

Original Research Article

<https://doi.org/10.20546/ijcmas.2018.707.318>

Developing a Selection Criterion for Terminal Heat Tolerance in Bread Wheat Based on Various Morpho-Physiological Traits

Devender Sharma*, J.P. Jaiswal, N.K. Singh, Anjana Chauhan and Navin Chander Gahtyari

Department of Genetics and Plant Breeding, G.B.Pant University of Agriculture & Technology, Pantnagar -263145 (Uttarakhand), India

*Corresponding author

ABSTRACT

Keywords

Wheat, heat stress, Canopy temperature depression; membrane thermostability, 1000 Grain Weight, Normalizes Difference Vegetation index

Article Info

Accepted:
 20 June 2018
 Available Online:
 10 July 2018

Wheat (*Triticum aestivum* L.), a staple food crop is of great commercial importance. Its production is restricted due to various abiotic stresses. There are indications that the wheat production is consistently limited by terminal heat stress. Here, performance of forty genotypes of wheat was undertaken for assessment of direct selection parameters (variability, heritability and genetic advance) and their relation with heat tolerance. The plants were sown in late planting (first fortnight of December) to expose them to terminal heat stress. Observations were recorded on fourteen morpho-physiological traits *i.e.* days to heading, days to maturity, grain filling duration, number of tillers per plant, spike length, grain yield per plant, 1000-kernel weight, CTD-I, CTD-II, CTD-III, NDVI-I, NDVI-II, NDVI-III and membrane thermostability. High heritability associated with high genetic advance reflected for physiological traits like canopy temperature depression and membrane thermostability. That indicated effectiveness of selection for the improvement of these traits. Moderate estimate of genetic advance (25%-50%) exhibited for number of tillers per plant, NDVI I, CTD (I & II) and spike length. For all the morpho-physiological traits studied, the estimates of phenotypic variance were exhibited higher than their corresponding genotypic variances, indicating the influence of environment on the expression of these morpho-physiological characters were observed. These finding suggests the relative importance of various physiological traits in formulating the selection criteria for developing thermotolerant wheat cultivars.

Introduction

Wheat (*Triticum aestivum* L.), a cereal grass belong to Poaceae family and of the genus *Triticum*, is the world's largest cereal crop extensively grown as staple food in the world. Wheat is grown on 223.67 million hectares throughout the world, which produces 735.3

million tons of grain (USDA, 2017). It provides, on an average, 20% of daily calories and protein for 4.5 billion people (Shiferaw *et al.*, 2013). Wheat in India is grown over an area of 30.72 million ha producing 98.30 million tonnes (ICAR-IIWBR, 2017). It occupies an inimitable position in human life as it is the major source of food and energy

with a large number of products like chapathi, biscuits, bread and pasta, even it is a good source of fodder for animals.

Wheat production is limited by current and upcoming challenges including reduced land, reduced water availability increased temperature due to global warming under climatic shift (Fischer *et al.*, 2002). Among these, increased temperature stress is increasingly causing a concern as the global air temperature is predicted to rise by 0.2 °C per decade, leading to temperatures 1.8–4.0 °C higher than the current level by 2100 (IPCC 2007). Even now heat stress affects 40% of the wheat growing area of the world covering about 36 million ha (Reynolds *et al.*, 2001). Every 1°C rise in temperature above the optimal 28°C reduces wheat yield by 3-4% (Wardlaw *et al.*, 1989).

The terminal heat stress at anthesis and grain filling stages accelerate maturity and significantly reduce grain size, weight and yield (Rane *et al.*, 2000; Lane *et al.*, 2007; Kosina *et al.*, 2007). Physiological responses of wheat crop to terminal heat stress have been found to effectively determine genotype tolerance or susceptibility (Almeselmani *et al.*, 2000). There is urgent need for immediate attention to develop heat tolerance wheat genotypes by combining different approaches.

