

Original Research Article

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Criterion and Performance of Elite Bread Wheat Genotypes Pertaining to Physiological Traits under Abiotic Conditions

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A B S T R A C T

Due to increasing temperature drastic reduction in wheat yield was observed. In late sown condition plants face high temperature stress. In the present study the effect of late sown/stressed condition on yield and yield related attributes was investigated in comparison to timely sown/non-stressed condition at Punjab Agricultural University, Ludhiana. The experiment comprised of two sowing dates non-stressed/timely sown and stressed/late sown. Performance of twenty-five genotypes was evaluated under both sowing conditions. Results revealed that significant variation for number of productive tillers, Biomass/net plot, grain weight/net plot, thousand grain weight, grain weight and grain number per spike and yield was observed between non-stressed and stressed condition. The contents were higher in case of non-stressed condition. There was no influence of stressed condition on crop emergence. Genotypes DBW 14, PBW 820 and WH 1239 perform better under timely sown conditions. In late sown condition high temperature at reproductive stage is one of the major factor for yield loss. In stressed condition number of productive tillers decrease by 12.97%, grain weight by 22.32% and yield by 22.46%. Whereas, genotypes PBW 796 and PBW 821 perform better in stressed condition. Among all the genotypes PBW 821 gives superior results for yield and yield related parameters in stress condition.

Keywords

Heat stress, grain yield, NDVI, chlorophyll, canopy temperature

Article Info

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Introduction

Wheat (*Triticum aestivum* L.) is one of the most significant food crop for burgeoning population of the world. It is staple food in India and grown on an area of 31.19Mha with production of 95.91Mt and productivity of 2.4t/ha which contributes around 12 percent of total food grain production (Paswan *et al.*, 2017). In Punjab, it was grown on an area of

34.95 lakh hectares during 2016-17 with production of 176.36 lakh tonnes and average yield of 50.46 quintals per hectare (Anonymous 2019).

In India it is grown in winters as a rabi crop (November to March). It requires cool and moist weather at vegetative stage, and warm and dry weather during reproductive phase. Being a sensitive crop, moisture and

temperature at sowing time, and temperature at grain filling time are the two most critical factors (Pandey *et al.*, 2015). The crop sown on different sowing dates is exposed to variable climatic conditions which has an impact on its growth and yield. Optimum temperature at anthesis and grain filling ranges between 12–22°C, whereas temperature >30°C at pre or post-anthesis stage reduces grain filling in wheat.

Rising of mean global temperature to 0.3% per decade may cause 50% decline in wheat yields in South Asia by 2050. This is due to the heat stress that causes physiological, biochemical and morphological changes in wheat (Wahid *et al.*, 2007). Sowing of wheat begins as fields get vacated by previous *kharif* crop. If the earlier crop is harvested late, the wheat sowing is delayed which has severe impact on the mature crop which is exposed to terminal heat stress resulting in drastic reduction of yield. One of the primary factors in timely sown wheat is lengthening of vegetative phase, which is helpful for increasing the plant height along with sugar reservoirs (Kumar and Kumawat 2014).

There is a very close relationship between temperature and plant development, which impacts various physiological changes like photosynthetic and transpiration rate, stomatal conductance, chlorophyll content, canopy temperature etc. Singh *et al.*, (2017) found that under late sown condition, photosynthesis and stomatal conductance was decreased drastically. However, heat tolerant genotypes maintain high photosynthetic rate and stomatal conductance after anthesis under late sown (stressed) conditions.

Decline in NDVI (normalized difference vegetation index) and chlorophyll content depicts the susceptible and tolerant nature of genotypes under timely and late sown condition. So, measurement of both NDVI

and chlorophyll will be advantageous in selection of genotypes (Sharma *et al.*, 2015). High value of chlorophyll and NDVI will lead to longer stay green trait during high temperature, that will contribute to longer grain filling period ultimately resulted in high grain yield (Ramya *et al.*, 2015).

Canopy temperature (CT) is affected by number of physiological parameters directly or indirectly and it indicates fitness of a genotype under adverse conditions. Keeping this in view, the study was conducted to evaluate different physiological parameters, chlorophyll content, NDVI and canopy temperature for identifying promising wheat genotypes under late sown condition which can mitigate the effects of temperature stress.

Materials and Methods

Experimental layout

Field experiment was conducted during the rabi season of 2018-19 under two environmental conditions at Punjab Agricultural University, Ludhiana, Punjab, INDIA. Which is situated between 30° 54' north latitude and 75° 48' east longitude. The experiment was conducted to assess the functioning of wheat varieties under non-stressed/timely sown (13-Nov-2018) and stressed/late sown (12-Dec-2018) conditions.

Timely sown crop was harvested on 30-April-2019 and late sown crop was harvested on 5-May-2019. Soil of the experimental field was sandy loam. During the season (Nov 2018–April 2019) average air temperature recorded was 17.6°C, relative humidity was 65.9% and rainfall was 28.8mm.

Figure 1 depicted the weekly average temperature, humidity and rainfall data. Recommended package of practices were followed for raising of crop.

Plant material

The study material consists of 25 genotypes of *Triticum aestivum* under timely sown (Non-stressed) and late sown (stressed) conditions. Field trial was put in lattice design (5X5), with row length of 3.0 m and row spacing of 0.23 m.

Growth characteristics

Different parameters of growth were recorded from germination to end of the vegetative phase for both sowing conditions. Germination percentage was recorded after 12 days of sowing. Days to heading observations were recorded after two months of sowing. Data for days to anthesis was recorded separately from days to heading in both timely sown and late sown conditions. Number of productive tillers were recorded from 3m length of each row for all the genotypes. Biomass per net plot was taken as weight of whole plants with spikes and foliage/net plot. At harvest, plants were threshed and grains obtained per plot were weighed to determine grain weight per plot. Thousand grains were weighed separately to find thousand grain weight of each genotype under non-stressed and stressed conditions. To find grain number per spike and grain weight per spike eight to ten mature spikes from each genotype were selected and hand threshed. Grains obtained from these spikes were counted and weighed. Yield (q/ha) was calculated from grain yield per net plot.

Chlorophyll and NDVI

Chlorophyll and NDVI content was measured at two stages, stage-I (at anthesis) and stage-II (15 DAA; Day after anthesis) under non-stressed and stressed conditions. Chlorophyll content was measured using hand held chlorophyll meter (SPAD-502 Konica Minolta Sensing, INC, Japan).

