultivars in barley depends upon the choice of suitable parents for hybridization and the breeding methodology to be followed. Some success has been reported by Chandra (1981) in this direction. This would in turn depend upon the genetic architecture of the parents involved and the expression of genetic components under a given environment and the nature of gene action in the populations derived from them. Therefore, the present investigation was conducted in order to obtain information about the nature and magnitude of gene effects on yield and its components in three crosses of barley under normal and saline-alkali soil conditions. In addition, it suggests a breeding strategy for respective soil conditions.

Materials and methods

Six homozygous and genetically diverse varieties of barley (*Hordeum vulgare* L.), namely, 'C 164', 'BG 25', 'BH 15', 'RD 103', 'NP 21' and 'EB 1556' were chosen for building up the experimental material. The parents, F_1, F_2, F_3, BC_1, BC_2, BC_{11}, BC_{12}, BC_{21} and BC_{22} from cross 'C 164'×'EB 1556' and parents, F_1, F_2, F_3, BC_1 and BC_2 from 'BG 25'×'NP 21' and 'BH 15'×'RD 103' crosses formed the experimental material. The experiment was laid out with complete randomization of individual plants from each family in micro-plots of three replicate blocks (normal and two replicate blocks in saline-alkali soils) at the Division of Genetics and Plant Physiology at Central Soil Salinity Research Institute, Karnal (India). Variance of each family mean within a block was calculated

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and averaged over blocks and its reciprocal value was used in weighted least square analysis of generation means (Mather and Jinks 1971, 1977). In each microplot, a 1 m long single row spaced 30 cm apart and 5 cm between plants within row distance was maintained. The micro-plots measuring 2×2×0.5 m were filled with artificially salinized soil, having a sandy loam texture and electrical conductivity of 16.2 m mhos/cm and containing NaCl, $CaCl_2$ and Na_2SO_4 in a proportion of 7 : 2 : 1 on a milliequivalent basis. The entire soil profile was uniformly salinized at the time of planting but was subsequently exposed to natural dynamics of salt movement. As a result, different sections of the vertical profile underwent changes resulting from rainfall, application of irrigation, etc, which may be considered as a simulation of changes in the open fields. The micro-plots, like the field, were laterally closed but had an open ground system allowing leaching of water through a controlled outlet which could be monitored quantitatively and qualitatively for salinity status of the leachate.

Ten competitive plants were selected randomly from each row of each block for recording the observation on days to heading, plant height, tillers per plant, ear length, grains per ear, 100-grain weight and grain yield per plant.

The weighted least square estimates of gene effects were estimated following the 3-parameter and 6-parameter models by Hayman (1958).

3-parameter model or non-epistatic model

$y = m + C_1 (d) + C_2 (h)$

where,

y = generation mean
m = mean effect
(d) = pooled additive gene effects
(h) = pooled dominance gene effects
C_1, C_2 = coefficients for gene effects.

6-parameter model or epistatic model

$y = m + C_1 (d) + C_2 (h) + C_3 (i) + C_4 (j) + C_5 (l)$.

Where,

y = generation mean
m = mean effect
(d) = pooled additive gene effects
(h) = pooled dominance gene effects
(i) = pooled additive × additive epistatic effects
(j) = pooled additive × dominance epistatic effects
(l) = pooled dominance × dominance epistatic effects
C_1, $C_2 \ldots C_5$ = coefficients for gene effects.

The 3-parameter model was first fitted for m, (d) and (h) and then tested for non-allelic interaction by the joint scaling test of Cavalli (1952). In cases where a 3-parameter model failed to fit, an attempt was made to find a fit to the 6-parameter model.

