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GENOTYPIC ANALYSIS FOR HEAT SUSCEPTIBILITY INDEX IN TWO ENVIRONMENTS IN BARLEY FOR GRAIN YIELD AND ITS ASSOCIATE TRAITS

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Abstract

The present investigation was carried out to study Heat susceptibility index in barley (*Hordeum vulgare L.*). Ten genotypes along with their 45 F_1's and 45 F_2's were evaluated in 3 environments created by three different dates of sowing *i.e.* timely sown, late sown and very late sown, with 3 replications in a randomized block design during *Rabi* 2015-16 at Agricultural Research Farm of RARI Durgapura, Jaipur (Rajasthan), India. Each replication contained two parts. Row length was kept 3 meter. Row to row and plant to plant distance was kept 30 cm and 10 cm, respectively. Observations were recorded for days to heading, days to maturity, plant height, number of tillers per plant, flag leaf area, peduncle area, spike length and grain yield per plant on 20 randomly selected plants in each of the F_1's progenies along with each parent, while 60 plants were selected in F_2's population from each replication. The impact of climate change is clearly evident from recent vagaries across regions in India. Although North-West Plain Zone (NWPZ) has weather conditions more favourable in comparison to Central Zone (CZ), the barley yield under late sown condition is comparatively lower in this zone of the country. Hence, national programme leaders identified improving thermal tolerance of barley as being a major research priority.Therefore, breeding aimed at selecting genotypes with thermal stress tolerance is one of the most vital objectives of the barley breeders.

Keeping the above facts in view, the present study was conducted to magnify the yield level of barley in high temperature areas by selecting stress tolerant parents for future breeding programme. The results of present investigation demonstrated that in comparison to normal sown (E_1), mean performance of parents, declined under very late sown (E_2) conditions.

The HSI value of parents and crosses has been ranked for each trait as per the criterion mentioned in above. The overall ranking indicated that parent RD 2786, RD 2715 and RD 2035 were most desirable parents in both the environments as they were included in top three parents for most of the characters. Among the crosses, RD 2786 × RD 2715 and RD 2786 × BH 946 in E_1 and in E_2 were most desirable for future breeding programme as they attained top five rank for more characters.

Key words : Barley, HSI, associate characters, grain yield, environments.

Introduction

Barley (*Hordium vulgare* L. 2n = 2x = 14) is the worlds' 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. Today barley is grown in 49781 thousand ha. The world production of barley is about 144755 thousand tons with Europe largest of producer, due to the highest yield (Anonymous, 2014). The major barley producing countries of world are Canada, USA, Germany, France, Spain, Turkey, UK, Denmark, Russia, Central Asian States and Australia. Barley has also been very important winter cereal crop in India. 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 (Anonymous, 2014). Barley is an important Rabi cereal next to wheat in acreage and production in Rajasthan also. In Rajasthan, it is grown over an area about 393 thousand ha with annual production of 942 thousand tonnes with an average yield of 30.00q/ha (Anonymous, 2014). Barley cultivation in India is now becoming oriented towards industrial utilization. Though, presently only 12-15% of total produce

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7is being utilised 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 utilisation. 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 × environment interactions.

Materials and Methods

The experiment was conducted at RARI Durgapura Jaipur is situated at latitude of 26^0 49' north longitude of $75^0$48' east and altitude of 450 meters above sea label in Jaipur district of Rajasthan. This region falls under agro climatic zone, III a (semi-arid eastern plain) of the state. Durgapura Jaipur has semi-arid type of climate with an average annual rainfall of about 400 mm, most of which 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 present study. The ten 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, late and very late sown conditions during *Rabi* 2015-2016 (table 1). Each plot was consisting of 3 m long two rows for non-segregating material *i.e.* parents and F_1's and six rows in F_2's. Row to row and plant to plant distance were kept at 30 cm and 10 cm, respectively under all the two environments Twenty competitive 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.* days to heading, days to maturity, plant height, number of tillers per plant, 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 E_1 (Normal sowing 15.11.2015) and (Very Late sowing 15.12.2015), separately. Heat susceptibility index was calculated for grain yield and other attributes over high temperature stress (late sown) and non-stress (normal sown) by using the formula as suggested by Fisher and Maurer (1978):

$$\text{Heat susceptible index} = \frac{(1-Yd/Yp)}{D}$$

Where,

Yd = mean of the yield of genotypes in stress environment (late sown).

