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Evaluation of some wheat genotypes growing under heat stress condition in two environments in Bangladesh

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Abstract. The study was carried out from November to March 2013-2014 in two agricultural research centers/stations: Wheat Research Centre (WRC; 23° 11' 14.52" N, 89° 11' 11.99" E; 10.4 meters above sea level, masl), Nashipur, Dinajpur and Regional Agricultural Research Station (RARS), Jashore (23° 11' 14.52" N, 89° 11' 11.99" E; 10.4 masl) of the Bangladesh Agricultural Research Institute (BARI). Sixteen genotypes, along with two check varieties BARI Gom 21 and BARI Gom 26, were evaluated in Randomized Complete Block Design (RCBD) with three replications under irrigated timely sown (ITS) and irrigated late sown heat stress (ILS) conditions to find out the heat-tolerant wheat lines for a future breeding program to develop heat-tolerant wheat varieties. Significant variations were observed among tested genotypes on phenology, yield, and yield contributing characters are at late sown heat stress condition (ILS) in both locations. The higher yield across location and genotype was recorded in ITS condition (4224 kg ha^{-1}) than ILS condition (3113 kg ha^{-1}). Regarding environmental locations, Dinajpur was better placed for wheat production. Gen-3, gen-8, Gen-10, Gen-11, and Gen-16 showed better performance under ILS conditions among the tested genotypes, and these genotypes were selected for future breeding programs to develop heat-tolerant varieties. The selected genotypes had high yield, bold and plump grains with better tolerance to Bipolaris leaf blight (BpLB) and resistance to leaf rust diseases.

Keywords: *Grain yield, yield components, genotypes, early sown, late sown, heat stress*

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1. Introduction

Wheat is the staple food of one-third population of the world and is one of the primary foods for Asia. It is originated in southwestern Asia and a major agricultural commodity since prehistoric times. Among the cereals, it is the most widely cultivated one. Wheat is grown in all temperate countries and most of the sub-tropical countries, and at high elevations of some tropical countries.

Wheat is nutritious, concentrated, readily stored and transported, and quickly processed to give highly refined raw foods. It is used as human food to achieve calories and protein. Wheat grains contain 17 percent calories and 19 percent protein [1]. The consumption of wheat per capita has increased from 17.4 kg in 1972 to 60 kg in 2007 [2] in developing countries.

It is the second most crucial grain crop after rice and plays an essential role in attaining food security in Bangladesh, but its yield is lower than other wheat-growing countries in the world [3]. Till now, the maximum yield of existing wheat varieties in the research field is 4.0-5.0 t ha^{-1} [4, 5], but in farmers' fields, it is <3 t h a^{-1} [6] due to several stresses.

Heat stress is one of the significant constraints for wheat cultivation in Bangladesh. Late planting receives heat stress in Bangladesh and affects wheat growth, resulting in yield loss of wheat compared to optimum sowing. Each day delay in sowing of wheat after November 30 onward decreases grain yield at the rate of 36 kg ha $^{-1}$ day $^{-1}$ [7]. A considerable amount of land in Bangladesh where wheat is followed by the transplanted Aman rice or where soil remains wet due to excessive rainfall, seeding is continued up to January, and wheat crop falls in heat stress condition resulting in lower yield [8, 9, 10]. Therefore, genotypes having heat resistance traits are most desirable for wheat cultivation in this region. In this regard, this trial was conducted to identify heat-tolerant wheat varieties for future breeding programs.

2. Materials and methods

2.1. Locations

The trial was conducted at WRC, Nashipur, Dinajpur (23° 11' 14.52" N, 89° 11' 11.99" E; 10.4 masl) and the RARS, BARI, Jashore (23° 11' 14.52" N, 89° 11' 11.99" E; 10.4 masl) during the Rabi season (November-March) of 2013-2014 [11].

