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Performance of eighteen advanced wheat lines grown under irrigated optimum and late sown conditions in different regions of Bangladesh

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Abstract. Eighteen advanced wheat lines were evaluated for irrigated optimum and late sown conditions in different environmental regions of Bangladesh. The experiments were conducted at Bangladesh Wheat and Maize Research Institute (BWMRI), Dinajpur, Regional Wheat Research Centre, Joydebpur, and Regional Agricultural Research Station, Jashore, Bangladesh. The advanced wheat lines, along with two check varieties BARI Gom 21 and BARI Gom 32, were evaluated in Randomized Complete Block Design (RCBD) with three replications under irrigated timely sown (ITS) and irrigated late sown (ILS) conditions. The study's objective was to find out the heat-tolerant wheat lines for future breeding programs to develop heat-tolerant wheat varieties. Significant variations were observed among tested genotypes on phenology, yield, and yield contributing characters at different seeding conditions in different locations. The highest thousand-grain weight (TGW) (60.9 g) was achieved in BAW 1328 in ITS conditions at Dinajpur, followed by BAW 1333 (60.4 g) and BAW 1333 (58 g) in the exact location and same seeding time. The lowest TGW (23 g) was obtained in the ILS condition at Jashore. The highest grain yield (GY) (6312 kg ha^{-1}) was obtained in BARI Gom 32 at Dinajpur in the ITS condition. The lowest grain yield, 1501 kg ha^{-1}, was obtained in BAW 1331 at Jashore under ILS condition. Regarding environmental locations, Dinajpur was better placed for wheat production. Among the advanced, tested lines, BAW 1322, BAW 1334, BAW 1337, and BAW 1338 showed better performance under ILS conditions, and these advanced lines were selected for future breeding programs to develop heat-tolerant varieties. The selected advanced lines had a high yield with better tolerance to Bipolaris leaf blight (BpLB), leaf blast, and resistance to leaf rust diseases.

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

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1. Introduction

The most fundamental activity of the people of Bangladesh is agriculture. Wheat is the second most important cereal after rice in the food security basket in Bangladesh [1] and is one of the primary foods for Asia. It is originated in southwestern Asia and a major agricultural commodity since prehistoric times.

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. Wheat is an essential source of carbohydrate [2]. Globally, it is the leading source of vegetal protein in human food, having a protein content of about 13%, which is relatively high compared to other significant cereals but relatively low in protein quality for supplying essential amino acids.

When eaten as a whole grain, wheat is a source of multiple nutrients and dietary fiber [3]. The consumption of wheat per capita has increased from 17.4 kg in 1972 to 60 kg in 2007 [4] in developing countries. Wheat yield is lower compared to other wheat-growing countries in the world [5]. Till now, the maximum yield of existing wheat varieties in the research field is 4.0-5.0 t ha^{-1} [6,7], but in farmers' fields, it is <3 t ha^{-1} [8] due to several stresses. Drought and high temperatures are key stress factors 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} [9]. Therefore, advanced lines 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 lines for future breeding programs.

2. Materials and methods

2.1. Locations

The experiment was conducted at BWMRI, Nashipur, Dinajpur (23° 11' 14.52" N, 89° 11' 11.99" E; 10.4 meters above sea level, masl) and the RARS, BARI, Jashore (23° 11' 14.52" N, 89° 11' 11.99" E; 10.4 masl) and Joydebpur (23° 59' 20.45" N and 90° 25' 5.40" E.) during the Rabi season (November-March) of 2017-2018.

2.2. Designs and experimental procedures

Eighteen advanced wheat lines and two checks (BARI Gom 21 and BARI Gom 32) were evaluated in this study to identify suitable advanced lines for growing in Bangladesh's condition. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The advanced lines were evaluated under irrigated timely sown (ITS) and irrigated late sown (ILS) conditions at the three locations. In timely sown condition, all advanced lines were sown by hand on November 21 at Dinajpur, November 23 at Jashore, and November 18 at Joydebpur, whereas in late sown heat stress condition, all the advanced lines were sown on December 25 at Dinajpur, December 26 at Jashore and December 26 at Joydebpur (Table 1). The seeding rate was 120 kg ha^{-1} for each advanced line. Before sowing, seeds of all lines were treated with a popular fungicide, pro-vax-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 ha^{-1} for controlling soil-borne insects. Seeds were sown continuously in a 5 m long 6 rows plot with a row spacing of 20 cm.