The genetic potential of different cultivars for the presence of diversity, stability in performance are measured by statistical parameters such as mean, variance, coefficient of variation (%), heritability and genetic gain (Ali *et al.*, 2008). Grain yield is a complex trait and is greatly influenced by various environmental factors. Various morpho-physiological traits contribute to grain yield in heat stress conditions. Each of these component traits has its own genetic systems. Therefore, it is necessary to separate the total variation into heritable and non-heritable components with the help of genetic

parameters *i.e.* genotypic and phenotypic coefficient of variation, heritability and genetic gain (Kahrizi *et al.*, 2010). The phenotypic variance measures the magnitude of variance arising due to genetic component and environmental factors. The heritability is a measure of the genetic relationship between parents and progeny, hence considerable research work has been carried out to incorporate desirable genes in the present wheat varieties to increase the productivity of the crop (Memon *et al.*, 2007). Here, Morpho-physiological evaluation of wheat genotypes was performed under late sown condition to assess genetic variability and develop selection criteria for developing thermotolerant cultivars.

Materials and Methods

A set 40 diverse wheat genotypes (*Triticum aestivum* L.) were selected (Table 1) for field experiments conducted at Dr. N.E. Borlaug Crop Research Centre of GB Pant University Agriculture and Technology, Pantnagar, India in *rabi* season during 2017–2018. The plants were sown in late planting (first fortnight of December) to expose them to terminal heat stress. The experiment was conducted in three replicates; in randomized block design with three rows and 23 cm inter row spacing. Seven morphological traits *i.e.* days to heading, days to maturity, grain filling duration, number of tillers per plant, spike length, grain yield per plant, 1000-kernel weight, CTD-I, CTD-II, CTD-III, NDVI-I, NDVI-II, NDVI- III and membrane thermostability. Nineteen morpho-physiological traits *i.e.* days to heading, days to maturity, grain filling duration, plant height, peduncle length, number of tillers per plant, spike length, total number of spikelets per ear, biological yield per plant, grain yield per plant, harvest index, 1000-kernel weight

Seven morphological traits *i.e.* days to heading, days to maturity, grain filling

duration, number of tillers per plant, spike length, grain yield per plant, 1000-kernel weight and three physiological traits i.e. canopy temperature depression (CTD recorded separately at three growth stages), Normalized difference vegetation index (recorded separately at three growth stages) and membrane thermostability were studied in late sown conditions during *rabi*2017-18. The method for recording these physiological traits is described below.

Canopy temperature depression (CTD)

The ambient temperature and canopy temperature of whole plant was taken between 1200 hours and 1400 hours at heading stage of the crop. Canopy temperature depression (CTD) is the difference between ambient temperature and canopy temperature. CTD was measured with the help of Infra-red thermometer. Canopy temperature depression: Canopy temperature depression was recorded at 10 days interval. In which first reading was recorded at 50 percent flowering (CTD-I), second at 10 days after 50 percent flowering (CTD-II) and third at 20 days after 50 percent flowering (CTD-III),

Normalized difference vegetation index (NDVI)

Observation collected using green seeker instrument at different stages of the crop plant. The observations were taken at 50% flowering stage (NDVI-I), at 10 days after 50% flowering stage (NDVI-II), at 20 days after 50% flowering stage (NDVI-III).

Membrane thermostability

Leaf samples were taken from the uppermost fully expanded leaves and 3-5 cm long segments were excised from each of 10 healthy seedlings from each replication per genotype. For removal of any adherent these

samples were rinsed twice with deionized water, and placed in 22×150 mm test tubes with 10 ml of deionized water. The test tube was covered with an aluminium foil. Severe heat stress was applied by submerging test tubes to a depth equal to the height of water in tubes (about 4 cm) in a water bath at 49°C for 30 minutes. After that, the test tubes were held over night at room temperature. Very next day, electrical conductivity of each test tube sample was measured with an electrical conductivity meter after standardizing it with a KCl solution. Then the kill the leaf tissues of the test tubes were then autoclaved for ten minutes at 120°C and 0.10 MPa and their conductance was measured again as an indication of the maximum potential leakage from a given sample (Ibrahim *et al.*, 2001)..

Membrane thermostability was calculated by using the following formula (Sullivan 1972):

$$MTS = \left(1 - \frac{T1}{T2}\right) \times 100$$

Where, T1 and T2 are the conductivity readings before and after autoclaving, respectively.

Observations were statistically analysed with the help of OPSTAT for genetic variability parameter to determine allelic diversity (Johnson *et al.*, 1955; Burton 1952).

