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Heat Stress Implications on Yield and Yield Component in Recombinant Inbred Lines of Bread Wheat at Reproductive Stage

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ABSTRACT

Heat stress has adverse impacts on many physiological and morphological traits in crops. An experiment was conducted to evaluate the effects of heat stress on 100 advanced recombinant inbred lines (RILs) of wheat developed through WH1021×WH711 cross. The experiment was laid out in randomized block design at Wheat Research Area, Department of Genetics and Plant Breeding, CCSHAU, Hisar (Haryana), India during 2015-16 and 2016-17 growing season. To create heat stress at reproductive stage the sowing of crop for heat stress experiment was delayed by 4 weeks from normal period of sowing. Percent variation in mean values of yield traits showed significant effect of heat stress on yield components. Grain yield showed maximum percent variation and is also significantly correlated with grains number/spike, grains weight/spike and 100 grains weight. This percent variation in genotypes varied and less variation was observed in WH1021, which is an identified tolerant genotype, and some RILs which indicated about their tolerance to heat stress. So these RILs would form an important resource for the development of high yielding varieties under heat stress.

Key words: *Grain yield, Heat stress, Recombinant Inbred Lines, Reproductive stage, Tolerance.*

INTRODUCTION

Heat stress has been defined as brief episodes of high temperature exhibit outside the range typically experienced[1], lead to irreversible yield reductions[2]. Global warming has become a significant threat all over the world. A drastic reduction in the food production is predicted due to elevation in frequency and severity of heat stress [3]. Considerable rise is observed in ambient temperature as a part of current global climate change. Instead of average global increase in temperature, there are significant spatial and temporal differences with further negative impacts on agriculture[4]. Wheat is second most important crop in production among cereals after rice. The average global grain yield of major cereal crops forecasted by FAO is 2594 million tonnes in 2017 of which contribution by wheat is 743.2 million tonnes[5].

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Wheat is cultivated on 30% of world's cereal area and provides food to 36% of the global population[6,7]. By sharing 12% in global wheat production India ranked as second largest wheat producing country. The total FAO forecasted wheat production in India during 2016-17 is 97.4 million tonnes which was higher than 92.3 and 86.5 million tonnes for 2015-16 and 2014-15 respectively. In coming years to fulfill the demand an annual increase of 1.6% is required with the limited available resources and climate change[5]. In India more than 13.5 million ha of wheat cultivation area is under heat stress. As reported by Joshi *et al*[8] and Singh *et al*[9] Eastern gangatic plain, central and Penisular India and Bangladesh are most susceptible regions to heat stress in South Asia for wheat growing. In late sowing wheat particularly during grain filling stage severe damage was observed and results in adverse effect on crop productivity[10]. In major wheat cultivars during late sown conditions yield loss of 33.6% indicate that there is an urge to incorporate heat tolerance in wheat cultivars to achieve sustainable production [8,11].

Yield loss is frequently attributed to reduction in number of viable seed produced [12,1] and acceleration in crop development due to decrease in duration of crop growth[13]. Vara prasad *et al*[14] predicted that increase in temperature variations results in short episodes of heat stress coinciding with susceptible reproductive processes leading to significant reduction in floret fertility in crops. Increment of 5-6 ºC temperature from 25 ºC increases grain filling rate, although resulted in declined final grain yield due to shortening of grain filling period[15]. For wheat the upper threshold temperature accepted is 31 ºC without causing reduction in grain number[16], but sensitivity towards this depends on the developmental state[17], genotype[18] and water status of the crop[19]. Final grain weight is based on duration and grain filling rate[20]. Grain filling period of wheat is decreased by 12 days due to 5 ºC increase in temperature above 20 ºC[21]. High temperature significantly declined grain yield, number of grains per spike, plant height, grain filling duration and 1000 kernel weight[22]. Singh *et al*[9] reported considerable decline in grain yield per plant, biological yield per plant, and grain yield per spike under late sown conditions. Differences in response of different cultivars to temperature increase during post anthesis stage have been reported by Mian *et al*[23] for number of grains per spike and grain weight. Two promising genotypes 'WH1021' and 'WH730' showing enhanced yield under heat stress were developed[24]. Likewise three synthetic wheat lines, SYN11, SYN36 and SYN44 were declared as tolerant to high temperature based on cluster analysis of morphological attributes and ISSR markers[25].

