



Identification of suitable trait index for selection of heat tolerant wheat (*Triticum aestivum*) genotypes

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ABSTRACT

Terminal heat stress is one of the major production constraints in wheat-producing areas of south-east Asia. The selection of genotypes based on grain yield *per se* is not effective under stress condition. In the present study 30 wheat (*Triticum aestivum* L.) genotypes were evaluated under normal and heat stress conditions during 2016-17 and 2017-18 to determine the suitable trait index for selection of genotypes under non-stress and heat stress environments and identification of heat tolerant genotypes. The observation was recorded for 13 morphological, biochemical and physiological traits. The index based on seven characters like grain yield, days to heading, biological yield, green fodder yield, dry matter content, catalase and peroxidase was most suitable with the genetic gain of 4856.09% and the genetic advancement of 33.09 in normal condition and the index based on five characters comprising days to heading, biological yield, number of tillers, catalase and peroxidase was most suitable with an expected genetic gain of 20101.32% and genetic advance of 35.09. The genotypes RAJ 3765, BRW 3794, HD 2643, SW 129, DBW 14, SW 160, BRW 3759, BRW 3762 and BRW 3800 were identified as moderately tolerant considering selection index score and heat susceptibility index. These genotypes may be promoted for cultivation under late sown conditions and used as parents for the development of genotypes tolerant to terminal heat stress.

Key words: Abiotic stress, Climate change, Efficiency of selection, HSI, Selection index

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops grown in nearly 89 countries with a total acreage of 218 million ha and total production of 762 MT worldwide in the year 2018-19. India produced record production of 101.2 million tons wheat with the average productivity of 3424 kg/ha in the year 2018-19. However, due to climatic change wheat production has become more vulnerable. It was estimated that annual yield loss due to climate change would cost nearly 7.7 billion dollars (Kumar *et al.* 2013). Optimum temperature for anthesis and grain filling in wheat is 12-22°C, when the maximum temperature exceeds more than 30°C is considered as terminal heat stress (Farook *et al.* 2011). Presently, terminal heat stress is major production constraints for wheat producing areas in the Gangatic plains of India and Bangladesh (Hays *et al.* 2007, Kumar *et al.* 2012).

Genetic gain through direct selection for quantitative traits is very low. Further, selection of low heritable traits like yield under stress condition is not effective. In addition, heat tolerance is the attributes of several characters and selection of all the associated characters while breeding for heat tolerance genotype is quite difficult. Hence, identifying the set of efficient traits and their effectiveness under selection

in a particular environment is important. Use of selection index proposed by Smith (1936) is an effective measure to determine the traits to be used in breeding program. It helps in the simultaneous selection of the various characters having relatively high economic contributions to trait under consideration. On the other hand, heat susceptibility index (HSI) was used to determine the genotypes tolerant to heat stress in wheat (Pandey *et al.* 2015). The present experiment was carried out to select an effective trait index for selection of genotypes for heat stress environment and identification of tolerant genotypes for terminal heat stress.

MATERIALS AND METHODS

The experiment was conducted using 30 diverse genotypes of bread wheat during two consecutive years 2016-17 and 2017-18 using randomized block design in three replications at university farm, Bihar Agricultural University, Sabour, Bihar, India. Each genotype was sown in six-row plot of 4.0 m length on 3rd week of November under non-stress environment with a row to row spacing of 20 cm and for stress environment sowing was done in last week of December with 18 cm row spacing. The observation was recorded on various morphological, physiological and biochemical characters like days to heading, biological yield per plant (g), green fodder yield per plant (g), dry matter content per plant (g), days to maturity, grain yield

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per plant (g), thousand kernel weight (g), number of tillers per plant, panicle length (cm), chlorophyll content (SPAD value), canopy temperature depression ($^{\circ}\text{C}$), catalase (EU), peroxidase (EU). Selection indexes were constructed for normal or non-stress and heat stress condition following Smith index (1936). The expected genetic advance through selection of the different combinations of characters was also estimated. All the traits including grain yield were considered to be equal economic values. The relative efficiency of different discriminate functions in relation to direct selection for grain yield were assessed and compared, assuming the efficiency of selection for grain yield *per se* as 100%. Heat susceptibility index (HSI) was used to identify tolerance genotypes. Based on grain yield in stress and non-stress conditions heat susceptibility index (HSI) was estimated following Fisher and Maurer (1978).