Table 1. The sowing dates at different locations

Locations	Sowing dates	
	Irrigated timely sown	Irrigated late sown
Dinajpur	21 November 2017	25 December 2017
Jashore	23 November 2017	26 December 2017
Joydebpur	18 November 2017	26 December 2017

2.3. Intercultural operation

BWMRI recommended fertilizer doses such as 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 total 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. Phenological 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 2018. 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 [10].

2.4. Evaluation of disease reactions

All of these genotypes from different sources, along with checks, were evaluated against bipolaris leaf blight (BpLB) under field conditions of disease development. Leaf blight severity was scored three times on a double-digit scale (00-99), commencing from the water ripe to the early dough stage [11]. Disease data were converted to percent diseased leaf area (% DLA), and the area under the disease progress curve (AUDPC) was calculated according to Sharma and Duveiller [12]. Wheat blast severity was recorded as a percentage of spike infected and percentage of disease area on the spike.

% BpLB severity = $D_1/9 \times D_2/9 \times 100$

where, D_1 = First digit, representing relative disease height, and D_2 = The second digit, indicating disease severity on the foliage

AUDPC = $[(Y_{i+1} + Y_i) \times 0.5] [T_{i+1} - T_i]$

where, Y_i = Disease severity at the ith observation, T_i = Time (days) of the ith observation and n = Total number of observations (at least 3 observations).

% Disease severity = (% spike incidence/100) × (% diseased area on spike/100) × 100

2.5. 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 growth or developmental stages are specific times at which recognizable physical changes are seen on the plant. 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 advanced lines [14,15]. Days to the heading of different advanced lines were significantly varied by genotypes, locations, and sowing times (Table 2, 3, 4, 5). In case of environmental conditions, maximum advanced lines took a long time to head both sowing conditions under the weather condition of Dinajpur than Jashore and Joydebpur. Most of the advanced lines showed faster heading at late sowing conditions than optimum sowing conditions under the weather condition of Joydebpur. This result was matched with Hossain et al. [16], where they showed days to heading was faster in late sowing conditions than timely sowing conditions in some spring wheat genotypes. Most advanced lines took less time than check variety BARI Gom 21 but a longer time compared to check variety BARI Gom 32. The variations of days to the heading of different wheat advanced lines under ITS and ILS condition in three locations might be due to environmental fluctuation, especially temperature variation also confirmed by various studies as reported [17,18,19, 20] who reported that under high temperature, the crop completes its life cycle much faster than under normal temperature conditions. However, the variations of phenological stages depend on genotypes [21].

Table 2. Effect of sowing times on yield and yield contributing characters of advanced wheat lines, 2017-2018

Seeding time	Heading (days)	Maturity (days)	Plant height (cm)	Spike per square meter	Thousand-grain weight (g)	Yield (kg ha^{-1})
Irrigated timely sown	64	107	99	318	48.3	4550
Irrigated late sown	62	95	90	293	38.1	2686
F-test	**	**	**	**	**	**
LSD (0.05)	0.29	0.32	0.77	9.25	0.32	86.02
CV (%)	1.8	1.2	3.2	11.9	2.9	9.3

** = 1% level of significance

3.2. Days to maturity

In the present study, days to maturity of wheat were significantly influenced by sowing time, environmental locations, and genotypes (Table 2, 3, 4, 5). In that locations, late sown wheat advanced lines completed their life cycle very quickly than timely sown while all advanced lines took a long time to complete their life cycle under the weather condition of Dinajpur than

Joydebpur and Jashore condition might be due the environmental factors, especially temperature. All of the advanced lines except BAW 1336 and BAW 1337 took a short time for maturity than check variety BARI Gom 21 and longtime than BARI Gom 32 might be due to the different genetic makeup. This result was similar to Hossain et al. [16], 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 [22, 23, 24].

