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Assessment of genetic variability in bread Wheat (*Triticum aestivum*) under heat stress

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ABSTRACT

The present study was carried out during *rabi* 2017–18, at wheat research farm, Department of genetics and plant breeding, CCS Haryana Agricultural University, Hisar, Haryana to assess the genetic diversity of 64 genotypes of bread wheat (*Triticum aestivum* L.) under late sown conditions based on the morpho-physiological traits. Analysis of variance depicted significant differences for all morpho-physiological traits under heat stress. Mean sum of squares due to genotypes were found significant for all the traits, indicating the presence of sufficient genetic variability among the genotypes. High estimates of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and high heritability coupled with high genetic advance were observed for traits, viz. spike weight, relative stress injury, chlorophyll stability index and GGR28 indicating additive gene action in expression of the traits and simple selection will be effective for the improvement of these traits. Correlation coefficient analysis revealed that increased grain yield under heat stress conditions was significantly contributed by spike weight (0.699), spike length (0.646), harvest index (0.616), spikelets per spike (0.445), number of productive tillers (0.393), grains per spike (0.390), 1000-grain weight (0.364), biological yield (0.360), GGR14 (0.332) and chlorophyll stability index (0.330). Among the traits studied, biological yield per plot (0.8421) and harvest index (0.9686) recorded for highest positive direct effect on grain yield in late sown conditions. The grain yield is indirectly contributed by spike length, spike weight, spikelets per spike, CSI, GGR14 through harvest index and number of productive tillers per meter, spike weight, thousand grain weight, GGR14 through biological yield.

Keywords: Diversity, Grain yield, Heat stress, Wheat

Wheat (*Triticum aestivum* L.) is the most widely cultivated crop on earth and is the dominant food grain crop. It contributes about a fifth of the total calories consumed by humans. India is second-largest wheat producer after China, the latest estimates indicate total wheat grown an about 30.55 mha with production and productivity of about 107.18 MT and 3508 kg/ha, respectively (Anonymous 2020). Wheat belongs to Poaceae family, tribe Triticeae and placed in the genus Triticum. Temperatures above the optimum for growth can be deleterious, causing injury or irreversible damage, which is generally called heat stress. However, heat stress is a complex function of intensity, duration and rate of increase in temperature (Wahid *et al*. 2007). Wheat is cultivated under diverse environmental conditions varying from cool rain-fed to hot dry-land areas. In many parts of the world, heat stress is the major limiting factor for wheat production. Global wheat production is estimated to fall by an additional 6% for each degree of global temperature rise (Asseng *et al*. 2015). In addition, the development of early maturing genotypes is crucial in order to escape the terminal heat stress in crops (Joshi 2007). There is an urgency to efforts to develop genotypes which are either tolerant to terminal heat stress or could mature very early. Availability of diverse genetic resources and the ability to maintain yield across different environments makes a crop improvement programme really effective. It becomes more significant under the harsh and fluctuating climatic conditions leading to more genotype and environment interactions. The utilization of this available genetic diversity depends upon identification of trait(s) specific germplasm could be use in crop improvement.

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MATERIALS AND METHODS

A set of 64 wheat genotypes were used including advance lines with four popular standard checks, viz. HD 3059, WH 1021, WH 1124 and DBW 90, differing in their performance under heat stress under late sown conditions. The late sown was done to create heat stress at anthesis and the reproductive stage. The experiments were conducted in a randomized complete block design with three replications and with a plot size of six rows, each of 6 m length with a 20 cm × 5 cm spacing within rows and between plants. Data on average of five competitive plants selected randomly from each plot were recorded for Days to 75% heading, Days to 75% anthesis, Plant height (cm), Spike length (cm), Spike weight (g), 1000 grain weight (g), Number of grains per spike, Number of effective tillers per meter, Grain yield/ plot (g), Biological yield/plot (g), Harvest index (%) and physiological traits e.g. Canopy temperature, Chlorophyll stability index (CSI) and Relative stress injury (RSI). The average of observations was recorded on five selected plants and considered for statistical analysis. Mean values were used for statistical analysis using R statistical programme (Package Agricolae - CRAN, version – 4.1.0).

