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Mineral nutritional status of blast infected rice plant and allied soil

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ABSTRACT

In recent years, the outbreak of rice blast is causing severe damage to rice production in Bangladesh. A research work was carried out at the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh to determine the concentration of different plant nutrients in rice blast infected plant and allied prior to harvest soil samples and also to recognize the role of plant nutrients in rice blast disease outbreak through comparing them with different reference values. A total of 20 infected mature rice plants and allied prior to harvest soil samples were randomly collected from Gazipur sadar upazila and Mymensingh sadar upazila of Bangladesh in April 2018. Comparison with the reference value suggested that Si and Ca concentrations in all the infected rice plant samples, and S and Mg concentrations of 70% samples were within the low level and K concentration in all the infected samples were found at very low level. The concentrations of P in all the plant samples were within the high level and the concentration of B was greater than the high level as compared to the reference values. The available concentrations of P, K and Si in soil samples was low but B concentration was high and the concentration of S was adequate. On the other hand, Ca and Zn concentrations of 70% and 60% samples were within the high category, respectively. The analyzed result revealed that available Ca concentration in soil was adequate but the plant could not uptake enough Ca and it found at a low level in the infected plant. Both soil and plant samples contained a high level of B which might lead to toxicity and increase the susceptibility of rice plants for blast infection. Both the collected plants and allied prior to harvest soil samples contained low amount of Si which might be the reason for the occurrence of blast disease in rice. Plant nutrients like Ca, B and Si should be considered in outlining rice blast disease management plan due to their vital role.

Introduction

Rice (*Oryza sativa* L.) is consumed as a staple food for half of the world's population (Molina *et al.,* 2012). This crop is cultivated in the world over a large area and under varied climatic conditions ranging from sub-tropical to temperate. In Bangladesh, rice is the mostly cultivated cereal crop and central to country's economy accounting for nearly 20% of gross domestic product (GDP) providing about one-sixth of the national income (Thomas *et al.,* 2013). However, this wide spread cultivation of rice has always attracted a number of constraints and resulted in the emergence of various biotic and abiotic inhibitions. The blast is one of the most devastating diseases in rice growing regions of the world and is responsible for yield loss up to 20% in many production zones annually and up to 80-100% during epidemic (Ou, 1985; Prabhu *et al*., 2009). This is the most important fungal disease of rice (Couch and Kohn, 2002) caused by *Magnaporthae oryzae* firstly documented in the year 1637 in China and then in Japan in 1704. It occurs in nearly all rice-growing environments and is highly destructive in lowland rice in temperate and subtropical Asia, and in upland rice in Latin America and Africa (Ou, 1985). Outbreak of rice blast is a serious and recurrent problem in all rice growing regions of the world. The disease is strongly influenced by essential plant nutrients. It attacks the crop at all stages and symptoms appear on the leaves, nodes as well as the panicle (Seebold *et al.,* 2004). The effects of rice blast are more severe in case of neck node blast leading to higher yield loss. The disease has been observed by literally every country where rice is grown and it is the most important disease of rice in the world (Couch and Kohn, 2002). Blast disease affects rice yield and production seriously (Skamnioti and Gurr, 2009) causing an economic loss and therefore causing a threat to food security of a country. The incidence and severity of blast disease is very common in Bangladesh as in that period the water scarcity is universal compared to Aman

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season. Already 267 races of rice blast have already been identified in our environment (Biswas *et al.,* 2017). In Bangladesh, the frequency of blast occurrence has increased with invasion into new areas (North and North-West parts of the country) in recent years. The BRRI dhan28 and BRRI dhan29 are the most popular and mega varieties recognized highly susceptible to blast disease (Anonymous, 2011). Moreover, all the local and improved aromatic rice varieties grown in wet season are vulnerable to neck blast. Recent outbreak of the disease coupled with lack of knowledge on how to reduce the disease has resulted in increased rice blast incidence leading to yield drop. The use of resistant cultivars is one of the most efficient ways of protecting crops from the disease. However, disease control is not always durable, because the resistance of new rice cultivars often breaks down a few years after they are released (Tanaka *et al*., 2015). Blast control through chemical fungicides may lead to the establishment of races of the pathogen resistant to these chemicals. Moreover, indiscriminate use of pesticides may result in serious negative effects to the environment. An integration of more than one control measure is necessary since chemicals are expensive and unfriendly to the environment. Therefore, it is important to develop alternative environment friendly strategies for management of this plant disease (Gao *et al.*, 2010).

