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EFFECT OF LATE SEEDING WARMER CONDITION ON PHENOLOGY AND YIELD OF WHEAT

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Abstract

Four wheat variety/genotype (BARI Gom-26, BAW-1202, BAW-1182 and BARI Gom-27) were tested under three heat stress regimes (normal, moderate and severe) to evaluate the effect of late seeding warmer condition on phenology and yield of wheat, as well as to identify suitable cultivars to develop heat-tolerant genotypes at Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during November, 2016 to April, 2017. Results revealed that genotype BAW-1182 and BAW-1202 showed greater thermostability of cell membrane with acceptable yield performance under heat stress condition. The order of tolerance based on heat susceptibility index (based on grain yield) was BAW-1182>BAW-1202>BARI Gom-27>BARI Gom-26 under heat stress conditions. Thus, BAW-1182 and BAW-1202 have the greatest potential to be used as high-yielding wheat genotypes under warm to hot environments and could be used in a breeding programme to develop heat-tolerant wheat.

Introduction

Wheat (*Triticum aestivum* L.) is an important cereal crop ranking number one globally and number two in Bangladesh both in terms of production and acreage. Generally, wheat is sown in mid-November to ensure optimal crop growth and avoid high-temperature stress. However, about 60% of the wheat is cultivated in late sowing conditions after harvesting the transplanted aman rice (Baharuddin *et al.,* 1994). An important limitation to wheat productivity is the heat stress that affects different growth stages, specially anthesis and grain filling as evident from late sowing (Din *et al*., 2010). Despite the low yield of wheat due to terminal heat stress, its cultivation cannot be avoided totally. The adverse effect of temperature can be minimized by breeding heat-tolerant genotypes that could be sown late with a high grain yield. In this context, this study aimed to evaluate the effect of late seeding warmer condition on phenology and yield of wheat genotypes followed by screening high-temperature stress-tolerant traits of wheat genotypes in the breeding program.

Materials and Methods

The experiment was set up at Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during November, 2016 to April, 2017. The experimental site was situated under the Dinajpur Sadar Upazila and located at 25º39′ N latitude and 88º41′ E longitude with an elevation of 37.58 meter above sea level. The experimental field was a medium high land belonging to the Non calcareous Dark Grey Floodplain soil under the Agro-ecological Zone (AEZ-1) of the Old Himalayan Piedmont Plain. Three growing conditions -normal sowing in November 20, moderate heat stress sowing in December 20 and severe heat stress sowing in January 10 were placed in the main plots whereas four wheat variety/genotypes: BARI Gom-26, BAW-1202, BAW-1182 and BARI Gom-27 were placed in sub-plots following split-plot design. Seeds were sown in rows of 20 cm apart, at the rate of 120 kg ha^{-1}. A fertilizer dose of 140-35-75-18-2-0.5 kg ha^{-1} N, P, K, S, Zn and B was applied following fertilizer recommendation.

Phenological stages like anthesis, physiological maturity were observed and recorded in days when 50% of plants of each plot reached a definite stage (Zadoks *et al.*, 1974). Cell membrane thermostability test was done as described by Blum and Ebercon (1981). Heat susceptibility index (S) was calculated for yield as following Fischer and Maurer (1978). Data were collected on yield and yield contributing characters of wheat. The data were analyzed by partitioning the total variance with the help of a computer using the MSTATC program. The treatment means were compared using Tukey's test at a 5% level of significance.

Results and Discussion

Late sown (20 December and 10 January sown) wheat genotypes exposed to heat stress (>20°C) during most of their reproductive growth phase but the wheat genotypes sown on 20 November experienced more or less 20°C temperature throughout their whole reproductive growth phase and considered as normal growing condition (Fig. 1). The optimum temperature for wheat crop growth is about 20°C (Al-Khatib and Paulsen, 1984). Temperature in the range of 20 to 25°C has been considered favorable for wheat seed germination, seedling emergence and optimum plant establishment (Behl *et al.*, 1993).

