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Canopy Temperature Effects on Yield and Grain growth of Different Wheat Genotypes

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Abstract: *This study was conducted to compare adaptation of wheat genotypes in warmer environment by means of canopy temperature depression (CTD). CTD of four wheat genotypes (BARI gom 25, BARI gom 26, BAW 1135 and Pavon 76) was determined at different sowing dates (29 November, 5 December, 16 December, 23 December and 30 December) along with corresponding changes of yield components and yield. CTD on 29 November sowing was almost similar in all genotypes (mean CTD at different stages was 5.9°C for BARI gom 26 and 5.5°C for Pavon 76). In 30 December sowing BARI gom 26 showed higher mean value of CTD (2.32°C) whereas Pavon 76 showed lower value (0.88°C) at different stages indicating that BARI gom 26 maintained cooler canopies even at post anthesis heat stress condition compared to Pavon 76. On 30 December sowing BARI gom 25 and BARI gom 26 continued to increase grain dry matter upto 32 DAA which stopped 8 days earlier in Pavon 76, reflecting higher relative 1000-grain weight (96%) and grain yield (89%) in BARI gom 26 compared to Pavon 76. BARI gom 26 that maintained higher CTD was found to be better in grain growth and yield under warmer environment.*

Keywords- *Canopy Temperature Depression (CTD), Grain growth, Heat stress, Wheat, Yield.*

I. Introduction

Canopy temperature depression (CTD) is usually expressed as air temperature minus canopy temperature and this value is higher and positive in well irrigated wheat [1]. When wheat genotypes are exposed to different growing temperature they differed widely in canopy temperature. As a consequence of diverging canopy temperature the heat sensitive activities of the genotypes beginning from germination to end of heterotrophic seedling phase may vary widely among the genotypes. CTD effected by biological and environmental factors like water status of soil, wind, evapotranspiration, cloudiness, conduction systems, plant metabolism, air temperature, relative humidity and continuous radiation [2], has preferably been measured as high air temperature and low relative humidity because of high vapor pressure deficit conditions [3]. CTD has been used as a selection criterion for tolerance to drought and high temperature stress in wheat breeding and the used breeding method is generally mass selection in early generations like F_3 [2]. CTD plays an important role to sustain physiological basis of grain yield of wheat when exposed to heat stress. Cool canopy during grain filling period in wheat is an important physiological principle for heat stress tolerance [4]. CTD is positively correlated with grain yield, spike yield and grain numbers per spike in varieties which has relatively cooler canopy [5].

Limited reports are available on genotypic differences regarding pattern of CTD changes from anthesis to maturity period. Also genotypic differences have not been clearly elucidated to understand whether CTD of the genotypes exerts any influence on yield components and grain yield of wheat. In the present study, influence of high temperature on seed reserve utilization and seedling development of the genotypes differing in CTD was also investigated in order to further validate the heat tolerance of the genotypes with variable CTD. Considering above circumstances the present study was carried out –

1. To find out the genotypic differences in canopy temperature depression, grain growth and yield of some wheat genotypes due to exposure to late planting elevated temperature.

II. Materials and Methods

The experiment was conducted at the research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur during November, 2010 to April, 2011. It is located at the center of Madhupur Tract (24°05' N latitude and 90°25' E longitude) at an elevation of 8.4 m above the sea level.

The experiment was conducted in a split plot design with three replications. The unit plot size was 3m x 2.5m having a plot to plot and block to block distance of 0.5 m. The distance between the main plots was 1.0 m. Five sowing dates were placed in the main plots as main plot treatments (Factor A) whereas four wheat genotypes were placed randomly in the sub-plots as sub-plot treatments (Factor B).

Seeds of four wheat genotypes (BARI gom 25, BARI gom 26, BAW 1135 and Pavon 76) were sown on five different sowing dates in rows of 20 cm apart, at the rate of 120 kg/ha seeds. Sowing dates were selected on weekly basis. After sowing slight irrigation with overhead sprinkler was given for uniform germination.

