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Estimation of heat stress tolerance for grain yield and its contributing traits in bread wheat (*Triticum aestivum*)

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Abstract
Hence the research work was performed to analyze the effect of late season heat stress on grain yield and yield components of ten bread wheat cultivars and 45 F_1's. Based on heat susceptibility index the wheat genotypes Raj 3077, Raj 1482 and Raj 3777 were highly tolerant to increased temperature as compared to other wheat genotypes. The cross combinations Raj 4079 x Raj 3765, Raj 3077 x PBW 550, WH 1021 x DBW 90, Raj 1482 x HD 3086 and Raj 4238 x WH 1021 which demonstrated comparatively more tolerance for grain yield per plant. These were predictable for thermo tolerance in very late sown conditions. The HSI could be taken as important criteria for breeding wheat genotypes suitable for late sown conditions. These genotypes can be used in wheat breeding programmes related to high temperature stress. In very late sown condition the parents Raj 3765, Raj 3077 and WH 1021 and cross combinations WH 1021 x PBW 550, Raj 3765 x Raj 3077 and Raj 4238 x WH 1021 emerged as good general combiner and specific cross combinations. Therefore, these genotypes may be used in the future breeding programme for development of a heat tolerant wheat variety suitable for warmer areas to maximize production.

Keywords: Heat susceptibility index, wheat, genotypes, heat tolerance

Introduction
High temperature remains a huge problem for edible crops world-wide with unexpected spatial and temporal variations causing reduced crops yield and productivity (Parent *et al.* 2010) [11]. It is known that an increase in temperature of 1 °C in different crops reduces yield 3–10 percent (You *et al.* 2009) [20]. In India, wheat yield is sensitive to heat stress in flowering and seed ripening stages. During these periods, heat stress delays the growth, causes premature ripening, decrease the number of grain, decreases grain weight and ultimately results in decrease in total grains yield and quality deterioration (Khan *et al.*, 2007, Wahid *et al.*, 2007, Din *et al*. 2010) [6, 19, 2]. Wheat production is delicate to heat stress as high temperature declines wheat production by 20-30 percent in different developing countries. Global warming adversely affects wheat grain yield, which increases food uncertainty and shortage (Ortiz *et al.*, 2008) [10]. Therefore, there is an urgent need to develop different wheat cultivars which can be able to tolerate heat stress at different vegetative and reproductive stages of plant growth seasons. The study was conducted to investigate the morphological traits for heat stress tolerance at various vegetative and reproductive stages in ten bread wheat genotypes along with 45 F_1's and reliable strategies for heat stress tolerance that can be utilized in wheat breeding programs in India and other countries.

Materials and Methods
The experimental material for the present study consisted of ten diverse wheat varieties (selected on the basis of genetic diversity, thermal tolerance and their stability for different yield traits) and their all possible F_1's (Excluding reciprocals). Crosses among the ten genotypes were made in diallel fashion excluding reciprocals, during Rabi 20116-17 at RARI, Durgapura. A number of plants randomly selected in a parent were crossed with a number of randomly selected plants from other parent. In Rabi 2017-18 ten genotypes along with their 45 F_1's were evaluated in three environments (three different dates of sowing 15 November, 1 December and 15 December) timely sown, late sown and very late sown with 3 replications at Research farm, College of Agriculture, SKRAU, Bikaner.
Observations were recorded for days to heading, days to maturity, grain filling period, plant height, flag leaf area, number of effective tillers per plant, spike length, number of grains per

spike, 1000-grain weight, biological yield per plant, harvest index and grain yield per plant. Mean values over selected plants was used for analysis of heat susceptibility index.

Heat susceptibility index (HSI) was calculated for grain yield and other attributes over high temperature stress (late sown) and non-stress environment (normal sown) by using the formula as suggested by Fischer and Maurer (1978) [3].