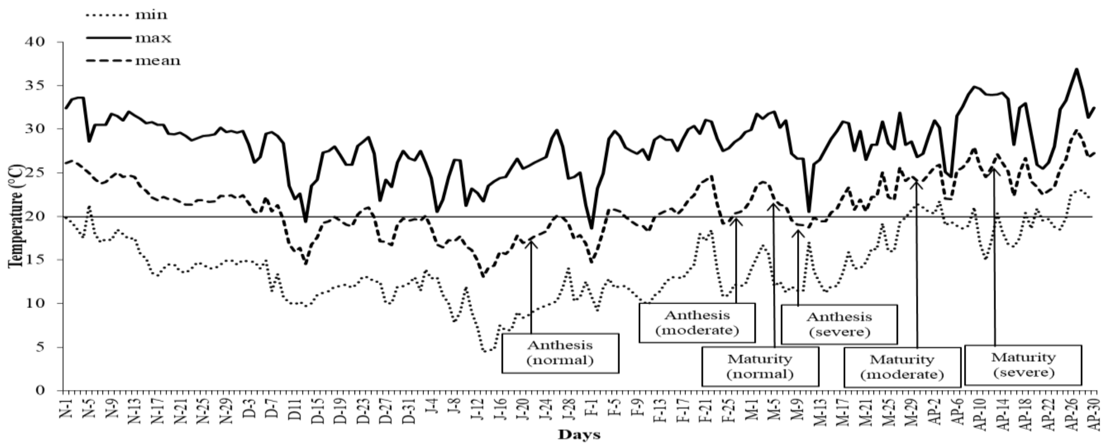

Fig. 1. Maximum, minimum and mean air temperature from 01 November 2016 to 30 April 2017 showing the period of anthesis and maturity of normal, moderate heat stress and severe heat stress.

Phenology

Days to anthesis

Days required to anthesis were significantly influenced by the interaction effect of growing conditions and wheat genotypes (Table 1). Under the normal growing condition, BAW-1182 required the highest number of days (73 days) for anthesis which was followed by BARI Gom-27 (72 days) and BARI Gom-26 (72 days) whereas BAW-1202 required the lowest number of days (66 days) for anthesis. Due to late seeding warmer conditions (both at moderate and severe heat stress conditions) anthesis occurred earlier than normal growing condition in all the wheat genotypes except in BAW-1202 at moderate heat stress condition. But earliness of anthesis due to heat stress conditions (both at moderate and severe heat stress conditions) were not similar for all wheat genotypes at moderate and severe heat stress conditions. Delay in sowing (both at moderate and severe heat stress conditions) decreased the number of days required to anthesis. Days to anthesis required a lower number of days under heat stress conditions and similar results were found by Dias *et al.* (2009) and Nahar *et al.* (2010).

Table 1. Effect of late seeding warmer condition and wheat genotypes on days to anthesis

Genotypes	Days to anthesis (days)		
	Growing conditions		
	Normal	**Moderate heat stress**	**Severe heat stress**
V1 (BARI Gom-26)	72 ab	69 bc	60 d
V2 (BAW-1202)	66 c	69 bc	59 d
V3 (BAW-1182)	73 a	69 bc	62 d
V4 (BARI Gom-27)	72 ab	70 ab	60 d
Level of Significance		**	
CV (%)		1.65	

Means followed by the same letter(s) did not differ significantly at 5% level by MSTATC program. ** Significant at the 1% probability level

Physiological maturity

Days required to physiological maturity were significantly influenced by the interaction effect of growing conditions and wheat genotypes (Table 2). Under the normal growing condition, BARI Gom-26, BAW-1182 and BARI Gom-27 required the highest number of days (106 days) for physiological maturity whereas BAW-1202 required the lowest number of days (100 days) for physiological maturity. Due to late seeding warmer conditions (both at moderate and severe heat stress conditions) physiological maturity occurred earlier compared to the normal growing condition in all the wheat genotypes. But earliness of anthesis due to heat stress conditions (both at moderate and severe heat stress conditions) were not similar for all wheat genotypes. Hossain *et al.* (2011, 2012a) and Hakim *et al.* (2012) also found that the duration of maturity of spring wheat genotypes reduced by high temperature stress in northern Bangladesh. The increasing temperature during grain tended to stop grain growth prematurely and to hasten physiological maturity. A similar result was found by Amrawat *et al.* (2013).

