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Identification of heat stress tolerant genotypes in bread wheat

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Abstract
Heat stress affects a number of physiological and morphological traits in crops. The present study was undertaken to identify heat tolerant wheat genotypes based on their response for days to flowering and days to maturity. A set of 95 wheat genotypes was evaluated under normal and late sowing conditions. Data analysis revealed that location, sowing time and genotype has marked effect on days to flowering; and sowing time and genotype has significant effect on days to maturity. Based on the time taken by the genotypes to flower and mature under late sowing condition, six genotypes showing heat tolerance in at least two locations were found to be resistant. Heat susceptibility index value was used to identify a total of thirteen genotypes as tolerant to heat for both the traits. The genotypes identified as heat tolerant would form an important resource for the development of high-yielding varieties under heat stress.

Key words: Wheat, heat stress, Heat susceptibility index, genotypes

Introduction

Wheat is an important crop globally and ranks second next to rice in production as a cereal crop. India has largest area (26.3 m ha) under wheat cultivation in the world followed by China (22.5 m ha). The total wheat production for 2013-14 in India was approximately 95.85 million tonnes for the year 2013-14, which was higher than 94.88 and 93.51 million tonnes for 2011-12 and 2012-13, respectively (www.icar.org.in). This was largely due to the use of better agricultural practices and improved seed quality during the last decade. However, to meet the demand for food of the ever growing Indian population, a significant increase in grain production is required for cereals including wheat. This can be made possible by developing higher yielding varieties under different stress conditions, of which abiotic stress is the most important.

Wheat production is affected by a number of abiotic stresses like drought, floods, high temperature, salinity, chilling etc. in the world including India. Terminal heat stress (high temperature > 32˚C), as a result of global warming, at the time of grain filling is a major limitation to wheat production in many environments and is major cause of yield reduction (Hays *et al*. 2007). A significant portion of the wheat grown in South Asia is considered to be affected by heat stress, of which the majority is present in India (Joshi *et al*. 2007). The losses of upto 50% in yield potential have been estimated when crop is exposed to 32-38˚C temperature at crucial grain formation stage (Wardlaw *et al*. 1989).

A number of traits like chlorophyll content, canopy temperature depression, photosynthetic rate, biomass, thousand grain weight, grain yield are yield associated traits affected by heat stress. Grain filling duration has been widely used as a measurement of heat tolerance (Fokar *et al*. 1998). Heat stress during grain filling is responsible for shortening of grain growth period and improper grain filling which affects over-all yield of wheat crop (Rane *et al*. 2007). The heat stress tolerant varieties/genotypes can be identified by calculating heat susceptibility index (HSI) following field evaluation for a number of agronomic traits. HSI has been used in previous studies for measuring heat tolerance in crops like soybean and wheat (Ayeneh *et al*. 2002; Githiri *et al*. 2006; Kirigwi *et al*. 2007; Mohammadi *et al*. 2008; Mason *et al*. 2010, 2011). A total of eight QTLs on different chromosomes were detected in a study that involved use of HSI for thousand grain weight, grain filling duration, grain yield and canopy temperature depression (Paliwal *et al*. 2012). In another study, HSI for short term reproductive stage heat stress was calculated and used for the identification of twenty seven QTLs (Mason *et al*. 2010). HSI was used for identification of five heat tolerant varieties, on their

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relative performance in yield components, grain yield and heat susceptibility indices, among a pool of 25 spring wheat genotypes (Khan *et al*. 2014). The use of HSI and performance under late sowing heat stressed conditions has also been reported in a number of studies earlier as well (Mohammadi *et al*. 2008; Pinto *et al*. 2010; Yang *et al*. 2010; Barakat *et al*. 2011; Mason *et al*. 2010, 2011).

The present study was aimed at identifying heat tolerant genotypes on the basis of heat susceptibility index (HSI) and performance under late sowing heat stressed conditions for days to flowering and days to maturity.

Materials and methods

Planting material and field evaluation

A set of 95 diverse wheat genotypes, obtained from CCSU, Meerut, U.P (India) were used for heat stress evaluation. The wheat genotypes were sown under two regimes of sowing i.e normal sowing and late sowing, both in replicated trails at two locations viz SKUAST-J, Chatha and SKUAST-J, R.S Pura herein referred to as Chatha and RS Pura. Alpha-lattice experimental design with two replications (each for normal and late sowing) was used. Each genotype was sown in plots of 5.0 m^2 with row-to-row spacing of 0.25cm. All agronomic practices recommended for the normal wheat crop were followed. The phenotypic data for days to flowering (DTF) and days to maturity (DTM) was recorded for each genotype in each replication**.** DTF was recorded as the number of days required for half the length of spikes to emerge out in 50% of plants in a plot. Similarly days to maturity was recorded as the number of days required for 50% of a plot to become physiologically mature as evident from yellowing of plants.