RESULTS AND DISCUSSION

The maximum temperature exceeded the critical limit (30°C) in March, 2016-17 and 2017-18. The weekly maximum and minimum temperature during the crop growing period is depicted in Fig 1. Most of the genotypes grown under stress environment were experienced the terminal heats stress at flowering or booting stage. However, in normal condition the maximum temperature was below 25°C which was congenial for grain development.

Selection index, expected genetic advance and genetic gain: Improvement of complex traits like grain yield under heat stress condition is slow as the genetic gain for selection of yield *per se* is low. Hence, the selection based

on the combination of correlated traits is always effective. Quantitative traits are highly influenced by environmental conditions. Thus, the set of traits used for selection in normal conditions may not well suit for selection of genotypes under stress condition. We prepared selection indexes for non-stress and heat stress conditions considering grain yield as trait of interest to be improved (Table 1). It was observed that the number of traits increased in the indexes, the expected genetic gain and genetic advance were increased. Indirect selection using green fodder yield and peroxidase was more effective than the selection for grain yield *per se*. Addition of one trait, i.e. days to heading over the best two trait indexes (green fodder yield and peroxidase content) has increased of expected genetic advance from 18.77-23.38 and the genetic gain from 2754.6-3431.16%. Shah *et al.* (2016) also found similar results in wheat under normal sown condition. Smith index was used for grain yield improvement of oat (*Avena sativa* L.) where grain yield, growth rate and number of spikelets per panicle have been reported to be important traits for selection (Roy and Verma 2017). Among all the indexes, the maximum genetic gain of 5000.28% and genetic advancement of 34.03 was recorded with the combination of 12 traits. Genetic gain depends with the number of traits present in the index and the selection efficiency of the index. Zhang *et al.* (2011) reported that when the selection accuracy increased, a corresponding increase was also noticed in genetic gain for breeding of tea-tree (*Melaleuca alternifolia* (Maiden and Betche) Cheel). Similarly, expected genetic gain was increased with the increase in accuracy of the index for a breeding program of Tasmanian blue gum (*Eucalyptus globules* Labill.) in Chile (Sanhueza *et al.* 2002).

Selection of plants considering all the 12 traits is difficult. An efficient index would be comprised of a limited number of traits with comparable genetic gain. Hence, a comparable genetic gain of 4856.09% with the genetic advance of 33.09 may be a suitable index combining seven traits as grain yield, days to heading, biological yield, green fodder yield, dry matter content, catalase and peroxidase for non-stress environment. Raiyani *et al.* (2015) proposed selection index which includes six characters, viz. grain yield, grain weight per main spike, number of grain per main

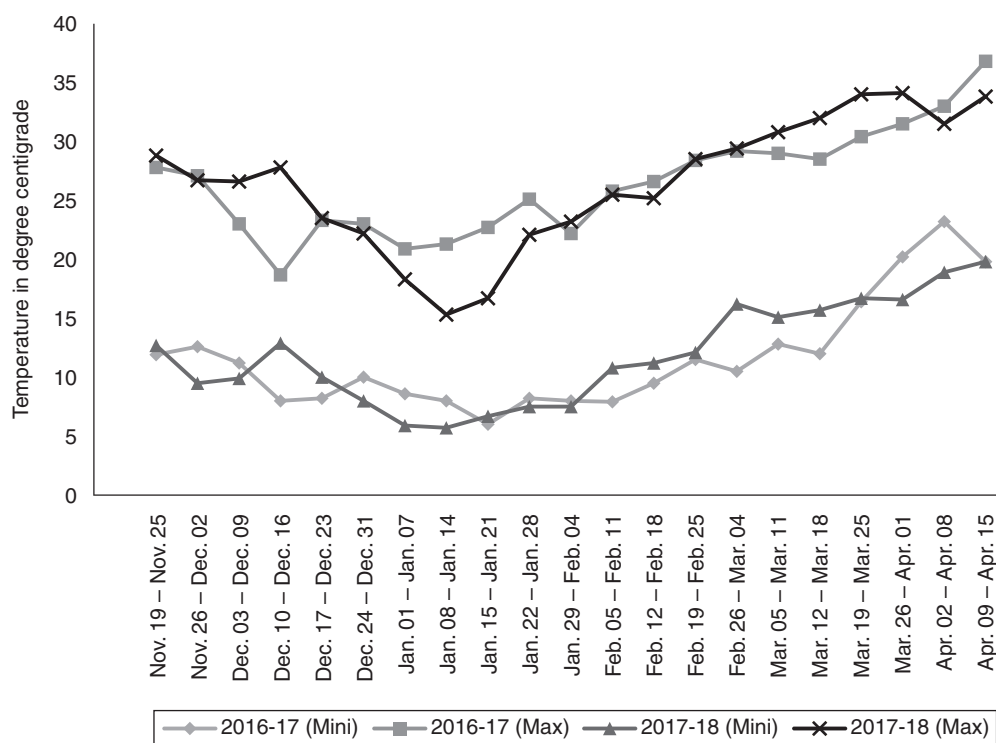


Fig 1 Weekly minimum and maximum temperature ($^{\circ}\text{C}$) in wheat growing season of 2016-17 and 2017-18.