2.1 Measurement of canopy temperature depression

A hand held infra-red thermometer (Model: Crop TRAK, Item No. 2955L - Spectrum Techno-logies, Inc.) was used to measure canopy temperature. The canopy temperature was recorded at 8 days after anthesis during noon period (12 pm-2 pm) and continues upto maturity. The viewing angle was around 45° to the horizontal line above the canopy so as to avoid the confounding effect of soil temperature (Amani *et al*., 1996). Then canopy temperature depression (CTD) was calculated as- CTD (^{o}C) = Ambient temperature (^{o}C) – Canopy temperature (^{o}C)

2.2 Grain growth rate

At anthesis 40 main shoots were tagged at each plot sowing on 29 November and 30 December only. Sowing at 29 November is considered as normal growing condition and sowing at 30 December is considered as post-anthesis heat stress growing condition. Spike from three tagged main shoots were harvested at every 4th day beginning from anthesis to quantify grain growth in all genotypes. The harvesting of spike from tagged main shoot in all genotypes was continued up to maturity in case of two selected sowing dates. The harvested spike was then kept in oven at 70^{0}C for 72 hours. After oven drying 17 grains were separated from the middle two spikelets of each three spike in all genotypes. Then weight of 17 grains of each spike was taken with analytical balance (AND Electronic Balance Model ER 180A A & D Company Limited, Tokyo, Japan).

2.3 Thousand grain weight

From each plot thousand grains were taken randomly from dried sample and weighed. **G**rain yield were expressed in t/ha, grain yield also adjusted to 12% moisture.

2.4 Relative performance

The relative performance was calculated by the following formula [6]-

$$\text{Relative performance} = \frac{\text{Variable measured under stress condition}}{\text{Variable measured under normal condition}}$$

2.5 Statistical analysis

The findings were analyzed by partitioning the total variance with the help of computer by using MSTAT-C program. The treatment means were compared using Duncun's Multiple Range Test (DMRT) at 5% level of significance. Simple correlation was estimated using Microsoft Excel 2003.

III. Results and Discussions

3.1 Canopy temperature depression (CTD)

Canopy temperature depression (CTD) is an important parameter to assess avoidance of heat stress in a genotype. Increasing CTD was recorded from 8 DAA until 24 DAA in all wheat genotypes whether sown on 29 November (Fig. 1) or on 5 December (Fig. 2). As early as 8 DAA, the CTD varied between 5.6^{o}C (BAW 1135) to 5.9^{o}C in BARI gom 26 as well as Pavon 76 when planted on 29 November (Fig. 1). Crops planted on 5 December experienced range of CTD between 4.9^{o}C (Pavon 76) and 5.7^{o}C (BARI gom 26) at 8 DAA (Fig. 2).

The CTD was lowered in all genotypes particularly during the period after 24 DAA in case of 29 November and 5 December planting. At 32 DAA, higher CTD was observed in BARI gom 26 (4.5) followed by BARI gom 25 (4.3) and BAW 1135 (3.8) and the lowest CTD was in Pavon 76 (3.1) when sown on 29 November (Fig. 1). Difference of CTD among the genotypes was rather closer until 24 DAA. Under 5 December sowing, higher value was observed in BARI gom 25 (4.6) followed by BAW 1135 (4.4), BARI gom 26 (4.3) and Pavon 76 (3.2) at 32 DAA (Fig. 2).

So from Fig. 1 and Fig. 2, it was clear that tendency of increasing CTD from 8 DAA to 24 DAA and then decreased significantly after 24 DAA in all of the genotypes.

Under 16 December sowing, higher value in CTD was observed in BARI gom 26 (6.2) followed by BAW 1135 (5.7), BARI gom 25 (5.3) and Pavon 76 (5.3) at 8 DAA (Fig. 3). Delayed planting of genotypes after starting 16 December and on worth was found to lower their CTD as early as at 16 DAA in all genotypes (Fig. 3, Fig. 4 and Fig. 5). Decreasing of CTD values was recorded in all of the genotypes after 8 DAA and reached to the lowest value on 32 DAA. Higher value of CTD was observed in BARI gom 26 (3.9) followed by BARI gom 25 (3.8), BAW 1135 (3.3) and Pavon 76 (2.9) at 32 DAA when planted on 16 December.

Under 23 December sowing, higher value in CTD was observed in BARI gom 26 (6.5) and BARI gom 25 (6.5) followed by BAW 1135 (6.0), and Pavon 76 (6.0) at 8 DAA (Figure 1.5). At 32 DAA, higher value was observed in BARI gom 26 (3.9) followed by BARI gom 25 (3.2) and lower value was in Pavon 76 (2.1) followed by BAW 1135 (3.06).

