Field response of bread wheat (*Triticum aestivum* L.) genotypesto heat resistance using different parameters

Abstract

Increased temperature is a major yield declining factor in wheat production. Current study was intended to evaluate the impact of increased temperature on the pre and post reproductive major yield attributing biometrical traits through the use of stress tolerance indices and trait reduction ratio (%) of all the traits studied. A set of 27 genotypes including 2 check entries viz., Shriram 303 and HD 2967 was evaluated in two separate trials, timely sown (non-stress) and late sown (heat stress) conditions in RBD design with three replications during rabi 2020-21 at the agriculture research farm of Rama university, Kanpur. Significant dropping in major yield attributing traits have Such as grain yield/plant, grain yield/spike and tillers/plantexhibited 54.41%, 39.31 % and 34.22% reduction, respectively thought the estimation of trait reduction ration (%) specially for the trials conducted under the late sown (heat stress) condition as compared to the normal sown trial. Five stress tolerance indices viz., susceptibility index (HSI), mean productivity (MP), tolerance (TOL), heat tolerance index (STI) and trait stability index (TSI) have been estimated to find out the heat stress tolerance and susceptible genotypes for grain yield under high temperature stress conditions.

Correlation estimatesof different heat stress tolerance indices with grain yield in non-stress condition (timely sown) exhibited significant positive association with MP (0.766**), HTI (0.622**), TSI (0.414*), and TOL (0.284). Though, underheat stress condition (late sown), grain yield displayed a significant positive correlation with HTI (0.713**), MP (0.707**), TOL (0.517**), TSI (0.656**) and negative correlation with HSI (-0.608**). Through the correlation analysis estimates, four heat stress indices viz. HSI (heat susceptibility index), MP (mean productivity), STI (stress tolerance index) and TSI (trait stability index) have been used in assorting the heat tolerant wheat genotypes. Current estimates directedthat 14 genotypes (PBW 152, HUW-206, WL-2, WL-8, WL-13, DBW-71, DBW-39, WH-1105, HUW-318, PBW-154, ALWL-5, WL-14, PBW-502 and Shriram 303) were heat tolerant genotypes while 8 genotypes (Jamuni, F 2004, Allahabad Local, Black, U. P Local, YOUDA, U. P B2425 and HD 2967)have

been observed high temperature susceptible. WhileWH-1105 and PBW-154have been observed high yielding genotypes under heat stress environment. Therefore, genotypes WH-1105 and PBW-154were acknowledged as a suitable genotype for late sown trial. Further, these two genotypes could be utilize in breeding programme to develope heat tolerant varieties of wheat.

Key words: *Wheat, Heat tolerance, Grain yield, Heat tolerance indices.*

Introduction:

Wheat (Triticum aestivum L.) is the world's most important cereal crop after rice and maize. It covers 17% of the world's cultivated area, with 718.31 million metric tons of production. Alone wheat crop is capable to feed 40% of the world's population. It provides more than 20% of all food calories and protein in human diet (Gupta et al., 2008). FAO estimated that global need of wheat grain will increase by 198 million tonnes additionally by 2050 (Sharma et al., 2015) and estimates that this future demand can only be fulfilled with the increased in yield by 2.5% per annum. Global warming has increased annual temperatures and reduced the water availability for smooth agriculture practices. Increased average temperatures and climate change are having major impacts on global crop production. There is a serious need to develop heat-tolerant wheat genotypes suitable to produced more stable yield under the high temperature stress condition. During reproductive and post reproductive stage increased temperature (30-35 0C) can adversely most of the major directly yield attributing traits, consequently reduces the seed yield (Hossain et al. 2012; Porter 2005; Gupta et al. 2013). High temperature stress, especially during peak flowering and grain filling stage become serious factor of reduced grain yield in India (Reynolds et al., 1994). It has been observed that late sowing, after the third week of November will result in grain yield loss of 35-45 kg per hectare per day. Thus 10 million annual global yield loss due to high temperature stress have been recorded. In case of delay sowing, wheat crop directly faces the high temperature during flowering stage and become the major factor of yield reduction. Popular wheat varieties currently grown in the Indo-Gangetic plains are very sensitive to heat stress. Therefore, in order to increase productivity under high temperature stress, it is necessary to develop wheat varieties that can withstand high temperatures during the reproductive and grain filling stages of the crop. Analysis and evaluation of wheat varieties with higher heat tolerance is one of the most important goals in wheat breeding. The main objective of this study is to screen 27 wheat genotypes by investigating the percentage reduction in various stress parameters and other important factors for wheat crops, including two controls for identification of heat tolerance wheat genotypes. Genotypes identified as high temperature stress tolerance would be further utilize in wheat breeding program to develop the wheat variety with heat-tolerant, high-yielding and suitable for delay cropping ecology.