RESULTS AND DISCUSSION

Analysis of variance and mean performance: Analysis of variance revealed significant differences between the genotypes for all the traits, indicating the prevalence of sufficient genetic variation in the advance lines under study for further selection and improvement. Jee *et al.* (2019) also found that the analysis of variance was significant among the genotypes under their study. From the screened genotypes, 21 genotypes, some of which, viz. P4149 (3.40), P4262 (3.36), P4195 (3.30), P13773 (3.29) etc. exhibited significantly higher mean grain yield as compared to standard checks and one or more heat stress related traits like canopy temperature, chlorophyll stability index and relative stress injury. It was an indication of complementation of high yielding and heat tolerant genes in these genotypes which may be used for getting high grain yield under heat stress conditions (Fig 1, 2). Genotype P12968 (3.93) has highest CSI and six other genotypes exhibited significantly higher CSI as compare to standard checks. Genotype P13574 (2.27) has lowest RSI and seven genotypes, possessed significantly lower RSI as compare to standard checks which indicates that these are heat tolerant genotypes. Similarly, Thapa *et al*. (2018) also reported same results for grain yield, canopy temperature, days to heading and productive tillers per meter. The above genotypes could be used as source for introgression of heat tolerant genes in high yielding commercially available cultivar's background.

Phenotypic and Genotypic Coefficient of Variation: The high PCV was recorded for the traits, viz. RSI (27.32), GGR28 (26.31) and CSI (20.36) (Table 1). The higher estimates of PCV, suggested that adequate variability is present for these traits hence there is a scope for improvement in these traits under heat stress conditions. The high GCV was observed for the trait's RSI (26.30) and GGR28 (23.41). In the present study, it was recorded that PCV values were higher than GCV value for all the traits. This indicated more effect of environment on the traits under heat stress conditions. Results were significantly concurrence with Neeru *et al*. (2017) and Ramanuj *et al*. (2018).

Heritability and genetic advance: High broad sense heritability was recorded for almost all traits like plant height (97.69%) followed by RSI (92.71%), spike weight (81.95%), days to heading (80.06%) etc. except harvest index (41.69%) and grain yield (40.85%). The harvest index and grain yield have low heritability indicating the effect of environment on the expression of these traits. High heritability coupled with high genetic advance was recorded for spike weight, RSI, GGR28 and CSI. Similar results were observed by Fellahi *et al*. (2013) and Kumar *et al*. (2014). These may be attributed to the presence of additive gene action and possessed high selective value and thus, selection pressure could be applied on these traits for their rationale improvement.

Correlation coefficient analysis: Results revealed,

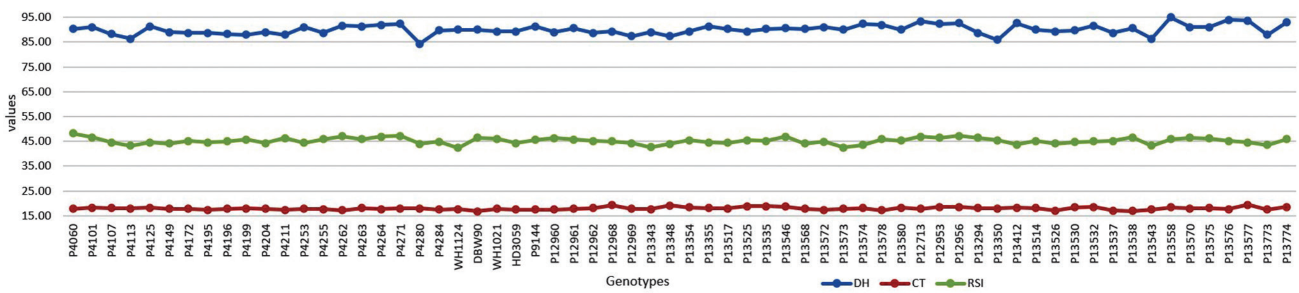

Fig 1 Mean performance of wheat genotypes for day to heading (DH), Canopy temperature (CT) and relative stress injury (RSI) under late sown conditions.