Statistical analysis

The analysis of variance (ANOVA) was carried out to study the effect of different factors on the days to flowering and days to maturity under normal and late sowing. The paired t-test was carried out to understand the effect of late sowing on two traits. All the data analysis was carried using SPSS statistical package.

Heat Susceptibility Index (HSI)

Heat susceptibility index (HSI) was used to evaluate the effect of heat stress on days to flowering and days to maturity. The formula used for HSI calculation, taken from Paliwal *et al*. (2012), is given below:

HSI of X= [(1- Xheat stress/ Xcontrol)/D]

Where,

X represents DTF and DTM

Xheat stress represents phenotypic values of individual genotypes for DTF and DTM under late sowing

Xcontrol represents phenotypic values of individual genotypes for DTF and DTM under normal sowing

D (stress intensity) = (1- Yheat stress/ Ycontrol)

Yheat stress= Mean of Xheat stress of all genotypes

Ycontrol= Mean of Xcontrol of all genotypes

Results and discussion

Phenotypic evaluation of genotypes

The data on 95 wheat genotypes was evaluated for days to flowering (DTF) and days to maturity (DTM) under two regimes of sowing *i.e* normal sowing and late sowing. The DTF was scored at two different locations (Chatha and RS Pura) in the year 2014-15 while DTM was scored at one location (Chatha) only in 2014-15. The initial data analysis suggested that there were significant differences in the DTF and DTM between two sowing times and for DTF between two locations. DTF under normal sowing ranged from 91.5 to 114.5 (Chatha) and 99.5 to 120.5 (RS Pura). For late sowing, DTF ranged from 52 to 63.5 and 71.5 to 79 for Chatha and RS Pura locations, respectively. The mean days to flowering for early sowing was 102.89 (Chatha) and 110.25 (RS Pura) and for late sowing was 58.3 (Chatha) and 75.8 (RS Pura) (Fig 1). DTM under normal sowing ranged from 141.5 to 146.5 with an average of 143.8 days and for late sowing it ranged from 112 to 130 with an average of 115.3 days (Fig 2).

The ANOVA analysis was conducted by taking DTF and DTM as dependent variable and location, sowing time and genotype as independent variables with random effects for DTF; and sowing time and genotype as independent variables with random effects for DTM (Table 1 & Table 2). The analysis revealed that location, sowing time and genotype has significant effects on the DTF and sowing time and genotype has significant effects on the DTM. The main effect interactions location*sowing time, location*genotype and sowing time*genotype showed significant differences for days to flowering and sowing time*genotype showed significant differences for days to maturity.

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Identification of heat stress tolerant genotypes

The performances under late sowing condition revealed significant effects of heat stress on the both traits. A total of 11 genotypes namely, C4, C12, C16, C18, C24, C26, C31, C34, C36, C65 and C76 showed delayed flowering in Chatha location suggesting their ability to withstand heat stress. Ten genotypes (C7, C19, C24, C26, C27, C49, C65, C66, C81 and C83) identified showed delayed flowering in RS Pura location suggesting tolerant nature to heat stress. A total of 11 genotypes identified namely, C1, C5, C12, C15, C19, C26, C34, C58, C71, C87 and C91 showed delayed maturity suggesting their tolerance to heat stress under late sowing conditions (Table 3). Based on the overall performance in late sowing conditions for DTF and DTM, C12, C19, C24, C26, C34 and C65, were found to be resistant to heat stress.

Heat Susceptibility Index (HSI) of wheat genotypes

To estimate the effect of heat on the genotypes, paired t-test was employed using data of DTF and DTM from normal and late sowing conditions (Table 4). Significant differences between normal sowing and late sowing environments were found for both the traits. The HSI for DTF ranged from 0.91 to 1.07 for Chatha (Fig. 3) with mean value of 0.99 and from 0.78 to 1.20 for RS Pura with mean value of 0.99 (Fig. 4). Similarly, HSI ranged from 0.42-1.08 for DTM with an average of 0.99 at Chatha (Fig. 5). These values were used to identify heat tolerant genotypes. Low values of HSI (less than 1) are synonymous with high stress tolerance (Fischer and Maurer 1978). Values of stress intensity (D) indicated that both the traits were highly affected by heat stress.