Table 2. Effect of late seeding warmer condition and wheat genotypes on physiological maturity

Genotypes	Physiological maturity (days)		
	Growing conditions		
	Normal	**Moderate heat stress**	**Severe heat stress**
BARI Gom-26	106 a	100 b	95 c
BAW-1202	100 b	96 c	90 d
BAW-1182	106 a	102 b	95 c
BARI Gom-27	106 a	102 b	90 d
Level of Significance		**	
CV (%)		0.88	

Means followed by the same letter(s) did not differ significantly at 5% level by MSTATC program. ** Significant at the 1% probability level

Cell membrane thermostability

Cell membrane thermostability (CMT) of flag leaf at 18 days after anthesis differed among the wheat genotypes tested (Fig. 2). The highest cell membrane thermostability was found in BAW-1202 (53.8%) which was followed by BARI Gom-26 (53.1%). On the other hand, BAW-1182 (42.8%) showed moderate cell membrane thermostability and BARI Gom-27 (29.7%) showed the lowest cell membrane thermostability. The results indicated that the wheat genotypes BAW-1202 and BARI Gom-26 were more tolerant against heat stress conditions than BAW-1182 and BARI Gom-27. Genotypic differences in membrane injury of flag leaf at anthesis of the field-grown wheat were also reported by Hasan *et al.* (2007) and Mohi-Ud-Din *et al.* (2007).

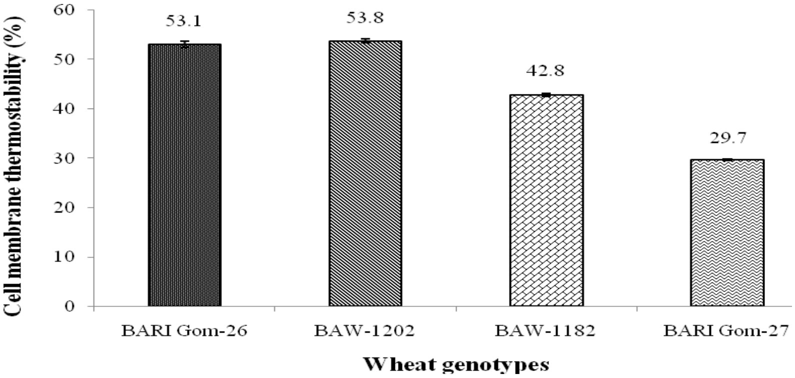

Fig. 2. Cell membrane thermostability of different wheat genotypes at 18 days after anthesis.

Tillers m^{-2}

Tillers per m^2 of four wheat genotypes at different growing conditions are presented in Table 3. Results showed that the interaction effect of growing conditions and wheat genotypes on tillers m^{-2} was significant. Under the normal growing condition, BAW-1202 showed the maximum tillers m^{-2} (332.3) which was statistically similar to BARI Gom-27 (320.2). Genotype BAW-1182 (275.3) showed the lowest number of tillers m^{-2} which was statistically similar to BARI Gom-26 (273.0). Under moderate heat stress condition, BARI Gom-27 showed the highest tillers m^{-2} (336.3). BAW-1182 showed moderate (296.7) which was statistically similar to BAW- 1202 (278.8). BARI Gom-26 showed the lowest tillers m^{-2} (226.3). Under severe heat stress condition, BARI Gom-27 showed the maximum tillers m^{-2} (215.8) which was statistically similar to BAW-1202 (214.5). Genotype BAW-1182 (179.0) showed moderate tillers m^{-2} and lowest in BARI Gom-26 (107.7).

Table 3. Effect of late seeding warmer condition and wheat genotypes on tillers m^{-2}

Genotypes	Tillers m^{-2} (no.)		
	Growing conditions		
	Normal	Moderate heat stress	Severe heat stress
BARI Gom-26	273.0 c	226.3 d	107.7 f
BAW-1202	332.3 a	278.8 c	214.5 d
BAW-1182	275.3 c	296.7 bc	179.0 e
BARI Gom-27	320.2 ab	336.3 a	215.8 d
Level of Significance		**	
CV (%)		4.33	

Means followed by the same letter(s) did not differ significantly at the 5% level by the MSTATC program. ** Significant at the 1% probability level

