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RESEARCH ARTICLE

Variation of Wheat Cultivars in Their Relationship between Seed Reserve Utilization and Leaf Temperature under Elevated Temperature

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Abstract

An investigation on physiological changes was carried out in three wheat genotypes (BARI Gom 25, BARI Gom 26, and Pavon 76) through seed reserve utilization efficiency (SRUE) and leaf cooling under normal (15 / 25°C) and elevated (25 / 35°C) temperatures in the growth chamber. At high temperature, Pavon 76 required more days to initiate the fully autotrophic stage. After germination, seedling and remnant seed dry weight was the same at day 5 in BARI Gom 26 and day 6 in BARI Gom 25 and Pavon 76. At high temperature, maximum translocation efficiency and seed reserve utilization efficiency (SRUE) were observed in BARI Gom 26 and at a minimum value in Pavon 76. High leaf cooling was recorded in BARI Gom 26. At high temperature, due to high leaf temperature and low transpiration rate of Pavon 76, maximum reduction of seedling growth was recorded in Pavon 76 (17%) as compared to minimum in BARI Gom 26 (5%). It appeared from the result that at high temperature the better seed reserved utilization efficiency and subsequently larger leaf cooling collectively contributed a positive role for seedling development in BARI Gom 25 and BARI Gom 26. The relationship of seed reserve utilization efficiency and leaf temperature were prominent in the case of Pavon 76 (r = -0.768) compared to other genotypes. This relationship indicated that Pavon 76 was the most sensitive genotype and BARI Gom 25 and BARI Gom 26 was the tolerant genotype to heat stress in respect to seed reserve utilization efficiency during seed reserve dependent phase and leaf temperature of photosynthetic-dependent phase.

Key words : Elevated temperature, Leaf temperature, SRUE, Wheat cultivars

Introduction

Wheat is one of the most important thermo-sensitive crops. The optimum temperature of the crop varies at different stages of growth and development. The crop grows better in a temperature range from 15 to 18°C (Choudhury and Wardlaw 1978). The temperature from 20 to 25°C was found to be favorable for wheat seed germination, seedling emergence, and optimum plant establishment (Behl et al. 1993). Exposure to temperatures above 26°C can significantly reduce grain yield (Tewolde et al. 2006). High temperature reduces the grain growth duration and hence reduces the grain size (Tahir and Nakata 2005).

Reduced grain size contributes to yield reduction under heat stress environment. Development of heat tolerant wheat variety that can withstand late planting-high temperature stress and that restricts the loss of grain size can be a possible way to overcome heat stress. Some wheat varieties have already been identified based of their yield performance under terminal heat stress conditions.

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Separate investigatons have been carried out on the basis of different physio-morphological traits such as membrane thermo stability (Hasan 2009), stem reserves mobilization (Blum et al. 1994; Sikder and Paul 2010), endosperm utilization efficiency (Blum et al. 1994; Hasan et al. 2013; Khatun 2013), leaf temperature depression (Khatun 2013; Renolds et al. 1994) stomatal conductance (Renolds et al. 1994), etc.

However, the present investigation was undertaken to study the seed reserve utilization efficiency and leaf cooling of wheat under two temperature regimes. During the period of seed germination, the developing wheat seedling is totally dependent on the utilization of the carbon stored in the seed endosperm. Heat stress affected the seed reserve utilization efficiency during germination (Gangadhar and Sinha 1993) and the magnitude of variation was different in different genotypes (Gophane et al. 2005). Lately the leaf temperature has been in use as a selection criterion for tolerance against drought and high temperature stresses in wheat (Reynolds et al. 1994).

Leaf cooling has played an important role to search for the physiological basis of sustaining grain yield of wheat. Seed reserve utilization efficiency during seed germination and leaf cooling during seedling development in wheat are both important physiological prerequisites for developing a high-yielding, heat-tolerant wheat variety.

