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Precise phenotyping approach or characterization of terminal heat tolerance in bread wheat (*Triticum aestivum* L.)

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ABSTRACT

The investigation of study of terminal heat tolerance carried out at experimental field of Krishi Vigyan Kendra, Banasthali Vidyapith, Rajasthan during crop season 2020-2021. The experiments were established in a precise phenotyping approach with 3 replications. Germination rate; days to heading (DH), days to anthesis (DA), days to maturity (DM), grain filling duration (GFD), plant vigor, canopy temperature data was collected. A vital quality to improve establishment is plant vigour, water- use efficiency and grain yield for wheat. Dates of heading, anthesis and maturity were determined when 50% of the plant in a field had reached under TS and LS conditions. The traits days to heading should be invariably considered for wheat improvement. The average values of heading, anthesis, maturity and grain filling duration under timely sown showed higher values as compared to late sown. The plant vigour and germination rate data have been reported. The average value of germination rate of the genotypes under timely and late sown were 13.88 and 15.48 respectively. When compared to timely sowing, the genotypes germination rates for late sowing were higher. The effects of temperature were more on LS as compared to TS. The ten genotypes examined showed fairly diverse variability for the various traits evaluated and were significantly associated with yields that could be used in breeding programs in wheat breeding.

Key words: *Wheat, Days to heading (DH),Days toanthesis (DA), Days to maturity (DM), Grain filling duration (GFD), Germination rate, Plant vigour, Canopy temperature.*

Introduction

Wheat is an essential crop and sustains billions of family daily while its production is approximately reduced under high temperature (Rehman *et al.*, 2021). In India wheat is sown in November and December and harvested in April and May. 12-22 p C temperature required for the for the timely planted wheat crop during reproductive and vegetative growth period especially during anthesis & grain filling stages (Rehman *et al.*, 2021). Heat stress break off important biochemical and physiological development in plant. Knowledge of the physiological, biochemical and morphological effects of heat stress is crucial for creating novel crop types that can withstand changing climatic conditions. Heat stress interrupts the important physiological and biochemical process of the plant (Poudel and Poudel, 2020). Pandey *et al.*, 2013 studied phenotypic selection's challenges in tolerance and marker-assisted selection (MAS) has been regarded as a successful strategy for enhancing plant stress resistance due to the overall complexity of abiotic stress tolerance.

Spielmeyer *et al.*, (2007) found wheat crops with greater early vigour shade the soil surface more rapidly and reduce water loss. Evaporation losses impair water utilization, especially in arid areas where most precipitation is reduced before the canopy closes, in the early growing season. The vitality of young plants is an important physiological property for improving wheat colonization, water utilization efficiency and grain yield (Duan *et al.*, 2016). Previous studies assessing the increase in small genotypes of young plants have shown the potential to boost grain and biomass production through vitality selection in the Mediterranean environment (Whan *et al.*, (1991) and Khan *et al.*, (2007) therefore, high temperatures during late development of wheat, especially at the beginning and a later flowering (terminal or late heat stress), are treated as key factors limiting wheat production in different wheat developing areas. Improving the heat resistance of late planted wheat is actually important for increasing and stabilizing the production of wheat in the country. Therefore, breeding or selected genotypes with improved heat resistance is one of the key goals of the wheat improvement program.

Zadok's growth scale

This scale uses a 1- 11 numbering system, with each number representing a new growth event. To further define a stage, each number can be sub divided using decimals. When more than half of the plants in wheat field have progressed to the next growth stage, the field has reached a new growth stage (Zadok *et al.*, 1974).

Materials and Methods

Plant material

10 wheat genotypes (*Triticum aestivum* L.) viz., GW322, HI617, K0402, K68, Raj 4037, Raj 3765, GW496, Raj 3777, Raj 4238 and K9423were selected for field experiments for the support of heat tolerance and heat susceptibility will be sown at the research plot of KVK for distinct agro climatic conditions admitted the plant material for the present study.

Plot information and data collection

The experiment comprising two sets of conditions, timely sown (mid November to last November) and late has sown (mid December to last December). A randomized block design was used for the field trials in three replicates. The plot area was 72msq. Irrigation was performed as needed fertilizer application followed recommended agricultural packages and practices. Observations were recorded for biophenology and yield-related traits of all genotypes. The considered traits were plant vigour, germination rate, days to heading (DTH), days to anthesis, days to maturity, grain filling duration, canopy temperature. The days of heading, days to anthesis and days to maturity were determined when 50% of the plant in a field had reached under TS and LS conditions.

