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Yield Performance and Blast Susceptibility of Some Wheat (*Triticum aestivum*) Varieties in Jashore

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Abstract

A trial was conducted during 2015-16 to 2017-18 at the Regional Agricultural Research Station (RARS) of Bangladesh Agricultural Research Institute (BARI), Jashore to select some tolerant varieties against wheat blast. Fourteen varieties including eight old varieties (Sonalika, Kanchan, Sourav, Gourab, Shatabdi, Sufi, Bijoy, Prodip) and six newly released varieties (BARI Gom 25, BARI Gom 26, BARI Gom 27, BARI Gom 28, BARI Gom 29 and BARI Gom 30) were evaluated. The experiments were non-replicated and were planted in two sowing dates, at optimum (mid November) and late (mid December) conditions. Three irrigations were applied, at crown root initiation (CRI), heading and grain filling stages. Plants of border rows were inoculated by *Magnaporthe oryzae triticum* (MoT) spores (10^4 conidia ml^{-1}) for infection once per week from three weeks after sowing until primary infection was observed. The significantly higher grain yield was observed in 2016-17 (3505 kg ha^{-1}) which was similar to 2017-18 (3448 kg ha^{-1}) and the lowest was in 2015-16 (1680 kg ha^{-1}). The higher grain yield was obtained due to the higher grains spike^{-1} (45 no.) and 1000 grain weight (36.6 g) and lower blast disease incidence (% blast index 18.1%). In all three years, there was heavy infection of wheat blast in late sowing condition (% blast index 40.7) compared to the optimum sowing condition (% blast index 1.4), resulting in very poor crop yield (1696 kg ha^{-1}). Among the varieties, the variety Gourab produced the highest yield (3395 kg ha^{-1}) which was similar to the newly released variety BARI Gom 28 (3196 kg ha^{-1}) and BARI Gom 30 (3134 kg ha^{-1}). In case of blast disease severity, old varieties were less infested with some exception in Sonalika and Kanchan. On the other hand, BARI Gom 25 and BARI Gom 26 were more susceptible (% blast index 35.3-36.5) to wheat blast compared to BARI Gom 28 and BARI Gom 30 (% blast index 20.2-22.5).

Keywords: Wheat blast, Variety, *Magnaporthe oryzae*, Temperature, Tolerance.

1. Introduction

Wheat (*Triticum aestivum*) is the second most important grain crop in Bangladesh after rice. Several biotic and abiotic stresses are the major constraints for the widespread cultivation of wheat. Among the diseases, leaf rust, leaf blight, head blight etc. are usually prevalent in this environment. However, wheat blast (or brusone), a new devastating wheat disease caused by *Magnaporthe oryzae* B.C. Couch (synonym *Pyricularia oryzae* Cavara) pathotype *Triticum*

(MoT) emerged for the first time in 2016 in several southwestern and southern districts of Bangladesh. The disease was widespread accounting for approximately 15% of Bangladesh's total wheat area, which underscored a concern about the potential spread of wheat blast to other wheat producing areas in Bangladesh, South Asia and beyond. Wheat blast is new to Asia, known to cause significant crop losses in some South American countries with warm and humid condition. Comparative genome analyses revealed that the fungal isolates appeared in Bangladesh was clonal and closely related to highly aggressive MoT isolates from South America (Farman *et al*., 2017; Islam *et al.*, 2016; Malaker *et al*., 2016). The disease was first observed in the state of Paraná, Brazil, in 1985 (Igarashi *et al*., 1986). Later on it spreads to Bolivia, Argentina and Paraguay (Duveiller *et al*., 2016). Due to lack of resistant cultivar and in effectiveness of fungicides at higher disease pressure, wheat blast is widely distributed across the wheat growing areas in Brazil, causing yield losses from 40-100% (Silva *et al*., 2009; Maciel 2013; Castroagudin *et al*., 2016). In South America, more specifically Brazil, have some regions where the farmers don't go to grow wheat because of the disease (Callaway, 2016). The disease was also spotted in Kentucky, USA in 2011, however, vigorous surveillance helped to stop its spread over the country (Callaway, 2016).

