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Genetic Diversity, Heritability and Correlation Studies for Yield and its Components in Bread Wheat under Heat Stress Conditions

Anzer Ul Islam[1], A. K. Chhabra[1], S. S. Dhanda[1] and Ovais H. Peerzada[2]
[1]*Department of Genetics and Plant Breeding, CCS HAU, Hisar 125004, India*
[2]*Department of Seed Science and Technology, CCS HAU, Hisar 125004, India*

Abstract: *One hundred diverse bread wheat genotypes were studied for various morpho-physiological traits under timely sown and late sown conditions. The experiment were conducted during the cropping seasons 2012-13 and 2013-14 at research area of Wheat and Barley Section, Department of Genetics and Plant Breeding, CCSHAU, Hisar. Yield and yield contributing traits were found significant under both conditions. The estimates of GCV, PCV, heritability and genetic advance were high to moderate in timely sown and late sown conditions for the traits yield per plant, number of productive tillers, 1000 grain weight, spike length, number of spikelet per spike, flag leaf area, biological yield, cell membrane stability and grain filling rate. Correlation coefficients revealed that number of productive tillers, 1000 grain weight, number of grains per spike, biological yield, flag leaf area, cell membrane stability, grain filling duration and grain filling rate gave the positive associations with grain yield in both environments. Consequently, selection can be based on these traits in both environments for breeding of bread wheat under heat stress condition.*

Keywords: *Bread wheat, Correlations, Genetic diversity, Heat stress, Morpho-physiological traits*

I. Introduction

Around the globe, global warming is predicted to increase the frequency and severity of heat stress leading to drastic reduction in the food production (Talukder *et al.,* 2014). As a major cereal crop, wheat accounts for about 30% of the world's cereal area to provide food for 36% of the global population (Cossani & Reynolds, 2012; Prerna *et al.,* 2013). It has been estimated that global mean temperature is rising at 0.3% per decade which may cause 50% decline in wheat yields in South Asia by 2050 (IFPRI, 2009). Since 1980s, global wheat productivity is estimated to have been reduced by as much as 5% due to increasing temperature (Lobell *et al.*, 2011). It has been shown to lose 3–4% of yield per °C above the optimum daytime temperature of 15- 20°C (Wardlaw *et al.,* 1989). Wheat is traditionally grown as a cool season crop, but continuous high-temperature exerts an opposite force to reduce the plant morpho-physiological activity. Due to influence of temperature stress at anthesis and grain filling period the per plant average grain yield reduce. Several studies have confirmed that rise in temperature above a daily average temperature of 15°C during grain filling period reduced grain yield (Soyema *et al.,* 2016 and Hussian *et al.*, 2014). Now days continue fluctuation in climatic condition results in temperature climb up. In NWPZ environments of India, terminal heat stress during anthesis and grain filling period is an important constraint to limiting grain yield in winter sown spring wheat cultivars. In these areas wheat, rice cropping system laid late wheat planting and exposed crop to high temperature at the reproductive stage resulting in reduction of average grain yield in cooler regions, because the temperatures often exceeds 30° C during grain filling period. Terminal or late heat stress during the last phases of wheat development especially from booting, heading, anthesis and grain filling stages of the spring wheat cultivars is considered as one of the major environmental constraints that drastically reduces grain number per spike and grain weight and consequently significant reduction in wheat grain yield throughout most of the bread wheat growing areas in this region and other warm and dry regions of India. Conjoint research results from worldwide consistent, multimodal climate change assessment for major crops with explicit characterization of uncertainty (Frieler *et al.,* 2015; Rosenzweig *et al.,* 2014) show that climate change will fundamentally alter global food production patterns. Overall climate change will also increase variability in crop yields in many regions.