It measures chlorophyll content by light transmittance (absorption of red light at 650 nm and infrared light at 940nm).NDVI data was recorded by using handheld Green Seeker (The Trimble Navigation Limited, US) crop sensing system. NDVI measures vegetation by calculating the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs), its value vary from -1 to +1.

$$\text{NDVI} = \frac{\text{NIR}-\text{Red}}{\text{NIR}+\text{Red}}$$

NIR= Near infrared reflected, Red: Absorbed red light

Canopy temperature (CT)

Canopy temperature ($^{\circ}\text{C}$) was determined using infrared thermometer (LT 300 Sixth sense) for both sowing conditions at anthesis and 15 DAA.

Results and Discussion

The experiment was conducted to screen the genotypes having good physiological characters, yield and yield attributes under non-stressed and stressed conditions. Phenology data like days to heading, days to anthesis and days to maturity was taken during growth of the crop. Wheat genotypes under study did not show any significant difference for average percent germination 89% under non-stressed and stressed conditions (Fig 2, 4a), whereas difference was recorded in days to heading and anthesis under both sowing conditions (Fig 3). In non-stressed condition average number of days to heading and anthesis were 101 and 107 whereas in stressed condition it was 89 and 95 respectively (Fig 4b and 4c).Under stressed condition on an average genotypes take 132 days to mature as compare to non-stressed

condition, which takes 154 days to mature (Fig 4d). In non-stress condition genotype HD 3293 (132days) and in stress condition genotype RAJ 4529 (125days) takes least number of days to mature (Fig 3). Data presented in Fig 3 and Fig 4e shows that average number of productive tillers/m³ in non-stressed condition were higher (239 tillers) than stressed condition (208 tillers).

It was found that non-stressed condition brought about 14.7 percent higher number of tillers/m³ as compare to stressed condition. This might be due to favorable temperature for wheat growth and accumulation of photosynthetic metabolites under timely sown conditions that results in higher yield. Maximum number of productive tillers/m³ were found in HD-2932, PBW 796 and PBW 821 genotypes under non-stressed conditions (Fig 3).

Stress conditions decreased grain weight per net plot, biomass per net plot, 1000 grain weight, grain number and weight/spike, and yield. Sowing at time significantly influence entire attributes of yield and significantly superior than late sowing conditions.

Grain weight/net plot

Grain weight (g) per net plot for non-stressed and stressed conditions is shown in Fig 5. Average grain weight taken under non-stressed condition (1707g) was 22.3% higher than the stressed condition (1326g) (Fig 8b).

Maximum grain weight per net plot under non-stressed condition is shown by genotypes HD 2932 (2265g), PBW 820 (2164g) and WH 1239 (2176g), whereas under stressed condition it was found in PBW 796 (1626g) (Fig 5). Genotypes NW 7049, RWP-2018-31 and WH 730 give better grain weight/net plot in stressed condition than under non-stressed condition.

Biomass/plot

Biomass was ranged from 2873g to 5050g in non-stressed and 2377g to 4212g in stressed condition. Average biomass/ plot decrease by 16.9% under stressed condition as compare to non-stressed condition, and the content was 4033g in non-stressed and 3349g in stressed condition (Fig 8a). Under non-stressed condition genotypes PBW 820 and WH 1239 recorded the highest biomass (5055g/plot). Whereas genotype PBW 821 accumulate higher biomass under stressed condition.

Grain number and grain weight/spike

Grain number and grain weight/spike presented in (Fig 6). It revealed that in non-stressed condition the average number of grains/spike is higher than stressed condition (Fig 8d). Under non-stressed condition there were 6.1% more number of grains per spike as compare to stressed condition. Genotypes DBW 14, DBW 257 and PBW 781 shows maximum number of grains/spike under non-stressed condition. Under stress condition genotypes like PBW 821, RWP-2018-26, RWP-2018-28 and SBP-MABB2 shows increase in number of grains per spike from that under non-stressed condition (Fig 6). Regarding the average grain weight/spike it was higher in non-stressed condition as compare to stressed condition (Fig 8e). Genotypes DBW 14, DBW 257, DBW 71 and PBW 781 shows highest grain weight per spike under non-stressed condition. Whereas, genotypes HD 3293, PBW 821, RWP-2018-26 and RWP-2018-28 showed small increase in grain weight per spike under stressed condition (Fig 6).

Thousand grain weight

Under non-stressed condition highest thousand grain weight of 43g and 42.5g was found in NW 7049 and DBW 71 genotype

(Fig 7). Average thousand grain was higher in non-stressed conditions as compare to stressed condition (Fig 8c). Thousand grain weight in genotypes DBW 273, PBW 821, RWP-2018-30 and RWP-2018-31 was at par under both sowing conditions whereas, under stressed condition three genotypes HD 3293, PBW 820 and RAJ-3765 shows increase in thousand grain weight as compare to wheat genotypes under non-stressed condition (Fig 7).

Grain yield

Wheat under non-stressed condition had significantly higher yield as compare to stressed condition (Fig 7). Under non-stressed condition average yield was 61.9 q/ha whereas, under stress condition it was 48.0 q/ha (Fig. 8f). There is 22.4% decrease in yield (q/ha) under stress condition from non-stress condition, this decrease was mainly due to elevated temperature during milking and grain filling stage. Highest yield was recorded in HD 2932 (82.1 q/ha) followed by WH 1239 (78.9 q/ha) and PBW 820 (78.4 q/ha) under non-stressed condition (Fig 7). Under stressed condition highest percent decrease in yield of 41.2% was found in genotype DBW 14 followed by 37% in RWP-2018-27 and 35.6% in HD 2932 whereas genotype WH 730 under similar condition reported 16.4% increase in yield(q/ha).

Chlorophyll content

Observation of average chlorophyll content at anthesis and 15DAA were at par in non-stressed condition. Whereas, under stress condition decrease of 9.4% was observed (Fig 12a, b). This decrease may be due to high temperature in stressed condition at anthesis and 15DAA. At anthesis stage highest chlorophyll content was recorded under stressed condition in genotypes PBW 796(44.1), PBW 821(44.4) and RWP-2018-

31(44.3). Whereas in 15DAA highest chlorophyll content was found under non-stressed condition in genotypes RWP-2018-27(44.2), RWP-2018-28 (43.9), NW 7049(43.4), PBW 781(43.4), and WH 1239 (43.4).