Yp = mean of the genotypes under non-stress environment (normal sown).

D = 1 – (mean of Yd of all genotypes/ mean of Yp of all genotypes).

Results and Discussion

Perusal of table 1 revealed that among the parents, RD 2035, RD 2715 and RD 2786; in F_1 crosses RD 2786 × RD 2035, RD 2786 × JYOTI, RD 2832 × RD 2878, RD 2832 × RD 2715, RD 2715 × RD 2035 and RD 2832 × RD 2592 and in F_2, RD 2786 × BH 946, RD 2786 × RD 2878, RD 2786 × RD2832 and Raj PL751 × JYOTI were least affected under late sown conditions (E_3) for grain yield per plant.

High grain yield of a genotype under late sown condition indicated the presence of genes for heat tolerance. Comparison across the environments indicated that the crosses RD 2786 × RD 2035, RD 2786 × PL 751, RD 2832 × RD 2878, RD 2715 × RD 2035 and RD 2215 × RD 2592 in F_1 and RD 2786 × BH 946, RD 2786 × RD 2878, RD 2786 × RD 2832 RD 2786 × RD 2035 and PL 751 × JYOTI in F_2 emerged as highly heat tolerant for grain yield per plant while resemblance across the generations for different characters indicated the superiority of the crosses RD 2878 × RD 2035 and RD 2832 × RD 2035 under very late sown condition (E_3).

The HSI value of parents and crosses has been ranked for each trait as per the criterion described above. The overall ranking indicated that parent RD 2786, RD 2035 and RD 2715 were most desirable parents in both the environments as they were included in top three parents for most of the characters. Among the crosses, RD 2878 × RD 2035 followed by RD 2832 × RD 2878, RD 2832 × RD 2715, and RD 2832 × RD 2035, RD 2878 × RD 2715, BH 946 × RD 2715 and BH 902 × RD 2035, in E_3F_1 and RD 2786 × RD 2832 followed by RD 2786 × RD 2878, RD 2786 × RD 2715 and RD 2832 × RD 2715, in E_3 F_2 were most desirable as they attained top five rank for more than two characters.

Low value of heat stress intensity (D-value) indicated that parameters *viz*., plant height, flag leaf area, harvest index, spike length and 1000 grain weight, showed more tolerance in E_3F_1 while plant height, flag leaf area, peduncle area, spike length showed more tolerance in E_3F_2. Similar findings were also observed for days to heading, days to maturity, spike length, plant height and harvest index by Singh *et al*. (2011).

The characters *viz*., grain yield per plant, peduncle

Table 1 : Heat susceptibility indices for various characters in E_3 in comparison to E_1 environment in barley.