Several authors have reported shorter life cycle, reduced tillering, less biomass production, reduced fertilization and grain development, reduced head size, reduction in number of spikes per m^2, number of grains per spike and grain weight as the consequences of heat stress, and all these changes are lead in reduction of grain yield under heat stress conditions (Gibson and Paulson, 1999, Ayeneh *et al.,* 2002 and Irfaq *et al.,* 2005). Choosing a suitable planting date and cultivar with the appropriate phenology that matches crop growth to the climate conditions will lead to optimum grain yields (Chen *et al.*, 2003). Generally, cultivars are tested across space and time under field conditions by manipulation of date of sowing or choosing sites, which are featured by high temperature at grain filling period (Rane and Nagarajan, 2004). Increased heat tolerance in late planted wheat is very essential to enhance and stabilize wheat productivity in the tropical and subtropical countries (Irfaq-Khan *et al.,* 2007). The magnitude of variability in the cultivars varies in different zones and poses practical limitations in evaluating their effective adaptation (Ali *et al.*, 2008; Baril, 1992). To develop an effective way to find out the problem in searching the possibility for those genotypic characters which are not easily influenced by the environmental factors. Such characters, if made available to the wheat breeders will help to develop cultivars with stable performance over a wide range of heat prone areas. The suitable cultivars will then be used in wheat breeding programs for development of germplasm adapted to terminal heat stress conditions in the target environment. Grain yield is a complex trait and highly influenced by many genetic factors and environmental fluctuations. In plant breeding programme, direct selection for yield as such could be misleading. A successful selection depends upon the information on the genetic variability and association of morpho-agronomic traits with grain yield. The main goal of this study was to identify genetic sources tolerant to heat stresses that have better performance in environments with heat stress intensities.

II. Materials And Method

The diverse bread wheat germplasm consisted of 100 genotypes collected from different National Yield Trials at different locations including exotic lines from CIMMYT. The details of origin/source of selected genotypes are given in Table 1.

Table 1: List of wheat genotypes used in the study

Sr. No.	Genotype	Developed at/Source	S. No.	Genotype	Developed at/source
1	HUW 544	BHU, Varanasi	51	PBW528	PAU, Ludhiana
2	2016L	IIWBR, Karnal	52	UP2473	GBPUA&T, Pantnagar
3	C518	Lyallpur	53	PBW503	PAU, Ludhiana
4	SG8809	CCSHAU, Hisar	54	4209	IIWBR, Karnal
5	PR45	IIWBR, Karnal	55	PBW511	PAU, Ludhiana
6	2044L	IIWBR, Karnal	56	UP2565L	GBPUA&T, Pantnagar
7	WH1021	CCSHAU, Hisar	57	4202	IIWBR, Karnal
8	WH1135	CCSHAU, Hisar	58	4208	IIWBR, Karnal
9	Sonalika	CIMMYT, Mexico/IARI	59	Kanchan	IARI, New Delhi
10	WH1155	CCSHAU, Hisar	60	PBW621	PAU, Ludhiana
11	VL803	VPKAS, Almora	61	PBW373	PAU, Ludhiana
12	NIAW1188	MPKV, Niphad	62	2060	IIWBR, Karnal
13	2002	IIWBR, Karnal	63	4204	IIWBR, Karnal
14	WH787	CCSHAU, Hisar	64	PBW533	PAU, Ludhiana
15	WH1158	CCSHAU, Hisar	65	UP2660	GBPUA&T, Pantnagar
16	WH1159	CCSHAU, Hisar	66	HD3064	IARI, New Delhi
17	2045	IIWBR, Karnal	67	4207	IIWBR, Karnal
18	DBW14	IIWBR, Karnal	68	2084	IIWBR, Karnal
19	NW1014	NDUA&T, Faizabad	69	SGP-6	CCSHAU, Hisar
20	NW2069	NDUA&T, Faizabad	70	2082	IIWBR, Karnal
21	RAJ3765	SKRAU, Durgapura	71	SGP13	CCSHAU, Hisar
22	HD2888L	IARI, New Delhi	72	HD2830	IARI, New Delhi
23	HD1869	IARI, New Delhi	73	SGP-1	CCSHAU, Hisar
24	2042	IIWBR, Karnal	74	PHS829	IIWBR, Karnal
25	WH715	CCSHAU, Hisar	75	2049	IIWBR, Karnal
26	WH1124	CCSHAU, Hisar	76	2047	IIWBR, Karnal
27	WH1151	CCSHAU, Hisar	77	Kundan	IARI, New Delhi
28	HW2036	IARI, RS, Wellington	78	2099	IIWBR, Karnal
29	HD 2285	IARI, New Delhi	79	2025	IIWBR, Karnal
30	WH1165	CCSHAU, Hisar	80	PHR1017	IIWBR, Karnal
31	WH1131	CCSHAU, Hisar	81	HD2705	IARI, New Delhi
32	WH1164	CCSHAU, Hisar	82	DBW347	IIWBR, Karnal
33	WH1133	CCSHAU, Hisar	83	SYN-4	CIMMYT, Mexico
34	HUW234	BHU, Varanasi	84	PBW550	PAU, Ludhiana
35	HD2687	IARI, New Delhi	85	2041	IIWBR, Karnal
36	RAJ4101	SKRAU, Durgapura	86	PBW527	PAU, Ludhiana
37	MB-1	IIWBR, Karnal	87	SYN-14	CIMMYT, Mexico
38	WH1156	CCSHAU, Hisar	88	PHR109	IIWBR, Karnal
39	4062	IIWBR, Karnal	89	PHR1006	IIWBR, Karnal
40	DBW11	IIWBR, Karnal	90	PBW475	PAU, Ludhiana
41	4066	IIWBR, Karnal	91	HD 2643	IARI, New Delhi
42	SGP-7	CCSHAU, Hisar	92	WH1061	CCSHAU, Hisar
43	Sonak	CCSHAU, Hisar	93	WH789	CCSHAU, Hisar
44	PBW175	PAU, Ludhiana	94	PHR1001	IIWBR, Karnal
45	PHS210	IIWBR, Karnal	95	SYN-8	CIMMYT, Mexico
46	PHS824	IIWBR, Karnal	96	PHR1022	IIWBR, Karnal
47	2072	IIWBR, Karnal	97	UP2338	GBPUA&T, Pantnagar
48	UP2425	GBPUA&T, Pantnagar	98	PHR1007	IIWBR, Karnal
49	4063	IIWBR, Karnal	99	PBW486	PAU, Ludhiana
50	SGP-5	CCSHAU, Hisar	100	WH1140	CCSHAU, Hisar