Material and Methods

This experiment was conducted in a growth chamber (ATTEMPTER, Advantec, Japan) in the Crop Botany Laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh during the period from October 2012 to December 2012. In this study, two heat-tolerant (BARI Gom 25, BARI Gom 26) and one heat-sensitive (Pavon 76) were planted in a growth chamber under two temperature treatments, which were collected from the Wheat Research Center, Bangladesh. In the growth chamber, treatment consisted of 25°C temperature maintained with day / night of 25 / 15 (±1)°C and treatment of 35°C temperature maintained with day / night of 35 / 25 (± 1)°C with 90 ± 1% relative humidity and 16 h photoperiod, a light intensity of 200 µE m^{-2} S^{-1}. Seeds were placed sequentially according to the marking number in a plastic glass filled with pure sand and adequate moisture placed in a plastic tray in the growth chamber. Plastic glasses were irrigated at 2-day-intervals with half-strength Hoagland's nutrient solution. Twelve germinating seeds were sampled daily from 2 to 13 days after germination (DAG). The shoot and root were separated from the seed and were defined as seedling. The remnant seeds and seedlings were weighed after drying at 70°C for 72 hr. Dry matter translocation (from seed to seedling) efficiency was calculated by the seedling dry weight per unit initial seed weight and expressed as percentage. Seed reserve utilization efficiency (SRUE) was also calculated as the ratio of seedling dry mass gain to remnant seed dry mass loss during the period when seedling development totally depends on seed (Blum and Sinmena 1994).

Leaf temperature was measured using a hand-held infrared thermometer (Model: Crop TRAK, Item No. 2955L - Spectrum Technologies, Inc.) maintaining the angle of approximately 45° to the horizontal in a range of directions. The leaf temperature was recorded daily from 8 to 13 days after germination at noon (12 pm). Then from the recorded leaf temperature, leaf cooling was calculated as the difference between ambient temperature (°C) and leaf temperature (°C). Transpiration rate was recorded during 11, 12, and 13 days after germination by the following formula:

$$Transpiration\ Rate = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{1}{LA}\ (mg\ cm^{-2}\ h^{-1})$$

where, W_1 = weight at initial time, T_1 = initial time, W_2 = weight at final time, T_2 = final time, LA = leaf area.

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

$$Relative\ Performance\ (\%) = \frac{Variable\ measured\ under\ stress\ condition}{Variable\ measured\ under\ normal\ condition} \times 100$$

All statistical analyses were performed by the MSTAT program. The treatment means were compared using Duncan's Multiple Range Test (DMRT) at 5% level of significance and simple data were calculated by using Microsoft Excel 2007.

Results and Discussion

Total dry matter (TDM) of remnant seed and seedling

Wheat seeds were imbibed for 48 h for germination and the beginning of germination was recorded with the first visible development of plumule and radicle. Dry weight of plumule and radicle plus remnant seeds constituted the total dry matter (TDM). Recording of TDM was started from day 2 after germination (DAG) and continued daily until 13 days after germination (DAG). TDM was found to decrease immediately after germination as that continued until day 5 in BARI Gom 26 and day 6 in BARI Gom 25 and Pavon 76 after germination (Fig. 1). The decrease in TDM was because of respiratory loss from seed and seedling. Result indicated a larger amount of respiratory loss at high temperature (35°C) as compared to that at normal temperature (25°C).

The quantity of respiratory loss was obtained by the amount of decrease of TDM from the initial seed dry weight and hence the negative value indicated respiratory loss with the progress of seedling development. Respiratory loss started to compensate with the increase of TDM after reaching the maximum TDM. When total dry weight increasing rate reached the initial seed dry weight, the seedling is considered to be fully autotrophic plant. It was noted from the results that the initial seed dry weight of Pavon 76 was attained at 16

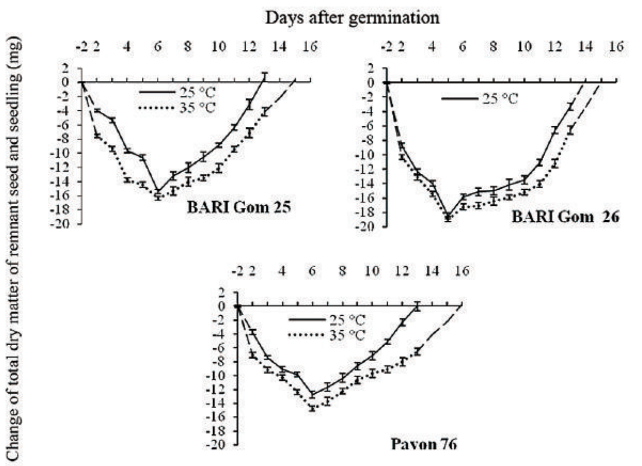

Fig. 1. Daily change of TDM of remnant seed and seedling compare with initial seed weight from 2 to 13 days after germination of three wheat genotypes at 25°C and 35°C temperature. Minus (-) value indicates decreasing TDM which depends on seed. Vertical lines are standard errors of selected data points. Dashed line is an extrapolation. Initial seed weight of BARI Gom 25 and BARI Gom 26 was 50 mg and Pavon 76 was 32 mg.