Nutrients play important roles for plant growth and development becoming vital factors to control various diseases caused by microorganisms (Agrios, 2005). Mineral nutrition regulates the resistance or susceptibility of a plant to disease, histological or morphological structure or properties, and the virulence or ability of pathogens to survive. Plant nutrients are the major defense against diseases which influence all parts of the disease "pyramid" (Huber and Haneklaus, 2007). Nitrogen-enhanced susceptibility was reported earlier for this disease (Suzuki, 1935). Silicon in rice must be classified as essential (Mengel and Kirkby, 1987) because of its positive effects: it increases rice resistance to pest and diseases, and prevents Fe and Mn toxicity. The role of Si in the blast resistance mechanism of the host plants has been recognized by some researchers (Volk *et al*., 1958). Magdoff and Van (2000) indicated that the nutrition management offers one of the most important practices for high production system that may affect response of rice to diseases. Research on the influence of mineral nutrition on plant diseases, especially on rice blast, is very limited. Keeping these facts in mind this experiment was designed to investigate the mineral nutritional perspective of rice blast disease outbreak in Bangladesh by determining the concentration of different plant nutrients of rice blast infected plant and allied soil samples comparing them with different reference values.

Materials and Methods

Infected mature rice plants and allied prior to harvest soil samples were randomly collected at the depth of 0-15 cm from 10 severely infected fields of Gazipur district and 10 fields from Mymensingh district of Bangladesh in April 2018 as mentioned in Table 1. About 500-600g soil sample was collected from each location. Soil and plant samples were put into individual polythene bag with definite marking and tagging. Then the collected samples were brought to the laboratory of Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh for physical and chemical analysis.

Table 1. Information regarding soil and plant sampling sites of Gazipur and Mymensingh districts in Bangladesh

Sl No.	Location	Latitude	Longitude
1.	BRRI experimental farm-I, Gazipur	23°69'28.89"N	90°23'47.73"E
2.	BRRI experimental farm-II, Gazipur	23°59'29.64"N	90°23'53.40"E
3.	BRRI experimental farm-III, Gazipur	23°59'31.16"N	90°24'04.32"E
4.	BRRI experimental farm-IV, Gazipur	23°59'31.76"N	90°24'13.43"E
5.	BRRI experimental farm-V, Gazipur	23°59'25.73"N	90°24'11.73"E
6.	BRRI experimental farm-VI, Gazipur	23°59'22.71"N	90°24'00.94"E
7.	BRRI experimental farm-VII, Gazipur	23°59'25.19"N	90°23'52.47"E
8.	BRRI experimental farm-VIII, Gazipur	23°59'18.40"N	90°23'52.48"E
9.	BRRI experimental farm-IX, Gazipur	23°59'29.07"N	90°23'51.56"E
10.	BRRI experimental farm, Gazipur	23°59'25.21"N	90°23'56.36"E
11.	Charnilakshia, Bhatipara-I, Mymensingh	24°43'18.14"N	90°28'00.32"E
12.	Charnilakshia, Bhatipara-II, Mymensingh	24°43'42.08"N	90°28'03.28"E
13.	Charnilakshia, Dashpara-I, Mymensingh	24°43'41.57"N	90°28'31.65"E
14.	Charnilakshia, Dashpara-II, Mymensingh	24°43'55.69"N	90°28'13.39"E
15.	Charnilakshia, Diglapara-III	24°43'52.13"N	90°28'52.49"E
16.	Sutiakhali Moor -I, Mymensingh	24°41'15.64"N	90°27'44.45"E
17.	Sutiakhali Moor-II, Mymensingh	24°42'13.06"N	90°27'21.87"E
18.	Sutiakhali, Jalil doctorbari, Mymensingh	24°41'29.24"N	90°27'16.64"E
19.	Fulpur, Mymensingh	24°40'41.60"N	90°27'27.55"E
20.	Bhabakhali, Mymensingh	24°28'16.95"N	90°26'59.36"E

The ccollected rice plant samples were dried in an oven (model no.: KD 200NUVE, Turkey) at 65°C for 48 hours and after cooling, were ground by a grinding machine (model no.: IKA A11B). For the determination of different mineral nutrients (except Si), rice plant extract was prepared by wet oxidation method using di-acid mixture (HNO_3: $HClO_4$= 2:1) following the techniques described by Singh *et al.* (1999). The extracts were preserved separately in plastic bottles for subsequent chemical analysis. For Si determination, the plant extract was prepared following Estefan *et al.* (2013). Exactly, 0.1 g of finely ground plant material was taken into a 100 mL polypropylene tube (e.g., round centrifuge tubes) and 2 mL H_2O_2 (500 g L^{-1}) solution was added to it. Then, the concentration was agitated for a few seconds with the magnetic stirrer. About 3 mL NaOH (500 g L^{-1}) solution was added and agitated again. The tubes were placed in 85°C water bath for 1 hour. Once the sample has stopped releasing fumes, the stopper on the tubes was placed and kept into an autoclave for 1 hour at 123°C and 1.5 bar (150 k Pa). Exactly 45 mL deionized water was added and the extracts were transfer into plastic cups. Samples were left until the residues have settled at the bottom of the cup. The extracts were also preserved separately in plastic bottles for Si analysis.

