Study of Grain Growth, Floret Sterility and Seed Size of Wheat Cultivars as Influenced by Post-anthesis Heat Stress

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Abstract

Four heat tolerant (Gourab, Sourav, Kanchan and Shatabdi) and two heat sensitive (Sonora and Kalyansona) wheat cultivars, were tested under normal and late growing post-anthesis heat stress conditions by seeding them November 30 and December 30 of 2005 to evaluate their grain growth pattern, floret sterility and seed size. A sigmoid pattern of grain growth was found in all the cultivars for both the growing conditions. At normal growing condition, both the heat tolerant and heat sensitive cultivars had similar grain growth duration (35 DAA). But in late growing heat stress condition, heat tolerant cultivars had longer grain filling duration (30 DAA) compared to heat sensitive cultivars (25 DAA). In both the growing conditions, heat tolerant cultivars had higher grain growth rate than the heat sensitive cultivars. Results showed that irrespective of growing conditions heat sensitive cultivars showed higher floret sterility compared to heat tolerant cultivars. Both the heat tolerant and heat sensitive cultivars showed a common tendency of higher floret sterility under post-anthesis condition. But the degree of increments of floret sterility was much lower in heat tolerant cultivars than those of heat sensitive cultivars. From heat susceptibility index it was observed that cultivars Gourab, Kanchan and Shatabdi were clearly lower heat susceptible (S<1.0) in individual seed weight compared to cultivars Sonora and Kalyansona (S>1.0).

Keywords: wheat, grain growth, seed size, floret sterility, heat susceptibility

Introduction

Wheat (Triticum aestivum L.) is the second most important cereal crop next to rice in Bangladesh. Here it is grown under hot and humid climate and in a short winter. Currently the national average of wheat yield is about 2.0 t ha\(^{-1}\) with a total production of 0.765 million ton in 0.373 million hectare (BBS, 2007) which is about four fold lower than the potential of some released varieties (Razzaque et al., 1992). The yield gap between the potential and national average is associated with many limiting factors of which high temperature stress is the vital physiological factor (Ahmed and Meisner, 1996). About 80-85% of wheat in Bangladesh is grown after transplanted aman rice of which 60% of area is planted to late due to delay in harvesting of previous rice (Badaruddin et al., 1994) and the crop frequently encounters high temperature stress during the reproductive stage of growth. High temperature at post-anthesis period shortens the duration of grain filling such as that each degree increase during grain filling results in about 3 days decrease in duration of grain filling regardless of cultivars (Bagga and Rawson, 1977).

The optimum temperature for grain development of wheat lies with a range of 15/10 to 18/150C (day night\(^{-1}\)) temperature (Choudhury and Wardlaw, 1978). The apparent sensitivity of metabolic processes to heat stress from supra optimal
temperature during grain filling in the field is associated with acceleration of physic development (Shpilar and Blum, 1991) accelerated senescence (Renolds et al., 1994), reduction in photosynthesis (Blum, 1986; Al-Khatib and Paulsen, 1999), increase in respiration (Berry and Bjorkman, 1980) and the inhibition of starch synthesis in the growing kernel (Rijven, 1986). Due to overall shortening of reproductive stage, the opportunity of the fixation of photosynthesis and its translocation to grain is also causing significant reduction of grain size (Acevedo et al., 1991). Heat stress also causes abortion of late florets which increases floret sterility (Blum, 1988) and reduces the potential grain number (Hu and Rajaram, 1993; Al-Khatib and Paulsen, 1990 and Bhatta et al., 1994). The net effect of heat stress at reproductive stage lowers the kernel weight due to reduced grain filling period, grain filling rate or the combined effect of both (Tashiro and Wardlaw, 1989).

Identification of wheat varieties through morphological analysis of grain development, floret sterility and individual seed size would be an important step for achieving high yield potential of wheat. Considering the above important aspects the present investigation was undertaken to study the grain growth pattern, floret sterility and seed size of wheat cultivars in relation to their heat tolerance.

