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Performance of different genotypes of wheat (*Triticum aestivum* L.) in heat stress conditions

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Abstract

The experiment was carried out in the research field of Wheat Research Centre (WRC), Bangladesh Agricultural Research institute (BARI), Nashipur, Dinajpur, Bangladesh in the *Rabi* season (from November, 2012 to April. 2013), 2012-13 to observe the effect of heat stress in irrigated late sowing conditions (ILS) on the yield and yield attributes of different wheat genotypes and thereby to search heat tolerant genotypes. The treatments were 4 dates of sowing viz. 30 Nov (D_1), 15 Dec (D_2), 30 Dec (D_3) & 14 Jan (D_4) and 4 genotypes viz. BARI Gom 26 (V_1), BAW 1051 (V_2), BAW 1120 (V_3) & BAW 1141 (V_4) . The genotypes V_2, V_3, and V_4 were taken as test genotypes and V_1 as check. The design was split-plot with 3 replications. In ILS conditions, all genotypes faced high temperature in different stages which hampered the normal growth of the yield contributing attributes resulting the extreme yield reduction of all except V_4. But, all yield contributing characters of V_4 performed the best in heat stress condition. The yield reduction percentage was the lowest in V_4 (16.6-31.5%) of all genotypes. The advanced line, V_4 can be sown up to 15 December as heat tolerant genotypes to get yield more than 3.5 t ha^{-1} as the most heat tolerant and one of the shortest life span genotypes of all.

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Introduction

Wheat is the most nutritious food grain of all cereal grains in the world. According to its genotypic adaptability it grows world-wide. Due to various reasons, it is the stable food of the universe people and the second main food of Bangladeshi people also. Accounting for a fifth of humanity's food, wheat is also second after rice as a source of calories in the diets of consumers in developing countries and is the first as a source of protein (Braun *et al.,* 2010). Wheat is an especially critical "staff of life" for the approximately 1.2 billion "wheat-dependent" to 2.5 billion "wheat-consuming" poor-men, women and children-who live on less than $ US 2/day (FAOSTAT, 2010). 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).

The temperature of Bangladesh rises day by day. The annual mean temperature of Bangladesh is 25.75°C, which is expected to rise about 0.21°C by 2050 (Karmakar and Shrestha, 2000). 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.

The heat tolerant wheat variety release is a demand of time of Bangladesh due to global warming or from the insight of the worst effect aspect of climate change. The optimum time of wheat seeding is 15 to 30 November in our country but it can delay up to 7 December in Northern part of Bangladesh due to cold weather compared to that of other parts of the country. Generally, the farmer of our country cultivates wheat in *Rabi* season after harvesting of T. *aman* rice. This 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 wheat seeds in optimum time. Most of the farmers sow wheat seeds on the last 15 days of December.

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; Reynolds *et al.,* 1994). 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 (Reynolds *et al.,* 1985). 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 fertilization 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 (Hakim *et al.*, 2012; Hossain *et al.,* 2009, 2011, 2012a, 2012b, 2012c; Nahar *et al.,* 2010; Rahman *et al.,* 2009). 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.

Recently, some high yielding advanced genotypes were identified by Barma *et al.,* (2008). As plant responses to high temperature varies with plant species, varieties, locations and phenological stages, it is essential to observe the performance of advanced genotypes as heat tolerant. Therefore, the trial was undertaken to identify heat tolerant suitable genotype (s) for growing in ILS conditions.

Materials and methods

Experimental site

The experiment was carried out in the *Rabi* season of 2012-13 (from November to April) in the research field of Wheat Research Centre (WRC), Bangladesh Agricultural Research institute (BARI), Nashipur, Dinajpur, Bangladesh. The soil of the experimental field belongs to under the old himalayan piedmont plain designated as 'Agro-Ecological Zone' # 3 (FAO/UNDP, 1988), characterized by flood free highland, fine in texture (Sandy loam and Silty loam), poor in organic matter content and strongly acidic (P^H ranges from 4.5 to 5.5) (WRC, 2009). It is situated in northern part of Bangladesh and geographically the area lies between 25°38" N, 88°41" E and 38.20 m above from sea level.