Material And Methods

During rabi 2020-21, 27 rice genotypes, including two check entries were evaluated in 3 replications with RBD field experimental design at the research farm of Rama university, Kanpur. 25 cm row to row and 10 cm plant to plant spacing have been maintained. All recommended agronomic practices have been done to raise the good crop. Observation for all the eleven characters viz., Days to 50% flowering, plant height (cm), tillers/plant, spike length (cm), grain yield/ spike, grains / spike, days to maturity, biological yield/ plant (g), test weight (g), grain filling duration and grain yield / plant (g). for calculating the different stress tolerance parameters following formula is used-

Heatsusceptibilityindex(HSI): Heat susceptibility index of all individual genotypes have been estimated through the followingformula(FischerandMaurer,1978).

$$\boldsymbol{HSI = \frac{1-(\frac{Yp}{Ys})}{1-(\overline{Yp}/\overline{Ys})}}$$

Note: According to Reynolds et al. 1994 HIS indicates the following results-

- Low HIS value means: Heat stress tolerance genotype.
- High HIS value means: heat susceptible genotypes

1. **Meanproductivity(MP):Mean productivity is used to screen the** heat tolerance and susceptible genotypes. Hossain*etal*,1990 suggested the following formula for the estimation of Mean productivity.

$$\boldsymbol{MP = \frac{(Yp+Ys)}{2}}$$

Note: If MP value is high then it indicates heat tolerance genotypes while low MP value is the indicator of heat susceptible genotypes (Hossain et al. 1990; Mardeh et al. 2006).

2. **Tolerance (TOL):** Tolerance is also an importance index to screen the heat susceptible and tolerance genotypes. Its estimation formula has been given below (Hossain et al.1990.)

$$\boxed{TOL = Yp - Ys}$$

Note:-Ve TOL value shows higher tolerance genotype to heat stress (Hossain et al. 1990).

3. **Heat tolerance index (HTI):**HTI can be estimated to screen out the individual genotype tolerance to heat stress has been calculated by the following formula (Fernandez 1992).

$$\boxed{HTI = \frac{(Yp\ x\ Ys)}{(\overline{Yp})^2}}$$

Note: Highest value of heat tolerance index exhibits well performing genotypes under heat stress and non-stress environmental condition(Fernandez 1992, Mardeh*et al.*2006).

4. **Trait stability index (TSI):** This is also a very important estimates to find out the heat stress susceptible and tolerance genotypes individually under changing environmental conditions. It can be estimated through the formula suggested by Bouslama andSchapaugh (1984).

$$\boxed{TSI = Yp/Ys}$$

Note: Extremevalue of TSIrepresentbest performing genotypes under high temperature stressenvironment(BouslamaandSchapaugh1984).

5. **Trait Reduction(TR) %:**Reduction in each selected individual character can be estimated through the following suggested formula-

$$\boxed{TR\ (\%) = \frac{Yp - Ys}{Yp}\ x\ 100}$$

Where:

Yp= Grain yield under timely sown trial
Ys= Grain yield under late sown trial.

$\overline{Yp}$ = Mean grain yield under timely sown trial
$\overline{Ys}$ = Mean grain yield under late sown environment

RESULTSANDDISCUSSION

The study reveals that heat stress significantly impacts the growth and development of wheat genotypes, with a reduction in mean values of phenological traits involving yield and yield-contributing traits. This suggests that increased temperature leads to rapid completion of the wheat life cycle, resulting in poor expression of yield-contributing traits and lower grain yield. Three traits, grain yield/plant, grain yield/spike, and tillers/plant, showed a significant reduction under heat stress, indicating their high impact. This decline in mean values of various traits in wheat has been reported in previous studies(Kirby 1967, Darwinkel et al. 1977, Al-Khatib and Paulsen 1984, Jain et al. 1992, Kumar et al. 1994, Calenderini et al. 1999, Wardlaw 2002, Shazad et al. 2002, Shahid et al. 2005, Irfaq et al. 2005, Okuyama et al. 2005, Thakur et al.2020). However, among the 11 traits studied, plant height (cm) showed the least reduction in trait reduction % value (6.09%), followed by days to 50% flowering (15.89%) and days to maturity (23.80%) (Table 1). These traits may be used as important morpho-physiological traits for screening heat stress tolerance in wheat.

