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Physiological Mechanism of Thermotolerance in Wheat (*Triticum aestivum* Lin.) Seedlings

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Abstract

A research work was performed under sub-tropical condition (24˚8'N, 90˚0'E) at Bangabandhu Sheikh Mujibur Rahman Agricultural University with three wheat genotypes (BARI Gom 25, BARI Gom 26 and Pavon 76) to observe the mobilization of seed reserve and seedling growth under normal (15˚C/25˚C) and elevated (25˚C/35˚C) temperature in growth chamber. The effect of high temperature on wheat seedling was observed in terms of mobilized seed reserve, respiration and transpiration efficiency and seedling growth. At 35˚C temperature, maximum mobilization of seed reserve was observed in BARI Gom varieties (BARI Gom 25 and 26) but the respiration efficiency was higher in Pavon 76 in comparison to other genotypes. Maximum loss of respiration and transpiration at 35˚C temperature was found to produce low seedling growth in Pavon 76. It appeared from the result that at high temperature the maximum mobilized seed reserve and subsequently minimum loss of respiration and transpiration collectively contributed a positive role for better seedling growth in BARI Gom 25 and BARI Gom 26. Therefore the better mobilized seed reserve and subsequently minimum loss of respiration and transpiration during seedling development are indicators of the thermo tolerance in growing wheat seedling.

Keywords

Thermo Tolerance, Mobilized Seed Reserve, Heat Stress, Wheat

1. Introduction

Seed germination is a factor which contributes grain yield. Among the abiotic factors, temperature is considered an important issue for wheat germination,

because it persuades the rate of water absorption and additional substrates necessary for growth and development. Plant temperature, depending upon absorption of radiation and loss of heat through transpiration, may rise above ambient temperature and hence cause heat stress [1]. Heat stress adversely affects seed germination, seedling development and ultimately limits wheat productivity in many regions of the world. The temperature from 20˚C - 25˚C is found to be favorable for wheat seed germination, seedling emergence and optimum plant establishment [2]. In Pakistan, it is believed that wheat could be sown during October to December when temperature ranges from 20˚C - 30˚C. However, fluctuation in temperature may influence germination of wheat which could be predicted due to genotypic variation. Germination may be dependent on the ability of seed to utilize seed reserves more efficiently [3] or by mobilization of seed reserves for germination traits [4]. Temperature is a modifying factor in germination since it can influence the rate of water absorption and other substrates supplies are necessary for growth and development [5]. The rapid and uniform field emergence is essential to achieve better seedling growth and subsequently high yield [6]. Seed characteristics are usually essential process in seedling establishment and plant development to obtain seedling numbers those results in higher seed yield [7] [8]. The influence of high temperatures on growth and development of wheat seedling and other crops is well documented [9] [10]. At the molecular level, high temperatures adversely affect cell metabolism [11] [12] and cause changes in the pattern of protein synthesis [13]. Supra-optimal temperatures suppress the synthesis of the normal complement of cellular proteins and at the same time induce the synthesis and accumulation of many new proteins including heat shock proteins [14]. The minimum and maximum temperatures can be affected from seed germination to seed maturation [15] suggested that in case of wheat varieties, genetic variances are of greater magnitude than environmental variances for most of the traits [16]. During the period of seed germination the developing wheat seedling is totally depend on the mobilization of the carbon stored in the seed endosperm. Heat stress affected the mobilized seed reserve utilization efficiency during germination [17] and the magnitude of variation was different in different genotypes [18]. Mobilized seed reserve, respiration and transpiration efficiency played an important role to search physiological basis of sustaining seedling growth which contributed to grain yield of wheat. This research work therefore was set to determine thermo tolerance of wheat seedling through seed germinating physiological traits.

