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GENOTYPIC VARIANCES AND INTERACTIONS WITH ENVIRONMENTS IN BARLEY GENOTYPES USING HALF DIALLELE ANALYSIS FOR GRAIN YIELD AND ITS ASSOCIATE CHARACTERS

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SUMMARY

The present investigation was carried out to study components of genetic variance, for yield and yield contributing traits in barley (*Hordeum vulgare* L.) using half diallele analysis. Ten genotypes along with their 45 F_1's and 45 F_2's were evaluated in three environments created by three different dates of sowing i. e. timely sown, late sown and very late sown, with three replications in a randomized block design during **rabi** 2015-16 at Agricultural Research Farm of RARI, Durgapura, Jaipur. Each replication contained two parts. First part consisted 10 parents and 45 F_1's sown in two rows plot, while the plots of second part consisted six rows of 45 F_2's. The pooled analysis of variance depicted significant differences for all the studied traits and indicated the influence of environment on the expression of these characters. Further, the mean sum of squares due to parents' *vs* F_1 and F_2 displayed significant difference for all the characters studied except plant height and tillers per plant. The G × E interaction was also found significant for most of the characters except tillers per plant, flag leaf area, spike length, taking into consideration, significant G × E interaction for most of the characters, the analysis of variance was done for the individual environment separately.

Key words : Genotypic variance, half diallele anaalysis, barley

Barley (*Hordeum vulgare* L. 2n=2x=14) is the world's fourth most important cereal crop after wheat, maize and rice. It is one of the widely grown **rabi** cereals in the temperate and tropical regions of the world. In India, it is grown on more than 671 thousand ha with the production of more than 1626 thousand tonnes with productivity of 2.5 q/ha. In Rajasthan, it is grown over an area about 393 thousand ha with annual production of 942 thousand tonnes with an average yield of 30.00 q/ha (Anonymous, 2014). Barley cultivation in India is now becoming oriented towards industrial utilization. Though presently only 12-15 per cent of total produce is being utilized for malting/brewing, but it is projected that by 2020 the demand will be more than double. Challenge to the breeders to breed varieties with high yield potential along with high malt requirement and greater stability for industrial utilization. The improved malt genotypes with early maturing and better tillering can further bridge the yield gap and can be helpful to meet the demand of quality grain for malting purpose. However, grain yield as well as component characters are highly influenced by environmental fluctuations, thus the study based on solitary environment may not be much useful because of genotype x environment interactions.

MATERIALS AND METHODS

The experiment was conducted at RARI, Durgapura, Jaipur which is situated at latitude of 26^0 49′north longitude of $75^0$48′ east and altitude of 450 metres above sea level in Jaipur district of Rajasthan. This region falls under agro-climatic zone-III a (semi-arid eastern plain) of the state. Durgapura has semi-arid type of climate with an average annual rainfall of about 400 mm, most of which is received between July to early September. Weather parameters play an important role in affecting plant growth and development of crop. Ten genetically diverse parents, namely, RD 2786, RD 2832, RD 2878, BH 946, BH 902, RD 2715, RD 2035, RD 2592, PL 751 and Jyoti, were selected for the present study. The 10 parents and their resulting 45 F_1's and 45 F_2's were grown in a randomized block design with three replications under normal (E_1), late (E_2) and very late (E_3) sown conditions during **rabi** 2015-16 (Table 1). Each plot was consisting of 3 m long two rows for non-segregating material i. e. parents and F_1s and six rows in F_2's. Row to row and plant to plant distance was kept at 30 and 10 cm, respectively, under all the three environments (Table 2 and Fig. 1). Twenty competitive

TABLE 1

Analysis of variance showing mean squares in individual environment of parents, F1's and F2's for yield and its contributing traits

