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Study of heat susceptibility indices for yield and its attributes in barley (*Hordeum vulgare* L.)

Naresh Parashar, DK Gothwal and Guman Singh

Abstract
The present experiment was undertaken to understand the impact of high temperature on yield and its attributing traits and to select heat stress tolerant parents and cross combinations for future breeding programme. To fulfill the requirement of this objective, the experiment was conducted in two environments i.e. normal and heat stress, with 10 diverse genotypes, their 45 F1's and F2's. In the present study, the Heat Susceptibility Index value of parents and crosses for different quantitative characters was calculated and genotypes were classified in to four different categories i.e. highly heat tolerant, heat tolerant, moderately heat tolerant and heat susceptible. From the result of heat susceptibility index (HSI), it could be visualized that the parents RD-2035, RD-2052 and RD-2508 were found most desirable for most of the characters under heat stress environment. Among the crosses, RD-2052XRD-2503, RD-2052XRD-2786, RD-2503XRD-2794, RD-2503XRD-2592, RD-2503XRD-2715, RD-2794XRD-2660 and RD-2592XRD-2508 were found most suitable as they attained top ranks for more than two yield contributing characters and could be utilized as a promising breeding material for the development of new set of thermal/heat stress tolerant barley varieties.

Keywords: Barley, heat susceptibility index (HSI), heat stress, high temperature stress

Introduction
Barley (*Hordeum vulgare* L.) is an important *rabi* cereal crop grown throughout the temperate and tropical regions of the world. Barley assumes the fourth position in total cereal production in the world after wheat, rice and maize, each of which covers nearly 30 per cent of the world's total cereal production (FAOSTAT, 2004) [4].

In the light of climate changes and global warming, which indicate a gradual increase in the atmospheric temperature and an increase in the frequency and extent of heat stress periods in the near future, high temperature is considered as a key stress factor with high potential impact on crop yield. Furthermore, high temperatures are also commonly accompanied by extended periods of drought, and the simultaneous occurrence of these two abiotic stresses under field conditions could have a negative impact on crop productivity worldwide and have terrible consequences on food security. Heat stress is an important abiotic stress causing substantial crop losses worldwide. Heat tolerance is a complex polygenic trait involving epistatic interactions among loci and powerful genotype × environment interactions (Abou-Elwafa and Amein, 2016) [1].

High temperature is now a major concern for crop production and approaches for sustaining high yields of crop plants under high temperature stress, are important agricultural goals (Hasanuzzaman *et al.*, 2013) [7]. Heat stress after anthesis is the major limiting factor for grain yield in winter sown barley and wheat as well. Now a day, the development of early maturing heat tolerant barley varieties coupled with high yield has become one of the most important aspects of breeding because unfavorable temperature during late sown condition affects crop productivity and there are yield losses due to high temperature in warmer areas (Howard, 1924; Fisher and Maurer, 1978; Wardlaw, 1994; Stone and Nicolas, 1995) [8, 6, 15, 12].

Heat tolerance is a function of integrated plant system at the tissue, organ and whole plant level and is determined by different combinations of genes which are critical for heat tolerance at different stages of the life cycle and in various tissues. Hence, understanding the physiological responses of barley crop to heat stress is prerequisite in identifying the characters to be used for breeding heat tolerance. The genetic studies will require utmost attention when objective is breeding for high grain yield along with high temperature tolerance. Though a number of studies have been attempted to get reliable information regarding inheritance of these characters, but it still require some more work. Thus, an effective breeding strategy can be developed for breeding high yielding heat tolerant barley genotypes.

Therefore, in the present investigation an attempt has been made to understand the response of barley genotypes to high temperature stress, genetic makeup of grain yield under normal and heat stress environments and to suggest the suitable breeding methodology for further improvement in barley yield potential.

Terminal heat stress is a common abiotic factor responsible for reducing yield and there is a need to identify heat tolerant genotypes. Modhej *et al.* (2005) [9] showed that the higher heat stress tolerance of barley after anthesis was due to its shorter crop growth duration as compared to wheat. Heat stress is a major challenge to barley productivity in India. The impact of climate change is clearly evident from recent vagaries across regions in India. Therefore, breeding aimed at selecting genotypes with high temperature stress tolerance is one of the most vital objectives of the barley breeder.