Materials and Methods

The experiment was conducted at the research farm of Crop Physiology and Ecology Department of Hajee Mohammad Danesh Science and Technology University, Dinajpur during 2005-06. Six wheat cultivars were used as study materials. On the basis of membrane thermo stability out of six cultivars four (Gourab, Sourav, Kanchan and Shatabdi) were heat tolerant and rest two (Sonora and Kalyansona) were heat sensitive (Sikder and Paul, 2010). The seeds were sown on November 30 and December 30 of 2005. November 30 sowing was considered as normal growing condition, whereas December 30 sowing was regarded as late growing post-anthesis heat stress condition (Figure 1). The experiment was replicated thrice in a split plot design where two growing conditions (sowing times) were placed in main plots and six wheat cultivars were in sub-plots. Seeds were sown in rows 20 cm apart at the rate of 120 kg ha⁻¹ in a unit plot size of 3m x 2m. Crop management was done properly.

Grain Growth

At anthesis 50 ears were tagged from each plot. Five tagged ear were harvested to quantify grain growth at every 5th day beginning from 5 day after anthesis. The harvesting of all cultivars were continued up to 45 days after anthesis (DAA) for normal growing condition (November 30 sowing) and 35 days after anthesis for late growing heat stress conditions (December 30 sowing). The harvested ear was kept at 70°C for 72 hours for drying. The grain was separated from husk and 100 grains of each treatment was weighed with an analytical balance (Model: MR-220, YMC Co. Ltd, Japan).

The absolute grain growth rate (AGR) was calculated using the formula as Sikder et al. (1999).

\[ AGR = \frac{W_2 - W_1}{T_2 - T_1} \]

Where, \( W_1 = \) grain dry weight at initial time  \\
\( W_2 = \) grain dry weight at final time  \\
\( T_1 = \) Initial time  \\
\( T_2 = \) Final time

Floret Sterility (%)

It was calculated at maturity period by using the following formula as Sikder (2008)

\[ \text{Floret sterility} (%) = 1 - \frac{\text{No. of kernels/spike}}{\text{No. of florets/spike}} \times 100 \]

Seed Size

From the each plot, thousand grains were taken randomly from dried samples and the total weight was recorded. From the grain weight average seed size was calculated.

Heat Susceptibility Index

Heat susceptibility index (S) was calculated for different parameters as described by Fischer and Maurer (1976).

\[ S = (1 - Y/Y_p) / (1 - X/X_p) \]
Figure 1 Mean air temperature (0 C) from anthesis to maturity of different wheat cultivars.

Where,

\[ Y = \text{Variable of a cultivar in a stress environment} \]
\[ Y_p = \text{Variable of a cultivar in a stress-free environment} \]
\[ X = \text{Mean of } Y \text{ of all the cultivars} \]
\[ X_p = \text{Mean of } Y_p \text{ of all the cultivars}. \]
\[ (S < 1.0, \text{stress tolerant and } S > 1.0, \text{stress susceptible}) \]

Statistical Analysis

The data were analyzed by partitioning the total variance with the help of computer by using MSTAT program. The treatment means were compared using Duncan’s Multiple Range Test (DMRT).

Results

Grain Growth

The influence of growing conditions on grain growth of six wheat cultivars at different days after anthesis is shown in Figure 2. From the analysis of variance it was observed that interaction effect of sowing times and cultivars were significant at all the DAA. A sigmoid pattern of grain growth was found in all the cultivars. Grain dry matter accumulation followed more or less similar pattern in four heat tolerant and two heat sensitive cultivars under both the growing post-anthesis heat stress conditions. Results showed that generally the grain growth pattern had an initial lag period (low growth) just after anthesis before linear increase in dry weight. The linear growth phase (rapid growth phase) was followed by a decreasing growth rate during maturity. Under normal growing condition both the heat tolerant and heat sensitive cultivars attained their physiological maturity at 35 DAA. At this growing condition, the dry weight of grain in Gourab, Sourav, Kanchan Shatabdi, Sonora and Kalyansona were observed to be increased up to 41.97, 42.12, 39.40, 44.72, 30.71 and 33.68 mg/grain, respectively at 35 DAA and thereafter declined slowly. In this condition both the tolerant and sensitive groups maintained their initial lag period for about 10 DAA and linear growth phase for about 25 DAA. In case of absolute growth rate (AGR) all the cultivars maintained a rapid growth rate (more than 1 mg day\(^{-1}\) grain\(^{-1}\)) up to 25 DAA at normal growing condition (Figures 3). But in general the heat tolerant cultivars (Gourab, Sourav, Kanchan and Shatabdi) had higher growth rate than the heat sensitive cultivars (Sonora and Kalyansona). Finally, heat tolerant group attained higher grain weight (39.40 to 44.72 mg grain\(^{-1}\)) compared to heat sensitive ones (30.71 to 33.68 mg grain\(^{-1}\)) due to its higher growth rate.

