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EFFECT OF POST-ANTHESIS HEAT STRESS ON GRAIN DEVELOPMENT OF WHEAT CULTIVARS

S. Sikder[1], M.A. Hasan[1], M. Hasanuzzaman[2], A.K.M.M.B. Chowdhury[1] and M.H.R Hafiz[1]

ABSTRACT

Grain development of four heat tolerant (Gourab, Sourav, Kanchan and Shatabdi) and two heat sensitive (Sonora and Kalyansona) wheat cultivars were evaluated under normal and late growing post-anthesis heat stress conditions by seeding them on 30 November and 30 December of 2006 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 days after anthesis (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. Higher seed weight was found at normal growing condition compared to late growing condition. Heat tolerant cultivars had distinctly higher individual seed size than the heat sensitive ones. From heat susceptibility index it was observed that cultivars Sourav, Kanchan and Shatabdi were remarkably lower heat susceptible in seed size compared to Sonora and Kalyansona.

Key words: Wheat, grain development, seed size, floret sterility, heat susceptibility

INTRDUCTION

Wheat (*Triticum aesivum* L.) is the first ranking cereal crop in the globe in terms of area and importance. It 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 wheat yield is 2.05 t/ha with a total production of 0.765 million ton in 0.373 million hectare (BBS, 2007) which is much lower than the potential yield of recent released varieties. 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% area is planted late due to delay in harvesting of rice (Badaruddin *et al*., 1994) and the crop frequently suffer from high temperature stress during the reproductive stage. High temperature at post-anthesis period shortens the duration of grain filling. For each degree increase during grain filling results in about 3 days decrease in duration of grain filling regardless of cultivars (Bagga and Rawson, 1977).

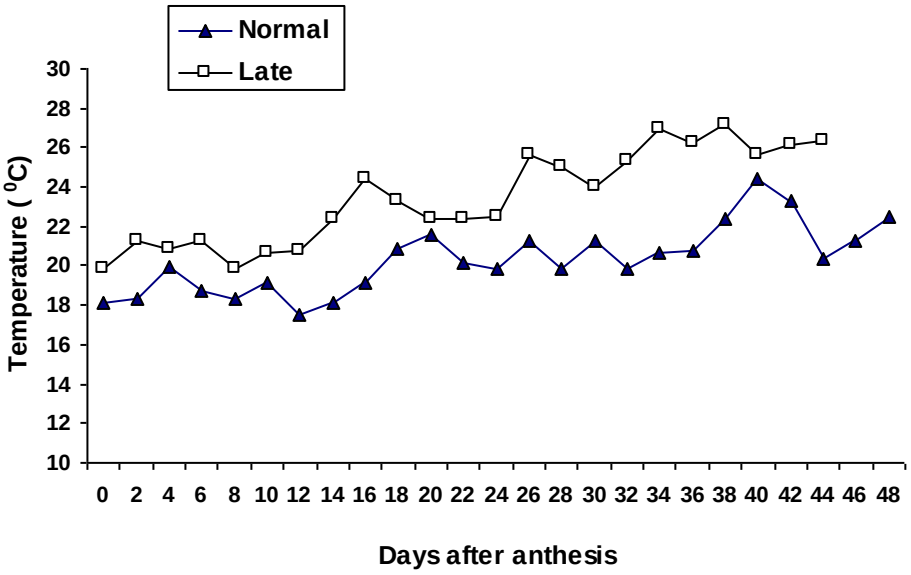
The optimum temperature for grain development of wheat lies with a range of 15/10 to 18/15^{0}C (day/night) temperature (Choudhury and Wardlaw, 1978). The apparent sensitivity of metabolic processes to heat stress from supra optimal temperature during grain filling in the field is associated with acceleration of phasic 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

[1]Department of Crop Physiology and Ecology and [2]Department of Genetics and Plant Breeding, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.

photosynthates and its translocation to grain is decreased resulting significant reduction of grain size (Acevedo *et al.*, 1991). 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). 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.

MATERIAL AND METHODS

The experiment was conducted at the research farm of Crop Physiology and Ecology Department of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during 2006-07. Six wheat cultivars were used as study materials. On the basis of membrane thermostability four cultivars (Gourab, Sourav, Kanchan and Shatabdi) were heat tolerant and the rest two (Sonora and Kalyansona) were heat sensitive. Seeds were sown on 30 November and 30 December of 2006. Sowing of 30 November was considered as normal growing condition, whereas 30 December 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 in sub-plots. Seeds were sown continuously in rows 20 cm apart at the rate of 120 kg ha^{-1} in a unit plot size of 3m x 2m. Crop managements were done accordingly to the recommendations of wheat Research Centre, BARI.



