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# PHENOLOGY AND HEAT USE EFFICIENCY OF WHEAT GENOTYPES UNDER HEAT STRESS CONDITION

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**ABSTRACT**

Phenology, growing degree days and heat use efficiency of four wheat genotypes (BAW-1170, BARI Gom 25, BARI Gom 26 and E 22) were studied under normal sowing and late sowing heat stress conditions in a split plot design. The requirement of days to attain various phenological stages was highest in BAW-1170 and the lowest in E 22 under both growing conditions. The growing degree days (GDD) and heat use efficiency were slightly higher under normal sowing compared to late sowing. The lowest heat unit requirement was observed in seedling emergence stage, whereas in the successive phenological stages there were an increasing trend of heat unit (GDD) requirement for all the genotypes in each sowing and the highest heat unit (GDD) requirement was observed at maturity stage. The highest GDD (1031.20 at normal and 1146.00 at heat stress) and HUE (3.37 at normal and 2.33 at heat stress) were found in BAW-1170, whereas the lowest GDD (902.00 at normal and 963.80 at heat stress) and HUE (2.76 at normal and 1.61 at heat stress) were found in E 22. Based on phenology, growing degree days and heat use efficiency BAW-1170 can be suggested as comparatively heat tolerant genotype than other three genotypes.

## 1. Introduction

Wheat *(Triticum aestivum* L.) is the most widely grown cereal in temperate environments and is also cultivated in many tropical cropping systems. Wheat is the second main source of world's energy and nutrition. In Bangladesh, wheat is the second most important cereal crop next to rice and grown over an area of 0.44 million hectares with an annual production of about 1.31 million metric tons (BBS 2017). Though, wheat is a cereal crop in Bangladesh, its average yield is low compared to that of the other countries of the world. About 50% of the wheat is cultivated at late sowing condition after harvesting of transplanted aman rice. As such, this late-sown wheat faces high temperature stress during grain filling stage. This affects wheat grain formation as well as grain development causing significant yield loss (Hakim *et al*. 2012). Late planting wheat exposed to high temperature (mean air temperature > 26ºC) at reproductive stage causing reduction in yield and it is one of the major reasons of yield gap (Hasan and Ahmed 2005). It was also predicted that an increase of 1ºC temperature will results in 4-5 million tons

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(3-4%) of loss in wheat production (Wardlaw *et al.* 1989). However, this problem will be further increased due to global warming. Responses to high temperature of plant vary with plant species, variety and phenological stages. The present study was aimed at studying the phenology, growing degree days and heat use efficiency of wheat genotypes and to identify the relatively heat tolerant genotype(s).

## 2. Materials and methods

The experiment was conducted at the research field of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during November 2015 to April 2016. The experiment was conducted in a split-plot design with three replications. The treatments were- A) Main plot: Two temperature regimes (Normal sowing at November 30 and late sowing at December 30) and B) Sub plot: Four wheat genotypes (BAW-1170, BARI Gom 25, BARI Gom 26 and E 22). The unit plot size was 3.0 m × 2.0 m having 0.5 m distance between sub plots and 1.5 m distance between main plots and blocks. Seeds were sown at a rate of 120 kg $ha^{-1}$ maintaining a row to row distance of 20 cm.

Phenological stages include seedling emergence, tillering, booting, anthesis, physiological maturity and harvest maturity. The growing degree days (GDD) and heat use efficiency (HUE) were calculated following Rajput (1980).

Growing degree days (GDD) = $\sum [(T_{max}+T_{min})/2-T_b]$. Here, ($T_b$ = Base temperature = 10ºC)

Heat use efficiency (HUE) = Grain yield(kg/ha)/GDD

The data were analyzed by partitioning the total variance with the help of computer using STATA program and the treatment means were compared using Tukey's test at $P \leq 5\%$ level.

## 3. Results and Discussion

### 3.1 Phenology

Phenology of four wheat genotypes in Table 1 shows that phenology was significantly influenced by the interaction effect of sowing times and four wheat genotypes. For each genotype a definite days were required to attain certain physiological stage of growth. The number of days for different phenological stages differed from genotype to genotype. Under normal growing condition, BAW-1170 required the highest number of days for seedling emergence, tillering, booting, anthesis, physiological maturity and harvest maturity. In this growing condition, BAW-1170 required 6 days for seedling emergence, 24 days for tillering, 58 days for booting, 69 days for anthesis, 105 days for physiological maturity and 112 days for harvest maturity, whereas E 22 required the lowest number of days to attain at different phenological stages (5, 22, 53, 65, 98 and 103 days, respectively).