Spikes m^{-2}

Spikes per m^2 of four wheat genotypes at different growing conditions are presented in Table 4. Results showed that the interaction effect of growing conditions and wheat genotypes on spikes m^{-2} was significant. Under the normal growing condition, BAW-1202 showed the maximum spikes m^{-2} (327.5) which was statistically similar to BARI Gom-27 (315.8). Genotype BAW-1182 (268.3) showed the lowest number of spikes m^{-2} which was statistically similar to BARI Gom-26 (270.0). Under moderate heat stress conditions, BARI Gom-27 showed the highest spikes m^{-2} (327.2). Genotype BAW-1182 showed moderate (290.3), which was statistically similar to BAW-1202 (272.5). BARI Gom-26 showed the lowest spikes m^{-2} (239.5), which was also statistically similar to BAW-1202 (272.5). Under severe heat stress conditions, BARI Gom-26 showed the maximum spikes m^{-2} (240.7) which was statistically similar to BAW-1202 (209.8). Genotype BAW-1182 showed the lowest spikes m^{-2} (174.8), which was statistically similar to BARI Gom-27 (176.7). BARI Gom-27 is also statistically similar to BAW-1202. Results from other studies showed that spike number plant^{-1} was not significantly influenced by late sowing (Hasan *et al.*, 2007). Hu and Rajaram (1994) reported that spike number plant^{-1} was less sensitive while the yield, grains spike^{-1}, biomass and plant height were more sensitive to high temperature.

Table 4. Effect of late seeding warmer condition and wheat genotypes on spikes m^{-2}

Genotypes	Spikes m^{-2} (no.)		
	Growing conditions		
	Normal	Moderate heat stress	Severe heat stress
BARI Gom-26	270.0 cd	239.5 de	240.7 de
BAW-1202	327.5 a	272.5 cd	209.8 ef
BAW-1182	268.3 cd	290.3 bc	174.8 g
BARI Gom-27	315.8 ab	327.2 a	176.7 fg
Level of Significance		**	
CV (%)		4.21	

Means followed by the same letter(s) did not differ significantly at 5% level by MSTATC program. ** Significant at the 1% probability level

Spikelets spike^{-1}

Spikelets spike^{-1} of four wheat genotypes at different growing conditions is presented in Table 5. Results showed that the interaction effect of growing conditions and wheat genotypes on spikelets spike^{-1} was significant.

Table 5. Effect of late seeding warmer condition and wheat genotypes on spikelets spike^{-1}

Genotypes	Spikelets spike^{-1} (no.)		
	Growing conditions		
	Normal	Moderate heat stress	Severe heat stress
BARI Gom-26	18.83 bcd	21.47 a	18.30 bcd
BAW-1202	17.57 d	20.00 ab	18.23 bcd
BAW-1182	19.07 bcd	21.67 a	19.43 bc
BARI Gom-27	18.13 cd	18.53 bcd	17.30 d
Level of Significance		*	
CV (%)		3.06	

Means followed by the same letter(s) did not differ significantly at the 5% level by the MSTATC program. * Significant at the 5% probability level

Under the normal growing condition, BAW-1182 showed the maximum number of spikelets spike^{-1} (19.07), which was statistically similar to BARI Gom-26 (18.83), BARI Gom-27 (18.13) and BAW-1202 (17.57). Genotype BAW-1202 showed the lowest number of spikelets spike^{-1}. Under moderate heat stress conditions, BAW-1182 showed the maximum number of spikelets spike^{-1} (21.67) which was statistically similar to BARI Gom-26 (21.47) and BAW-1202 (20.00). BARI Gom-27 showed the lowest spikelets spike^{-1} (18.53), which was also statistically similar to BAW-1202 (20.00). Under severe heat stress condition, BAW-1182 showed the maximum number of spikelets spike^{-1} (19.43), which was statistically similar to BARI Gom-26 (18.30) and BAW-1202 (18.23). BARI Gom-27 showed the lowest (17.30) which was also statistically similar to BARI Gom-26 and BAW-1202.