By keeping the above facts in view, there is a need to develop new genotypes having genetic structure to tolerate thermal stress to sustain and enhance productivity of barley under warmer areas of India particularly in Rajasthan.

Materials and Methods

In the present investigation, ten barley (*Hordeum vulgare* L.) varieties/genotypes namely: RD-2552, RD-2035, RD-2052, RD-2503, RD-2794, RD-2786, RD-2592, RD-2715, RD-2508 and RD-2660 were crossed in half diallel fashion during *rabi* 2015-16. For generation advancement, all the resulting 45 F_1's were grown in a single row plot at Wheat Research Station, Wellington (Tamil Nadu) during summer 2016 to get F_2 seeds. Heat stress environment in the field condition was created by manipulating the date of sowing. The experimental material consisting ten parents and their resulting 45 F_1's and 45 F_2's, were evaluated in a randomized block design with three replications under normal and high temperature condition during *rabi* 2016-17 at Agronomy farm, S.K.N. College of Agriculture, Jobner. Sowing was done about 20 days later than normal date of sowing which created heat stress environment at post anthesis. The parents and F_1's were grown in a plot of two rows of 2 meter length, while the segregating generation i.e. F_2 was sown in a plot of four rows of 2 meter length with row to row distance of 30 cm and plant to plant distance of 10 cm under both normal and heat stress environments. Observations were recorded for days to anthesis, duration from anthesis to maturity, days to maturity, plant height, number of effective tillers per plant, flag leaf area, peduncle length, spike length, number of grains per spike, 1000-grain weight, biological yield per plant, grain yield per plant and harvest index, on 10 randomly selected plants in each of the F_1's progenies and in each parent while 30 plants were selected in F_2's population from each replication. Mean values over selected plants were used for analysis of heat susceptibility index. Heat susceptibility index (HSI) was calculated for grain yield and its attributes over high temperature/heat stress environment (E_2) and non-stress environment (E_1) by using the formula as suggested by Fisher and Maurer (1978) [6].

$$HSI = [l - Y_D/Y_P]/D$$

Where,

D = Heat stress intensity

Y_D = mean of the genotype in stress environment.

Y_P = mean of the genotype under non-stress environment.

D =1-[mean of all genotypes in stress environment/mean of all genotypes in normal environment].

The HSI values were used to characterize the relative tolerance of genotypes based on minimization of yield losses as compared to normal environmental condition.

Results and Discussion

Increased ambient temperature as a result of global warming and climate changes is emerging as a great threat to the growth and development of most crop plants. A significant reduction was observed in mean performance of the genotypes in late sown condition as compared to timely sown condition for all the traits *viz.,* days to anthesis, duration from anthesis to maturity, days to maturity, plant height, flag leaf area, number of effective tillers per plant, peduncle length, spike length, number of grains per spike, 1000-grain weight, grain yield per plant, biological yield per plant and harvest index. When temperatures are elevated from anthesis to grain maturity, grain yield is reduced because of the reduced time to capture resources (Farooq *et al.,* 2011) [5]. The drastic reduction in morphological and yield contributing traits i.e., plant height, number of tillers/plant, spike length, thousand kernel weight and plant yield under heat stress conditions could be due to the inhibition of photosynthesis as one of the most striking consequences of heat stress on photosynthetic tissues which is reflected by the reduction in chlorophyll content of the leaves under heat stress conditions (Abou-Elwafa and Amein, 2016) [1]. Modhej *et al.* (2015) [9] reported average grain yield reduction in barley and bread wheat genotypes by 17% and 23%, respectively when these crops were exposed to heat stress after anthesis. Vaezi *et al.* (2010) [14] reported reduction in grain yield of two–row and six– row barley genotypes by 39.59% and 31.39% respectively which was caused by delayed sowing and also found average reduction in number of spikes per square meter, grain number per spike and 1000–grain weight of two–row barleys caused by late sowing, by 30.01%, 4.5% and 9.51%, respectively, while in six–rows barleys by 20.36%, 12.07% and 7.9%, respectively.