For the determination of total mineral elements in soil, the digestion was carried out in Teflon containers following Tessier (1979). Available P was determined by extracting the sample with 0.5 M $NaHCO_3$ solution having pH 8.5 following the method as outlined by Olsen (1954). Exchangeable K, Na, Ca and Mg concentrations in soil samples were extracted using neutral ammonium acetate (1N) as soil extractant. Available S in soil samples was extracted using 0.01 M calcium bi phosphate extracting solution. Extraction of available metals (Zn, Cu, Mn, and Fe) was done using DTPA extracting solution as soil extractant. Available B and Si concentrations in soil samples were extracted using 0.01 M calcium chloride extracting solution following Estefan *et al.* (2013). The contents of K, Na, S, P, Ca, and Mg in plant and soil samples were determined following standard methods of analyses (Jackson, 1973; Page *et al.,* 1982; Ghosh *et al.,* 1983; Tandon, 1995). Boron content in plant and soil samples was determined by Azomethine-H method (Page *et al.,* 1982). The concentrations of Zn, Cu, Fe and Mn in both the plant and soil samples was analyzed by atomic absorption spectrophotometer (AAS) (model: Shimadzo, AA7000, Japan). The content of Si in plant and soil samples were determined by spectrophotometric method following Estefan *et al.* (2013). The recorded data were compiled, tabulated and subjected to statistical analysis with the help of computer software package, Minitab version 17 (Minitab 2017; Minitab Inc, USA). To compare the concentration of different plant nutrients of rice blast infected whole plant samples were conducted with the following guideline values of plant nutrients in whole shoots and young leaves of rice (Jones *et al.*, 1991). To compare the concentrations of different plant nutrients of rice blast infected allied prior to harvest soil samples were conducted following critical limit-based soil test values for the interpretation of loamy to clayey soils for upland crops, as proposed in Fertilizer Recommendation Guide (FRG, 2012).