2.1 EXPERIMENTAL FIELD

The experiment were grown in a randomized block design with three replications at Research Area Wheat and Barley Section, Department of Genetics and Plant Breeding CCS Haryana Agricultural University, Hisar in two consecutive years during Rabi 2012-13 and 2013-14. The experiment were conducted in two separate date of sowing first timely sowing dated 15 November and late sowing for heat treatment dated 25 December in both season. Each plot consisted of single row of 3.0 m length with 22.5 cm and 10 cm spacing between row to row and plant to plant, respectively. All the agronomic practices were kept constant with proper irrigation. Weeds were removed manually as and when required.

2.2 WEATHER INFORMATION

The precipitation and average temperature for the 2012-13 and 2013-14 cropping season in CCS Haryana Agricultural University, Hisar Campus are presented in Table 2.

Table 2: Temperature and rainfall during wheat crop season of 2012-13 and 2013-14 (Source: Agro-Meteorological Observatory Unit CCS HAU, Hisar)

Month	Temperature (°C)				Rainfall (mm)	
	2012-13		2013-14			
	Min	Max	Min	Max	2012-13	2013-14
December	6.0	20.8	7.0	21.8	5.5	0.0
January	4.8	18.4	5.6	18.0	14.4	2.0
February	8.3	21.0	7.6	20.8	0.0	12.5
March	11.9	28.0	12.2	26.3	0.0	47.0
April	17.1	35.0	17.1	34.1	33.3	17.1

2.3 TRAITS STUDIED

2.3.1 PHENOTYPIC PARAMETER

At maturity five plants from central row were selected at random from each plot in each replication for recording data on grain yield per plant (gm) and biological yield (gm) recorded after physiological maturity. Thousand grain weights (gm), number of grains per spike, spike length (cm), number of spikelets per spike were taken after post harvest. Plant height (cm) and number of productive tillers per plant were taken at physiological maturity. Harvest index was calculated by divided the grain yield with biological yield above ground. Flag leaf area (cm^2) was calculated at the time of flowering. Days to heading recorded at the time of anthesis and days to maturity were recorded when color of plant turns green to yellowish.

2.4 STATISTICAL ANALYSIS

The mean data were subjected to analysis of variance to test the level of significance among the genotypes for various characters. Genotypic and phenotypic variances, genotypic and phenotypic coefficient of variability, broad sense heritability and correlation coefficients were computed according to the method suggested by Singh & Chaudhary (1985).