Grains spike^{-1}

Grains spike^{-1} at different growing conditions are presented in Table 6. From the results it was observed that grains per spike were significantly influenced by growing conditions. Irrespective of growing conditions, normal growing conditions showed the maximum grains spike^{-1} (50.20) which was statistically similar to moderate heat stress (49.14) whereas severe heat stress showed the lowest grains spike^{-1} (42.32). Due to heat stress, grains per spike were decreased in severe heat stress condition (15.70%) and moderate heat stress condition (2.11%). Sowing of seed at normal growing conditions may have enjoyed a longer duration and favorable temperature for growth and development as compared to others and produced a maximum number of grains spike^{-1}. Heat stress, singly or in combination with drought, is a common constraint during anthesis and grain filling stages in many cereal crops of the temperate region (Nahar *et al.,* 2010).

Grains spike^{-1} of four wheat genotypes are presented in Table 7. From the results it was observed that grains spike^{-1} were significantly influenced by wheat genotypes but the combined effect insignificant. In the case of variety /genotype, BARI Gom-26 had the highest grains spike^{-1} (54.80) where BAW-1182 had a moderate number (49.00) which was statistically similar to BARI Gom-27 (44.30). Genotype BAW-1202 showed the lowest number of grains spike^{-1} (40.78) which was also statistically similar to BARI Gom-27. Significant differences among the genotypes for the number of grains spike^{-1} were found in wheat (Falaki *et al.*, 2009) and it may be due to the variation in the genetic potential.

Grain weight spike^{-1}

Grain weight spike^{-1} of four wheat genotypes at different growing conditions is presented in Table 6. Results showed that the interaction effect of growing conditions and wheat genotypes on grain weight spike^{-1} was significant. Under the normal growing conditions, BAW-1182 showed the maximum grain weight (2.51 g), which was statistically similar to BARI Gom-26 (2.42 g) and BARI Gom-27 (2.24 g). Genotype BAW-1202 showed the lowest grain weight (2.14 g) which was also statistically similar to BARI Gom-26 (2.42 g) and BARI Gom-27 (2.24 g). Under moderate heat stress conditions, BARI Gom-26 showed the highest grain weight (2.69 g) whereas BAW-1182 showed moderate weight (2.21 g) but similar to BAW-1202 (2.16 g). BARI Gom-27 showed the lowest grain weight (1.60 g). Under severe heat stress condition, BARI Gom-26 showed the maximum grain weight (1.82 g), which was statistically similar to BAW-1182 (1.68 g) and BAW-1202 (1.64 g). BARI Gom-27 showed the lowest grain weight (1.25 g). Significant variations were observed among the genotypes in the reduction of grain weight spike^{-1} under heat stress of 26 C mean temperature (Fokar *et al.,* 1998).

Table 6. Effect of late seeding warmer condition and wheat genotypes on grain wt. spike^{-1}

Genotypes	Grain wt. spike^{-1} (g)		
	Growing conditions		
	Normal	Moderate heat stress	Severe heat stress
BARI Gom-26	2.42 abc	2.69 a	1.82 de
BAW-1202	2.14 cd	2.16 bcd	1.64 e
BAW-1182	2.51 ab	2.21 bc	1.68 e
BARI Gom-27	2.24 bc	1.60 ef	1.25 f
Level of Significance		**	
CV (%)		5.63	

Means followed by the same letter(s) did not differ significantly at the 5% level by the MSTATC program. ** Significant at the 1% probability level

1000-grain weight

The 1000-grain weight at different growing conditions is presented in Table 7. From the results, it was observed that 1000-grain weight was significantly influenced by growing conditions. In the case of growing conditions, normal growing conditions showed the highest 1000-grain weight (48.11 g) and moderate heat stress showed medium 1000-grain weight (40.82 g), whereas severe heat stress showed the lowest 1000-grain weight (36.32 g). Delayed sowing shortened the duration of each developmental phase, which ultimately reduces the grain filling period and lowers the grain weight (Spinks *et al.*, 2004).

The 1000-grain weight of four wheat genotypes is presented in Table 7. From the results it was observed that 1000-grain weight was significantly influenced by wheat genotypes but the combined effect was insignificant. Irrespective of genotypes, BAW-1202 showed the maximum 1000-grain weight (46.82 g), which was statistically similar to BARI Gom-26 (43.51 g) and BARI Gom-27 showed the lowest 1000-grain weight (35.03 g). Again, BAW-1182 (41.65 g) was moderate in weight and statistically similar to BARI Gom-26 (43.51 g). Reduced grain size under heat stress conditions might be due to the rapid reduction in grain growth duration. The 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 (Tashiro and Wardlaw, 1989).