2. Materials and Methods

This experiment was conducted in growth chamber (ATTEMPTER, Advantec, Japan) in Crop Botany Laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh during the period from June, 2012 to December, 2012. During this study, three wheat genotypes (BARI Gom 25, BARI Gom 26 and Pavon 76) were planted in growth chamber under two temperature treatments. 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, ensuring light intensity of 200 μE/m^2/S. Seeds were weighed and placed sequentially according to the marking number in a plastic glass filled with pure sand and the adequate moisture placed in a plastic tray in growth chamber. Wheat seeds were imbibed for 48 hr for germination and beginning of germination was recorded with the first visible development of plumule and radicle. Plastic glasses were irrigated every two days interval with half-strength Hoagland's nutrient solution. Twelve germinating seeds were sampled daily from 2 to 15 days after germination (DAG). The plumule and radical were separated from the seed and are defined as seedling. The remnant seeds and seedlings were weighed by using analytical balance (Electronic Balance Model: AGN220C) after drying at 70˚C temperature for 72 hr and defined as Total Dry Matter (TDM). Recording of TDM was started from 2 day after germination (DAG) and continued daily until 15 day after germination (DAG). Mobilized seed reserve indicates the amount of seed reserved material which is mobilized from the germinating seeds to the growing radicle and plumule. The ratio of mobilized seed reserve to initial seed dry weight was considered as seed reserve depletion percentage (SRDP) [19]. Mobilized seed reserve and seed reserve depletion was calculated as Harb (2013) by the following formulae [20]:

$$\text{Mobilized seed reserve}\left(\frac{\text{mg}}{\text{seed}}\right)=\frac{\text{Original seed weight}-\text{dry weight of remnant seed}}{\text{Number of seed}}$$

$$\text{Seed reserve depletion}(\%)=\frac{\text{weight of mobilized seed reserve}}{\text{original seed weight}}\times 100$$

The respiration efficiency was calculated by the following formula:

$$\text{Respiration efficiency}(\%)=\frac{\text{Original seed weight}-\text{Total seedling dry matter}}{\text{Original seed weight}}\times 100$$

Transpiration rate was recorded during 11, 12 and 13 days after germination by the following formula:

$$\text{Transpiration Rate}=\frac{W_2-W_1}{T_2-T_1}\times\frac{1}{LA}\ \ \text{mg}/\text{cm}^2/\text{hr}$$

where,

W_1 = weight at initial time, T_1= Initial time.

W_2 = weight at final time, T_2 = Final time.

LA = Leaf area.

$$\text{Transpiration Efficiency}(\%)=\frac{\text{Transpiration Rate}}{\text{Original seed weight}}\times 100$$

All statistical analysis was performed by 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.

3. Results

Seed germination and vigorous seedlings are important characteristics for wheat which could provide advantages for crop establishment. In this study, temperature significantly influenced germination and related traits of various wheat varieties. Mobilized seed reserve (MSR) was more or less similar at 25˚C in three wheat genotypes. But at 35˚C Mobilized seed reserve (MSR) was higher in BARI Gom varieties (BARI Gom 25 and 26) in comparison to Pavon 76 at 5, 10 and 15 Days after germination (DAG) (**Figure 1**). At 35˚C Mobilized seed reserve (MSR) of Pavon 76 affected more at 10 and 15 DAG. 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 [21]. Many other researchers [22] [23] also reported the same trend of seed reserve utilization efficiency.

The results of seed reserve depletion (SRD) showed the same trend as that shown for Mobilized Seed Reserve (MSR) (**Figure 2**). Percent of seed reserve depletion (SRD) was more or less similar at both 25˚C and 35˚C in BARI Gom 25 and BARI Gom 26. But with the increase of temperature from 25˚C to 35˚C percent of seed reserved depletion was decreased in Pavon 76 at 5, 10 and 15 days after germination (DAG) due to maximum reduction of reserve mobilization at high temperature. Other researchers [19] [24] and [25] also found same result under drought stress condition in wheat seedling.