MATERIAL AND METHODS

Field material and experimental design:
The experiment was conducted at Wheat Research Area, Department of Genetics and Plant Breeding, CCSHAU, Hisar (Haryana), India during 2015-16 and 2016-17 growing season. Plant material consisted of mapping population of 100 Recombinant Inbred Lines (RILs) of advanced generation developed from a cross between WH1021×WH711. The experiment was carried out in randomized block design with three replications. Each plot was consist of two rows of 1 m length with a 23×10 cm spacing within rows and between plants. To create heat stress at anthesis and reproductive stage the sowing of experiment was delayed by 4 weeks from normal period of sowing. The experiment under timely sown environment was sown in the second week of November and the experiment under late sown was sown in last week of December. Data regarding temperature were recorded from Meteorological Laboratory, CCS Haryana Agriculture University, Hisar, India.

Determination of yield and yield components:
Grain yield and biological yield were measured after physiological maturity by harvesting five plants from each row separately. The spikelets per spike, spike length, grains per spike and grain weight per spike were calculated based on ten spikes. Average numbers of tillers per plants were counted from a single row. Weight of hundred grains was determined by counting the

hundred grains and then weighing on analytical balance.

Statistical analysis:

Pearson's correlation between various yield components was performed by using OPSTAT software available at CCSHAU website hau.ernet.in. The mean comparison was calculated by percent variation of yield and yield components between timely sown and late sown conditions during both years.

RESULTS

Mean performance of genotypes:

Grain yield of WH711 during timely sown in both years (2015-16 & 2016-17) was 15.213±0.009g/plant & 13.658±0.733g/plant respectively showed its better performance as compare to WH1021 (11.363±0.041g/plant & 11.810±0.323g/plant in 2015-16 & 2016-17 respectively). But the range of RILs (6.587-17.449g/plant & 5.600-21.000g/plant in 2015-16 & 2016-17 respectively) showed that there are some RILs which performs better than WH711 while the mean of RILs for yield and all yield components lies between the mean of two parents WH1021×WH711 (Table 1 & 2). During late sown heat stress causes reduction in grain yield per plant in WH711 (7.340±0.007g/plant & 7.743±0.200g/plant in 2015-16 & 2106-17 respectively), while this reduction is less in WH1021 (8.905±0.016g/plant & 9.254±0.054g/plant in 2015-16 & 2016-17 respectively) as WH1021 is comparatively heat tolerant genotype than WH711 which is heat sensitive. Range of RILs for these components (Table 1 & 2) indicated that there lines in population (RIL19, RIL32, RIL48, RIL65, RIL76) which performed better than heat tolerant genotype (WH1021) under heat stress conditions.

Variation in yield and its components:

To estimate the effect of heat stress on the parents and its RILs percent variation was calculated based upon variation in the values of yield and its components during timely sown and late sown conditions. The percent variation was much higher for grain yield (51.75% & 43.31%), biological yield (54.53% & 54.57%) and number of tillers (49.33% & 50.65%) in heat sensitive parent (WH711) as compare to less variation in heat tolerant parent (WH1021) for grain yield (21.63% & 21.64%), biological yield (20.45% & 23.65%) and number of tillers (17.24% & 25.40%) in both years 2015-16 and 2016-17. Percent variation in means of RILs for grain yield, biological yield and number of tillers lies between the heat tolerant parent (WH1021) and heat sensitive parent (WH711). Other yield components like spike length, spikelets per spike, grains per spike and 100 grains weight showed considerable variation in timely sown and late sown conditions during both years (Table 3 & 4).