Under late growing condition all the genotypes significantly decreased the requirement of days to attaining different phenological stages of growth. At late growing condition again the genotype BAW-1170 needed highest number of days for attaining seedling emergence (5 days), tillering (22 days), booting (53 days), anthesis (65days), physiological maturity (100 days) and harvest maturity (105 days), whereas E 22 required the lowest number of days for different phenological stages (5, 20, 48, 61, 90 and 94 days, respectively).

Similar results were observed by Dias and Lindon (2009) and Nahar *et al*. (2010) in wheat. In the present study, late sowing caused unfavorable high temperature at reproductive phase and low temperature at the early vegetative phase resulting in reduced number of days for attaining different phenological stages. Hossain *et al*. (2011, 2012 a) and Hakim *et al*. (2012) also found that duration of maturity of spring wheat genotypes reduced by high temperature stress in northern Bangladesh.

**Table 1. Phenology at days after sowing of four wheat genotypes as influenced by normal and late sowing heat stress condition**

| Wheat genotypes | Growing conditions | Seedling emergence | Tillering | Booting | Anthesis | Physiological maturity | Harvest maturity |
|---|---|---|---|---|---|---|---|
| BAW-1170 | Normal | 6 a | 24 a | 58 a | 69 a | 105 a | 112 a |
| | Heat | 5 ab | 22 abc | 53 b | 65 bcd | 100 cd | 105 b |
| BARI Gom 25 | Normal | 4 c | 23 ab | 57 a | 67 ab | 103 ab | 110 ab |
| | Heat | 4 c | 22 abc | 52 bc | 64 cd | 99 d | 102 d |
| BARI Gom 26 | Normal | 5 ab | 24 a | 57 a | 66 bc | 102 bc | 108 b |
| | Heat | 5 ab | 21 bc | 50 cd | 63 de | 99 d | 101 d |
| E 22 | Normal | 5 ab | 22 abc | 53 b | 65 bcd | 98 d | 103 cd |
| | Heat | 5 ab | 20 c | 48 d | 61 e | 90 e | 94 e |
| Level of significance | | * | ** | * | * | ** | ** |
| CV (%) | | 10.23 | 4.2 | 4.72 | 2.89 | 1.51 | 1.83 |

**In a column, means followed by the same letter(s) did not differ significantly at 5% level by Tukey.**

### 3.2 Growing degree days

Growing degree days from sowing to different phenological stage of four wheat genotypes in Table 2 indicate that the interaction effect of sowing times and genotypes on heat unit (GDD) was significant at all the phenological stages. The lowest heat unit requirement was observed in seedling emergence stage, whereas in the successive phenological stages like tillering, booting, anthesis, physiological maturity and harvest maturity stages there were an increasing trend of heat unit (GDD) requirement for all the genotypes in each sowing and the highest heat unit (GDD) requirement was observed at maturity stage.

Under normal growing condition, BAW-1170 needed highest heat unit at all the phenological stages followed by BARI Gom 25 and BARI Gom 26, whereas E 22 required the lowest heat unit (GDD) for attaining different phenological stages. In the normal growing condition, the GDD values in BAW-1170 were 70 for seedling emergence, 202.2 for tillering, 417.1 for booting, 484.8 for anthesis, 933.5 for physiological maturity and 1031.2 for harvest maturity. The lowest values of GDD attained by E 22 were 47.5 for seedling emergence, 189.7 for tillering, 398.7 for booting, 456.7 for anthesis, 823.4 for physiological maturity and 902 for harvest maturity.

At late growing high temperature stress condition all the genotypes had reduced heat unit (GDD) requirement to attaining different phenological stages of growth. In the late sowing condition again the genotype BAW-1170 showed the highest heat unit (GDD) to attaining all the growth stage which was followed by other genotypes BARI Gom 25 and BARI Gom 26, whereas E 22 had the lowest heat unit requirement for attaining different phenological stages. In this high temperature stress condition, the attainment of GDD values in BAW-1170 were 37.4 for seedling emergence, 155.8 for tillering, 385.1 for booting, 536 for anthesis, 1051.2 for physiological maturity and 1146 for harvest maturity and the lowest values of GDD attained by E 22 were 28.7 for seedling emergence, 142.9 for tillering, 329.2 for booting, 483 for anthesis, 907.2 for physiological maturity and 963.8 for harvest maturity. The early sown wheat has availed the longest period for completion of phenological stages and thus attained maximum values for GDD and it appeared to be reduced with subsequent delayed sowing. Khichar and Niwas (2007) and Pandy *et al*. (2010) also reported lower consumption of heat units under delayed sowing.