HSI = [l-YD/YP]/D

Where, YD = mean of the genotypes in stress environment. YP = mean of the genotypes under non-stress environment. D = 1-[mean YD of all genotypes/mean YP of all genotypes].

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

Results and Discussion

The high temperature stress occurring at grain filling stage, commonly known as terminal heat stress is most severe for wheat production (Wahid *et al*, 2007) [19]. About 40 percent of wheat producing areas face this problem worldwide (Reynolds *et al.*, 1994) [15]. In India, nearly 60 percent of wheat area is planted late due to the late harvesting of kharif crops. Under such circumstances where on one side demand of wheat production is increasing to feed the huge population of the world and on other side elevated temperature due to global warming is creating problem in sustaining wheat productivity, there is a quick need to identify genotypes which can perform well under temperature stress conditions. Keeping the above facts in view, the present study was conducted to magnify the yield level of wheat in high temperature areas by selecting stress tolerant parents and cross combinations for future breeding programme.

The results of this study demonstrated that in comparison to normal sown (E_1), mean performance of parents and their F_1's declined under late sown (E_2) and very late sown (E_3) conditions. The results are in agreement with Patil *et al.* (2003) [12], Singh and Madanpal (2003) [18], Raj and Bhardwaj (2004) [14], Kaur and Behl (2010) [5], Nazeem *et al*. (2014) [9], Shashi Bala *et al.* (2014) [17], Sallam *et al.* (2014) [16], Moshatatia *et al.* (2017) [8], Irfan and Ali (2018) [4] and Abdallah *et al.* (2019) [1]. It is fairly accepted that yield is complex attribute and an ultimate product of the action and interaction of a number of component traits. Thus, a selection based on yield *per se* will not be much effective. Therefore, in order to determine the tolerance of different parents and cross combination 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 work, genotypes were classified in to 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).

Examination of Table 1 depicted that among the parents, Raj 1482, DBW 90, Raj 4238, and Raj 3077 and in F_1 crosses Raj 3077 x Raj 1482, Raj 4079 x Raj 3777, Raj 4238 x Raj 3077, Raj 3765 x Raj 3777 and Raj 3765 x DBW 90 were least affected under late sown conditions (E_2) for grain yield per plant.

Results of Table 2 depicted that the parents Raj 3077, Raj 1482 and Raj 3777 and in F_1 crosses Raj 4079 x Raj 3765, Raj 3077 x PBW 550, WH 1021 x DBW 90, Raj 1482 x HD 3086 and Raj 4238 x WH 1021 exhibited comparatively more tolerance for grain yield per plant under very late sown conditions (E_3).

High grain yield of a genotype under late sown condition indicated the presence of genes for heat tolerance. The cross combinations Raj 3077 x Raj 1482, Raj 4079 x Raj 3777, Raj 4238 x Raj 3077, Raj 3765 x Raj 3777 and Raj 3765 × DBW 90 emerged as highly heat tolerant for grain yield per plant under late sown condition (E_2) whereas under very late sown (E_3) condition the cross combinations Raj 4079 x Raj 3765, Raj 3077 x PBW 550, WH 1021 x DBW 90, Raj 1482 x HD 3086 and Raj 4238 x WH 1021 registered as highly heat tolerant for grain yield per plant.

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 Raj 3077, Raj 1482 and DBW 90 in E_2 and parents Raj 4079, Raj 3077 and DBW 90 in E_3 Were most desirable parents as they were included in top three parents for most of the characters. Among the crosses, Raj 3765 x DBW 90 followed by Raj 3077 × Raj 1482 and Raj 4079 × Raj 3777 in E_2 and Raj 4079 x Raj 3765 followed by WH 1021 x DBW 90 and Raj 3077 x PBW 550 in E_3 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.*, harvest index, plant height, days to heading, days to maturity and number of effective tillers per plant showed more tolerance in E_2 while days to heading, harvest index, plant height, days to maturity, spike length and number of effective tillers per plant showed more tolerance in E_3. Similar findings were also observed for days to heading by Prakash *et al.* (2007) [13] and Kumar *et al.* (2018) [7].