Results

The joint scaling test indicated that a 3-parameter model was not fit for any character in either of the environments for generations derived from 'C 164' × 'EB 1556' cross (Table 1). The joint scaling test was not significant in the case of 'BG 25' × 'NP 21' for tillering per plant, 100-grain weight and grain yield in both environments. In this cross, the character grains per ear differed in this regard, that is, it was non-significant in saline-alkali soil, but significant in normal soil (Table 2). In cross 'BH 15' × 'RD 103', the χ^2 for the joint scaling test was significant for all characters in the saline-alkali soil and in the normal soil, excepting days

Table 1. Estimation of the components of generation means on a three-parameter model (weighted) for seven characters in barley cross 'C164' × 'EB 1556'

Character	Environment	Gene effect			Joint scaling test	
		(m)	(d)	(h)	(X^2) 8 d.f.	*P*
Days to heading	E_1	95.40 ±0.55	0.42 ±0.27	5.41** ±0.59	319.70**	0.0005
	E_2	84.51** ±0.19	0.77 ±0.40	3.82** ±0.68	158.44**	0.0005
Plant height (cm)	E_1	112.48** ±0.32	2.45** ±0.57	10.73** ±0.15	315.13**	0.0005
	E_2	52.48** ±0.31	1.78* ±0.84	−4.68** ±1.08	52.50**	0.0005
Tillers per plant	E_1	11.85** ±0.46	0.51 ±0.28	3.51** ±0.52	122.68**	0.0005
	E_2	3.67** ±0.05	0.12 ±0.12	0.04 ±0.18	25.44**	0.005 – 0.001
Ear length (cm)	E_1	6.44** ±0.05	0.81** ±0.06	0.25* ±0.12	103.48**	0.0005
	E_2	6.67** ±0.04	0.47** ±0.08	−0.24 ±0.14	150.44**	0.0005
Grains per ear	E_1	65.65** ±0.40	2.58** ±0.74	1.52** ±0.26	39.11**	0.0005
	E_2	61.58** ±0.44	3.30** ±0.89	−4.99** ±1.76	38.15**	0.0005
100-grain weight (g)	E_1	3.42** ±0.03	0.06 ±0.05	0.16 ±0.09	23.30**	0.005 – 0.001
	E_2	3.56** ±0.02	0.11** ±0.04	−0.27** ±0.08	38.88**	0.005
Yield per plant (g)	E_1	30.31** ±0.39	2.69** ±0.75	3.32** ±0.41	30.62**	0.0005
	E_2	7.73** ±0.08	0.13 ±0.17	−0.86** ±0.31	44.20**	0.0005

* Significant at 5% level; ** Significant at 1% level; E_1 = Normal soil; E_2 = Saline alkali soil

Table 2. Estimation of the components of generations means on a 3-parameter model (weighted) for seven characters in barley cross 'BG 25' × 'NP 21'

Character	Environment	Gene effect			Joint scaling test	
		(m)	(d)	(h)	(χ^2) 4 d.f.	*P*
Days to heading	E_1	93.71** ± 0.27	0.60 ± 0.69	4.49** ± 0.99	71.14**	0.0005
	E_2	84.76** ± 0.29	2.07 ± 0.56	7.14** ± 0.01	47.06**	0.0005
Plant height (cm)	E_1	107.43** ± 0.50	9.51** ± 0.12	15.98** ± 2.06	127.92**	0.0005
	E_2	68.88** ± 0.40	1.23 ± 0.87	− 1.98 ± 1.71	129.52**	0.0005
Tillers per plant	E_1	10.99** ± 0.13	0.25 ± 0.46	4.52** ± 0.67	8.78	0.1 − 0.05
	E_2	3.40** ± 0.07	0.74** ± 0.14	− 0.03 ± 0.25	5.69	0.3 − 0.2
Ear length (cm)	E_1	7.89** ± 0.11	0.04 ± 0.28	− 0.40 ± 0.65	28.01**	0.0005
	E_2	7.66** ± 0.07	0.37** ± 0.13	− 1.26** ± 0.23	20.60**	0.0005
Grains per ear	E_1	71.84** ± 0.67	2.33 ± 1.69	− 8.23* ± 3.30	10.38*	0.05 − 0.025
	E_2	61.05** ± 0.56	3.06** ± 0.11	− 11.96** ± 2.18	2.58	0.7 − 0.6
100-grain weight (g)	E_1	4.54** ± 0.03	0.10 ± 0.08	− 0.43** ± 0.05	6.31	0.2 − 0.1
	E_2	3.37** ± 0.03	0.08** ± 0.01	− 0.02 ± 0.11	7.27	0.2 − 0.3
Yield per plant (g)	E_1	35.10** ± 0.81	0.17* ± 0.08	10.40** ± 2.93	4.51	0.4 − 0.3
	E_2	8.32** ± 0.21	2.12** ± 0.42	− 1.23 ± 0.72	8.15	0.1 − 0.05