At 25˚C the respiration efficiency was more or less similar in all three wheat genotypes. But at 35˚C the respiration efficiency was higher in Pavon 76 compare to other genotypes and maximum was observer at 10 days after germination (DAG) (**Figure 3**). On the other hand transpiration efficiency was increased with increasing temperature from 25˚C to 35˚C in all the three wheat genotypes. Maximum transpiration efficiency was observed in Pavon 76 (**Figure 4**). The result proved that respiration and transpiration was accelerated and mobilized seed reserve depletion was decelerated by the effect of high temperature. Therefore,

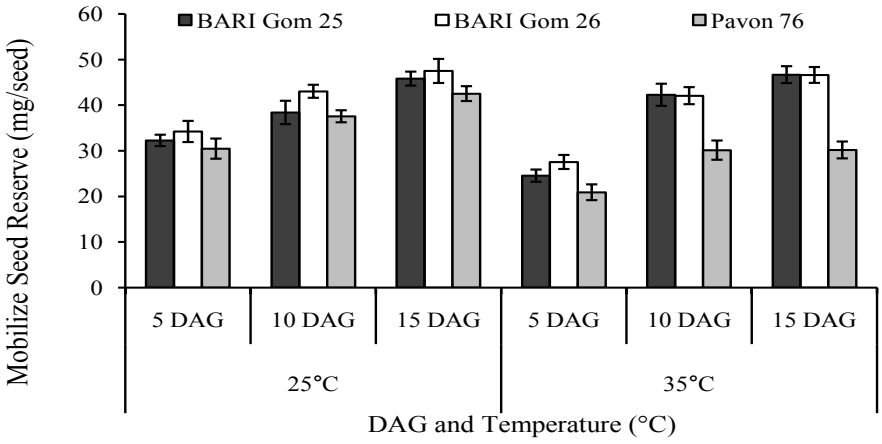

Figure 1. Mobilized seed reserve (mg/seed) of three wheat genotypes at 25˚C and 35˚C temperature at 5, 10 and 15 DAG. Vertical lines are standard errors of selected data points.

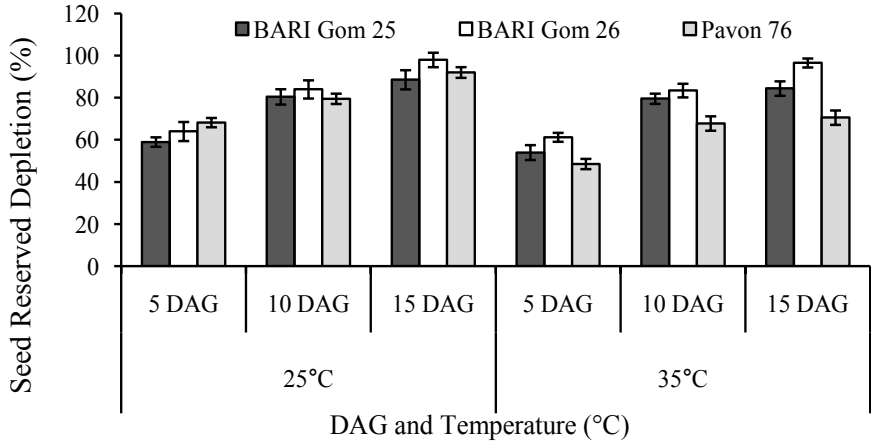

Figure 2. Seed reserved Depletion (%) of three wheat genotypes at 25˚C and 35˚C temperature at 5, 10 and 15 DAG. Vertical lines are standard errors of selected data points.