Treatments and design

Three advanced genotypes viz. BAW 1051 (V2), BAW 1120 (V3) and BAW 1141 (V4) were used as test genotypes and BARI Gom (V1) as check. One irrigated timely sowing (ITS) and three irrigated late sowings (ILS) were imposed to provide terminal high temperature over the test genotypes. The ITS was Nov 30 (D1) and three ILSs were Dec 15 (D_2), Dec 30 (D_3) & Jan 14 (D_4). Sowing times were accommodated in main-plot and the test genotypes were assigned to sub-plot. The unit plot size was 4 × 5 m.

Fertilizering and Seeding

The land was ploughed four times horizontally with power tiller followed by 12-15 cm depth. Each of the sub-plots was fertilized @ 100-27-50-20-1-4.5-5000 kg ha^{-1} as N-P-K-S-B-Zn-Cow dung. The source of N, P, K, S, B and Zn were used as Urea, TSP, MoP, Gypsum, Boric acid and Zinc sulphate, respectively. All of TSP, MoP, Gypsum, Boric acid, Zinc Sulphate, Cow dung and two-third of Urea were applied as basal dose during final land preparation. Seeds were treated with Provax 200 WP @ 3g/Kg seed, is a seed-treated fungicide containing Carboxin and Thiram. Research conducted at the WRC (2009) indicated that Provax-200 WP is a perfect match for controlling fungi in Bangladesh soil, for achieving excellent seed germination and for protecting wheat cultivars from fungal infection during the seedling stage. This fungicide is marketed by Hossain Enterprise CC Bangladesh Ltd., an agrochemical company engaged in crop protection and seed treatment, in association with Chemtura Corp., USA. After well preparation of land seeds @ 120 kg ha^{-1} of each variety/genotypes were sown continuously in lines 20 cm apart in 3-4 cm depth.

Other intercultural operations

Rest amount of Urea was applied as top-dress at CRI (Crown Root Initiation) stage followed by first irrigation (Zadoks stage 2.1). The second irrigation was applied at late booting stage (Zadoks stage 4.5) and another was applied at early grain filling stage (Zadoks stage 7.7). Each sub-plot was kept free from weeds by applying affinity @ 2.5 g/litre water at 27 DAS after 1st irrigation. Tilt was sprayed two times @ 0.5 ml/litre water, one just before spike initiation and another was applied 15 days after full heading to control fungal disease, Bipolaris leaf blight (BpLB) caused by fungus, *Bipolaris sorokiniana*. Each of genotypes was harvested after its maturity.

Data collection and their processing

The crop was harvested plot-wise at full maturity according to treatments. Before harvesting, spikes were counted in one m length from randomized selected 5 rows of sub-plot.

Sample plants were harvested separately with sickle from an area of 3 × 3 m (i.e., 3 m long, 15 middle rows), avoiding border effects. The harvested sample crop of each sub-plot was bundled separately, tagged and taken to a threshing floor. The bundles were thoroughly dried under bright sunshine until fully dried, then weighed and threshed. Threshed grains of each sub-plot were again dried with sunshine and weighed; lastly grain yield was converted into t ha^{-1}. On the other hand, 10 plants were chosen randomly outside sample area from standing crop of the field to measure spike length (cm), to count spikelet (s) $spike^{-1}$ and grain (s) $spike^{-1}$. Thousand grains was counted and weighed, expressed in gram (g).

To obtain the actual yield of all genotypes, grain yield weight was adjusted at 12% moisture by the following equation (Hellevang, 1995):

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

Where, Y (M2) = weight of grain at expected moisture percentage (generally 12% for wheat); Y (M1) = weight of grain at present moisture percentage; M1 = present moisture percentage; M2 = expected moisture percentage.

Temperature data was recorded regularly by HOBO U12 Family of Data Loggers (MicroDAQ.com) at the meteorological station, WRC, Nashipur, Dinajpur, Bangladesh and was presented in Fig. 1.

Data was analyzed using MSTAT-C (Russell, 1994). Treatment means were compared for significance by the least significant difference (LSD) test at $p = 0.05$.

Result and discussion

Spike m^{-2}

Spike density is one of the most important yield contributing factors for wheat yield production. To get yield 5 t ha^{-1}, 500 effective spikes must be produced per square metre (Rawson *et al.,* 2000). It may be varied due to different stress conditions.