Results and Discussion

The analysis of variance for different morpho-physiological characters is presented in Table 2. The results showed highly significant difference for most of the characters under study among twenty genotypes. This suggested that there is an inherent genetic difference among the genotypes.

Physiological traits revealed relative importance of their contribution towards

terminal heat tolerance. Canopy temperature depression and normalized difference vegetation index exhibited the same trend with respect to different growth stages (Singh and Jaiswal, 2013; Abdipur *et al.*, 2013) As the crop matures the depression value goes on decreasing because canopy gets hotter and results in lower photosynthetic assimilation which leads to lower yield (Fig. 1). NDVI reflects the chlorophyll content in the plant. As the crop matures or plant gets under heat stress, there is breakdown of chlorophyll present in the leaves (Dwivedi *et al.*, 2003). The genotypes showing higher NDVI values will result in greater photosynthetic accumulation and tolerance to heat stress (Fig. 2). Membrane thermostability represents the ability of cell membrane to resist leakage of solutes from the cells. The genotypes exhibiting more leakage of solutes were mainly heat sensitive genotypes (Reynoldas *et al.*, 1994, Abdipur *et al.*, 2013; Rehman *et al.*, 2016).

An assessment of genetic variability revealed that there was an ample amount of genetic variation among the genotypes. In general values of phenotypic coefficient of variation (PCV) were found higher than their respective genotypic coefficient of variation (GCV) indicating the considerable influence of environment in the performance of these genotypes. For all characters under study, PCV was found slightly higher than GCV in each case, revealing the prominent role of environment in the expression of these characters. The estimates of range, mean, PCV, GCV, heritability (broad sense) and genetic advance are presented in Table 3. The characters like canopy temperature depression (I, II & III), exhibited higher values of phenotypic variance while other traits also showed similar trend. This suggests that there is a good scope of selection for these factors (Singh *et al.*, 2007; Dwivedi *et al.*, 2003). The phenotypic coefficient of variation was higher

than their respective genotypic coefficient of variation for all the traits (Dixit 1990; Singh *et al.*, 2008; Tripathi *et al.*, 2015). Canopy temperature depression showed maximum phenotypic coefficient of variation. This variation was minimum for days to maturity (Porwal *et al.*, 2006; Jaiswal *et al.*, 2010).

Estimates of phenotypic variance (σ^2_p) were higher than genotypic variance (σ^2_g) (Table 2). A wide range of (σ^2_p) was observed for canopy temperature depression (I, II & III) while moderate range of variance showed by the traits number of tillers per plant spike length, NDVI III and thermostability at different physiological stages. The result of phenotypic coefficient of variation revealed that CTD-III exhibited highest phenotypic coefficient of variation (43.37) followed by CTD-II (33.21). Also CTD-I at different stages showed wide phenotypic coefficient of variation while, the remaining characters showed moderate to low phenotypic coefficient of variation.

Genotypic coefficient of variation was high for CTD-III (33.99) followed by yield per plant (26.61). Also chlorophyll content and CTD at different stages showed wide genotypic coefficient of variation. And remaining characters showed moderate to low genotypic coefficient of variation [Panwar and Singh (2000); Ali *et al.*, (2008), Arvind and Raj (2015)]. The minimum value of genotypic coefficient of variation was observed for days to anthesis, days to maturity and CTD. Thus, the traits with high GCV are to be considered during selection (Arya and Jaiswal, 2015).

Similar studies with respect to PCV and GCV were carried out by various workers. High genotypic and phenotypic coefficient of variation for canopy temperature depression (at anthesis), canopy temperature depression (at 10 days after anthesis) was also in agreement with Gowda *et al.*, (2011). The

substantial differences observed between genotypic and phenotypic coefficient of variation showed the effect of environment in determining the total phenotypic variation Jaiswal *et al.*, (2010). High estimates of genotypic and phenotypic coefficient of variation for canopy temperature depression (III) suggest sufficient variability, therefore offers scope of genetic improvement of the character through selection.