* Significant at 5% level; ** Significant at 1% level; E_1 = Normal soil; E_2 = Saline-alkali soil

Table 3. Estimation of the components of generation means on a 3-parameter model (weighted) for seven characters in barley cross 'BH 15' × 'RD 103'

Character	Environment	Gene effect			Joint scaling test	
		(m)	(d)	(h)	(χ^2) 4 d.f.	*P*
Days to heading	E_1	94.83** ± 0.26	0.36 ± 0.62	1.01** ± 0.07	10.70	0.05 − 0.025
	E_2	84.87** ± 0.26	0.15 ± 0.48	2.15* ± 0.98	34.24**	0.0005
Plant height (cm)	E_1	101.99** ± 0.50	13.99** ± 0.76	5.93** ± 0.42	58.26**	0.0005
	E_2	62.73** ± 0.46	0.42 ± 1.21	− 8.46** ± 2.72	235.96**	0.0005
Tillers per plant	E_1	11.45** ± 0.21	1.17* ± 0.50	0.54** ± 0.71	40.93**	0.0005
	E_2	4.23** ± 0.07	0.60* ± 0.26	− 1.06** ± 0.28	32.81**	0.0005
Ear length (cm)	E_1	8.95** ± 0.07	0.81 ± 0.63	0.78** ± 0.26	73.50**	0.0005
	E_2	8.08** ± 0.05	0.33* ± 0.13	1.10** ± 0.29	100.33**	0.0005
Grains per ear	E_1	73.25** ± 0.60	4.29** ± 0.29	0.33 ± 0.26	46.49**	0.0005
	E_2	66.63** ± 0.47	5.39** ± 1.26	0.13 ± 1.96	20.34**	0.0005
100-grain weight (g)	E_1	4.31** ± 0.03	0.10 ± 0.07	0.43** ± 0.05	7.64	0.2 − 0.1
	E_2	3.92** ± 0.03	0.06 ± 0.08	− 0.36** ± 0.03	23.58*	0.0005
Yield per plant (g)	E_1	32.73** ± 0.78	1.40 ± 1.32	0.23 ± 2.53	15.81**	0.005 − 0.0001
	E_2	10.24** ± 0.15	0.07 ± 0.39	− 2.85** ± 0.64	92.87**	0.0005

* Significant at 5% level; Significant at 1% level; E_1 = Normal soil; E_2 = Saline-alkali soil

to heading and 100-grain weight in normal soil (Table 3). In the cross 'BH 25' × 'NP 21', the additive effect was significant for tillers per plant and grains per ear in the stress environment (saline-alkali soil), and for yield per plant in both environments. The dominance effect was positive and significant for tillers per plant and yield per plant in normal soil, but a negative and significant dominance effect was observed for grains per ear and 100-grain weight in saline-alkali soil and in normal soil, respectively. The cross 'BH 15' × 'RD 103' exhibited a non-significant genetic effect for days to heading and 100-grain weight in normal soil. For the remaining characters, the 3-parameter model was found suitable under normal as well as under saline-alkali soil environments.