In this study, both the main effect of terminal high temperature forced by sowing times and genotypes was significant on spike density. Spike density decreased with the delay of sowings. Under irrigated timely sowing (ITS) condition, BAW 1120 succeeded to produce significantly the maximum number (347) of spike per unit area (Table 1). On the contrary, minimum number (281) of spike m^{-2} was observed in BARI gom 26. The genotype BAW 1051 produced second highest number (312) of spike m^{-2} and the value was statistically identical to the value (308) noted from BAW 1141. The genotypes, BAW 1120 also resulted in higher number of spikes ILS conditions (Spike m^{-2} 334 in D_2, 311 in D_3 and also 311 in D_4 seeding). In the very late sowing condition (D_4), all advanced genotypes produced higher spikes per unit area than that of the recently released variety, BARI Gom 26 (Table 1). Among the advanced genotypes, BAW 1120 and BAW 1141 performed better both in ITS and ILS conditions.

Moreover, spike reduction percentage per square meter was the highest in D_4 seeding (15.3%) of all ILS conditions in BAW 1141 (Fig. 2) while it was 11.4 (%) in D_2 and 13.0 (%) in D_3 sowing compared to ITS condition (D_1). Because, with the passing of day, temperature was being increased gradually (Fig. 1). During D_4 growth period, minimum, maximum & mean temperature and relative humidity (%) prevailed 13.3, 27.3 & 15.9 °C and 75.8% RH while those were 12.8, 26.4 & 14.9 °C and 77.6% RH during D_1 growth period. But, spike production of BARI Gom 26 and BAW 1051 was increased in D_2 seeding compared to those of D_1 sowing. Perhaps, those genotypes were positively sensitive to cold temperature and high RH (%). The similar result was found by Hossain *et al.,* (2012).

Spike length (cm)

The highest spike length was observed in ITS condition (10.6 cm in V_4) and the lowest was in D3 and D4 seeding (9.7 cm in V_1 each) (Table 2). It is noticeable that the spike length was reduced gradually across the late of sowing time.

It can be occurred due to high temperature as it reduces the life span of wheat (Reynolds *et al.*, 1985). On an averaged of genotypes performance, the biggest spike length was determined in BAW 1141 (10.6 cm) from D_1 seeding. The very high spike length reduction (%) was observed in BARI Gom 26 (6%) seeded on D_4 compared to normal sowing (D_1) (Fig. 3).

Spikelet spike^{-1}

The number of spikelet per spike is another important factor to get higher yield. In ILS condition, the plant is exposed to extremely high temperature which reduces the pollen viability and dries the stigma causing pollination hampered. In ITS condition, the highest spikelet was attained from BAW 1141 (15.4) and the lowest from BAW 1051 (14.1). But the highest spikelet spike^{-1} was counted from BAW 1051 while it was seeded on 15 Dec and from BAW 1141 (16.1) seeded on 30 Dec. It is cited that along with the late sowing, all genotypes produced lower spikelet spike^{-1} except some cases (Table 3). Spikelet spike^{-1} reduction (%) was higher in BARI Gom 26 (7.8-15.7%) in all ILS conditions compared to ITS condition (Fig. 4). In case of BAW 1051, the production of spikelet spike^{-1} was an increasing pattern in all ILS conditions compared to ITS condition. This increasing trend was 4.3-9.2%.

Grains spike^{-1}

Number of grains spike^{-1} is also one of the major criteria to influence grain yield of wheat. Heat stress, singly or in combination with drought, it is common constraint during anthesis and grain filling stages in many cereal crops of temperate region (Nahar, *et al.*, 2010). In this study, terminal high temperature imposed by late sowings had significant effect on number of grains spike^{-1} (Table 4). Among the tested genotypes, BARI Gom 26 significantly resulted in the highest number (46.7) of grains spike^{-1} averaged over sowing times and other genotypes performed similarly. Here, all genotypes' production of grains spike^{-1} lower in all late seeding conditions without BAW 1051 in D2, BAW 1120 and BAW 1141 in D3 seeding. In these sowing, the production of grains spike^{-1} was being increased. BAW 1141 produced 6.9, 6.0 and 5.8% higher number grains spike^{-1} over BAW 1120, BARI Gom 26 and BAW 1051, respectively. Due to late sowings (D_2, D_3, D_4) the number of grains spike^{-1} was reduced by 3.8-5.0%. 1.1-14.7 % and 0.7-18.4%, respectively over ITS condition. In ILS conditions, higher temperature during anthesis and maturity period reduced number of grains spike^{-1}(Table 4 and Fig. 1 & 5). This finding is in close conformity with findings of Guilioni *et al.* (2003). They point out that kernel density and weight is lost by up to 7% in spring wheat due heat stress.