The heritability ranged from 52.02 percent to 97.1 percent. High heritability estimate was exhibited by membrane thermostability (93.35), NDVI-III (87.10), NDVI-I (8.10) and NDVI-II (85.77). The remaining traits showed moderate levels of heritability (Dwivedi *et al.*, 2003; Atta *et al.*, 2008; Zecevic *et al.*, 2010).

The estimates of heritability alone cannot predict the response to selection. Heritability estimates appear to be more meaningful when accompanied by the estimates of genetic advance than alone (Johnson *et al.*, 1955). Thus genetic advance has an added edge over heritability as a guiding factor to breeders in various selection programmes. Genetic advance expressed as a percentage of mean was observed to be high (>50%) for canopy temperature depression (CTD I) and membrane thermostability (Zecevic *et al.*, 2010, Rehman *et al.*, 2016). Genetic advance coupled with high heritability was reported for canopy temperature depression and membrane injury percentage (Kumar *et al.*, 2016; Gowda *et al.*, 2011), which is in conformity with the present findings.

Table.1 List of wheat genotypes used in the experiment

S. No.	Genotype	S. No.	Genotype	S. No.	Genotype
1	PBN-51	15	HD2864	29	IC252874
2	BWL-0814	16	RAJ4083	30	IC212185
3	BWL-1771	17	DBW-14	31	SALEMBO
4	BWL-9022	18	BARKAEE	32	ARIANA66
5	BWL-0924	19	Giza168	33	GIZA155
6	BWL-1793	20	IC32586	34	BACANORA88
7	CUS/79/PRULLA	21	K9465	35	IC118737
8	IEPACA RABE	22	RAJ4037	36	C-306
9	SIDS1	23	TEPOKO	37	HD2967
10	SUNSTAR	24	BABAX	38	PBW343
11	CHIRYA-3	25	OTHERI EGYPT	39	RAJ3765
12	DHARWAD DRY	26	IC532653	40	WH730
13	HD3086	27	SERI82		
14	HI1563	28	SONORA64		

Table.2 Analysis of variance for different characters

Source		Mean squares of morpho-physiological traits													
Character	d.f.	DH	DM	GFD	TILLER	SL	GY	TKW	CTD I	CTD II	CTD III	NDVI I	NDVI II	NDV III	MSI
Replication	2	1.13	2.16	1.26	1.98	0.01	2.06	1.56	0.54	2.29	2.21	1.76	1.45	3.66	0.82
Treatments	39	3.87**	6.04*	8.05**	19.38**	8.27**	7.22**	31.45**	10.83**	8.48**	6.01**	56.98**	107.28**	262.66**	205.88**
Error	78	0.7	1.55	1.16	1.74	0.93	1.07	1.13	1.9	1.99	1.04	2.68	5.62	2.62	1.85

DH-Days to heading, DM- Days to maturity, GFD- Grain filling duration, TILLER- Number of tillers per plant, SL- Spike length (cm), GY- Grain yield per plant (g)TKW-1000-kernel weight, MSI- Membrane thermostability

Table.3 Estimates of parameter of variability for wheat genotypes

Traits		DH	DM	GFD	TILLER	SL	GY	TKW	CTD I	CTD II	CTD III	NDVI I	NDVI II	NDV III	MSI
Mean		78.07	111.17	33.10	9.79	10.65	21.82	35.56	7.26	6.09	3.83	0.75	0.64	0.45	30.95
S.E(m)		0.48	0.42	0.62	0.42	0.82	0.77	0.21	0.79	0.52	0.12	0.47	0.47	0.46	0.53
Range	Max	75.33	108.67	29.12	5.67	6.33	19.30	29.65	5.56	3.39	0.58	0.67	0.43	0.22	14.89
	Min	84.67	118.33	39.33	15.33	15.17	24.31	40.95	9.78	8.32	6.97	0.83	0.74	0.62	49.64
PCV (%)		1.71	1.39	5.63	28.19	17.26	8.10	9.45	30.41	33.21	43.37	6.05	9.94	20.89	26.97
GCV (%)		1.32	1.22	4.59	24.76	14.69	6.57	8.96	23.76	23.95	33.99	5.65	9.20	20.58	26.61
ECV (%)		1.08	0.67	3.26	13.47	9.06	4.74	3.00	18.98	23.01	26.94	2.17	3.75	3.58	4.39
Heritability h ² bs (%)		60.15	76.83	66.46	77.16	72.46	65.72	89.94	61.04	52.02	61.42	87.10	85.77	97.07	97.35
Expected GA (%)		2.11	2.21	7.70	44.81	25.76	10.96	17.50	38.24	35.59	54.87	10.86	17.56	41.78	54.09