Grain growth

At anthesis, 50 spikes were tagged from each plot. Five tagged spikes 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 (30 November sowing) and 35days after anthesis for late growing heat stress conditions (30 December sowing). The harvested ear was kept at 70^{0}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 formulae

$$AGR = \frac{W_2 - W_1}{T_2 - T_1}$$

where, W_1= grain dry weight at initial time, W_2= grain dry weight at final time, T_1 = Initial time and T_2 = Final time.

Seed size

From 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.

Relative performance

The relative performance for seed size was calculated as Asana and Williams (1965) by the following formula:

$$\text{Relative performance (\%)} = \frac{\text{Individual seed weight under stress condition}}{\text{Individual seed weight under normal condition}} \times 100$$

Heat susceptibility index

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

$S = (1- Y/Y_p) / (1- X/X_p)$

Where,

Y = Variable of a cultivar in a stress environment

Y_p = Variable of a cultivar in a stress-free environment

X = Mean of Y of all the cultivars

X_p = Mean of Y_p of all the cultivars.

($S < 1.0$, stress tolerant and $S > 1.0$, stress susceptible)

Statistical analysis

The data were analyzed by partitioning the total variance with the help of computer by using MSTAT-C programme. The treatment means were compared using Duncun's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Grain growth

From the analysis of variance it was observed that interaction effect of sowing times and cultivars was significant at all the days after anthesis (Figure 2). 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 cultivars viz., Gourab, Sourav, Kanchan and Shatabdi and two heat sensitive cultivars e.g. Sonora and Kalyansona under both the normal and late 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 44.18, 45.30, 42.36, 49.15, 34.53 and 38.77 mg/grain, respectively and after 35 DAA 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/ grain) 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 (42.36 to 49.15 mg/grain) compared to heat sensitive ones (34.53 to 38.71 mg/grain) 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 34.28, 36.10, 35.16, 37.53, 25.32 and 28.95 mg/grain. 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