Thousand grain weight (TGW)

TGW is the most important factor of all yield contributing characters. It plays a vital role to increase the yield of any genotype sown in any time. In the present study, it was also influenced by the terminal high temperature imposed by late sowing times. TGW averaged over genotypes also decreased with the delay of sowing times. The maximum TGW (50.2 g) was record from D_1 seeding of BAW 1141 (Table 5).

All genotypes performed better in ITS condition. In case of all genotypes, TGW was decreased along with the delay sowing. Because, temperature was increased and RH (%) was decreased with the delay seeding (Fig. 1). It is remarkable that of BAW 1141 produced the highest TGW (39.4-45.3 g) in all ILS conditions except 45.7 and 43.6 g produced from BAW 1051 seeded on 30 Dec and 14 Jan, respectively (Table 5). In very late seeding (Jan 14), TGW of all genotypes was severely decreased. TGW reduction (%) was observed from 21. 5 to 25.4% in D_2 seeding compared to D_1 seeding (Fig. 6). BAW 1120 exhibited the highest TGW reduction (%) in all ILS conditions (6.1-25.4%) and was the lowest in BAW 1051 (0.2%) in D_2 seeding compared to ITS condition. This genotype's TGW was increased (3.6-8.6%) in between D3 and D4 sowing conditions compared to timely sowing. Similar result was found out by Chio *et al.,* 1992; Liszewski, 1999; Michiyama *et al.,* 1998; & Pecio and Wielgo, 1999.

Table 1. Effect of terminal high temperature on spike density (m^{-2}) of wheat genotypes (V).

D × V	D_1	D_2	D_3	D_4
V_1	281	297	277	256
V_2	312	322	261	286
V_3	347	334	311	311
V_4	308	273	268	261
LSD (0.05)	=25.2	CV (%)	=3.75	

D_1 = 30 Nov, D_2 = 15 Dec, D_3 = 30 Dec, D_4 = 14 Jan, V_1 = BARI Gom 26, V_2 = BAW 1051, V_3 = BAW 1120, V_4= BAW 1141, LSD = Least significance difference, CV = Coefficient of variance

Table 2. Effect of terminal high temperature on spike length (cm) of wheat genotypes (V) imposed by late sowing times (D).

D × V	D_1	D_2	D_3	D_4
V_1	10.4	10.4	9.7	9.7
V_2	10.5	10.5	10.4	10.3
V_3	10.2	10.2	10.2	10
V_4	10.6	10.4	10.2	10.1
LSD(0.05)	=0.60	CV (%)	=2.55	

D_1 = 30 Nov, D_2 = 15 Dec, D_3 = 30 Dec, D_4 = 14 Jan, V_1 = BARI Gom 26, V_2 = BAW 1051, V_3 = BAW 1120, V_4= BAW 1141, LSD = Least significance difference, CV = Coefficient of variance

Grain yield

Wheat is the most temperature sensitive cereal crop of all. In Bangladesh, early wheat faces high temperature stress at the vegetative stage and LS (Late sowing) 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 GY (Hossain *et al.*, 2011; 2012c). Every 1 °C rise in temperature above the optimum (15°C) reduces yield by 3-4% per spike (Wardlaw *et al.*, 1989a; 1989b). In ITS condition, all the genotypes resulted in significantly higher grain yield and thereafter yield decreased with the delay of sowing times. The yield of all genotypes recorded from ITS condition was significantly higher than those of all ILS conditions. Under ITS condition, BARI Gom 26 produced significantly the highest grain yield (4.96 t ha^{-1}) (Table 6). This yield was statistically identical to the yield noted from other genotypes (4.67-4.92 t ha^{-1}).

Table 3. Effect of terminal high temperature on spikelet spike^{-1} of wheat genotypes (V) imposed by late sowing times (D)

D × V	D_1	D2	D3	D4
V_1	15.3	13.5	14.1	12.9
V_2	14.1	14.9	15.4	14.7
V_3	14.4	15.2	14.2	13.4
V_4	15.4	14.9	16.1	13.8
LSD(0.05)	=0.57	CV (%)	=1.73	

D1 = 30 Nov, D2 = 15 Dec, D3 = 30 Dec, D4 = 14 Jan, V1 = BARI Gom 26, V2 = BAW 1051, V3 = BAW 1120, V4= BAW 1141, LSD = Least significance difference, CV = Coefficient of variance

Table 4. Effect of terminal high temperature on grains spike^{-1} of wheat genotypes (V) imposed by late sowing times (D).