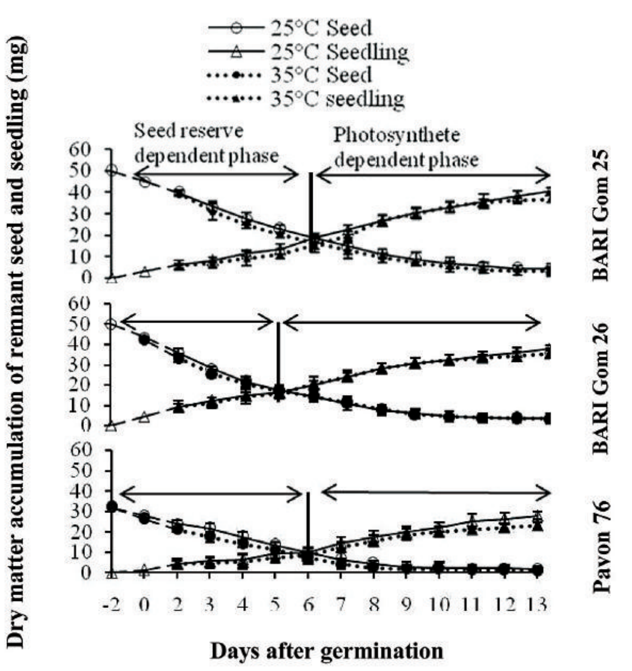

Fig. 2. Dry matter accumulation of remnant seed and seedling from 2 to 13 DAG in three wheat genotypes at 25°C and 35°C temperature. Vertical lines are standard errors of selected data points. Dashed line is an extrapolation.

DAG at high temperature as compared to 13 DAG at normal temperature (Fig. 1). Total dry weight reached the initial seed dry weight at 2 days later in BARI Gom 25 and 1 day later in BARI Gom 26 at high temperature compared to that attained at normal temperature (Fig. 1). It was clear from the results that Pavon 76 was 2 days later than BARI Gom 26 to reach autotrophic phase under high temperature conditions.

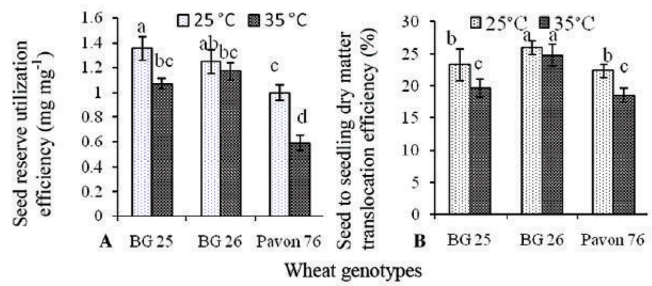

Fig. 3. A Seed reserve utilization efficiency and B Seed to seedling dry matter translocation efficiency in three wheat genotypes at 25°C and 35°C during the period of the seed reserve dependent phase. Vertical lines are standard errors of the data point. BG means BARI Gom.

Seedling development

Seedling dry weight was found to increase from the day of germination with a concomitant decrease of remnant seed dry weight (Fig. 2). Increase of seeding dry weight occurred at a higher rate under normal temperature (25°C) than under high temperature (35°C), but the difference was not significant. The developing seedling depended on the seed reserve until remnant seed dry weight reached the seedling dry weight. Results indicated that the seed reserve dependent phase of seeding development continued up to day 5 in BARI Gom 26 and day 6 in the rest of two genotypes after germination. During subsequent stages of seedling development, the contribution of remnant seed dry weight was gradually reduced and the contribution from current photosynthesis generally increased.

