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Characterization of lines for morpho-physiological, yield and yield-related traits under heat stress

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Abstract
The Present investigation entitled was undertaken during *Rabi* season 2021-22 at Crop Research Center, GBPUAT, Pantnagar, Uttarakhand. The experiment was carried out to derive Analysis of Variance, general mean, GCV, PCV, Genetic advance as a percent of mean, broad sense heritability, correlation coefficient upon analyzing different lines for various traits in wheat relating to heat stress. The experiment was carried out with 14 different varities/genotypes for yield and yield contributing characters under terminal heat stress. The trial consisted of three replications of each genotype in RBD design. High genetic advance was seen for characters-chlorophyll content, grain yield per plant and 1000 grain weight. The correlation coefficients showed positive and significant correlation between grain yield per plant with plant height, number of tillers per plant, days to 50% flowering, number of grains per spike, spikelets per spike, relative water content and chlorophyll content. The high magnitude of direct effect of number of grains per spike, number of spikelets per spike, 1000 grain weight along with highly significant correlation in the desirable direction towards grain yield per plant indicated the true and strong relationship between grain yield and these characters suggesting direct selection based on these character would help in selecting the high yielding genotypes in wheat under heat stress conditions.

Keywords: Correlation coefficient, genetic advance, wheat, high yielding genotypes

Introduction
Wheat (*Triticum aestivum* L.) is a crucial cereal crop globally, serving as a staple food for approximately 35% of the world's population (FAO, 2022) [5]. It provides essential nutrients, including carbohydrates, proteins, and micronutrients, which are vital for human nutrition and food security. In 2023, global wheat production was estimated at around 778 million metric tons, highlighting its significance in the agricultural sector (FAOSTAT, 2023) [6].

Despite its importance, wheat production faces significant challenges from various abiotic stresses, with heat stress being one of the most critical due to the ongoing global climate change. Heat stress, characterized by temperatures exceeding optimal growth levels, adversely affects wheat's physiological and biochemical processes, resulting in decreased yield and quality (Asseng *et al*. 2015) [2]. The Intergovernmental Panel on Climate Change (IPCC) projects that average global temperatures could rise by 1.5 to 2 °C by the end of the century, potentially reducing wheat yields by up to 21% without adaptive interventions (IPCC, 2021) [8].

The impact of heat stress on wheat includes a shorter grain filling period, impaired photosynthesis, increased respiration, and accelerated senescence, all contributing to yield losses (Farooq *et al*. 2011) [7]. For example, temperatures above 30 °C during the grain-filling stage can reduce grain weight by 5-10% per °C increase (Lobell *et al*. 2012) [11]. Therefore, developing heat-tolerant wheat genotypes is essential to maintaining productivity under rising temperatures.

The range is a simple measure of variability that indicates the difference between the highest and lowest values in a dataset. It provides a quick understanding of the extent of variation in traits such as yield, grain quality, and heat tolerance among wheat genotypes. In the context of heat stress tolerance, a wide range signifies substantial genetic diversity, which is crucial for selecting and breeding heat-resistant varieties (Smith *et al*. 2020) [15].

The Genotypic Coefficient of Variation (GCV) quantifies the genetic variability in a population by expressing the standard deviation of genotypic values as a percentage of the mean. High GCV values indicate substantial genetic diversity, which is essential for effective selection in breeding programs. For traits related to heat stress tolerance, high GCV suggests a greater potential for genetic improvement (Johnson *et al*. 1955) [9].

The Phenotypic Coefficient of Variation (PCV) measures the total variability in a trait, including both genetic and environmental factors. PCV provides insight into the overall variability observed in the population. A comparison of PCV and GCV values can help determine the proportion of phenotypic variance attributable to genetic factors. For heat stress tolerance in wheat, a smaller difference between PCV and GCV indicates that the trait is less influenced by environmental conditions (Burton, 1952) [3].

Broad sense heritability estimates the proportion of total phenotypic variance that is due to genetic variance. High heritability values indicate that a trait is predominantly controlled by genetic factors, making it more responsive to selection. In the context of heat stress tolerance, high heritability suggests that breeding for improved tolerance can be more effective and efficient (Falconer & Mackay, 1996) [4].