The characters *viz*., grain yield per plant, number of grains per spike, spike length, grain filling period and biological yield per plant in E_2 and grain yield per plant, flag leaf area, grain filling period, 1000-seed weight, biological yield per plant, number of grains per spike and number of effective tillers per plant in E_3 with high heat stress intensity (D- value) suffered more under E_3 environment. Prakash *et al.* (2007) [13] and Kumar *et al.* (2018) [7] also reported higher D-value for grain yield/m^2.

Conclusively, it has been suggested that diallel selective mating, bi-parental mating and multiple cross could be useful breeding approached for developing of heat tolerant genotypes and further amelioration of grain yield can be achieved in wheat.

Overall appraisal of the results in the present study, Tolerance to heat stress is a complex process and is controlled by various genes controlling a number of morphological and physiological changes. No single trait fully explains why some wheat varieties are able to generate better yield under heat stress. Heat tolerant genotypes should be utilized in breeding programs and wheat lines had potential to accept high temperature must be used under variety of warmer environment to improve their grain yield against heat stress.

Table 1: Heat susceptibility indices for various characters in E_2 in comparison to E_1 environment in wheat.

Genotypes	Days to Heading	Days to Maturity	Grain filling period	Plant Height (cm)	Flag leaf area (cm^2)	Number of effective tillers per plant	Spike Length (cm)	Number of grains per spike	1000-Seed weight (g)	Biological yield per plant (g)	Harvest Index (%)	Grain yield per plant (g)
Raj 4238	0.86	0.91	0.94	0.74	1.08	0.86	0.97	1.07	1.28	0.85	-2.05	0.42
Raj 4079	1.09	1.27	1.55	0.47	1.04	3.80	0.50	1.16	0.86	1.54	-0.01	1.29
Raj 3765	0.53	0.87	1.38	1.16	0.72	0.51	0.83	1.16	1.05	0.98	0.84	0.95
Raj 3077	1.24	0.97	0.61	1.18	1.00	0.57	0.69	0.94	0.84	1.35	-2.09	0.83
