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Use of Heat Susceptibility Index and Heat Response Index as a Measure of Heat Tolerance in Wheat and Triticale

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ABSTRACT

Wheat, a cool temperature-loving crop is encountering serious problem of high temperature particularly at the grain filling stage. The present investigation was carried out to compare wheat and triticale genotypes for heat tolerance using seven genotypes from each group. This experiment was conducted in randomized block design with three replications under two dates of showing *i.e.* 25th November and 25th December. Morphological traits like days to flowering, days to maturity, spike length, number of effective tillers per plant, grain yield per plant, biological yield per plant, harvest index and thousand grain-weight were studied and used for the calculation of heat susceptibility index (HSI). In wheat group wherein, genotypes Raj 3765, WH 1080 and WH 1142 showed minimum HSI; while in triticale group, almost all genotypes had minimum values of HSI for different traits, representing high temperature tolerance of these genotypes. Based on heat response index (HRI) also same results were revealed. Overall genotypes Raj 3765, WH 1142, TL 3001, TL 3002, TL 3005 and TL 2942 figured most suitable for late sown conditions. Further these results were also supported by correlation analysis in which HSI and HRI were negatively correlated with each other.

Keywords**:** wheat, triticale, heat stress, HSI, HRI

Introduction

Wheat (*Triticum aestivum* L em. Thell), the'king of cereals' is a member of *Poaceae* family. It is an important staple food all over the world. By the year 2020, the demand of wheat is expected to grow at 1.6 percent per annum, which can be fulfilled if productivity of wheat is increased upto 3.5 tons per hectare (Ortiz *et al*., 2008). However, the present scenario of global warming and climate change may pose problems in wheat production as wheat is seriously affected by elevated temperature. The global temperature is increasing at a rate of 0.13°C per decade since 1950 and still there is expectation that it will take pace of 0.2°C per decade in the next few decades (IPCC, 2007). As wheat is a winter season crop, it requires a long period of low temperature to give maximum yield. The mean temperature of 15 to 18°C is considered as optimum during vegetative growth of wheat (Chowdhury and Wardlaw, 1978). Wheat plant need a long period of low temperature at vegetative and grain filling stage and heat stress at any of these stages may result in decreased productivity of wheat. A mean temperature greater than 17.5°C in the coolest month is defined as heat stress for wheat plant (Fischer and Byerlee, 1991). For every one degree rise in ambient temperature there is a reduction of 3 to 4 percent wheat yield (Mishra *et al.,* 2002).

The high temperature stress occurring at grain filling stage, commonly known as terminal heat stress is most severe for wheat production (Wahid *et. al*, 2007). About 40 percent of wheat producing areas face this problem worldwide (Reynolds *et al*., 1994). This situation may be more severe in South Asian countries where rise in temperature is projected by as much as 3-4°C by the end of this century. In India, nearly 60 percent of wheat area is planted late due to the late harvesting of *kharif* crops. Under such circumstances where on one side demand of wheat production is increasing to feed the huge population of the world and on other side elevated temperature due to global warming is creating problem in sustaining wheat productivity, there is a quick need to identify genotypes which can perform well under temperature stress conditions. Triticale (*X Triticosecale*), the first man made cereal, can be an alternate option under such situation because it is a cross of wheat and rye (*Secale cereale*) (Wilson, 1876). Rye is more tolerant to abiotic stresses as compared to wheat. So it is possible that triticale genotypes with high yield and tolerance to abiotic stresses can be identified. In present investigation these both species are compared for their heat tolerance based on heat susceptibility index (HSI) and heat response index (HRI).

Material and Method

The present experiment was conducted during *Rabi* season of 2015-16 in research area of Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar. The research material was sown in randomized block design under two dates of sowing *i.e.* 25^{th} November (Normal sowing) and 25^{th} December (late sowing). The research material consisted of seven genotypes; each from bread wheat and triticale group. Genotypes included were WH 1080, WH 1105, WH 1142, PBW 550, HD 3086, DBW 88 and Raj 3765 from bread wheat group and TL 3001, TL 3002, TL 3003, TL 3004, TL 3005, TL 2942 and TL 2969 from triticale group. The experimental material was sown in paired rows of 2.5 m length, with row to row spacing 20 cm and plant to plant spacing 10 cm. All the recommended package and practices were followed.

