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BLAST: A THREAT TO CEREAL CROPS IN BANGLADESH

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Abstract

Rice and wheat are the most important cereal crops which play a significant role to global food security, as they consumed as a staple food near about two-third of the world population. However, the production of these important crops are in threat due to blast-a fungal disease of rice, wheat and grasses, that can destroy enough food supply to sustain millions of people. The rice blast disease is caused by the fungi *Pyricularia oryzae* (renamed as *Magnaporthae oryzae*) and first documented in 1637 in China, then in Japan in 1704. In Italy, the USA and India the disease was also identified in 1828, 1876 and 1913, respectively**.** In Bangladesh the blast disease was relatively unimportant in late sixties and early seventies. The outbreak of blast disease was recorded on 1980 and 1990 in boro season in Bangladesh. Until the 1980s, the blast disease was not known to affect wheat, a main staple crop critical to ensuring global food security. Wheat (*Triticum aestivum L.)* was first infected in 1985 at Paraná State, Brazil. It has since spread throughout many of the important wheat-producing areas of Brazil and to neighboring South American countries including Bolivia and Paraguay. In South America, wheat blast is caused by isolates of *Magnaporthe oryzae* (syn. *Pyricularia oryzae*) known as pathotype *Triticum* which is a fungal species. Since the outbreak of blast it is a major threat to wheat production in South America. Currently, wheat blast affects as much as 3 million hectares which is seriously limiting the potential production of wheat in the South America. The wheat blast was detected for the first time in Asia in February 2016, with reports of a severe outbreak in Bangladesh. The rice-infecting isolates of *M. oryzae* are genetically distinct from wheat-infecting isolates and generally do not infect wheat. At field level chemical control is mainly practiced for blast disease management and other options management is mostly tricky to practice. The growing media is an important factor to keep blast out of the constituency.

Keywords: Blast, Rice, Wheat, Biological management, Soil conditioners.

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1. Introduction

Rice (*Oryza sativa* L.) is consumed as a staple food for half of the world's population (Molina et al., 2012). In Bangladesh, rice is the most staple cereal crop and central to Bangladesh's economy, accounting for nearly 20 percent of gross domestic product (GDP) and providing about one-sixth of the national income of Bangladesh (Khandakar et al., 2013). The blast is one of the most devastating diseases in rice growing regions of the worldwide, is responsible for 11-15% yield loss annually (Zambryski et al., 1997). This disease is distributed in 85 countries in all continents where the rice plant is cultivated, in both paddy and upland conditions. The damage is very much influenced by environmental factors, the climatic changes, especially water scarcity helps researchers think to develop production technologies for cultivation of rice under lower water conditions which may increase the incidence of many rice diseases particularly disease causing *Pyricularia oryzae*. The pathogen might attack at any of the growth stages of the rice plant from seedling to the pre-maturity stage of the crop. A recent report says that the fungi are able to infect the root system also. The disease gets the name as per the affected organ of the plant. If the leaf is affected, the disease is called leaf blast, if a node, then it is called node blast, accordingly, neck-blast (neck = first node of panicle), panicle blast etc. The symptom varies with the organs affected. Leaf blast is characterized by eye shaped spot, neck and node blast are by their certain kind of necrosis. The extreme and irreparable damage is caused due to neck blast. The incidence and severity of blast disease is very common in Bangladesh as in that period the water scarcity is universal compared to Aman season. In Bangladesh the frequency of blast occurrence has increased with invasion into new areas (north and northwest parts of the country) in recent years. The BRRI dhan29 and BRRI dhan28 are the most popular and mega varieties recognized highly susceptible to blast disease (Anonymous, 2011). Moreover, all local and improved aromatic rice varieties grown in wet season are vulnerable to neck blast.

The wheat blast is a new disease caused by the fungus *Magnaporthe oryzae Triticum* pathotype (MoT). Typical symptoms of wheat blast on spikes are premature bleaching of spikelets and entire heads. Severely infected wheat heads can be killed, resulting in severe yield losses. The disease is generally spread by infected seeds and airborne spores, and the fungus can survive in infected crop residues and seeds (Yamamoto et al., 2000). The wheat blast was first reported in 1985 in Brazil and has become locally important in Brazil, Bolivia, and Paraguay since its emergence (Kohli et al., 2011). In 2009, the dual wheat blast and *Fusarium* head scab epidemics in Brazil were estimated to have decreases the national wheat production by 30%. The South American (SA) strains of

MoT are genetically diverse as evident in variable disease phenotypes on SA wheat genotypes. The wheat blast was reported on a single wheat plant in a research plot in Kentucky (USA) in 2012. In a comparative genomic analysis of the Kentucky strain with an SA strain indicated that they emerged from different *M. oryzae* populations. The Kentucky strain most likely emerged in Kentucky from the gray leaf spot pathogen of annual ryegrass and was not introduced from SA. The SA strain appears to have emerged from wild grass populations of *M. oryzae* in SA. The cultivation of wheat has expanded in Bangladesh, making it the second major food source after rice. The terrifying blast disease of wheat (*Triticum aestivum*) was occurred in Bangladesh and this was the first occurrence in the Asia (Callaway, 2016). The outbreak of wheat blast makes worried to crop scientists as its spread further to major wheat-producing areas in neighboring South Asian countries.