III. Results And Discussion

3.1 PHENOTYPIC VARIATION

The results from analyses of variance over two years in timely sown and late sown conditions for the various traits are presented in Table 3. In this experiment, grain yield and yield related traits of all genotypes were differed significantly (*, ** at 5% and 1% probability level, respectively), except harvest index in late sown condition. This indicated the prevalence of enough genetic variability in the materials under study for selection and improvement.

Table 3: Mean sum of squares for various traits under timely sown and late sown conditions

Source of variation	Degree of freedom	Envir-onment	Yield/ Plant (g)	No. of productive tillers/plant	1000 Grain wt.(g)	No. of grains /spike	Spike length (cm)	No. of spikelets /spike	Plant height (cm)	Biological yield (g)	Harvest index (%)
Replication	2	TS LS	3.94 0.173	2.45 0.944	2.26 1.509	1.64 53.7	1.81 1.609	14.80 2.58	21.15 158.57	49.38 3.65	4.35 5.38
Genotypes	99	TS LS	722** 579**	682** 329**	4,626** 3,684**	8625** 12214**	910** 444**	2,145** 1,479**	25,669** 15,834**	6,346** 4,285**	2,059** 824
Error	198	TS LS	193 119	139 98	101 129	2184 2554	165 136	590 358	1,922 815	1,567 1,044	617 466
C.D. (5%)		TS LS	**1.59** **1.25**	**1.35** **1.13**	**1.15** **1.30**	**5.35** **5.78**	**1.47** **1.34**	**2.78** **2.16**	**5.02** **3.27**	**4.53** **3.70**	**2.84** **2.47**
Mean		TS LS	**11.79** **8.11**	**8.02** **6.30**	**43.22** **35.26**	**58.45** **48.00**	**11.47** **9.99**	**20.38** **17.32**	**98.86** **79.07**	**31.50** **23.13**	**37.61** **35.09**

Source of variation	Degree of freedom	Environment	Flag leaf area (cm^2)	Days to heading	Days to maturity	Canopy temperature (°C)	Cell membrane stability	Grain filling duration	Grain filling rate (g/day)
Replication	2	TS	150	5.47	725	2.31	23.34	665	0.073
		LS	35.83	7.64	63.06	1.29	10.30	28.79	0.002
Genotypes	99	TS	19,934**	6,401**	3,874**	324**	10,932**	4,599**	0.847**
		LS	20,157**	3,066**	2,401**	356*	10,302**	2,225**	0.741**
Error	198	TS	2,819	223	1,455	127	1,046	1,383	0.314
		LS	1,405	194	438	172	1,280	519	0.233
C.D. (5%)		TS	**6.08**	**1.71**	**4.36**	**1.29**	**3.70**	**4.26**	**0.064**
		LS	**4.29**	**1.59**	**2.39**	**1.50**	**4.09**	**2.61**	**0.055**
Mean		TS	**53.28**	**99.69**	**141.00**	**27.36**	**57.77**	**36.79**	**0.323**
		LS	**42.40**	**87.50**	**121.24**	**29.99**	**46.29**	**30.12**	**0.272**

*, **; Significant at 5% and 1% level of probability, respectively; TS; Timely sown, LS; Late sown

3.2 ESTIMATES OF GENETIC VARIABILITY

Overall genetic and phenotypic variability depends on heritable and non-heritable components. While coefficients of variation measure the magnitude of variability present in a population, estimates of heritability and genetic advances are important preliminary steps in any breeding programs they provide information about effective selection. Genotypic coefficient of variability (GCV), phenotypic coefficient of variability (PCV), broad sense heritability, and genetic advance expressed as percentage of mean for thirteen traits under timely sown and late sown conditions are presented in Table 4.