Table 3. Effect of locations on yield and yield attributes of advanced wheat lines, 2017-2018

Location	Heading (days)	Maturity (days)	Plant height(cm)	Spike per square meter	Thousand-grain weight (g)	Yield (kg ha^{-1})
Dinajpur	66	105	102	347	49.2	4142
Joydebpur	60	96	90	290	45.0	3815
Jashore	64	102	92	279	35.3	2896
F-test	**	**	**	**	**	**
LSD (0.05)	0.13	0.14	0.34	4.05	0.39	105.35
CV (%)	1.8	1.2	3.2	11.9	2.9	9.3

** = 1% level of significance

Table 4. Yield and yield attributes of advanced wheat lines varied due to their inherent characters, 2017-2018

Genotypes	Heading (days)	Maturity (days)	Plant height(cm)	Spike per square meter	Thousand-grain weight (g)	Yield (kg ha^{-1})
BARI Gom 21	66	104	98	319	40.9	3526
BARI Gom 32	57	97	84	317	42.9	3926
BAW-1321	63	102	85	322	39.9	3590
BAW-1322	56	98	85	355	42.7	3722
BAW-1323	61	101	91	295	46.3	3077
BAW-1324	66	103	96	318	43.9	3926
BAW-1325	64	103	96	313	44.1	3976
BAW-1326	66	103	95	285	44.5	3687
BAW-1327	59	97	84	341	40.8	3347
BAW-1328	59	98	85	301	46.9	3778
BAW-1329	64	101	97	318	41.5	3782
BAW-1330	65	102	94	294	42.4	3482
BAW-1331	64	102	114	278	47.4	3030
BAW-1332	61	99	109	263	43.8	3419
BAW-1333	66	102	93	278	44.2	3703
BAW-1334	62	99	99	289	47.7	3864
BAW-1335	65	102	98	260	44.0	3703
BAW-1336	68	104	99	276	43.1	3252
BAW-1337	69	105	93	341	36.1	3644
BAW-1338	61	99	95	346	40.1	3923
F-test	**	**	**	**	**	**
LSD (0.05)	0.93	1.02	2.44	29.25	1.02	272.01
CV (%)	1.8	1.2	3.2	11.9	2.9	9.3

** = 1% level of significance

3.3. Plant height

Plant height is the most crucial parameter for crop yield estimation. Plant height was higher in the ITS condition than the ILS condition (Table 2). All of the advanced wheat lines showed higher plant height in Dinajpur than in other places. In our study, BAW-1331 showed the highest plant height than other advanced wheat lines (Table 4), while the BAW-1327 line was shorter than other lines. In Dinajpur, all wheat lines showed maximum plant height in the ITS condition than the other places. Among the three places, most of the wheat lines gave the lowest height in Joydebpur at ILS condition (Table 6). Variations of plant height were due to the genetic makeup of advanced lines and location-specific environmental factors.

Table 5. Effects of genotypes, location and sowing time interactions on heading days and maturity days, 2017-2018

Entry	Heading (days)						Maturity (days)					
	Dinajpur		Joydebpur		Jashore		Dinajpur		Joydebpur		Jashore	
	ITS	ILS	ITS	ILS	ITS	ILS	ITS	ILS	ITS	ILS	ITS	ILS
BARI Gom 21	72	70	61	62	68	63	117	102	102	93	115	99
BARI Gom 32	58	60	52	59	58	59	108	95	94	92	103	93
BAW-1321	67	65	60	61	67	61	115	98	101	93	110	94
BAW-1322	56	60	52	59	55	57	112	97	93	92	103	94
BAW-1323	66	63	57	62	60	59	114	100	101	95	106	94
BAW-1324	75	66	61	62	68	63	116	99	102	94	114	97
BAW-1325	71	65	61	61	67	62	116	99	101	94	112	98
BAW-1326	71	68	63	62	69	64	116	100	101	94	112	97
BAW-1327	59	61	52	59	58	63	108	94	95	90	103	93
BAW-1328	59	60	53	60	60	62	110	96	95	93	104	94
BAW-1329	69	64	62	61	65	64	115	96	100	93	105	98
BAW-1330	71	64	65	62	68	64	114	97	100	95	106	99
BAW-1331	67	64	61	61	67	62	111	96	101	94	110	100
BAW-1332	66	62	55	60	64	60	107	93	97	92	111	95
BAW-1333	73	65	61	62	71	63	112	98	102	94	114	95
BAW-1334	66	63	58	59	65	59	108	97	97	92	107	96
BAW-1335	72	67	62	61	68	63	112	97	101	90	113	96
BAW-1336	78	66	64	62	76	64	115	101	104	92	115	97
BAW-1337	78	67	67	64	76	63	117	101	106	94	115	97
BAW-1338	65	63	57	58	66	58	109	95	97	93	107	93
F-test	**						**					
LSD (0.05)	2.27						2.48					
CV (%)	1.8						1.2					