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 and cross combinations for future breeding programme.

The results of present investigation demonstrated that in comparison to normal sown condition (E_1), mean performance of grain yield per plant for parents, F_1's and F_2's were declined by 32.15%, 4.23% and 4.18% respectively, under heat stress condition (E_2). Similar results were also observed by Sultan *et al.* (2016) [13], Modhej *et al.* (2015) [9], Amer *et al.* (2011) [2], Vaezi *et al.* (2010) [14] and El-shawy (2008) [3] in barley. It is fairly accepted that yield is a complex trait and an ultimate product of the action and interaction of a number of component characters. Thus, a selection based on yield *per se* will not be much effective. Therefore, in order to determine the tolerance of different parents and crosses for heat stress, the heat susceptibility index was worked out based upon the values and direction of desirability of different traits used in the study. In the present study, genotypes were classified arbitrarily into four different categories i.e. highly heat tolerant (HSI $<$ 0.50), heat tolerant (HSI: 0.51-0.75), moderately heat tolerant (HSI: 0.76 – 1.00) and heat susceptible (HSI $>$ 1.00).

Perusal of Table-1 revealed that parents and F_2 generation revealed only moderate heat tolerance while F_1 generation showed both high and moderate heat tolerance.

In F_1 generation, the crosses RD-2552XRD-2503,RD-2052XRD-2786, RD-2503XRD-2715, RD-2503XRD-2508 and RD-2794XRD-2660 showed HSI value less than 0.50 therefore, these crosses were least affected under late sown condition (E_2) for grain yield per plant while among the parents, RD-2035, RD-2503 and RD-2508; in F_1, crosses RD-2552XRD-2592, RD-2552XRD-2508,RD-2035XRD-2503, RD-2052XRD-2503, RD-2052XRD-2794, RD-2052XRD-2508, RD-2503XRD-2660 and RD-2592XRD-2508 and in F_2, crosses RD-2552XRD-2592, RD-2035XRD-2052, RD-2035XRD-2715, RD-2052XRD-2503, RD-2052XRD-2794, RD-2052XRD-2786, RD-2052XRD-2715, RD-2503XRD-2715 and RD-2592XRD-2660 revealed HSI value 0.50-0.75, therefore, these parents and F_1 crosses were considered as moderate heat tolerant.

Resemblance across the generations for different characters indicated the superiority of the crosses RD-2552XRD-2592, RD-2052RD-2503 and RD-2052XRD-2794 as they attained moderate tolerance HSI values in both the generations.

The overall results indicated that parent RD-2035, RD-2508, RD-2052 and RD-2794 were the most desirable parents as they possessed high heat tolerance for most of the characters. Among the F_1 crosses, RD-2052XRD-2503, RD-2052XRD-2786, RD-2503XRD-2794, RD-2503XRD-2592,RD-2503XRD-2715, RD-2794XRD-2660, RD-2592XRD-2508 and in $F_{2,}$ crosses RD-2552XRD-2503, RD-2035XRD-2715, RD-2052XRD-2715,RD-2503XRD-2794, RD-2503XRD-2715, RD-2592XRD-2715 were found to be desirable for most of the characters on the basis of HSI.

An overall perusal of the Table-1 revealed that the crosses RD-2503XRD-2794 and RD-2503XRD-2715 were most desirable as they possessed high heat tolerance for more than two characters across the generations.

Low value of heat stress intensity (D-value) indicated that the characters namely days to anthesis (0.13), duration from anthesis to maturity (0.15), days to maturity (0.14), number of effective tillers per plant (0.20), peduncle length (0.05), spike length (0.13) and harvest index (0.04) showed more tolerance under heat stress environment (E_2) whereas plant height (0.27), flag leaf area (0.35), number of grains per spike (0.41), 1000-grain weight (0.23), biological yield per plant (0.27) and grain yield per plant (0.29) with high heat stress intensity, suffered more under E_2 environment. Similar findings were also observed for days to heading, days to maturity, spike length, plant height and harvest index by Singh *et al.* (2011) [11].