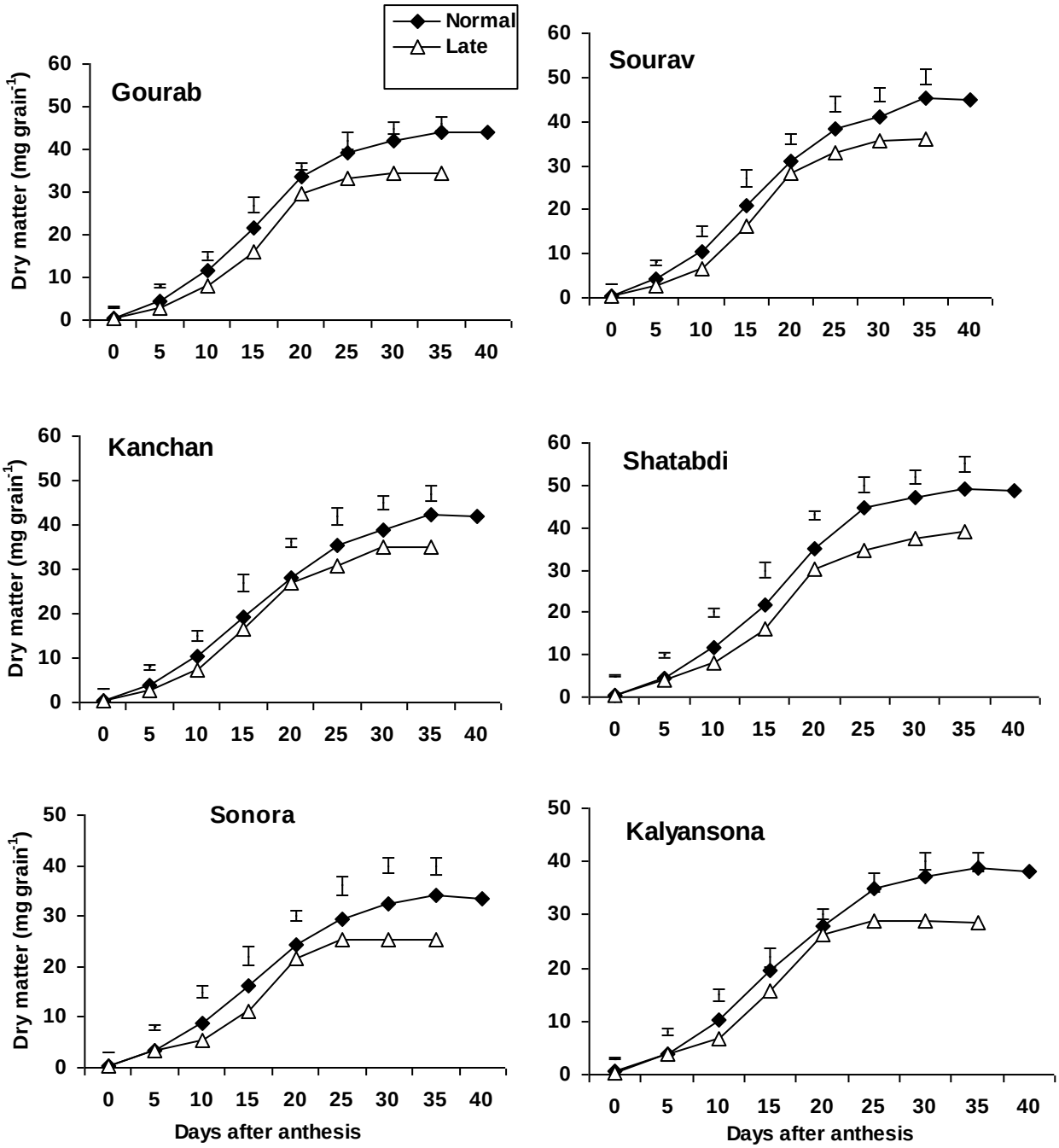


Figure 2. Grain dry matter accumulation of six wheat cultivars at different days after anthesis under normal and late growing post-anthesis heat stress conditions. Vertical bars indicate LSD value at 5% level of significance.

and heat sensitive cultivars. The reduction of grain filling period for the heat tolerant cultivars was 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/ grain) for 20 DAA in (Figures 3). But after that 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).