D × V	D_1	D_2	D_3	D_4
V_1	51.6	49	44	42.1
V_2	36	39	35.6	30.2
V_3	39.1	38.9	41.1	38.8
V_4	44.5	42.8	47.4	44.2
LSD(0.05)	=1.93	CV (%)	=2.04	

D_1 = 30 Nov, D_2 = 15 Dec, D_3 = 30 Dec, D_4 = 14 Jan, V_1 = BARI Gom 26, V_2 = BAW 1051, V_3 = BAW 1120, V_4= BAW 1141, LSD = Least significance difference, CV = Coefficient of variance

Table 5. Effect of terminal high temperature on TGW (g) of wheat genotypes (V) imposed by late sowing times (D).

D × V	D_1	D_2	D_3	D_4
V_1	42.1	40.1	37.3	32.4
V_2	42.1	42	45.7	43.6
V_3	42.9	40.3	35.8	32
V_4	50.2	45.3	43.7	39.4
LSD(0.05)	=0.01	CV (%)	=0.04	

. D_1 = 30 Nov, D_2 = 15 Dec, D_3 = 30 Dec, D_4 = 14 Jan, V_1 = BARI Gom 26, V_2 = BAW 1051, V_3 = BAW 1120, V_4= BAW 1141, LSD = Least significance difference, CV = Coefficient of variance

Table 6. Effect of terminal high temperature on grain yield (t ha^{-1}) of wheat genotypes (V) imposed by late sowing times (D).

D × V	D_1	D_2	D_3	D_4
V_1	4.96	3.82	3.2	2.52
V_2	4.92	3.71	3.26	2.57
V_3	4.67	3.92	3.11	2.69
V_4	4.89	4.08	3.41	3.35
Mean-D	5.44	4.38	3.52	2.26
LSD(0.05)	=0.01	CV (%)	=0.41	

. D_1 = 30 Nov, D_2 = 15 Dec, D_3 = 30 Dec, D_4 = 14 Jan, V_1 = BARI Gom 26, V_2 = BAW 1051, V_3 = BAW 1120, V_4= BAW 1141, LSD = Least significance difference, CV = Coefficient of variance

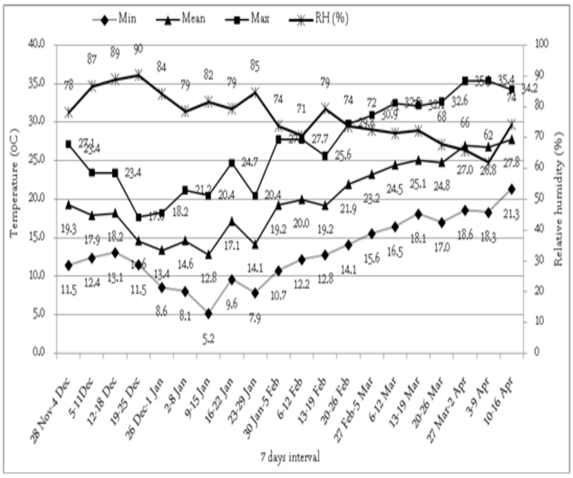

Fig. 1. 7 days interval average minimum, maximum & their mean temperature and relative humidity (% RH) during the growing period of wheat from 28 November, 2012 to 10 April, 2013 at WRC, Dinajpur.

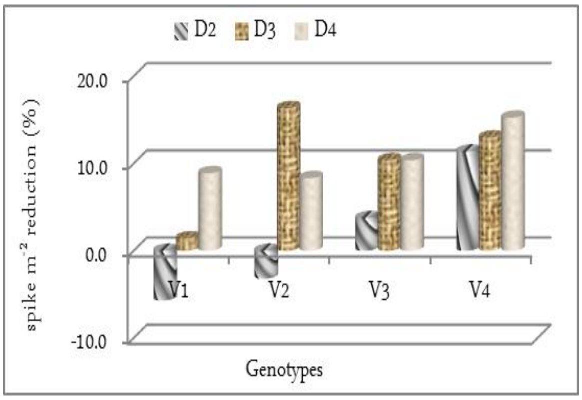

Fig. 2. Reduction percentage (%) of spike m^{-2} at different irrigated late sowing conditions (D_2, D_3 and D_4) comapered to irrigated timely sowing (D_1)