Raj 1482	0.67	1.38	2.21	1.12	0.80	-0.92	0.87	1.65	0.30	0.23	-1.17	-0.02
Raj 3777	0.53	0.89	1.39	1.26	0.99	1.16	0.76	1.22	0.68	0.82	1.87	0.96
WH 1021	0.63	1.09	1.50	0.73	0.70	0.86	0.62	0.84	1.41	1.91	1.63	1.82
DBW 90	0.66	1.15	1.73	-0.39	-0.81	1.23	1.05	0.99	2.11	-0.41	3.40	0.25
PBW 550	0.98	1.17	1.32	0.48	2.20	0.12	1.02	0.87	1.06	1.53	5.01	2.04
HD 3086	0.94	0.85	0.72	1.20	1.61	0.07	1.59	1.11	1.06	0.90	3.63	1.31
F_1 Crosses												
Raj 4238 x Raj 4079	1.66	0.58	-0.89	1.04	0.75	1.54	0.73	1.23	1.05	0.61	-1.11	0.32
Raj 4238 x Raj 3765	0.55	0.87	1.28	0.79	1.11	1.65	1.18	0.91	0.94	0.97	-0.55	0.74
Raj 4238 x Raj 3077	0.61	1.41	2.35	0.74	1.87	0.02	1.20	0.86	0.80	0.75	-3.59	0.08
Raj 4238 x Raj 1482	1.25	1.02	0.71	2.32	1.21	1.03	0.59	1.02	0.39	1.25	6.82	2.02
Raj 4238 x Raj 3777	0.72	0.87	1.00	1.22	1.91	0.67	1.51	0.91	0.98	0.98	2.46	1.18
Raj 4238 x WH 1021	0.58	0.97	1.39	1.27	0.30	0.14	0.48	0.78	1.23	1.02	2.50	1.22
Raj 4238 x DBW 90	0.31	0.90	1.48	1.73	0.59	1.81	1.17	0.97	1.49	1.09	-1.22	0.71
Raj 4238 x PBW 550	1.07	0.82	0.49	0.31	0.39	1.15	1.11	1.12	1.33	0.52	3.69	1.03
Raj 4238 x HD 3086	1.11	0.94	0.69	0.45	1.08	1.94	1.58	2.07	1.82	0.92	4.30	1.42
Raj 4079 x Raj 3765	1.24	0.60	-0.23	0.66	0.48	0.74	3.40	1.49	0.35	0.41	0.99	0.50
Raj 4079 x Raj 3077	1.18	1.05	0.86	1.85	1.81	1.12	0.87	0.95	0.57	1.33	2.17	1.42
Raj 4079 x Raj 1482	1.13	0.79	0.21	0.81	1.39	1.73	0.41	0.50	0.56	1.07	0.40	0.95
Raj 4079 x Raj 3777	1.07	1.02	0.95	1.17	0.51	1.51	1.75	1.91	-3.90	0.93	-4.60	0.06
Raj 4079 x WH 1021	0.93	1.28	1.61	0.62	1.94	1.02	0.32	2.03	1.54	1.54	3.94	1.86
Raj 4079 x DBW 90	0.77	0.85	0.99	1.55	-1.11	1.31	0.81	2.00	0.84	0.78	0.19	0.69
Raj 4079 x PBW 550	0.77	1.32	1.81	1.62	0.21	0.18	0.53	0.72	1.37	0.89	0.88	0.86
Raj 4079 x HD 3086	0.86	0.59	0.24	1.02	1.92	2.14	0.86	0.59	1.06	0.84	-2.28	0.36
Raj 3765 x Raj 3077	0.68	0.76	0.84	1.37	1.88	1.20	0.19	0.62	0.98	1.43	-1.26	0.99
Raj 3765 x Raj 1482	1.18	0.82	0.31	1.10	0.87	1.36	0.86	1.35	2.50	0.72	6.13	1.56
Raj 3765 x Raj 3777	1.03	0.97	0.86	1.96	0.69	1.37	0.96	1.99	1.87	0.85	-2.80	0.28