The weighted least square analysis of the six parameter model indicated the failure of the digenic model in the cross 'C 164' × 'EB 1556' for all the characters in both the environments except for 100-grain weight and grain yield in the normal environment (Table 4). In cross 'BH 25' × 'NP 21', the digenic 6-parameter model failed for days to heading and plant

Table 4. Estimation of the components of generation means on a 6-parameter model for seven characters in barley cross 'C' 164 × 'EB 1556'

Character	Environment	Gene effects							
		(m)	(d)	(h)	(i)	(j)	(l)	(χ^2) 5 d.f.	*P*
1	2	3	4	5	6	7	8	9	10
Days to heading	E_1	94.24** ±0.30	1.78** ±0.60	16.02** ± 0.54	14.86** ±0.45	−18.23** ± 0.65	−40.40** ± 2.89	106.29**	0.0005
	E_2	85.12** ±0.26	0.79 ±0.71	6.19** ± 0.85	4.90** ±0.83	0.16 ± 0.91	−17.86** ± 2.79	−108.58**	0.0005
Plant height (cm)	E_1	123.49** ±0.41	±6.27** ±0.26	20.56** ± 0.40	19.65** ±0.23	− 5.28** ± 0.48	−54.42** ± 4.92	47.45**	0.0005
	E_2	52.34** ±0.42	0.76 ±1.20	−10.38** ± 1.76	−6.59** ±1.79	1.83 ± 1.90	15.59** ± 4.28	34.35**	0.0005
Tillers per plant	E_1	10.61** ±0.20	0.19 ±0.72	2.56** ± 0.72	3.53** ±0.69	− 0.83** ± 0.80	21.55** ± 2.22	18.31**	0.005 – 0.001
	E_2	3.62** ±0.06	0.34 ±0.21	0.08 ± 0.19	0.24 ±0.19	− 0.92 ± 0.29	0.83 ± 0.73	13.07*	0.025 – 0.01
Ear length (cm)	E_1	6.81** ±0.08	0.13 ±0.20	0.96** ± 0.37	0.60 ±0.36	0.72** ± 0.24	− 3.98** ± 0.71	28.08**	0.0005
	E_2	6.69** ±0.05	0.22 ±0.16	− 0.71** ± 0.16	−0.69** ±0.14	0.88** ± 0.20	− 0.39 ± 0.59	82.69**	0.0005
Grains per ear	E_1	67.01** ±0.55	1.11 ±1.72	4.36* ± 2.08	3.56 ±2.00	5.02* ± 2.00	−21.20** ± 5.40	15.00*	0.025 – 0.01
	E_2	61.73** ±0.52	0.57 ±1.70	− 6.27** ± 2.03	− 2.78 ±1.52	6.10** ± 2.18	− 1.29 ± 7.92	25.05**	0.0005
100-grain weight (g)	E_1	3.35** ±0.03	0.18 ±0.10	0.24** ± 0.02	0.05 ±0.12	0.19** ± 0.03	0.85* ± 0.38	9.75	0.1 – 0.05
	E_2	3.53** ±0.03	0.01 ±0.08	− 0.36** ± 0.08	−0.23** ±0.08	−17 ± 0.11	0.74* ± 0.32	24.69**	0.0005
Yield per plant	E_1	32.44** ±0.63	3.51 ±2.56	3.85** ± 0.90	0.01 ±0.86	1.00 ± 2.58	−17.53** ± 5.78	7.04	0.3 – 0.2
	E_2	7.33** ±0.12	0.66* ±0.28	− 1.22** ± 0.32	−0.75** ±0.28	− 1.17** ± 0.46	6.67** ± 1.29	13.46*	0.025 – 0.01

* Significant at 5% level; **Significant at 1% level; E_1 = Normal soil; E_2 = Saline-alkali soil

height in saline-alkali soil environment, and for ear length in both environments. However, the 6-parameter model was satisfactory for days to heading, plant height and grains per ear in normal soil, while it was not fit for any of the characters in saline-alkali soil environments (Table 5). The analysis for cross 'BH 15' × 'RD 103' revealed a fit to a 6-parameter model for yield per plant under normal soil and for days to heading, tillers per plant, grains per ear and 100-grain weight under saline-alkali soil conditions. In this cross the failure of fit to a 6-parameter model was evident for tillers per plant and grains per ear in a normal environment, and for yield per plant in a saline-alkali soil environment and for plant height and ear length in both environments (Table 6).