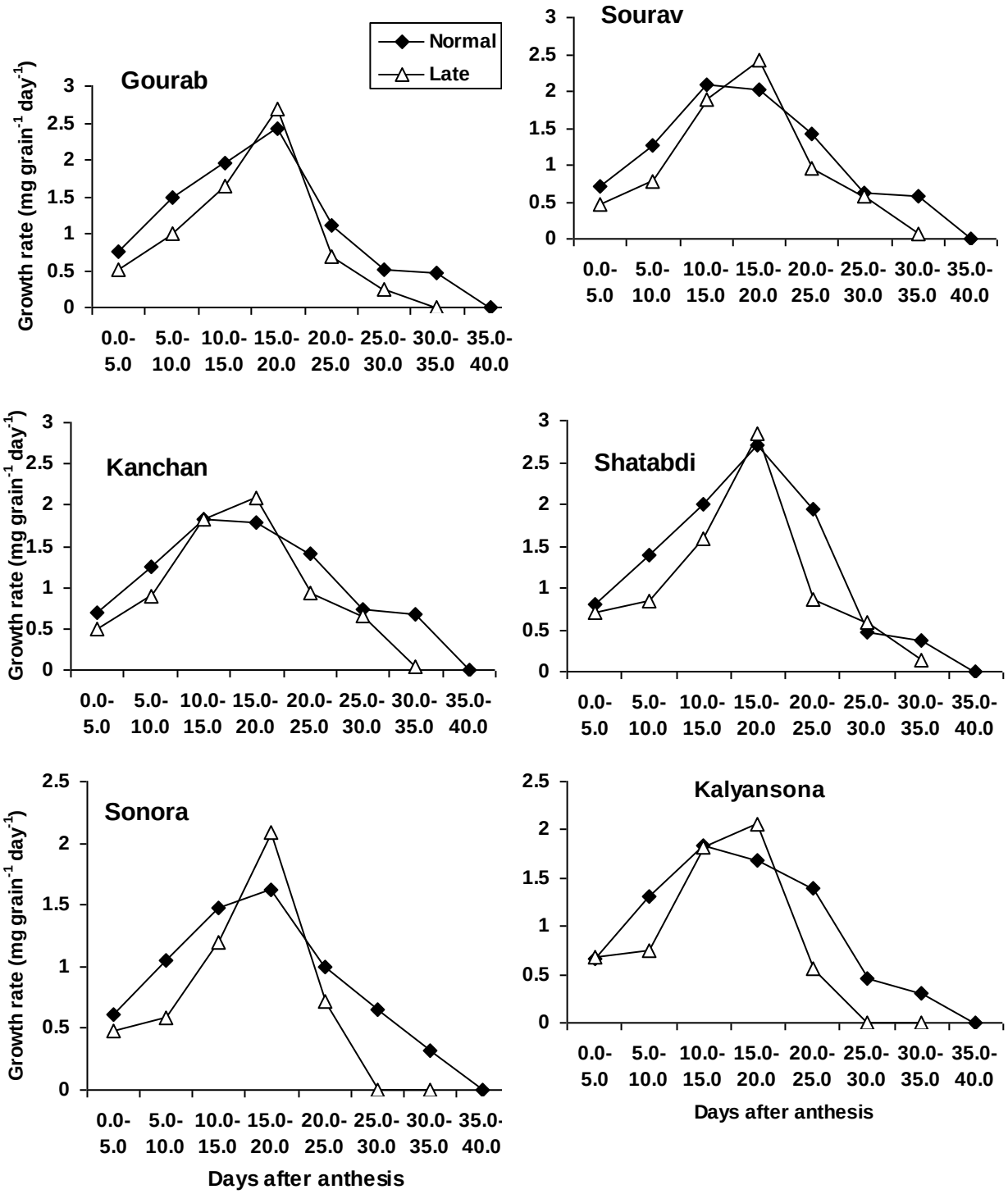


Figure 3: Grain growth rate of six wheat cultivars at different days after anthesis under normal and late growing heat stress conditions.

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 GS_3 (anthesis to maturity) phase was 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 induced high temperature stress condition at the grain filling period resulting in the reduced grain filling period but this reduction was 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 that 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 GS_3 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.

Seed size

The interaction effect of growing conditions and cultivars significantly influenced the individual grain size (Table 1). 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 (48.55 mg/grain) and Sonora obtained the lowest grain size (33.40 mg/grain). Grain size of Gourab was statistically similar to both Sourav and Kanchan, however, grain size of Sourav was significantly higher than that of Kanchan (Table 1).

At late seeding condition, grain size reduced significantly than that of normal seeding condition in all the tested cultivars. In this post-anthesis heat stress growing condition again the heat tolerant cultivar Shatabdi had the highest grain size and heat sensitive cultivar Sonora had 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 lower reduction than the heat sensitive cultivars Sonora and Kalyansona.

Table 1. Seed size of six wheat cultivars under normal and late growing conditions.

Cultivar	Seed size(mg/grain)		Heat susceptibility index (S)
	Normal growing condition	Late growing condition	
Gourab	44.10 bc	34.40 fg	1.06
Sourav	44.80 b	36.12 ef	0.92
Kanchan	41.85 c	35.16 fg	0.76
Shatabdi	48.55 a	38.88 d	0.95
Sonora	33.40 g	25.30 i	1.16
Kalyansona	38.15 de	28.57 h	1.20
CV (%)	3.82		-

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

Regarding relative performance for individual seed size, the heat tolerant cultivars had higher relative value than the heat sensitive ones (Figure 4). The relative seed size of Gourab, Sourav, Kanchan, Shatabdi, Sonora and Kalyansona were 77.78, 80.62, 84.01, 80.08, 75.74 and 74.86% respectively.

From heat susceptible index, it was found that Shatabdi, Kanchan and Sourav were graded as heat tolerant due to lower 'S' value (<1.0), whereas Sonora and Kalyansona were considered as heat susceptible (S>1). Though the heat susceptibility index of Gourab (S=1.06) was higher than Shatabdi and Kanchan, still it was lower than that of Sonora and Kalyansona.

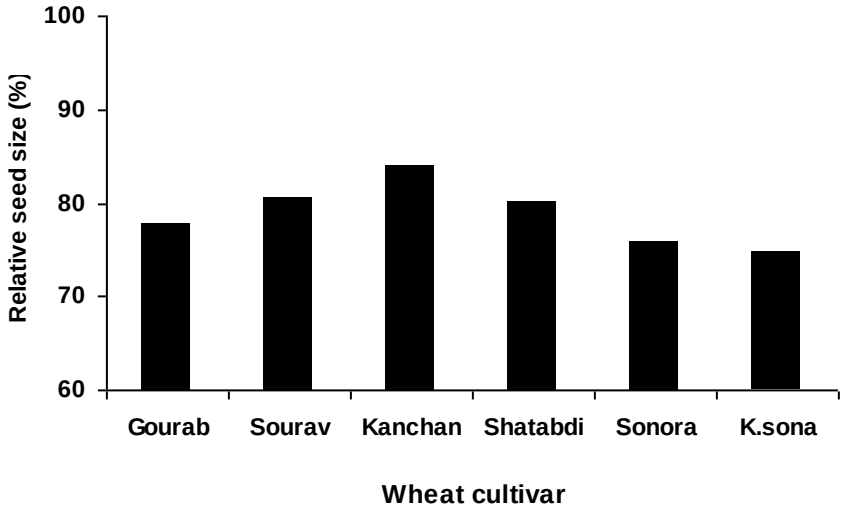


Figure 4: Relative seed size (%) of different wheat cultivars.

In the present study reduced grain size under heat stress condition was 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).

CONCLUSION

From the overall results of the present study it might be concluded that heat tolerant cultivars (Gourab, Sourav, Kanchan and Shatabdi) showed a longer grain filling duration with high filling rate 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.

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