Summary and Conclusion

Barley crop grown in Northern India under late sown condition is exposed to very low temperature upto booting stage but at later stages it has to face warm temperature that enables lower grain yield due to poor grain development under high temperature condition. For improvement with respect to heat stress tolerance, information regarding the genetic control of grain yield and its associated traits under heat stress environment and identification of good combining parents and cross combinations are the primary requirements for the present experiment.

In the present study, on the basis of heat susceptibility index, the parents RD-2035, RD-2508 and RD-2052 were most desirable under heat stress environment (E_2) as they attained high HSI values for yield and its attributing traits. Similarly, the crosses RD-2052XRD-2503, RD-2052XRD-2786, RD-2503XRD-2794, RD-2503XRD-2592, RD-2503XRD-2715, RD-2794XRD-2660 and RD-2592XRD-2508 were found most desirable as they attained top ranks for more than two characters. As a consequence, it is recommended that these genotypes may perform as potential donor for heat tolerance. These parents should be further exploited for improvement of grain yield under late and very late sown conditions. The HSI should be taken as an important criterion for breeding barley genotypes suitable for heat stress environment.

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Table 1: Heat susceptibility indices for yield and its attributes in E_2 in comparison to E_1 environment

Parents	DA	DAM	DM	PH (cm)	NETP	FLA (cm²)	PL (cm)	SL (cm)	NGP	TW (g)	BYP (g)	GYP (g)	HI (%)
RD-2552	0.85	0.92	0.89	0.78	1.11	1.11	1.44	0.84	0.80	0.65	0.75	0.79	0.73
RD-2035	0.73	1.46	1.05	0.69	0.53	1.11	0.47	0.51	1.37	1.85	0.65	0.58	2.79
RD-2052	1.15	0.33	0.86	0.91	0.53	1.07	1.98	0.37	0.94	1.12	0.65	1.06	3.76
RD-2503	1.38	0.24	0.96	0.84	1.76	1.13	0.76	1.00	0.90	1.33	0.27	0.73	3.40
RD-2794	1.35	0.44	1.03	0.87	1.63	0.94	0.56	1.17	0.82	1.34	0.80	0.89	1.32
RD-2786	0.95	1.32	1.10	1.04	0.95	1.15	1.67	1.17	1.06	1.75	0.96	0.93	0.13
RD-2592	1.11	0.51	0.89	0.94	1.12	1.05	1.51	0.48	0.98	1.12	1.11	1.15	0.84
RD-2715	0.73	1.99	1.28	0.80	0.62	1.17	0.82	1.39	0.82	1.15	1.08	1.04	0.39
RD-2508	0.75	1.77	1.16	0.66	0.65	1.09	0.64	1.43	1.38	1.27	0.60	0.62	0.58
RD-2660	1.28	1.16	1.24	0.72	0.10	1.34	2.66	2.00	1.34	1.35	0.61	0.80	1.80
F_1 crosses													
RD-2552xRD-2035	0.83	1.31	1.05	0.88	0.48	1.07	0.76	0.70	1.11	0.86	1.24	1.24	1.05
RD-2552xRD-2052	0.99	1.35	1.15	0.81	1.21	0.93	1.14	0.64	0.81	1.46	0.68	0.93	2.56
RD-2552xRD-2503	0.88	0.75	0.84	0.83	0.66	0.99	0.85	0.51	1.15	0.41	0.45	0.46	0.30
RD-2552xRD-2794	1.20	0.51	0.96	0.99	0.57	1.11	0.74	0.93	0.91	1.30	0.94	0.91	0.17
RD-2552xRD-2786	1.04	1.53	1.25	1.09	1.26	1.52	0.16	0.48	0.37	0.93	0.81	0.98	1.97
RD-2552xRD-2592	0.79	1.17	0.94	1.21	0.54	1.11	1.30	0.66	1.08	0.70	0.62	0.74	1.45
RD-2552xRD-2715	0.55	1.85	1.16	0.91	0.82	0.86	1.35	1.02	0.77	0.86	1.06	0.87	0.76
RD-2552xRD-2508	0.80	1.82	1.20	1.00	0.11	0.98	1.25	1.49	0.97	1.17	0.68	0.51	-1.10
RD-2552xRD-2660	0.84	1.68	1.28	0.82	0.14	0.94	1.11	1.78	1.09	0.94	1.19	1.13	0.40
RD-2035xRD-2052	0.39	1.60	0.90	1.02	0.64	0.78	0.71	1.85	1.54	1.36	0.84	0.93	1.43
RD-2035xRD-2503	1.06	0.70	0.93	1.02	1.46	0.94	0.35	2.53	1.50	1.39	0.36	0.67	2.48
RD-2035xRD-2794	0.83	0.91	0.87	0.99	1.41	1.26	1.63	0.35	1.55	1.39	1.96	1.80	0.11