Genetic advance as a percentage of mean (GAM) combines heritability and the selection differential to predict the expected improvement in a trait from one generation to the next. High GAM values indicate significant potential for genetic improvement through selection. For heat stress tolerance in wheat, GAM helps in estimating the progress that can be made in breeding programs under selection pressure (Allard, 1960) [1].

Correlation analysis examines the relationships between different traits, helping to identify whether selection for one trait will have positive, negative, or neutral effects on another. Understanding these relationships is crucial in breeding programs, particularly for complex traits like heat stress tolerance, which may be associated with other agronomic characteristics. Positive correlations between heat tolerance and yield-related traits, for example, would be beneficial for developing resilient wheat varieties (Pearson, 1895) [13].

Addressing the challenge of heat stress in wheat through the characterization and development of heat-tolerant genotypes is imperative for ensuring future food security. This research aims to evaluate a diverse set of wheat genotypes under heat stress conditions to identify potential candidates for breeding programs focused on enhancing heat tolerance.

Materials and Methods

The study was conducted at the Department of Genetics and Plant Breeding, G. B. Pant University of Agriculture and Technology, Pantnagar. Field experiment was scheduled during the *rabi* seasons of 2021-22 at the Norman E. Borlaug Crop Research Centre, GBPUAT in three replications in Randomized Complete Block Design.

Experimental material included 14 lines, namely

S.no	Variety/Genotype	Pedigree
1.	HUW832	ADAPTED VARIETY
2.	HUW826	ADAPTED VARIETY
3.	HI1628	ADAPTED VARIETY
4.	BN145	1455/2*PASTOR
5.	BN85	ALTAR84/AE
6.	BN97	VILI//KACHU
7.	WH1142	ADAPTED VARIETY
8.	BN171	KACHU/SAVAL/3/
9.	BN5	HPW381
10.	BN297	QUAIU/MUNAL//
11.	BN218	WAXWING/--
12.	BN239	ATTILA*2/PBW65
13.	BN279	ATTILA/3*BCN/1
14.	BN292	HEILO//MILAN/

Observations recorded included

1. Morphological observations - plant height (cm), number of tillers per plant, days to 50% heading, number of grains/spikes, number of spikelets/spike, days to maturity, 1000-grain weight (g), grain yield per plant (g)
2. Biochemical traits- chlorophyll contents, osmotic measurements
3. Physiological traits- Relative Water Content (RWC)

Statistical analysis were done using R (version 4) statistical software.

Results

The mean sum of squares for different characters under study highlighted that treatments for all the different traits are significant and positive, highlighting that variation for these traits among parents exist (Table 1).

The range, general mean, Genotypic coefficient of variation, Phenotypic coefficient of variation, broad sense heritability of 14 lines/varieties studied are given in Table 2. High genetic advance was seen for characters-chlorophyll content, grain yield per plant and 1000 grain weight.

The genotypic and phenotypic correlation coefficients showed positive and significant correlation between grain yield per plant with plant height, number of tillers per plant, days to 50% flowering, number of grains per spike, spikelets per spike, relative water content and chlorophyll content (Table 3). Similar findings have been reported by Kumar, A. *et al*. 2018 [10]; Sharma, D. *et al*. 2021 [14]; Nagar, U.S. 2021.

Table 1: Mean sum of squares for different traits under study; *, ** significant at 5% and 1% level, respectively

Source of Variations	df	Mean Sum of Squares										
		Plant height (cm)	No. of tillers per plant	Days to 50 percent flowering	No. of grains per spike	Spikelets per spike	Days to maturity	1000 grain weight (g)	Grain yield per plant (g)	Chlorophyll content	RWC	Osmotic potential
Replication	2	5.31	0.31	10.95	14.55	3.87	8.33	0.95	0.26	1.87	2.04	0.42
Treatments	13	15.99**	3.42*	49.93**	36.93**	25.08**	23.96**	45.04**	56.79**	38.89**	23.32**	20.32**
Error	26	23.20	2.05	3.29	31.01	3.13	2.12	0.70	0.63	1.12	0.38	0.94