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 (Mundi, 2016). Little is known about the physiology and genetics of the wheat blast pathogen, and our understanding of the molecular interactions of this pathogen with wheat remains limited. The blast disease also infect on grasses are caused by fungal species from the Pyriculariaceae and can occur on 50 grass species. This review is an update of information on blast infection in Bangladesh with the understand of controlling mechanism of its severity and find potential alternatives to explore and the elusive role of mineral nutrient and soil amendment in protecting cereals against blast disease.

2. Rice Blast in Bangladesh

The incidence of rice blast was recorded on Boro season (November to May: irrigated ecosystem) and Transplanted Aman (July to December: rainfed ecosystem) in all over Bangladesh. The government of Bangladesh is taking initiative to the extension of the Aus coverage. It means rice is grown with intensive care throughout the year. Thus the popular varieties are getting susceptible to some pest and diseases. Even the pests are getting the opportunities to change their races for better adaptation. At present 267 races of rice blast have already been identified in our environment (Biswas et al., 2017). Thus disease pressure is in increasing trend and may be a devastating experience in the near future. This phenomenon is not for Bangladesh but for the other 85 countries where rice is grown. Rice has tremendous adaptation ability from Hokkaido to Honolulu (Biswas et al., 2017). As a result the pests of rice also sustain everywhere. Hence, rice blast is considered as a serious and recurrent problem in many of rice growing countries.

The blast is a trans-boundary disease, travels through the air from one region to the other, one country to another country. Infected seed also act as a carrier too. The favorable weather is low night temperature (conversely higher day temperature), unusually windy and foggy weather in the morning, and dew on the leaf, drizzle etc. The drizzle brings down the spores (seeds of fungi able to grow as new fungi) on the leaf, node or on panicles. No sooner a spore drops on the rice plant it starts growing to produce conidiophore (a fungal hypha) and conidium (asexually produced spore) within 3-4 days. Within 7-10 days it starts growing millions of spores if favourable conditions prevail to cause a devastating impact on the rice crop. The intensity of the disease depends on the weather, the tolerance ability of a variety. The aromatic variety and the variety with sticky cooked rice are more susceptible to the disease than the ordinary variety. The crop might get susceptible nutritional imbalance i.e. excess nitrogen and low potassium. Inequity water supply to crops is a key factor to enhance the disease as well.

The resurgence of rice blast in the form of neck blast is dominant this year. Because there was rain during the flowering stage of BRRI dhan28, BRRI dhan50, BRRI dhan61 and BRRI dhan63 (the varieties are popular in those areas). None of these varieties is tolerant to the blast diseases. It may be mentioned that BRRI dhan28 was recorded as moderately tolerant during the time of release. But the rice blast has the ability to change its race for its existence. Accordingly, a tolerant rice variety may lose the potentiality to tolerate to the new race of fungi. This phenomenon is quite common even in the countries like Korea and Japan. The frequency of neck-blast in rice plant is so prompt that a farmer could hardly recognize the symptom prior to the damage. They are not much familiar with the disease. Though the department of agriculture extension, Bangladesh Rice Research Institute was aware of the probability of neck-blast as the expected weather could be unusual to some extent around the reproductive phase of the crop. They asked the farmer to take necessary measures such as keeping the field irrigated, application of Potash fertilizer (37kg per hectare), not to top dress urea anymore even due. Even they have suggested to spraying appropriate fungicide from Tri-cyclazol group during late booting to flowering stage of course in the afternoon. Unfortunately, farmers are failed to follow the instruction properly. Translating science to the farmer in Bangladesh is yet to be made easy. They were quite late to spray their crop. They did not, once the crop is attacked, no measurement is enough to cure the disease.

2.1. Causal Organism

The blast of rice caused by the Ascomycete fungus, *Magnaporthe oryzae* Barr (anamorph *Pyricularia grisea* Sacc., synonym *P. oryzae* Cav.): Pyriform macroconidia, *ca.* 20 X 10 μm (Fig. 1) are produced on conidiophores (Zeigler et al., 1994) which protrude from lesions on plants. These germinate and develop an appressorium Fig. 2 at the tip of the germ tube, which attaches to the surface of plant tissues; an infection-peg from the appresorium penetrates into plant tissues. The wall of conidiophores and appressorium are pigmented by melanin.

Fig. 1. Blast fugal Macroconidia

Fig. 2. Blast fungal Appressoria

2.2. Symptoms in the Field

2.2.1 Leaf blast

The symptoms appear at seedling and adult stages on the leaves, nodes and panicles shown in Fig. 3 (Srinivasprasad et al., 2016). During fungal attack in young leaf, purple spots are observed after an incubation period, changing into a spindle shape which has a gray centre with a purple-to-brown border, and then surrounded by a yellow zone as time passes. Brown spots appear only on the older leaves. In young or susceptible leaves, lesions coalesce and cause withering of the leaves themselves, especially at the seedling and tillering stages. Under favorable conditions, lesions on the leaves expand rapidly and tend to coalesce, leading to complete necrosis of infected leaves giving a burnt appearance from a distance. Hence the name rice blast given to this disease. Lesion formation on the n-leaf (where n is the top developing leaf), causes shortening of the n + 1 leaf sheath and the n + 2 leaf blade, with consequent stunting of the whole plant (Zeigler et al., 1994).

