

INVESTIGATION INTO DIFFERENT STRAINS OF WHEAT TRITICUM AESTIVUM L. FOR RESILIENCE IN EXCESSIVELY HIGH TEMPERATURES

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ABSTRACT

Terminal heat stress is a key yield-reducing factor in late sown wheat. Twenty-five bread wheat genotypes were evaluated for terminal heat tolerance by planting in normal (non-stress) and late (stress) environments. To check the tolerance level of genotypes to heat stress, indices namely mean performance of genotypes, heat susceptibility index, and heat susceptibility percent were studied. The analysis of variance revealed significant variation due to genotypes for all characters in two sowing dates except grain filling period. In heat stressed environment, genotypes DBW 107, HUW 688, UP 2883, K 1314, HD 3118, HI 1604 and HD 3159 had high per se performance for grain yield/m². Genotypes HD 3164, GW 463, PBW 718 and CG 1015 showed low heat susceptibility index (HSI<1) for grain yield/m² and were thus consider as heat tolerant genotypes. Reduction in grain yield/m² (14.97%) was mainly associated with a reduction in grain filling period (16.73%).

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) has a prominent position among the cereals that supplement nearly one-third of the total world population's diet by providing half of the dietary protein and more than half of the calories (Kasana *et al.*, 2016). During the last four decades of the 20th century, the global wheat production is doubled from 3 to 6 billion and by the year 2020 demand for wheat imposed by growing population is forecasted around 950 million tonnes. This target will be achieved only if global wheat production is increased by 2.5% per annum (Singh *et al.*, 2011). This increase in wheat production is much more challenging due to a shortage of water and changing climate.

Seasonal fluctuations have a potential impact on the crop development and grain yield. The variation in temperature requirements and temperature extremes varies widely for different cultivars of the same species, among species and it varies widely for most crops. Kalra *et al.* (2008) emphasized the need of studying the response of crops to weather variations for evaluating the impact of seasonal temperature change and estimating yield dependence of temperature rise of crops. Too early sowing of crop produces weak plants with poor root system as the temperature is above optimum whereas delay in sowing leads to irregular germination which results in poor tillering and finally reduction in yield (Yajam and Madani 2013). Many

authors have reported a reduced crop stand, shorter life cycle, reduced tillering, less biomass production, reduced fertilization and grain development, reduced head size, reduction in number of spikes per m², number of grains per spike and grain weight as the consequences of heat stress, and all these changes are translated in reduction of grain yield/m² under heat stress conditions (Moshatati *et al.*, 2012).

Wheat is very sensitive to high temperature (Slafer and Satorre 1999) and trends in increasing growing season temperatures have already been reported for the major wheat-producing regions (Gaffen and Ross 1998; Alexander *et al.*, 2006; Hennessy *et al.*, 2008). Wheat experiences heat stress to varying degrees at different phenological stages, but heat stress during the reproductive phase is more pronounced than during the vegetative phase due to the direct effect on grain number and dry weight (Wollenweber *et al.*, 2013).

Yield and yield components in stress condition, are still the most effective tools for stress evaluation (Ozkan *et al.*, 1998). Selection of different genotypes under environmental stress conditions is one of the main tasks of plant breeders for exploiting genetic variations to improve stress tolerant cultivars (Khan and Kabir 2014). Several screening methods and selection criteria have been proposed by different researchers, but very few were reported for screening heat tolerant genotypes in wheat. Stress indices based on loss of yield under stress conditions in comparison to normal conditions have been used for screening stress tolerant genotypes. Fischer and Maurer (1978) proposed genotype stress susceptibility index (SSI) as a ratio of genotypic performance under stress and non-stress conditions. They suggested the SSI for measurement of yield stability that apprehended the changes in both potential and actual yields in variable environments. Bansal and Sinha (1991) proposed to use SSI and grain yield/m² as stability parameters to identify drought resistant genotypes of wheat. Clarke *et al.*, (1992) used Stress susceptibility index (SSI) to distinguish between wheat (*Triticum aestivum* L.) genotypes and suggested that an SSI > 1 indicated above average susceptibility to drought stress. With this in mind, it was felt imperative to evaluate some improved wheat genotypes (Table 5) facing high temperatures during and after anthesis under field conditions to identify genotypes that have high yield potential in both relatively favourable and high-temperature environments for using in a breeding program.