Table 2: General mean, range, GCV (Genotypic coefficient of variation), PCV (Phenotypic coefficient of variation), Broad sense heritability, GA (Genetic Advance as a percentage of mean)

Traits	General Mean	Range	GCV	PCV	Broad Sense heritablity	GA as % of mean
Plant height (cm)	92.48±2.28	72.66-108.33	7.90	9.74	65.8	13.21
No. of tillers per plant	20.68±0.83	8.67-13.33	11.89	27.82	28.3	10.46
Days to 50% flowering	99.31±1.05	94-105.33	2.37	2.99	62.8	3.87
No. of grains per spike	29.85±3.22	20.53-42.8	11.59	21.96	47.9	12.60
Spikelets per spike	18.95±1.02	16.33-23	5.23	10.69	33.9	5.27
Days to maturity	136.65±0.84	133.67-138.67	0.57	1.21	62.4	14.59
1000 grain weight	38.48±0.48	29.03-46.40	9.98	10.22	85.4	42.10
Grain yield per plant	13.22±0.47	7.17-20.10	22.32	23.12	87.2	44.40
Chlorophyll content	42.78±0.61	39.67-68.33	27.68	27.79	84.2	46.79
Relative water content	60.47±0.42	45-85	17.48	17.57	72.6	33.21
Osmotic potential	659.73±0.83	544-787	12.13	12.39	41.21	29.72

Table 3: Genotypic and phenotypic correlation coefficient of traits under study; *, ** significant at 5% and 1% level, respectively

Traits		Plant height (cm)	No. of tillers per plant	Days to 50 % flowering	No. of grains per spike	Spikelet's per spike	Days to maturity	1000 grain weight (g)	Grain yield per plant	RWC	Chlorophyll content	Osmotic potential
Plant height (cm)	rg		0.276**	-0.428**	0.342**	0.081	-0.670**	0.193*	0.182**	0.006	0.046	-0.013
	rp		0.072	-0.288**	0.180*	0.106	-0.195*	0.166*	0.151*	0.041	0.049	-0.014
No. of tillers per plant	rg			-0.035	0.233*	-0.137	0.373**	0.174*	0.294**	0.107	0.038	0.031
	rp			-0.046	-0.019	0.027	0.279**	0.083	0.094	0.09	0.040	0.023
Days to 50 percent flowering	rg				0.068	0.425**	0.290**	0.220*	0.342**	-0.231*	0.238**	-0.133**
	rp				0.018	0.127	0.089	0.186*	0.320**	-0.169*	0.231**	-0.139**
No. of grains per spike	rg					0.223*	-0.448**	0.424**	0.383**	0.02	0.123*	-0.232**
	rp					0.005	-0.055	0.219*	0.197*	0.01	0.112*	-0.245**
Spikelets per spike	rg						-0.062	0.336**	0.580**	0.310**	0.012	-0.159**
	rp						0.141	0.339**	0.264**	0.129	0.001	-0.162**
Days to maturity	rg							-0.003	0.359**	-0.087	0.212**	-0.122**
	rp							0.014	0.347**	0.02	0.203**	-0.128**
1000 grain weight (g)	rg								0.273**	0.169*	0.312**	-0.321**
	rp								0.269**	0.163*	0.284**	-0.324**
Grain yield per plant	rg									-0.123	0.204**	-0.213**
	rp									-0.125	0.195**	-0.241**
RWC	rg										0.100	0.336**
	rp										0.095	0.322**
Chlorophyll content	rg											0.235**
	rp											0.132*
Osmotic potential	rg											
	rp											

Conclusion

In conclusion, heat stress represents a critical challenge in crop production, particularly in wheat, where it significantly impacts yield through various morphophysiological and biochemical disruptions during crucial reproductive stages. The observed reductions in grain number and weight, slower filling rates, diminished grain quality, and shortened filling durations underscore the severity of terminal heat stress effects. Plants have demonstrated adaptive responses through morphological, physiological, and biochemical adjustments, including modifications in enzyme activities. While advancements in identifying heat tolerance genes offer promise, further comprehensive research is essential to enhance crop resilience and meet global food demands. Prioritizing collaborative efforts in heat-tolerant wheat breeding and supporting international food policies will be crucial steps toward ensuring sustainable food security worldwide.

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