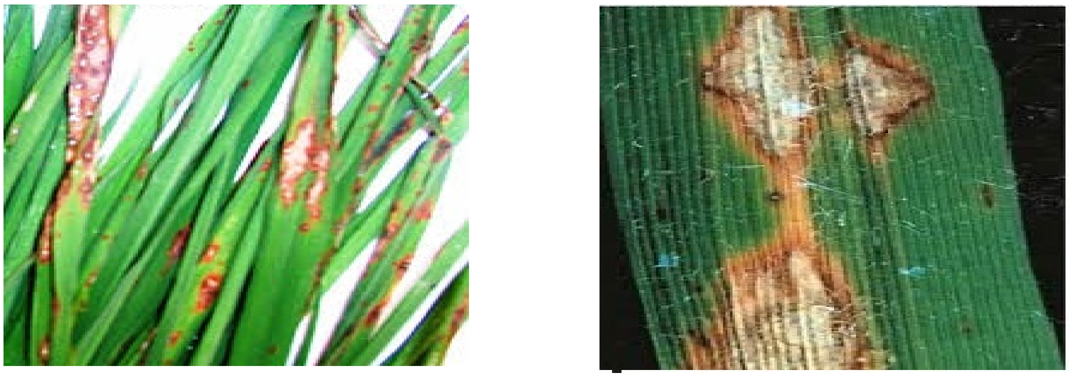

Fig. 3. Leaf blast in rice.

2.2.2. Node blast

The pathogen also infects the nodal region of the plant and the panicle. During heading, the stem nodes which appeared from the leaf sheaths are attacked and sometimes cause lodging (Fig. 4). Diseased nodes are brown or black in color (Srinivasprasad et al., 2016).

2.2.3. Neck rot and panicle blast

The infection to the neck node produces triangular purplish lesions, followed by lesion elongation to both sides of the neck node-symptoms which are very serious for grain development (Fig. 5). When young neck nodes are invaded, the panicles become white in colour -the so-called 'white head' that is sometimes misinterpreted as insect damage. Later infection causes incomplete grain filling, and poor grain quality. Panicle branches and glumes may also be infected. Spikelets become white in colour due to fungal attack and produce many conidia, which become the inoculum source after heading (Srinivasprasad et al., 2016).

Fig. 4. Node blast in rice.

Fig. 5. Neck rot and panicle blast.

2.3. Disease cycle

The pathogen perpetuates as mycelium and conidia on diseased rice straw and seed, and possibly on weed hosts (Fig. 6). The fungus produces conidia and releases in to the atmosphere when there is high relative humidity (>90%).The conidia are air borne and fall on the rice plant and adhere strongly to the leaves through the mucilage produced by them at the tip. The maximum number of spores produced was 20,000 on one lesion on leaves and 60,000 on one spikelet in one night (Srinivasprasad et al., 2016). Lesions on leaves become an inoculum source for panicles. Rice seedlings and young or tender tissues are more vulnerable than the older ones. At optimum temperatures, new blast lesions appear within 4-5 days after they fall on leaf surface. In warm and wet weather conditions, new conidia are produced within hours from the appearance of the lesions and this continues for several days. Most of the conidia are released between mid night and sunrise. This is a polycyclic disease and completes several cycles within a season and causes epidemics. The critical growth stages are seedling stages, tillering stage and panicle initiation stage of the crop.

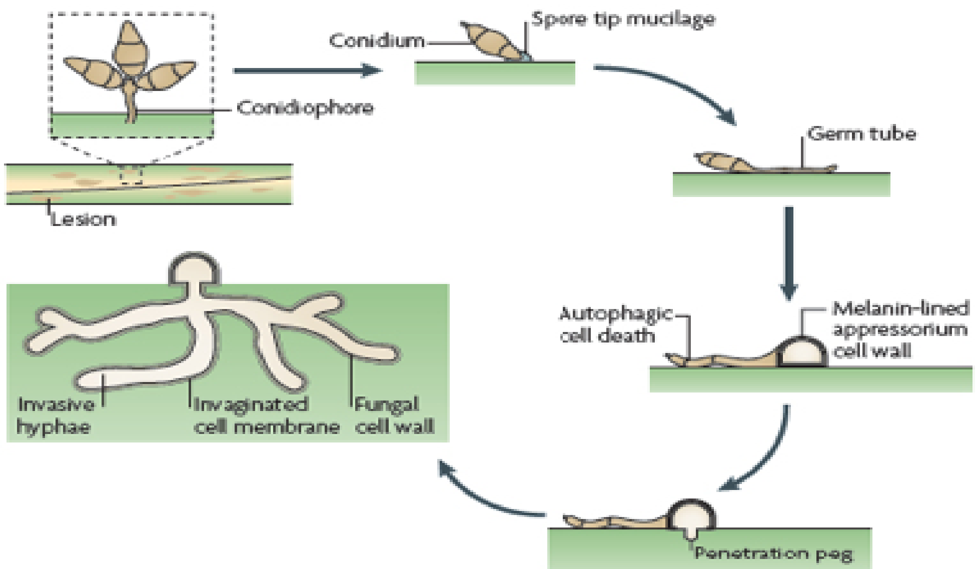

Fig. 6. Disease cycle of rice blast disease (Srinivasprasad et al., 2016).