2.2. Designs and experimental procedures

Sixteen promising wheat genotypes and two checks (BARI Gom 21 and BARI Gom 26) were evaluated in this study to identify suitable genotypes for growing in Bangladesh's condition. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The genotypes were evaluated under irrigated timely sown (ITS) and irrigated late sown (ILS) conditions at both locations. In a timely sown condition, all genotypes were sown in lines by hand on November 22 at Dinajpur and November 20 at Jashore, whereas in late sown heat stress condition, all the genotypes were sown on December 21 at Dinajpur and December 20 at Jashore. The seeding rate was 120 kg per hectare for each genotype. Before sowing, seeds of all varieties were treated with a popular fungicide, Provax-200 WP, which contains carboxin and Thiram (marketed by Hossain Enterprise Bangladesh Ltd., in association with Chemtura Corp., USA). Furadan 5G (containing carbofuran, marketed by FMC International S.A. Bangladesh Ltd.) was broadcasted at 15 kg per hectare for controlling soil-borne insects. Seeds were sown continuously in a 5 m long 6 rows plot with a row spacing of 20 cm.

2.3. Intercultural operations

WRC recommended fertilizers, N, P, K, S, and B, respectively, at 100, 27, 40, 20, 1 kg ha $^{-1}$, were applied. During final land preparation, two-thirds of N and a full amount of the other fertilizers were applied as basal. The remaining N fertilizer was applied immediately after the first irrigation (18 days after sowing, DAS), while second, third, and fourth irrigations were applied at 50, 75, and 85 DAS. Mulching was done at 25 DAS, and hand weeding at 45 DAS. Phenology data like days to heading and maturity were recorded during the crop growth stage. The crop was harvested at full maturity on March 30 in 2014. Grain yield (GY) and yield contributing characters were measured from the middle 4 rows (4 m^2 area) among 6 rows. The harvested samples from each plot were bundled separately, tagged, and manually threshed on a threshing floor after drying the bundles thoroughly in bright sunshine. GY and 1000-grain weight (TGW) were measured at 12% moisture in grain [12].

2.4. Statistical analysis

The CropStat program conducted the statistical analysis with an F-test at 1% and 5% levels.

3. Results and discussion

3.1. Days to heading

The developmental stage in which the spike partially appears to emerge from its enclosing sheath is also called heading [13]. The time taken for the heading is entirely dependent on growth conditions and the genetic makeup of specific genotypes [5, 8, 9]. Days to the heading of different genotypes were significantly varied by genotypes, locations, and sowing times (Table 1, 2, 3, 4). It was earlier at the optimum sowing condition. In the case of environmental conditions, maximum genotypes took a long time to head both sowing conditions under the weather conditions of Dinajpur than Jashore. Maximum genotypes showed faster heading at late sowing conditions than optimum sowing conditions under the weather condition of Jashore. This result was similar to Hossain et al. [14], where they found days to heading was faster in late sowing conditions than timely sowing conditions in some spring wheat genotypes. Among the genotypes, Gen.-4, Gen.-5, Gen.-6, and Gen.-10 took less time than check variety BARI Gom 21 and BARI Gom 26. These differences of days to heading under ITS and ILS conditions in both locations might be due to environmental instability, especially temperature. This result was confirmed by several studies [15, 16, 17, 18], where they found that the crops complete their life cycle much faster in high temperatures than normal temperature conditions. However, the variation of phenological stages depends on genotypes [19].

Table 1. Effect of sowing times on yield and yield contributing characters of wheat genotypes, 2013-2014

Seeding time	Heading days	Maturity days	Spike per square meter	Grains per spike	Thousand-grain weight (g)	Yield (kg ha^{-1})
Irrigated timely sown	63	109	358	47	46.3	4224
Irrigated late sown	64	97	336	44	38.3	3113
F-test	**	**	**	**	**	**
LSD (0.05)	0.17	0.34	8.24	1.25	1.12	95.92
CV (%)	1.00	1.20	8.80	10.30	9.80	9.70

** = 1% level of significance

Table 2. Effect of locations on yield and yield attributes of wheat genotypes, 2013-2014

Location	Heading (days)	Maturity (days)	Spike per square meter	Grains per spike	Thousand-grain weight (g)	Yield (kg ha^{-1})
Dinajpur	65	105	337	47	45.9	3826
Jashore	62	101	357	44	38.8	3510
F-test	**	**	**	**	**	**
LSD (0.05)	0.17	0.34	8.24	1.25	1.12	95.92
CV (%)	1.00	1.20	8.80	10.30	9.80	9.70