Wheat blast is mainly a disease of spike, however, can occur on all aerial plant parts. Severity of the disease greatly depends upon weather conditions, cultivars, and plant organs infected (Goulart *et al*., 2007; Urashima *et al*., 2009). Although exact weather conditions required for a field epidemic are not clear, most severe blast outbreaks have coincided with wet years; warm temperatures and high humidity (Urashima *et al*., 2009). Lack of a complete understanding of ecological and epidemiological factors that drive wheat blast epidemics makes disease management a challenging task. It is important to determine the relative importance of potential primary sources of inoculums such as infected seeds (Urashima *et al*., 1999). However, seed infection may play a limited role in epidemiology but being seed-borne, wheat blast can spread easily via commercial grain shipments or farmer-to-farmer seed exchanges. The disease can be managed by the use of fungicides, resistant cultivars, agronomic practices and biotechnological methods (Ribot *et al*., 2008). Wheat blast fungus has physiologically and genetically complex character, with a range of aggressiveness and pathotypes. Most of the wheat cultivars are susceptible to wheat blast in Bangladesh (Malaker *et al*., 2016). Tolerant cultivars should have to identify in specific areas, but still yet to develop variety with durable resistance.

Therefore, a trial was implemented to find out blast resistant wheat varieties among the old and newly released varieties in Bangladesh.

2. Materials and Methods

2.1 Soil and environment of site

The experiment was conducted at the experimental farm of the Regional Agricultural Research Station of Bangladesh Agricultural Research Institute at Jashore (23°11′ N, 89°14′ E and 16 m ASL) during 2015-2018, in *rabi* seasons. The climate was subtropical monsoon with average annual rainfall of 1590 mm, 90% of which falls from June to October (Alam *et al*., 2017). Monthly mean rainfall was lower in November to March (about 20 mm rainfall occurred both in the later two years (2016-17 and 2017-18), whereas it was higher (57 mm) in the first year (2015-16), especially more rainfall (42 mm) in the maturity stage (Fig. 1). Monthly mean maximum temperature ranges from 24^{o}C in December (2015-16) to 32^{o}C in March of 2016-17 (Fig. 1). The soil was a calcareous brown clay loam of the High Ganges River Floodplain (BARC, 2012). Bulk density was 1.4-1.5 g cm^{-3} throughout the profile, apart from a slightly denser layer at 20-25 cm. The topsoil (0-15 cm) was slightly alkaline (pH 7.7) and had low soil organic C (1%) content (Alam *et al*., 2017; 2018).

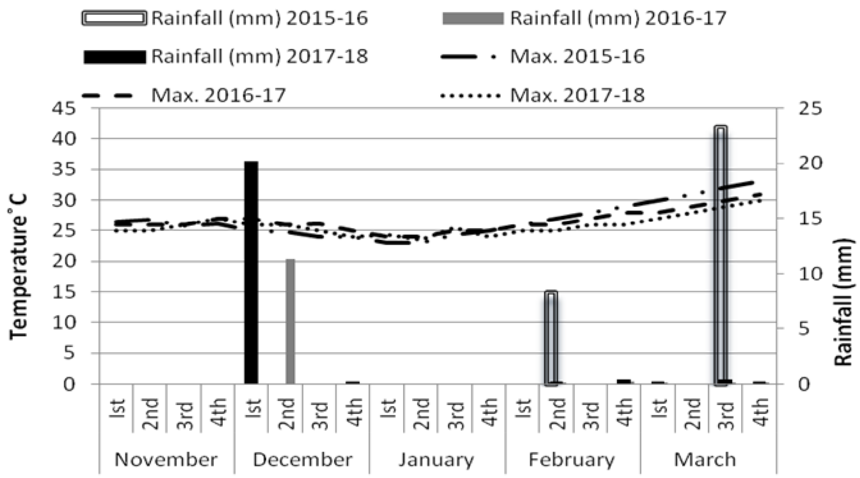

Fig. 1. Weekly average temperature and rainfall during Nov. to Aprl 2015 to 2018 at RARS wheat research field Jashore

2.2 Experimental design

The experiment was carried out with non-replications in field conditions. Eight old varieties (Sonalika, Kanchan, Sourav, Gourab, Shatabdi, Sufi, Bijoy and Prodip) and six newly released varieties (BARI Gom 25, BARI Gom 26, BARI Gom 27, BARI Gom 28, BARI Gom 29 and BARI Gom 30) were used in the on station trial.