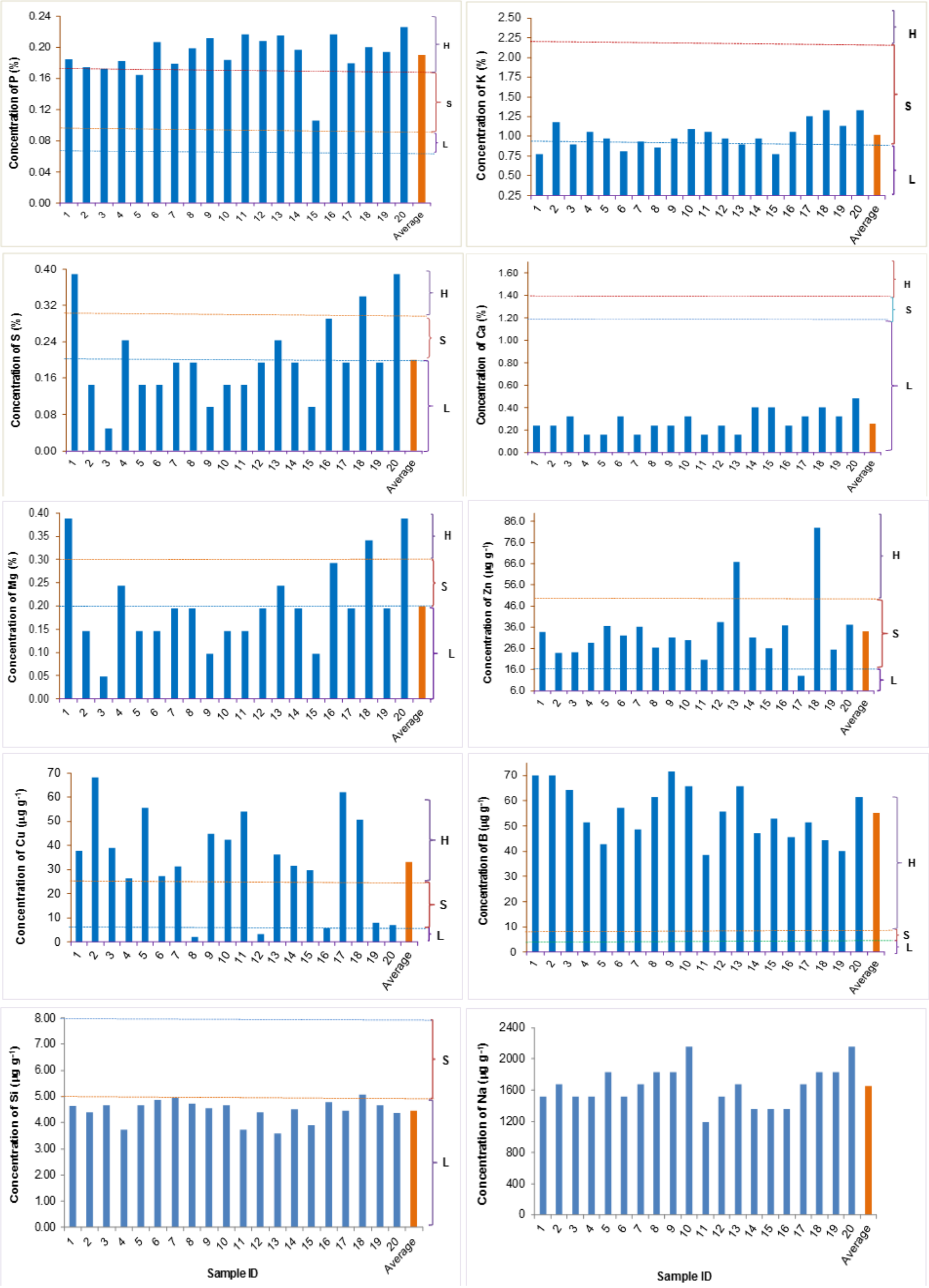
Results and Discussion

Macronutrient status of rice blast infected plants and allied soils

Macronutrients are commonly known as the major constituents of organic material which involved in enzymatic processes and assimilation by oxidation-reduction reactions (Marschner, 2012). Some previous reports indicated different macronutrients *i.e.,* P, K, S, Ca and Mg as disease resistance when they are present in an optimum concentration (Perrenoud, 1990; Tiwari, 2002; Chau *et al.,* 2003; Wang *et al.,* 2003; Sharma and Duveiller, 2004; Klikocka *et al.,* 2005).

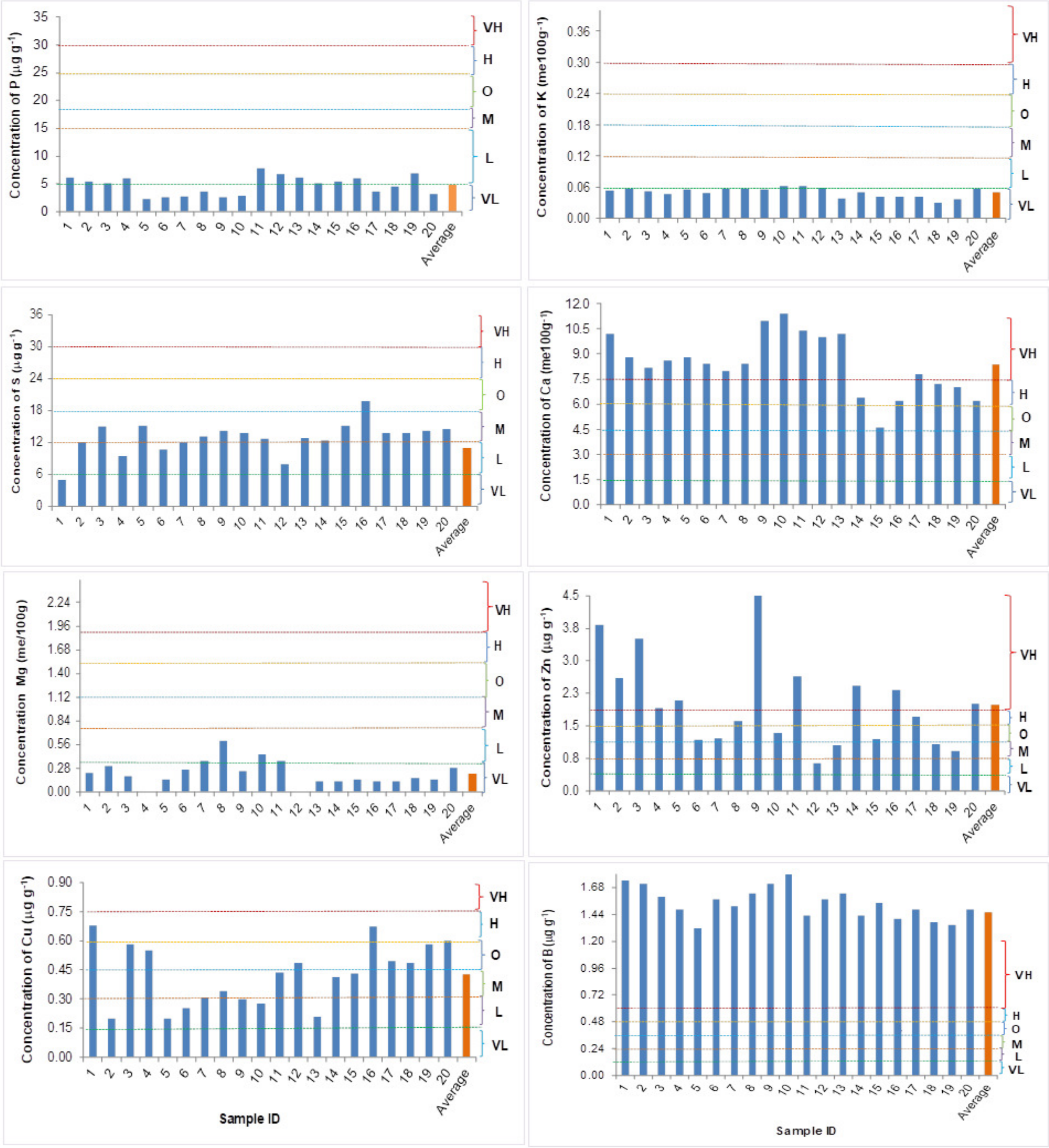
The concentration of P in plant samples collected from rice blast infected field was relatively high ranging from 0.11 to 0.23% with an average concentration of 0.19% (Fig. 1). The concentration of P in 85% of the infected plant samples was higher than the sufficient value (0.09-0.18%) for the normal and vigorous growth of rice plant as proposed by Jones *et al.* (1991) as reported in Table 2. The average concentration of available P in the allied soil samples was 4.75±1.67 μg g^{-1} (Fig. 2). According to Fertilizer Recommendation Guide (FRG, 2012), the available P concentration of all the collected soil samples was categorized as relatively very low which might be the reasons for blast disease incidence (Table 3). In the collected soil samples, total P concentration of the sampling location was within the range of 0.005 to 0.05% with an average concentration of 0.023% (Table 4). However, all the soil samples contained lower amount of P than the average shale value of 0.07% as referred by Turekian and Wedepohl (1961). It is well documented that P plays not only an essential role in energy transfer and metabolic regulation but also an important structural constituent of many molecules such as nucleotides, phospholipids and sugar phosphate (Lime *et al.,* 2003) for the deficiency or toxicity of this element hamper the metabolic activity which ultimately accelerate disease attack. This element can reduce rice blast disease and delays the onset of the disease; and lessens the severity of take-all disease incidence probably by increasing phenolic synthesis (Tiwari, 2002). On the contrary, Chau *et al.* (2003) reported that P did not affect the development and outbreak of insect pest and disease incidence.