D_2 = 15 December, D_3 = 30 December, D_4 = 14 January, V_1 = BARI Gom 26, V_2 = BAW 1051, V_3 = BAW 1120, V_4= BAW 1141

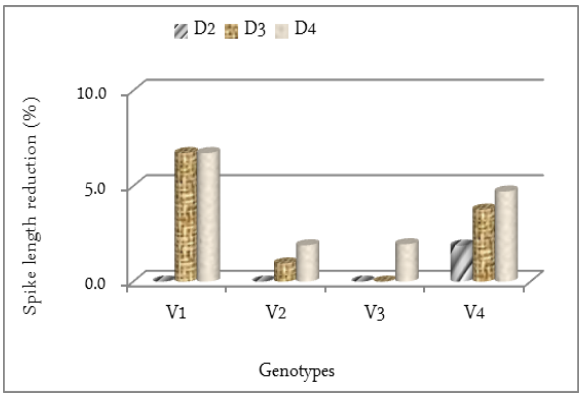

Fig. 3. Reduction percentage (%) of spike length (cm) at different irrigated late sowing conditions (D_2, D_3 and D_4) comapered to irrigated timely sowing (D_1)

D_2 = 15 December, D_3 = 30 December, D_4 = 14 January, V_1 = BARI Gom 26, V_2 = BAW 1051, V_3 = BAW 1120, V_4= BAW 1141

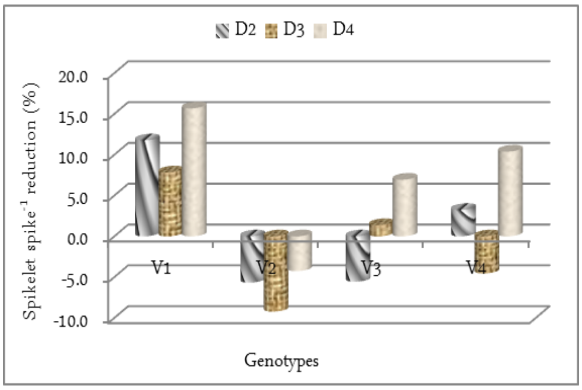

Fig. 4. Reduction percentage (%) of spiklet spike^{-1} at different irrigated late sowing conditions (D_2, D_3 and D_4) comapered to irrigated timely sowing (D_1).

D_2 = 15 December, D_3 = 30 December, D_4 = 14 January,, V_1 = BARI Gom 26, V_2 = BAW 1051, V_3 = BAW 1120, V_4= BAW 1141

This finding indicates that in ITS condition, the recently released variety BARI Gom 26 was superior to all advanced or promising genotypes. Just after 15-days of ITS i.e. in D_2 seeding, the significant yield reduction was found due to higher temperature and low humidity prevailed in their heading, flowering and grain filling stages (Fig. 1 & 7 and Table 6). In this sowing, yield reduction of the genotypes BARI Gom 26, BAW 1141, BAW 1120 and BAW 1051 was 23.0%, 16.6%, 16.1% and 24.6%, respectively as compared to ITS condition. The similar result was found by Hossain *et al.* (2012).

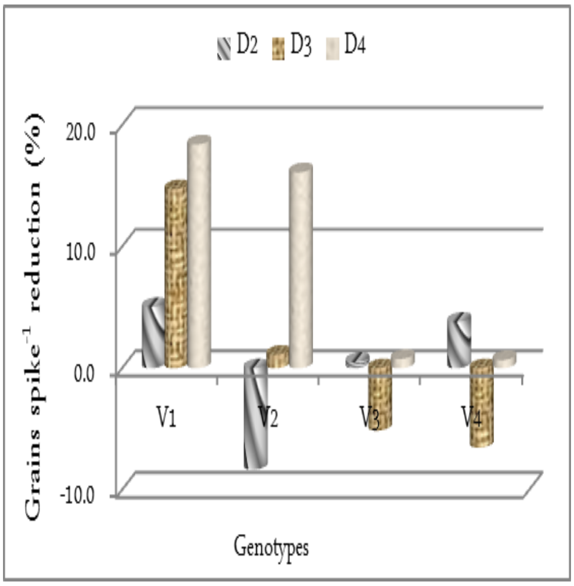

Fig. 5. Reduction percentage (%) of grain spike^{-1} at different irrigated late sowing conditions (D_2, D_3 and D_4) comapered to irrigated timely sowing (D_1).