2.4. Control

The scientists are in progress to develop different kinds of disease management strategies viz., (i) cultural practice (ii) chemical control (iii) host resistance cultivar introduce and (iv) biological management.

2.4.1. Cultural practice

Cultural management practice starts with the preparation of land. The soil should be fertilized with enough manure. Healthy seeds from a tolerant variety must be used. Unfortunately, most of the popular cultivated varieties are susceptible to the rice blast. Although some recently released Boro varieties BRRI dhan69, BRRI dhan74 are tolerant to rice blast. Out of the Aman varieties BRRI dhan10, BRRI dhan33, BRRI dhan44, though not recently released but can be considered as moderately tolerant to the disease. The Aus varieties i.e. BR20 and BR21 are tolerant to blast. These varieties contain monogenic (vertical resistance). So it might be broken down within few years. In Japan and Korea it was observed that a variety could hold its tolerance not more than three years if the variety is monogenic tolerant. Excess nitrogen fertilization must be prohibited. Balanced fertilization is a best practice. The seeding and transplanting date should be adjusted in such a way so that the booting to flowering stage must not coincide with the low night temperature in early March. In 2016 the late planted even susceptible variety has not been affected by the disease. Sowing into water eliminates disease transmission from seeds to seedlings because of the anaerobic condition that is unfavorable to the pathogen. On the contrary, sowing on wet soil allows seed transmission. Shade affects disease occurrence because of the longer wet condition.

2.4.4. Fertilizer and/or nutrient management

The degree of disease invasion depends on nitrogen and phosphorus content in the plants. Use of excess nitrogen fertilizer encourages disease development, while silica application reduces disease development. Therefore the amount and type of fertilizer must be carefully decided upon according to the cultivar used, soil condition, climatic conditions and disease risk.

2.4.5. Biological Control

The biological control of rice blast remains experimental since now. *Pseudomonas fluorescens* strain Pf1, inhibitory to the growth of the rice blast pathogen *P. oryzae* in vitro. Seed treatment and foliar spray treatment with talc-based powder formulation of *P. fluorescens* effectively controls the blast disease and increased the grain yield in rice (Vidyasekharan et al., 2007).

2.4.6. Chemical control

Several fungicides are used against blast disease, including benomyl, fthalide, edifenphos, iprobenfos, tricyclazole, isoprothiolane, probenazole, pyroquilon, felimzone (meferimzone), diclocymet, carpropamid, fenoxanil and metominostrobin, and antibiotics such as blasticidin and kasugamycin. Systemic fungicides are widely used to protect against leaf blast by seedling application and also to protect against panicle blast when applied more than 20 days before heading. The composition, amount, timing and application method of fungicide applied depends on the disease forecast or level of disease present. The observation of the weather pattern is very important. If the forecast says something favorable to the disease development and the crop is in its late booting to flowering stage, now recent advice is to go for chemical management. For instant knock-down of the disease, the fungicide from the tricyclazole group trooper is better. To enhance defense mechanism within the plant mixture Nativo (tebuconazol + trifloxystobin) is a better option as per BRRI scientists (Mansur et al., 2017). But this is not the complete solutions according to Meah (2017). Meah claimed that good results could be achieved by spraying Tow-in-One (Tricyclazol + Hexaconazol). In blast endemic areas treat the seeds with different chemical as shown in Table 1.

Table 1. Different chemical with doses use in control of rice blast (Srinivasprasad et al., 2016).

Sl. No.	Name of Chemical	Doses
1.	Tricyclazole 75 wp	1.5 g^{-1}kg seed.
2.	Carbendazim 50 wp	2 g^{-1}kg seed.
3.	Tricyclazole 75 wp	0.6g^{-1}l of water.
4.	Isoprothiolane 40 EC	1.5 ml^{-1}l of water.
5.	Iprobenphos 48 EC	2ml^{-1}l of water.
6.	Carbendazim 50 wp	1g^{-1}l of water.
7.	Tebuconazol + Trifloxystobin*	0.4g^{-1}1 of water.

***** Found more efficient than other chemicals. (Source: Meah, 2017.)

Many scientists stated that spraying botanical solutions might an eco-friendly solution in managing the diseases. In Cuttack, India, *Ocimum sanctum* (Tulasi) and *Aegle marmelos*

(Bael) are using as botanical solutions in controlling rice blast disease (Meah et al., 2017).