Germination rate

After seeding under TS and LS, germination data was collected after 25 days. Thermal stress in the range of 28-30 °C can change growth time of plant by shortening the germination and maturation time of seeds (Yamamoto *et al.*, 2008). Results revealed that both factors, i.e., genotype and temperature as well as their interaction significantly affected the germination percentage and other seed vigour parameters. Germination rate increase with increase in temperature in all the genotypes under late sown.Heat stress clearly has a negative impact on the growth and development of wheat plants.

Krupnik *et al.* (2015) report on this early sowing resulted in wheat escaping heat stress and late sown staggered wheat growth over a period of time. During that time high temperature occurs which ultimately leads to thermal stress and reduced yields. According to Llveras *et al.* (2004), the appropriate seeding rate differs significantly from region to region because of variations in environmental conditions, soil types, sowing dates, and wheat genotypes.

Plant vigour

The genotypes that produces greater early vitality grows faster after germination and blooms to increase leaf area and biomass (Lopez and Richards, 1994). The morphological factors that contribute to the early vitality phenotype and wheat is apparent for early leaf development defined Rebetzke and Richards, 1999. Fig. 1 depicts the spreading kind of plant as being heat tolerant and the erect type of plant as being heat sensitive.

Days to heading: It is calculated from the date of sowing to head emergence in 50% of plants (Zarei *et al.*, 2013).

Days to anthesis: Days to anthesis are the duration from the date of sowing to the extrusion in 50% of plants.

Days to maturity: The physiological maturity is calculated as duration from the date of sowing to straw attaining yellow colour.

Grain filling duration: Grain filling duration, is needed the period between days to anthesis and physiological maturity (Pandey *et al.*, 2013).

Canopy temperature

Canopy temperature is an integrative trait that reflects canopy coolness, or the balance between the shoot transpiration and root water uptake. Canopy temperature is measured with a portable infrared thermometer (Lepekhov *et al.*, 2022).

Results

Observation in field conditions

In field condition plant vigour data were taken showed semi spread, spread and erect type behavior.

(1.) (2.) (3.)

Fig. 1. Scoring plant type at seedling stage 1. Spread 2. Semi spread 3. Erect.

In our observations under TS condition the four plants are erect type, 3 plants are semi-spread and 3 plants are spread type. In late sown, 3 plants are semi-spread type, 3 plants are erect type and 4 plants are spread type.

Late-sown wheat types typically face extreme temperature stress, which reduce the number of

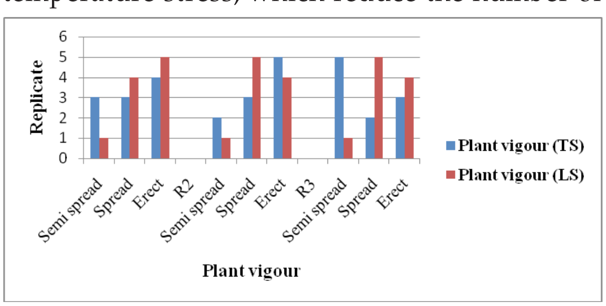

Fig. 2. The plant vigour of genotypes with three replications, R1, R2, and R3, is depicted on a graph under conditions of timely and late sowing.

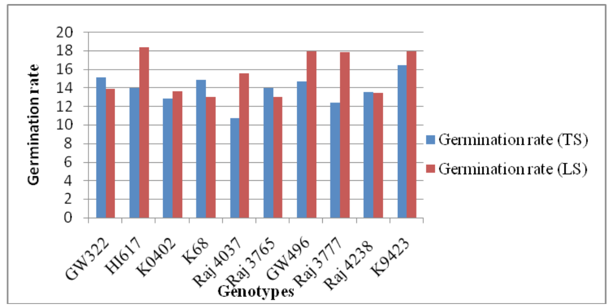

Fig. 3. The genotypes germination rates for timely and late sowing are depicted in a graph.