2.3 Crop management

A pre-sowing irrigation (50 mm) was applied about a week before sowing seeds. The experiments were earmarked for optimum (15-30 November) and late seeding (20-30 December), at 120 kg seed ha^{-1}, with a sowing depth of 3-5 cm and row spacing of 20 cm. The wheat seeds were treated with Provax-200 @ 3g kg$^{\mathbf{-1}}$ seed and sown by hand seeding by maintaining equal row spacing. Total fertilizer application was 100 kg N ha^{-1} as urea, 30 kg P ha^{-1} as triple superphosphate, 50 kg K ha^{-1} as muriate of potash, 20 kg S ha^{-1} as gypsum, 5 kg Zn ha^{-1} as zinc sulphate and 1 kg B ha^{-1} as boric acid. Two thirds of the N and all the P, K, S and B fertilizers were broadcast just before sowing, and the rest of the N was top dressed after the first irrigation at crown root initiation (CRI) stage. Weeds were well-controlled by one hand weeding at 25-30 days after sowing (DAS), and there was no significant damage by insect and pests. The crop received three post-sowing irrigations at CRI (17-21 DAS), heading (55-60 DAS) and grain filling (75-80 DAS) stages.

2.4 Artificial inoculation of MOT

The trials were surrounded by border rows with mixture of varieties susceptible to leaf rust and leaf blight. The plants of border rows were inoculated by MoT spores for infection once in a week starting from three weeks after sowing until primary infection was observed. The crop was harvested at full maturity in each season. The inoculum were supplied by plant pathology laboratory of Regional Agricultural Research Station Jashore.

2.4 Data collection

Plant counting was made for number of plants in 1m from each of 5 middle rows in case of yield trials (plants/m^2). Heading days was counted from sowing to the day when base of the 50% of the spikes just come out from the flag leaf sheath. Maturity days (physiological maturity) was determined visually and defined as the time when the 80% of the grains in the wheat spikes had turned yellowish.

Grain yield was determined by fresh harvesting of 3.2 m^2 area (4 m×0.8 m). Fresh grain yield was converted to grain yield (kg ha^{-1}) at 12% moisture content using the following formula:

$$Yadj = Y_{AC} \times \frac{(100 - M_{AC})}{(100 - M_{ST})}$$

Where,
Yadj = Adjusted yield, Y_{AC} = Yield at actual moisture percent, M_{AC} = Actual moisture percent, M_{ST} = Standard moisture percent

Grains spike^{-1} was determined from ten randomly selected spikes, threshed all 10 spikes and counts all the grains of those spikes and divides by ten. Thousand grain weights (dry) were determined by oven drying @ 70 °C for 2-3 days. Severity of wheat blast disease has scored at grain filling (80 DAS) stage according to following formula;

% DS = (% spike incidence/100)*(% disease area on spike /100)*100
Where, DS = Disease severity

Temperature and rainfall data during the experimental period were collected from the Regional Agricultural Research Meteorological Station, Jashore.

2.6 Statistical analysis

Data were analyzed by ANOVA (using Crop Stat 7.2) to evaluate differences between treatments, and the means were compared using least significant difference (LSD) at the 5% level of significance ($p<0.05$).

3. Results and Discussion

3.1 Effect of season (year) on crop growth and blast infestation

3.1.1 Effect on heading

The highest mean heading day was 63 in 2017-18 and the lowest one was 61 d in 2016-17. The maturity (physiological maturity) days was highest (103d) in 2016-17, followed by 101d in 2017-18 and the lowest one was 98 d in 2015-16 (Table 1). Thus heading and maturity days were 1-2 days and 3-5 days shorten 2015-16 compared to that of 2016-16 and 2017-18. It might be due to the increase of temperature from first week of February (grain filling stage) to end of March which resulted earlier maturity.

The reduction of duration for wheat maturity with increasing temperature as reported by Fischer, 1985; Hakim *et al.*, 2012; Hossain *et al.*, 2012.