Generally, K reduces the incidence of various diseases such as blast, bacterial leaf blight, sheath blight; stem rot and leaf spot in rice (Huber and Graham, 1999; Sharma and Duveiller, 2004). The concentration of K in the infected plant samples was relatively low having the range from 0.77 to 1.33% with an average value of 1.03% (Fig. 1 and Table 2). According to Jones *et al.* (1991), 60% of the infected plant samples contained lower amount of K than the sufficient value (1.0-2.20%). As the large amount of K present in plant cause lower disease incidence (Inoue and Uchino, 1963), the lower amount of K might be the reasons for the blast occurrence in the studied area. Previously, Perrenoud (1990) also observed that the increased level of K decreased the fungal diseases incidence in rice increasing crop yields. The average concentration of available K in the allied soil was 0.050 meq 100 g^{-1} with a range of 0.030 to 0.063 meq 100 g^{-1} (Fig. 2), which indicated the very low amount of K according to FRG (2012) causing the insufficient supply of the nutrient to rice plant (Table 3).



H = High, S = Sufficient and L = Low

Fig. 1. Concentrations of different nutrients in blast infected rice plant and its comparison with guidelines values



VH = Very high; H = High; O = Optimum; M=Medium; L = Low; VL = Very low

Fig. 2. Concentrations of different nutrients in blast infected rice field soils and its comparison with guidelines values

In the collected soil samples, the average concentration of total K was 1.94% within the range of 1.01 to 2.45% (Table 4). However, all the soil samples contained lower amount of K than the average shale value of 2.66% as referred by Turekian and Wedepohl (1961) (Table 4). The nutritional status of S strongly relates the cysteine concentration of plant tissues which have been shown to increase in plant resistant in response to attempted infection (Schnug, 1997; Vidhyasekaran, 2000). The concentration of S in the collected rice blast infected whole plant and prior to harvest soil samples have been presented in Figs. 1 and 2. Sulphur concentration of plant samples was ranged from 0.05 to 0.39% with an average concentration of 0.201%. Reference value for sufficient growth for rice plant should contain 0.21-0.33% S (Table 2). However, the concentrations of the available S in 14 samples were in lower, 2 in sufficient and 2 samples were within the range of high level. The average concentration of available S in the allied soil was 10.97 µg g^{-1}. Available S concentration of the sampling location was within the range of 5.00 to 19.76 µg g^{-1}. According to FRG (2012), concentrations of the available S in 15 soil samples were in medium, one in optimum and four samples were within the range of low level (Table 3). Previous reports showed increased resistance against fungal pathogens by applying S fertilizers on different crops under glass house and field conditions (Schnug *et al.,* 1995; Wang *et al.,* 2003; Klikocka *et al.,* 2005).

Calcium is an important component of the cell wall structure required in the middle lamella for cell wall stability. It affects the incidence of parasitic diseases (Marschner, 2012). When Ca concentration drops, there is an increased susceptibility to fungi which preferentially invade the xylem and dissolve the cell walls of the conducting vessels. Calcium protects the plant from various diseases such as adequate soil Ca is needed to protect peanut pods from infections by *Rhizoctonia* and *Pythium* and application of Ca to the soil eliminates the occurrence of the disease (Huber, 1980). Calcium confers resistance against *Pythium*, *Sclerotinia*, *Botrytis*a and *Fusarium* (Graham, 1983). Calcium concentration of plant samples was ranged from 0.16 to 0.48% with an average concentration of 0.26% (Fig. 1). Reference value for adequate growth for rice plant should contain 1.20-1.40% Ca. However, Ca concentrations of all the infected plant samples were within the lower range for the growth of rice which was categorized by Jones *et al.* (1991) (Table 2). The average concentration of available Ca in the allied soil was 8.39 meq 100 g^{-1}. Available Ca concentration of the sampling location was within the range of 4.6 to 11.4 meq 100 g^{-1} (Fig. 2). According to FRG (2012), 70% samples of available Ca were within the range of very high (Table 3). In the collected soil samples, the average concentration of total Ca in the infected soil sample was 0.29%. However, all the soil samples contained lower than the average shale value of 2.21% as referred by Turekian and Wedepohl (1961) (Table 4).