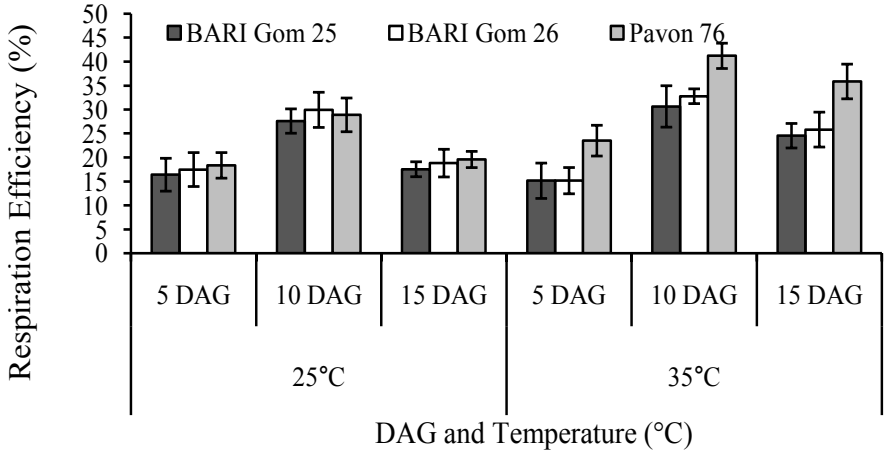

Figure 3. Respiration efficiency (%) of three wheat genotypes at 25˚C and 35˚C temperature at 5, 10 and 15 DAG. Vertical lines are standard errors of selected data points.

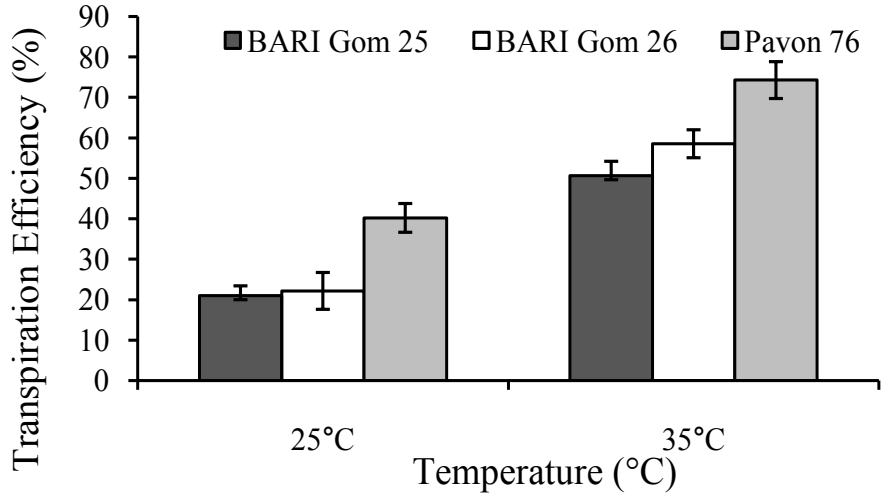

Figure 4. Transpiration efficiency (%) of three wheat genotypes at 25˚C and 35˚C temperature at 5, 10 and 15 DAG. Vertical lines are standard errors of selected data points.

more amount of seed dry matter was lost while performing respiratory and transpiration process rather than contributing to the growing seedlings under heat stress condition [26].

At 35˚C temperature trend of seedling growth found nearly same of 25˚C in BARI Gom 25 and BARI Gom 26 but it was different in Pavon 76 where seedling growth is about half of other two varieties. It was also observed that seedling growth decreased with the increase of temperature as well as days after germination (DAG) in all three wheat genotypes but maximum reduction observed in Pavon 76 (67.91%) especially at 10 to 15 DAG. The results indicated that heat stress reduced the conversion efficiency of mobilized seed reserve into seedling tissues but the degree of increase in respiratory loss of seed reserve was higher. So the degree of increase in seedling dry weight was lower at high (35˚C) temperature than under normal (25˚C) temperature. Decline in seedling growth under heat or drought stress also reported for wheat [26].

This result clearly indicated that wheat genotypes having maximum loss of respiration and transpiration at 35˚C temperature was found to produce low seedling dry matter. Growth inhibition of the developing seedling under heat stress can be a measurement of heat tolerance in growing seedlings.