Table 1 Expected genetic advance (GA), Selection intensity (SI) and genetic gain (%) of the indexes constructed under non-stress and heat stress environments (2016-17 & 2017-18)

Indexes Code	Non-stress environment			Indexes Code	Heat stress environment		
	Genetic advance	SI at 5%	Genetic gain (%)		Genetic advance	SI at 5%	Genetic gain (%)
1	0.68	1.40	100	1	0.17	0.36	100
D	15.05	31.01	2209.60	D	33.45	68.91	19160.2
4D	18.77	38.66	2754.64	2D	34.25	70.56	19617.2
24D	23.38	48.16	3431.16	2CD	34.68	71.44	19862.22
234D	27.32	56.28	4010.005	23CD	34.9	71.9	19989.51
234CD	29.69	61.17	4357.93	238CD	35.09	72.3	20101.32
2345CD	31.78	65.47	4664.15	2368CD	35.27	72.65	20200.23
12345CD	33.09	68.16	4856.09	2368ACD	35.41	72.95	20283.22
123456CD	33.42	68.85	4904.95	23689ACD	35.51	73.15	20336.94
1234569CD	33.74	69.50	4951.64	236789ACD	35.56	73.27	20371.04
1234569ACD	33.91	69.85	4976.52	236789ABCD	35.6	73.35	20393.07
1234569ABCD	34.03	70.10	4994.54	-	-	-	-
12345689ABCD	34.07	70.19	5000.28	-	-	-	-

Note: Code 1, grain yield; 2, days to heading; 3, biological yield, 4, grain fodder yield; 5, dry matter content; 6, days to maturity; 7, thousand kernel weight; 8, number of tillers; 9, panicle length; A, chlorophyll content; B, canopy temperature depression; C, catalase; D, peroxidase; GA, genetic advance and SI, selection intensity

spike, ear length, biological yield and harvest index had relative efficiency of 1217.45%. Shah *et al.* (2016) constructed selection indices with five components traits like grain yield per plant, 100-grain weight, days to maturity, harvest index and number of effective tillers with relative efficiency of 1867.41%.

Under heat stress, selection for grain yield *per se* would result the genetic advance of 0.17 (Table 1). Indirect selection based on peroxidase revealed maximum gain of 19160.20% with the highest genetic advance of 33.45. Peroxidase has been earlier reported as important trait under stress condition (Janda *et al.* 2019). It was found that the genetic gain under stress condition for each character combinations was less than the gain recorded under non-stress condition. This indicates to achieve the desired level of improvement under stress condition required more number of selection cycle. The maximum genetic gain was recorded for the index of ten traits considering days with heading, biological yield, days to maturity, thousand kernel weights, and number of tillers, panicle length, chlorophyll (SPAD value) content, canopy temperature depression, catalase and peroxidase content. Selection of index with five traits combination of days to heading, biological yield, number of tillers, catalase and peroxidase with the expected genetic gain of 20101.32% and genetic advance of 35.09 may be considered an effective index for selection the genotypes under stress environment. Days to heading, biological yield, peroxidase and catalase were found to be the most important traits under stress condition. Breeding for early maturing genotypes and higher biomass was suggested in a previous study (Chatrath *et al.* 2007, Joshi *et al.* 2007).

Scoring of each genotype under non-stress and stress environments using the index of maximum genetic gain

is given in Table 2. Under non-stress condition, the score varies from 504.77-389.24 produced by the genotype SW 108 and BRW 3794 respectively. Fifteen genotypes scored better than the mean score of all the genotypes. Similarly, in stress condition, the maximum score was attained by the genotype SW 161 (351.34) and the lowest score for BRW 3759 (241.85). Under stress condition, 14 genotypes were scored better than the intermediate score. It can be revealed that among the high scoring genotypes, 10 genotypes (SW 103; HD 2967; BRW 3807; SW 139; BRW 3723; BRW 3804; BRW 3768; BRW 934; BRW 3790 and SW 161) were common in non-stress and stress conditions. The genotypes HI 1563, DBW 14 HUW 468; BAZ, HUW 234 and BRW 934 are recommended varieties for cultivation under late sown condition (Joshi *et al.* 2007, Shivani *et al.* 2015).