Normalized difference vegetation index (NDVI)

NDVI values at anthesis and 15DAA under both sowing conditions presented in Fig 10. NDVI value was higher in stressed condition at both the stages (Fig 12c, d). Average value of NDVI was same at anthesis and 15DAA in non-stressed condition. Whereas, in stressed condition 17.0% decrease in average value of NDVI was observed. At anthesis maximum NDVI value of 0.62 was found in stressed condition in genotypes DBW 14 and WH 730 (Fig 10).

Canopy temperature (CT)

Canopy temperature under non-stressed and non-stressed condition at anthesis and 15DAA was depicted in Fig (12e, f) the. Average canopy temperature was lower under non-stressed condition than stressed condition at anthesis and 15DAA(12e, f). Under non-stressed condition genotype DBW 257 and RWP-2018-27 shows minimum canopy temperature at both the stages.

Temperature affect almost all the stages of wheat involving germination, tillering, booting, anthesis, grain filling and ripening. It influences water and nutrient supply necessary for the growth. Various authors studied the high temperature effect in timely sown and late sown conditions in wheat cultivars (Mahajan *et al.*, 2018, Kumar *et al.*, 2018, Pandey and Tiwari 2019). Different approaches have been used by various researchers to study the effect of elevated temperature on yield in wheat varieties, out of

which one of the approach is the late sown (stressed) condition. Late sown condition exposes the plants to low temperature stress at germination and high temperature stress at post anthesis stage which decrease the grain filling period that will consequently reduce yield (Pandey *et al.*, 2014). Temperature below or above the normal level leads to decrease in plant function and productivity (Hossain *et al.*, 2012). Temperature below 10-12°C results in poor or uneven germination (Timmermans *et al.*, 2007, Farooq *et al.*, 2008). In our study no significant difference was observed for percent germination between timely sown and late sown condition. This may be due to the average temperature of >19°C in timely sown and >13°C in late sown condition, which is favorable at time of germination. Average germination percentage was 89% in both sowing conditions (Fig 2, Fig 4a). Kumari *et al.*, (2018) reported almost equal germination percentage of 80-85% in both timely sown and late sown conditions.

Number of days to heading or ear emergence from its surrounding leaves is exclusively dependent on the environmental conditions and genetic makeup of the plant. Alteration in temperature will lead to change in number of days to ear emergence. In non-stressed and stressed condition significant difference in number of days to heading was observed i.e. 101 days in non-stressed and 89 days in stressed condition. Under stressed condition genotype DBW 14 takes minimum i.e. 81 days to heading followed by Raj 4529 and SBP-MABB1 which takes 84 days to heading (Fig2). In late sown condition heading was faster than timely sown condition, due to elevated temperature crop completes its life cycle faster than sown under non-stressed conditions. It is also confirmed by earlier studies (Nahar *et al.*, 2010, Hakim *et al.*, 2012). Early heading is more advantageous because more green leaves will be there at the time of anthesis (Hossain *et al.*, 2015).

Average number of days to anthesis was found to be less in stressed condition as compared to non-stressed condition that results in 22.4% reduction in yield. Ferrie *et al.*, 1998 reported 31°C temperature over 8 days at the time of anthesis will lead to 50% reduction in yield. Under late sown condition crop takes lesser number of days to mature due to high temperature at time of maturity. Under stressed condition on an average plants take 132 days to attain maturity and in non-stressed plants it takes 154 days to mature (Fig3). Many authors observed reduction in number of days to maturity under late sown conditions (Araus *et al.*, 2007, Shahzad *et al.*, 2007, Rahman *et al.*, 2009, Nahar *et al.*, 2010). Ubaidullah *et al.*, (2007) and Al-Karaki *et al.*, (2012) reported that under late sown condition plant will suffer high temperature stress that will lead to early heading and forced maturity, shortening of life cycle by plant will take place to overcome high temperature stress. Whereas lengthening of vegetative phase has been found in timely sown condition, which utilize enough time for enhancing their sugar reserve (Kumar and Kumawat 2014).

Number of productive tillers and grain weight per plant are the parameters for selection criteria to improve the grain yield. In late sown condition on an average 208 productive tillers were observed, whereas in non-stressed condition number of productive tillers was 239 in our study (Fig 4e). In timely sown condition number of productive tillers are more due to good germination conditions, extended vegetative phase and good stand establishment (Patil *et al.*, 2001, Singh and Pal 2003). Whereas in case of late sown condition factors responsible for reduction in number of productive tillers are high air and soil temperature, low humidity and soil moisture, (Tahir *et al.*, 2009, Alam *et al.*, 2013). Farooq *et al.*, (2008) observed that low temperature at time of germination in late

sown condition will lead to poor emergence that will result in fewer number of productive tillers. Biomass per net plot was observed to decrease by 16.7% in late sown condition as compare to non-stressed condition due to high temperature stress. Pandey and Tiwari (2019) reported 19.12% reduction in biomass in late sown condition. Analogous results were reported by Tahir and Nakata (2005) they found 20 to 44% reduction in biomass under late sown condition. High temperature at anthesis and later stages leads to reduction in biomass, grain yield, number of grains per spike, thousand grain weight etc. (Kumari *et al.*, 2013). Grain yield of wheat was influenced significantly due to extended sowing time (Shirpurkar *et al.*, 2008, Mukherjee 2012).

Timely sown condition is superior in grain weight per net plot, grain number and weight per spike, thousand grain weight, biomass production and yield. This may be attributed to better partitioning of photosynthetic metabolites and more time (due to long vegetative phase) for accumulation of more dry matter for high grain yield (Guilioni *et al.*, 2003, Shahzad *et al.*, 2002). Whereas in late sown condition high temperature stress followed by drought at reproductive phase have detrimental effects on anthesis, milking and dough stages. It will lead to decline in number of grains/spike, thousand grain weight and ultimately yield(Pardeshi *et al.*, 2009, Muduli *et al.*, 2010, Jat *et al.*, 2013, Bannayan *et al.*, 2013). Hays *et al.*, (2007) studied that ovule abortion linked to ethylene levels induce programmed cell death and pollen sterility due to high temperature stress at anthesis stage in late sown condition are the reasons for reduction in grain yield, grain number per spike and total yield. Al- Karaki *et al.*, 2007, Prasad *et al.*, 2008 also reported that reproductive phase is the most sensitive period during heat stress, heat stress will lead to ovule abortion, pollen sterility and grain

set. Due to high temperature at milking and grain filling stage there will be shrivelling of grain that will lead to reduction in grain weight per plot, number of grains per spike, 1000 grain weight (Kabir *et al.*, 2009, Kumar *et al.*, 2013).