3. Wheat Blast in Bangladesh

According to the Department of Agricultural Extension (DAE), the total area of wheat cultivation in Bangladesh in 2016 was 498,000 ha. The wheat blast symptoms appeared first in the middle of February of 2016 in Chuadanga and Meherpur districts and spread to adjacent four districts within two weeks quickly. Then this disease spread in eight southwestern districts, viz., Pabna, Kushtia, Meherpur, Chuadanga, Jhenaidah, Jessore, Barisal, and Bhola (Fig. 7). The total cultivated area of wheat in those districts was 101,660 ha and 15 % were affected by wheat blast. The DAE repot reveal that the infected area was estimated about 15,518 ha, which correspond to ~3.1% of total wheat fields in Bangladesh. The infected wheat fields were burned, which contributes to 15% decrease in wheat production of the eight infected districts (Islam et al., 2016; Malaker et al., 2016).The degree of severity and yield losses due to wheat blast varies from one district to another district. Seventy percentage of wheat fields was infected in Meherpur is number one position in case of infection (Table 2). Then Chuadanga (44 %), Jessore (37 %), Jhenaidah (8 %), Bhola (5 %), Kushtia (2 %), Barisal (1 %), and Pabna (0.2 %). In case of yield losses Jhenaidah was in first position (51 %) followed by Chuadanga (36 %), Meherpur (30 %), Jessore (25 %), Barisal (21 %), Pabna (18 %), Kushtia (10 %), and Bhola (5 %). Although the average yield loss was lower than 51 % across districts, yield losses in individual fields were as high as 100 %. The seed multiplication farms of Bangladesh Agricultural Development Corporation (BADC) were completely cleared by burning to destroy pathogen inocula in the affected districts (approximately 355 ha) by decision of the Ministry of Agriculture. Severely affected (~100 %) farmer wheat fields were also burned. The recent report also shows 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 Bengal 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.

Table 2. Total cultivable area, infected area with infection percentage of major wheat blast area of Bangladesh in 2016*.

Sl. No.	Name of District	Total cultivable area of wheat (hectare)	Total Infected area of wheat (hectare)	Infection percentage (%)
1.	Meherpur	13875	9713	70
2.	Chuadanga	5810	2556	44
3.	Jessore	4040	1496	37
4.	Jhenaidah	10320	826	8
5.	Bhola	9780	489	5
6.	Kushtia	16710	334	2
7.	Barisal	2728	27	1
8.	Pabna	38397	77	0.2

*Source: Department of Agricultural Extension, 2016

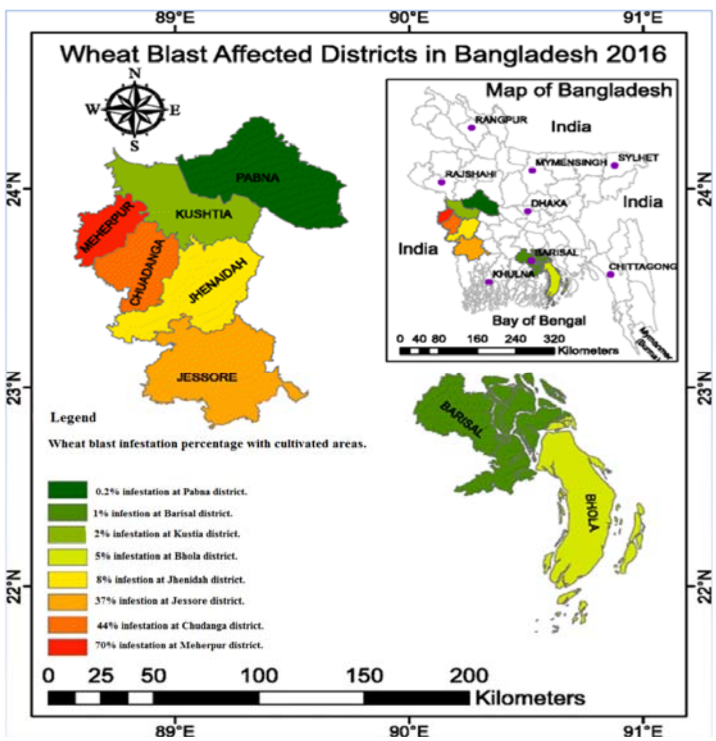

Fig. 7. Outbreak of wheat blast in Bangladesh (Sources: DAE, 2016).

3.1. Disease causal organism

The common blast causal organisms is *Magnaporthe oryzae* Barr (anamorph *Pyricularia grisea* Sacc.).

3.2. Climatic conditions favorable to disease development

However exact weather conditions required for disease epidemic are not clear, wet years (a prevalence of the El Niño phenomenon) is consider as severe blast years. Several days of continuous rains and average temperatures between 18-25°C during the flowering stage of the crop followed by sunny, hot and humid days are the climatic condition of this disease. The highest blast intensity at 30°C which increased with the duration of the wetting period, and lowest at 25°C with a wetting period of less than 10 h under controlled growth chamber conditions (Cardoso et al., 2008). The blast intensity exceeded 85% at 25°C and 40 h of wetting.

3.3. Seed and secondary hosts as source of primary inoculums

Wheat fungus is transmitted by Seed (Goulart and Paiva, 1990). It seems that seed infection play only a minor role in the epidemiology of the disease because spike infection comes from the air-borne conidia mainly from several secondary hosts (Prabhu et al., 1992; Urashima et al., 1993). The grass weeds namely (*Cenchrus echinatus, Eleusine indica, Digitaria sanguinalis, Brachiaria plantaginea, Echinocloa crusgalli, Pennisetum setosum, Hyparrhenia rufa and Rhynchelytrum roseum*) commonly grows in wheat and rice fields of Brazil are used as a secondary hosts of this fungal, but their role in the epidemiology of wheat blast is not well understood (Prabhu et al., 1992). The weed species *Eleusine indica, Digitaria sanguinalis* and *Rottboelia exaltata* have been identified with blast symptoms in Bolivia (Hurtado & Toledo, 2005). First infections on triticales were reported by Mehta and Baier (1998), and recently, blast infection in commercially grown black oats (*Avena strigosa*) has been added to this list (Mehta et al. 2006). In the Southern Cone region black oats and foxtail millet (*Setaria italica*) are widely used in the crop rotation system but their susceptibility to wheat blast may well make them candidates for the primary source of infection.