D_2 = 15 December, D_3 = 30 December, D_4 = 14 January, V_1 = BARI Gom 26, V_2 = BAW 1051, V_3 = BAW 1120, V_4= BAW 1141

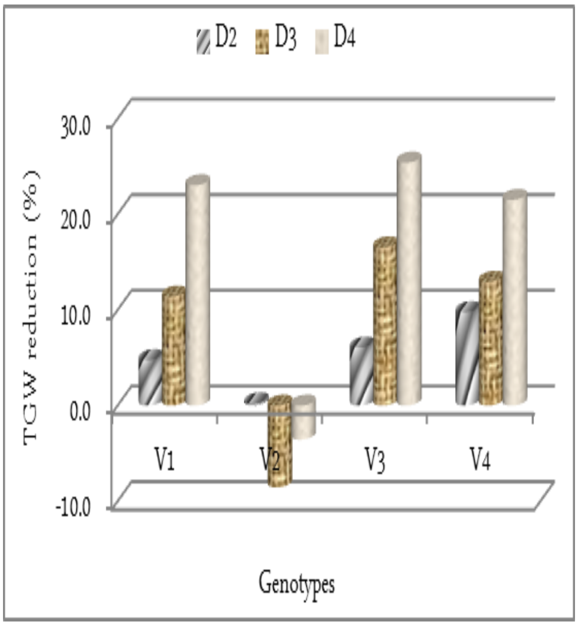

Fig. 6. Reduction percentage (%) of TGW at different irrigated late sowing conditions (D_2, D_3 and D_4) comapered to irrigated timely sowing (D_1).

D_2 = 15 December, D_3 = 30 December, D_4 = 14 January, V_1 = BARI Gom 26, V_2 = BAW 1051, V_3 = BAW 1120, V_4= BAW 1141

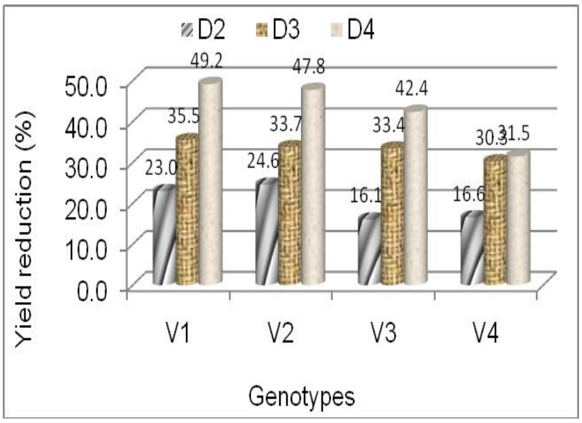

Fig. 7. Reduction percentage (%) of grain yield (t ha^{-1}) at different irrigated late sowing conditions (D_2, D_3 and D_4) comapered to irrigated timely sowing (D_1).

D_2 = 15 December, D_3 = 30 December, D_4 = 14 January, V_1 = BARI Gom 26, V_2 = BAW 1051, V_3 = BAW 1120, V_4= BAW 1141

In the late sowing (30 Dec), BAW 1141 gave significantly the highest yield (3.41 t ha^{-1}) and other genotypes statistically produced similar yields (3.11 - 3.26 t ha^{-1}). In this sowing, yield reduction of the genotypes BAW 1141, BARI Gom 26, BAW 1051 and BAW 1120 was 30.3%, %, 35.5%, 33.7% and 33.4%, respectively compared to ITS condition. In the very late sowing condition (14 Jan), BAW 1141 also produced significantly the highest grain yield (3.35 t ha^{-1}). On the contrary, the recently released variety gave the lowest yield (2.52 t ha^{-1}) in this seeding. Other two advanced genotypes performed statistically identical result (produced yield in between 2.52 to 2.69 t ha $^{-1}$) (Table 6).

At that time, the percent of yield reduction was remarkable and it was 31.5%%, 42.4 %, 47.8% and 49.2% in BAW 1141, BAW 1120, BAW 1051 and BARI Gom 26, respectively. The similar result was found by Alam *et al.* (2013). Previous research findings also indicated that high temperature significantly decreased all traits, especially GY (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). Considering the yield performance, the advanced line, BAW 1141 performed better than other genotypes in all sowing times, although there was significant yield reduction over timely sowing (30 Nov).

This line produced more than 3 t ha^{-1} grain yields on 30 Dec and 14 Jan sowing conditions. This indicated that among the tested genotypes, BAW 1141 was the best genotype of all in heat stress condition.

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