Grouping of genotypes based on heat susceptibility index: Heat susceptible index (HSI) based on the performance of genotypes under non-stress and stress condition revealed that 14 and 16 genotypes were moderately tolerant in 2016-17 and 2017-18, respectively (Table 2). Among them, eight genotypes BRW 3797, SW 129, BRW 3788, BRW 3794, BRW 3762, RAJ 3765, HD 2643 and HUW 468 were found to be moderately tolerant in both the year of evaluation. Several workers have used HSI to group the genotypes under heat stress (Paliwal *et al.* 2012, Pandey *et al.* 2015). The highest level of tolerance was recorded for BRW 3762 (0.790) and DBW 14 (0.602) in 2016-17 and 2017-18, respectively. Grouping of genotypes considering HSI and selection index score found that the genotypes SW 103; BRW 3768; BRW 3790 and HI 1563 in the year 2016-17 and the genotypes HD 2967; SW 161; BRW 3723; BRW 3790; SW 160; BAZ and DBW 14 in the year 2017-18 were moderately tolerant and having higher

Table 2 Scores of genotypes using smith index for non-stress and heat stress environments and heat susceptibility index for both the year of evaluation

Genotype	Smith index score		Heat susceptibility index score	
	Non-stress Environment	Stress Environment	2016-17	2017-18
SW 108	504.77	285.70	1.14 (S)	1.26 (S)
SW 103	498.39	309.85	0.97 (MT)	1.04 (S)
HD 2967	496.10	302.08	1.02 (S)	0.95 (MT)
BRW 3800	488.65	285.55	0.82 (MT)	1.07 (S)
BRW 3807	485.46	320.56	1.05 (S)	1.09 (S)
SW 139	480.70	318.70	1.13 (S)	1.02 (S)
BRW 3723	477.58	303.96	1.03 (S)	0.98 (MT)
BRW 3804	471.70	295.09	1.14 (S)	1.05 (S)
BRW 3768	471.1	304.3	0.94 (MT)	1.38 (S)
BRW 934	467.73	290.14	1.21 (S)	1.04 (S)
BRW 3790	466.91	298.69	0.93 (MT)	1.04 (S)
SW 161	466.35	351.34	1.06 (S)	0.93 (MT)
BRW 3797	465.09	273.39	0.85 (MT)	0.96 (MT)
HUW 468	461.46	272.67	0.87 (MT)	0.96 (MT)
BRW 3759	459.45	241.85	1.13 (S)	0.77 (MT)
SW 160	456.31	309.27	1.09 (S)	0.79 (MT)
BRW 3762	455.09	263.18	0.79 (MT)	0.87 (MT)
BAZ	452.71	293.11	1.09 (S)	0.85 (MT)
BRW 3788	452.38	278.10	0.89 (MT)	0.91 (MT)
PBW 343	450.62	282.07	0.97 (MT)	1.31 (S)
HD 2643	448.34	249.39	0.67 (MT)	0.97 (MT)
HI 1563	446.15	337.63	0.94 (MT)	1.17 (S)
CHIRYA 3	436.91	259.48	1.06 (S)	1.07 (S)
HD 2733	434.03	261.58	1.004 (S)	0.90 (MT)
HUW 234	433.78	286.85	1.002 (S)	1.04 (S)
DBW 14	421.92	290.99	1.15 (S)	0.60 (MT)
SW 129	414.56	278.01	0.93 (MT)	0.71 (MT)
BRW 967	402.68	246.98	1.09 (S)	1.13 (S)
RAJ 3765	394.88	266.70	0.55 (MT)	0.69 (MT)
BRW 3794	389.24	248.18	0.84 (MT)	0.92 (MT)

HSI: ≤ 0.5 is highly tolerant (HT), 0.5-1.0 is moderately tolerant (MT) and > 1.0 is susceptible (S)

index scored under stress condition. Use of these genotypes for cultivation under late sown condition and as parental materials for the development of heat-tolerant genotypes will be effective.

It can be concluded that peroxidase, days to heading, biological yield, number of tillers and catalase are important traits for the screening of genotypes under heat stress. Considering HSI and selection index score RAJ 3765, BRW 3794, HD 2643, SW 129, DBW 14, SW 160, BRW 3759, BRW 3762 and BRW 3800 were found to be moderately tolerant genotypes and can be used as parental lines in the

hybridization program to develop heat-tolerant varieties.

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