In order to study the heat tolerance and grain filling sensitivity of different wheat varieties, we used five stress indicators such as HIS, MP, TOL, HTI and TSI. All these indicators are calculated based on the seed yield of each species during the optimal period (early sowing) and under temperature stress environment (final sowing). Among them, we selected four main indicators express the significant correlation with grain yield under heat stress environment. Using these stress indices, we evaluated 27 genotypes, including two controls, based on correlation studies with grain yield under heat stress environments (Table 2). Based on the correlation study, the following results were obtained under normal and stress environments, as shown in Table 2. Grain yield per plant under normal conditions showed a significant and highly positive correlation with MP (0.766**), HTI (0.622**) and TSI (0.414*).

A significant and negative correlation was found for grain yield/ plant in the stress condition with HTI (713 **), MP (0.707 **), TOL (0.571 **) and TSI (0.656 **) in HIS (-0.608**).). A similar thermal stress selection pattern was previously observed in durum wheat (Talebi et al. 2008). In current study, out of 27 genotypes used in field screening regarding the heat stress tolerance and susceptible genotypes, including two check entries only in eight genotypes (Jamuni, F 2004, Allahabad Local, Black, U.P B2425 and HD 2967) has been observed as susceptible for high temperature. However, 12 genotypes viz., PBW 152, HUW-206, WL-2, WL-8, WL-13, DBW-71, DBW-39, WH-1105, HUW-318, PBW-154, ALWL-5 and WL - 14 has been observed as high temperature tolerance genotypes (Table 3). The screening is based on the estimates of heat tolerance indices such as such as HSI, MP, TOL, STI and TSI. From the above information it can be concluded that most wheat varieties used in the study have been observed as moderate to high heat tolerant except eight genotypes. our result is in close agreement with the finding of Okechukwu et al. 2016, Khan et al. 2014 and Khajuria et al.2016. for screening of heat tolerance genotypes.

Table 1. Trait reduction % of eleven quantitative characters of 27 bread wheat genotypes (including 02 checks) under late sown environment during rabi 2020-21.

Character	Average value of characters under study in normal sown environment	Average value of characters under study in late sown environment	Trait reduction %
Days to 50% flowering	78.45	65.98	15.89
Plant height (cm)	114.87	107.87	6.09
Tillers /plant	8.56	5.63	34.22
Spike length (cm)	14.68	9.89	32.62
Grain yield / spike (g)	2.34	1.42	39.31
Grains / spike	37.55	28.49	24.12

Days to maturity	125.78	95.84	23.80
Biological yield / plant	55.39	39.74	28.25
Test weight (g)	36.81	25.84	29.80
Grain filling duration	36.47	27.66	24.156
Grain yield/ Plant (g)	18.69	8.52	54.414