Various morphological and phenological observations were on traits like days to flowering, days to maturity, spike length, number of effective tillers per plant, grain yield per plant,biological yield per plant, harvest index and thousand grain weights were collected from randomly selected five plants per genotype per replication. Heat Susceptibility Index was calculated according to the formula given by Fisher and Maurer (1978)

$$HSI = (1\text{-}YD/YP)/D$$

Where,

YD = mean of the genotypes in stress environment

YP = mean of the genotypes under non-stress environment

D = 1-(mean YD of all genotypes/mean YP of all genotypes).

The Heat Response Index of individual genotype was computed using the formula given by Bidinger *et al.*, (1987) as

$$HRI = (Ya\text{-}\ Yest)/SES$$

Where,

Yest and Ya are the yields estimated by regression analysis and actual yields, respectively, and SES is the standard error of the dependent trait *i.e.* grain yield.

Results

Under both normal and late sown conditions, significant genotypic variability was present for all traits as shown by analysis of variance (Table 1). This variation can be exploited for selection of heat tolerant genotypes. Based on these traits, heat susceptibility index was calculated (Table 2). The genotypes with high positive HSI values are susceptible to higher temperature and vice versa (Fisher and Maurer, 1978). In wheat group, genotypes Raj 3765, WH 1080 and WH 1142 showed minimum HSI for a number of traits. While in triticale group, almost all genotypes have minimum values of HSI for different traits. HSI values for the three important traits *i.e.* grain yield per plant, biological yield per plant and harvest index can be utilized for selection of tolerant genotypes. HSI value for grain yield per plant was minimum for TL 3005 (0.39) followed by TL 3002 (0.47), TL 2942 (0.56), Raj 3765 (0.65), TL (0.73) and WH 1142 (0.89). For the trait biological yield per plant minimum HSI was shown by TL 3005 (-0.70) followed by TL 3002 (-0.19). Similarly, for harvest index HSI was minimum for genotype Raj 3765 (0.65). All these genotypes are more tolerant to high temperature than other genotypes.

Other than Heat Susceptibility Index, Heat Response Index (HRI) was also calculated to confirm the above results. HRI is more useful criteria of selection as it categorise the genotype based on the mechanism of heat tolerance *i.e.* escape, resistance or tolerance (Munjal and Dhanda, 2016). The HRI values of different genotypes is shown in table 3. Significant positive values of HRI denote heat tolerance, while negative values denote heat susceptibility. Maximum heat response index (HRI) in *T. aestivum* was noticed in Raj 3765 (1.05) followed by WH 1142 (0.94);while in triticale group maximum HRI was found in TL 3005 (0.86) followed by TL 2942 (0.83), TL 3002(0.77), TL 3001 (0.11) and TL 3004 (0.02). A negative value of HRI represents a genotype with susceptibility to high temperature. It is clear from both Heat Susceptibility Index and Heat Response Index that triticale genotypes are more tolerant to high temperature than wheat genotypes.

Similar study was also conducted by Bhardwaj *et. al* (2017) who classified wheat genotypes in four groups *i.e.* highly heat tolerant, tolerant, moderately tolerant and susceptible based on HSI values. Munjal and Dhanda (2016) used HSI and HRI to screen wheat genotypes tolerant to drought condition. There result revealed that significant variability exist in wheat genotypes for various yield attributing traits and Heat Response Index is very useful criteria for selection of genotypes tolerant to abiotic stress condition.

Further correlation coefficient analysis was carried out between percentage reduction of yield and heat Susceptibility Index and Heat Response Index (Table 4). It is clear that reduction in yield under late sown condition is significantly positively correlated with HSI (1.000) whereas it is negatively correlated with HRI (-0.870). There is a negative correlation between HSI and HRI (-0.867). These results reveals that yield reduction will be minimum if HSI is less and HRI is more for a genotype.