RD-2035xRD-2786	0.38	2.10	1.19	0.96	1.15	1.27	0.19	0.51	1.45	0.83	1.37	1.44	1.84
RD-2035xRD-2592	1.46	0.19	0.93	0.77	0.76	1.00	0.59	0.68	0.77	0.98	1.74	1.74	1.83
RD-2035xRD-2715	1.30	0.13	0.88	1.12	1.30	1.14	0.68	0.70	1.24	0.58	0.98	1.05	1.39
RD-2035xRD-2508	0.70	1.67	1.12	1.15	0.32	0.97	1.00	0.78	0.87	1.14	1.20	1.19	0.38
RD-2035xRD-2660	0.99	1.21	1.09	1.05	0.62	1.32	0.84	0.07	1.17	1.34	0.95	0.94	0.41
RD-2052xRD-2715	1.17	1.12	1.16	0.98	0.19	1.00	0.95	1.16	0.83	0.90	0.81	0.98	1.98
RD-2052xRD-2508	0.79	1.40	1.03	1.09	1.79	0.90	0.83	2.25	1.20	1.12	0.58	0.60	0.41
RD-2052xRD-2660	0.91	1.52	1.17	1.07	1.76	0.94	0.51	1.27	1.23	1.01	1.04	1.17	2.10
RD-2052xRD-2503	0.82	0.16	0.61	1.12	1.52	0.86	1.07	2.76	0.59	0.33	0.73	0.63	0.31
RD-2052xRD-2794	0.91	0.90	0.91	1.00	1.01	0.91	0.67	0.73	0.65	0.15	0.71	0.74	1.20
RD-2052xRD-2786	1.12	1.08	1.11	1.20	1.76	0.94	0.92	0.40	0.97	0.60	0.24	0.03	-1.34
RD-2052xRD-2592	1.70	0.24	0.98	0.97	1.03	0.94	0.71	0.19	0.82	0.53	1.46	1.24	1.03
RD-2503xRD-2794	1.54	0.07	0.85	0.99	0.63	1.31	0.77	0.61	0.54	0.24	0.86	0.95	1.20
RD-2503xRD-2786	1.10	0.98	1.06	0.95	1.47	0.91	0.44	1.00	1.18	0.77	0.94	1.06	2.06
RD-2503xRD-2592	0.51	1.96	1.13	1.08	1.03	0.80	1.15	0.31	0.98	0.35	0.63	0.79	1.79
RD-2503xRD-2715	0.89	1.30	1.05	0.99	1.88	0.97	0.62	1.35	0.54	0.54	0.14	0.38	1.72
RD-2503xRD-2508	1.01	1.14	1.06	0.91	0.77	0.81	0.42	1.10	0.99	1.34	0.13	0.25	0.91
RD-2503xRD-2660	0.56	1.57	1.00	1.15	1.02	1.20	1.21	0.88	1.18	0.96	0.50	0.58	0.94
RD-2794xRD-2786	0.73	1.21	0.93	0.97	1.29	1.00	0.64	0.55	0.97	1.87	1.12	1.32	2.65
RD-2794xRD-2592	1.04	1.30	1.15	1.12	1.19	1.25	0.48	1.52	0.87	1.64	1.68	1.39	0.30
RD-2794xRD-2715	0.95	1.55	1.18	0.90	2.12	1.18	0.47	0.96	0.52	1.61	1.71	1.45	0.25
RD-2794xRD-2508	1.07	1.08	1.08	0.84	0.52	1.12	1.62	1.51	1.09	0.02	0.97	1.17	2.37
RD-2794xRD-2660	0.59	1.25	0.88	1.06	0.30	0.99	1.18	0.51	0.92	0.94	0.06	0.11	0.50
RD-2786xRD-2592	1.12	0.42	0.87	1.00	1.01	1.06	0.41	0.47	1.08	0.91	0.78	0.83	1.09
RD-2786xRD-2715	0.94	0.97	0.96	1.18	1.96	1.41	0.10	1.28	0.98	0.73	1.75	1.73	1.79
RD-2786xRD-2508	1.90	0.17	0.93	0.91	1.47	1.33	2.14	2.73	1.33	0.13	1.39	1.43	0.94
RD-2786xRD-2660	1.19	0.69	0.98	1.05	0.23	0.78	0.86	1.46	0.92	1.47	1.42	1.41	1.37
RD-2592xRD-2715	1.03	1.69	1.29	1.11	1.24	0.79	0.76	0.54	0.77	0.75	0.85	1.06	2.41
RD-2592xRD-2508	0.43	2.30	1.31	1.10	0.39	0.96	0.79	0.19	1.13	0.95	0.92	0.71	-1.31
RD-2592xRD-2660	0.62	2.36	1.37	0.71	1.52	1.11	1.01	0.74	1.25	1.19	0.50	0.80	2.73
RD-2715xRD-2508	1.02	1.96	1.44	0.77	2.14	1.09	0.55	0.53	0.94	0.51	0.89	0.84	-0.02
RD-2715xRD-2660	1.26	1.62	1.45	1.02	0.64	1.23	0.43	0.69	1.08	1.91	1.29	1.38	2.11
RD-2508xRD-2660	1.34	0.57	1.06	0.75	1.35	0.98	0.46	1.43	1.06	1.31	1.40	1.05	-2.33
F_2 crosses													
RD-2552xRD-2035	0.99	0.91	0.97	0.79	0.86	0.87	0.88	0.54	1.40	0.87	1.63	1.47	0.01