Table 4: Mean, range, co-efficient of variation (phenotypic and genotypic), heritability (broad sense), and genetic advance (as % of mean) for various traits under timely and late sown conditions

Sr. No.	Characters		Mean ± SE	Range	Co-efficient of variations (%)		Heritability (broad sense)	Genetic advance as % of mean
					PCV	GCV		
1	**Yield /plant (g)**	**TS**	11.79±0.57	7.35-14.61	14.89	12.30	68.33	20.96
		LS	8.11±0.448	5.70-11.36	18.90	16.30	74.40	28.96
2	**No. of productive tillers/plant**	**TS**	8.02±0.485	5.33-12.00	20.74	17.90	74.54	31.84
		LS	6.30±0.407	4.83-9.33	19.03	15.40	65.52	25.69
3	**1000 Grain wt. (g)**	**TS**	43.22±0.414	31.33-51.76	9.23	9.08	96.77	18.40
		LS	35.26±0.466	25.46-45.00	10.16	9.90	94.92	19.86
4	**No. of grains/spike**	**TS**	58.80±1.91	44.83-68.66	10.32	8.61	69.68	14.81
		LS	48.00±2.07	35.33-62.66	14.68	12.64	74.05	22.41
5	**Spike length (cm)**	**TS**	11.47±0.528	8.41-20.35	16.60	14.55	76.88	26.28
		LS	9.99±0.48	7.78-15.00	14.01	11.26	64.67	18.66
6	**No. of spikelets/spike**	**TS**	20.38±0.997	14.66-29.66	14.89	12.24	67.61	20.73
		LS	17.32±0.776	11.50-24.33	14.36	12.08	70.76	20.93
7	**Plant height (cm)**	**TS**	98.86±1.79	84.39-130.44	9.75	9.22	89.54	17.98
		LS	79.40±1.17	68.64-99.16	9.47	9.11	92.65	18.07
8	**Biological yield (g)**	**TS**	31.50±1.62	21.67-41.83	16.39	13.73	70.28	23.72
		LS	23.13±1.32	16.25-33.33	18.32	15.38	70.60	26.63
9	**Harvest index (%)**	**TS**	37.61±1.02	32.42-45.42	7.98	6.45	65.42	10.75
		LS	35.09±0.88	31.39-39.62	5.94	4.02	45.78	5.60
10	**Flag leaf area (cm^2)**	**TS**	53.28±2.18	35.33-70.00	16.43	14.82	81.41	27.55
		LS	42.40±1.53	26.12-64.00	20.09	19.09	90.22	37.34
11	**Days to heading**	**TS**	99.69±0.613	88.83-110.66	4.74	4.61	94.93	9.26
		LS	87.50±0.572	79.00-99.00	3.79	3.61	91.04	7.10
12	**Days to maturity**	**TS**	141.00±1.56	135.00 - 152.63	3.00	2.31	59.04	3.65
		LS	121.24±0.859	116.00-133.50	2.55	2.24	76.83	4.03
13	**Canopy temperature (°C)**	**TS**	27.36±0.463	25.23-30.50	4.51	3.42	57.62	5.35
		LS	29.99±0.539	26.73-32.50	4.45	3.18	51.12	4.68
14	**Cell membrane stability**	**TS**	57.77±1.32	42.66-71.58	10.99	10.25	86.89	19.67
		LS	46.29±1.46	33.66-64.60	13.49	12.32	83.41	23.18
15	**Grain fill duration**	**TS**	36.79±1.52	27.85-42.50	12.23	9.88	65.31	16.45
		LS	30.12±0.935	24.50-38.60	10.09	8.54	71.61	14.88
16	**Grain fill rate (g/day)**	**TS**	0.323±0.023	0.207-0.457	19.15	14.76	59.43	23.45
		LS	0.272±0.02	0.167-0.413	21.06	16.87	64.16	27.84

3.3 GENOTYPIC AND PHENOTYPIC COEFFICIENTS OF VARIATION

The results revealed considerable phenotypic and genotypic variances among the genotypes for the traits under consideration. The estimates of GCV were high in timely sown and late sown conditions for number of productive tillers (17.90 and 15.40, respectively), flag leaf area (14.82 and 19.09, respectively), grain filling rate (14.76 and 16.87, respectively), yield per plant (12.30 and 16.30, respectively), biological yield (13.73 and

15.38, respectively), number of spikelet per spike and spike length (14.55 and 11.26, respectively). The PCV values were higher than GCV values for all the traits which reveal the influence of environment on the expression of traits.