Parents	Days to heading	Days to maturity	Spikelets per spike	Plant height (cm)	Flag leaf area (cm²)	Peduncle area (cm²)	Tillers per plant	Spike length (cm)	Spike area (cm²)	Number of grains per spike	1000-grain weight (g)	Harvest index (%)	Grain yield per plant (g)	Malt per cent
RD 2786 (1)	0.96	0.43	0.64	0.07	1.14	0.76	0.43	2.74	1.52	0.64	0.19	0.36	0.39	0.33
RD 2832 (2)	1.04	0.43	0.58	2.43	0.81	0.80	0.31	0.55	1.31	0.57	0.98	0.59	0.55	0.57
RD 2878 (3)	0.17	0.57	0.55	2.16	0.32	0.53	0.46	0.22	0.63	0.55	0.25	0.31	0.59	0.57
BH 946 (4)	0.69	0.30	0.97	2.81	2.19	1.35	0.91	1.12	0.39	0.97	0.46	0.67	1.04	1.14
BH 902 (5)	1.20	0.38	1.92	0.44	1.51	1.75	1.52	1.06	0.84	1.90	0.33	0.55	1.42	0.89
RD 2715 (6)	1.01	0.57	0.37	2.11	0.72	0.36	0.33	0.42	0.23	0.36	0.22	1.45	0.58	0.29
RD 2035 (7)	0.08	0.99	0.37	1.17	8.34	0.71	0.80	0.60	0.86	0.37	0.16	1.26	0.36	0.42
RD2592 (8)	0.58	0.69	1.23	2.04	0.15	0.35	0.58	0.36	1.12	1.23	0.49	1.77	0.31	0.49
PL 751(9)	0.62	0.60	0.95	1.47	1.66	1.41	1.97	1.67	1.13	0.94	0.73	0.17	1.33	1.69
JYOTI (10)	1.25	0.21	0.38	1.23	1.13	1.76	1.84	1.73	0.75	0.38	0.65	0.56	1.69	1.65
F_1 crosses														
P1 × P2	1.00	0.54	1.17	0.65	0.79	0.49	0.57	0.96	0.37	1.16	0.40	0.17	0.44	1.39
P1 × P3	1.11	0.43	0.63	1.02	0.05	0.73	0.54	0.66	0.50	0.63	0.25	0.43	0.38	0.77
P1 × P4	0.17	0.56	0.72	1.16	1.27	0.36	1.16	0.53	0.91	0.71	0.67	0.78	0.42	0.80
P1 × P5	0.25	0.16	1.15	0.53	1.78	1.24	1.44	0.97	1.16	1.15	0.46	0.64	0.53	0.62
P1 × P6	0.41	0.30	0.36	0.73	1.58	0.37	0.46	0.48	0.33	0.35	0.17	0.30	0.47	0.68
P1 × P7	0.85	0.26	0.55	0.88	0.32	0.63	0.50	0.63	0.45	0.54	0.21	0.46	0.30	0.24
P1 × P8	0.66	0.55	0.39	1.02	0.95	2.68	1.88	1.87	0.71	0.39	0.30	0.35	1.41	0.81
P1 × P9	0.47	0.35	1.82	0.87	2.19	1.19	4.10	4.83	5.24	1.81	1.30	1.67	0.13	1.15
P1 × P10	1.34	0.21	-0.96	0.59	1.86	0.59	2.88	0.36	0.93	-0.95	1.57	1.05	0.68	0.26
P2 × P3	0.64	0.58	0.05	0.79	2.50	0.83	4.87	0.11	0.20	0.05	0.14	0.48	0.33	1.15
P2 × P4	0.72	0.67	0.30	0.36	0.20	0.35	1.58	0.05	0.82	0.30	1.49	1.71	0.75	1.20
P2 × P5	1.11	0.67	0.78	1.23	0.16	0.80	0.84	1.89	2.05	0.78	1.51	2.17	0.77	1.34
P2 × P6	0.18	0.20	0.06	1.20	0.03	3.93	1.15	0.51	0.46	0.06	0.37	0.32	0.34	0.48
P2 × P7	0.43	0.30	0.11	1.41	0.81	4.02	1.18	0.28	0.14	0.11	0.16	0.34	0.37	0.61
P2 × P8	1.37	0.73	0.41	1.62	0.46	0.42	0.48	0.34	0.37	0.41	0.22	0.26	0.90	0.53
P2 × P9	1.13	0.91	1.17	0.37	0.37	2.33	-1.03	0.53	0.57	1.16	0.78	3.26	2.43	1.05
P2 × P10	1.43	0.58	1.29	1.02	0.70	3.22	1.18	0.52	0.56	1.28	1.42	2.49	0.91	1.20
P3 × P4	0.66	0.99	1.48	0.71	0.71	0.84	0.66	1.92	0.94	1.47	1.39	2.55	1.13	1.14
P3 × P5	0.41	1.05	2.04	1.89	0.11	2.51	0.78	1.82	0.67	2.03	0.60	0.30	1.25	1.65
P3 × P6	0.94	0.25	0.06	1.17	0.28	0.49	0.30	0.36	0.29	0.06	0.30	0.20	0.88	1.11
P3 × P7	1.80	0.44	0.18	0.77	1.11	2.73	0.07	0.21	0.18	0.18	0.32	0.22	1.16	1.43

Table 1 continued....

