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Growth performance of spring wheat under heat stress conditions

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Key words: Heat stress; tiller; leaf area; dry matter

Abstract

Three spring wheat varieties and one advanced line were evaluated under high temperature environment to find out the heat stress tolerant variety(s) and/or genotype suitable for cultivation in rising temperature all over the Bangladesh, even in the world. The field experiment was conducted with two environments; one was normal growing environment (seeded on 30 November) and another in late seeding (heat stress) environment (seeded on 30 December) at the field of Wheat Research Centre, Bangladesh Agricultural Research Institute, Nashipur, Dinajpur, Bangladesh. The varieties and advanced line phased higher temperature during late seeding condition compared to normal sowing. The advanced line and varieties performed better in normal growing environment compared to heat stress condition. In stress environment, BARI Gom-27 produced the maximum tillers (706.5, 503.2 & 296.5 m^{-2} at 40, 60 & 80 DAS, respectively) followed by BAW-1151 and BARI Gom-28 produced the second highest at 80 DAS (287.4 m^{-2}). BAW-1151 performed the best concerning dry matter (631.3 g m^{-2} at 80 DAS), then BARI Gom-28 (622.9 g m^{-2} at 80 DAS). In addition, BAW-1151 produced the most leaf area (3536.7 cm^3 m^{-2} at 80 DAS) followed by BARI Gom-28 (3199.7 cm^3 m^{-2} at 80 DAS). Moreover, BARI Gom-28 produced the highest yield in heat stress environment (3.59 t ha^{-1}) followed by BARI Gom-27 and BARI Gom-26 (each 3.08 t ha^{-1}), but BAW-1151 had the worst (2.9 t ha^{-1}). Considering overall performance, the BARI Gom-28 can be the prominent variety for heat stress followed by BARI Gom-27 or BARI Gom-26.

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Introduction

In late sowing condition, wheat crop faces high temperature stress. Heat stress lowers the grain yield significantly. Researchers have pointed out that wheat yield is considerably affected by sowing date (Chio *et al.*, 1992; Liszewski, 1999; Michiyama *et al.*, 1998; Pecio and Wielgo, 1999). In fact, due to variation of sowing time the air temperature varies widely that affects the phenology of crop plants. On the other hand, Genetic diversity for heat tolerance in cultivated wheat is well established (Midmore *et al.*, 1984; Al-Khatib and Pausen, 1990). Different in photosynthesis under heat stress have been shown to be associated with a loss of chlorophyll and a change in a: b chlorophyll ratio due to premature leaf senescence (Al-Khatib and Paulsen, 1984; Harding *et al.,* 1990). Under heat stress, wheat crop completes its life cycle much faster than under normal temperature conditions (Nahar *et al.*, 2010; Alam *et al.*, 2013a). If the crop has a short duration consequently, it gets fewer days to accumulate assimilates during life cycle and biomass production is reduced.

Reproductive processes are remarkably affected by high temperature in most plants, which ultimately affect pre- and post-fertilization processes leading to reduce crop yield (Wahid *et al.*, 2007). Several research findings noticed that temperature below (<10°C) or above (>25°C) the optimum (12 to 25°C) alter phenology, growth and development and finally reduce the yield of existing Bangladeshi wheat varieties (Rahman *et al.*, 2009; Hossain *et al.*, 2009; Ahamed *et al.*, 2010; Nahar *et al.*, 2010; Hossain *et al.*, 2011a; Hakim *et al.*, 2012; Hossain *et al.*, 2012a; Hossain *et al.*, 2013; Alam *et al.*, 2013a). Different phenological stages differ in their sensitivity to high temperature and this depends on species and genotype as there are great inter and intra specific variations (Wollenweber *et al.*, 2003; Howarth, 2005). Heat stress is a major factor affecting the rate of plant development (Hall, 1992; 2001; Marcum, 1998; Howarth, 2005). Thus, heat is the greatest threat to food security in Bangladesh where wheat is the second most important food grain and where population is rapidly increasing (Indexmundi, 2011). The IPCC (2007); CIMMYT-ICARDA (2011); CGIAR (2009) and OECD (2003) reported that world wheat production will decrease due to global warming and developing countries like Bangladesh will be highly affected.