Seed reserve utilization

During the period of the seed reserve-dependent phase, seed to seedling dry matter translocation efficiency (Fig. 3A) as well as seed reserve utilization efficiency (Fig. 3B) were lower at a higher temperature (35°C) than at a normal temperature (25°C). With increasing temperature from 25 to 35°C, a smaller decrease of translocation efficiency and seed reserve utilization efficiency was observed in BARI Gom 26 followed by BARI Gom 25 and the maximum decrease occurred in Pavon 76. It may happened that under high temperature a smaller loss in the process of respiration in BARI Gom 25 and BARI Gom 26 compare to Pavon 76 finally resulted in larger translocation of remnant seed to seedling.

This might be due to a smaller loss of remnant seed dry matter in respiration for same amount of dry matter translocation to seedling in BARI Gom 25 and BARI Gom 26 compared to Pavon 76. That's why SRUE was higher in BARI Gom 25 and BARI Gom 26 compared to Pavon 76. Although seed reserve utilization efficiency was found to decrease at high temperature stress condition in both tolerant and sensitive genotypes, but a smaller decrease was occurred in tolerant genotypes BARI Gom 25 and BARI Gom 26. Hasan 2009; Blum and Sinmena 1994 also reported the same trend of seed reserve utilization efficiency.

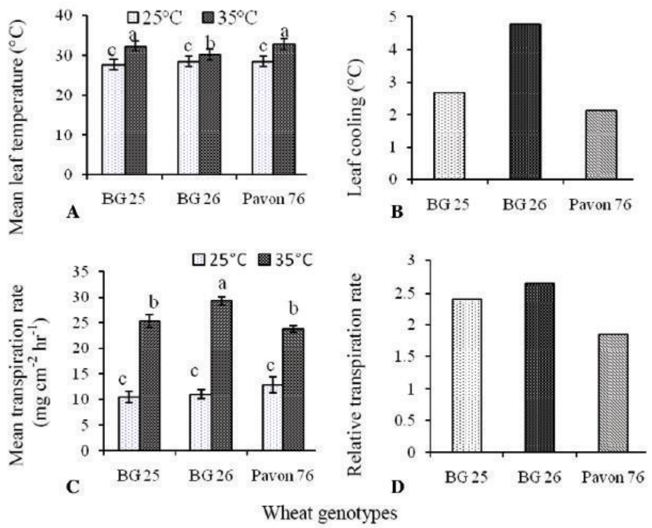

Fig. 4. A Mean leaf temperature, B leaf cooling C mean transpiration rate at 25°C and 35°C temperature and D relative transpiration rate of three wheat genotypes during 11 to 13 DAG. Vertical lines are standard errors of mean data point. BG means BARI Gom.

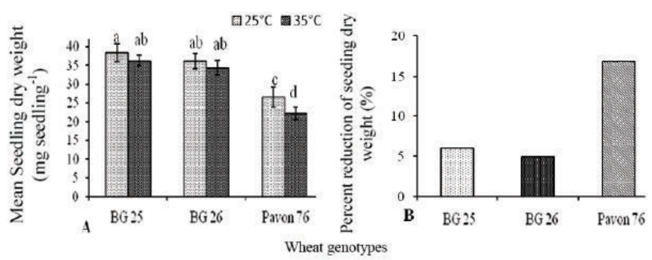

Fig. 5. A Mean Seedling (root + shoot) dry weight at 25°C and 35°C temperature and B percent reduction of seedling dry weight in three wheat genotypes during 11 to 13 DAG. Vertical lines are standard errors of mean data point. BG means BARI Gom.

Leaf Temperature

At a high growth chamber temperature (35°C), the leaf temperature was recorded with a range of 30.25 to 32.87°C during 11 to 13 DAG (Fig. 4A). During 11 to 13 DAG maximum leaf cooling was found by 4.75°C in BARI Gom 26, whereas leaf cooling was recorded at 2.67°C and 2.13°C in BARI Gom 25 and Pavon 76 respectively, when varieties were treated with 35°C temperature (Fig. 4B)

At a high temperature, maximum transpiration rate observed in BARI Gom 26 (29.28 mg cm^{-2} h^{-1}) and the minimum transpiration rate was recorded in Pavon76 (23.78 mg cm^{-2} h^{-1}) which was statistically similar with BARI Gom 25 (25.33 mg cm^{-2} h^{-1}) (Fig. 4C). Transpiration rate also increased with raising temperature from 25 to 35°C. Finally, the maximum relative transpiration rate in BARI Gom 26 (2.64) resulted for maximum leaf cooling (4.75°C) in BARI Gom 26 and the minimum in Pavon 76 (1.85) (Fig. 4D) was due to less leaf cooling.