In timely sown condition chlorophyll content at anthesis was at par with chlorophyll content 15DAA. Whereas in late sown condition chlorophyll content decrease from 39.9 to 36.8 from anthesis to 15DAA stage. This may be due to elevated temperature in late sown condition at time of anthesis that will lead to disruption of chloroplast and reduction of chlorophyll will takes place (Brestic *et al.*, 2016, Sunita *et al.*, 2018). Reduction in chlorophyll is associated with reduction in accumulation of photosynthetic metabolites that results in poor grain filling and yield loss (Shanmugam *et al.*, 2013, Ram *et al.*, 2017). Loss of chlorophyll is also associated with membrane damage and leaf senescence (Ristic *et al.*, 2007). In wheat stay green character is associated with ability of a plant to retain chlorophyll even at stressful conditions like heat stress. It will contribute longer grain filling period that will ultimately enhance yield even under high temperature stress (Sangwan *et al.*, 2018). NDVI is a measure of crop biomass production, senescence rate and yield performane. NDVI is associated with chlorophyll content, leaf nitrogen content and photosynthetic efficiency of plant (Tattaris *et al.*, 2016). No difference was observed in NDVI value at anthesis and 15DAA in timely sown condition, whereas reduction in NDVI value (0.53 to 0.44) was observed from anthesis to 15DAA in late sown condition. This may be due to high temperature stress at anthesis and 15DAA stage in late sown condition.

High temperature lead to chlorophyll damage and reduction of NDVI takes place because there is a positive correlation between

chlorophyll content and NDVI (Sangwan *et al.*, 2018).

High value of chlorophyll content and its association with NDVI resulted in cooler canopies that induces heat tolerance in plants (Ramya *et al.*, 2015, Munjal and Dhanda 2016). Average canopy temperature was lower at both stages (anthesis and 15DAA) in

non-stressed condition as compare to stressed condition. Which depicts healthiness of plants to undergo transpiration and to reduce canopy temperature to mitigate heat stress in non-stressed condition. Results are in accordance with Basu *et al.*, (2014) and Kumari *et al.*, (2018), which showed that canopy temperature of late sown crop was higher than timely sown crop.

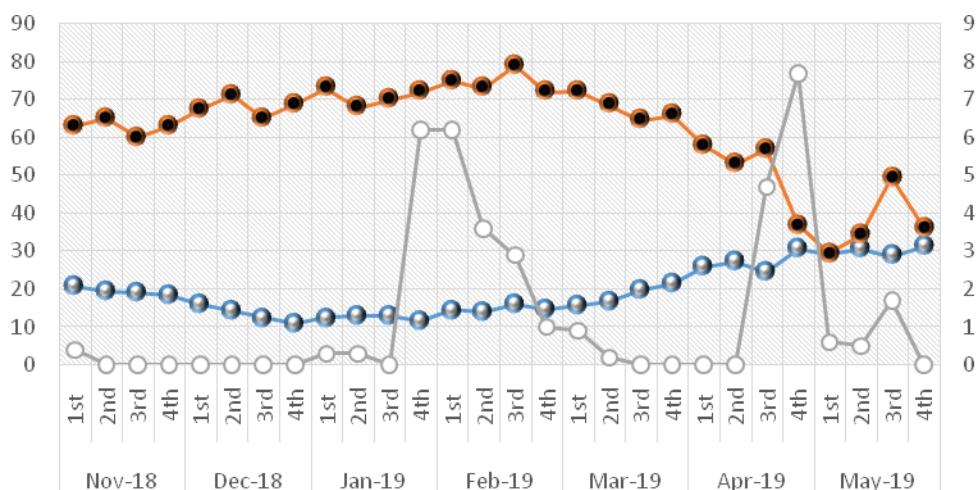


Fig.1 Weekly average temperature, humidity and rainfall during the crop season

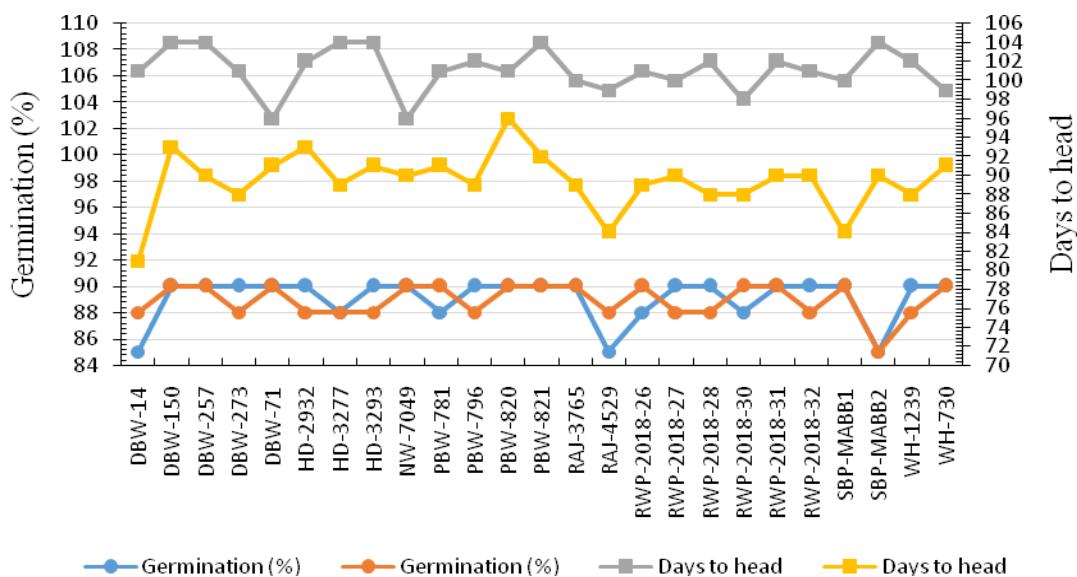


Fig.2 Observations of germination percentage and days to head under non-stress and stress conditions