Table 7. Effect of late seeding warmer condition and genotypes on grains spike^{-1} and 1000-grain wt.

Treatments	Grains spike^{-1} (no.)	1000-grain wt. (g)
Growing conditions		
Normal	50.20 a	48.11 a
Moderate heat stress	49.14 a	40.82 b
Severe heat stress	42.32 b	36.32 c
Level of Significance	**	**
CV (%)	5.71	6.63
Genotypes		
BARI Gom-26	54.80 a	43.51 ab
BAW-1202	40.78 c	46.82 a
BAW-1182	49.00 b	41.65 b
BARI Gom-27	44.30 bc	35.03 c
Level of Significance	**	**
CV (%)	7.61	8.52

Means followed by the same letter(s) did not differ significantly at the 5% level by the MSTATC program. ** Significant at the 1% probability level

Grain yield

The grain yield of four wheat genotypes at different growing conditions is presented in Table 8. Results showed that the interaction effect of growing conditions and wheat genotypes on grain yield was significant. At normal growing conditions, BARI Gom-26 produced the maximum grain yield (361.0 g m^{-2}), which was statistically similar to BARI Gom-27 (315.7 g m^{-2}). BARI Gom-27 also statistically similar to BAW-1202 (285.7 g m^{-2}) whereas BAW-1182 (242.7 g m^{-2}) gave the lowest grain yield which was identical to BAW-1202 (285.7 g m^{-2}). Under moderate heat stress conditions, BAW-1202 (270.0 g m^{-2}) attained the maximum grain yield, which was statistically similar to BAW-1182 (254.7 g m^{-2}), BARI Gom-27 (227.7 g m^{-2}) and BARI Gom-26 (226.3 g m^{-2}). Under severe heat stress condition, BAW-1202 (202.0 g m^{-2}) gave the maximum grain yield, which was statistically similar to BAW-1182 (181.0 g m^{-2}) and BARI Gom-27 (152.3 g m^{-2}). BARI Gom-26 (140.0 g m^{-2}) showed the lowest grain yield, which was statistically similar to BAW-1182 (181.0 g m^{-2}) and BARI Gom-27 (152.3 g m^{-2}). Results from other studies showed that in the case of late sowing, climate and soil moisture were unfavorable (high temperature, low relative humidity in the air and low soil moisture) for crop production, which ultimately affected crop growth and yield (Hossain *et al.,* 2012d; Hossain *et al.,* 2013). In sub-tropical climates like Bangladesh, excess radiation and high temperatures are often the most limiting factors affecting plant growth and final grain yield (Wahid *et al.*, 2007; Hossain *et al.*, 2009; Nahar *et al.*, 2010; Hossain *et al.*, 2011; Sikder, 2011; Hakim *et al.*, 2012).

Biological yield

The biological yield of four wheat genotypes at different growing conditions is presented in Table 9. Results showed that the interaction effect of growing conditions and wheat genotypes on biological yield was significant. At normal growing conditions, BAW-1182 attained the highest biological yield (1701 g m^{-2}). BARI Gom-26 showed moderate biological yield (1313 g m^{-2}), which was statistically similar to BAW-1202 (1299 g m^{-2}). BARI Gom-27 showed the lowest value of biological yield (1178 g m^{-2}). Under moderate heat stress condition, BAW-1182 (1397 g m^{-2}) attained the highest biological yield while BARI Gom-26 showed the lowest (1006 g m^{-2}) which was statistically similar to BARI Gom-27 (1035 g m^{-2}) and BAW-1202 (1064 g m^{-2}). Under severe heat stress conditions, BARI Gom-27 (808.7 g m^{-2}) attained the highest biological yield. BAW-1182 (705.3 g m^{-2}) showed a moderate value which was statistically similar to BAW-1202 (625.3 g m^{-2}). BARI Gom-26 (538.0 g m^{-2}) showed the lowest biological yield which was similar to BAW-1202 (625.3 g m^{-2}). Hossain *et al.* (2012c) and Hossain *et al.* (2012d) noticed that when wheat was grown from sowing to maturity at high temperatures, phenological development was rapid, leading to poor biomass production and consequently poor biological yield.