ITS=Irrigated timely sown, ILS=Irrigated late sown
** = 1% level of significance

3.4. Spike per square meter

Among all yield contributing characters' spike number/effective tiller is one of the critical parameters. The maximum number of spikes m^{-2} was at ITS condition in all three locations (Table 2, 3, 4, 6). In the present study, in locations, the favorable environment for spike m^{-2} was Dinajpur compared to Joydebpur and Jashore both in ITS and ILS conditions. The total number of tillers per m^2 was significantly higher on November 21 than December 25. 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 tillering was recorded at the sowing time on November 21; it might be due to a more extended vegetative phase. Considering the genotypes, the highest spikes m^{-2} was recorded inline 'BAW 1322 (355), followed by 'BAW 1338, 'BAW 1327, and BAW 1337, whereas the minimum spikes m^{-2} was produced by BAW 1335 (260) and BAW 1332 (263). Variations of spikes m^{-2} were due to the genetic makeup of advanced lines and location-specific environmental factors.

3.5. Thousand-grain weight

Thousand-grain weight decreased under late sown heat stress conditions while in optimum sowing time, higher TGW was gotten due to maximum individual grain weight due to favorable environmental conditions. In our present study, wheat is sown in ITS condition (21th November) produced the maximum TGW, and the minimum TGW was achieved from ILS condition (26th December sowing) (Table 2, 3, 4, 7). Considering on locations, the highest TGW was achieved in Dinajpur due to favorable weather conditions during the growth stage of wheat (Table 7). In advanced lines, the highest TGW was observed in BAW-1334

(47.7 g), followed by BAW-1331, BAW-1328, and BAW-1323, whereas the minimum TGW was in BAW-1337 (36.1 g). Location-specific sowing dates showed that all advanced lines achieved the highest TGW under ITS condition. While in ILS condition, 'BAW-1330, BAW-1325, and BAW-1328 achieved the top TGW in Dinajpur, Joydebpur, and Jashore. Reduced grain weight in three 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. Effects of genotypes, location and sowing time interactions on plant height and spikes per square meter, 2017-2018

Entry	Plant height (cm)						Spikes per square meter					
	Dinajpur		Joydebpur		Jashore		Dinajpur		Joydebpur		Jashore	
	ITS	ILS	ITS	ILS	ITS	ILS	ITS	ILS	ITS	ILS	ITS	ILS
BARI Gom 21	109	100	101	87	103	90	423	346	303	310	240	293
BARI Gom 32	95	84	84	79	83	78	441	307	330	296	246	283
BAW-1321	98	88	81	79	88	75	424	349	335	307	262	258
BAW-1322	98	95	83	80	85	74	431	351	366	329	377	274
BAW-1323	105	92	91	80	94	86	396	284	265	283	269	274
BAW-1324	106	98	99	86	104	82	369	315	318	281	330	296
BAW-1325	106	98	95	88	100	89	381	266	325	311	288	309
BAW-1326	108	96	97	86	100	85	357	269	242	299	297	246
BAW-1327	92	93	79	78	80	83	431	327	365	344	285	294
BAW-1328	95	89	87	72	86	82	389	301	300	267	257	294
BAW-1329	108	103	97	90	98	86	448	308	312	279	325	239
BAW-1330	103	98	97	84	91	93	384	263	277	265	294	283
BAW-1331	128	116	111	101	121	107	344	280	233	240	268	303
BAW-1332	125	111	103	99	114	105	309	279	226	252	236	275
BAW-1333	102	96	95	82	99	87	343	307	242	295	231	251
BAW-1334	111	102	99	91	105	86	352	289	288	252	269	284
BAW-1335	112	101	97	88	103	88	314	296	220	225	251	256
BAW-1336	111	108	104	86	103	86	299	330	235	265	274	253
BAW-1337	103	94	95	83	97	84	393	370	295	361	325	303
BAW-1338	105	99	97	84	102	84	438	386	310	380	296	266
F-test	**						NS					
LSD (0.05)	5.9						71.6					
CV (%)	3.2						11.9					