Among the genotypes, BARI gom 26 was maintained the maximum CTD at 32 DAA irrespective of planting dates (3.9^{o}C in 16 December and 23 December planting). At 32 DAA, the lowest CTD was recorded in Pavon 76 (2.9^{o}C on 16 December sowing and 2.1^{o}C in 23 December sowing) (Fig. 3 and Fig. 4).

Fig. 3 and Fig. 4 showed that although CTD was started to decrease from 8 DAA, maximum CTD was at 8 DAA and lowest at 32 DAA.

Under 30 December sowing, higher value in CTD was observed in BARI gom 26 (5.1) followed by BARI gom 25 (4.6) and lower value in BAW 1135 (4.2) and Pavon 76 (4.2) at 8 DAA. The difference in CTD among genotypes was 0.9. At 16 DAA, higher value was observed in BARI gom 26 (2.0) followed by BARI gom 25 (1.9) and lower value in BAW 1135 (1.4) followed by Pavon 76 (0.85). The difference in CTD among genotypes was 1.5. At 24 DAA, higher value was observed in BARI gom 26 (1.5) followed by BARI gom 25 (1.2) and lower value in Pavon 76 (-0.21) followed by BAW 1135 (0.72). The difference in CTD among genotypes was 1.71. At 32 DAA, higher value was observed in BARI gom 26 (0.68) followed by BARI gom 25 (-0.31) and lower value was Pavon 76 (-1.31) followed by BAW 1135 (-0.74). The difference in CTD among genotypes was 1.99 (Fig. 5).

Heating of leaves above ambient temperature was recorded at 30 December seeding in all genotypes except BARI gom 26.

Under normal growing condition, differences in CTD among the genotypes were more or less similar but when the genotypes fall into post anthesis heat stressed condition, then these values were greatly differed from one another. And under 3rd, 4th and 5th sowing always BARI gom 26 gave better CTD value than other genotypes and Pavon 76 gave the lower value of CTD indicated that Pavon 76 failed to cool canopy under post anthesis heat stressed condition and BARI gom 26 maintained cooler canopy even under heat stress growing condition which proved tolerance potentiality of BARI gom 26 and susceptibility of Pavon 76. Higher CTD indicates better cooling capacity of canopy and heat tolerance of wheat genotypes. [5], [7] and [3] agreed with these results. Greater leaf conductance [8] and better photosynthetic enzyme activity [9]; [10]; [11] results cooler canopy of heat tolerant genotypes and greater CTD in compare with sensitive genotypes.

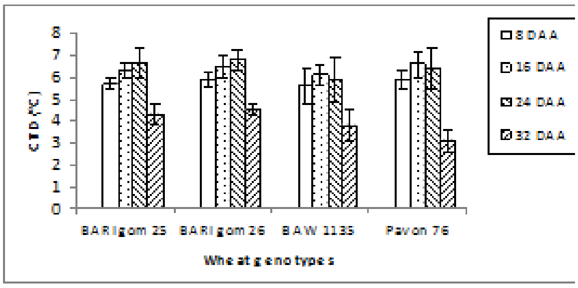


Fig. 1. Canopy temperature depression (CTD) at different stages during post anthesis period in four wheat genotypes sown on 29 November.

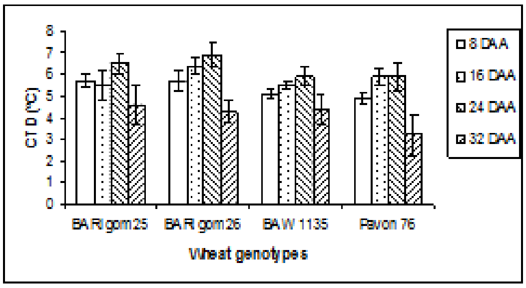


Fig. 2. Canopy temperature depression (CTD) at different stages during post anthesis period in four wheat genotypes sown on 5 December.