RD-2552xRD-2052	0.92	1.10	1.00	0.71	0.43	1.06	1.67	1.20	0.77	1.87	0.86	0.82	0.32
RD-2552xRD-2503	1.10	0.24	0.77	0.88	0.87	0.93	1.22	0.86	1.18	0.06	0.16	0.21	0.33
RD-2552xRD-2794	0.95	1.50	1.18	1.08	1.73	0.99	0.65	1.77	0.96	1.26	1.21	0.92	-0.87
RD-2552xRD-2786	0.72	1.39	0.99	1.08	1.44	1.07	0.89	0.52	0.76	1.04	1.25	1.21	0.58
RD-2552xRD-2592	0.96	0.42	0.77	1.22	1.08	1.00	0.81	0.61	0.83	0.82	0.90	0.75	-0.45
RD-2552xRD-2715	0.40	1.85	1.06	0.98	1.27	0.81	1.23	1.10	1.06	1.83	1.39	1.09	0.40
RD-2552xRD-2508	1.03	1.08	1.06	1.03	1.07	0.52	1.93	1.85	1.23	1.12	1.29	1.43	2.00
RD-2552xRD-2660	1.21	1.34	1.29	0.81	0.14	0.78	1.11	2.08	1.39	1.56	1.30	1.23	0.23
RD-2035xRD-2052	0.81	1.49	1.07	1.05	0.77	0.85	0.53	2.36	1.27	1.06	0.15	0.62	3.34
RD-2035xRD-2503	1.20	0.75	1.03	1.09	1.03	0.96	0.53	2.04	1.11	1.15	1.61	1.74	3.29
RD-2035xRD-2794	0.59	1.52	0.91	1.19	1.37	0.83	0.98	0.81	1.35	1.03	1.44	1.51	1.26
RD-2035xRD-2786	0.72	1.00	0.84	0.99	0.77	1.38	1.02	0.28	1.21	1.14	1.11	0.97	-0.67
RD-2035xRD-2592	0.76	0.89	0.82	0.92	0.48	1.00	0.66	0.24	0.81	1.28	1.50	1.27	0.45
RD-2035xRD-2715	1.31	0.12	0.86	1.07	0.64	0.96	0.79	0.25	1.01	1.82	0.05	0.63	3.83
RD-2035xRD-2508	0.59	0.92	0.75	1.07	1.20	0.89	1.86	1.06	0.79	1.12	1.47	1.46	0.47
RD-2035xRD-2660	0.96	0.91	0.95	1.13	0.99	0.96	0.99	2.02	1.15	1.43	0.95	0.98	1.12
RD-2052xRD-2503	1.12	0.38	0.89	1.11	1.46	1.08	1.33	0.80	0.88	0.43	1.18	0.74	0.32
RD-2052xRD-2794	1.04	0.57	0.88	0.83	1.33	1.13	1.78	0.51	0.40	0.01	0.65	0.65	0.42
RD-2052xRD-2786	0.69	1.55	1.04	1.42	1.51	0.68	0.55	1.27	0.96	1.45	0.75	0.70	-0.13
RD-2052xRD-2592	1.30	0.25	0.91	0.98	1.43	0.97	1.22	0.49	0.97	0.00	1.66	1.51	0.15
RD-2052xRD-2715	1.21	0.38	0.91	1.00	0.93	0.92	1.84	0.34	0.48	1.55	0.22	0.61	2.87
RD-2052xRD-2508	1.27	0.47	0.99	1.23	0.54	1.02	0.24	2.20	0.90	0.75	0.82	0.83	0.85
RD-2052xRD-2660	0.68	1.36	0.98	1.11	1.25	1.15	1.08	0.18	1.43	0.54	1.01	1.02	0.85
RD-2503xRD-2794	1.27	-0.07	0.83	1.18	0.22	0.96	0.65	0.67	0.45	0.06	0.87	0.88	0.81
RD-2503xRD-2786	1.10	0.53	0.91	1.18	0.78	1.19	1.50	0.38	0.59	0.10	1.51	1.39	0.25
RD-2503xRD-2592	1.10	0.28	0.82	0.99	1.08	0.87	2.22	0.43	0.23	0.81	1.59	1.54	0.96
RD-2503xRD-2715	0.83	0.88	0.85	0.90	1.04	0.53	0.61	1.22	0.52	0.63	0.46	0.63	1.58
RD-2503xRD-2508	1.14	0.23	0.85	0.76	0.72	0.76	1.02	1.30	0.84	1.64	1.25	1.15	-0.21
RD-2503xRD-2660	1.21	0.45	0.95	1.16	0.94	1.22	0.39	1.80	1.08	1.36	0.96	0.94	0.63
RD-2794xRD-2786	0.70	1.36	0.97	1.17	1.30	0.96	0.91	0.39	1.35	0.96	1.18	1.19	0.92
RD-2794xRD-2592	1.08	0.38	0.83	1.15	0.60	0.93	1.95	0.34	0.77	1.50	1.77	1.32	0.52
RD-2794xRD-2715	0.85	1.15	0.96	1.13	1.01	1.08	0.83	2.40	1.16	1.89	2.43	1.96	0.53
RD-2794xRD-2508	1.27	0.13	0.88	1.09	1.09	1.16	0.37	1.64	1.20	0.34	1.63	1.43	-0.11
RD-2794xRD-2660	1.07	0.56	0.89	1.12	0.59	1.09	0.48	1.50	0.59	0.64	1.15	1.06	0.02