Under the late growing condition, the maximum dry matter accumulation per grain and duration to attain that grain dry matter were decreased in all the cultivars. The maximum grain dry weight of cultivars Gourab, Sourav, Kanchan Shatabdi, Sonora and Kalyansona were 33.60, 32.30, 32.34, 36.34, 21.50 and 24.34 mg grain\(^{-1}\). The heat tolerant and heat sensitive cultivars had different grain growth duration and grain growth rate. Both the groups reduced their grain filling period at the late growing post-anthesis heat stress condition. But the magnitude of this reduction was different for heat tolerant and heat sensitive cultivars. The reduction of grain filling period for the heat tolerant cultivars was much lower than the heat sensitive cultivars. The time taken from anthesis to maturity was 30 and 25 DAA for heat tolerant and sensitive cultivars, respectively. Whereas, at normal growing condition both the groups had a common time (35DAA) for physiological maturity. Under late growing heat stress condition all the cultivars had an initial lag period of about 10 DAA and for linear growth phase took 20 DAA. In this growing condition both the tolerant and sensitive groups maintained a higher growth rate (more than 1 mg day\(^{-1}\) grain\(^{-1}\)) for 20 DAA in (Figure 3). But after that (20 DAA) the grain growth rate of heat sensitive
cultivars (Sonora and Kalyansona) were declined more rapidly than heat tolerant cultivars (Gourab, Sourav, Kanchan and Shatabdi) and reached their physiological maturity quickly (25 DAA).

Floret Sterility

The floret sterility of six wheat cultivars at different growing conditions is shown in Table 1. Results showed that floret sterility was significantly influenced by the interaction effect of growing conditions and cultivars. Irrespective of heat susceptibility all the cultivars showed statistically similar floret sterility though there were widely variations among the cultivars under normal growing conditions. In this growing condition the heat sensitive cultivars Sonora and Kalyansona had comparatively higher (33.79% and 38.84%) floret sterility than the heat tolerant cultivars (32.66% to 35.22%).

Therefore, the late growing post-anthesis heat stress condition increased the sterility in all the cultivars. But the degrees of increment among different cultivars were varied. These increments were significant for Sonora and Kalyansona. In case of relative change to normal sowing the heat sensitive cultivars Kalyansona and Sonora had the higher value (21.60% to 36.49%) compared to the heat tolerant cultivars Shatabdi, Kanchan, Sourav and Gourab (20.04% to 24.24%).

Figure 2 Grain dry matter accumulation of six wheat cultivars at different days after anthesis under normal and late growing post-anthesis heat stress conditions. Vertical bars indicate LSD value at 5% level of significance.
Seed Size