Conclusion

The global warming is a major challenge for crop production. Every year temperature is rising. Also within year fluctuations in temperature is more in recent years. Under such circumstances, only resistance genotypes is a solution for crop production. With this objective the present investigation was carried out using wheat and triticale genotypes. Heat Susceptibility Index and Heat Response Index were used to select genotypes tolerant to high temperature. Based on this study we can conclude that wheat genotype Raj 3765 and WH 1142 are highly tolerant to increased temperature as compared to other wheat genotypes. The second important result of this study was that triticale has genes for abiotic stress tolerance as most of the genotypes have shown very low HSI values for all the traits. Triticale has proved to be a good gene pool of abiotic stress tolerant genes. We can use these genes in wheat breeding programmes related to high temperature stress.

Table 1. Mean sum of squares for different traits under normal and late sown conditions.

Source of Variation		DF	MSS									
			DH	DM	T/P	PH	SL	GY	BY	HI	G/S	TW
Normal sown	Replication	2										
	Treatment	13	25.926*	48.888*	7.011*	343.742*	4.385*	114.919*	339.227*	65.743*	276.931*	24.969*
	Error	26	1.283	3.401	0.988	9.632	0.599	4.74	7.818	5.991	9.787	2.091
Late sown	Replication	2	2.21	8.21	8.16	1.96	0.24	19.06	6.52	0.67	2.14	23.83
	Treatment	27	49.56*	112.66*	86.74*	7.63*	6.68*	270.33*	106.46*	388.74*	227.30*	40.24*
	Error	54	1.49	1.7	2.41	0.783	0.284	6.87	10.55	3.03	20.1	13.42

* Significant at P≤0.05

Table 2: Heat Susceptibility Index (HSI) of different genotypes.

	Days to heading	Days to maturity	Tillers per plant	Spike length	Yield per plant	Biological yield per plant	Harvest index	Grains per plant	1000-grain weight
WH 1080	0.88*	0.99*	0.99*	0.85*	1.23	0.93*	1.60	0.42*	1.18
WH1105	0.23*	1.05	0.72*	1.38	1.25	0.97*	1.61	0.41*	2.56
WH 1142	0.96*	1.25	0.53*	-0.28*	0.89*	0.67*	1.10	1.14	2.19
PBW 550	1.09	1.27	0.92*	2.01	1.21	1.73	0.65*	1.37	1.85
HD 3086	1.34	1.01	0.72*	1.59	1.23	1.23	1.31	0.93*	1.98
DBW 88	0.97*	1.25	0.95*	0.69*	1.15	1.22	1.13	1.07	1.67
RAJ 3765	0.92*	0.84*	0.72*	0.44*	0.63*	1.01	0.15*	0.80*	1.72
TL 3001	1.07	0.80*	1.00	0.93*	0.96*	1.14	0.78*	1.03	0.79*
TL 3002	0.93	1.01	0.89*	0.76*	0.47*	-0.19*	1.08	0.12*	-1.22*
TL 3003	1.17	0.99*	1.56	1.93	1.19	1.53	0.90*	1.83	-0.77*
TL 3004	2.01	0.95*	1.29	0.75*	0.73*	0.51*	0.95*	1.01	-2.13*
TL 3005	1.07	0.98*	1.26	0.79*	0.39*	-0.70*	1.32	0.39*	0.64*
TL 2942	0.38*	0.64*	1.17	0.77*	0.56*	0.67*	0.43*	1.35	1.84
TL 2962	0.85*	1.02	1.35	1.05	1.53	2.45	0.58*	1.60	0.71*

* *Genotype showing low susceptibility to increasing temperature.*

Table 3. Heat Response Index (HRI) of wheat and triticale genotypes.

T. aestivum	HRI	Triticale	HRI
WH1080	-0.12	**TL 3001**	0.11*
WH1105	-0.18	**TL 3002**	0.77*
WH1142	0.94*	**TL 3003**	-0.33
PBW550	-0.19	**TL 3004**	0.02
HD 3086	-0.27	**TL 3005**	0.86*
DBW 88	0.03	**TL 2942**	0.83*
RAJ3765	1.05*	**TL 2969**	-0.44
CD	0.8	**-**	0.8

* Significant at P≤0.05

Table 4: Correlation Coefficients between reduction in grain yield HSI and HRI in wheat.

	Reduction (%) in yield	HSI	HRI
Reduction (%) in yield	1.000	-	-
HSI	1.000*	1.000	-
HRI	-0.870*	-0.867*	1.000

* Significant at P≤0.05

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