Raj 3765 x WH 1021	1.07	1.32	1.68	1.55	1.48	1.38	1.22	1.30	0.28	1.35	-3.68	0.55
Raj 3765 x DBW 90	0.89	0.53	0.08	0.08	-0.91	0.52	0.65	1.53	2.45	0.64	-1.40	0.32
Raj 3765 x PBW 550	0.75	0.82	0.87	0.83	1.07	0.89	1.24	1.43	1.12	0.95	-1.13	0.61
Raj 3765 x HD 3086	0.92	0.79	0.62	0.82	0.47	0.32	0.61	0.71	1.20	0.94	-0.52	0.73
Raj 3077 x Raj 1482	0.56	1.04	1.62	1.40	-0.31	0.19	0.81	0.80	0.83	1.30	-7.69	-0.04
Raj 3077 x Raj 3777	0.83	0.88	0.95	1.18	2.63	1.22	1.06	0.32	1.14	1.24	1.12	1.19
Raj 3077 x WH 1021	1.39	0.98	0.35	1.50	-1.32	0.92	-0.04	1.56	1.60	0.63	0.81	0.64
Raj 3077 x DBW 90	1.14	0.78	0.31	0.43	2.91	1.08	0.40	1.22	0.86	0.87	7.98	1.92
Raj 3077 x PBW 550	0.80	1.12	1.42	1.62	1.38	0.76	1.26	0.12	1.96	0.83	0.08	0.67
Raj 3077 x HD 3086	1.26	1.00	0.61	0.78	1.75	0.80	0.15	1.06	0.27	0.71	-0.16	0.56
Raj 1482 x Raj 3777	1.13	1.06	0.93	1.31	0.07	0.19	0.99	0.77	2.07	1.05	1.87	1.14
Raj 1482 x WH 1021	0.91	0.89	0.85	0.76	0.27	0.31	1.76	0.49	0.41	1.16	0.43	1.02
Raj 1482 x DBW 90	0.88	0.90	0.87	0.45	1.21	1.82	0.83	1.21	1.42	0.90	2.14	1.07
Raj 1482 x PBW 550	1.74	1.32	0.75	0.73	2.46	1.22	1.67	0.57	0.91	1.34	1.12	1.27
Raj 1482 x HD 3086	1.04	0.89	0.68	1.31	0.60	1.18	1.69	0.20	0.95	0.84	0.48	0.75
Raj 3777 x WH 1021	1.17	0.98	0.72	0.55	0.22	0.53	-0.38	1.09	0.81	0.90	10.22	2.33
Raj 3777 x DBW 90	0.76	1.41	2.00	0.21	-0.86	0.27	1.57	0.71	0.49	0.97	2.11	1.10
Raj 3777 x PBW 550	0.72	0.66	0.58	0.70	0.86	2.83	-0.28	1.58	0.81	1.43	1.92	1.45
Raj 3777 x HD 3086	0.87	1.09	1.39	1.13	1.34	0.14	0.90	0.79	1.05	0.89	1.45	0.99
WH 1021 x DBW 90	0.32	1.53	2.73	0.67	2.13	1.27	-0.19	0.82	0.91	1.04	1.31	1.02
WH 1021 x PBW 550	1.36	0.98	0.54	1.37	-0.67	1.50	1.12	1.02	1.48	1.03	1.03	1.07
WH 1021 x HD 3086	0.49	1.30	2.15	0.27	2.31	0.50	1.76	0.76	0.69	0.70	3.12	1.07
DBW 90 x PBW 550	1.09	1.17	1.26	0.87	1.46	0.32	0.78	0.56	0.81	1.07	0.44	0.96
DBW 90 x HD 3086	0.84	0.90	0.94	0.45	0.45	0.25	1.93	1.10	1.02	1.99	-4.26	1.00
PBW 550 x HD 3086	1.24	1.27	1.33	0.65	0.46	1.26	1.78	0.69	1.21	1.48	1.71	1.47