Heat Susceptibility Index (HSI) estimates for all genotypes showed both resistant and tolerant genotypes. For DTF, 51 (out of 95) genotypes showed resistance in one location (Chatha) and 50 genotypes showed resistance in second location (RS Pura). Overall, thirty two genotypes namely C5, C6, C7, C14, C15, C17, C18, C21, C23, C28, C43, C45, C47, C48, C52, C53, C54, C55, C59, C60, C66, C67, C68, C69, C71, C72, C74, C75, C81, C84, C93 and C95 were resistant for DTF in both the locations. HSI estimate for DTM showed a total of 44 resistant genotypes. Twenty four genotypes (C5, C15, C18, C19, C30, C31, C32, C36, C41, C45, C48, C53, C55, C65, C71, C74, C75, C81, C84, C85, C88, C92, C94 and C95) resistant for DTM were also resistance for DTF at Chatha location and twenty genotypes (C1, C5, C15, C18, C25, C45, C46, C48, C49, C53, C55, C71, C74, C75, C78, C81, C84, C86, C91 and C95) resistant for DTM were also resistant for DTF at RS Pura location.

From overall evaluation for HSI for both days to flowering and days to maturity C5, C15, C18, C45, C48, C53, C55, C71, C74, C75, C81, C84 and C95 were identified as heat tolerant genotypes.

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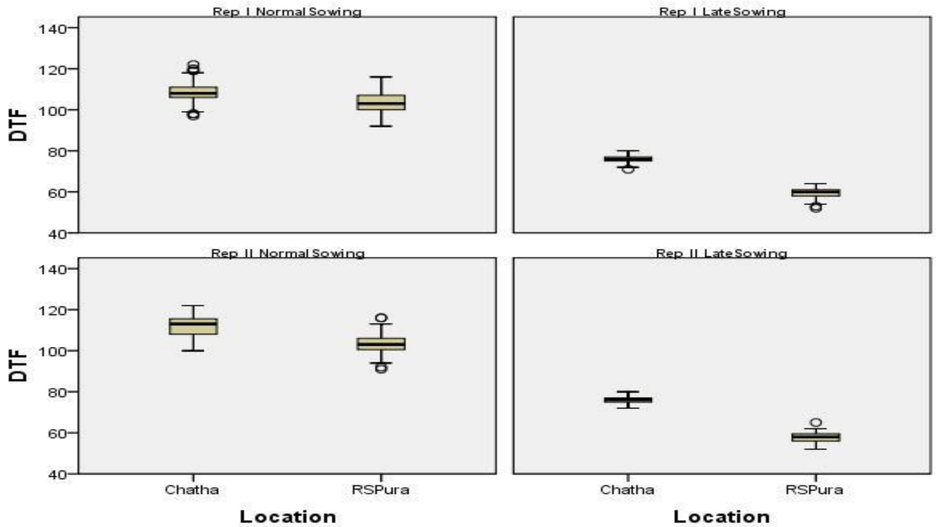

Fig. 1: Days to flowering (DTF) under normal and late sowing for two locations (Chatha and RS Pura).

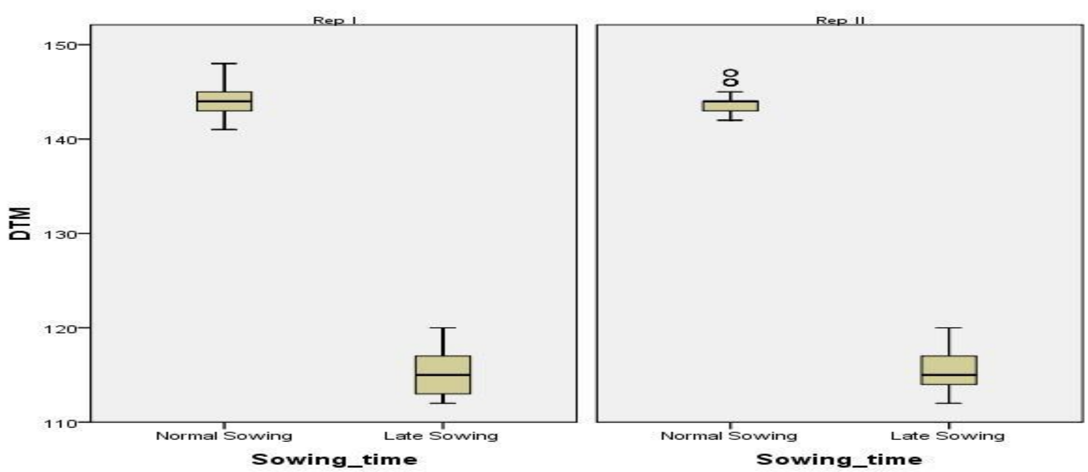

Fig. 2: Days to maturity (DTM) for normal and late sowing at Chatha location.