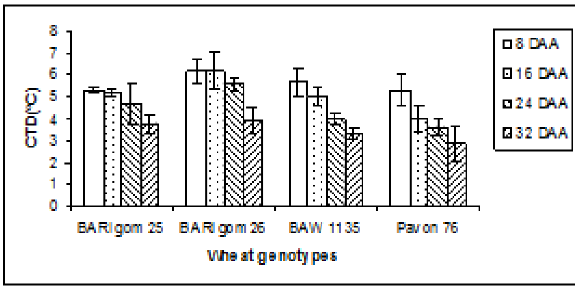


Fig. 3. Canopy temperature depression (CTD) at different stages during post anthesis period in four wheat genotypes sown on 16 December.

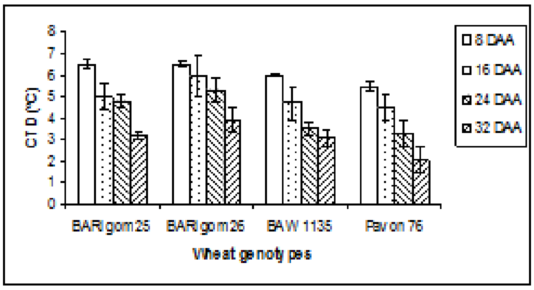


Fig. 4. Canopy temperature depression (CTD) at different stages during post anthesis period in four wheat genotypes sown on 23 December.

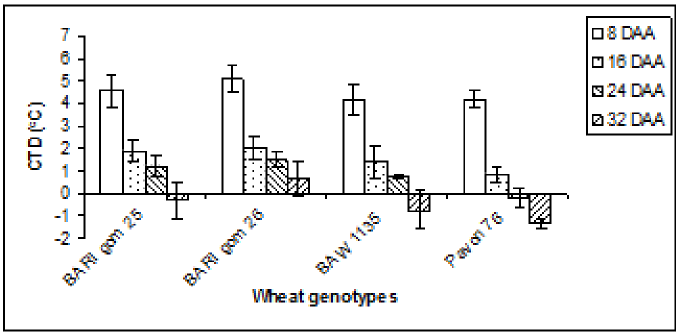


Fig. 5. Canopy temperature depression (CTD) at different stages during post anthesis period in four wheat genotypes sown on 30 December.

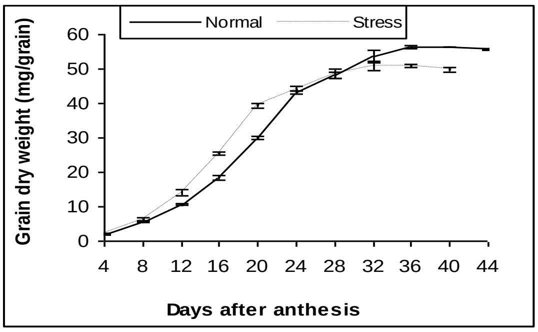
3.2 Grain dry matter accumulation

A typical sigmoid pattern in grain dry matter accumulation was shown in four wheat genotypes (BARI gom 25, BARI gom 26, BAW 1135 and Pavon 76) under both normal and heat stress conditions (Fig. 6). Under normal seeding date, the grain dry weight was increased upto 36 days after anthesis. Delayed planting condition reduced duration of grain dry weight gain in all genotypes, but the extent of reduction was not same. As a result, the grain dry weight reduction was recorded to range from 3.93% in BARI gom 26 to high as 22.93% in Pavon 76.

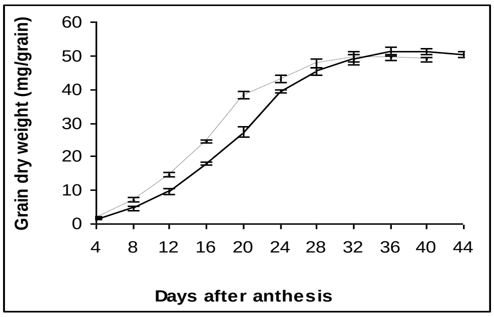
The reduction in duration required to attain the maximum grain dry weight was 4 days in BARI gom 25 and BARI gom 26 whereas it was 8 days in BAW 1135 and 12 days in Pavon 76 (Fig. 7). Under normal growing condition, no significant difference in canopy temperature depression was observed which reflecting unaffected grain filling period (36 day) irrespective of genotypes. But under post anthesis heat stress condition, a significant difference among CTD was observed which apparently induced different grain filling duration among four wheat genotypes (Fig. 7). Genotypes with maximum CTD also maintained long grain filling duration. A large reduction in grain filling duration of BAW 1135 and Pavon 76 could be due to high canopy temperature as contributed by smaller CTD value. Thus, the results suggest that early attainment of physiological maturity due to smaller CTD contributed to larger reduction of kernel dry matter in Pavon 76. These results also indicated that grain filling of genotype Pavon 76 was most sensitive which that of BARI gom 25 and BARI gom 26 was least sensitive to warmer canopy.