**Table 2. Growing degree days at different phenological stages of four wheat genotypes as influenced by normal and late sowing heat stress condition**

| Wheat genotypes | Growing conditions | Seedling emergence | Tillering | Booting | Anthesis | Physiological maturity | Harvest maturity |
|---|---|---|---|---|---|---|---|
| BAW-1170 | Normal | 70 a | 202.2 a | 417.1 a | 484.8 c | 933.5 b | 1031.2 bc |
| | Heat | 37.4 ab | 155.8 bc | 385.1 b | 536 a | 1051.2 a | 1146 a |
| BARI Gom 25 | Normal | 59.3 ab | 195.5 ab | 413.5 a | 472.1 cd | 902 bc | 1003.3 c |
| | Heat | 37.4 ab | 155.8 bc | 373.8 bc | 522.6 ab | 1033.8 a | 1089.4 ab |
| BARI Gom 26 | Normal | 59.3 ab | 202.2 a | 413.5 a | 464 de | 886.1 bc | 975.2 cd |
| | Heat | 37.4 ab | 149.7 bc | 351.2 cd | 508.9 bc | 1033.8 a | 1069.8 b |
| E 22 | Normal | 47.5 c | 189.7 ab | 398.7 b | 456.7 e | 823.4 d | 902 d |
| | Heat | 28.7 c | 142.9 c | 329.2 d | 483 c | 907.2 b | 963.8 d |
| Level of significance | | * | * | ** | ** | ** | * |
| CV (%) | | 7.46 | 2.09 | 4.67 | 2.89 | 3.21 | 4.56 |

**In a column, means followed by the same letter(s) did not differ significantly at 5% level by Tukey.**

### 3.3 Heat use efficiency

The interaction of sowing times and genotypes significantly influenced the heat use efficiency (HUE) (Table 3). All the genotypes used heat more efficiently at normal growing condition compared to late growing condition. Under normal growing condition genotype BAW-1170 had significantly highest HUE (3.37) which was followed by other two genotypes (BARI Gom 25 and BARI Gom 26), whereas genotype E 22 had the lowest HUE (2.76).

**Table 3. Heat use efficiency of four wheat genotypes as influenced by normal and late sowing heat stress condition**

| Wheat genotypes | Growing conditions | Heat use efficiency | Relative change over normal (%) |
|---|---|---|---|
| BAW-1170 | Normal | 3.37 a | -30.86 |
| | Heat | 2.33 b | |
| BARI Gom 25 | Normal | 3.123 a | -30.19 |
| | Heat | 2.18 bc | |
| BARI Gom 26 | Normal | 2.95 a | -29.15 |
| | Heat | 2.09 c | |
| E 22 | Normal | 2.76 a | -41.67 |
| | Heat | 1.61 d | |
| Level of significance | | ** | - |
| CV (%) | | 1.84 | - |

**In a column, means followed by the same letter(s) did not differ significantly at 5% level by Tukey.**

At late growing condition, all the genotypes significantly reduced their HUE at various magnitudes compared to normal growing condition but their reductions were not similar. Due to high temperature stress, BAW-1170 attained the highest HUE (2.33) which was identical to BARI Gom 25 (2.18), whereas E 22 showed the lowest HUE (1.61) which was followed by BARI Gom 26 (2.09). In relative change to normal the HUE for genotype E 22 was lower (41.67%) compared to BAW-1170 (30.86%), BARI Gom 25 (30.19%) and BARI Gom 26 (29.15%). The higher heat use efficiency in timely sown wheat genotypes might be due to higher production of crop biomass per heat unit absorbed. The lower HUE in delayed sowing can be expected due to accumulation of comparable GDD to that of early sowing at later crop growth stage. The results are in close agreement with those of Pandy *et al*. (2010). Similar result was also reported by Sikder (2009) and Paul and Sarker (2000).

## 4. Conclusions

Based on phenology, growing degree days and heat use efficiency BAW-1170 was comparatively heat tolerant genotype whereas, E 22 was heat sensitive genotype and other two (BARI Gom 25 and BARI Gom 26) were moderate heat tolerant genotypes. The findings of the present study will help in achieving sustainable wheat cultivation under high temperature stress condition.

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