3.4 HERITABILITY IN BROAD SENSE

The genotypic coefficient of variation along with estimates of heritability in broad sense provide bona-fide estimates of the amount of genetic advance to be expected through phenotypic selection (Burton, 1952). The results of the present study indicated that- The estimates of heritability in broad sense were high in timely sown and late sown conditions for 1000 grain weight (96.77 and 94.92, respectively), days to heading (94.93 and 91.04, respectively), plant height (89.59 and 92.65, respectively), flag leaf area (81.41 and 90.22, respectively), cell membrane stability (86.89 and 83.41, respectively). Moderate heritability were estimate in timely sown and late sown conditions for number of productive tillers (74.54 and 65.52, respectively), yield per plant (68.33 and 74.40, respectively), spike length (76.88 and 64.67, respectively) and number of spikelet per spike (67.61 and 70.76, respectively). High heritability were also calculates and reported by Riaz-Ud-Din, *et al.,* 2010; Sachan and Singh, 2003 ; Adewale *et al.*, 2010; Rahim *et al.*, 2010, for grain yield, number of spikelets per spike, number of seeds per spike, plant height, 100-seed weight and number of tillers per plant.

3.5 GENETIC ADVANCE AS PERCENT OF MEAN

High heritability along with high genetic advance is an important factor for predicting the resultant effect for selection the best individuals. Values are expressed as percentage of the mean for each trait so that comparison could be made among various traits, which had different units of measurement. The estimates of genetic advance as percent of means were high in timely sown and late sown conditions for number of productive tillers (31.84 and 25.69, respectively), flag leaf area (27.55 and 34.34, respectively), grain filling rate (23.45 and 27.84, respectively), biological yield (23.72 and 26.63, respectively), yield per plant (20.96 and 28.96, respectively), number of spikelet per spike (20.73 and 20.93, respectively) and cell membrane stability (19.67 and 23.18, respectively). From the above discussion, in timely sown and late sown conditions yield per plant, number of productive tillers, spike length, number of spikelet per spike, flag leaf area, cell membrane stability, grain filling rate, biological yield and 1000 grain weight showed ample genetic variance, high to moderate heritability and high to moderate genetic gain. Therefore selection can be based on these traits in both environments.

3.6 GENOTYPIC CORRELATION AMONG CHARACTERS

The genotypic correlations for various morpho-physiological traits are presented in Table 5. An understanding of inter-character correlation is essential to successful selection of useful genotypes from the whole population but intensive selection for any characteristic might result in losses in others (Lebsock and Amaya, 1969).

Table 5: Genotypic and phenotypic (bold) correlations for various traits under timely sown and late sown conditions