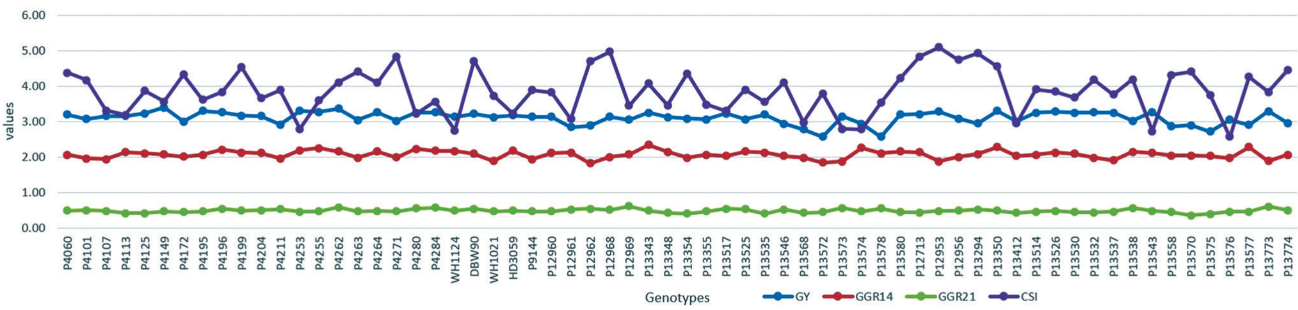

Fig 2 Mean performance of wheat genotypes for Grain yield GY), GGR14, GGR21 and Chlorophyll stability index (CSI) under late sown conditions.

Table 1 Phenotypic correlation coefficients among various traits of wheat genotypes and estimates of phenotypic and genotypic coefficient of variance, heritability and genetic advance

Variable/ trait	DH	DA	GGR14	GGR21	GGR28	CT	CSI	RSI	DM	PH	PTM	SL	SS	SW	GS	TGW	BY	HI	GY
DH	1																		
DA	0.433**	1																	
GGR14	-0.071	0.265*	1																
GGR21	-0.310*	0.180	0.030	1															
GGR28	-0.039	0.270*	-0.091	-0.204	1														
CT	0.189	-0.167	-0.011	-0.229	-0.095	1													
CSI	0.053	-0.139	0.086	-0.057	-0.189	0.053	1												
RSI	0.146	-0.246*	-0.239	-0.021	-0.035	0.035	-0.102	1											
DM	0.468**	0.173	0.044	-0.108	-0.080	0.008	0.198	-0.134	1										
PH	-0.084	-0.185	-0.032	-0.037	0.025	0.067	0.015	0.083	-0.022	1									
PTM	0.196	0.262*	0.053	-0.049	-0.172	-0.069	0.134	-0.033	0.119	-0.161	1								
SL	-0.471**	-0.169	0.190	0.245	-0.077	-0.123	0.010	-0.080	-0.318*	0.009	-0.023	1							
SS	-0.316*	0.055	0.168	0.198	-0.089	-0.110	0.270*	-0.025	-0.136	0.143	-0.023	0.364**	1						
SW	-0.277*	0.167	0.202	0.358**	-0.057	-0.165	0.297*	-0.115	-0.180	-0.034	0.064	0.221	0.255*	1					
GS	-0.077	0.327**	0.400**	0.115	0.052	-0.198	0.260*	-0.092	0.029	0.256*	-0.119	0.270*	0.295*	0.408**	1				
TGW	-0.078	0.012	0.088	0.107	-0.258*	0.064	0.017	-0.279*	-0.057	0.024	0.091	-0.021	0.016	0.284*	0.031	1			
BY	-0.103	0.034	0.155	0.108	-0.070	0.001	0.029	-0.089	0.336**	-0.112	0.441**	0.063	0.020	0.208	0.146	0.199	1		
HI	-0.309*	0.030	0.160	0.066	-0.033	-0.303*	0.284*	-0.110	-0.424**	0.119	-0.008	0.531**	0.380**	0.466**	0.219	0.166	-0.513**	1	
GY	-0.439**	0.084	0.332**	0.181	-0.096	-0.348**	0.330**	-0.218**	-0.158	0.042	0.393**	0.646**	0.445**	0.699**	0.390**	0.364**	0.360**	0.616**	1
PCV	2.23	2.71	6.34	13.74	26.31	2.98	20.36	27.32	1.93	5.52	10.52	5.46	5.42	15.13	10.69	6.38	5.67	8.19	7.33
GCV	1.99	2.4	5.18	10.96	23.41	2.37	18.21	26.3	1.51	5.46	8.69	4.35	4.2	13.7	9.36	5.21	4.5	5.29	4.69
H^2	80.06	78.9	66.77	63.64	79.17	63.28	79.96	92.71	60.9	97.69	68.16	63.45	60.11	81.95	76.6	66.75	63.02	41.69	40.85
GA (%)	3.68	4.4	8.71	18.01	42.91	3.88	33.54	52.17	2.43	11.11	14.78	7.14	6.71	25.55	16.87	8.77	7.36	7.04	6.17