Results showed that the interaction effect of growing conditions and cultivars statistically influenced the individual grain size (Table 2). Heat tolerant cultivars attained higher grain size than the heat sensitive cultivars in both the growing conditions. Under normal growing condition, Shatabdi had the highest grain size (44.60 mg grain⁻¹) and Sonora obtained the lowest grain size (30.1 mg grain⁻¹). Cultivars Gourab, Sourav and Kanchan attained statistically similar grain size. At late growing condition, all the cultivars significantly reduced their grain size compared to normal growing condition. In this post-anthesis heat stress growing condition again the heat tolerant cultivar Shatabdi had the highest seed size and heat sensitive cultivar Sonora showed the lowest grain size. Cultivars Gourab, Sourav and Kanchan gave statistically similar grain size at heat stress condition. Though all the cultivars reduced their grain size at heat stress condition but the degree of reduction varied among the cultivars. Comparatively heat tolerant cultivars (Gourab, Sourav, Kanchan and Shatabdi) showed much lower reduction than the heat sensitive cultivars Sonora and Kalyansona.
Table 1 Floret sterility (%) of six wheat cultivars under normal and late growing conditions.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Normal growing condition</th>
<th>Late growing condition</th>
<th>Differences</th>
<th>Relative change to normal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gourab</td>
<td>32.66 c</td>
<td>40.58 b</td>
<td>+ 7.92</td>
<td>+ 24.24</td>
</tr>
<tr>
<td>Sourav</td>
<td>33.32 c</td>
<td>41.85 b</td>
<td>+ 8.53</td>
<td>+ 25.60</td>
</tr>
<tr>
<td>Kanchan</td>
<td>35.22 c</td>
<td>42.49 b</td>
<td>+ 7.27</td>
<td>+ 20.64</td>
</tr>
<tr>
<td>Shatabdi</td>
<td>34.23 c</td>
<td>41.09 b</td>
<td>+ 6.86</td>
<td>+ 20.04</td>
</tr>
<tr>
<td>Sonora</td>
<td>33.79 c</td>
<td>46.12 a</td>
<td>+ 12.33</td>
<td>+ 36.49</td>
</tr>
<tr>
<td>Kalyansona</td>
<td>38.84 c</td>
<td>47.23 a</td>
<td>+ 8.39</td>
<td>+ 21.60</td>
</tr>
<tr>
<td>CV (%)</td>
<td>5.21</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean followed by same letter(s) did not differ significantly at 5% level of significance.

Table 2 Seed size of six wheat cultivars under normal and late growing conditions.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Seed size(mg grain⁻¹)</th>
<th>Reduction (%) at late growing condition</th>
<th>Heat susceptibility index (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal growing condition</td>
<td>Late growing condition</td>
<td></td>
</tr>
<tr>
<td>Gourab</td>
<td>42.30 ab</td>
<td>33.85 de</td>
<td>19.98</td>
</tr>
<tr>
<td>Sourav</td>
<td>41.75 abc</td>
<td>32.80 e</td>
<td>21.44</td>
</tr>
<tr>
<td>Kanchan</td>
<td>39.50 bc</td>
<td>32.50 e</td>
<td>17.73</td>
</tr>
<tr>
<td>Shatabdi</td>
<td>44.60 a</td>
<td>37.50 cd</td>
<td>15.92</td>
</tr>
<tr>
<td>Sonora</td>
<td>30.10 e</td>
<td>21.66 f</td>
<td>27.75</td>
</tr>
<tr>
<td>Kalyansona</td>
<td>33.20 e</td>
<td>24.50 f</td>
<td>26.20</td>
</tr>
<tr>
<td>CV (%)</td>
<td>6.94</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Mean followed by same letter(s) did not differ significantly at 5% level of significance.

From heat susceptible index, it was found that cultivars Shatabdi, Kanchan and Gourab were graded as heat tolerant due to lower ‘S’ value (<1.0), whereas Sonora and Kalyansona were considered as heat susceptible (S>1). The heat susceptibility of Sourav (S=1.02) was lower than Sonora and Kalyansona but higher than Shatabdi and Kanchan.