With respect to the cross 'C 164' × 'EB 1556', dominance × dominance gene effects were significant for both 100-grain weight and yield per plant; the additive × dominance gene effects were significant for 100-grain weight only. Additive × additive gene effects were not significant in either of these two cases. The dominance × dominance as well as the additive × additive components were significant for days to heading, plant height as well as for grains per ear in the 'BH 25' × 'NP 21' cross under normal soil condition. However, the additive × dominance component was significant only in the case of grains per ear in this cross.

The study of cross 'BH 15' × 'RD 103' showed that for days to heading, only the additive × dominance component was significant, while for tillers per plant and grains per ear, both additive × additive and dominance × dominance components were significant under the saline-alkali soil condition. In this cross, however, only the dominance × dominance component was

Table 5. Estimation of the components of generation means of a 6-parameter model for seven characters in barley cross 'BG 25'×'NP 21'

Character	Environment	Gene effects							
		(m)	(d)	(h)	(i)	(j)	(l)	(χ^2) 1 d.f.	*P*
1	2	3	4	5	6	7	8	9	10
Days to heading	E_1	93.14** ±0.15	0.01 ±0.03	8.15** ±0.19	2.45** ±0.42	−1.77 ±0.93	−30.34** ± 3.91	0.02	0.9 – 0.8
	E_2	85.80** ±0.36	0.72 ±1.08	7.21** ±1.51	1.19 ±1.41	2.06 ±1.27	−16.28** ± 3.59	61.20**	0.0005
Plant height (cm)	E_1	107.80** ±0.03	1.53* ±0.75	14.23** ±2.75	28.49** ±5.11	9.76 ±7.13	−41.90** ± 0.03	0.03	0.9 – 0.8
	E_2	68.63** ±0.50	4.11** ±1.71	−8.12** ±2.16	−8.89** ±2.04	−7.32** ±2.17	33.10** ± 5.75	14.47*	0.0005
Ear length (cm)	E_1	7.36** ±0.12	0.68 −3.31	− 1.95 ± 1.36	4.98** ±0.01	3.90** ±0.05	1.96 ± 4.36	9.05	0.005 – 0.001
	E_2	7.64** ±0.08	0.79** ±0.25	− 0.77** ± 0.14	0.60 ±0.40	0.60* ±0.29	− 1.65 ± 0.95	12.25*	0.0005
Grains per ear	E_1	70.19** ±0.03	7.79** ±2.32	−15.58** ± 4.14	9.91 ±6.21	20.35** ±7.03	23.02** ± 6.20	1.78	0.2 – 0.1

* Significant at 5% level; ** Significant at 1% level; E_1 = Normal soil; E_2 = Saline-alkali soil

Table 6. Estimation of the components of generation means on a 6-parameter model for seven characters in barley cross 'BH 15'×'RD 103'