2. MATERIAL AND METHODS

The experimental material comprised of 25 bread wheat genotypes were planted in randomized block design with two replications for timely sown (TS) and late sown (LS) conditions during Rabi 2014/2015. Late sown planting was done 30 days after TS planting to subject the late sown experiment to terminal heat at grain filling stage. The two planting dates represented no-stress (10th November, E₁) and heat stress (10th December, E₂) environments. Each genotype was grown in a plot having 6 rows of 3m length. The trial was conducted in the experimental area of Department of Plant Breeding and Genetics, Punjab Agricultural University,

Ludhiana. All the recommended cultural and agronomical practices were followed to raise the good crop. Data were recorded for yield and yield component traits viz., Grain filling period, plant height (cm), biomass (gm/m²), productive tillers (spikes/m²), test weight (gm/1000 grains), grain number (GN/5 spikes), grain weight (GW/ 5 spikes) and grain filling period for each genotype and performance of each genotype was compared over two environments.

Heat susceptibility index (HSI) was calculated for grain yield/m² and other attributes over hightemperature stress (late sown) and no-stress environment (timely sown) by using the formula as suggested by Fischer and Maurer (1978).

$$HSI = (1 - X_h/X) / 1 - Y_h/Y$$

where, X_h and X are the phenotypic means for each genotype under heat stress and no stress conditions, respectively, and Y_h and Y are the phenotypic means for all the genotypes together under heat stress and control conditions, respectively. Besides that, heat susceptibility (percent) was worked out as a reduction in genotypic mean under stress environment from that under no-stress environment.

3. RESULTS AND DISCUSSION

The meteorological variations have a great impact on the production and yield factors, as said above the increasing temperature has caused a decline in the production during 2014-15. It has been seen that the mean maximum and minimum temperatures remained high during March and April (Fig. 1).

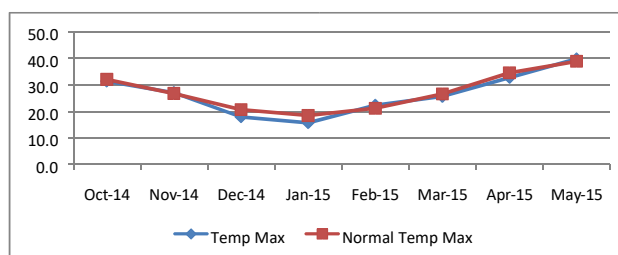


Fig. 1: Schematic representation of difference of maximum and minimum temperature during *rabi* season

ANALYSIS OF VARIANCE

The analyses of variance for grain yield/m² and other yield components in both timely and late sowing environments are given in Table 1. The results revealed highly significant differences among two dates of sowing for all the characters. The test of significance among the genotypes revealed highly significant differences for all the characters studied except grain filling period. This suggested that the magnitude of

differences in genotypes was sufficient to provide some scope for selecting genotypes with improved heat stress tolerance and such genotypes can be used to create desirable genetic variability for heat stress tolerance. Similarly, the genotypes interacted highly significantly with dates of sowing for all the traits showing that genotypes performed differently in normal sown and late sown conditions thus indicating the influence of sowing condition on genotypes and traits. Kaur *et al.* (2013) confirmed that high-temperature stress, created by delayed sowing, caused significant stress conditions for the crop by affecting these traits. The results were also supported by the findings of Singh and Ahmad (1997) and Sharma *et al.* (2004).