Seedling growth decreased with the increase of days after germination (DAG) (**Figure 5**). Percent reduction of seedling growth found maximum (67.91%) in Pavon 76 whereas it was nearly same in BARI Gom 25 and BARI Gom 26 at both 5 - 10 DAG and 10 - 15 DAG (**Figure 6**). This result revealed that with the increase of days after germination the seed reserve is decreased which expressed as reduction of seedling growth.

Under high temperature conditions the better mobilized seed reserve, seed reserve depletion and subsequently minimum loss of respiration and transpiration collectively contributed a positive role for better seedling development in BARI Gom 25 and BARI Gom 26. There is indication that seed metabolic efficiency could be poor in Pavon 76 due to alternate oxides pathway in seed

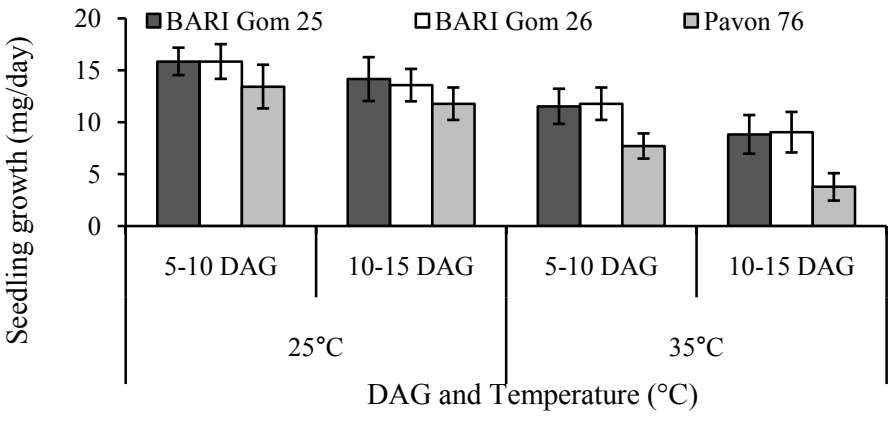

Figure 5. Seedling growth (mg/day) of three wheat genotypes at 25˚C and 35˚C temperature at 5 to 10 and 10 to 15 DAG. Vertical lines are standard errors of selected data points.

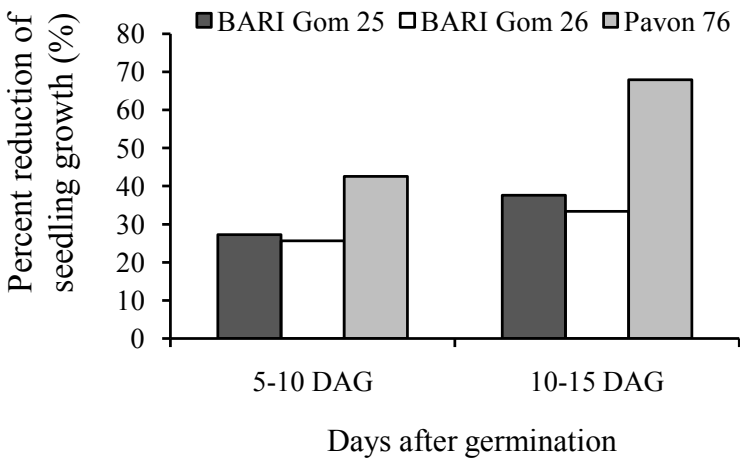

Figure 6. Percent reduction of Seedling growth (%) of three wheat genotypes at 25˚C to 35˚C temperature at 5 to 10 and 10 to 15 DAG.

respiration [17]. 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 autotrophic seedling development of plants was found to be well-associated with Mobilized Seed Reserve (MSR) and Seed Reserve Depletion (SRD) which agreed with other researchers [20] [22] and [23].

4. Discussion

The present experiment suggested that the better mobilized seed reserve, seed reserve depletion and subsequently minimum loss of respiration and transpiration during seedling development are indicators of the thermo tolerance in growing wheat seedling. Therefore, on the basis of seed metabolism and seedling growth, 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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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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