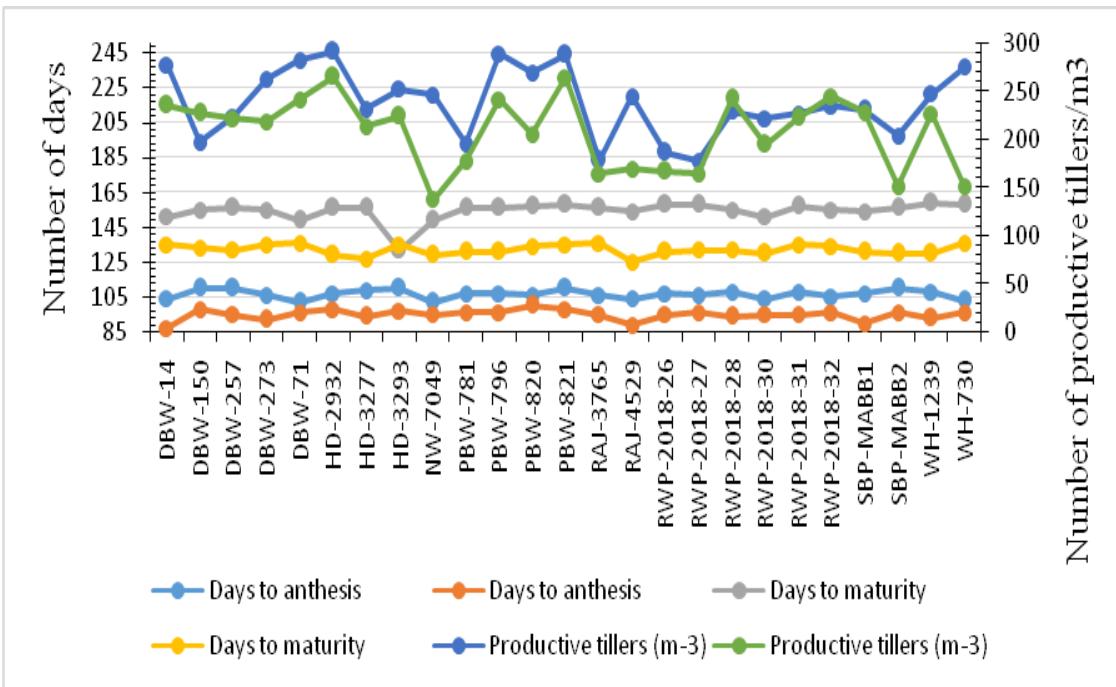


Fig.3 Observations of days to anthesis, days to maturity and number of productive tillers under non-stress and stress conditions

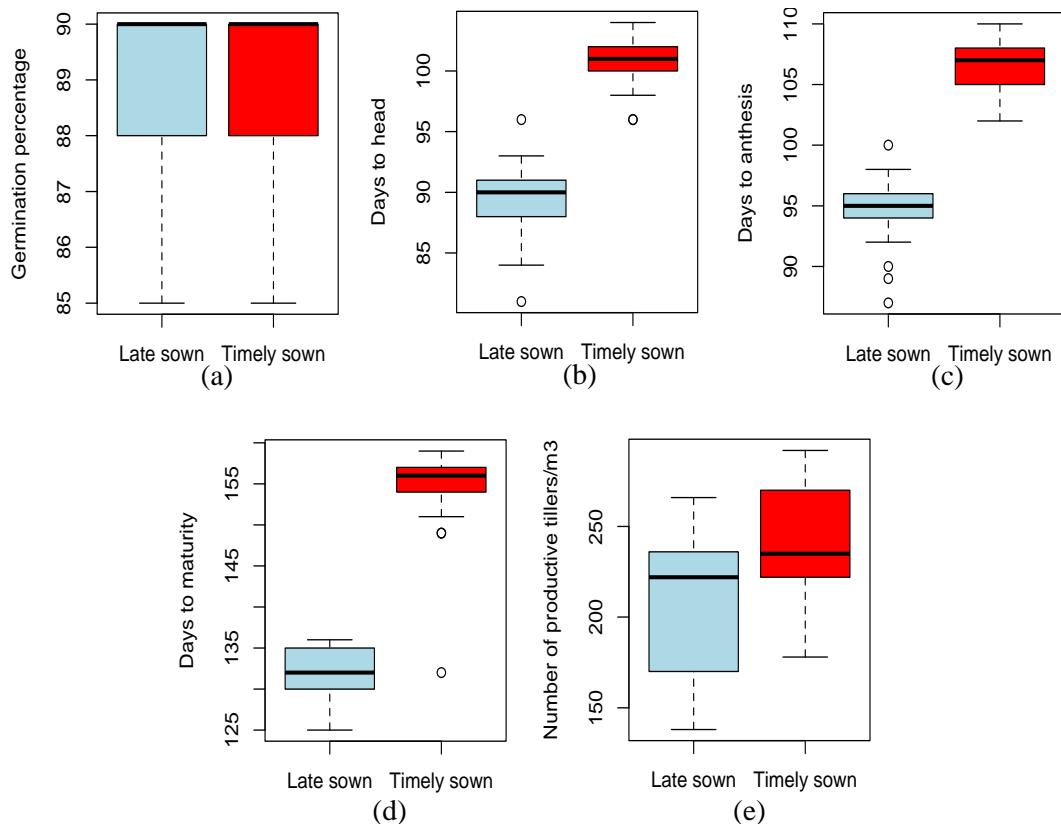


Fig.4 Box plot showing average germination percentage, days to head, days to maturity and number of productive tillers under non-stress and stress conditions