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	TS	1	0.523**	0.427**	0.419**	0.288**	0.192**	-0.026	0.876**	0.097	0.439**	-0.204**	-0.133*	-0.298**	0.451**	0.068	0.744**
	LS		0.484**	0.477**	0.421**	0.264**	0.020	0.067	0.951**	0.272**	0.392**	-0.029	-0.005	-0.001	0.639**	0.031	0.882**
2	TS	0.537**	1	0.239**	0.261**	0.146*	0.091	-0.071	0.487**	-0.015	0.250**	-0.106	-0.136*	-0.118	0.388**	-0.025	0.407**
	LS	0.487**		0.230**	0.323**	0.133*	0.039	0.039	0.509**	-0.042	0.364**	-0.062	-0.138*	0.114*	0.453**	-0.078	0.456**
3	TS	0.439**	0.238**	1	0.113	0.014	-0.031	-0.012	0.375**	0.027	0.263**	-0.117*	-0.177**	-0.066	0.422**	-0.052	0.351**
	LS	0.492**	0.239**		0.226**	0.159**	-0.056	0.167**	0.416**	0.253**	0.259**	-0.256**	-0.030	-0.033	0.480**	0.230**	0.335**
4	TS	0.455**	0.314**	0.088	1	0.321**	0.323**	-0.045	0.410**	-0.026	0.266**	0.009	0.026	-0.167**	0.180**	0.001	0.323**
	LS	0.368**	0.256**	0.201**		0.481**	0.375**	0.154**	0.417**	0.054	0.480**	0.210**	0.116*	0.192**	0.387**	-0.098	0.427**
5	TS	0.141*	0.042	-0.045	0.315**	1	0.690**	0.319**	0.182**	0.170**	0.329**	0.206**	0.180**	-0.188**	0.023	-0.056	0.305**
	LS	0.092	-0.083	0.112	0.415**		0.416**	0.300**	0.255**	0.075	0.305**	0.166**	0.171**	0.120*	0.169**	-0.013	0.255**
6	TS	-0.013	-0.035	-0.114*	0.280**	0.681**	1	0.248**	0.134*	0.078	0.221**	0.304**	0.321**	-0.140*	0.094	-0.018	0.187**
	LS	-0.151**	-0.139*	-0.130*	0.355**	0.355**		0.085	0.009	0.029	0.269**	0.493**	0.302**	0.186**	0.031	-0.201**	0.123*
7	TS	-0.039	-0.095	-0.011	-0.074	0.369**	0.304**	1	-0.022	-0.019	0.095	0.231**	0.361**	-0.012	-0.105	0.073	-0.039
	LS	0.074	0.036	0.173**	0.192**	0.396**	0.090		0.090	-0.048	0.229**	0.067	0.249**	-0.098	0.034	0.164**	-0.008
8	TS	0.886**	0.503**	0.376**	0.426**	0.010	-0.093	-0.030	1	-0.387**	0.392**	-0.206**	-0.186**	-0.198**	0.481**	0.040	0.657**
	LS	0.967**	0.512**	0.430**	0.377**	0.060	-0.160**	0.111		-0.034	0.393**	0.009	-0.011	0.035	0.617**	-0.014	0.856**
9	TS	0.060	-0.033	0.034	0.00	0.257**	0.149**	-0.038	-0.403**	1	0.035	0.025	0.141*	-0.169**	-0.128*	0.068	0.046
	LS	0.372**	-0.004	0.374**	0.048	0.162**	-0.007	-0.102	0.127*		0.033	-0.131*	0.036	-0.098	0.138*	0.173**	0.176**
10	TS	0.511**	0.276**	0.278**	0.321**	0.371**	0.206**	0.118*	0.436**	0.070	1	-0.033	0.041	-0.210**	0.235**	0.046	0.303**
	LS	0.343**	0.347**	0.232**	0.456**	0.239**	0.252**	0.251**	0.351**	0.035		0.203**	0.084	0.086	0.436**	-0.124*	0.420**
11	TS	-0.344**	-0.176**	-0.142*	-0.048	0.176**	0.306**	0.242**	-0.334**	0.032	-0.047	1	0.339**	0.042	-0.019	-0.616**	0.261**
	LS	-0.108	-0.165**	-0.303**	0.182**	0.114*	0.556**	0.071	-0.079	-0.151**	0.177**		0.476**	0.048	-0.075	-0.550**	0.222**
12	TS	-0.206**	-0.135*	-0.218**	0.073	0.317**	0.509**	0.515**	-0.283**	0.220**	0.031	0.466**	1	0.008	-0.104	0.509**	-0.409**
	LS	0.034	-0.181**	-0.013	0.176**	0.258**	0.419**	0.296**	0.036	0.018	0.116*	0.581**		-0.015	-0.018	0.458**	-0.216**
13	TS	-0.177**	-0.054	-0.025	-0.127*	-0.067	0.057	-0.026	-0.035	-0.267**	-0.264**	0.136*	0.048	1	-0.057	-0.025	-0.221**
	LS	-0.363**	-0.126*	-0.161**	-0.032	-0.264**	0.094	-0.148*	-0.333**	-0.199**	-0.091	-0.057	0.038		0.007	-0.071	0.036
14	TS	0.407**	0.400**	0.415**	0.132*	-0.116*	-0.048	-0.129*	0.450**	-0.165**	0.235**	-0.068	-0.116*	0.074	1	-0.056	0.399**
	LS	0.628**	0.449**	0.478**	0.336**	0.018	-0.076	0.031	0.609**	0.221**	0.388**	-0.156**	-0.009	-0.252**		0.068	0.545**
15	TS	0.207**	0.076	-0.030	0.093	0.033	0.051	0.121*	0.152**	0.105	0.055	-0.712**	0.257**	-0.104	0.005	1	-0.592**
	LS	0.149**	-0.011	0.328**	-0.042	0.102	-0.210**	0.206**	0.117*	0.198**	-0.093	-0.567**	0.333**	0.087	0.173**		-0.429**
16	TS	0.713**	0.371**	0.367**	0.326**	0.151**	-0.011	-0.081	0.638**	0.011	0.372**	0.230**	-0.326**	-0.094	0.345**	-0.525**	1
	LS	0.883**	0.443**	0.332**	0.370**	0.051	-0.032	-0.015	0.863**	0.277**	0.384**	0.161**	-0.124*	-0.392**	0.522**	-0.327**	