The global temperature lies on the path of increasing. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013) predicts that global surface temperature change for the end of the 21st century is likely to exceed 1.5°C relative to 1850 to 1900 for all RCP (Representative Concentration Pathways) scenarios except RCP2.6. The International Food Policy Research Institute (IFPRI) projections indicate that the world demand for wheat will rise from 552 million tons in 1993 to 775 million tons by 2020, and 60% in total by 2050 (Rosegrant *et al.*, 1997; Rosegrant and Agcaoili, 2010). At the same time, climate change-induced temperature increases are likely to reduce wheat production in developing countries (where around 66% of all wheat is produced) by 20-30% (Esterling *et al.*, 2007; Lobell *et al.*, 2008; Rosegrant and Agcaoili, 2010). The IPCC (2007) noticed that global climate change (GCC) will have a major impact on crop production. CIMMYT-ICARDA (2011) estimated that 20-30% of wheat yield losses will occur by 2050 in developing countries as a result of an assumed temperature increase of 2-3°C on a global scale, but these yield losses will not be fully compensated by yield gains in high latitude regions, estimated at 10-15% (OECD-FAO, 2009).

The temperature of Bangladesh also rises day after day. Bangladesh stands at the most risk of global climate change. Karmakar and Shrestha (2000) studied that the annual mean temperature of Bangladesh is 25.75°C, which is expected to rise about 0.21°C by 2050. The Organization for Economic Co-operation and Development (OECD; 2003) estimated a rise in temperature of 1.4°C by 2050 and 2.4°C by 2100 in Bangladesh. Islam (2009) estimated from 34 meteorological climate sites in Bangladesh that temperature increases over the past 100 years for all Bangladesh of 0.62°C (maximum) and 1.54°C (minimum) occurred in February. Poulton and Rawson (2011) reported that temperature in Bangladesh increased over the past two decades by 0.035°C/year. If this trend continues, temperatures will have increased 2.13°C more than 1990 levels by 2050.

Wheat occupies the second place in terms of grain production in Bangladesh (BBS, 2012) and its area is increasing consistently every year (BBS, 2012). WRC (2013) reported that wheat was cultivated in 0.417 million ha lands, grains were produced 1.26 million tons and average yield was 3.01 t ha^{-1} during 2012-13 growing season. However, according to the findings of the Wheat Research Centre, BARI, the potential yield of released varieties is 4.8-5.7 t ha^{-1} (Akhter *et al.*, 2013). Such a wide yield gap between potential yield and actual yield needs to be reduced to meet up the food deficit of the country. The reason of low yield may be due to the lack of awareness among the farmers about the use of proper agronomic management like variety, sowing time, seed rate, balanced dose of fertilizers and other associated factors of crop production (Quayyum, 1994).

A release of heat tolerant spring wheat variety is a demand of time in context of Bangladesh due to global warming. The optimum time of seeding of spring wheat in Bangladesh is from 15 to 30 November but it can delay up to 7 December in Northern part of Bangladesh due to cold weather compared as other parts of the country. Generally, the farmer of our country cultivates wheat in winter season after harvesting of transplanted (T) *aman* rice. The rice cultivation fully depends on natural rainfall. Due to lack of timely or sufficient rainfall, T. *aman* rice can't be planted in time. Ultimately harvesting is done lately. So farmers can't sow seeds in optimum time. Most of the farmers sow wheat seeds on last 15 days of December. Result, wheat crop faces high temperature during grain filling. As plant responses to high temperature stress varies with its species, varieties, locations and phenology, it is essential to observe the performance of varieties and advanced lines in respect of growth parameters and yield in heat stress condition. Therefore, the trial was conducted to evaluate the performance of three recently released wheat varieties and one advanced line in respect of tillers, leaf area and dry matter production as well as yield in normal and heat stress environments