Table 1 continued....

P3 × P8	1.33	0.91	0.36	0.81	0.52	0.94	-0.79	0.33	0.36	0.36	0.04	0.71	0.69	1.23
P3 × P9	1.83	0.89	1.41	1.08	0.99	3.62	0.61	4.25	4.61	1.40	0.87	1.52	1.20	1.41
P3 × P10	1.31	1.06	0.79	0.88	0.66	1.45	1.46	2.22	2.41	0.78	1.43	0.65	1.11	0.68
P4 × P5	2.24	1.36	2.17	1.03	1.26	0.59	1.58	0.45	1.25	2.16	1.96	5.54	2.16	1.67
P4 × P6	3.11	1.46	0.14	0.70	1.52	0.28	0.17	1.65	1.79	0.14	0.51	1.62	1.18	1.12
P4 × P7	0.90	1.53	0.49	0.41	1.29	1.76	0.30	0.08	0.09	0.48	0.33	0.53	1.17	1.46
P4 × P8	1.72	1.50	2.08	1.06	0.75	1.39	0.84	0.79	0.86	2.06	1.73	1.39	1.66	0.97
P4 × P9	1.20	1.38	2.30	0.71	1.41	1.62	1.21	3.21	3.49	2.29	0.84	0.04	1.98	1.58
P4 × P10	1.35	1.13	0.44	0.59	3.07	0.71	2.17	0.67	0.73	0.44	0.59	2.79	2.66	1.10
P5 × P6	1.56	1.37	0.12	1.12	0.51	1.22	2.30	0.58	0.63	0.12	0.16	0.76	1.37	1.90
P5 × P7	0.25	1.33	0.06	1.11	1.04	0.48	3.27	1.35	1.46	0.06	0.40	0.53	0.93	0.90
P5 × P8	1.30	1.17	1.20	0.71	2.33	1.82	1.32	1.33	1.45	1.19	1.35	0.52	1.79	1.25
P5 × P9	3.07	1.23	1.43	0.48	2.12	0.44	1.23	2.04	2.22	1.42	0.21	1.33	2.58	0.79
P5 × P10	1.74	1.28	2.04	0.50	0.94	0.86	1.25	0.86	0.94	2.03	0.41	1.10	2.26	1.22
P6 × P7	0.17	0.25	1.34	0.62	0.87	0.34	0.69	0.36	0.42	1.33	0.37	0.84	0.15	1.47
P6 × P8	0.42	0.25	0.70	1.62	0.53	2.05	0.74	1.06	0.46	0.70	0.23	0.62	0.26	1.42
P6 × P9	1.09	0.50	0.99	0.62	0.77	1.03	0.82	3.31	3.59	0.98	0.93	2.97	1.08	0.88
P6 × P10	1.10	1.04	0.91	0.68	1.00	0.24	1.52	0.83	0.91	0.91	0.36	0.41	1.82	1.57
P7 × P8	0.87	1.07	2.22	0.66	1.71	1.42	0.75	0.61	0.35	2.21	0.44	1.59	1.47	1.85
P7 × P9	1.04	1.10	1.35	0.03	0.91	0.49	0.77	1.76	1.91	1.34	0.62	0.89	1.76	0.94
P7 × P10	0.86	1.04	0.94	0.74	1.32	1.06	0.45	0.90	0.20	0.94	0.44	0.38	0.47	0.64
P8 × P9	0.86	0.54	1.35	0.63	1.11	1.00	0.28	0.48	0.52	1.34	0.50	0.24	0.95	0.45
P8 × P10	1.47	0.65	1.02	0.50	0.90	0.32	1.88	0.64	0.70	1.01	0.40	0.55	1.40	0.96
P9 × P10	2.23	0.54	2.22	1.21	1.57	1.71	1.90	1.68	1.16	2.20	0.25	0.84	0.43	0.53
F_2 crosses														
P1 × P2	0.81	0.14	0.35	0.24	0.14	1.84	0.53	1.05	0.65	0.35	0.09	0.38	0.21	1.30
P1 × P3	0.83	0.23	1.33	0.20	-0.50	1.43	0.91	0.58	0.61	1.32	0.14	0.33	0.20	1.11
P1 × P4	0.33	0.11	1.55	2.54	1.86	1.43	0.43	2.00	1.73	1.54	0.62	0.33	0.16	0.85
P1 × P5	0.59	0.83	2.17	1.31	1.90	1.22	0.63	2.52	1.81	2.16	0.75	0.78	0.55	1.19
P1 × P6	0.25	0.45	0.48	0.35	-0.22	0.64	0.54	0.40	0.47	0.48	0.08	0.27	0.27	1.44
P1 × P7	0.49	0.37	0.73	0.73	1.10	0.41	0.54	1.01	0.32	0.72	0.30	0.47	0.21	1.07
P1 × P8	0.41	0.79	0.56	0.70	2.11	1.48	0.90	0.20	0.52	0.55	0.08	0.91	1.94	1.07
P1 × P9	0.77	1.13	0.84	0.87	0.50	0.68	2.16	1.01	1.10	0.83	1.44	0.18	1.89	0.96
P1 × P10	1.39	0.99	1.13	0.14	2.79	0.24	1.60	0.29	0.68	1.13	1.67	2.05	1.71	0.34
P2 × P3	0.70	0.69	1.26	0.85	2.76	2.53	0.47	1.12	0.93	1.25	0.07	0.90	3.03	0.71