A highly significant correlation was found between canopy temperature depression and grain filling period (Fig. 8). Sowing under 29 November results cool canopy temperature reflecting higher grain filling duration. But under heat stress growing condition, CTD value was decreased which affected grain filling duration. The equation y= 1.8661x + 25.763 gave a good fit to the data and r^2= 0.8269 showed that it fitted regression line had a significant regression co-efficient.

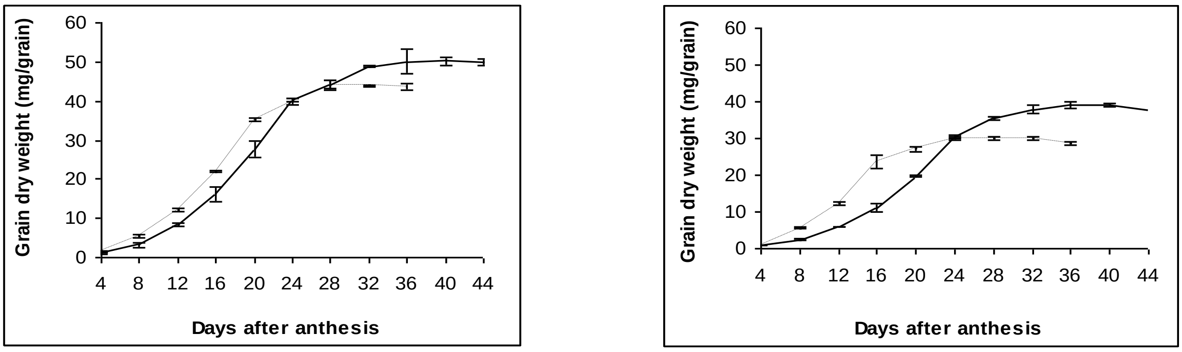
Sigmoid pattern of kernel dry matter accumulation was also found in wheat by [12], [13], [14], [15]; [16]; [17] and [18]. Some study revealed that high temperature stress at grain filling period caused reduced grain size and grain filling period and reductions were lower in heat tolerant genotypes than those in sensitive genotypes. [19], [20], [21], [17], [22] and [12] made similar statement. Under heat-stressed environment, earlier onset of flag leaf senescence due to highest level of soluble sugar content in flag leaf in heat sensitive genotypes is the important cause of shorter kernel filling duration [13].



BARI gom 25



BARI gom 26



BAW 1135 **Pavon 76**

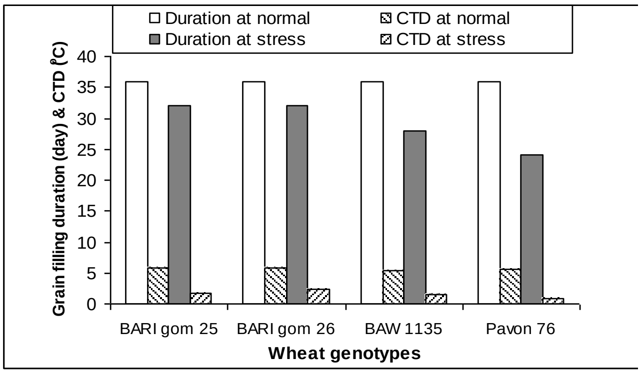
Fig. 6. Grain dry weight of four wheat genotypes at different days after anthesis under normal (29 November) and heat stressed (30 December) condition.