Materials and methods

Experimental site

The trial was carried out during *Rabi* season of 2011-12 and 2012-13 (from November to April) in the research farm of WRC, BARI, Nashipur, Dinajpur, Bangladesh. The soil of the experimental field belongs to under the 'Old Himalayan Piedmont Plain' designated as Agro Ecological Zone (AEZ) # 1 (FAO/UNDP, 1988) characterized by flood free highland, fine in texture (Sandy loam and Silty loam), poor in organic matter content and strongly acidic (pH ranges from 4.5 to 5.5) (WRC, 2009). It is situated in the northern part of Bangladesh and geographically the area lies between 25°38" N and 88°41" E, and 38.20 m above from the sea level.

Treatments and design

The treatments were two dates of sowing viz. 30 November (D_1) & 30 December (D_2) and four genotypes viz. BARI Gom-26 (V_1), BAW (Bangladesh Advanced Wheat)-1151 (V_2), BARI Gom-27 (V_3) & BARI Gom-28 (V_4). The experimental design was Split-plot. Sowing times were accommodated in main plot and the genotypes were assigned to subplot. The unit plot size was 4×4 m.

Land preparation and fertilizers application

The land was prepared with four times ploughing horizontally with power tiller followed by laddering in 12-15 cm depth. Each of the subplots was fertilized @ 120-30-60-20-1-4.5-5000 kg ha^{-1} as N-P-K-S-B-Zn-cowdung. Urea, Triple superphosphate (TSP), Muriate of potash (MoP), Gypsum, Boric acid and Zinc sulphate were used as the source of N, P, K, S, B and Zn, respectively. All of TSP, MoP, gypsum, boric acid, zinc sulphate, cowdung and 2/3 3rd of urea were applied as basal dose during final land preparation. Seeds were treated with Provax 200 WP @ 3g/Kg seeds which contains Carboxin and Thiram. After well preparation of land, seeds @ 140 kg ha^{-1} of each genotype were sown continuously in 20 cm apart rows in 2.5-5.0 cm depth. One sowing was performed on 30 November (Normal growing environment; NS) and another on 30 December (heat stress environment; LS).

Intercultural operations

The rest amount of urea was applied as top dress at crown root initiation (CRI) stage followed by first irrigation (at 20 Days after sowing; DAS). The second irrigation was applied at late booting stage (55 DAS) and another applied at early grain filling stage (75 DAS). 2 extra irrigations were applied in case of late seeding condition. The land was kept from weeds by hand weeding.

Data recording and analysis

The data of numbers of tillers, leaf area and dry matter were taken at 20, 40, 60 and 80 DAS of each subplot. The number of tillers was counted from randomly selected five lines (each length 1.0 m) in the field standing crop. To measure leaf area, the plants (with dews) were uprooted in early morning from 1.0 m of a line of each subplot. The leaves were cut off with scissors from culm, and then measured with Leaf area meter (Model-CI-202, CID Inc., USA). After measuring leaf area, all parts (leaves, culm) of plants were packed with thin brown paper made envelope and kept inside of electric oven at 72 ^{0}C until they reached at constant weight. At this condition, dried materials were weighed with electric digital balance and expressed into g m^{-2}. After full maturity, the crop was harvested plot wise according to treatments. Sample plants were harvested separately with sickle from an area of 2.4×3 m (i.e., 3 m long, 12 middle rows) of each subplot avoiding border effects. The harvested crop of each subplot was bundled separately, tagged and taken to a threshing floor. The bundles were thoroughly dried in bright sunshine until fully dried, then weighed and threshed. Threshed grains of each subplot were again dried with sunshine and weighed; lastly grain yield was converted into t ha^{-1}. To obtain the actual yield of all genotypes, grain yield weight was adjusted at 12% moisture by the following equation (Hellevang, 1995):

$$Y(M_2) = \frac{100\text{-}M_1}{100\text{-}M_2} \times Y(M_1)$$

Where, $Y(M_2)$ = weight of grain at expected moisture percentage (generally 12% for wheat)