DH-Days to heading, DM- Days to maturity, GFD- Grain filling duration, TILLER- Number of tillers per plant, SL- Spike length (cm), GY- Grain yield per plant (g)TKW-1000-kernel weight, MSI- Membrane thermostability

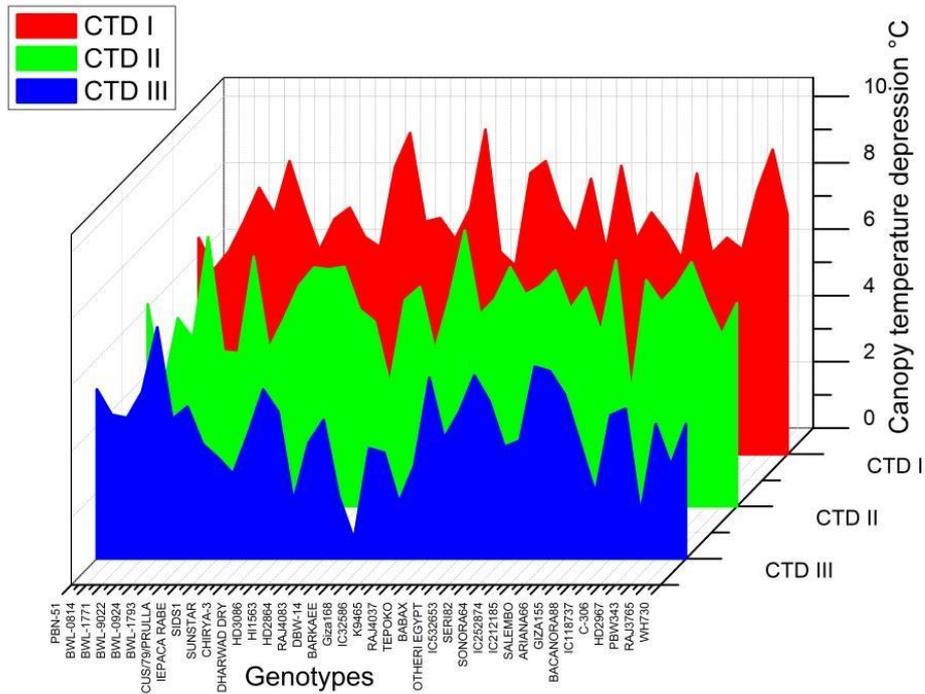


Fig.1 Comparative presentation of Canopy temperature depression at different growth