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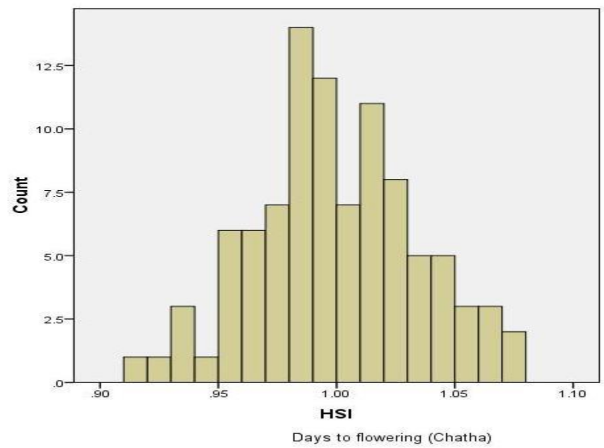

Fig. 3: Graph showing range of HSI for all genotypes for days to flowering at Chatha.

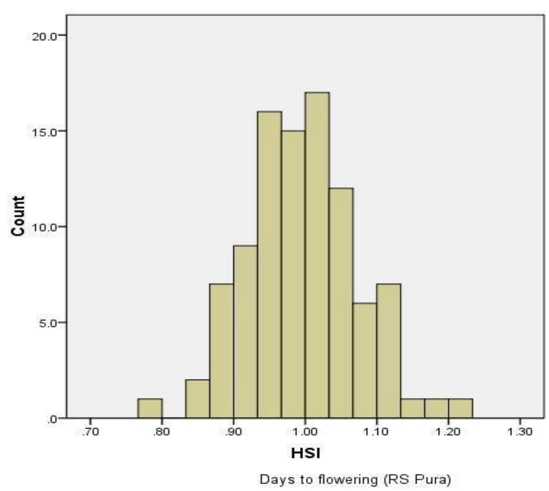

Fig. 4: Graph showing range of HSI for all genotypes for days to flowering at RS Pura.

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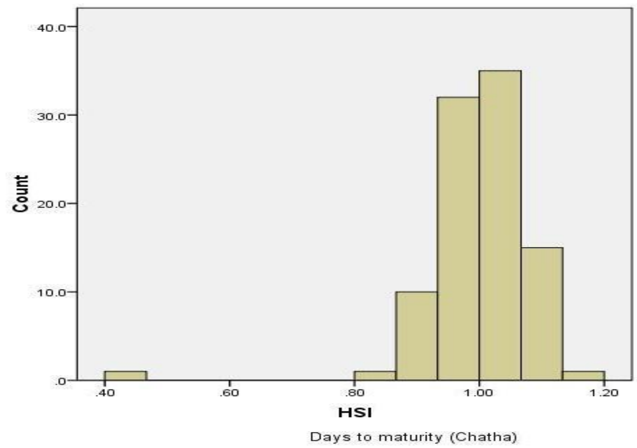

Fig. 5: Graph showing range of HSI for all genotypes for days to maturity at Chatha.

Table 1. Analysis of variance for days to flowering under normal and late sowing conditions

Source of variation	Degree of freedom (df)	Mean square	Significance level
Location	1	29500.3	0*
Sowing time	1	296408	0*
Genotype	94	74.68	0*
Location * Sowing time	1	4936.80	0*
Location * Genotype	94	8.03	0.21
Sowing time* Genotype	94	21.49	0*
Location * Sowing time * Genotype	94	4.57	0.99

* indicate significant at 0.05 level of probability

Table 2. Analysis of variance for days to maturity under normal and late sowing conditions

Source of variation	Degree of freedom (df)	Mean square	Significance level
Sowing time	1	77706.2	0*
Genotype	94	4.12	0*
Sowing time * Genotype	94	3.45	0.01*

* indicate significant at 0.05 level of probability

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Table 3: Heat stress tolerant genotypes identified for days to flowering (DTF) and days to maturity (DTM).

S.No.	DTF CHATHA	DTF RSPURA	DTM CHATHA
1.	C4	C7	C1
2.	C12	C19	C5
3.	C16	C24	C12
4.	C18	C26	C15
5.	C24	C27	C19
6.	C26	C49	C26
7.	C31	C65	C34
8.	C34	C66	C58
9.	C36	C81	C71
10.	C65	C83	C87
11.	C76		C91

Table 4: Paired t-test for days to flowering and days to maturity using means of early and late sowing.

Trait	Mean Difference	Std. Deviation	t- value	95 % Confidence interval of the difference	
				Lower	Upper
Days to Flowering	39.49	6.80	113.20*	38.81	40.18
Days to Maturity	28.60	2.31	170.23*	28.26	28.93

* indicate significant at 0.05 level of probability