3.1.2 Effect on plant density (no. m^{-2})

The highest mean plant density (no. m^{-2}) was in 2016-17 (88 no. m^{-2}) followed by 2017-18 and the lowest one (56 no.m^{-2}) was in 2015-16 (Table 2). The variation in plant density might be due to variation of germination (%) or other unrecorded causes.

3.1.3 Effect on yield and yield attributes of wheat

Seasonal variation affected yield and yield attributes significantly in wheat (Table 2). The highest yield (3505 kg ha^{-1}) was observed in 2016-17 similar to 2017-18 (3448 kg ha^{-1}) and the lowest one (1680 kg ha^{-1}) was in 2015-16. Yield losses up to 100% are reported for susceptible cultivars (Goulart and Paiva, 2000).
The spike density (grain spike $^{-1}$) was the highest (45) in 2016-17, followed by 44 in 2017-18 and the lowest one (43) was in 2015-16 (Table 2). Lower spike density in 2015-16 might be due to higher blast infestation.

The highest 1000 grain weight **(**36.6 g) was significantly higher in 2016-17, and the lowest (31.8 g) was in 2015-16 (Table 2), similar to 2017-18 (32.1 g). The reason was due to the heavy infection of blast both in optimum and late sowing condition, the severity and intensity were more devastating in late season sowing crop (% blast index 33), which resulted small, shriveled and less seed weight (Goulart *et al*., 2007).

Table 1. Effect of sowing time on the time from sowing to heading, physiological maturity and % blast disease index of old and newly released wheat varieties

Variation source	Heading days (no.)	Maturity days (no.)	% blast disease index
Year (Y)			
2015-16	62	98	33.0
2016-17	61	103	18.1
2017-18	63	101	12.1
Sowing time (T)			
Optimum	62	107	1.4
Late	61	93	40.7
Variety (V)			
Sonalika	59	99	23.5
Kanchan	65	101	22.0
Sourav	65	102	2.3
Gourab	59	101	9.9
Shatabdi	67	104	6.8
Sufi	59	100	17.0
Bijoy	64	102	18.7
Prodip	63	101	20.7
BARI Gom 25	62	102	35.3
BARI Gom 26	61	99	36.5
BARI Gom 27	65	100	28.7
BARI Gom 28	59	100	22.5
BARI Gom 29	59	100	30.7
BARI Gom 30	58	98	20.2
$LSD_{0.05}$			
Y	1.0	0.8	7.1
T	0.8	0.7	5.8
V	2.2	1.8	15.2
Y×T	ns	1.2	9.9
T×V	3.1	2.6	21.5
Y×V	ns	ns	ns
Y×T×V	ns	ns	ns

Y = Year, V = Variety, T = Sowing time

3.1.4 Effect on severity of wheat blast (% blast index)

The significantly higher disease severity was 33% in 2015-16 followed by 18.1% in 2016-17 and the lowest one was 12.1% in 2017-18 (Table 1). Epidemic years are characterized by several days of continuous rains and average temperatures of 25–30 °C with spike wetness between 25 and 40 hrs during the flowering stage of the crop (Cardoso *et al*., 2008). However, temperature was comparatively higher during grain formation period (temperature raised 1-3 °C started from 2nd week of February and continued up to March) and also 15 mm rainfall at second week of February 2016, which played a crucial role on more disease severity (33%) in 2015-16 (Fig. 1). Kohli *et al*. (2011) reported that wheat blast occurred from 18-25 ^{o}C during flowering, followed by hot and humid conditions. On the other hand, Cardoso *et al*. (2008) indicated that minimum temperature for disease infection is 10^{o}C and the maximum is 32

^{o}C, with optimum between 25-30 ^{o}C, was similar to our study.

3.2 Effect of sowing time on the performance of wheat

3.2.1 Effect of sowing time on crop development

There is a significant effect of sowing time between optimum and late sowing condition on crop development of wheat. The highest mean heading time (62 days) and maturity time (107 days) were observed in optimum sowing and the lowest heading (61 days) and maturity (93 days) in late sowing (Table 1). In case of optimum sowing (15-30 November), heading usually occurred at mid-January (average temperature 24 °C), favourable for anthesis and resulted delay maturity. On the contrary, in late sowing (20-30 December), heading occurred after mid-February with higher temperature (27 °C)enhanced forced maturity and required less days (about 2 weeks) for attaining the maturity. It was observed that all cultivars sown in early need higher days compared to late sown (Hossain *et al.*, 2012).