Seedling growth

Recording mean seedling growth between 11 and 13 DAG

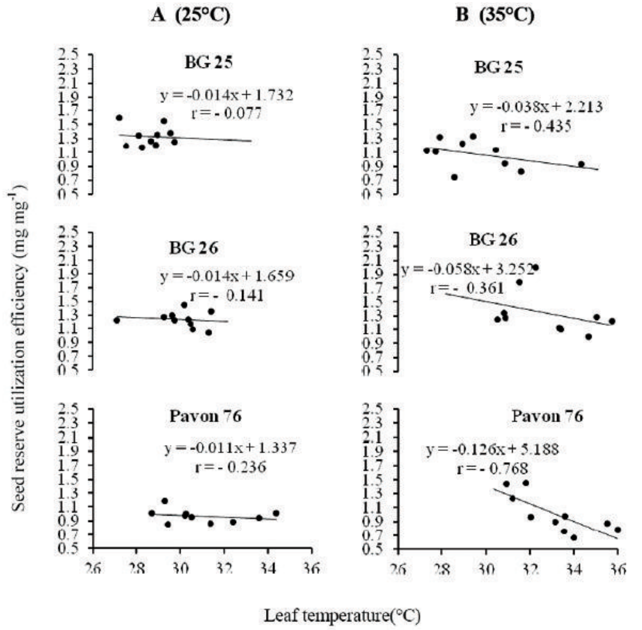

Fig. 6. Association between seed reserve utilization (SRUE) and leaf temperature at 25°C A and 35°C B in three wheat genotypes.

in BARI Gom 25 was 36.23 mg $seedling^{-1}$, in BARI Gom 26 it was 34.34 mg / $seedling^{-1}$, and in Pavon 76 it was 22.16 mg $seedling^{-1}$ at 35°C temperature (Fig. 5A). Results indicated that a higher reduction in seedling growth was in Pavon 76 (17%) whereas growth reduction was 6% in BARI Gom 25 and 5% in BARI Gom 26 (Fig. 5B). This result clearly indicated that wheat genotypes that resisted increased leaf temperature at 35°C temperature was found to produce high seedling dry matter. Growth inhibition of the developing seedling under heat stress can be a measurement of heat tolerance in growing seedlings. A similar relationship was recorded by Alkhatib and Paulsn (1999) in the case of thermo-tolerance autotrophic wheat seedlings. It appeared from the results that under high temperature conditions the better seed reserved utilization efficiency and subsequently larger leaf cooling collectively contributed a positive role for better seedling development in BARI Gom 25 and BARI Gom 26. The autotrophic seedling development of plants was found to be well-associated with SRUE which agreed with Hasan (2009) and Blum and Sinmena (1994).

Seed Reserve Utilization Efficiency and leaf temperature generally maintains a negative relationship which was prominent under high temperature. At high temperature conditions, increasing leaf temperature maintained the strongest negative relation (r = -0.768) with SRUE in Pavon 76 whereas the relationship was the weakest in BARI Gom 25 (r = -0.435) and BARI Gom 26 (r = -0.361) (Fig. 6B). It appeared from the results that Pavon 76 was found to be less effective in terms of leaf cooling and as well as SRUE. There is indication that seed metabolic efficiency could be poor due to alternate oxides pathway in seed respiration (Gangadhar and Sinha 1993). The result of the present experiment also agreed that the high alternate oxides pathway activity might cause a larger loss of CO_2 with minimal reserve translocation to seedling.

The overall results from the present experiment suggested that better use of seed dry matter during germination and leaf temperature during seedling development are indicators of the thermo tolerance in subsequently growing wheat seedling. Therefore, the basis of the relationship between SRUE and leaf temperature, BARI Gom 25 and BARI Gom 26 can be concluded as the heat-tolerant genotype and Pavon 76 as the heat-sensitive genotype.

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