$Y(M_1)$ = weight of grain at present moisture percentage

M_1 = present moisture percentage

M_2 = expected moisture percentage

Temperature data was recorded regularly by HOBO U12 Family of Data Loggers (MicroDAQ.com) at the meteorological station, WRC, BARI, Nashipur, Dinajpur, Bangladesh and was presented in Fig. 1. Data were analyzed using MSTAT-C (Russell, 1994). Treatment means were compared for significance by the least significant difference (LSD) test at P ≤ 0.05

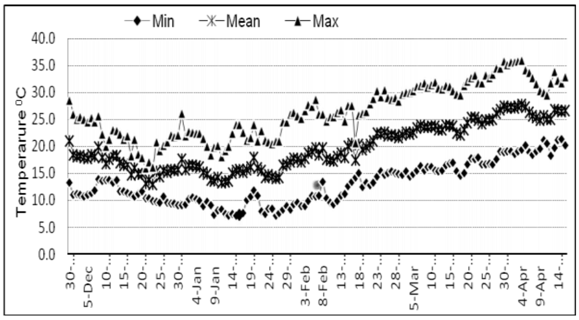

Fig. 1. Minimum, maximum and mean temperature during the wheat growing period (Source: Meteorological Station, Wheat Research Centre, BARI, Nashipur, Dinajpur-5200, Bangladesh).

Results and discussion

Weather condition during the trial

It was observed that in the sowing of 30 November, the minimum (min), maximum (max) and mean temperature was from 7-19°C, 15-25°C & 12-17°C at vegetative period (from 1 Dec to15 Jan); were 7-10°C, 20-28°C & 14-20°C at reproductive period (from 16 Jan to 13 Feb) and were from 11-17°C, 24-31°C & 17-19°C at grain filling period (from 14 Feb to 15 Mar), respectively. On the other hand, during late sowing environment the min, max and mean temperature were from 7-15°C, 18-28°C &13-17°C at vegetative stage (from 31 Dec to 18 Feb), were from 12-21°C, 25-31°C & 19-24°C at reproductive period (from 19 Feb to 9 Mar) and were from 15-19°C, 24.5-35.5°C & 21.5-

25.5°C at grain filling period (from 10 to 29 Mar), respectively (Fig. 1). So, the late planted set of wheat crop obviously phased high temperature stress in their growing period. This high temperature altered the growth pattern and dry matter accumulation in wheat genotypes which were reflected in measuring growth parameters of wheat genotypes in two spell seeding times.

Tiller production

Number of tiller per meter square (m^{-2}) produced by various genotypes in different days was statistically highly significant different. Spring wheat genotypes began to produce tiller at just before 20 DAS (Day after sowing). It was the preliminary stage of tiller production. The maximum tillers were produced by various genotypes at 40 DAS (Fig. 2). Then this period, tiller's mortality had started and number of tillers was being reduced. In the study, at 20 DAS the maximum tillers were produced by BAW-1151 in both seeding conditions, then by BARI Gom-27 (Fig. 2). At 40 DAS all genotypes produced more tillers in LS condition than in NS. At this time, the BARI Gom-27 produced the maximum tillers (706.5) followed by BARI Gom-26 (698.3) in LS and also in NS environment the maximum tiller was produced by BAW-1151 (546.6) followed by BARI Gom-26 (512.8) (Fig. 2). This might be caused due to higher temperature from 20 to 40 DAS in LS condition than NS. The fig. 1 showed in this period that the mean temperature was from 12-17°C in LS, but from 14 to 20°C in NS which affected the tiller production in this time of all genotypes. All genotypes also more tillers in LS than in NS at 60 DAS. At 80 DAS, the tiller mortality reached at static condition. In this period, the number of tillers of all genotypes was observed higher in NS compared to LS condition. The BARI Gom-26 produced more tillers (324.3) in NS, but lower tiller number (255.1) in LS. The BARI Gom-28 produced the second highest tillers (287.4) in LS condition amoung the genotypes where it was lower in (305.5) NS condition. The fig. 5 showed that finally (at 80 DAS) tiller reduction rate was the lowest in BARI Gom-27 (3.5%) in LS and then in BARI Gom-28 (5.9%) compared to NS. Moreover, tiller reduction rate was the highest inV_1. It indicated that the BARI Gom-27 had the more tiller producing capability in high temperature stress than normal growing environment due to genetic makeup, then BARI Gom-28.