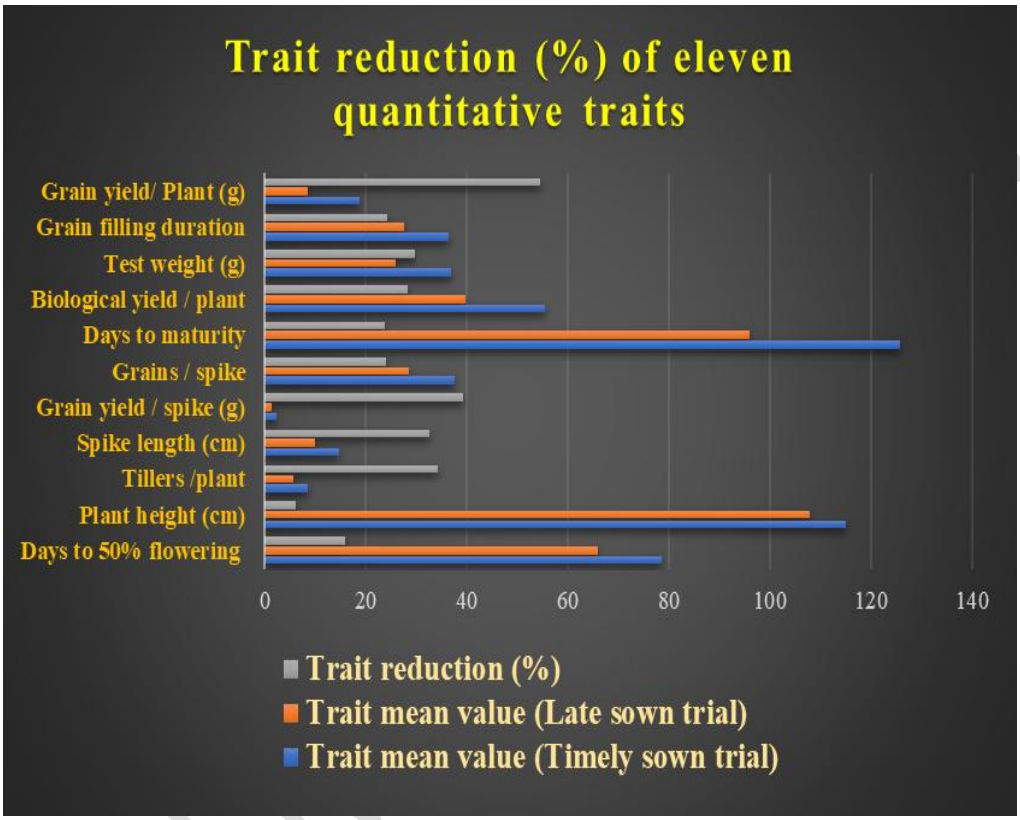

Figure 1. Reduction % of eleven quantitative traits under heat stress condition.

Table 2. Correlation between grain yield and different heat tolerance indicesundertimelysown trial and delayedsowntrial for 27 bread wheat genotypes along with two checks

Character	**Yp**	**Ys**	**Heat Susceptibility Index (HIS)**	**Mean productivity (MP)**	**Tolerance (TOL)**	**Heat tolerance index (HTI)**	**Trait stability index (TSI)**
Yp	1.000	0.587**	0.416*	0.766**	0.284	**0.622****	0.414*
Ys		1.000	**-0.608****	**0.707****	0.571**	**0.713****	**0.656****
Heat Susceptibility Index (HIS)			1.000	-0.252	0.366	-0.343	**0.815****
Mean productivity (MP)				1.000	-0.348	**0.731****	-0.374
Tolerance (TOL)					1.000	0.235	0.589**
Heat tolerance index (HTI)						1.000	-0.574*
Trait stability index							1.000

(TSI)							

Table 3.high temperature tolerant and susceptible genotypes of wheatas per the estimates of heat tolerance indices .

Heat susceptible genotypes	**Yp**	**Ys**	**HSI**	**MP**	**TOL**	**HTI**	**TSI**
Jamuni	14.78	6.11	1.76	10.445	2.79	0.26	5.67
F 2004	15.22	5.44	2.11	10.33	1.86	0.25	4.44
Allahabad Local	15.82	4.67	1.68	10.245	2.42	0.21	6.77
Black	14.78	6.11	1.57	10.445	2.49	0.29	4.68
UP LOCAL	14.78	4.67	1.48	9.725	2.16	0.24	3.89
YOUDA	11.76	5.12	1.43	8.44	5.36	0.22	4.07
U.P B2425	13.67	5.89	1.32	9.78	4.98	0.27	5.12
HD 2967 (Ch)	12.77	4.73	1.52	8.75	4.80	0.25	3.88
Heat tolerant genotypes	**Yp**	**Ys**	**HSI**	**MP**	**TOL**	**STI**	**TSI**
PBW-152	15.67	11.67	0.69	13.67	4	0.45	1.6
HUW-206	14.56	8.87	0.78	11.72	5.69	0.89	1.81
WL-2	16.68	8.67	0.81	12.68	8.01	0.39	1.77
WL-8	16.17	10.55	0.89	13.36	5.62	0.79	1.96
WL-13	15.44	8.82	0.77	12.13	6.62	0.47	1.49
DBW-71	13.94	10.68	0.76	12.31	3.26	0.41	1.76
DBW-39	23.56	20.77	0.75	22.17	8.67	0.55	1.38
WH-1105	26.54	24.68	0.53	25.61	9.78	0.48	1.67
HUW-318	19.88	17.46	0.85	18.67	11.15	0.67	1.94
PBW-154	22.66	20.17	0.61	21.42	8.67	0.57	1.56
ALWL-5	15.55	13.39	0.68	14.47	10.11	0.69	1.43
WL-14	17.89	12.53	0.64	15.21	6.64	0.66	1.68
PBW-502	16.63	11.65	0.79	14.14	7.78	0.62	1.47
Shriram 303	15.95	11.15	0.79	13.55	8.04	0.64	1.96

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