HIS: < 0.5 Highly heat tolerant, 0.51- 0.75 Heat tolerant, 0.76- 1.00 Moderately heat tolerant, >1.0 Susceptible to heat stress

Table 2: eat susceptibility indices for various characters in E_3 in comparison to E_1 environment in wheat.

Genotypes	Days to Heading	Days to Maturity	Grain filling period	Plant Height (cm)	Flag leaf area (cm^2)	Number of effective tillers per plant	Spike Length (cm)	Number of grains per spike	1000-Seed weight (g)	Biological yield per plant (g)	Harvest Index (%)	Grain yield per plant (g)
Raj 4238	0.59	0.84	1.07	1.00	1.00	0.79	0.99	0.88	0.99	1.11	0.59	0.93
Raj 4079	1.48	1.12	0.73	0.80	0.82	0.73	0.67	1.37	1.02	1.25	1.39	1.26
Raj 3765	1.19	0.95	0.70	0.96	0.77	0.88	0.77	1.05	1.00	0.86	1.00	0.91
Raj 3077	0.73	0.95	1.18	1.38	0.87	1.25	1.21	0.92	0.93	0.61	0.41	0.57
Raj 1482	1.01	1.01	1.01	1.10	1.11	1.20	1.54	1.26	1.00	0.68	1.01	0.82
Raj 3777	1.00	1.09	1.24	1.04	1.09	1.07	0.90	1.01	0.97	0.88	0.91	0.90
WH 1021	0.99	1.12	1.19	1.31	1.07	0.35	0.87	1.14	1.02	1.27	0.71	1.07
DBW 90	1.05	1.07	1.09	0.75	0.53	1.31	1.04	0.84	1.42	0.69	2.32	1.27
PBW 550	1.07	1.05	1.01	0.77	1.24	1.47	0.93	1.42	0.84	1.15	0.65	0.98
HD 3086	0.97	1.08	1.20	1.05	0.97	0.32	1.48	0.77	1.09	1.05	2.35	1.43
F_1 Crosses												
Raj 4238 x Raj 4079	1.01	0.97	0.96	0.76	0.47	1.19	0.86	0.81	1.00	0.87	0.60	0.79
Raj 4238 x Raj 3765	1.07	0.84	0.59	0.66	0.88	1.29	1.14	0.98	0.94	1.35	0.35	1.05
Raj 4238 x Raj 3077	0.85	1.08	1.31	0.86	0.84	1.08	0.89	0.59	0.94	0.93	0.46	0.79
Raj 4238 x Raj 1482	1.07	0.78	0.47	1.01	1.00	0.63	0.69	0.85	1.13	1.18	2.12	1.43
Raj 4238 x Raj 3777	0.95	1.25	1.51	0.82	0.94	1.10	1.30	0.63	0.99	0.97	1.51	1.14
Raj 4238 x WH 1021	0.81	0.88	0.92	1.24	1.01	0.81	0.70	0.82	1.08	0.73	0.62	0.73
Raj 4238 x DBW 90	0.58	1.07	1.49	0.82	0.75	0.88	1.01	0.80	1.18	1.20	1.92	1.37
Raj 4238 x PBW 550	1.04	1.06	1.11	0.49	0.49	1.19	1.38	0.94	1.01	1.03	1.80	1.27
Raj 4238 x HD 3086	1.36	1.21	1.08	0.51	1.02	1.01	1.08	1.06	1.32	1.10	1.52	1.22
Raj 4079 x Raj 3765	1.27	0.82	0.34	0.92	0.39	0.83	0.83	1.11	1.23	0.47	0.24	0.41
Raj 4079 x Raj 3077	0.84	0.99	1.12	1.33	1.64	0.70	1.50	1.05	0.89	1.12	0.55	0.92
Raj 4079 x Raj 1482	1.22	0.89	0.49	0.70	0.81	1.01	0.45	0.40	0.93	0.97	1.17	1.03
Raj 4079 x Raj 3777	1.27	1.04	0.81	1.28	0.80	0.78	1.33	1.67	-0.35	1.00	1.49	1.16
Raj 4079 x WH 1021	0.76	0.79	0.80	0.92	1.30	1.29	0.63	1.18	1.30	1.55	0.74	1.25
Raj 4079 x DBW 90	1.06	0.71	0.30	1.43	0.03	0.93	1.10	1.40	0.87	0.94	1.19	1.02
Raj 4079 x PBW 550	0.59	1.11	1.51	0.95	1.43	0.55	0.77	0.80	1.25	0.88	0.56	0.78