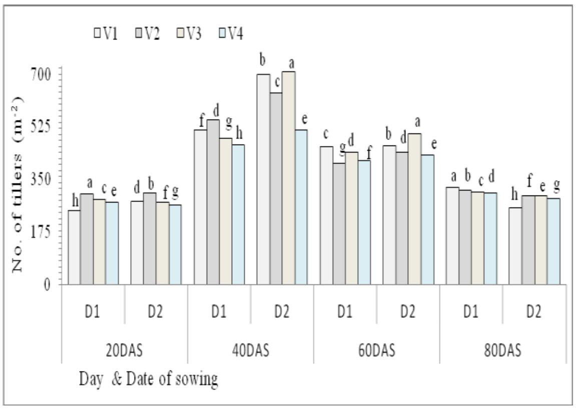

Fig. 2. Number of tillers (m^{-2}) of four spring wheat genotypes when seeded under normal and late growing environments. Mean (±SD) was calculated from three replicates for each treatment. Bars with different letters are significantly different at P≤0.05 (Duncan's test) (V_1 = BARI Gom-26, V_2 = BAW-1151, V_3 = BARI Gom-27, V_4 = BARI Gom-28; D_1 = 30 November, D_2 = 30 December)

Since genetic effects are dependent on environmental effects, most genotypes do not perform satisfactorily in all environments. Moreover when an interaction between a genotype and the environment occurs, the relative ranking of cultivars for yield often differs when genotypes are compared over a series of environments and/or years (Al-Otayk, 2010). These results indicate that the genotypes studied responded differently to different environmental conditions suggesting the importance of assessing genotypes under different environments in order to identify the best genetic make up for a particular environment. Similar results were observed by El-Morshidy *et al.*, 2001; Abd-El-Majeed *et al.*, 2005 and Tawfelis, 2006. The findings of the research in respect of number of tillers (Fig. 2) showed a parallel resemblance to the following findings in wheat: In the late sowing environment, soil temperature can be expected to be below 10°C, which affects seed germination and stand establishment, ultimately producing few tillers and finally decreasing grain yield (Farooq *et al.*, 2008; Hakim *et al.*, 2012; Hossain *et al.*, 2013). Hossain *et* *al.* (2013) and Ahamed *et al.* (2010) found that spring wheat seeded on the last week of December which crop is exposed to an unfavorable environment (high temperature) at the vegetative stage in sub-tropical countries like Bangladesh, India and Pakistan resulting the crop becomes thin and produces fewer tillers, ultimately reducing the yield of late sowing crop.

Dry matter production

Treatment means were also highly significant different in both sowing conditions. Dry matter production (DM) of all genotypes in NS environment was always higher than those genotypes seeded in LS except DM produced in LS by all genotypes at 60 DAS (Fig. 3). Because, the comparatively lower temperature remained during early vegetative stage in LS than in NS condition resulting in poor germination, lower plant population, loss of viable leaf area and a decrease in green leaf duration, ultimately hampering photosynthesis (Fig. 3). DM produced at 20 DAS by all genotypes in both spell seedings is statistically difference.