** = 1% level of significance, NS = Non significant

3.6. Grain yield

It was significantly influenced by sowing time, environmental locations, and genotypes (Table 2, 3, 4, 7). The highest yield was obtained in ITS condition than ILS condition. Late sown wheat faced high-temperature stress in field conditions, followed by drought, causing significant yield reduction. Several reports showed similar results [14, 16, 25]. The poor GY of wheat sown on December 26 may be assigned to a decrease in the number of productive tillers spike^{-1} and grains spike^{-1}. Considering environmental conditions among the three locations, Dinajpur was a suitable place for good GY than Joydebpur and Jashore (Table 2, 7). Among the Advanced lines, BAW-1325 gave the highest GY (3976 kg ha^{-1}), followed by BAW-1324 and BAW-1338, respectively. The higher yields of these wheat advanced lines assigned to a higher number of spikes m^{-2} and 1000 grain weight.

3.7. Percent yield losses due to late sowing and disease reactions

Among tested genotypes, BAW-1322, BAW-1323, BAW-1334, BAW-1336, BAW-1337, and BAW-1338 lost their yield less than both check varieties due to late sowing (Table 8). The most negligible yield loss was found in genotype BAW-1337. Regarding area under disease progressive curve (AUDPC) against bipolaris leaf blight (BpLB), BAW-1335 and BAW-1336 showed less AUDPC than both check varieties. In the case of blast incidence, there was no incidence in genotypes BAW-1328, BAW-1337, and BAW-1338. Genotypes BAW-1323, BAW-1326, and BAW-1332 showed a lower incidence compared to both checks. Regarding blast severity, there was no severity found in genotypes BAW-1328, BAW-1337, and BAW-1338. Genotype BAW-1332 showed lower disease severity than both checks.

Table 7. Effects of genotypes, location and sowing time interactions on thousand-grain weight (g) and yield, 2017-2018

Entry	Thousand-grain weight (g)						Yield (kg ha-1)					
	Dinajpur		Joydebpur		Jashore		Dinajpur		Joydebpur		Jashore	
	ITS	ILS	ITS	ILS	ITS	ILS	ITS	ILS	ITS	ILS	ITS	ILS
BARI Gom 21	42.5	42.7	46.5	39.0	44.0	31	4866	2402	4728	3338	3880	1942
BARI Gom 32	53.3	47.2	46.1	40.0	44.0	27	6312	3688	4673	3108	3571	2206
BAW-1321	45.1	41.3	47.6	40.7	42.0	23	5240	3052	4933	2404	4296	1613
BAW-1322	54.3	46.3	47.2	37.3	41.0	30	5684	3642	4265	2732	3623	2389
BAW-1323	53.0	48.5	52.5	43.7	49.0	31	3134	2778	4387	2585	3439	2140
BAW-1324	55.3	47.2	47.6	43.4	44.0	26	5552	3002	5429	3461	4189	1925
BAW-1325	53.6	46.8	54.4	44.1	43.0	23	5842	2922	5082	3485	4388	2136
BAW-1326	56.1	43.9	53.7	43.0	46.0	24	5704	2640	5236	2839	4170	1531
BAW-1327	49.8	41.4	48.0	37.8	40.0	28	4766	3196	3659	2837	3958	1669
BAW-1328	60.9	48.2	50.0	42.2	44.0	36	5966	3060	4399	3259	3911	2073
BAW-1329	48.8	45.7	45.8	39.5	41.0	28	5612	3592	4736	2797	4126	1829
BAW-1330	46.4	51.7	48.3	40.1	45.0	23	4808	3014	4672	3269	3418	1709
BAW-1331	56.4	50.9	53.3	43.8	50.0	30	4636	2672	3245	2738	3390	1501
BAW-1332	53.9	50.3	49.0	33.7	48.0	28	5098	2660	3834	3005	4064	1850
BAW-1333	55.6	42.7	54.8	43.1	44.0	25	5524	2958	5215	3138	3591	1794
BAW-1334	60.4	51.1	51.8	43.8	50.0	29	5590	3608	4698	3171	3844	2271
BAW-1335	58.0	46.0	55.1	40.2	41.0	24	5570	2674	5082	3359	3877	1656
BAW-1336	55.8	43.1	55.8	40.8	38.0	25	4078	2876	4708	3095	3191	1563
BAW-1337	36.1	43.6	37.8	38.4	32.0	29	4832	3020	3801	3313	4172	2725
BAW-1338	47.4	46.7	44.8	35.1	38.0	29	5974	3444	4328	3563	4008	2224
F-test			**						**			
LSD (0.05)			2.49						666			
CV (%)			2.9						9.3			