Characters	Env.	Replications (2)	Treatment (99)	Parents (9)	Generation (89)	F1's (44)	F2's (44)	F_1vsF_2 (1)	Pvs generation	Error (198)
Spike area (cm^2)	E_1	4.09	53.54**	21.07**	54.06**	53.07**	55.81**	20.69*	300.00**	3.50
	E_2	4.13	57.20**	19.08**	57.91*	59.54**	57.06**	23.58**	337.36**	3.16
	E_3	1.73	57.86**	18.65**	58.99**	58.87**	59.53**	40.66**	310.58**	3.18
No. of spikelets/spike	E_1	0.60	13.94**	6.54**	14.75**	14.72**	15.07**	2.23	8.79**	1.13
	E_2	2.24	14.27**	6.80**	15.09**	15.36**	15.05**	5.03	8.31*	1.34
	E_3	1.15	12.76**	7.34**	13.42**	15.34**	11.80**	0.03	3.46	1.06
No. of grains/spike	E_1	21.77	501.98**	235.61**	531.00**	529.75**	542.51**	80.14	316.61**	40.81
	E_2	80.58	513.72**	244.74**	543.33**	553.12**	541.78**	180.96	299.20*	48.13
	E_3	41.29	459.54**	264.12**	483.06**	552.25**	424.83**	1.02	124.64	38.29
1000-grain weight (g)	E_1	4.21	118.00**	38.12**	127.36**	169.25**	82.89**	241.48**	3.39	3.10
	E_2	3.14	131.76**	47.77**	141.72**	176.09**	108.68**	83.14**	2.01	3.27
	E_3	0.39	210.83**	53.12**	226.74**	195.80**	252.64**	448.15**	214.07**	2.90
Harvest index (%)	E_1	0.46	27.98**	0.12	31.09**	60.86**	0.48	68.40**	1.48	0.67
	E_2	0.59	33.78**	0.16	37.55**	74.04**	0.60	57.98**	0.94	1.68
	E_3	2.75	33.61**	0.63	37.32**	71.45**	2.89	50.74**	0.07	2.95
Grain yield/plant (g)	E_1	0.23	274.26**	89.30**	286.74**	253.18**	309.85**	746.00**	828.50**	2.29
	E_2	0.22	274.25**	88.13**	286.85**	253.09**	310.14**	747.24**	827.90**	3.12
	E_3	0.19	307.79**	97.13**	326.29**	286.33**	357.86**	696.04**	556.83**	2.59
Malt per cent	E_1	0.03	57.60**	38.80**	59.80**	56.46**	63.35**	50.74**	30.42**	0.52
	E_2	0.01	58.87**	44.66**	60.14**	57.32**	62.78**	68.19**	73.89**	0.61
	E_3	0.09	56.61**	40.53**	58.49**	54.92**	62.74**	29.00**	34.24**	0.79

TABLE 2

Mean values of genotypes for yield and its contributing attributes

Character	Spike area (cm^2)			Spike length (cm)			No. of spikelets/spike			No. of grains/spike		
Parent/Env.	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
P_1	28.01	27.94	26.04	9.62	9.60	8.29	11.37	11.40	10.86	68.22	68.42	65.16
P_2	28.33	27.38	26.61	7.77	7.62	7.55	9.70	9.57	9.31	58.20	57.40	55.86
P_3	25.79	25.72	25.04	8.06	8.07	7.97	9.57	9.20	9.20	57.40	55.20	55.20
P_4	25.48	25.50	25.45	8.18	8.17	7.72	9.67	9.34	9.02	58.04	56.04	54.10
P_5	25.45	25.45	24.45	8.10	8.10	7.67	8.12	8.05	7.03	48.70	48.30	42.20
P_6	28.80	29.11	28.48	9.17	9.15	8.97	11.08	11.04	10.80	66.48	66.22	64.78
P_7	30.76	30.15	29.53	8.88	8.82	8.62	10.30	10.17	10.03	61.80	61.00	60.20
P_8	30.13	29.52	28.56	8.09	8.07	7.94	7.99	7.70	7.30	47.94	46.18	43.82
P_9	24.18	24.16	22.91	6.41	6.41	5.87	7.60	7.51	7.10	45.62	45.08	42.60
P_{10}	22.62	22.33	21.83	6.26	6.26	5.72	7.10	7.02	6.91	42.60	42.12	41.48