Per se Performance

For each genotype mean values of the replications were calculated under each thermal regime in order to identify genotypes excelling for each trait (Table 2). The genotypes showed wide ranges of variations with respect to per se performance for various traits studied. The results exhibited wide differences among genotypes for their sensitivity to heat stress. Genotypes with better per se performance were identified under each thermal regime. Genotypes viz., UAS 360, HD 3165, UAS 361, HI 1604, DBW 150, PBW 716 and UP 2883 had longer grain filling period under normal conditions. Genotype PBW 716 was able to maintain a longer grain filling period under late sown conditions and may possess heat tolerance for grain filling period. The data on plant height revealed that both the sowing dates and varieties affected the plant height significantly. PBW 718, WH 1179 and UAS 360 were tall genotypes, whereas IC 138852 and HUW 688 were dwarf genotypes under both environments. Under normal environment, maximum biomass was observed in PBW 709 followed by PBW 716, HD 3164, K 1312, HUW 688 and DBW 150 whereas; DBW 147 had more biomass under late sown environment. HUW 688, UAS 360, PBW 709, UP 2883, HI 1604 and K 1312 were genotypes with more productive tillers under normal conditions. In some cases the delayed sowing as the temperature was not favouring the tillering requirement, resulting in less number of tillers m². Differences in a number of tillers m² among varieties might be attributed to their genetic diversity. These results are in accordance with those of Aslam *et al.*, (2003); Shah *et al.*, (2006) for differences in a number of tillers m²

table 1: Analysis of variance for experimental design for various traits in bread wheat

source of Variation	d.f.	Mean squares							
		GFP	Ph	Biomass	Pt	tW	Gn/5 spikes	GW/5 spikes	GY
Replications	1	7.30	0.97	900.16	1997.28	51.83	249.50	1.16	4.65
Dates (A)	1	2470.10**	4678.57**	10574.12**	28730.08**	15.99*	1339.42**	15.99**	82.35**
Genotypes (B)	24	1.66	40.93*	30658.33**	3764.63**	45.71**	1761.04**	2.84*	2.35*
AB	24	28.07*	28.73**	17925.49**	3661.29**	13.10**	2808.46**	3.86**	1.40*

As low HSI is synonymous with high-stress tolerance, the genotypes HD 3164, GW 463, PBW 718 and CG 1015 had lowest HSI value for grain yield, therefore, these genotypes had low heat susceptibility indicating their specific suitability under late sowing condition. These results are in conformity with those of Khan *et al.* (2007) concurred that some genotypes have potential to produce high yield even under high temperature. In contrast, genotype WH 1179, followed by UP 2883 and DBW 150 with the highest HSI values could be identified as highly susceptible to heat. Several authors (Khanna-Chopra, Viswanathan 1999; Singh *et al.*, 2011; Sharma *et al.*, 2013) evaluated stress susceptibility indices of yield and its different components of wheat genotypes for heat stress tolerance and grouped them into highly tolerant, tolerant and susceptible genotypes based on their stress susceptibility indices values.

Heat Susceptibility (Percent Reduction)

The overall comparison of percentage reduction of group means of all genotypes under heat stress over no-stress environment indicated that the most sensitive trait to heat stress was grain filling period (16.73%) followed by grain yield/m² (14.97%), plant height (13.42%). Sohail *et al.* (2014) reported that late sowing reduced the wheat grain upto 29% Percentage reduction in grain number and grain weight per 5 spikes was not observed under heat stress environment indicating that the genotypes evaluated in this study were more tolerant to heat stress for these traits.

The study revealed that grain yield/m² was significantly affected by high temperature. Considering grain yield/m² as the final product of different physiological processes, the two entries viz., HD 3164 and GW 463 displayed the uppermost grain yield/m² under the heat stress and were identified as superior genotypes. These genotypes can be utilized in breeding programs for development of wheat varieties having heat tolerance at the terminal growth stage.

4. CONCLUSION

Heat stress is a complex trait. A thermotolerant genotype needs adaptation for all physiological traits at all plant developmental stages. Hence from the present study, it was concluded that genotypes viz., DBW 107, HUW 688, UP 2883, K 1314, HD 3118, HI 1604 and HD 3159 had high per se performance for grain yield. Genotypes HD 3164, GW 463, PBW 718 and CG 1015 showed low heat susceptibility index (HSI<1) for grain yield/m² and were thus consider as heat tolerant genotypes. Thus the genotypes identified on the basis of both these criteria could be of immense use for further exploitation in a breeding programme.

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