3.2.2 Effect of sowing time on plant density (no. m^{-2})

The highest plants density (no. m^{-2}) was observed in optimum sowing (74 plants m^{-2})and lowest in late sowing (70 plants m^{-2}) (Table 2). The reason might be low temperature (about 2 °C) at the sowing time in late sowing than that of optimum sowing time.

3.2.3 Effect sowing time on yield and yield attributes of wheat

Sowing time had significant effect on yield and yield attributes of wheat. The significantly higher yield (4060 kg ha^{-1}) was recorded in optimum sowing time and the lowest yield (1695 kg ha^{-1}**)** was in late sowing (Table 2). In optimum sowing environment were favourable for good grain formation but in late sowing temperature became higher up to 37.6 ºC resulted forced maturity. Furthermore, in late sowing plants, the severity and intensity of wheat blast was more (% blast index 40.7%), resulted less grain weight and grains spike^{-1} which contributed a significant yield loss. Highest yield losses occur when spike infections begin during flowering or early grain formation (Goulart *et al.*, 2007).

The mean grain spike^{-1} was significantly higher in optimum sowing time (44) and the lowest (40) in late sowing condition (Table 2). The grain spike^{-1}was higher (17%) in optimum sowing condition than in late seeding condition. This may be due to the higher temperature (2 °C) at grain filling stage in optimum sowing than late sowing, caused sterility and produced lower grains. The 1000 grain weight **(**43.6 g) was higher in optimum sowing time and the lower(23.3g) in late sowing (Table 2).

3.2.4 Effect on disease severity (% blast index)

The higher disease infestation occurred (mean % blast disease index 40.7%) was in late sowing whereas, it was very minimum (mean % blast disease index1.4%) in optimum sowing condition (Table1). In late condition, the severity and intensity were forty times more devastating than that of optimum sowing condition. Our observations was higher temperature, with some rainfall (15 mm in 2015-16,0.2 mm in 2016-17 and 0.2 mm in 2017-18), accelerates the severity and intensity of wheat blast at grain formation period in each of the years similar to that of Urashima *et al*. (2009).

3.3 Effect of variety on the performance of wheat

3.3.1 Effect of cultivar/variety on crop development

Among varieties there was significant variation on heading duration and maturity days of wheat. The higher heading period was required in the variety Shatabdi (67 d), similar to Kanchan, Saurav, and BARI Gom 27 at 65 d and the lower in the BARI Gom 30 (58 d) (Table 1). Similarly, the higher days were recorded in Shatabdi (104 d), followed by 102 d in Kanchan, Bijoy and BARI Gom 25 and the lower in BARI Gom 30 (98 d). The difference in crop development (both in heading and maturity) among the wheat varieties may be due the varietal character (crop duration/life duration). Days to physiological maturity of wheat cultivars also showed a significant variation due to inherent differences between the cultivars (Shahzad *et al*., 2007). Up to 29 November Gourab need minimum and after 29 November Sufi need minimum days to get physiological maturity. Spink *et al.* (1993) also observed that delayed sowing shortens the duration of each development phase due to rising of temperature.

3.3.2 Effect of cultivar/variety time on plant density (no. m^{-2})

Plant density (no. m^{-2}) was also significantly influenced by the variety. The significant highest plant density (no. m^{-2}) was observed in Sonalika (80 no. m^{-2}), similar to Kanchan (79), Sourav (74) and BARI Gom 28 (76) and the lowest (62) in the variety Prodip (Table 2).