DH, Days to heading; DA, Days to anthesis; GGR14, Grain growth rate at 14th days of anthesis (mg/day); GGR21, Grain growth rate at 21st days of anthesis (mg/day); GGR28, Grain growth rate at 28th days of anthesis (mg/day); CT, Canopy temperature (˚C); CSI, Chlorophyll stability index, RSI, Relative stress injury (%); DM, Days to maturity, PH, Plant height (cm); PTM, Productive tillers per meter; SL, Spike length (cm); SS, Spikelets per spike; SW, Spike weight (g); GS, Grains per spike; TGW, 1000-grain weight (g); BY, Biological yield per plot (Kg); GY, Grain yield per plot (Kg), HI, Harvest index (%).

Table 2 Direct (diagonal) and indirect effects of components traits on grain yield per plot in late sown wheat genotypes

Variable/ trait	DH	DA	GGR14	GGR21	GGR28	CT	CSI	RSI	DM	PH	PTM	SL	SS	SW	GS	TGW	BY	HI
DH	0.0749	-0.0142	0.0009	-0.0230	0.0004	0.0071	-0.0028	-0.0062	-0.0224	0.0011	-0.0169	0.0682	0.0015	0.0371	-0.0030	0.0059	-0.1199	-0.4279
DA	0.0324	-0.0328	-0.0032	0.0133	-0.0026	-0.0062	0.0074	0.0105	-0.0083	0.0024	-0.0225	0.0244	-0.0003	-0.0224	0.0125	-0.0009	0.0396	0.0408
GGR14	-0.0053	-0.0087	-0.0123	0.0022	0.0009	-0.0004	-0.0046	0.0102	-0.0021	0.0004	-0.0045	-0.0275	-0.0008	-0.0270	0.0153	-0.0066	0.1812	0.2211
GGR21	-0.0233	-0.0059	-0.0004	0.0741	0.0020	-0.0086	0.0030	0.0009	0.0052	0.0005	0.0042	-0.0355	-0.0009	-0.0480	0.0044	-0.0081	0.1260	0.0914
GGR28	-0.0029	-0.0089	0.0011	-0.0151	-0.0096	-0.0036	0.0100	0.0015	0.0038	-0.0003	0.0148	0.0111	0.0004	0.0076	0.0020	0.0195	-0.0822	-0.0455
CT	0.0142	0.0055	0.0001	-0.0170	0.0009	0.0374	-0.0028	-0.0015	-0.0004	-0.0009	0.0059	0.0178	0.0005	0.0221	-0.0076	-0.0049	0.0011	-0.4189
CSI	0.0040	0.0046	-0.0011	-0.0042	0.0018	0.0020	-0.0530	0.0043	-0.0095	-0.0002	-0.0115	-0.0014	-0.0013	-0.0398	0.0100	-0.0013	0.0342	0.3923
RSI	0.0109	0.0081	0.0029	-0.0015	0.0003	0.0013	0.0054	-0.0426	0.0064	-0.0011	0.0028	0.0115	0.0001	0.0153	-0.0035	0.0211	-0.1037	-0.1522
DM	0.0351	-0.0057	-0.0005	-0.0080	0.0008	0.0003	-0.0105	0.0057	-0.0478	0.0003	-0.0102	0.0460	0.0006	0.0241	0.0011	0.0043	0.3924	-0.5863
PH	-0.0063	0.0061	0.0004	-0.0028	-0.0002	0.0025	-0.0008	-0.0035	0.0011	-0.0132	0.0139	-0.0014	-0.0007	0.0046	0.0098	-0.0018	-0.1304	0.1648
PTM	0.0147	-0.0086	-0.0007	-0.0036	0.0017	-0.0026	-0.0071	0.0014	-0.0057	0.0021	-0.0859	0.0033	0.0001	-0.0086	-0.0046	-0.0069	0.5150	-0.0107
SL	-0.0353	0.0055	-0.0023	0.0182	0.0007	-0.0046	-0.0005	0.0034	0.0152	-0.0001	0.0020	-0.1448	-0.0017	-0.0296	0.0104	0.0016	0.0731	0.7350
SS	-0.0237	-0.0018	-0.0021	0.0147	0.0009	-0.0041	-0.0143	0.0011	0.0065	-0.0019	0.0019	-0.0527	-0.0047	-0.0342	0.0113	-0.0012	0.0238	0.5255
SW	-0.0208	-0.0055	-0.0025	0.0266	0.0006	-0.0062	-0.0157	0.0049	0.0086	0.0005	-0.0055	-0.0320	-0.0012	-0.1339	0.0156	-0.0214	0.2427	0.6440
GS	-0.0058	-0.0107	-0.0049	0.0085	-0.0005	-0.0074	-0.0138	0.0039	-0.0014	-0.0034	0.0102	-0.0391	-0.0014	-0.0546	0.0384	-0.0023	0.1710	0.3029
TGW	-0.0058	-0.0004	-0.0011	0.0079	0.0025	0.0024	-0.0009	0.0119	0.0027	-0.0003	-0.0078	0.0030	-0.0001	-0.0380	0.0012	-0.0755	0.2327	0.2293
BY	-0.0077	-0.0011	-0.0019	0.0080	0.0007	0.0000	-0.0016	0.0038	-0.0161	0.0015	0.2880	-0.0091	-0.0001	-0.0278	0.0056	-0.0150	0.8241	-0.7090
HI	-0.0232	-0.0010	-0.0020	0.0049	0.0003	-0.0113	-0.0150	0.0047	0.0203	-0.0016	0.0007	-0.0769	-0.0018	0.3523	0.0084	-0.0125	-0.5987	0.9686