Table 1 continued....

Table 1 continued....

P2 × P4	1.88	1.08	0.85	0.12	1.87	0.17	0.89	0.87	0.94	0.85	1.44	4.36	0.94	1.34
P2 × P5	1.12	1.00	1.42	1.66	3.60	1.65	1.36	0.05	0.51	1.41	1.58	0.15	1.49	1.30
P2 × P6	0.97	0.23	0.65	1.35	0.06	0.99	0.52	0.89	0.49	0.65	0.23	0.50	0.38	0.78
P2 × P7	0.60	0.39	1.37	1.08	0.05	0.76	1.42	0.10	0.27	1.36	2.74	0.33	0.51	1.14
P2 × P8	1.13	1.47	1.19	1.52	0.54	0.56	1.18	0.41	0.44	1.18	2.61	1.33	0.76	0.94
P2 × P9	0.53	1.33	1.80	0.16	0.11	1.86	0.75	1.42	1.54	1.79	3.04	1.63	0.97	1.16
P2 × P10	0.56	1.54	0.56	0.94	0.92	1.10	0.58	2.93	3.18	0.56	2.93	0.86	1.66	0.97
P3 × P4	1.20	1.71	1.08	0.83	0.97	0.83	1.33	1.79	1.95	1.07	3.21	2.94	1.76	1.21
P3 × P5	1.36	1.07	2.00	2.31	0.41	1.47	0.52	0.35	-0.38	1.99	2.31	1.60	1.49	1.28
P3 × P6	0.16	1.20	0.61	0.79	0.01	0.92	2.32	0.37	0.57	0.61	2.65	0.31	0.28	1.08
P3 × P7	0.75	0.36	0.51	1.11	1.08	0.10	2.18	0.82	0.45	0.50	2.18	0.31	1.04	1.18
P3 × P8	1.29	0.22	0.82	1.65	0.96	0.33	0.43	0.48	0.52	0.81	1.47	0.38	0.51	1.37
P3 × P9	1.36	1.24	1.65	1.43	1.43	0.08	0.36	1.19	1.29	1.64	1.98	0.29	2.33	1.20
P3 × P10	0.64	1.60	0.44	0.97	1.02	2.11	0.83	0.35	0.38	0.43	2.19	0.96	2.11	1.51
P4 × P5	0.41	1.68	1.77	0.54	1.12	0.57	1.70	0.91	0.99	1.76	2.16	0.46	1.80	1.19
P4 × P6	0.94	1.43	0.85	1.63	1.66	0.42	0.38	0.91	0.99	0.85	2.37	0.63	0.85	1.05
P4 × P7	0.33	1.29	4.13	2.56	0.93	0.63	0.56	0.12	0.52	4.11	1.20	1.39	0.73	0.97
P4 × P8	1.44	1.26	0.75	1.37	0.97	0.49	0.74	2.84	3.09	0.75	1.98	0.72	0.62	1.11
P4 × P9	1.04	1.63	0.81	0.75	1.39	0.33	0.73	1.30	1.67	0.80	0.19	2.11	1.30	0.70
P4 × P10	1.07	1.33	1.32	0.19	3.18	0.85	1.00	2.39	2.60	1.31	2.24	2.06	1.06	1.22