** = 1% level of significance

Table 3. Yield and yield attributes of wheat genotypes varied due to their inherent characters, 2013-2014

Genotypes	Heading (days)	Maturity (days)	Spike per square meter	Grains per spike	Thousand-grain weight (g)	Yield (kg ha^{-1})
BARI Gom 21	69	107	368	44	42.2	3631
BARI Gom 26	64	103	332	51	42.6	3850
Gen-3	64	103	382	38	42.9	3872
Gen-4	58	99	335	42	40.2	3334
Gen-5	58	98	349	45	40.7	3649
Gen-6	63	104	332	43	43.9	3879
Gen-7	66	104	315	46	41.2	3464
Gen-8	70	107	347	57	39.6	4032
Gen-9	67	104	351	53	37.0	3684
Gen-10	61	101	370	37	47.2	3827
Gen-11	64	105	335	45	43.2	3725
Gen-12	65	105	371	51	40.4	3575
Gen-13	62	103	329	43	49.6	3542
Gen-14	62	102	329	42	49.4	3802
Gen-15	64	103	371	41	43.4	4002
Gen-16	63	101	319	51	40.7	3730
Gen-17	66	105	340	46	36.2	2754
Gen-18	58	101	375	43	41.5	3679
F-test	**	**	**	**	**	**
LSD (0.05)	0.52	1.01	24.72	3.76	3.36	287.76
CV (%)	1.00	1.20	8.80	10.30	9.80	9.70

** = 1% level of significance

3.2. Days to maturity

Similarly, in the present study, days to heading days to maturity of wheat were also significantly influenced by sowing time, environmental locations, and genotypes (Table 1, 2, 3, 4). In both locations, late sown wheat genotypes completed their life cycle very quickly than timely sown, while all genotypes took a long time to complete their life cycle under the weather condition of Dinajpur than Jashore condition might be due the environmental factors, especially temperature. Among the genotypes, Gen.-4, Gen.-5, Gen.-10, Gen.-14, Gen.-16, and Gen.-18 took a short time for maturity than both check varieties might be due to the different genetic makeup. This result was similar to Hossain et al. [14], where they reported that late sown; wheat completed their life cycle faster than timely sown wheat. Several reports showed that days to maturity of wheat genotypes are affected by environmental factors, especially temperature and inherent characters [20, 21, 22].

Table 4. Effects of genotypes, locations and sowing times on heading and maturity days, 2013-2014

Genotype	Heading days				Maturity days			
	Dinajpur		Jashore		Dinajpur		Jashore	
	Optimum	Late	Optimum	Late	Optimum	Late	Optimum	Late
BARI Gom 21	73	67	68	68	115	100	110	102
BARI Gom 26	65	66	61	63	112	99	107	94
Gen-3	65	63	64	63	113	96	106	98
Gen-4	55	62	56	58	106	93	104	91
Gen-5	58	58	58	57	106	92	103	91
Gen-6	63	64	64	62	112	99	109	97
Gen-7	69	67	65	64	113	99	108	96
Gen-8	75	68	71	66	116	101	112	101
Gen-9	67	67	68	65	112	100	107	97
Gen-10	60	65	59	59	106	98	105	94
Gen-11	65	66	62	63	115	100	108	97
Gen-12	65	66	65	63	115	100	108	96
Gen-13	62	66	60	60	109	100	107	96
Gen-14	62	66	61	60	108	99	107	96
Gen-15	64	67	62	63	112	99	106	95
Gen-16	63	66	59	62	108	99	104	94
Gen-17	66	69	64	64	115	103	107	95
Gen-18	56	62	57	57	108	97	105	94
F-test	**				**			
CV (%)	1.00				1.20			