** = 1% level of significance

Table 8. Mean yield, disease reaction and percent yield losses (%) due to late sowing of wheat genotypes, 2017-2018

Genotypes	Irrigated timely sown	Irrigated late sown	Mean	Yield Loss (%)	AUDPC of Bipolaris leaf blight	Blast	
						Incidence	Severity
BARI Gom 21	4491	2561	3526	43	79	2	40
BARI Gom 32	4852	3001	3926	38	170	70	60
BAW-1321	4823	2356	3590	51	88	75	70
BAW-1322	4524	2921	3722	35	257	2	60
BAW-1323	3653	2501	3077	32	132	1	70
BAW-1324	5057	2796	3926	45	105	10	60
BAW-1325	5104	2848	3976	44	110	5	50
BAW-1326	5037	2337	3687	54	142	1	50
BAW-1327	4128	2567	3347	38	187	20	80
BAW-1328	4759	2797	3778	41	165	0	0
BAW-1329	4825	2739	3782	43	110	2	60
BAW-1330	4299	2664	3482	38	202	50	50
BAW-1331	3757	2303	3030	39	226	10	60
BAW-1332	4332	2505	3419	42	207	1	20
BAW-1333	4777	2630	3703	45	103	5	40
BAW-1334	4711	3017	3864	36	85	20	60
BAW-1335	4843	2563	3703	47	77	30	70
BAW-1336	3992	2511	3252	37	72	5	50
BAW-1337	4268	3019	3644	29	174	0	0
BAW-1338	4770	3077	3923	35	144	0	0

AUDPC: Area under Disease Progressive Curve

4. Conclusion

Considering the overall performance from the experimental results, it can be concluded that all advanced lines are better in all respect in irrigated timely sowing as compared to irrigated late sowing conditions. In late sowing conditions, BAW-1334, BAW-1337, and BAW-1338 showed comparatively higher yield than optimum time sowing; that is why these three lines might be promising heat stress-tolerant lines and it can be said that Dinajpur is the best place for wheat cultivation among these three locations.

Conflicts of interest. There is no conflict of interest.

References

[1] Timsina, J., Wolf, J., Guilpart, N., van Bussel, L.G.J., Grassini, P., van Wart, J., Hossain, A., Rashid, H., Islam, S., van Ittersum, M.K. (2018). Can Bangladesh produce enough cereals to meet future demand? Agric. Syst. 163, 36-44.

[2] Shewry, P.R. & Hey, S.J. (2015). "Review: The contribution of wheat to human diet and health". Food Energy Secur. 4, 178-202.

[3] FAOSTAT (2019). Available at http://faostat.fao.org/site/339/default (access online: January, 2019).

[4] Ghimire, Y.N., Gautam, S., Nepali, M.B. (2012). Wheat Research and development during 25 years of NARC-CIMMYT collaboration: A review. In: *Proceedings of the 10th National Outreach Workshop* held at Regional Agricultural Research Station, Lumle, Kaski during 27-28 February, p.320-328.

[5] Hossain, A., Slam, M.R., Rahman, K.A.M.M., Rashid, M.H., Anwari, A. (2017). Comparative performance of three wheat (*Triticum aestivum* L.) varieties under heat stress. Int. J. Nat. Social Sci. 4(3), 26-42.

[6] Statista, (2016). Global wheat yield per hectare from 2010/2011 to 2025/2026 (in metric tons). Statista, Inc., New York, NY, USA.

[7] BARI (Bangladesh Agricultural Research Insti-tute) (2016). Wheat Varieties Released by Bangladesh Agricultural Research Institute. BARI, Joydebpur, Gazipur-1701, Bangladesh. http://baritechnology.org/en/home/tech_commodity#result (Accessed on 25 July 2018).

[8] BBS (Bangladesh Bureau of Statistics) (2016). Statistical Year Book of Bangladesh. Statistics Division, Ministry of Finance and Planning, Government of Peoples Republic of Bangladesh, Dhaka.

[9] Hussain, A., Maqsood, M., Ahmad, A., Aftab, S., Ahmad, Z. (1998). Effect of irrigation during various development stages on yield, components of yield and harvest index of different wheat cultivars. Pak. J. Agric. Sci. 34, 104–107.