Structurally, Mg is a constituent of chlorophyll and a component of the middle lamella (Marschner, 2012). Magnesium is also associated with rapid growth, active mitosis, high protein levels, carbohydrate metabolism and oxidative phosphorylation; in addition to its participation in energy transfer reactions, respiration, DNA and RNA formation and as a co-factor for numerous enzymes (Marschner, 2012). Magnesium induced susceptibility to leaf blast when plants grown with the highest Mg concentration suffered extensive cellular damage and degradation of photosynthetic pigments as a result of high disease severity. The concentration of Mg in plant samples ranged from 0.05 to 0.39% with the average concentration of 1.12% (Fig. 1). Reference value for adequate growth for rice plant should contain 0.20-0.30% Mg (Jones *et al.,* 1991). However, the concentration of Mg in 70% infected plant samples were low, 15% sufficient and 15% high (Table 2). The average concentration of available Mg in the allied soil was 1.12 meq 100 g^{-1}. Available Mg concentration of the sampling location was within the range of 0.1 to 2.20 meq 100 g^{-1} (Fig. 2). According to FRG (2012), the concentration of available Mg in 2 samples were in very low, 6 in low, 4 in medium, 4 in optimum, 2 in high and 2 in very high level (Table 3). In the collected soil samples, the average concentration of total Mg in the infected soil sample was 1.13%. Total Mg concentration of the sampling location was within the range of 0.49 to 1.58%. However, Mg concentrations of 95% samples were lower than the average shale value of 1.5% as referred by Turekian and Wedepohl (1961) (Table 4).

Micronutrient status of rice blast infected plant and allied soils

Micronutrients are involved in many processes including plant physiology and biochemistry reducing the severity of diseases by affecting the response of plants to pathogens (Marschner, 1995). Micronutrients also have indirect effects on disease resistance, but sometimes become more suitable for feeding as some metabolites *i.e.,* reducing sugars and amino acids secrete outside the plant cell (Dordas, 2008). Graham and Webb (1991) found that these minor nutrients have important role on plant metabolic system by increasing the membrane stability in such a way which controls the contents of phenolics and lignin. Among the micronutrients, Zn was found to have a number of different effects as in some cases it decreases, in others increases, and in others has no effect on plant susceptibility to disease (Graham and Webb, 1991). In most cases, the application of Zn reduces disease severity, which could be because of the toxic effect of Zn on the pathogen directly and not through the plant's metabolism (Graham and Webb, 1991). The concentration of Zn in the collected rice blast infected whole plant and prior to harvest soil samples have been presented in Figs. 1 and 2. The concentration of Zn in plant samples was ranged from 13 to 82 µg g^{-1} with an average concentration of 34.04 µg g^{-1}. Reference value for adequate growth of rice plant should contain 18-50 µg g^{-1} Zn. From the collected plant samples, Zn concentration of 17 samples were in sufficient level, two samples in high level and one sample was in low level. So, Zn concentration in the plant samples was sufficient. The average concentration of available Zn in the allied soil was 1.99 µg g^{-1}. According to FRG (2012), the available Zn concentration of 10 samples were in very high level, 2 samples in high, 1 sample in low, 3 samples in medium and 4 samples within the range of optimum level. In the collected soil samples, the average concentration of total Zn in the infected soil sample was 60.83 µg g^{-1}. Total Zn concentration of the sampling location was within the range of 29.57 to 105 µg g^{-1}. However, almost all the soil samples contained lower than the average shale value of 95 µg g^{-1} as referred by Turekian and Wedepohl (1961).

Copper is a redox-active transition element with roles in photosynthesis, respiration, C and N metabolism, and provides protection against oxidative stress. Like Fe, it forms highly stable complexes and participates in electron transfer reactions. Divalent Cu is reduced readily to monovalent Cu which is unstable (Marschner, 2012). Stunted growth, distortion of young leaves, chlorosis/necrosis starting at the apical meristem extending down the leaf margins, and bleaching of young leaves (‘white tip’ or ‘reclamation disease’ of cereals grown in organic soils), and/or ‘summer dieback’ in trees are typical visible symptoms of Cu deficiency (Rahimi and Bussler, 1973). The concentration of Cu in concentration of plant samples was ranged from 2.23 to 68.31 μg g^{-1} with an average concentration of 33.18 μg g^{-1} (Figs. 1 and Table 2). Reference value for adequate growth for rice plant should contain 8-25 μg g^{-1} Cu. However, the concentration of Cu of 15 collected plant samples were in high level and 5 samples in low level which was categorized by Reuter *et al.,* (1986). The average concentration of available Cu in the allied soil was 4.24 μg g^{-1}. Available Cu concentration of the sampling location was within the range of 1.96 to 6.80 μg g^{-1} (Fig. 2). According to FRG (2012), the available Cu concentrations of two collected soil samples were in high level, 7 samples in optimum level, 4 samples in medium level and 7 samples were within the range of low level (Table 3). In the collected soil samples, the average concentration of total Cu in the infected soil sample was 26.93 μg g^{-1}. Total Cu concentration of the sampling location was within the range of 3.85 to 41.92 μg g^{-1}. However, all the soil samples contained lower than the average shale value of 45 μg g^{-1} as referred by Turekian and Wedepohl (1961) (Table 4). So, the overall status of total Cu in the collected soil sample was in deficient level. The function that B has in reducing disease susceptibility could be because of the function of B in cell wall structure, the function of B in cell membrane permeability, stability or function, or its role in metabolism of phenolics or lignin (Brown *et al.,* 2002; Blevins and Lukaszewski, 1998).