3.3 1000-grain weight

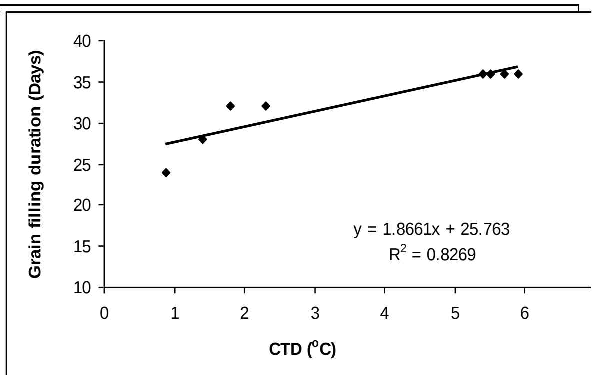
A general tendency of decreasing 1000-grain weight was recorded in all of the wheat genotypes due to delay seeding after 29 November Relative grain weight recorded from normal seeding date was higher in BARI gom 26 (0.96) followed by BARI gom 25 (0.94) and lower value was recorded in Pavon 76 (0.84) followed by BAW 1135 (0.87) (Fig. 9). Reduced grain size under heat stress condition might be due to the reduction in rapid kernel growth duration which again was contributed by small canopy temperature depression.

A highly significant correlation was found between 1000-grain weight and canopy temperature depression (Fig. 10). Wheat genotypes with larger CTD like BARI gom 26 and BARI gom 25 had a minimal reduction in 1000-grain weight compared the remaining genotypes which had smaller CTD. The equation y= 5.0699x + 23.294 gave a good fit to the data and R^2= 0.8342 showed that it fitted regression line had a significant regression co-efficient.

Significant variation in reduction in grain size under heat stress among different wheat genotypes was observed by [23], [24] and [25]. [26] stated that reduced starch deposition is the main reason of reductions in grain weight.



Grain filling duration and mean canopy temperature depression (CTD) at all stages during post anthesis stage of four wheat genotypes under normal (29 November) and heat stress (30 December) growing condition.



Relationship between canopy temperature depression (CTD) and grain filling duration of four wheat genotypes under normal (29 November) and heat stress (30 December) growing condition.

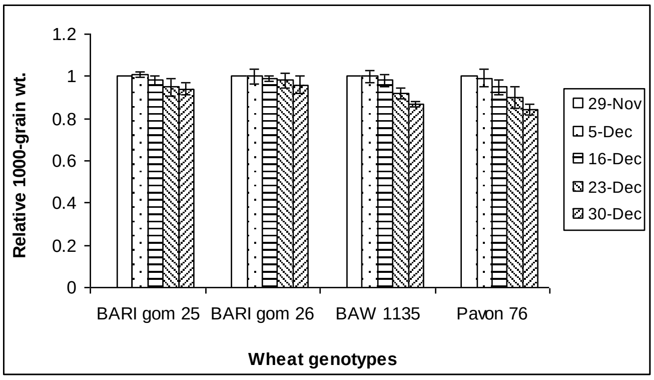


Fig. 9. Relative 1000-grain weight of four wheat genotypes at five sowing dates starting from 29 November to 30 December.

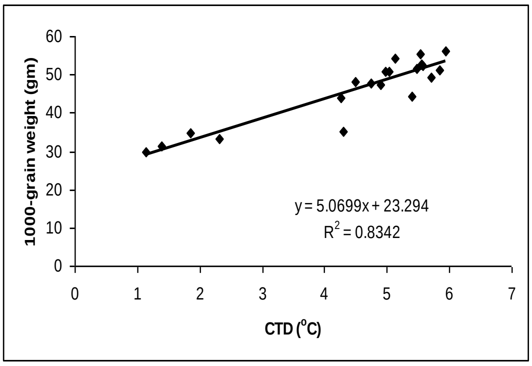


Fig. 10. Relationship between canopy temperature depression (CTD) and 1000-grain weight at five sowing dates of four wheat genotypes.

3.4 Grain yield

Grain yield (t/ha) was greatly influenced by sowing dates and wheat genotypes. Under normal condition the highest value was recorded in BAW 1135 (5.66) followed by Pavon 76 (5.5), BARI gom 26 (5.35) and BARI gom 25 (5.25) which was statistically insignificant with each other (TABLE 1). Grain yield did not reduce with delaying sowing dates until mid December in BARI gom 25, BARI gom 26 and BAW 1135 except Pavon 76. In Pavon 76, grain yield reduction was found significant after 6 December seeding and lowest yield was recorded in 30 December seeding. Relative yield was higher when seeds were sown on 30 December in BARI gom 26 (0.89) followed by BARI gom 25 (0.81), BAW 1135 (0.66) and lowest in Pavon 76 (0.56) (Fig. 11). Pavon 76 failed to maintain cooler canopy under post anthesis heat stress growing condition as induced late planting affected grain yield most adversely compared to all other genotypes.