Correlation of yield with its components:

Grains number per spike, grains weight per spike and 100 grain weight showed significant positive correlation with grain yield per plant under both timely sown and late sown environments during both growing seasons (Table5 & 6). Grain yield has correlation 0.796^{**}, 0.424^{**} (TS) and 0.706^{**}, 0.609^{**} (LS) with grains number per spike during both years. The correlation between grain yield and grains weight per spike was 0.875^{**}, 0.775^{**} in timely sown and 0.886^{**}, 0.826^{**} in late sown during 2015-16 and 2016-17. Grain yield showed correlation of 0.773^{**}, 0.611^{**}during 2015-16 in timely sown and late sown respectively and 0.636^{**}, 0.616^{**} during 2016-17 in timely sown and late sown respectively. Biological yield per plant was negatively correlated with the grain yield per plant. Number of tillers per plant significantly correlated with biological yield but not with grain yield. Spike length was significantly correlated with grain yield per plant, grains number per spike and grains weight per spike during timely sown condition (Table 5 & 6).

DISCUSSION

A set of 100 RILs and two parents evaluated in this work exhibited a high phenotypic variability for yield and its components. Many developmental processes of wheat crop during grain filling period are directly or indirectly affected by the high temperature. High temperature episodes cause great reduction in yield and yield components. It is observed from the result of mean comparison (Table 1 & 2) that delaying in the sowing significantly decreased grain yield, biological yield and numbers of tillers. Decline in 100 grain weight during late sown is due to high temperature in March and April which coincide with grain filling period. Mian *et al*.[23] also reported lower thousand grain weight due to heat stress. Crop duration decrease due to high temperature is correlated with lower biological yield, the same results were also observed by Rane et al.[26]. Grain number per spike was recorded higher during timely sown conditions but reduced in late sown (Table 1 & 2) which showed its association with cooler temperature in January for timely sown and high temperature in March for late sown. This is supported by Khan *et al.*[27]. WH1021 and some RILs were less affected and showed less reduction in their yield while WH711 and other RILs showed higher reduction under high temperature. Highest reduction was observed in grain yield and least in spikelets per spike due to heat stress. This showed variation in sensitivity of traits and genotypes to high temperature which differ from trait to trait and genotype to genotype under different temperature conditions. These findings indicate that to avoid the heat stress in wheat crop timely sowing is advisable. It also emphasizes the importance of variation in grains number and grain weight per spike are main yield components to compensate for the effect of heat stress at anthesis and post anthesis stages.

Table 1: Mean and range of parents and RILs for yield and its components during 2015-16

Parents	WH1021		WH711		RILS			
Traits	TS	LS	TS	LS	TS		LS	
					Mean	Range	Mean	Range
Number of tillers/plant	5.8±0.3	4.8±0.3	7.5±0.4	3.8±0.3	4.8±0.2	3.3-7.4	3.6±1.1	1.5-5.0
SL(cm)	13.4±1.0	11.3±0.6	12.8±0.5	10.5±0.6	13.1±0.3	10.9-15.9	11.3±0.1	9.3-13.5
SPS	19.8±0.1	18.1±0.3	21.1±0.2	17.6±0.4	20.1±0.1	14.5-23.4	17.9±0.3	12.9-22.0
GY(g/plant)	11.363±0.041	8.905±0.016	15.213±0.009	7.340±0.007	13.503±0.125	6.587-17.449	7.818±0.096	3.775-11.252
BY(g/plant)	26.820±0.035	21.336±0.19	33.296±0.041	15.140±0.128	27.403±0.416	12.000-44.759	16.403±0.243	7.400-27.600
GNS	66.4±0.3	56.1±0.5	56.7±0.4	48.1±0.5	68.5±1.9	42.0-91.0	55.1±1.356	30.3-74.3
GWS(g)	2.388±0.062	1.968±0.054	2.571±0.043	1.780±0.027	2.511±0.180	1.049-3.974	1.735±0.165	0.458-2.947
100 GW(g)	3.676±0.078	3.181±0.037	4.484±0.015	3.181±0.037	3.680±0.183	2.093-4.965	2.691±0.0.041	1.719-3.566

TS- Timely sown, LS- late sown, SL-Spike length, SPS-Spikelets/spike, GY-Grain yield/plant, BY- Biological yield/plant, GNS-Grains number/spike, GWS-Grains weight/spike, 100GW-100 grains weight

Table 2: Mean and range of parents and RILs for yield and its components during 2016-17