** = 1% level of significance

3.3. Spike per square meter

Among the parameters of yield contributing characters, spikes/effective tillers are one of the essential parameters. The maximum number of spikes per m^{-2} was at ITS condition in both locations (Table 1, 2, 3, 5). In the present study, in the case of locations, the favorable environment for spike m^{-2} was Dinajpur compared to Jashore both in ITS and ILS conditions. Tahir et al. [23] also confirmed our result, who noticed that the total number of tillers per m^2 was significantly higher on November 20 than December 20. The tillering capacity of the late sowing crop was lower due to less soil moisture (drought), high soil and air temperature, and low relative humidity (RH). The highest tiller production on November 15 sowing was due to elongate vegetative phase weather during this period, as reported. It was considering the genotypes, highest spikes m^{-2} was recorded in genotype 'Gen.-3, followed by 'Gen.-18, 'Gen.Gen-7 and Gen.-16 produced-12, Gen.-15, and Gen-10 and the minimum. Genotype-specific spikes m^{-2} were due to the genetic makeup of a genotype as well as location-specific environmental factors.

3.4. Grains per spike

Performance of the genotypes for the trait grains per spike under different sowing times and locations was presented in Tables 1, 2, 3, 5. The wheat reproductive stage is the most sensitive period to temperature [14]. In high-temperature stress (above 30 °C) at the flowering stage, nearly all field crops reducing grain set ultimately decreased the grain number per spike due to lower fertilization caused by pollen sterility and/or ovule abortion that ultimately decreases the grain number per spike

[24,16]. In the present study, the highest grains spike^{-1} was recorded in ITS condition (Table 2), due to friendly weather condition, that finally helps to increase grain set. In the case of environmental conditions, the environmental condition of Dinajpur was better for setting grains per spike than Jashore (Table 3). Among the genotypes tested in this study, Gen-8 and Gen-9 produced higher grains per spike than both checks. The genotypic difference might be due to the genetic variation, climatic and edaphic factors determining the field conditions.

Table 5. Effects of locations, sowing times and genotypes on spike per square meter and grains per spike, 2013-2014

	Spike per square meter				Grains per spike			
Genotype	Dinajpur		Jashore		Dinajpur		Jashore	
	Optimum	Late	Optimum	Late	Optimum	Late	Optimum	Late
BARI Gom 21	361	359	369	381	52.8	41.6	45.0	34.7
BARI Gom 26	338	278	350	361	48.3	49.9	54.3	49.7
Gen-3	453	349	365	360	36.4	38.6	42.7	36.0
Gen-4	354	286	353	347	40.2	43.4	40.3	46.0
Gen-5	364	330	355	346	47.9	45.4	42.7	43.7
Gen-6	364	281	342	343	41.1	49.3	45.0	36.0
Gen-7	284	292	344	339	47.4	49.1	45.0	42.3
Gen-8	347	324	363	353	62.1	54.4	60.7	51.7
Gen-9	344	337	360	363	58.2	53.2	55.0	47.0
Gen-10	384	353	365	380	38.1	38.3	36.3	34.0
Gen-11	326	304	345	366	51.0	40.9	50.3	38.7
Gen-12	362	316	418	388	58.3	49.8	47.7	48.0
Gen-13	329	281	352	353	51.4	39.0	43.3	38.3
Gen-14	319	320	339	338	46.1	40.1	43.7	36.7
Gen-15	396	350	374	364	42.2	43.9	40.0	38.0
Gen-16	284	314	349	329	48.8	48.2	55.0	51.3
Gen-17	357	320	381	302	50.1	49.9	43.3	39.7
Gen-18	434	354	378	336	45.1	42.5	42.3	40.7
F-test	**				**			
CV (%)	8.80				10.30			

** = 1% level of significance

3.5. Thousand-grain weight

Heat stress under late sown conditions reduces TGW due to decreased individual grain weight while in optimum sowing. Top TGW is gotten due to the maximum individual grain weight due to favorable environmental conditions. In our present study, wheat is sown in ITS condition (November 20) produced the maximum TGW, and the minimum TGW was achieved from ILS condition (30th December sowing) (Table 1, 2, 3, 6). Considering the locations, the highest TGW was achieved in Dinajpur due to favorable weather conditions during the wheat growth stage (Table 6). In genotypes, the highest TGW was observed in Gen.-16, followed by Gen.-7, 13 and check BARI Gom 26, and the minimum TGW was in 'Gen.-9'. Location-specific sowing dates showed that all genotypes achieved the highest TGW under ITS condition. While in ILS condition, 'Gen.14 achieved the top TGW in Dinajpur, and 'Gen.-13' gave the highest TGW in the Jashore location. Reduced grain weight in two locations might be due to late sowing that decreased in the growth stage and curl of grain due to high-temperature dominance during in milk and grain filling stage. High temperature (soil, air) and a shortage of soil moisture (drought) in late sowing reduced individual grain weight, which finally affected 1000-grain weight due to early heading and abnormal maturity.