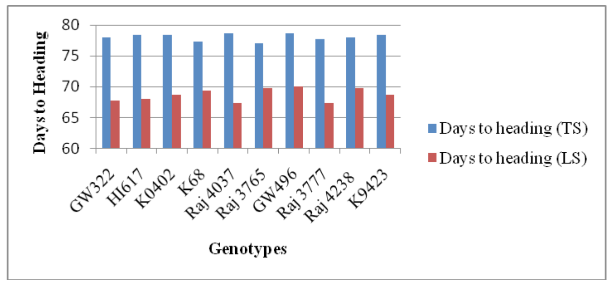

Fig. 4. The graph displays the genotypes' days to heading under TS and LS.

Fig. 5. Wheat growth stage – Heading stage.

days to heading (Akter and Islam, 2017). Timely sown showed highest days to heading as compared to late sown.

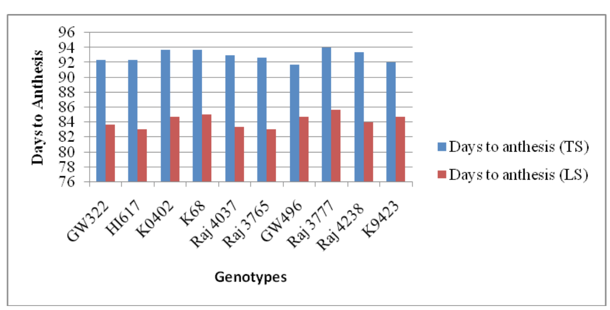

Fig. 6. The graph displays the genotypes days toanthesis under TS and LS.

Analysis of Days to Anthesis

In Fig.6, timely sown showed higher days toanthesis as compared to late sown.

Analysis of Days to Physiological Maturity

In Fig. 7, timely sown showed higher days to maturity as compared to late sown.

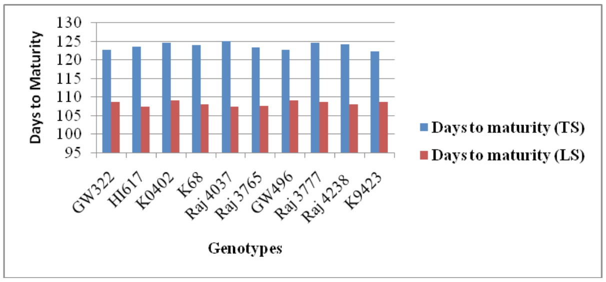

Fig. 7. The graph displays the genotypes days to maturity under TS and LS.

Analysis of Grain filling duration

In Fig. 8, timely sown showed higher grain filling duration as compared to late sown.

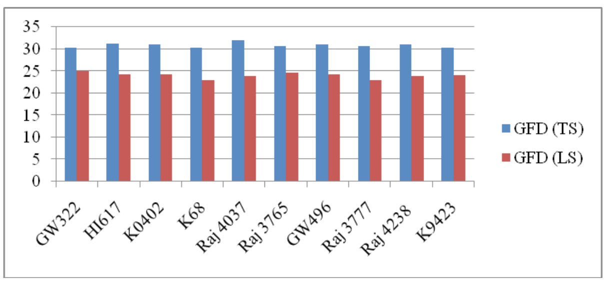

Fig. 8. The graph displays the genotypes grain filling duration under TS and LS.

Canopy temperature

The average values of canopy temperature of wheat genotypes under TS and LS were recorded. In timely sown, genotype Raj 4037 showed higher average temperature i.e., 40.3 °C and K68 showed the

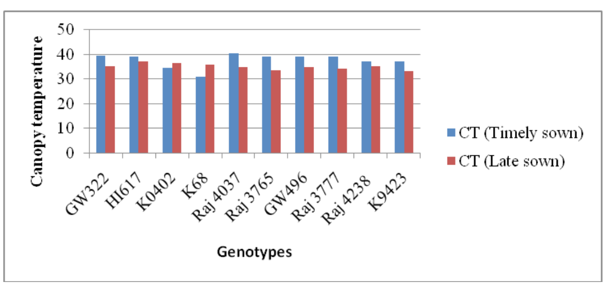

Fig. 9. Graph shows the canopy temperature of genotypes under timely and late sown conditions.

lowest average temperature i.e., 30.9 °C. In late sown, genotype HI617 showed higher average temperature i.e., 37.2 °C and genotype K9423 showed lowest temperature i.e., 33.3 °C.