1	Yield/plant	7	Plant height	13	Canopy temperature
2	Number of productive tillers/plant	8	Biological yield	14	Cell membrane stability
3	1000 grain weight	9	Harvest index	15	Grain filling duration
4	No. of grains/spike	10	Flag leaf area	16	Grain filling rate
5	Spike length	11	Days to heading		
6	No. of spikelets/spike	12	Days to maturity		

Bread wheat number of productive tiller (0.537** & 0.487**), 1000 grain weight (0.439** & 0.492**), number of grains per spike (0.455** & 0.368**), biological yield (0886** & 0.967**), flag leaf area (0.511** & 0.343**), cell membrane stability (0.407** & 0.628**), grain filling duration (0.207** & 0.149**) and grain filling rate (0.713** & 0.883**) gave the positive associations with grain yield in both the environments, respectively *viz.*, timely sown and late sown, while harvest index (0.372**) showed positive correlation only in late sown. Grain yield had negative correlation with days to heading (-0.344**) in timely sown condition, indicating that selecting early heading genotypes with long grain filling period. Grain yield had negative correlation with canopy temperature (-0.177** & -0.363**) in timely sown and late sown conditions, respectively, indicating that cell functioning *viz.*, transpiration and photosynthesis is proper when canopy temperature is low during the grain filling period. Number of productive tiller had positive correlation with 1000 grain weight (0.238** & 0.239**), biological yield (0.503** & 0.512**), flag leaf area (0.276** & 0.347**), cell membrane stability (0.400** & 0.449**) and grain filling duration (0.371** & 0.443**) in both environments, respectively and had negative correlation with canopy temperature (-0.126*) in late sown condition. The results of correlation coefficients revealed that high grain yield under timely sown condition is due to significant correlations of above physiological and yield attributing traits for grain yield. In both environments bread wheat grain yield were significantly associated with yield attributing traits and physiological traits. Therefore, selection of these traits could be useful in wheat breeding program designed for heat stress condition. Bhutto *et al.* (2016) reported correlations of plant height which has significantly positively associated with spikelet's per spike, tillers per plant and grains per spike. In bread wheat Bahar *et al.* (2011) were found significant negative correlations between canopy temperature (CT) and grain yield (GY). Cell membrane stability showed positive correlation with bread wheat grain yield Dhanda and Munjal (2012) concluded lesser leakage of solutes from cellular membrane (r = 0.39*) help in better grain filling under heat stress condition, similar correlation were calculated in the present investigation.

IV. Conclusion

The present study revealed that the mean sum of squares due to genotypes was recorded significant for all the traits studied except harvest index in late sown condition. This indicated the prevalence of enough genetic variability in the genotypes for selection and improvement. Association study resulted that grain yield per plant had strong and positive genotypic correlation with number of productive tiller per plant, 1000 grain weight, number of grain per spike, biological yield, flag leaf area and cell membrane stability in both environments *viz.*, timely sown and late sown. These traits were the key contributors to yield per plant suggesting the need of more emphasis on these components for increasing the grain yield in wheat while grain yield had negative correlation with days to heading in timely sown condition, indicating that selecting early heading genotypes with long grain filling period. The study of associations among various traits is useful to breeders in selecting genotypes possessing groups of desired traits. In timely sown and late sown conditions yield per plant, number of productive tillers per plant, spike length, number of spikelet per spike, flag leaf area, cell membrane stability, grain filling rate, biological yield and 1000 grain weight showed ample genetic variance, recorded high to moderate heritability and high to moderate genetic gain. Therefore, selection can be based on these traits in both environments. In this investigation, an attempt was made to generate information on inheritance, relationships of yield and its components and their implication in selection of better genotypes of wheat for the development or improvement of cultivars and germplasm under heat stress conditions.

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