RD-2786xRD-2592	0.88	0.23	0.68	1.37	0.39	0.98	1.91	0.82	1.24	0.37	0.94	0.89	0.29
RD-2786xRD-2715	1.00	0.65	0.89	1.03	1.08	0.78	0.74	1.19	1.02	0.31	1.22	1.09	0.01
RD-2786xRD-2508	1.01	0.31	0.72	1.08	0.88	0.98	1.22	1.26	1.12	0.43	1.14	1.10	0.47
RD-2786xRD-2660	2.03	-0.75	1.00	0.90	0.64	0.85	2.94	1.58	0.71	1.21	1.26	1.13	-0.13
RD-2592xRD-2715	1.09	0.15	0.79	0.98	1.83	0.48	0.27	0.48	0.50	0.07	0.64	0.81	1.81
RD-2592xRD-2508	0.99	0.68	0.89	1.21	0.83	0.55	1.75	0.89	1.32	0.83	1.59	1.43	-0.02
RD-2592xRD-2660	1.08	0.49	0.87	0.79	0.27	0.71	0.57	0.72	1.14	0.55	0.64	0.72	1.11
RD-2715xRD-2508	1.06	0.79	0.96	0.91	1.01	0.59	1.56	0.38	0.97	0.73	0.85	0.88	0.96
RD-2715xRD-2660	1.75	-0.41	0.93	0.94	0.85	1.00	0.48	0.57	0.84	1.97	0.81	0.84	0.92
RD-2508xRD-2660	0.88	1.16	1.00	1.10	0.76	0.84	1.84	0.93	0.91	0.51	1.07	0.94	-0.01