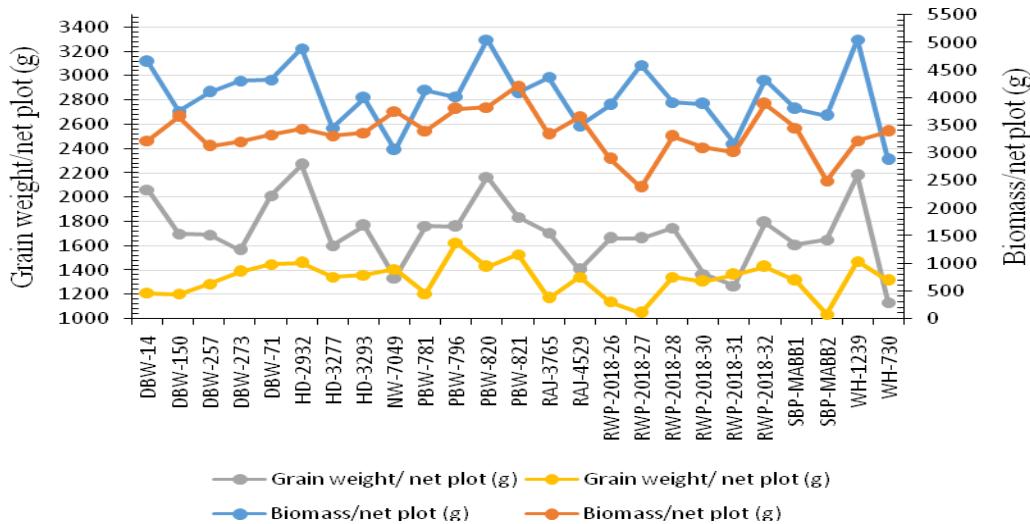


Fig.5 Observations of biomass/net plot and grain weight/net plot non-stress and stress conditions

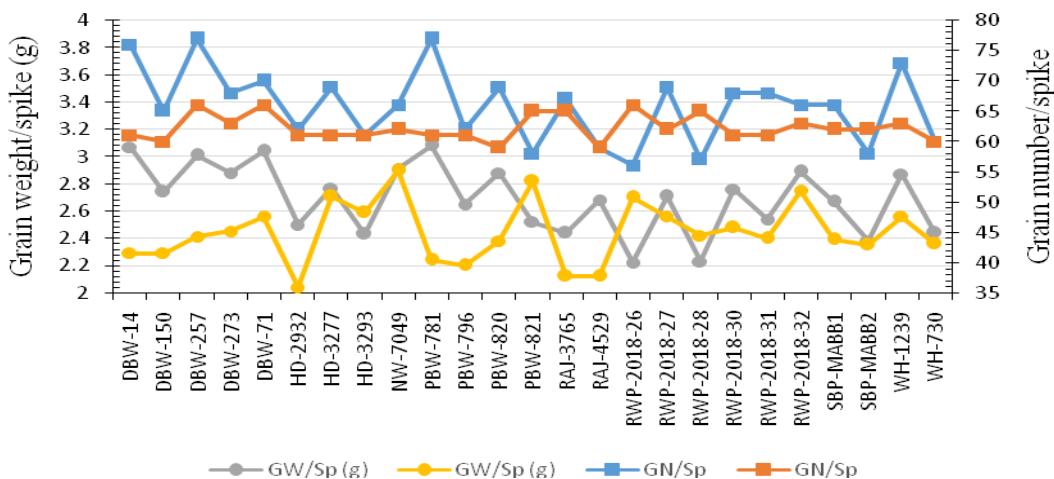


Fig.6 Observations of grain weight/spike and grain number/spike under non-stress and stress conditions

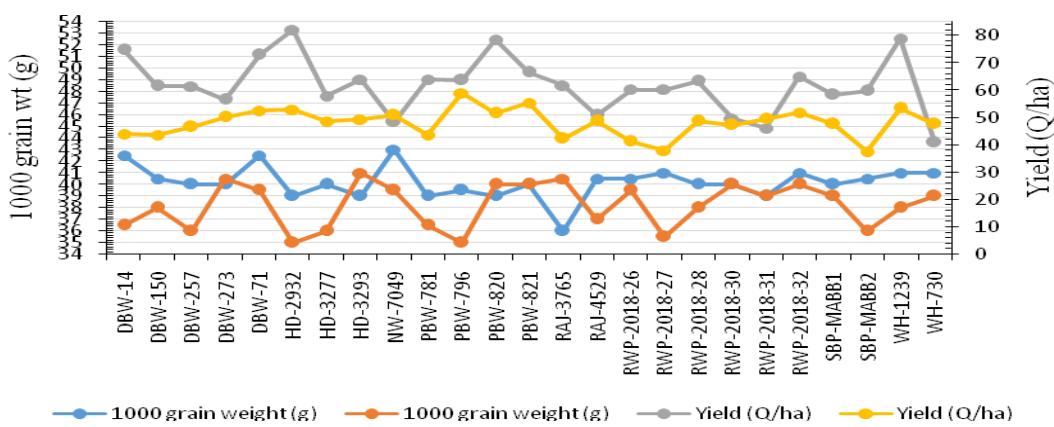


Fig.7 Observations of thousand grain weight and yield (Q/ha) non stress and stress conditions