Parents	WH1021		WH711		RILS			
Traits	TS	LS	TS	LS	TS		LS	
					Mean	Range	Mean	Range
Number of tillers/plant	6.3±0.4	4.7±0.1	7.7±0.3	3.8±0.6	5.5±0.5	3.3-8.3	4.0±0.4	2.0-6.0
SL(cm)	13.8±0.1	11.5±0.2	12.7±0.3	10.7±0.1	13.2±0.4	10.4-15.9	11.3±0.3	9.1-13.6
SPS	21.5±0.4	19.6±0.2	20.8±0.3	18.1±0.5	22.4±0.6	18.3-24.7	20.1±0.6	15.3-22.0
GY(g/plant)	11.810±0.323	9.254±0.054	13.658±0.733	7.743±0.200	14.254±0.234	5.600-21.000	8.285±0.127	2.658-15.567
BY(g/plant)	27.833±0.441	21.250±0.382	32.872±0.613	14.933±0.176	25.603±0.425	10.200-42.959	14.903±0.246	5.900-26.100
GNS	64.0±0.5	56.9±0.2	59.7±0.7	49.2±0.1	67.5±0.987	44.6-94.0	56.3±0.918	34.3-78.7
GWS(g)	2.480±0.009	1.731±0.005	2.569±0.031	1.622±0.013	2.725±0.043	0.933-4.371	1.766±0.026	0.679-3.033
100 GW(g)	3.861±0.008	3.027±0.017	4.322±0.073	3.320±0.02	4.001±0.057	1.795-6.836	3.126±0.069	1.165-4.887

TS- timely sown, LS- late sown, SL-Spike length, SPS-Spikelets/spike, GY-Grain yield/plant, BY- Biological yield/plant, GNS-Grains number/spike, GWS-Grains weight/spike, 100GW-100 grains weight

Table3: Variation in yield and its component of parents & RILs of bread wheat during 2015-16

Traits	Percent variation		
	WH1021	**WH711**	**RILs**
Number of tillers/plant	17.24	49.33	25.00
SL(cm)	15.67	17.97	13.08
SPS	8.59	16.59	10.95
GY(g/plant)	21.63	51.75	42.10
BY(g/plant)	20.45	54.53	40.14
GNS	15.51	15.17	19.56
GWS(g)	17.59	30.77	30.90
100 GW(g)	13.47	29.06	26.88

Table4: Variation in yield and its component of parents & RILs of bread wheat during 2016-17

Traits	Percent variation		
	WH1021	**WH711**	**RILs**
Number of tillers/plant	25.40	50.65	27.27
SL(cm)	16.67	15.75	14.39
SPS	8.84	12.98	10.27
GY(g/plant)	21.64	43.31	41.88
BY(g/plant)	23.65	54.57	41.79
GNS	11.09	17.59	16.59
GWS(g)	30.20	36.86	35.19
100 GW(g)	21.60	23.18	21.87

SL-Spike length, SPS-Spikelets/spike, GY-Grain yield/plant, BY- Biological yield/plant, GNS-Grains number/spike, GWS-Grains weight/spike, 100GW-100 grains weight

Table 5: Correlation matrix of yield and yield components during 2015-16

Traits		NT		SL		SPS		GY		BY		GNS		GWS		100GW	
		TS	**LS**	**TS**	**LS**	**TS**	**LS**	**TS**	**LS**	**TS**	**LS**	**TS**	**LS**	**TS**	**LS**	**TS**	**LS**
NT	**TS**	1	0.626**	-0.074	-0.205	0.129	0.151	0.122	-0.046	0.071	0.438**	0.099	-0.091	0.15	-0.125	0.169	0.064
	LS		1	-0.213	-0.124	-0.173	0.129	-0.02	-0.059	-0.021	0.398**	0.065	-0.057	0.051	-0.143	0.007	-0.002
SL	**TS**			1	0.146	0.584**	-0.056	0.328**	0.214	0.305**	-0.065	0.293**	0.211	0.333**	0.163	0.242*	0.184
	LS				1	0.003	0.623**	0.048	0.201	0.139	0.052	0.057	0.207	0.066	0.213	0.093	0.006
SPS	**TS**					1	0.165	0.376**	0.217	0.057	0.022	0.380**	0.268*	0.395**	0.122	0.256*	0.225*
	LS						1	0.079	0.174	0.095	0.11	0.129	0.244*	0.122	0.094	0.031	-0.002
GY	**TS**							1	0.396**	0.093	-0.025	0.796**	0.353**	0.875**	0.336**	0.773**	0.405**
	LS								1	0.024	0.072	0.277*	0.706**	0.399**	0.886**	0.393**	0.611**
BY	**TS**									1	-0.044	0.045	-0.102	0.077	-0.006	0.062	0.18
	LS										1	-0.021	0.009	-0.026	0.014	0.036	-0.019
GNS	**TS**											1	0.425**	0.831**	0.18	0.323**	0.224*
	LS												1	0.359**	0.599**	0.168	0.119
GWS	**TS**													1	0.328**	0.762**	0.400**
	LS														1	0.388**	0.495**
100GW	**TS**															1	0.418**
	LS																1