3.4. Wheat blast symptoms in the field

The disease symptoms associated with affected wheat fields included completely or a partially bleached (dead) spike which is similar to symptoms reported for Brazilian wheat blast epidemics and symptoms reported from Bangladesh in 2016. The fungal pathogen attacked the base or upper part of the rachis, severely affecting spikelet formation above the point of infection. As a result, the spike above the point of infection becomes partial bleaching of with either no grain or shriveled grain. Fungal sporulations are present at the bleached heads with traces of gray, indicate the point of infection. In case of severe infection typical eye-shaped necrotic disease lesions with gray centers in the leaves is appeared. At the time of flowering stage, head may infected resulted in no grain production, whereas small, shriveled, light in weight, and discolored (pale) grains may result at the grain filling stage of infection. Different typical symptoms of blast disease which appears in spikes, leaves, and seeds of wheat is shown in the (Fig. 8) that was collected from a farmer's field in Jhenaidah in 2016.

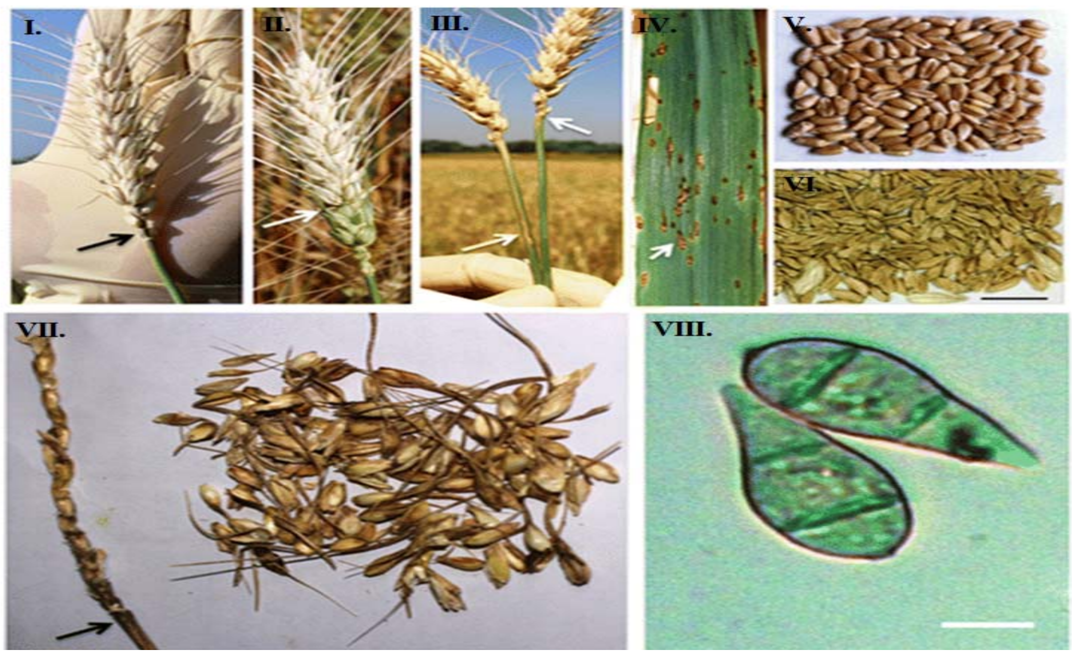

Fig. 8. Different symptoms of wheat blast with conidia of pathogen: (I) wheat spike that is completely bleached with traces of gray from blast sporulation at the neck (arrow) of the spike, (II) A wheat spike due to the complete bleaching above the point (arrow) of infection, **(**III) Two spikes which is completely bleached with traces of gray (upper arrow) and a lesion (lower arrow) from blast sporulation at the base, (IV) After severe infection typical eye-shaped lesion (arrow) and dark gray spots on wheat leaf, (V) Slightly shriveled wheat seeds due to mild blast disease infection, (VI) Shriveled and pale wheat seeds after severe infection of blast, (VII) A severely infected rachis with dark gray blast sporulation at the neck (arrow) and severely damaged spikelet (VIII) Micrograph of two conidia (*Magnaporthe oryzae)* isolated from the infected spike of wheat. Scale bars in V and VI = 1 cm and in VIII = 10 µm (DAE, 2016).

3.6. Control

Number of steps should be taken to eradicate the wheat blast disease in Bangladesh**:**

3.6.1. Cultural control

The cultivation of alternative crops like oil seed and pulses crops instead of wheat and following the crop rotation is one of important cultural practices which can reduce the pathogen inoculums from the field. Crop residues and weeds must be eliminate from the wheat field after harvesting, which will destroy the alternative hosts of the blast pathogen because inoculums survive on weeds and in crop residues. Barley (*Hordeum vulgare*), oats (*Avena sayiva*), signal grass (*Urochloa brizantha*), and more other grasses are the source of host of blast pathogen (Castroagudín et al., 2016). At present, the government of Bangladesh take initiative so that farmers are come into crop rotation practice and at least cultivate legume or oilseed crops in the wheat blast infected regions for three years. Most of the cultivated wheat varieties are very susceptible to blast disease (CIMMYT, 2016). Release of blast resistant varieties is one of the best solutions to control 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). Recently, Cruz et al., (2016) 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 (will inspire wheat breeders to breed blast-resistant wheat variety.