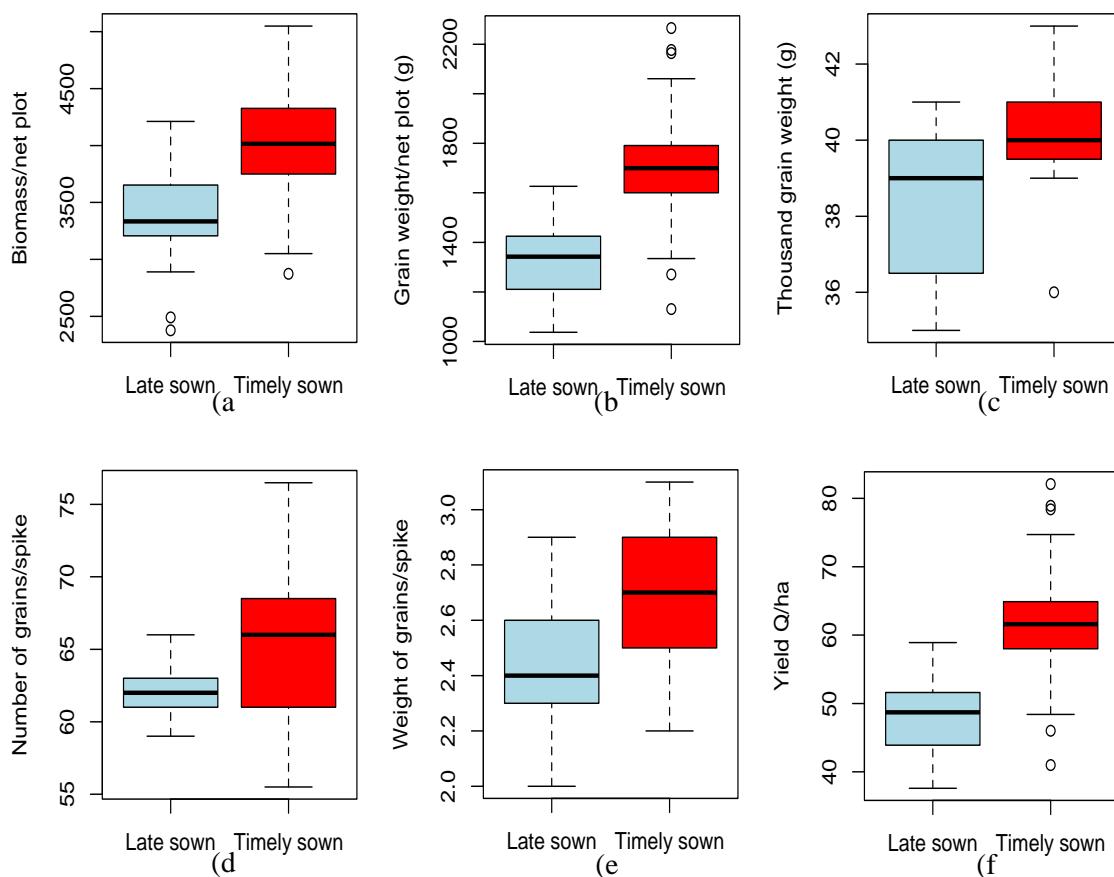


Fig.8 Box plot showing average biomass/net plot, grain weight/net plot, thousand grain weight, grain number/spike, grain weight/spike and yield non-stress and stress conditions

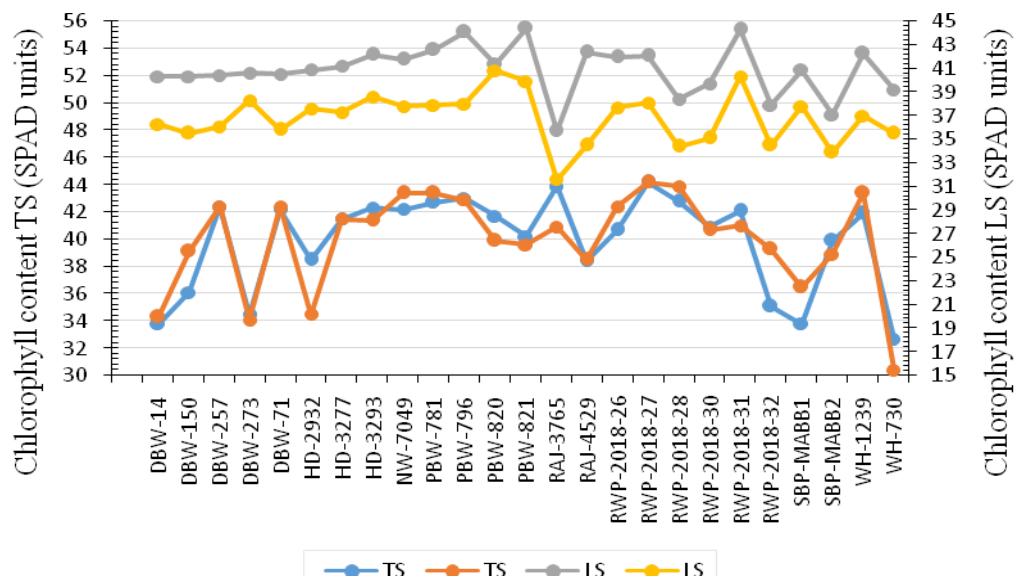


Fig.9 Observations of chlorophyll content at anthesis and 15 DAA non-stress and stress conditions

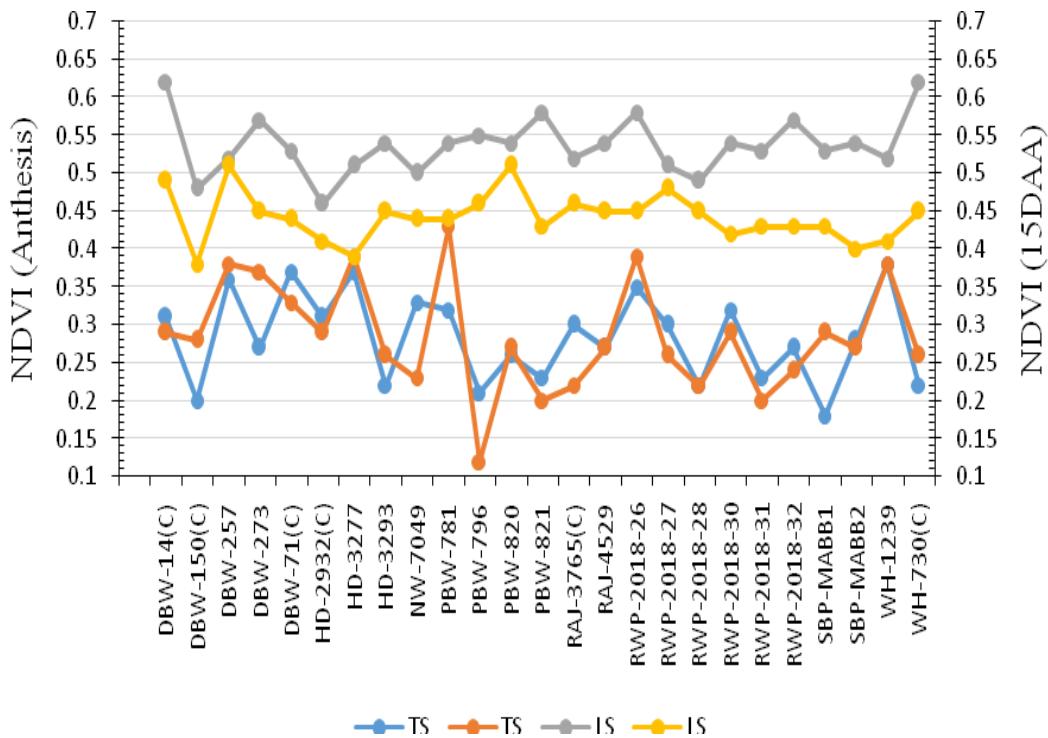


Fig.10 Observations of NDVI at anthesis and 15 DAA under non-stress and stress conditions