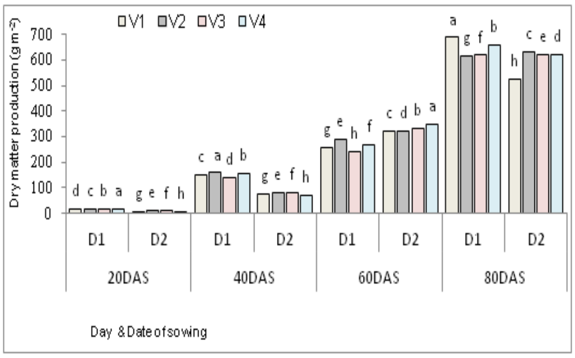

Fig. 3. Dry matter production (g m^{-2}) of 4 spring wheat genotypes when seeded under normal and late growing environments. Mean (±SD) was calculated from three replicates for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ (LSD test) (V_1 = BARI Gom-26, V_2 = BAW-1151, V_3 = BARI Gom-27, V_4 = BARI Gom-28; D_1=30 November, D_2 = 30 December)

The variety BARI Gom-28 produced the highest DM (19.5 g m^{-2}) at 20 DAS in NS, but the lowest (8.0) in LS condition (Fig. 3). The similar trend dry matter production of all genotypes like at 20 DAS was observed at 40 DAS. It was observed that the dry matter production in both sowing was increased along with passage of time. At 60 DAS, DM was produced higher by all genotypes in LS than in NS environment (Fig. 3). It might be the reason of higher tiller production in LS at 40 and 60 DAS than NS (Fig. 2). At 80 DAS, BARI Gom-26 produced the highest DM in NS, but the lowest in LS. On the other hand, the lowest DM was produced by BAW-1151 (615.9) in NS, but the highest amount produced (631.3) in NS. DM production reduction rate at 80 DAS was the lowest in BARI Gom-28, (5.3%) but the highest in BARI Gom-26 (23.9%) in LS compared to NS (Fig. 5).

Heat stress is one of the most important causes of reduced yield and dry matter production in many crops, including maize and wheat (Giaveno and Ferrero, 2003). The major impact of high temperatures on shoot growth is a severe reduction in the length of the first internodes resulting in the premature death of plants (Hall, 1992). Ahamed *et al.* (2010); Hossain *et al.* (2013) and Alam *et al.* (2013a) noticed that when wheat was grown from sowing to maturity at high temperatures, phenological development was rapid, leading to poor biomass production and sterility, and consequently poor yield. Guttieri *et al.* (2001) reported that dry matter accumulation decreased due to a decrease in kernel number, leaf number, kernel weight and acceleration of leaf senescence. Our findings related to dry matter reduction (Fig. 3 & 5) in stress conditions are in agreement with observations made by Ahamed *et al.* (2010) and Hossain *et al.* (2013).

Leaf area production

Leaf area (LA) production was statistically significant difference in both sowing conditions. LA was always produced much by all genotypes in NS than in LS since the temperature prevailed more in LS than in NS (Fig. 1 & 4). In the study, it was observed that at 20 and 80 DAS, BARI Gom-27 produced the most LA in NS, but in LS by BAW-1151. In addition, the BARI Gom-28 produced the second most LA at 80 DAS (3199.7 cm^3 m^{-2}) in LS. Oppositely, at 40 and 60 DAS, the highest LA was produced by BAW-1151 in NS, also at 40 DAS in LS, but BARI Gom-26 produced the highest LA at 60 DAS in LS. Comparing normal growing environment to late growing condition, the LA reduction rate was the lowest in BARI Gom-26 except at 20 DAS and the highest in BARI Gom-27 except at 40 DAS (Fig. 5).