Character	1000-grain weight (g)			Harvest index (%)			Grain yield/plant (g)			Malt per cent		
Parent/Env.	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
P_1	48.11	48.12	47.06	50.23	49.39	49.48	29.45	29.38	28.12	82.49	82.86	82.05
P_2	42.99	40.16	38.00	46.78	46.57	45.68	18.38	18.27	17.15	76.50	75.46	75.79
P_3	41.34	41.46	40.12	47.77	47.29	47.17	20.17	20.12	18.71	74.87	74.31	74.18
P_4	40.01	39.97	37.83	48.93	48.47	47.62	25.41	25.30	22.16	72.84	72.52	71.50
P_5	40.18	40.30	38.64	48.52	48.32	47.46	23.41	23.11	19.35	74.69	74.63	73.61
P_6	46.34	46.26	45.14	51.14	50.15	48.17	27.91	27.86	25.93	77.61	77.69	77.25
P_7	44.49	44.41	43.64	52.31	51.49	49.68	26.93	26.87	25.75	83.06	82.38	82.50
P_8	43.87	42.87	41.31	49.85	48.80	46.33	21.11	21.08	20.22	77.73	77.17	77.12
P_9	40.30	38.60	36.83	46.78	46.36	46.45	16.31	16.30	13.53	79.75	78.44	77.58
P_{10}	35.82	34.24	33.08	40.92	40.70	40.01	12.51	12.56	9.91	73.20	71.18	71.25

P_1=RD2786, P_2=RD2832, P_3=RD2878, P_4=BH946, P_5=BH902, P_6=RD2715, P_7=RD2035, P_8=RD2592, P_9=PL751 and P_{10}=Jyoti plants in parents and F_1's and 60 plants in F_2's progenies were selected randomly for recording observations for following characters i.e. spike area, spikelets per spike, number of grains per spike, 1000-grain weight, harvest index, grain yield per plant and malt per cent under three environments (dates of sowing) separately. The mean values of different parents, F_1's and F_2's for all the characters were subjected to analysis of variance separately for individual environment as well as for pooled data to determine the significance of differences among genotypes, environments and genotype x environment interaction effects (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

The significant differences among all the three environments for all the studied traits viz., spike area, spikelets per spike, number of grains per spike, 1000-grain weight, harvest index, grain yield per plant and malt per cent were observed. Pooled analysis of variance possessed diversified effects of environment on the expression of these traits.

In view of significant G x E interaction for 50 per cent of the characters, the analysis of variance was done in the individual environment separately (Table 1). The results showed significant differences in the genotypes (parents, F_1's and F_2's); parents; generation (F_1's and F_2's); for all the characters in each environment. The genotypic mean squares were further partitioned into components due to parents *vs* generation (F_1's and F_2's); and generation in to F_1's vs. F_2's. Among parents *vs* generation (F_1's and F_2's) the mean squares were found significant for most of the traits (except 1000 grain weight in E_1&E_2 and harvest index in E_1, E_2 & E_3) and F_1's vs F_2's (except spikelets per spike and number of grains per spike) for all the studied traits in all the three environments.

The pooled analysis of variance revealed highly significant differences among the genotypes indicating that material used had enough genetic diversity (Table 2). Significant differences among sowing dates also indicated the differential influence of environment on the character expression. The genotypes x environment interaction were found significant for 50 per cent of the characters except spike area, spikelets per spike, number of grains per spike and malt per cent indicating existing of non-linear response of genotypes to the varying environments. This is in conformity with reports that G × E interaction is common in crop plant species (Arati *et al*., 2015; Patial *et al*. 2016). Taking into consideration, significant G × E interaction for most of the characters, the analysis of variance was done for the individual environment separately. The analysis of variance in individual environment revealed significant differences among the genotypes for all the characters, consequently established the circumstances that the characters manifested the presence of ample genetic diversity among the parents. Further analysis revealed significant mean squares due to generations and parents (except harvest index) for all the characters in all the three environments. Mean squares due to F_1 and F_2 (except harvest index) were found significant for all the characters in all the environments. Mean squares due to F_1 *vs* F_2 were found significant for all the characters except for spikelets per spike and number of grains per spike which supported the presence of inbreeding depression in all the three environments. The differences among parents *vs* generations were significant for all the traits indicating the presence of heterosis in all the three environments except for tillers per plant, in three environments (Table 4), Raikwar *et al.* (2014) for flag leaf area, while Singh *et. al.* (2003) for plant height, number of tillers per plant, flag leaf area and harvest index.