Table 1. Table shows the ANOVAs for germination rate, days to heading, days to anthesis, days to maturity and grain filling duration under timely and late sown.

Source of Variations	Replicate	Treatments	Error
df	2	9	18
(GR) Mean Squares (TS)	0.300	7.367	9.300
(GR) Mean Squares (LS)	9.300	14.148	11.004
(GR) Probability (TS)	0.968	0.628	NA
(GR) Probability (LS)	0.446	0.309	NA
(DH) Mean Squares (TS)	0.533	0.922	0.311
(DH) Mean Squares (LS)	0.033	3.070	0.293
(DH) Probability (TS)	0.208	0.024*	NA
(DH) Probability (LS)	0.893	0.000***	NA
(DA) Mean Squares (TS)	0.033	1.867	0.256
(DA) Mean Squares (LS)	0.033	2.463	0.219
(DA) Probability (TS)	0.879	0.000***	NA
(DA) Probability (LS)	0.86	0.00**	NA
(DM) Mean Squares (TS)	0.033	2.726	0.293
(DM) Mean Squares (LS)	0.433	1.263	0.507
(DM) Probability (TS)	0.893	0.000***	NA
(DM) Probability (LS)	0.442	0.048*	NA
(GFD) Mean Squares (TS)	0.033	0.830	0.330
(GFD) Mean Squares (LS)	0.233	1.244	0.789
(GFD)Probability (TS)	0.904	0.046*	NA
(GFD) Probability (LS)	0.748	0.196	NA

Discussion

Field-based research provides a better way to study terminal heat tolerance. Late sowing provides a better opportunity to assess genotype for adaptability to high temperatures. From early growth stage to maturity, this is usually a sudden spurt in temperature that impacts timely sown growing crops.

Variation in performance may also be attributable to seasonal influences. The temperature of the soil in late planting season is projected to be below 10 °C affecting stand establishment and seed germination. Like other cool-season crops, wheat is frequently sown early to ensure optimal development, growth, and maturity. Due to differences in genetic potential, the response of wheat genotypes to the day of planting depends on the traits that promote yield.

Days to heading is a statistically significant under timely and late sown conditions, days to anthesis is an also statistically significant for timely and late sown conditions. Days to maturity are also significant for timely and late sown conditions and GFD is a significant under timely sown conditions.

As a result of the interaction between date of sowing and genotype, very significant mean differences were observed for all genotypes. In our results, we find all genotypes took more days to germinate with normal sowing than in late sowing as similar result earlier reported by Khan *et al.* 2007. Germination rate increases with increase in temperature in all the genotypes under late sown. Late sown showed highest germination rate as compared to timely sown.

Under optimum sowing (Timely sown) condition the genotypes showed more days for heading under field trials (TS and LS). In our observation the length of the heading period shortens as the heat stress rises and same type of the observations were reported by (Soliman, 2006). Because early sowing delivers larger yields than late sowing due to the longer time, late planting has an impact on wheat growth, yield, and quality. Lower and high temperatures change plant function and productivity. Wheat breeding for yield selection uses canopy temperature (CT), which exhibits a strong and dependable correlation with heat-stressed yield, but little is known about its genetic control (Pierre *et al.*, 2010). CT is an indirect measurement of total chlorophyll content and instantaneous transpiration of plant water status (Araus, 2003; Reynolds *et al.*, 2001). Canopy temperature is recognized as a crucial screening criterion to identifying potential genotypes that can avoid the effect of heat stress by more efficiently obtaining water from soils with good root systems (Singh *et al*., 2022). The substantial correlation between grain yield and CT provided support for its usage as a selection criterion to increase heat tolerance. In late wheat, the low temperature during germination has a great effect on germination and seedling germination (Timmermans *et al.*, 2007). When sowing late, early germination and seedling growth are very important for a better wheat harvest. This may be due to its ability to withstand low temperatures during germination.

Conclusion

The overall finding suggested that timely seeded crops performed better in terms of wheat yield and growth. High temperature adversely reduced the development and growth of wheat by inhibiting physiological process and metabolic activities. CT suitability as a choice criterion for improving stress tolerance based on association of CT and grain yield. This study finds that different wheat genotypes respond and tolerate heat stress in different ways. This may serve as a genetic stock for developing wheat tolerant varieties in breeding programs.

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Conflict of interest

There is no conflict of interest

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