3.6.2. Biological management

Biological agent *Bacillus methylotrophicus* has been suggested as an efficient and alternative control means against wheat blast (Nascimento et al. 2016).

3.6.3. Chemical control

Spraying of chemical will be an effective way to protect the blast disease in Bangladesh. The government suggested farmers to use Trifloxystrobin or Tebuconazole for controlling wheat blast. In addition, phosphite minerals and silicate treatment had shown effective in the field trials (Pagani et al. 2014). As wheat blast pathogens attack both leaves and heads, the fungicide must be sprayed before disease symptoms appear on the heads. Seed treatments with benomyl may help to prevent this disease during seedling stage as it is a seed borne disease.

4. Is there any relationship between rice and wheat blast?

In 2016, there was an outbreak of the wheat blast in some parts of the mid-western Bangladesh. The causal organism of the disease is the same as that of rice blast. So many people take into consideration that wheat blast may infect rice plant also. Some of the electronic Medias have already expressed their concern as "disease of wheat is transformed to rice So, BRRI scientists have communicated some relevant authorities in the field of the different rice and agricultural research institutes like Africa Rice, IRRI and JIRCAS. All of them assured that there was no record as the *Magnaporthe oryzae* from rice blast origin could infect a wheat crop. Conversely, *Magnaporthe oryzae* from the wheat blast source have no ability to infect a rice crop. Yes, the same fungi *Magnaporthe oryzae* is responsible for the blast disease both for rice as well as wheat. They are morphologically same but genetically different. That is why their pathotype is different. *Magnaporthe oryzae Oryza* pathotype is exclusively confined to rice plant. On the other hand, *Magnaporthe oryzae Triticum* pathotype is exclusively responsible for the wheat blast. Recently, BRRI scientists (Ali et al., 2016) had a study on whether the two pathotypes of the same fungus (*Magnaporthe oryzae*) could infect rice and wheat simultaneously or not. It was a collaborative work between Wheat Research Center, BARI and Plant Pathology Division of BRRI. Twelve wheat blast isolates were inoculated on BARI Gom25, BARI Gom26, popular susceptible rice varieties BRRI dha34, BRRI dhan29 and LTH (an international universal susceptible variety). Disease incidence and severity data were recorded as per rule. It was found that only blast symptom developed on wheat seedlings but not on rice. The trial was repeated thrice under Green House conditions. Conversely, three rice blast isolates were inoculated on BARI Gom 25, BARI Gom 26, popular susceptible rice varieties BRRI dhan34, BRRI dhan29 and LTH. After the assessment, it was found that blast symptom developed only on rice leaves not on wheat leaves. This trial was repeated thrice also. Since wheat blast pathogen did not infect rice plant, and conversely rice blast pathogen did not infect the wheat plant, therefore it is evident that wheat and rice blast pathogen are two different pathotypes of the same fungi *Magnaporthe oryzae*. So the occurrence of rice blast in the Midwestern part of the country is not the carryover effect of the wheat blast.

5. Keep blast out of Bangladesh

Though blast in both rice and wheat is a devastating one, some procedures are to be followed to keep our country blast free in some extent.

Step 1: Proper management of quarantine system

Bangladesh is one of the major rice growing countries and produces least amount of wheat also. To meet the requirement of the country it is necessary to import both rice and wheat. At the time of seed import from any country either for cultivation or consumption purposes plant quarantine rules must be followed properly. A number of quarantine centers are located throughout the country but it has not 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.

Step 2: Adaptation with hygiene condition of field

Diseased straw and stubble must be burned or composted; otherwise they can become inoculums sources for the next crop season.

Step 3: Develop proper monitoring system

The expansion of wheat blast disease from one area to another can be reduced through continuous monitoring and surveillance of wheat fields. The government can appoint more experts to the field level through the existing crop monitoring cells for the sustainable wheat cultivation throughout the country.

Step 4: Proper management of mineral nutrients in growth media

The mineral nutrients play a philanthropic role in the growth and production of crops and also responsible to changes in the morphological, anatomical and physiological characteristics as well as chemical composition of the plants. The resistance of plants to pathogens and pests is depends on mineral nutrients in soils either it's increase or decrease and also considered as an important factors in controlling diseases (Huber and Graham, 1999; Marschner, 2002). The severity of the majority of plant diseases especially blast can be reduced through improved mineral nutrition management. Proper modifications of the availability of particular nutrients or improving the efficiency of absorption and utilization by the plant this can be achieved (Huber, 1997; Hodson et al., 2005). Many scientists reveal that severity of rice blast is directly related with silicon deficiency in soils (Kim et al. 2002; Rodrigues et al. 2003; Ranganathan et al., 2006). The soils classified as Oxisols (with silicon deficiency) is responsible to rice blast in Colombia. It was stated that different levels and sources of silicon including Calcium Meta Silicate, as well as slag used as a silicon fertilization significantly reduced the severity of leaf blast (26%) and neck blast (53%) in non-treated plots to 15% in silicon-treated ones. The silicon acts as a mechanical barrier against fungal appressorial penetration (Hayasaka et al. 2008) which is known as physical resistance. Conversely, it induces the induction of resistance to plants is the result of phenolics and phytoalexins accumulation and is related to the activity of P-R genes (Rodrigues & Datnoff, 2005). Rodrigues et al, (2003) investigated the ultrastructural changes of the rice- *P. oryzae* interaction upon silicon application, which provided the first cytological evidence that silicon-mediated resistant to *P. oryzae* was related with the deposition of the osmophilic material that occluded the epidermal cells. These amorphous materials contain phenolic compounds which play a crucial role in rice defence response against infection by *P. oryzae*.