Perusal of Table 3 established an interesting relation between sca effects of grain yield per plant and other yield attributing traits. The crosses, which showed desirable sca effects for grain yield per plant, also exhibited desirable sca effects for one or more yield attributing traits. The crosses PL 751 x Jyoti, RD 2832 x RD 2035 and RD 2786 x RD 2715 in E_1, PL 751 x Jyoti, RD 2786 x BH 946 and RD 2786 x RD 2035 in E_2 and PL 751 x Jyoti, RD 2786 x BH 946 and RD 2786 x RD 2035 in E_3 appeared as good specific cross combinations for grain yield and some associated traits. The parents RD 2786, RD 2715, RD 2035, PL 751 and Jyoti involved in these crosses were good general combiners for grain yield and one or two yield contributing traits, while the other parents were emerged as poor combiners. An overall appraisal revealed that the crosses RD 2786 x RD 2715 and RD 2786 x BH 946 in all the three environments emerged

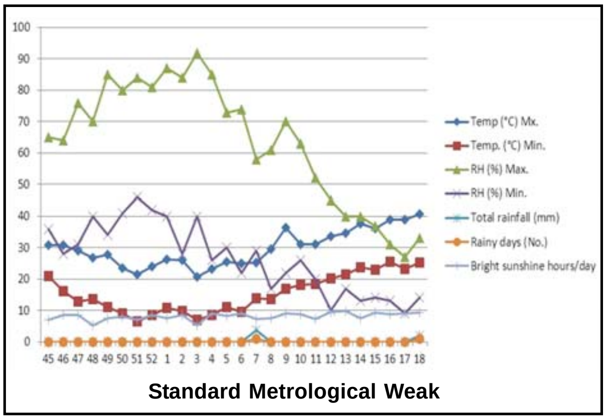

Fig. 1. Meteorological data of Durgapura for **rabi** 2015-16.

TABLE 3

Top crosses possessing high sca effects along with their *per se* performance for grain yield per plant and significant desirable (+) sca effects for other characters in different environments in F_1's and F_2's

Environments	Generation	Best crosses based on desirable gca effects and *per* se performance for grain yield/plant	Spike area (cm²)	Spike length (cm)	No. of spikelets/ spike	No. of grains/ spike	1000-grain weight (g)	Harvest index (%)	Malt per cent
E_1	F_1	RD2786 x RD2715	-	+	+	+	-	-	-
	F_2	RD2786 x BH946	-	-	-	-	-	-	-
E_2	F_1	RD2786 x BH946	-	+	+	+	-	-	-
	F_2	RD2786 x BH946	-	+	-	-	-	-	-
	F_1	RD2786 x RD2715	-	+	+	+	-	-	-
	F_2	RD2786 x RD2715	-	-	+	+	-	-	-
E_3	F_1	RD2786 x BH946	-	+	+	+	-	-	-
	F_2	RD2786 x BH946	-	-	-	-	-	-	-
	F_1	RD2786 x RD2715	--	+	+	+	-	-	-
	F_2	RD2786 x RD2715	-	-	+	+	-	-	-

TABLE 4

Top crosses possessing high heterosis and heterobeltiosis for grain yield per plant (g) along with desirable (+) heterotic expression for other characters in different environments

Particulars	Environments	Crosses	Spike area (cm²)	Spike length (cm)	No. of spikelets/ (cm)	No. of grains/ spike	1000-grain weight (g)	Harvest index	Malt per cent
Heterosis	E_2	RD2786 x RD2715	-	+	+	+	-	-	+
		RD2786 x RD2035	-	+	-	-	+	-	-
	E_3	RD2786 x RD2715	-	+	+	+	-	-	-
		RD2786 x RD2035	-	+	-	-	+	+	-
Heterobeltiosis	E_1	RD2786 x RD2715	+	+	+	+	+	+	+
		RD2786 x RD2035	-	+	+	+	+	-	+
	E_2	RD2786 x RD2715	-	+	+	+	-	-	+
		RD2786 x RD2035	-	+	+	+	+	-	+
	E_3	RD2786 x RD2715	-	+	+	+	+	-	+
		RD2786 x RD2035	-	+	+	+	-	-	+

as good specific cross combinations for grain yield.

Best heterotic and heterobeltiotic crosses for grain yield per plant are presented in Table 4. Perusal of this table indicate that the crosses PL 751 x Jyoti, RD 2832 x RD 2035 and RD 2832 x RD 2715 in E_1, E_2 and E_3 emerged as good heterotic as well as heterobeltiotic crosses for grain yield per plant. Among top three crosses for grain yield per plant in all the environments, the crosses PL 751 x Jyoti, RD 2832 x RD 2035 and RD 2832 x RD 2715 showed desirable heterosis and heterobeltiosis for one or more characters in all the environments. Hence, these crosses may be considered as promising type for tangible advancement of six-rowed barley yield under normal sown and thermal stress condition.

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