Table 2. Comparison of plant nutrients in plant for rice growth of rice with reference values

Plant nutrient	Avg. value (Mean±sd)	Reference values*			Remarks
		Low	Sufficient	High	
Macronutrient (% dry wt.)					
P	0.19±0.026	0.07-0.08	0.09-0.18	>0.18	85% of the samples were high. So, the overall P content in the plant samples was relatively high
K	1.02±0.168	0.80-0.90	1-2.20	>2.20	60% of the samples were lower. So, K content in the plant samples was relatively low
S	0.20±0.092	<0.15	0.15	0.2-0.3	70% samples were in lower, 10% in sufficient and rest samples were within the range of high level
Ca	0.26±0.095	<0.20	1.20-1.40	>1.40	70% samples were within the sufficient range
Mg	0.20±0.092	<0.20	0.20-0.30	>0.30	70% samples were low, 15% sufficient and 15% high
Micronutrient (μg g^{-1} dry wt.)					
Cu	33.18±20.03	6-7	8-25	>25	75% samples were in high level and 25% samples in low level
Zn	34.04±15.55	16-17	18-50	>50	85% samples were in sufficient level, 10% in high level and 5% in low level
B	55.28±10.51	4-5	6-7	>7	All the samples were within the high level

* Jones et al. (1991)

Table 3. Comparison of available mineral nutrients in soil samples with reference values based on critical limits of loamy to clayey soils for Upland Crops proposed by FRG (2012)

Soil Nutrient	Avg. value (Mean±sd)	Reference values*						Remarks
		Very Low	Low	Medium	Optimum	High	Very High	
P (μg g^{-1}) (Olsen method)	4.75±1.67	≤ 6.0	6.1-12.0	12.1-18.0	18.1-24.0	24.1-30.0	>30.0	All the samples were within the range of very low level
S (μg g^{-1})	10.97±3.052	≤ 6.0	6.1-12.0	12.1-18.0	18.1-24.0	24.1-30.0	>30.0	75% samples were in medium, 5% in optimum and 20% samples were within the range of low level.
K (meq 100g^{-1})	0.050±0.009	≤ 0.06	0.061-0.12	0.121-0.18	0.181-0.24	0.241-0.3	>0.3	All the samples were within the range of very low level
Ca (meq 100g^{-1})	8.39±1.795	≤ 1.5	1.51-3.0	3.1-4.5	4.51-6.0	6.1-7.5	>7.5	70% samples of available Ca were within the range of very high
Mg (meq 100g^{-1})	0.21±0.146	≤ 0.375	0.376-0.75	0.751-1.125	1.126-1.5	1.51-1.875	>1.875	10% samples were in very low, 30% in low, 20% in medium, 20% in optimum, 10% in high and rests in very high level
Cu (μg g^{-1})	4.24±1.58	≤ 0.15	0.151-0.3	0.31-0.45	0.451-0.6	0.61-0.75	>0.75	35% samples in optimum level, 20% in medium level and 35% within the range of low level
Zn (μg g^{-1})	1.99±1.04	≤ 0.375	0.376-0.75	0.751-1.125	1.126-1.5	1.51-1.875	>1.875	50% samples were in very high level, 10% in high, 5% in low, 15% in medium and 20% within the range of optimum level
B (μg g^{-1})	1.46±0.14	≤ 0.12	0.121-0.24	0.241-0.36	0.361-0.48	0.481-0.6	>0.6	All the samples were within the range of very high level

*FRG= Fertilizer Recommendation Guide

Table 4. Comparison of total mineral nutrients in soil samples with reference values for shale/ soil as proposed by Turekian and Wedepohl (1961)

Soil Nutrient	Average values	Reference values*	Remarks
Macronutrient (%)			
P	0.023	0.07	All the samples were lower than reference values
K	1.94	2.66	
Ca	0.66	2.21	
Mg	1.13	1.5	
Micronutrient (µg g^{-1} soil)			
Zn	60.83	95	All the samples were lower than reference values
Cu	26.93	45	All the samples were lower than reference values
B	185.33	100	All the samples were higher than reference values
Na	13687.31	9600	All the samples were higher than reference values