Table 8. Effect of late seeding warmer condition and wheat genotypes on grain yield

Genotypes	Grain yield (g m^{-2})		
	Growing conditions		
	Normal	Moderate heat stress	Severe heat stress
BARI Gom-26	361.0 a	226.3 def	140.0 h
BAW-1202	285.7 bc	270.0 bcd	202.0 efg
BAW-1182	242.7 cde	254.7 cd	181.0 fgh
BARI Gom-27	315.7 ab	227.7 def	152.3 gh
Level of Significance		**	
CV (%)		6.89	

Means followed by the same letter(s) did not differ significantly at the 5% level by the MSTATC program. ** Significant at the 1% probability level

Table 9. Effect of late seeding warmer condition and wheat genotypes on biological yield

Genotypes	Biological yield (g m^{-2})		
	Growing conditions		
	Normal	Moderate heat stress	Severe heat stress
BARI Gom-26	1313 bc	1006 e	53 8.0 h
BAW-1202	1299 c	1064 e	625.3 gh
BAW-1182	1701 a	1397 b	705.3 g
BARI Gom-27	1178 d	1035 e	808.7 f
Level of Significance		**	
CV (%)		2.87	

Means followed by the same letter(s) did not differ significantly at the 5% level by the MSTATC program. ** Significant at the 1% probability level

Heat susceptibility index (HSI)

Heat susceptibility index (HSI) based on grain yield varied in different wheat genotypes both at moderate and severe heat stress conditions. A lower susceptibility index indicates higher tolerance. According to heat susceptibility index, the order of tolerance was BAW-1182 (-0.26)>BAW-1202 (0.26)>BARI Gom-27 (1.47)>BARI Gom-26 (1.95) under moderate heat stress condition and BAW-1182 (0.57)>BAW-1202 (0.66)>BARI Gom-27 (1.18)>BARI Gom-26 (1.39) under severe stress condition. Hossain and Teixeira de Silva (2012a) and Hossain *et al.* (2012b) stated HSI to be a measure of yield stability. Therefore, a stress-tolerant genotype as defined by HSI needs not necessarily to have a high yield potential. The ideal wheat genotype should be high yielding under any environmental conditions.

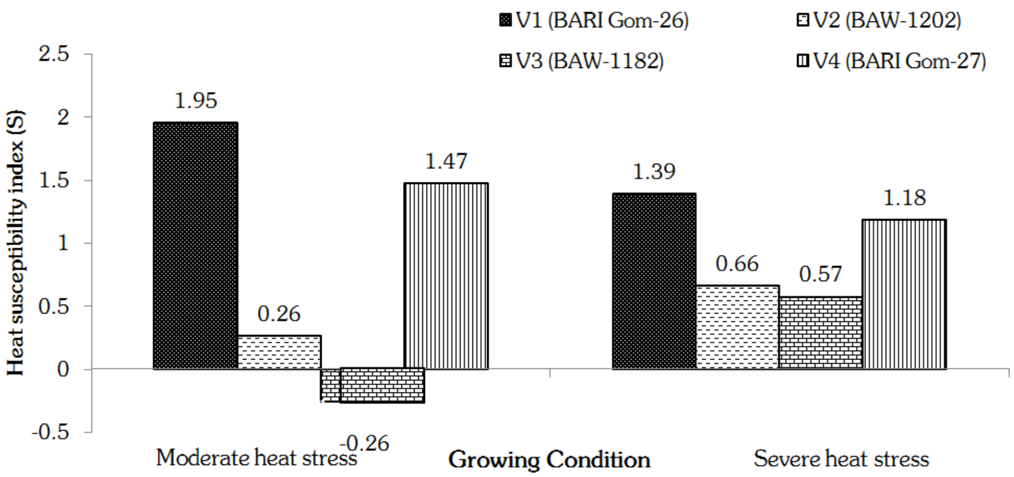

Fig. 4. Heat susceptibility index of different wheat genotypes based on grain yield (g/m^2) at moderate and severe heat stress.

Conclusion

Wheat genotypes BAW-1182 and BAW-1202 showed greater thermostability of cell membrane under heat stress conditions and came out with potential yield harvest. However, based on the heat susceptibility index for grain yield (under moderate and severe heat stress), BAW-1182 was found as most tolerant.

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