(RE = 0.0019)

Refer to the footnote of Table 1 for Variable/Trait abbreviations.

increased grain yield under heat stress conditions was significantly contributed by spike weight (0.699), spike length (0.646), harvest index (0.616), spikelets per spike (0.445), productive tillers (0.393), grains per spike (0.390), 1000-grain weight (0.364), biological yield (0.360), GGR14 (0.332) and CSI (0.330) (Table 1). This suggested the considerable role of above traits selecting for higher grain yield under heat stress. Similarly, significant results for correlation were recorded for grain yield with other traits by Okechukwu *et al*. (2015), Mecha *et al*. (2017) and Ramanuj *et al*. (2018). Days to heading (-0.439), canopy temperature (-0.348) and relative stress injury (-0.218) were showed significant negative correlation with grain yield. Similar results for these traits were also reported earlier (Dutamo *et al*. 2015, Menshawy 2007). Grain yield significantly negatively correlated with days to heading indicating the faster the crop matures, the lesser the crop is exposed to the extended heat stress; hence, more grain yield will be achieved. Relative stress injury has significant negative correlation with 1000-grain weight (-0.279) which indicate that heat stress leads to decrease in grain weight which ultimately reduce grain yield.

Path coefficient analysis: Results revealed that harvest index (0.9686) and biological yield (0.8421) had the high positive direct effect on grain yield (Table 2). The traits, viz. GGR21 (0.0741) and days to heading (0.0749) also exhibit positive direct effects on grain yield. Similar results were also recorded for these traits by Shenavar and Golparvar (2015), Neeru *et al*. (2017), Rajshree and Singh (2018) and Ramanuj *et al*. (2018). The highest negative direct effect was recorded for spike length (-0.1448), spike weight (-0.1339), 1000-grain weight (-0.0755), productive tillers (-0.0859), CSI (-0.0530), RSI (-0.0426) and days to anthesis (-0.0328). Grain yield is contributed by harvest index via spike length (0.7350), spike weight (0.6440), spikelets per spike (0.5255) and by biological yield via productive tillers (0.5150). Biological yield and harvest index are the most contributing trait in grain yield as they have maximum direct as well indirect effect via different traits. Low residual effects (0.0019) in path coefficient analysis indicated a high contribution of independent traits to the dependent traits.

Based on present investigation the yield and its contributing traits genotypes, viz. P4280, P13350, P13543, P13348 and P4113 were observed to be promising for early maturity and also reported important for better performance under heat stress with low reduction of the grain yield. The wheat genotypes, viz. P4149, P13343, P13574, P12968, P13350 and P13543 were found to be optimum for physiological traits, viz. CSI, RSI and CT, and could be used in wheat hybridization breeding program for developing heat tolerance varieties. The genotypes could be exploited in wheat improvement programs for developing improved heat tolerance varieties under late sown conditions. Genotypes, viz. P4149, P4196, P4195, P13343, P13773, P13543, P4284, P4280, P4264, P4262, P4125 exhibited significantly higher mean grain yield and its contributing traits along with heat tolerance related traits under heat stress conditions.

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