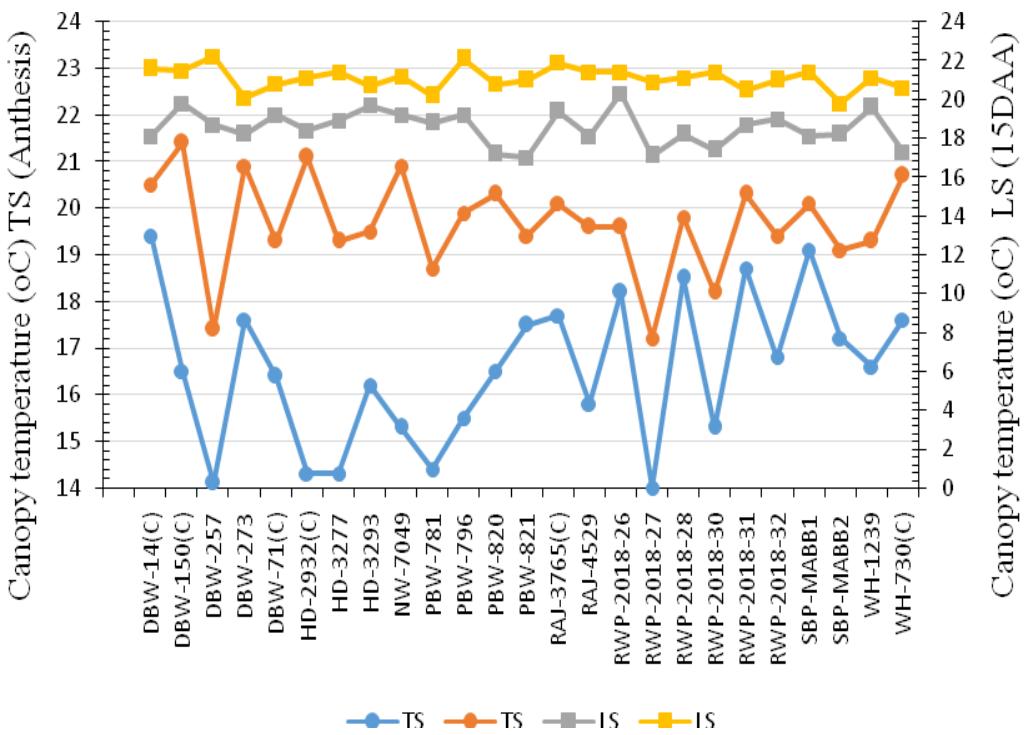


Fig.11 Observations of canopy temperature (CT) at anthesis and 15 DAA under non-stress and stress conditions

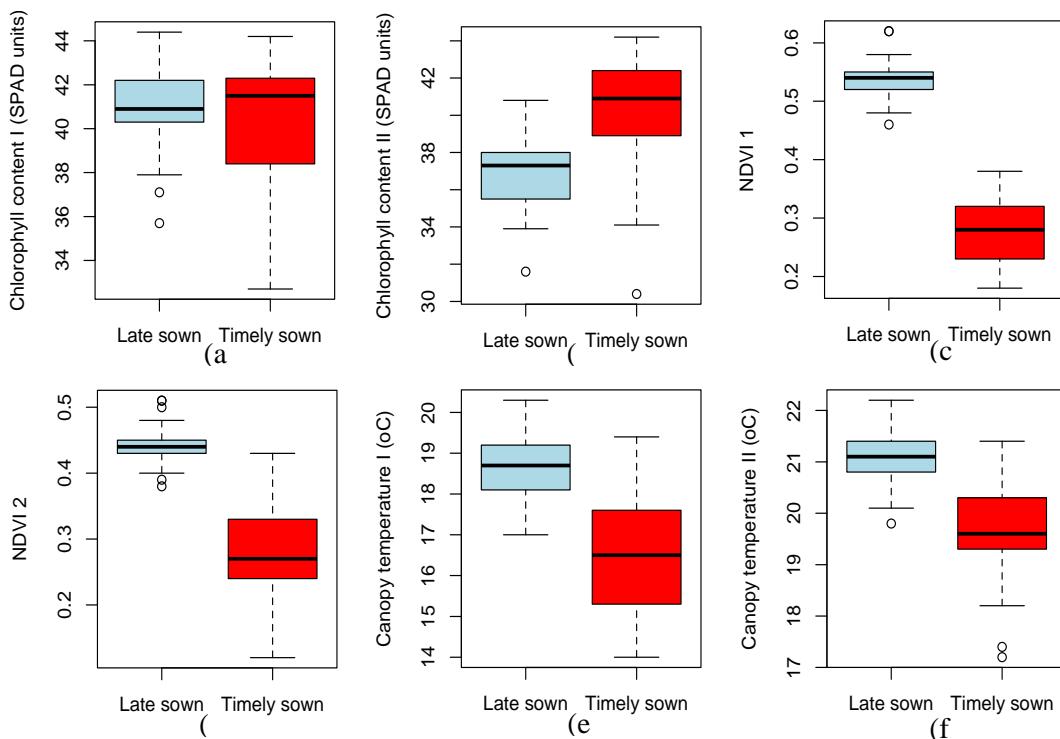


Fig.12 Box plot showing average chlorophyll content, canopy temperature and NDVI value under non-stress and stress conditions at anthesis (I) and 15DAA (II)

From the present study, it can be concluded that genotypes DBW 14, PBW 820 and WH 1239 have high number of productive tillers, Biomass/net plot, grain weight/net plot, thousand grain weight, grain number and weight/spike and yield under timely sown condition. Two genotypes DBW 71 and HD 2932 perform better under both conditions but the content of various yield and yield related parameters was lower under stress condition as compared to non-stressed condition, but these genotypes perform better than other genotypes under study in stress condition. Two genotypes PBW 796 and PBW 821 were found to perform better in stress condition. From these, PBW 821 perform better at developmental stages (germination percentage, days to heading, days to anthesis, days to maturity) under stressed and non-stressed conditions. Whereas, under late sown condition when temperature is high at reproductive stage, PBW 821 shows higher biomass production, grain weight/net plot,

grain number/weight per spike, 1000 grain weight, yield (q/ha), chlorophyll and NDVI at anthesis and 15 DAA, and lower canopy temperature at anthesis. Hence, this genotype may be used in wheat breeding programme for development of heat tolerant varieties.

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