Discussion

The present investigation was undertaken to study the grain growth pattern, floret sterility and seed size of wheat cultivars in relation to their heat tolerance. A typical sigmoid pattern of seed dry matter accumulation in wheat was found by Chanda et al. (1999). At late growing post-anthesis heat stress condition, the grain growth duration and grain growth rate of all the cultivars were reduced and ultimately attained lower final individual grain weight. But the reduction was lower in heat tolerant cultivars (Gourab, Sourav, Kanchan and Shatabdi) compared to heat sensitive cultivars (Sonora and Kalyansona). Time taken to attain physiological maturity was 5 days earlier in heat tolerant cultivars and 10 days earlier in heat sensitive cultivars. These results were due to post-anthesis heat stress. Because, in the present study, all the cultivars faced post-anthesis high temperature stress in late sowing condition. The net effect of heat stress at GS3 (anthesis to maturity ) phase is lower grain weight due to reduction of grain filling duration and grain filling rate or combined effect of both (Tashiro and Wardlaw, 1989). At late sowing, heat tolerant cultivars had longer grain filling period with high filling rate compared to heat sensitive cultivars. This result agrees with those of Bhatta et al. (1994). Delayed sowing caused high temperature stress
condition at the grain filling period resulting in the reduced grain filling duration but this reduction was much lower in the heat tolerant cultivars than those of the heat sensitive cultivars. Similar statement was made by Bagga and Rawson (1977) and Jhala and Jadon (1989). Accelerated development enhanced respiration and numerous indirect effects complicated interpretation of high temperature injury to plants (Chowdhury and Wardlaw, 1978; Fischer, 1985; Rawson, 1986). Al-Khatib and Paulsen (1984) reported that grain filling duration generally has inverse relationship with the prevailing temperature. Heat stress during GS3 phase (anthesis to maturity) results in faster senescence of foliage; poor assimilate availability, reduced translocation of photosynthates to the developing grain and greater respiratory loss.

In the present study, there were wide variations in floret sterility among the six cultivars. This was due to their genetic character. Genetic variation in floret sterility was also found by Rawson (1986) in wheat. Late growing post-anthesis heat stress condition increased the sterility in all the cultivars. But the degree of increment was higher in heat sensitive cultivars (Sonora and Kalyansona) compared to heat tolerant cultivars (Gourab, Sourav, Kanchan and Shatabdi). Results from other studies indicated that high temperature resulted in higher floret sterility (Rawson, 1986). Late planting wheat experienced high temperature at the reproductive stage causing abortion of florets (Warrington et al., 1977). Late sowing showed higher grain abortion than the optimum sowing because of comparatively higher temperature at the grain filling stage. Number of grain that developed in an ear is dependent on the number of florets and effective fertilization of them after anthesis (Evans and Wardlaw, 1976). On the other hand, reduction of grain number per ear is associated with high temperature during anthesis stage (Saini et al., 1983; Zeng et al., 1985). Murty et al. (1979) stated that unfavorable environmental condition, particularly temperature attributed reduction in grain per ear and grain growth. In the most of the cases with increasing temperature, there was progressive decrease in number of grains that confirmed the grain abortion. At the grain filling stage, the increased temperature induced sterility of pollen tube that causes grain abortion in ear. Higher temperature prevailed at delayed sowing was responsible for higher grain abortion (Saini et al., 1983).

In the present study reduced grain size under heat stress condition might be due to the rapid reduction in grain growth duration. Tashiro and Wardlaw (1989) reported that net effect of heat stress in the grain filling period was lower grain weight due to the reduction in grain filling period, grain filling rate or combined effect of both. Late sowing or heat stress condition caused reduced seed size was also reported by Islam et al. (1993), Shukla et al. (1992), Hu and Rajaram (1993), Al-Khatib and Paulsen (1990) and Bhatta et al. (1994) in different wheat genotypes. Genotypic differences in relative grain weight were reported by Al-Khatib and Paulsen (1990). Grain size is a very stable character for all the varieties of wheat to the developmental and synthetic activity of grain as an important determinant of grain yield (Asana and Williams, 1965).

From the overall results it might be concluded that heat tolerant cultivars (Gourab, Sourav, Kanchan and Shatabdi) showed a longer grain filling duration with high filling rate, lower floret sterility and less heat susceptibility in seed size compared to heat sensitive cultivars (Sonora and Kalyansona) and these may be considered as indicators of heat tolerant.

Acknowledgments

We are grateful to the Director of Wheat Research Center, Dinajpur for providing seeds. The financial assistance received from University Grants Commission of Bangladesh is gratefully acknowledged.

References