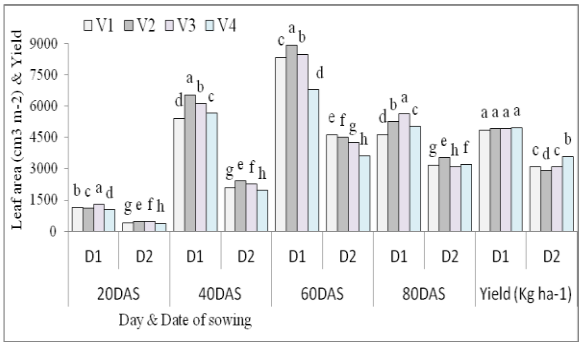

Fig. 4. Leaf area (cm³ m⁻²) and yield (Kg ha⁻¹) of four spring wheat genotypes when seeded under normal and late growing environments. Mean (±SD) was calculated from three replicates for each treatment. Bars with different letters are significantly different at P≤0.05 (LSD test) (V_1 = BARI Gom-26, V_2 = BAW-1151, V_3 = BARI Gom-27, V_4 = BARI Gom-28; D_1 = 30 November, D_2 = 30 December)

Leaf is one of the most important parts of plant body which is responsible for photosynthesis, transpiration and gaseous exchange. High temperature (41°C) causes a decrease in the potential photosynthetic rate in both heat resistant and susceptible variety (Volkova and Koshin, 1984). Ubaidullah *et al.* (2006) concluded that heat stress causes reduction in leaf area which is the ultimate result of reduced leaf length and leaf breadth. In the study LA was significantly affected by late sowing (high temperature or heat stress) (Fig. 4). High temperatures can cause considerable pre- and post-harvest damages, including scorching of leaves and twigs, sunburns on leaves, branches and stems, leaf senescence and abscission, shoot and root growth inhibition, fruit discoloration and damage, and reduced yield (Guilioni *et al.*, 1997; Ismail and Hall, 1990; Vollenweider and Gunthardt-Goerg, 2005). Heat stress accelerated the decline in viable leaf blade area and photosynthetic activity per unit leaf area (Al-Khatib and Pallsen, 1984). Higher temperature enhances leaf senescence causing reduction in green leaf area and number during reproductive stages (Al-Khatib and Pallsen, 1984; Randall and Moss, 1990; Stone *et al.*, 1995, Wardlaw and Moncur, 1995; Altenbach *et al.*, 2003). The leaf area that is the photosynthetic area has a great effect on the amount of photosynthesis. So, the varieties with higher leaf area even in high temperature will be benefited in this sense.

Grain Yield

In the study, BARI Gom-28 produced the highest yield (4.97 t ha⁻¹) while 4.93 t ha⁻¹ was produced by each BAW-1151 & BARI Gom-27 and BARI Gom-27 produced the lowest (4.85 t ha⁻¹) which were statistical significantly indifference with each other in NS. During grain filling period the higher temperature remained in LS (mean temperature from 21.5 to 25.5 °C during 10 to 29 March) than NS (mean temperature from 17-19 °C during 13 February to 15 March) which influenced carbohydrates assimilation from sources to sink (Fig. 1). In high temperature, the yield reduction was the lowest in BARI Gom-28 (28%) followed by BARI Gom-26 and BARI Gom-27 (36.7% in each), but the highest in BAW-1151 (40.8%) in LS compared to NS (Fig. 5). The genotype BARI Gom-28 also produced the highest yield (3.59 t ha⁻¹) in LS while BAW-1151 and BARI Gom-27 each had the second lowest (3.08 t ha⁻¹) (Fig. 4). Numbers of tillers, DM and LA production have the combined influence on the grain yield production. In addition, in tropical climates like Bangladesh, excess of radiation and high temperatures are often the most limiting factors affecting plant growth and final crop yield (Wahid *et al.*, 2007; Hossain *et al.*, 2009; Hossain *et al.*, 2013; Alam *et al.*, 2013a; Alam *et al.*, 2013c). Heat stress, singly or in combination with drought, is a common constraint during anthesis and grain filling stages in many cereal crops of temperate regions. For example, heat stress extended the duration of grain filling with reduction in kernel growth leading to losses in kernel density and weight by up to 7% in spring wheat (Guilioni *et al.*, 2003).