**significant at 1%, * significant at 5%, TS- Timely sown, LS- late sown, NT-number of tillers/plant, SL-Spike length, SPS-Spikelets/spike, GY-Grain yield/plant,
BY- Biological yield/plant, GNS-Grains number/spike, GWS-Grains weight/spike, 100GW-100 grains weight

Table 6: Correlation matrix of yield and yield components during 2016-17

Traits		NT		SL		SPS		GY		BY		GNS		GWS		100GW	
		TS	**LS**	**TS**	**LS**	**TS**	**LS**	**TS**	**LS**	**TS**	**LS**	**TS**	**LS**	**TS**	**LS**	**TS**	**LS**
NT	**TS**	1	0.087	-0.243*	-0.231*	-0.088	-0.139	-0.129	-0.069	0.002	0.149	-0.499**	-0.072	-0.652**	-0.199	-0.437**	-0.218*
	LS		1	0.121	0.128	0.118	0.108	-0.03	0.342**	-0.148	0.142	0.052	-0.01	-0.084	0.019	-0.16	0.027
SL	**TS**			1	0.436**	0.625**	0.155	0.219*	0.043	0.17	0.002	0.227*	0.081	0.299**	0.115	0.185	0.111
	LS				1	0.280*	0.702**	0.148	0.103	-0.025	0.098	0.269*	0.109	0.266*	0.093	0.125	0.028
SPS	**TS**					1	0.328**	0.138	0.073	0.038	0.157	0.216	0.137	0.116	0.122	-0.004	0.074
	LS						1	0.041	0.178	-0.136	0.055	0.177	0.255*	0.117	0.216	0.031	0.069
GY	**TS**							1	0.167	0.212	-0.068	0.424**	0.047	0.775**	0.231*	0.636**	0.294**
	LS								1	-0.148	0.171	0.122	0.609**	0.157	0.826**	0.079	0.616**
BY	**TS**									1	-0.033	-0.006	0.051	0.129	-0.038	0.189	-0.089
	LS										1	-0.107	0.01	-0.115	0.049	-0.042	0.065
G NS	**TS**											1	0.095	0.637**	0.119	-0.01	0.078
	LS												1	0.054	0.707**	-0.005	0.138
GWS	**TS**													1	0.275*	0.752**	0.344**
	LS														1	0.234*	0.790**
100GW	**TS**															1	0.346**
	LS																1

** Significant at 1%, * significant at 5%, TS- Timely sown, LS- late sown, NT-number of tillers/plant, SL-Spike length, SPS-Spikelets/spike, GY-Grain yield/plant,
BY- Biological yield/plant, GNS-Grains number/spike, GWS-Grains weight/spike, 100GW-100 grains weight

CONCLUSION

It is concluded that delay in wheat crop sowing beyond optimum sowing dates results in high temperature episodes during grain filling period which significantly reduce the grain yield and yield components of bread wheat. But this maximum reduction is in sensitive variety WH711 as compare to tolerant variety WH1021. There are some RILs developed from the cross of two varieties which perform better than the tolerant variety WH1021. This study confirmed that genetic variability exist between the RILs developed with cross WH1021×WH711 for post anthesis heat tolerance, which could be utilized to develop high yielding and heat tolerant wheat genotypes.

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