World wheat production is now under threat due to the wheat blast outbreak in Bangladesh in early March 2016. This is a new disease in this area, indicating the higher possibility of this pathogen spreading throughout the Asia, the world’s largest wheat producing area. Occurrence of this disease caused ~3.5% reduction of the total wheat fields in Bangladesh. Its economic effect on the Bangladesh wheat market was little because wheat contributes to 3% of total cereal consumption, among which ~70% have been imported from other countries. However, as a long-term perspective, much greater losses will occur once this disease spreads to other major wheat producing areas of Bangladesh, India, and Pakistan due to the existing favorable condition for the blast pathogen. The wheat blast pathogen belongs to the Magnaporthe oryzae species complex causing blast disease on multiple hosts in the Poaceae family. Phylogenetic analysis revealed that the Bangladesh outbreak strains and the Brazil outbreak strains were the same phylogenetic lineage, suggesting that they might be migrated from Brazil to Bangladesh during the seed import. To protect wheat production of Bangladesh and its neighbors, several measures including rigorous testing of seed health, use of chemicals, crop rotation, reinforcement of quarantine procedures, and increased field monitoring should be implemented. Development of blast resistant wheat varieties should be a long-term solution and combination of different methods with partial resistant lines may suppress this disease for some time.

**Keywords**: disease control, Magnaporthe oryzae, Pyricularia graminis-tritici, Pyricularia oryzae, wheat blast outbreak

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Terrifying blast disease of wheat (*Triticum aestivum*) was spotted in Bangladesh and this was the first occurrence in the Asia (Callaway, 2016). Recent outbreak proved the predictions of International Maize and Wheat Improvement Center (CIMMYT) experts that wheat blast can be spread to Asia and Africa from disease existing countries because of similar climatic conditions in these regions (CIMMYT, 2016). Plant pathologists from Wheat Research Center (WRC) of Bangladesh also warned that this disease has the chance to spread to India, Pakistan, and China which ranks third, seventh, second in the world wheat production, respectively (Index Mundi, 2016).

Wheat blast symptoms appeared first in the middle of February of 2016 in Chuadanga and Meherpur districts and rapidly spread to adjacent four districts within two weeks (http://en.prothom-alo.com/bangladesh/news/102091/) (red circles in Fig. 1). The recent report also indicated the high risk of wheat production throughout the Bangladesh and in neighbor countries, because blast disease also found in other region which is quite far from the first spotted place (Barisal and Bhola districts) (Islam et al., 2016). Blast pathogen attacks at the base or upper part of the rachis affecting the spike formation that makes the spike partial or complete dead resulting shriveled seeds or no grain, respectively (Islam et al., 2016). However, there was no report of wheat blast in West Ben-
gal state of India, which is very close to the wheat blast infected areas of Bangladesh. This area of India is considered as a minor wheat producing region and the wheat harvesting season had already finished at the time disease was first recorded in Bangladesh (http://indianexpress.com/article/explained/wheat-blast-disease-bangladesh-wheat-crop-wheat-fungal-disease-wheat-blast-2805978/).

Officials from the Department of Agricultural Extension (DAE) informed that the infected area was estimated about 15,000 ha, which correspond to ~3.5% of total wheat fields in Bangladesh. The infected wheat fields were burned, which contributes to 15% decrease in wheat production of the nine infected districts (Islam et al., 2016; Malaker et al., 2016; http://www.thedailystar.net/backpage/wheat-blast-threatens-yield-784372). In spite of such decrease, total wheat production in Bangladesh increased a little (35,000 metric ton [MT], 2.7%) in 2016 compared to that of 2015. Increasing of total harvested areas (420,000–425,000 ha) and yields (3.10–3.14 MT/ha) contributed to the total wheat production in 2016 (Production, Supply and Distribution [PSD] online: https://apps.fas.usda.gov/psdonline/app/index.html#/app/downloads).
Wheat blast was first reported in Parana province of Brazil in 1985 (Igarashi et al., 1986). But first epidemic was reported in the year of 1996 in Bolivia (Barea and Toledo, 1996) and then in Paraguay and Argentina in 2002 and 2007, respectively causing 70–80% wheat production loss (Alberione et al., 2008; Viedma and Morel, 2002). There are still some regions in South America where wheat is not cultivated because of the potential threat of this disease (Callaway, 2016). As mentioned above, no case was reported outside of South America except one in the experimental field in USA in 2011 (Callaway, 2016).