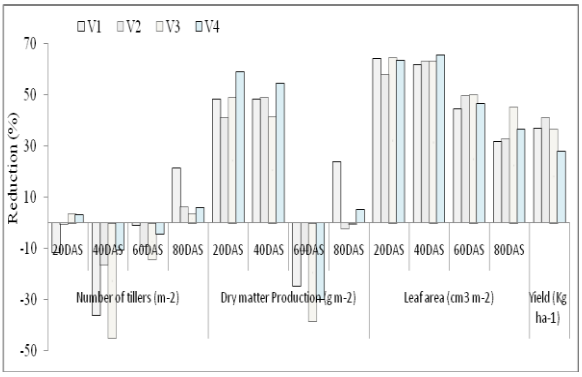

Fig. 5. Reduction rate (%) of tillers, dry matter & leaf area production and yield of four spring wheat genotypes in late sowing compared to normal growing condition, but bar (s) opposite direction indicated they were increased in late seeding than normal seeding condition (V_1 = BARI Gom-26, V_2 = BAW-1151, V_3 = BARI Gom-27, V_4 = BARI Gom-28; D_1 = 30 November, D_2 = 30 December)

In Bangladesh, early spring wheat faces high temperature stress at the vegetative stage and late wheat is affected at two stages: germination by low temperature stress (<10°C) and at the reproductive stage by high temperature (>25°C), which ultimately affects grain yield (Hossain *et al.*, 2011a; Hossain *et al.*, 2012a; Hossain *et al.*, 2012c). Hossain *et al.* (2013) and Nahar *et al.* (2010) also observed yield reduction of five genotypes ('Sourav', 'Shatabdi', 'Sufi', 'Bijoy' and 'Prodip') under late heat stress condition. Buriro *et al.* (2011) also evaluated five wheat genotypes ('TJ-83', 'Imdad-2005', 'Abadgar-93', 'Moomal-2000' and 'Mehran-89') under heat stress. Among these genotypes,'Moomal-2000' and 'Mehran-89' performed better under heat stress (20-30°C air temperature) while the remaining three cultivars were found to be heat-sensitive. Every 1°C rise in temperature above the optimum (15°C) reduces yield by 3-4% per spike (Wardlaw *et al.*, 1989a; Wardlaw *et al.*, 1989b). Hasan (2002) reported that grain yield was found to be reduced by about 2.6 to 5.8% in heat tolerant and 7.2% in heat sensitive genotype for each 1°C rise in average mean air temperature from normal growing condition during anthesis to maturity. In our research, fluctuations in weather conditions (Fig. 1) were reflected in phenology, crop growth and development (Fig. 2, 3 & 4) and ultimately grain yield, which is common to several crops (Martiniello and Teixeira da Silva, 2011a; Hossain *et al.*, 2013). Previous study findings also indicated that high temperature significantly decreased all traits, especially grain yield (by 46.63%), 1000 kernel weight (by 20.61%) and grain filling duration (by 20.42%) under high temperature stress (>25 to 30°C) (Modarresi *et al.*, 2010). The similar result was found by Nahar *et al.*, 2010, Hossain *et al.*, 2011a, Hossain *et al.*, 2012a, Hakim *et al.*, 2012, Alam *et al.*, 2013a and Alam *et al.*, 2013c.

Conclusion

It was concluded that the heat stress significantly influenced tiller, leaf growth and dry matter production as well as the yield of wheat cultivars. BARI Gom-28 performed better in respect of tiller, dry matter and leaf area production as well as the yield in heat stress condition followed by BARI Gom-27 or BARI Gom-26. Considering overall performance, the BARI Gom-28 can be the prominent variety for cultivation in heat stress followed by BARI Gom-27 or BARI Gom-26.

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