A significant correlation was observed between canopy temperature depression (CTD) and grain yield (Fig. 12). CTD was decreased with late sown condition in all genotypes and grain yield also decreased with delaying sowing dates that's why a positive significant relationship exists between them (R^2= 0.6392).

Reduced grain size were the major factors for reducing the grain yield under late planting heat stress condition in the present experiment compared to normal growing period. Reduction of grain number per spike with delay sowing largely contributed to reduce the corresponding grain yield largely in Pavon 76 and BAW 1135 but a smaller decrease in grains number per spike support the tolerance in terms of grain yield in BARI gom 25 and BARI gom 26. Significant variation due to heat stress in different wheat genotypes was also found by [27] and [12]. High relative grain yield which was the results of stable and/or long duration of phosynthetic activity under heat stress condition and the character can be used as a selection criterion for heat tolerance of wheat genotypes was concluded by [28].

Table 1. Grain yield (ton/ha) of four wheat genotypes at five different sowing dates

Sowing Dates	**Genotypes**			
	BARI gom 25	BARI gom 26	BAW 1135	Pavon 76
29 Nov	5.25 abc	5.35 abc	5.66 a	5.50 ab
5 Dec	5.23 abc	5.33 abc	5.63 a	5.47 ab
16 Dec	5.00 abcd	5.13 abc	5.06 abcd	4.68 cde
23 Dec	4.51 de	4.90 bcde	4.26 ef	3.76 fg
30 Dec	4.23 ef	4.75 cde	3.75 fg	3.08 h
		CV (%) 7.47		

In this table, values followed by the different letter(s) are significantly different from each other by DMRT at 5% level.

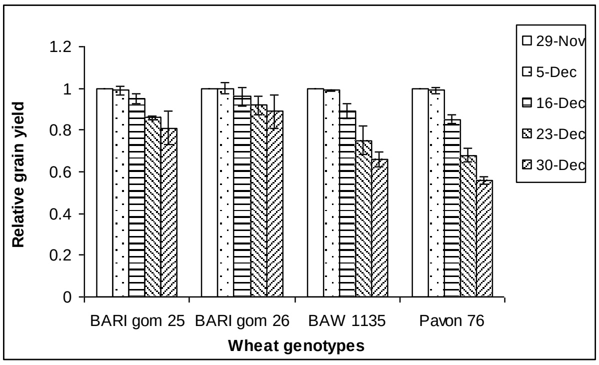


Fig.11. Relative grain yield of four wheat genotypes at five sowing dates starting from 29 November to 30 December.

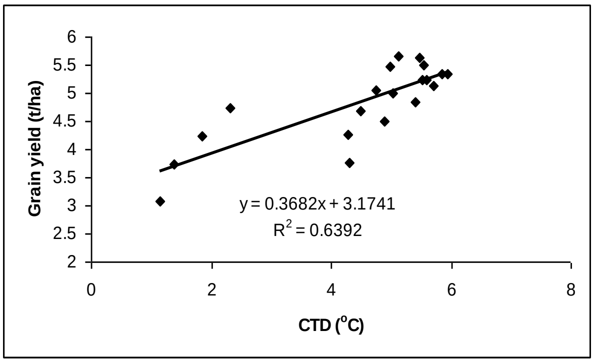


Fig. 12. Relationship between canopy temperature depression (CTD) and grain yield at five sowing dates of four wheat genotypes.

IV. Conclusion

Among the four genotypes in the present experiment, higher canopy temperature depression (CTD) was observed in genotypes BARI gom 26 and BARI gom 25 under heat stressed condition in comparison with genotypes Pavon 76 and BAW 1135. Genotypes having cooler canopies (higher CTD) showed longer grain filling period and consequently maintained less reduction of 1000-grain weight under heat stress condition. Late planting potential can be understood by higher canopy temperature depression during post anthesis heat stress condition which might be used as selection criteria.

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