P5 × P6	0.60	1.48	2.55	0.99	0.07	0.07	1.14	0.68	0.74	2.54	2.30	1.88	0.56	1.02
P5 × P7	1.64	1.67	0.41	0.95	0.95	1.37	0.97	3.18	3.45	0.41	1.71	0.92	0.39	0.42
P5 × P8	0.78	1.47	0.59	0.64	2.58	2.42	0.75	2.85	3.09	0.59	1.65	0.77	2.17	1.08
P5 × P9	1.28	1.09	1.15	0.21	2.20	0.72	1.06	1.12	1.22	1.14	3.36	5.19	1.53	1.11
P5 × P10	1.38	1.38	0.51	0.03	0.85	0.06	1.89	1.12	1.22	0.51	0.59	0.39	1.68	1.16
P6 × P7	0.51	0.20	0.99	1.11	0.94	1.22	0.59	0.42	0.33	0.99	0.07	0.94	0.27	0.75
P6 × P8	0.42	0.25	0.74	1.41	0.80	0.45	1.46	4.26	0.59	0.73	0.24	0.45	0.26	1.05
P6 × P9	1.10	1.38	0.77	0.51	0.76	0.45	1.28	1.15	1.25	0.77	0.52	2.14	1.03	0.70
P6 × P10	1.44	1.43	0.53	0.79	0.29	0.57	0.26	2.20	1.69	0.53	2.70	0.93	2.09	1.16
P7 × P8	1.70	1.76	0.95	1.14	1.43	0.30	0.78	0.63	0.67	0.94	2.39	1.24	0.42	0.38
P7 × P9	1.36	1.33	1.57	0.17	1.64	0.90	0.60	-0.18	0.87	1.56	2.98	3.10	2.94	1.29
P7 × P10	0.51	1.36	1.45	1.58	0.44	0.49	1.15	0.45	1.27	1.44	2.52	1.51	1.99	0.96
P8 × P9	1.33	1.51	0.89	0.10	0.70	0.70	1.08	0.13	0.60	0.88	0.61	2.94	1.28	1.16
P8 × P10	1.51	0.55	0.71	0.26	0.89	2.40	0.93	1.09	1.18	0.70	2.49	3.54	2.84	1.02
P9 × P10	0.41	0.92	1.81	0.88	2.63	0.32	1.55	1.04	1.65	1.80	0.19	1.09	0.17	1.11

area, tillers per plant, spike area, harvest index, and spike length in E_2F_1 and grain yield per plant, number of grains per spike, spikelets per spike, flag leaf area, and spike area, 1000 grain weight and harvest index in E_3F_2 with high heat stress intensity (D-value) suffered more under E_3 environment. Ved Prakash *et al*. (2007) also reported higher D-value for grain yield/m^2.

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