Character	Environment	Gene effects							
		(m)	(d)	(h)	(i)	(j)	(l)	(χ^2) 1 d.f.	*P*
1	2	3	4	5	6	7	8	9	10
Days to heading	E_2	85.26** ±0.32	5.97** ±1.18	2.25 ± 2.12	0.39 ± 0.93	− 6.98** ± 1.30	− 3.31 ± 3.73	2.82	0.1 – 0.05
Plant height (cm)	E_1	103.22** ±0.67	1.12 ±2.42	0.58 ± 3.20	0.85** ± 0.07	−16.76** ± 2.55	−12.25 ± 7.14	9.30	0.005 – 0.001
	E_2	59.78** ±0.64	9.04** ±2.19	−18.26** ± 1.96	−23.75** ± 1.98	−25.66** ± 2.55	54.98** ± 6.24	35.51**	0.0005
Tillers per plant	E_1	11.06** ±0.29	2.35** ±0.20	0.75 ± 1.00	0.04 ± 0.93	5.22** ± 1.24	8.02** ± 2.91	5.17	0.025 – 0.01
	E_2	4.01** ±0.08	0.23 ±0.31	− 1.32** ± 0.31	− 1.24** ± 0.27	0.46 ± 0.97	4.74** ± 1.32	1.94	0.02 – 0.01
Ear length (cm)	E_1	8.96** ±0.08	0.39 ±0.26	0.79 ± 0.45	0.63 ± 0.40	2.67** ± 0.30	− 3.39** ± 0.09	19.64**	0.0005
	E_2	7.89** ±0.07	1.64** ±0.26	1.05** ± 0.22	− 0.13 ± 0.21	− 2.52** ± 0.31	2.77** ± 0.71	16.36**	0.0005
Grains per ear	E_1	73.51** ±0.61	5.51* ±2.27	0.31 ± 3.45	1.01 ± 3.13	−13.99** ± 2.67	13.95 ± 8.05	13.19*	0.0005
	E_2	65.22** ±0.58	4.99* ±2.54	− 0.33 ± 2.02	− 6.27** ± 1.94	− 0.91** ± 2.93	28.91** ± 6.82	1.04	0.04 – 0.3
100-grain weight (g)	E_2	3.87** ±0.04	0.19 ±0.18	− 0.14 ± 0.14	0.10 ± 0.13	− 0.35 ± 0.20	1.44** ± 0.49	0.83	0.4 – 0.3
Yield per plant (g)	E_1	30.09** ±1.17	11.52 ±6.26	− 0.83 ± 3.89	− 4.15 ± 3.88	10.57** ± 6.45	34.86** ±12.56	3.14	0.1 – 0.5
	E_2	9.41** ±0.18	0.13 ±0.69	− 2.90 ± 0.68	− 0.41 ± 0.63	0.14 ± 0.85	20.02** ± 2.18	4.40	0.05 – 0.025

* Significant at 5% level; ** Significant at 1% level; E_1 = Normal soil; E_2 = Saline-alkali soil

found significant for grain yield under normal soil conditions.

The cross 'C 164' × 'EB 1556' exhibited a complementary epistatic interaction for 100-grain weight, while that for grain yield conformed to a duplicate epistatic system. However, the detected estimates of components of epistasis for days to heading, plant height and grains per ear in the case of 'BG 25' × 'NP 21' corresponded to the requirement of duplicate epistatic systems (h and l having opposite algebraic sign). As regards 'BH 15' × 'RD 103', the complementary type of epistasis was observed for days to heading (normal soil) only, while it belonged to the duplicate type for days of heading (saline-alkali soil), tillers per plant, grains per ear and yield per plant (normal soil).

Discussion

The joint scaling test of Cavalli (1952) indicated that differences for any of the characters in the cross 'C 164' × 'EB 1556'; for days to heading, plant height and ear length in 'BG 25' × 'NP 21'; and for plant height, tillers per plant, ear length, grains per ear and yield per plant in the cross 'BH 15' × 'RD 103' could not be explained by 3-parameter model either in normal soil or in saline-alkali soil. The high incidence of the non-conformity of the various characters to a 3-parameter model implies that the assumption of no epistasis among them was unrealistic. The joint scaling test given by Cavalli (1952) effectively combines the whole set of scaling tests and offers a more general, convenient, adaptable and informative approach for estimating gene effects and testing the adequacy of a simple additive-dominance model.

Many recent studies reported in self-pollinated crops also showed the importance of non-allelic interactions (Stuber 1970; Chapman and McNeal 1971; Singh and Ramanujam 1972; Sun et al. 1976; Gill et al. 1977; Singh and Singh 1978; Naidu 1979).