Step 5: Introduce proper training to extension agents and farmers

To control of blast disease required effective training of farmers as well as the extension agents (DAE staff, NGO workers and voluntary persons) on soil health, plant health and weather report monitoring for predicting possible insect and disease attack will be helpful.

Step 6: Introduce disease resistant and/or genetically modified (GM) cultivars

Race-specific and race-nonspecific resistant cultivars have been bred all over the world. Based on the information of distribution of races, these cultivars can be selected.

Step 7: Utilization of healthy and disease free seed

To obtain healthy seeds, the seeds must be collected from the field located under unfavorable conditions for the pathogen, and fungicide must be applied if necessary. Gravity separation methods for seeds are useful. Any salt solution, 200 g^{-1} l, or ammonium sulfate solution, 230 g^{-1}l, is used to separate sufficiently matured seeds, followed by chemical treatment for seed disinfection against a range of pathogens.

Step 8: Improve forecasting system

In Japan and Korea forecasting systems of blast disease have been successfully developed (BLASTAM: Koshimizu, 1982; Uehara et al., 1988; Kim et al., 1988; Kang et al., 2010), based on meteorological data. In India and Thailand, simple models have been developed but are not widely used. More recent models (Luo et al. 1998), integrating CERES-Rice, a rice growth simulation model with BLASTSIM, a blast epidemic simulation model; and Calvero et al., (1996) have been successful in predicting leaf blast at specific locations but require further validation. In general, reliable forecasting models are not yet available in the tropics. Empirical (Pinnschmidt et al. 1994) and mechanistic models relating disease intensity to yield loss are being utilized to construct damage functions to aid timely intervention with control measures. Guidelines for the integration of control measures are being developed (Teng, 1994). According to Katsantonis et al. (2017) the following table shows the country wise published rice blast prediction models. However, there is no such type of published prediction model in Bangladesh. In this regards, we should coming forward to develop this type of prediction models.

Table 3. Country distribution of published rice blast prediction models.*

Sl. no.	Country name	Blast prediction model (%)
1.	Japan	38
2.	Korea	13
3.	India	11
4.	Philippines	10
5.	China	4
6.	Iran	4
7.	Thailand	2
8.	Taiwan	2
9.	Indonesia	2
10.	Australia	2
11.	Italy	4
12.	Others	8

*Source: Katsantonis et al., 2017.

6. Conclusion and Recommendations

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. There is a little impact of blast outbreak on wheat production and price in this year (2016) in Bangladesh this might cause a global problem 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 means to suppress the blast epidemic in the field. The incidence of blast disease is higher in Boro than in Transplanted Aman rice across the country. Cultivation of a non-rice crop in between two rice crops reduces blast disease incidence. The disease tolerant variety must be a better option to manage this disease. However, monogenic tolerance variety is not a proper option. As a result, variety with a polygenic tolerance is the better option for a sustainable management practice. To develop a variety with polygenic tolerance through conventional breeding methods is not elegant. Recently, BRRI take initiative to develop varieties with polygenic tolerance through Marker-assisted pyramiding of disease resistance genes with collaboration with JIRCAS (Japan International Research Centre for Agricultural Sciences). In our conditions, three blast resistant genes like Pish, Pi9, and Pita-2 already been identified. With the assistance of JIRCAS introgressions of these genes are in progress (gene pyramiding) in the varieties viz. BRRI dhan29, BRRI dhan34, BRRI dhan64. Blast resistant BCF3F1 and BC2F1 advance generations are in hand. Numerous plant pathologists (Ali et al., 2016) expected some breeding generations for advance trial within 3-4 years makes easy to release horizontal tolerance variety. That would be nice for a stepping towards a variety with horizontal tolerance to rice as well as wheat blast. The following points should be considered to mitigate blast disease:

I. Abrupt climatic change causes of blast disease as it declines the disease resistance mechanism of plants. Hence, eco-efficient disease management practice as well as uses of climate change potential species of cultivar should be adopted.

II. Mineral nutrient ratio and forms in plant growth medium should keep in appropriate amount to discontinue the host and pathogen life cycles.

III. The severity in most of the pathogens can be reduced by improving plant growth media, changing plant density and sequences.

IV. Foliar application of ammonium lignosulfonate and potassium phosphate may reduce the infestation of blast disease.

V. Characterize the casual agent of blast fungi with a polyphatic taxonomy of molecular characterization, phenotypic characterization, DNA-DNA hybridization, RT-PCR, HMA and pathogenecity tests.

VI. Guidelines for monitoring blast fungi as mentioned earlier should be followed properly.

VII. Blast susceptible areas should be monitored regularly especially during growing season.

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