Table 2. Yield and yield attributes of wheat under optimum and late sowing conditions

Variation source	Plants density (no. m^{-2})	Grains $spike^{-1}$	1000 grain weight (g)	Grain yield (kg ha^{-1})
Year (Y)				
2015-16	56	43	31.8	1680
2016-17	88	45	36.6	3505
2017-18	72	44	32.1	3448
Sowing time (T)				
Optimum	74	48	43.6	4060
Late	70	41	23.4	1696
Variety (V)				
Sonalika	80	39	31.2	2584
Kanchan	79	42	32.3	2479
Sourav	74	52	26.2	2963
Gourab	77	40	37.5	3395
Shatabdi	72	46	34.0	3160
Sufi	69	51	31.8	3193
Bijoy	75	41	34.7	2869
Prodip	62	48	41.0	3096
BARI Gom 25	65	40	37.8	2621
BARI Gom 26	67	47	31.3	2464
BARI Gom 27	69	45	28.3	2339
BARI Gom 28	76	44	35.0	3196
BARI Gom 29	73	42	34.5	2798
BARI Gom 30	73	41	33.0	3134
$LSD_{0.05}$				
Y	2.9	1.2	1.7	153.9
T	2.4	0.9	1.4	125.7
V	6.3	2.5	3.6	332.5
Y×T	4.1	1.6	2.4	217.7
T×V	8.8	3.5	5.1	470.3
Y×V	ns	ns	ns	ns
Y×T×V	ns	ns	ns	ns

Y = Year, V = Variety, T = Sowing time

3.3.3 Effect cultivars/varieties on yield and yield attributes of wheat

There were significant effect on yield and yield attributes of wheat due to the effect of different crop varieties both in optimum and later sowing condition (Table 2). The highest grain yield (kg ha^{-1}) was observed in the wheat variety Gourab (3395 kg ha^{-1}), similar to BARI Gom 28 (3196 kg ha^{-1}), Sufi (3193 kg ha^{-1}), Shatabdi (3160 kg ha^{-1}) and BARI Gom 30 (3134kg ha^{-1}) and lowest in Kanchan (2479 kg ha^{-1}) and Sonalika (2584 kg ha^{-1}), the old varieties, similar to the newly released wheat varieties like BARI Gom 26 (2464 kg ha^{-1}) and BARI Gom 27 (2339 kg ha^{-1}).The reason of good crop yield due to the more grain weight (34-37.5 gm in the old varieties and 33-35 gm in the new varieties) as well as less blast infection (%index 6.8-9.9 in the old verities and 20.2-22.5% in the newly released varieties). The highest grain $spike^{-1}$ was observed in Sourav (52 gains $spike^{-1}$), similar to Sufi (51 gains $spike^{-1}$) and lowest in Sonalika (39 gains $spike^{-1}$) showed in Table 2. The intensity and severity of wheat blast were not affecting on grain $spike^{-1}$ at last three consecutive years.

The highest 1000 grain weight recorded in the variety Prodip (41 g), similar to BARI Gom 25 (37.7 g) and lowest in Sourav (26.2 g).Grains from blast-infected spikes from highly susceptible cultivars are often small, shrivelled and deformed, with low test weight (Goulart *et al.*,2007).

3.3.4 Effect cultivars/varieties on disease severity of wheat blast (% blast index)

There were wide ranges (2.3-36.5%) of wheat blast disease infestation among the varieties with significant differences (Table 1). The highest disease infestation was recorded in BARI Gom 26 (36.5%), similar to BARI Gom 25, 27 and 29 (28.7-35.3%) and lowest in Sourav (2.3%), similar to Shatabdi (6.8%) and Gourab (9.9%). The newer varieties were more susceptible to wheat blast disease (% blast disease index 20-2-36.5%) compared to the older varieties (% blast disease index 2.3-23.5%).

4. Conclusions

From the above results it may be concluded that virulent inoculums, higher temperature (30-32 ºC) and some rainfall (10-20 mm) especially in heading stage (58-67 d in different varieties) played a key role for wheat blast disease development. However, the variety BARI Gom 28 and 30 (newly released) and Sourav, Gourab and Shatabdi (old variety) were found some tolerant capacity against wheat blast disease maintaining a good yield of over 3 t ha^{-1}. In addition, timely or early sowing (15-30 November) of wheat is very much crucial to avoid what blast disease infection. This is due to less chance of rainfall occur in heading to flowering stage. Research should be done to find out the proper resistant line against wheat blast disease screening through artificial inoculations, and proper control measures should be suggested against controlling of wheat blast disease in collaboration with local and international research organizations.

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