Table 6. Effect of genotypes, sowing times and locations on TGW and grain yield, 2013-2014

Genotype	Thousand-grain weight (g)				Yield (Kg ha^{-1})			
	Dinajpur		Jashore		Dinajpur		Jashore	
	Optimum	Late	Optimum	Late	Optimum	Late	Optimum	Late
BARI Gom 21	45.6	39.0	43.7	40.7	4291	2952	4147	3135
BARI Gom 26	57.5	35.8	42.3	34.7	4859	2532	4474	3537
Gen-3	55.3	40.9	41.0	34.3	5177	3297	3471	3541
Gen-4	49.7	39.0	41.3	31.0	4460	2347	3948	2582
Gen-5	51.9	38.0	41.0	32.0	4388	3276	3747	3185
Gen-6	54.0	42.2	44.0	35.3	5096	3027	4228	3164
Gen-7	57.2	37.2	37.0	33.3	4631	2803	3703	2718
Gen-8	43.4	40.9	38.0	36.0	4874	3556	3915	3782
Gen-9	41.7	34.8	38.0	33.7	4716	2965	3784	3271
Gen-10	54.2	48.2	46.3	40.0	4477	3337	4094	3398
Gen-11	49.9	40.4	43.0	39.3	4843	3219	3469	3369
Gen-12	47.3	38.8	41.0	34.3	4276	2937	3776	3312
Gen-13	56.3	48.0	47.0	47.0	4155	3063	3578	3374
Gen-14	54.2	49.0	49.7	44.7	4637	3157	3716	3697
Gen-15	51.5	44.0	41.3	36.7	4997	3756	4128	3126
Gen-16	57.6	34.4	39.0	32.0	4699	3220	3683	3319
Gen-17	43.4	37.7	34.7	29.0	3653	1673	3514	2174
Gen-18	48.4	44.2	40.3	33.0	4807	3592	3638	2678
F-test	**				**			
CV (%)	9.80				9.70			

** = 1% level of significance

3.6. Grain yield

It was significantly influenced by sowing time, environmental locations, and genotypes (Table 1, 2, 3, 6). The highest yield was obtained in ITS condition than ILS condition in both locations. Late sown wheat faced high-temperature stress in field conditions, followed by drought, causing significant yield reduction. Several reports showed similar results [8, 9, 14]. The poor GY of wheat sown on December 30 may be assigned to a decrease in the number of productive tillers/spikes and grains per spike. Considering on environmental conditions of the two locations, Dinajpur was a suitable place for good GY than Jashore. Among the genotypes, Gen.-8 gave the highest GY, followed by Gen.-15, Gen.-6, and Gen.-3, respectively. The higher yields of these wheat genotypes assigned to a higher number of spikes per square meter, grains per spike, 1000 grain weight.

4. Conclusion

Considering the overall performance from the experimental results, it can be concluded that irrigated timely sown is better than irrigated late sown conditions for wheat production. In a timely sowing condition, genotype Gen-3, Gen-6, Gen-15, Gen-8 showed better performance in the Dinajpur location, while genotype Gen-15, Gen-18, Gen-8 showed better performance in the Jashore location. Genotype Gen-15, Gen-18, Gen-8 showed better performance in the Dinajpur location in the late sowing condition, whereas genotype Gen-8, Gen-14, Gen-3 showed better performance in the Jashore location. Therefore, genotype Gen-8, Gen-3, gen-14, Gen-15, Gen-18 might be promising heat stress-tolerant genotypes. Regarding location, Dinajpur is the best place for wheat cultivation.

Conflicts of interest. There is no conflict of interest.

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