DA – Days to anthesis, DAM – Days from anthesis to maturity, DM – Days to maturity,
PH – Plant height, NETP – Number of effective tillers per plant, FLA – Flag leaf area,
PL – Peduncle length, SL – Spike length, NGP – Number of grains per spike,
TW – Test weight (1000-grain weight), BYP- Biological yield per plant,
GYP – Grain yield per plant, HI – Harvest index

References

1. Abou-Elwafa SF, Amein KA. Genetic diversity and potential high temperature tolerance in barley (*Hordeum vulgare* L.). World J Agric. Res. 2016; 4(1):1-8.
2. Amer KA, Eid AA, El-Sayed MMA. Genetic analysis of yield and its components under normal and drought conditions in some barley crosses. Egypt. J Plant Breed. 2011; 15(2):65-79.
3. El-Shawy EEA. Genetic analysis of some important traits of six-rowed barley in normal and saline affected fields. M.Sc. Thesis, Fac. Agric., Kafr El-Sheikh, Tanta Univ., Egypt, 2008.
4. FAOSTAT. http:/apps.fao.org/faostat/default.jsp, accessed. Feb, 2004.
5. Farooq J, Khaliq I, Ali MA, Kashif M, Rehman A, Naveed M *et al*. Inheritance pattern of yield attributes in spring wheat at grain filling stage under different temperature regimes. AJCS. 2011; 5(13):1745-1753.
6. Fisher RA, Maurer R. Drought resistance in spring wheat cultivars I. Grain yield responses. Aust. J Agric. Res. 1978; 29(5):897-912.
7. Hasanuzzaman M, Nahar K, Alam MM, Roychowdhury R, Fujita M. Physiological, biochemical and molecular mechanisms of heat stress tolerance in plants. Int. J Mol. Sci. 2013; 14:9643-9684.
8. Howard A. Crop production in India: A critical survey of its problems. Oxford Univ. Press, Oxford, UK, 1924, 156.
9. Modhej A, Farhoudi R and Afrous A. Effect of post-anthesis heat stress on grain yield of barley, durum and bread wheat genotypes. Journal of Scientific Research and Development. 2015; 2(6):127-131.
10. Modhej A, Nadery A, Siadat A. Effect of heat stress after anthesis on grain yield of wheat and barley cultivars. Scientific J of Agric. 2005; 72:82-99.
11. Singh K, Sharma SN, Sharma Y. Effect of high temperature on yield attributing traits in bread wheat. Bangladesh J Agril. Res. 2011; 36(3):415-426.
12. Stone PJ, Nicolas ME. Effect of timing of heat stress during grain filling on two wheat varieties differing in heat tolerance I. grain growth. Aust. J Pl. Physiol. 1995; 22:927-934.
13. Sultan MS, Abdel-Moneam MA, Haffez SH. Estimation of combining ability for yield and its components in barley under normal and drought condition. J. Plant Production, Mansoura Univ. 2016; 7(6):553-558.
14. Vaezi B, Bavei V, Shiran B, Moghadam NR. Different contributions of yield components to grain yield in two and six row barley genotypes under terminal heat stress. Int. J Appl. Agric. Res. 2010; 5(3):385-400.
15. Wardlaw IF, Wrigley CW. Heat tolerance in temperature cereals: an overview. Aust. J Pl. Physiol. 1994; 21:695-703.