The wheat blast pathogen belongs to the Magnaporthe oryzae (syn. Pyricularia oryzae) species complex (Couch and Kohn, 2002; Zhang et al., 2016). The members of this species complex causes blast disease on more than a hundred of species in the Poaceae family including rice, wheat, barley and rye (Choi et al., 2013). Several phylogenetic species (e.g., pathotypes) are proposed by cladistic analyses based on the multi-gene sequence and the host specificity (Choi et al., 2013; Hirata, 2007; Kato et al., 2000; Tosa et al., 2004). In concordance with it, the recent phylogenetic studies revealed that the Bangladesh outbreak isolates (5.LIB21750 and 12.LIB21752) located to the same clade with the wheat-infecting isolates from Brazil (strains B71, PY0925, 12.1.053i, 12.1.117, and 12.1.037) (Islam et al., 2016; Malaker et al., 2016) and were named the operating taxon unit as the “M. oryzae wheat-infecting lineage” (Islam et al., 2016) or Pyricularia graminis-tritici (Castroagudín et al., 2016). They were clearly divided from the M. oryzae rice-infecting lineage (syn. P. oryzae pathotype Oryzae) (Castroagudín et al., 2016; Islam et al., 2016).

What does it mean that the Bangladesh outbreak strains is determined as having a close phylogenetic relationship with one of the Brazil wheat blast isolates? The wheat blast strains might be migrated from South America to Bangladesh via man-made transport. A local newspaper also reported that the seeds imported from Brazil in 2015 for the consumption purpose were seen as unhealthy (http://www.kalerkantho.com/print-edition/first-page/2015/06/18/234885 [in Bengali]) and that unhealthy seeds might have been infected by the blast pathogen. But it is still unclear how those unhealthy seeds reached to the cultivated field.

How will this introduction of wheat blast influence on the future wheat production of Bangladesh? Wheat is the second major cereal crop (3% of total cereal consumption) after rice (93% of total cereal production) in Bangladesh (BBS, 2014). However during the last decade, wheat consumption has been increasing gradually and it was almost doubled to six million MT in 2016 (Fig. 2A). The Bangladesh government imported wheat from other countries to fulfill the domestic requirement, because the wheat production stayed around one million MT for last ten years (Fig. 2A). Therefore, the price of wheat was highly dependent on the amount of the wheat import. This might be one of the reasons that the Bangladesh government allows to increase wheat import from diverse sources including Brazil and Argentina. After the outbreak, domestic consumption suddenly increased to 16.4% where last three years (2012–2015) average increasing rate was 11.2%. In proportion to this, the amount of wheat import increased and this made the wheat price stable in Bangladesh (Index Mundi, 2016; http://dam.portal.gov.bd/). The Bangladesh government should take strategies to increase wheat production as a long term goal which will reduce

![Fig. 2](image-url). Economic importance of wheat in Bangladesh. Annual trend of wheat production (blue), imports (red), and domestic consumption (green) (A), and market price (B) in Bangladesh. MT, metric ton; USD, United States dollar. The original data were obtained from the Production, Supply and Distribution (PSD) online (USDA, 2016).
food dependency of Bangladesh. Compared to rice, wheat has much less economic impact on Bangladesh. And the government might not consider the wheat blast seriously if it does not occur next year. However, as a pathological point of view, this pathogen must be managed carefully and preemptively. Our diagnosis leads to suggestions of some strategies to sustain the wheat cultivation in Bangladesh. Scarcity availability of healthy seeds is one of the major impediments for achieving high yields in Bangladesh (Singh et al., 2015). Farmers get wheat seeds for cultivation only from the government agencies (Bangladesh Agricultural Development Corporation [BADC] and DAE). Although, the seed requirement for wheat cultivation has increased constantly (Table 1) (BADC, 2015), the government agencies fulfilled only 40–50% of the total seed requirement of the country (Jaim and Akter, 2012). The remaining of the seed requirement might be fulfilled by farmers themselves from their own seed stock or from the local seed dealer. However, the seed health of those sources is not guaranteed. To solve seed deficiency, the government can produce more healthy seeds from the existing seed-producing firms throughout the country and also import healthy seeds for cultivation through proper quarantine processes.