The estimates of the different components of gene effects indicated that in general the expression of the dominance component suffered more than the additive component in stress soil. However, the estimates of various effects are valid under the assumptions: (i) diploid segregation (ii) homozygous parents (iii) absence of multiple alleles (iv) absence of linkage (v) absence of lethal genes and (vi) no genotype-environment interaction. The first two assumptions are fairly met in a barley population. The other assumptions could not be tested. The failure of any assumption may cause bias in the estimates. The estimates of effects are expected to be biased due to linkage in the presence of epistasis only (Kempthorne 1957). Nevertheless, from components of epistasis it was evident that the additive × additive and dominance × dominance types of epistasis were important in 'BG 25' × 'NP 21', while dominance × dominance type of epistasis was more important in the other two crosses. However, in all the cases where the presence of epistasis was detected in the present material, the dominance × dominance (l) type was significant, except for the case of days to heading in the cross 'BH 15' × 'RD 103' under saline-alkali soil conditions. Moreover, the epistasis conformed to an expectation of the duplicate type rather than of the complementary one, the only exception being 100-grain weight of cross 'C 164' × EB 1556' under normal soil conditions.

The duplicate type of gene action has also been reported by Chapman and McNeal (1971) for number of spikes; by Katata et al. (1976) for heading date and grain yield; by Gill et al. (1977) for tiller number, plant height, spike length, spikelets per spike and grain yield. The duplicate of epistasis will create a problem to the breeder for improving such characters.

A comparision of normal *versus* saline-alkali soil environments with respect to estimates of gene effects revealed a high sensitiveness of the crosses to the adverse soil condition, particularly that of 'C 164' × 'EB 1556', which showed a complete departure from a 3-parameter model and an almost complete departure from a 6-parameter one based on the different characters. Similarly, all three characters of 'BG 25' × 'NP 21' which were to be tested for a fit to a 6-parameter model under saline-alkali soil deviated from this expectation. The cross 'BH 15' × 'RD 103', however, appeared to be far less sensitive and yielded a fit to a 6-parameter model for four of the characters. This cross can therefore be singled out as relatively the least sensitive to a saline-alkali soil condition among those tested and may be exploited for evolving the genotypes for saline-alkali soil conditions. These conclusions were also borne out by the relative mean values of the characters under consideration. The occurrence of epistasis for most of the characters indicated that the selection for such characters should be deferred until later generations; however, selection for various other characters such as tillers per plant, 100-grain weight and yield per plant in cross 'BG 25' × 'NP 21' can be practised in early generations.

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Book reviews

Hecht, M.K.; Wallace, B.; Prance, Gh.T. (eds): Evolutionary Biology, vol. 15. New York London: Plenum Press 1982. xiv + 442 pp., several figs. and tabs. Hard bound $ 49.50.

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One of the most interesting results of this study can be summarized as follows: In contrary to other studies in which evolution of a new metabolic function required only constitutive enzyme synthesis, evolution of the ability to use β-galactoside sugars required mutations in both regulatory and structural genes.

The purpose of Paper No. 3: "A Comparative Summary of Genetic Distances in the Vertebrates. Patterns and Correlations" by J. C. Avise and C. F. Aquadro is to review specifically the literature of genetic distances between vertebrate species based on conventional electrophoretic analyses of proteins. To be included in this review, a study had to satisfy the following criteria: a) calculated genetic distances must be based on information from 14 or more genetic loci, and b) at least three species from a genus must have been examined (or, in comparisons among genera, at least three genera per family). Studies on a total of 44 vertebrate genera and 16 families, representing over 3,800 pairwise comparisons of species, satisfy these criteria. Under neutral mutation pressure, low and intermediate values of NEI's D statistic are linearly related to time of divergence of two populations. These concepts and results have been intensively discussed using the above mentioned data of 44 genera and 16 families.

Finally, two characteristics of vertebrates, roughly correlated with D, are briefly discussed with reference to the