* Turekian and Wedepohl (1961)

The stability and rigidity of the cell wall structure is largely dependent on B content which ultimately influence the shape and strength of the plant cell (Brown *et al.,* 2002; Marschner, 1995). It has been reported that B can reduce diseases caused by *Plasmodiophora brassicae* in crucifers, *Verticillium albo-atrum* in tomato and cotton, *Fusarium solani* in bean, and tobacco mosaic virus in bean. The concentration of B in the collected rice blast infected plant and prior to harvest soil samples have been presented in Figs. 1 and 2. The concentration of B of plant samples was ranged from 38.37 to 71.43 µg g^{-1} with a mean concentration of 55.28 µg g^{-1}. Reference value for adequate growth of rice plant should contain 6-7 µg g^{-1} B. However, B concentrations of all the infected plant samples were in high level which was categorized by *Jones et al.* (1991). The average concentration of available B in the allied soil was 1.46 µg g^{-1}. According to FRG (2012), the available B concentration of all the collected soil samples was within the range of very high level. In the collected soil samples, the average concentration of total B in the infected soil sample was 185.33 µg g^{-1}. However, all the soil samples contained higher than the average shale value of 100 µg g^{-1} as referred by Turekian and Wedepohl, (1961). Dordas (2008) found B to reduce the severity of many plant diseases because their special functions on cell wall structure, plant membranes and plant metabolism.

Silicon and sodium status of rice blast infected plant and allied soils

Sodium and silicon are included in the beneficial nutrients but have not yet been established as essential elements for all higher plants (Fageria *et al.,* 2002; Daroub and Snyder, 2007). Cereal crops, particularly rice, are Si accumulator plants and it has capability to actively absorb Si in high amounts. The concentration of Si in leaves is negatively correlated with the number of eye spots caused by fungi such as rice blast, indicating greater resistance to the disease (Marschner, 2012). Nakata *et al.* (2008) and Epstein (1994) reported increased photosynthesis, improved water use, enhanced resistance against insects and diseases and increased erectness of leaves in presence of adequate Si in rice tissues. The diseases like blast, brown spot and sheath blight become extremely threatening to rice cultivation due to the deficient amount of Si (Rodrigues and Datnoff, 2005). Prabhu *et al.* (2001) found that rice cultivar that accumulated more silicon on the shoots showed less incidence of rice blast. The concentration of Si in plant samples was ranged from 3.58 to 5.06 % with an average concentration of 4.47% (Fig. 1). Reference value for adequate growth of rice plant should contain 5% Si. However, Si concentrations of all the infected plant samples were in low level which was categorized by Rao and Susmitha (2017). In respect to infected soil samples, the average value of available Si was 2.46 µg g^{-1} and ranging from 0.99 to 3.91 µg g^{-1} (Fig. 2 and Table 3). Rao and Susmitha (2017) reported that the critical level of Si in soil was 40 µg g^{-1}. However, all the soil samples contained lower than the average shale value of 40 µg g^{-1}. Lower amount of Si in plant sample might be linked to relatively low amount of available soil Si and might be responsible for disease incidence. Previous reports showed reduced mineral toxicities and better disease and insect resistance in rice crop in the presence of optimum Si (Alvarez and Datnoff, 2001; Seebold *et al.,* 2004).

Typically, our mental reference to Na in plant nutrition and culture is toxicity, necrosis, tip burn, chlorosis, scorching, bronzing and even death. It is an element that can increase yield, quality and disease resistance in some species. The concentration of Na in collected rice blast infected whole plant and prior to harvest soil samples are displayed in Figs. 1 and 2. Sodium concentration of plant samples was ranged from 1193.84 to 2156.61 µg g^{-1} with an average concentration of 1651.15 µg g^{-1}. The average concentration of available Na in the allied soil was 64.22 µg g^{-1}. In the collected soil samples, the average concentration of total Na in the infected soil sample was 13687.31 µg g^{-1}. Total concentration of Na in the sampling location was within the range of 3822.53 to 21245.54 µg g^{-1}. However, the concentration of Na in 13 samples were within the higher and 7 were in lower than the average shale value of 9600 µg g^{-1} as referred by Turekian and Wedepohl (1961).

Conclusion

Rice blast is a serious disease-causing yield failures and significant economic losses in every year. The incidence of rice blast was recorded in *boro* season (November to May: irrigated ecosystem) and transplanted *aman* (July to December: rainfed ecosystem) in all over Bangladesh. Rice production is now under threat due to the rice blast outbreak in Bangladesh. The result of this study may be used as a baseline data in establishment of the relationship between plant nutrients and rice blast disease outbreak. Plant nutrient like Ca, B and Si played vital role in rice blast disease incidence and should be considered in outlining its management plan. Routine analysis of Ca, B and Si should be carried out for plant and soil. Considering different susceptible and resistant rice varieties of infected and non-infected plants, further studies on mineral nutrients may be conducted for better understanding.

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