When growing wheat in Bangladesh, the use of chemicals will be a safe way to protect the disease. The government suggested farmers to use Trifloxystrobin or Tebuconazole for controlling wheat blast. In addition, phosphate minerals and silicate treatment had shown effective in the field trials (Pagani et al., 2014). However, because wheat blast pathogens attack both leaves and heads, the fungicide must be sprayed before disease symptoms appear on the heads. Wheat blast is a seed borne disease, seed treatments with benomyl may help to prevent this disease during seedling stage. The government must find a way to increase the chemical supply and to make farmers apply to fields. Recently, a biological agent Bacillus methylotrophicus has been suggested as an efficient and alternative control means against wheat blast (de Oliveira Nascimento et al., 2016).

Cultivating alternative crops like oil seed crops and pulses instead of wheat and following the crop rotation is one of important cultural practices which can reduce the pathogen inoculums from the field. Eliminating crop residues immediately after harvesting of wheat and keeping crop fields weed-free will destroy the alternative hosts of the blast pathogen because inoculums can also survive on weeds and in crop residues. The available host of the wheat blast pathogen are barley (Hordeum vulgare), oats (Avena sativa), signal grass (Urochloa brizantha), and more other grasses (Castroagudín et al., 2016). Recently, the Bangladesh government informed farmers to practice crop rotation process and to cultivate legume or oilseed crops in the wheat blast infected regions for at least three years (https://www.youtube.com/watch?v=GwE7QMKwAPK4 [in Bengali]).

Plant quarantine rules must be followed properly during seed import from any country either for cultivation or for consumption purposes. Although the Bangladesh government has quarantine centers across the country, those centers often do not maintain adequate staffs and up-to-date equipment. Those lacking sometimes permit imported seeds to get entry just after seeing the labels of the packets provided from the exporter countries. To overcome this situation, the government should employ more experts and use improved tools and protocols to detect unhealthy seeds. International cooperation is required from India, Pakistan, and China and from wheat-exporting countries to solve this quarantine issue.

Continuous monitoring and surveillance of wheat fields is another important measure to protect against the expansion of wheat blast to other areas of Bangladesh or other countries in Asia. The government can appoint more experts to the field level through the existing crop monitoring cells for the sustainable wheat cultivation throughout the country. Training of farmers (soil health monitoring, plant health monitoring and weather report monitoring for predicting possible insect and disease attack) will be helpful to identify the wheat blast disease and take immediate action to control it.

Most of the cultivated wheat varieties are very susceptible to blast disease (CIMMYT, 2016). Developing blast resistant varieties is one of the best solutions to control

| Table 1 | Farmer’s requirement of wheat seeds (Req.) for cultivation and government’s distribution to the farmers (Dist.) in Bangladesh from 2009 to 2014 |
|---------|------------------------------------------------------------------------------------------------------------------------------------|
|         | 2009–2010 | 2010–2011 | 2011–2012 | 2012–2013 | 2013–2014 |
| Wheat seed (1,000 MT) | Req. | Dist. | Req. | Dist. | Req. | Dist. | Req. | Dist. | Req. | Dist. |
| MT, metric tons. | | | | | | | | | | |
| Data source: Annual report of Bangladesh Agricultural Development Corporation 2014–2015 (BADC, 2015). |
this disease. However, natural levels of disease resistance in the *Triticum aestivum* germplasm seem to provide insufficient protection in favorable conditions, at least in Brazil (Pagani et al., 2014). A recent study described the possibility of breeding blast resistant wheat cultivar through introducing a short chromosomal segment called “2NS” from *Aegilops ventricosa* to the wheat. In a greenhouse experiment, wheat lines having the 2NS segment showed significant reduction against wheat blast (Cruz et al., 2016). This finding will inspire wheat breeders to breed blast-resistant wheat variety.

In this review, we incorporated available information to report recent outbreak of wheat blast in Bangladesh and wanted to warn epidemic of this disease to the other wheat producing countries in Asia. Although wheat blast outbreak had little effect on wheat production and price in Bangladesh this year (2016), this might cause a global problems in a near future if the Bangladesh government overlooks this contagious source and does not take proper prevention measures. We provided several suggestions and recommendations to eradicate this disease and stop spreading to the other new regions in Bangladesh. As single measure cannot control blast disease sufficiently, several management practices together will give efficient results to suppress the blast epidemic in the field.

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