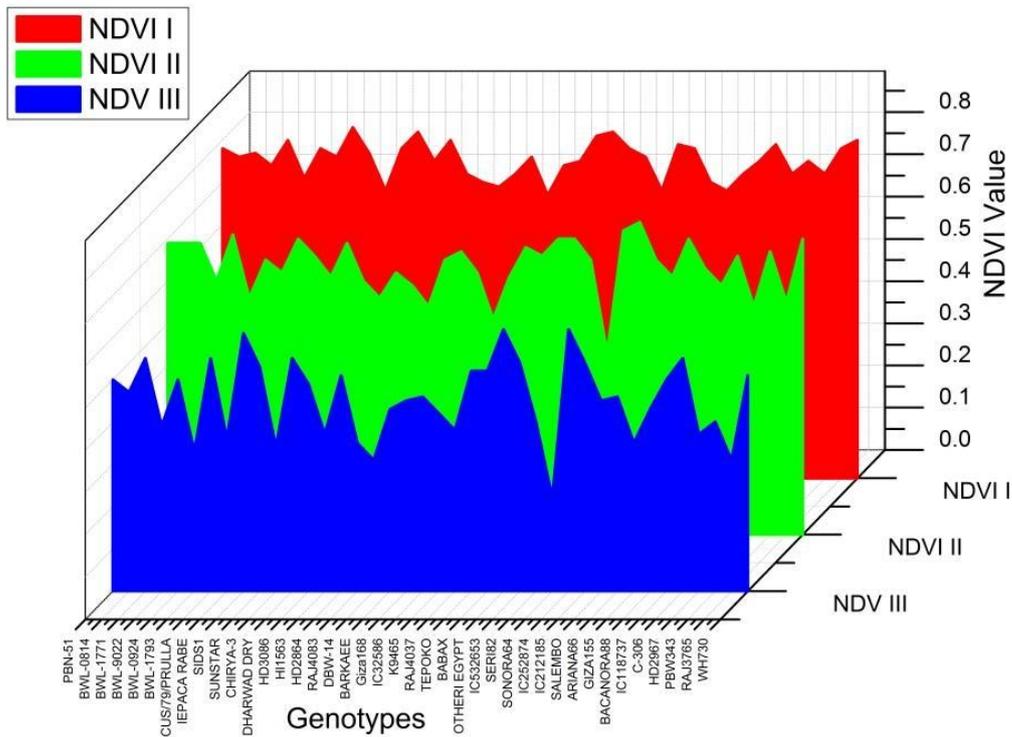


Fig.2 Comparative presentation of chlorophyll content (NDVI value) at different growth

Moderate estimate of genetic advance (25%-50%) was reported for number of tillers per plant, NDVI I, CTD (I & II) and spike length, whereas low estimate of genetic advance was reported for rest of the traits like grain yield per plant and 1000 kernel weight (Singh *et al.*, 2008; Tripathi *et al.*, 2015; Zecevic *et al.*, 2010). To predict the reliable estimates of additive or non-additive effects, heritability should be considered in conjunction with genetic advance (Burton 1952, Johnson *et al.*, 1955). High heritability with high genetic advance was found for membrane thermostability indicated the additive effect of genes and selection may be effective for the trait. High heritability with moderate genetic advance was reported by NDVI, grain weight per spike and flag leaf length, which revealed the presence of both additive and non-additive gene effects (Soumitra *et al.*, 2016). However, traits like 1000 kernel weight, NDVI (II & III) with high heritability and low genetic advance indicated the role of non-additive gene action (Reynoldas *et al.*, 1994). Thus improvement of such traits was suggested through hybridization followed by selection.

In conclusion, climate change and sustainable development are interlinked problems that pose a serious challenge to humanity. High temperature stress in the recent years has been major factor affecting the wheat productivity. The selection of wheat genotypes with better grain yield and tolerance is the principal aim of wheat production. It can be concluded from the above mentioned findings that the genotypes used in the study exhibited considerable variability for various morpho-physiological traits under study, thus providing the ample scope for selection of elite genotypes which can be further utilised for developing thermotolerant cultivars. Physiological traits *i.e.* canopy temperature depression, chlorophyll content and memberane thermostability exhibited higher than their corresponding genotypic coefficient

of variation, it can be interpreted as less difference in the estimates of genotypic and phenotypic variance reflected little influence of environment on these traits. Higher genotypic variances compared to environmental variances for all the characters suggested that the variability present among the genotypes were mainly due to genetic reason with minimum influence of environment and hence heritable. These physiological traits exhibited high genetic gain, which indicates that these traits will directly respond to selection due to presence of additive genes. So, formulating a selection criterion for developing thermotolerant cultivars these physiological traits must be kept in mind. These physiological traits can be coupled in addition to morphological traits for developing thermotolerant cultivars.

Acknowledgments

Authors are thankful to Director Research, G. B. Pant University of Agriculture and Technology, Pantnagar-263 145 (Uttaranchal, India) for providing research facilities and Washington State University, Pullman, USA for sharing the research material. Work on plant stress tolerance in laboratory is partially supported by Department of Biotechnology (DBT), Government of India.

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How to cite this article:

Devender Sharma, J.P. Jaiswal, N.K. Singh, Anjana Chauhan and NavinChanderGahtyari. 2018. Developing a Selection Criterion for Terminal Heat Tolerance in Bread Wheat Based on Various Mopho-Physiological Traits. *Int.J.Curr.Microbiol.App.Sci*. 7(07): 2716-2726. doi: <https://doi.org/10.20546/ijcmas.2018.707.318>