Raj 4079 x HD 3086	0.99	0.96	0.95	0.74	1.79	0.79	1.33	1.35	1.19	0.90	1.41	1.09
Raj 3765 x Raj 3077	0.83	0.98	1.13	0.90	0.80	0.59	0.64	0.67	0.86	0.89	0.45	0.75
Raj 3765 x Raj 1482	1.06	0.84	0.61	1.62	0.64	1.01	1.27	1.39	1.40	0.98	1.60	1.18
Raj 3765 x Raj 3777	0.85	1.09	1.32	1.46	1.69	1.22	1.02	1.41	1.51	1.20	0.43	0.96
Raj 3765 x WH 1021	1.14	1.01	0.90	0.99	0.54	1.33	1.13	1.35	0.32	1.06	0.22	0.78
Raj 3765 x DBW 90	0.75	0.60	0.45	0.25	1.37	0.79	0.87	1.24	1.23	1.07	0.31	0.82
Raj 3765 x PBW 550	1.06	0.97	0.86	0.99	0.81	1.11	1.05	1.10	0.99	1.10	1.41	1.18
Raj 3765 x HD 3086	0.94	1.03	1.09	0.84	1.35	0.85	0.71	0.94	0.94	1.09	0.24	0.82
Raj 3077 x Raj 1482	0.90	0.96	1.03	0.96	1.34	0.43	1.08	0.99	0.87	1.14	0.46	0.91
Raj 3077 x Raj 3777	0.99	0.93	0.89	0.90	0.98	0.99	0.72	0.57	0.91	0.75	0.89	0.81
Raj 3077 x WH 1021	1.09	1.13	1.27	1.26	1.01	0.99	0.44	1.23	1.49	0.92	0.59	0.81
Raj 3077 x DBW 90	0.97	0.76	0.55	0.82	1.22	0.96	0.78	0.99	0.73	0.92	2.63	1.47
Raj 3077 x PBW 550	1.08	1.18	1.25	1.33	0.66	0.91	1.06	0.53	1.38	0.92	-0.61	0.43
Raj 3077 x HD 3086	1.26	0.67	-0.03	0.89	1.03	1.11	0.96	0.93	0.81	1.06	1.11	1.07
Raj 1482 x Raj 3777	0.94	1.08	1.18	0.90	0.74	0.95	0.85	1.38	1.61	0.84	2.36	1.35
Raj 1482 x WH 1021	1.22	1.09	0.96	1.46	1.53	0.55	1.46	0.76	0.78	0.93	0.37	0.75
Raj 1482 x DBW 90	0.99	1.20	1.34	1.14	1.13	1.96	0.79	0.97	1.19	1.02	1.76	1.23
Raj 1482 x PBW 550	1.25	1.18	1.13	0.78	1.30	1.46	1.30	0.99	0.92	1.26	1.56	1.30
Raj 1482 x HD 3086	1.24	1.01	0.78	1.31	1.22	1.20	1.55	0.77	1.20	0.82	0.32	0.66
Raj 3777 x WH 1021	1.30	0.53	-0.43	0.94	0.14	0.44	0.54	1.03	0.83	0.83	1.20	0.96
Raj 3777 x DBW 90	0.72	1.15	1.48	0.81	0.55	0.50	1.38	0.70	0.81	1.05	1.61	1.20
Raj 3777 x PBW 550	1.26	1.22	1.18	1.07	0.61	1.81	1.13	1.26	1.02	1.10	0.29	0.84
Raj 3777 x HD 3086	1.05	1.21	1.46	0.75	1.05	1.08	0.74	0.97	0.75	0.96	1.46	1.12
WH 1021 x DBW 90	0.69	1.16	1.53	1.18	1.31	1.69	0.62	0.94	0.89	0.86	0.19	0.63
WH 1021 x PBW 550	0.99	1.00	0.97	1.10	0.71	1.21	0.71	0.89	0.76	0.92	0.48	0.82
WH 1021 x HD 3086	0.67	1.08	1.44	0.82	1.58	0.33	1.30	0.70	0.94	0.95	1.50	1.13
DBW 90 x PBW 550	0.96	1.09	1.25	1.20	0.65	0.86	0.82	0.68	0.81	0.89	1.19	0.99
DBW 90 x HD 3086	0.86	1.18	1.50	1.25	1.40	1.26	1.61	1.20	1.51	1.34	1.16	1.21
PBW 550 x HD 3086	1.01	1.11	1.30	1.29	1.46	1.09	1.14	0.79	1.27	1.15	1.86	1.34

HIS: < 0.5 Highly heat tolerant, 0.51- 0.75 Heat tolerant, 0.76- 1.00 Moderately heat tolerant, >1.0 Susceptible to heat stress

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