[10] Hellevang, K.J. (1995). Grain moisture content effects and management. Department of Agricultural and Biosystems Engineering, North Dakota State University.

[11] Zadoks, J.C., Chang, T.T., Konzak, C.F. (1974). A decimal code for the growth stages of cereals. Weeds Res. 14, 415.

[12] Sharma, R.C., Duveiller, E. (2003). Selection index for improving helminthosporium leaf blight resistance, maturity, and kernel weight in spring wheat. Crop Sci. 43, 2031-2036.

[13] Acevedo, E., Silva, P., Silva, H. (2002). Wheat growth and physiology. In: Curtis, B.C., Rajaram, S. and Macpherson, H.G. (eds.) Bread Wheat Improvement and Production, FAO Plant Production and Protection Series, No. 30. Food and Agriculture Organization of the United Nations, Rome, Italy.

[14] Hossain, A., Teixeira da Silva, J.A., Lozovskaya, M.V., Zvolinsky, V.P. (2012). The Effect of high temperature stress on the phenology, growth and yield of five wheat (*Triticum aes-tivum* L.) genotypes. The Asian and Aust. J. Plant Sci. Biotech. 6(1), 14-13.

[15] Hossain, A., Sarker, M.A.Z., Saifuzzaman, M., Teixeira da Silva, J.A., Lozovskaya, M.V., Akhter, M.M. (2013). Evaluation of growth, yield, relative performance and heat susceptibility of eight wheat (*Triticum aestivum* L.) genotypes grown under heat stress. Int. J. Plant Prod. 7(3), 615-636.

[16] Hossain, M., Hossain, A., Alam, A., Sabagh, A.E.I., Murad, K.F.I., Haque, M., Muniruzzaman., Islam, Z., Das, S., Celaleddin Barutcular, C., Kizilgeci, F. (2018). Evaluation of fifty irrigated spring wheat genotypes grown under late sown heat stress condition in multiple environments of Bangladesh. Fresen. Environ. Bull. 27(9), 5993-6004.

[17] Fischer, R.A. (1985). Number of kernels in wheat crops and the influence of solar radiation and temperature. J. Agric. Sci. 105(02), 447- 461.

[18] Yang, J., Sears, R.G., Gill, B.S., Paulsen, G.M. (2002). Growth and senescence characteristics associated with tolerance of wheat-alien amphiploids to high temperature under controlled conditions. Euphytica 126, 185–193.

[19] Nahar, K., Ahamed, K.U., Fujita, M. (2010). Phenological variation and its relation with yield in several wheat (*Triticum aestivum* L.) cultivars under normal and late sown mediated heat stress condition. Not. Sci. Biol. 2(3), 51-56.

[20] Hakim, M.A., Hossain, A., Teixeira da Silva, J.A., Zvolinsky, V.P., Khan, M.M. (2012). Yield, protein and starch content of 20 wheat (*Triticum aestivum* L.) genotypes exposed to high temperature under late sowing conditions. J. Sci. Res. 4(2), 477-489.

[21] Wahid, A., Gelani, S., Ashraf, M., Foolad, M.R. (2007). Heat tolerance in plants: An overview. Env. Exp. Bot. 61, 199-233.

[22] Spink, J.H., Clare, R.W., Kilpatricks, J.B. (1993). Grain quality of milling wheat at different sowing dates. App. Biol. 36, 231-240.

[23] Araus, J., Ferrio, J., Buxo, R., Voltas, J. (2007). The historical perspective of dry land agriculture: lessons learned from 10000 years of wheat cultivation. J Exp. Bot. 58(2), 131-145.

[24] Shahzad, M.A., Sahi, S.T., Khan, M.M., Ahmad, M. (2007). Effect of sowing dates and seed treatment on grain yield and quality of wheat. Pak. J. Agril. Sci. 44, 581-583.

[25] Hossain, A., Sarker, M.A.Z., Saifuzzaman, M., Teixeira da Silva, J.A., Lozovskaya, M.V., Akhter, M.M. (2013). Evaluation of growth, yield, relative performance and heat susceptibility of eight wheat (*Triticum aestivum* L.) genotypes grown under heat stress. Int. J. Plant Prod. 7(3), 615-636.