Original Research Article

Effect of Sulphur and Boron on Growth and Yield of Boro Rice in Calcareous Soil of Bangladesh

Abstract

The experiment was constructed with Sulphur (S) and Boron (B) with three doses of each, i.*e.,* S_0: without Sulphur (control), S_{20}: 20kg S/ha, S_{30}: 30kg S/ha and B_0: without Boron (control), B_2: 2kg B/ha, B_3: 3kg B/ha to study the effect on Boro rice (*cv.* BRRI dhan-28).In case of Sulphur, the treatment S_{20} obtained the maximum plant height (97.811cm), maximum tillers hill^{-1} (26.184) at harvest, highest panicle length (24.98cm), maximum grains panicle^{-1} (167.37), maximum 1000-grain weight (27.57g), maximum grain yield (5.46t/ha) and straw yield (5.71t/ha), maximum biological yield (11.17t/ha) and HI (48.88%). Whereas, maximum filled grains panicle^{-1} (147.37) and minimum unfilled grains panicle^{-1} (17.89) were found in S_{30}. In case of Boron, the highest plant height (96.378cm) was found in B_3. Highest number of total tiller hill^{-1} (25.149), longest panicle (24.17cm), highest number of total grains panicle^{-1} (165.78), filled grains panicle^{-1} (144.04) and minimum unfilled grains panicle^{-1} (21.74), maximum 1000-grain weight (25.24g), highest grain, straw and biological yield (4.84, 5.43 and 10.27t/ha, respectively) and highest HI (47.13%) were found in B_2.The treatment combination $S_{20}B_2$ performed the best response than other treatments. Plant height was highest (100.30cm) in $S_{20}B_3$ treatment combination at harvest. However, the maximum tillers hill^{-1} (28.78) at harvest, highest panicle length (26.94cm), maximum grains panicle^{-1} (177.57), maximum filled grains panicle^{-1} (150.27) and minimum unfilled grains panicle^{-1} (27.30), highest 1000-grain weight (29.75g), highest grain, straw and biological yield (6.30, 5.91 and 12.21t/ha, respectively) and higher HI (51.60%) were found in $S_{20}B_2$ treatment combination.

Keywords: Calcareous Soil, Sulphur, Boron, Growth, Yield, Boro Rice.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important crops that provide food for more than half of the world population (Malik *et al.,* 2008). It is the staple food of Bangladesh and is the world's second important food grain. Rice contributes 91.12% of the total grain production and covers 68% of the total calorie intake of this country's people (MOA, 1996). Fertilizer is one of the most important measures for sustainable agricultural production. In modern farming, fertilizer application is an essential component contributing about 50% of the world's production

(Pradhan, 1992). Nutrient stresses in Bangladesh soils are increasing day by day. Before 1980's deficiency of NPK was a major problem but there after NPK, deficiency along with secondary and micronutrients (S and B) are frequently reported (Islam *et al.,* 1995, Islam and Hossain, 1998; Haque and Jahiruddin, 1999). Sulphur (S) is an essential plant nutrient and plays a vital role in the synthesis of amino acids (methionine, cystein and cystine), proteins, chlorophyll and certain vitamins (Havlin*et al.,* 2004; Tiwari and Gupta, 2006). Plants absorb S mainly in the form of inorganic sulphate (SO_4^{2-}) ions through the roots, thus sulphate must be present in soils in sufficient amount in order to meet crop S requirements (Brady and Weil, 2002). Insufficient availability of Sulphur to crop plants not only declines their growth and yield but can also deteriorate nutritional quality of the production (Hawkesford, 2000; Schonhof*et al.,* 2007). The major causes of S deficiency in Bangladesh include intensive cropping with high yielding varieties of different crops, soils remaining water logged due to wet land rice culture, shifting toward virtually Sulphur free fertilizer, depletion of soil organic matter through the removal of organic residues from the field and loss of S by leaching in light textured soils in high rain fall areas (Islam *et al.,* 2009). Sulphur deficiency in crops results in a reduction of leaf area, seed number, seed weight, delayed floral initiation and anthesis (Jamal *et al.,* 2005). It reduces the growth rate and plant protein, chlorophyll content and photosynthetic CO_2 fixation (Tiwari *et al.,* 1994). Nitrogen assimilation is hampered due to the inadequate supply of S containing amino acids and thus nitrogen uptake and translocation are impeded (Badruddin, 1999). Boron (B) is essential for plants and B availability in soil and irrigation water is an important determinant of agricultural production (Tanaka and Fujiwara, 2007). It is responsible for better pollination, seed setting and grain formation in different rice varieties (Rehman*et al.,* 2012). Among the micronutrients boron Boron deficiency causes great depreciation in grain set and results in severe yield reduction in many of the world's grain producing countries (Rerkasem*et al.,* 2004). Rice plant is sensitive to Boron deficiency especially at the panicle formation stage and insufficient Boron application may lead to failure in panicle formation (Dobbermann and Fairhurst, 2000). Keeping this in view, the experiment was carried out to determine the appropriate dose of Sulphur and Boron, their effect on growth and yield of boro rice (BRRI dhan -28); and to find out the responses of Sulphur and Boron and their combinations in calcareous soils.

2. MATERIALS AND METHODS

2.1. Location and Site

The experiment was conducted at the field laboratory of Department of Crop Science and Technology, University of Rajshahi, Bangladesh during the period from November 2015 to April 2016 in Boro Season.

Geographically the experimental field is located at 24°22′36″ N latitude and 88°38′27″ E longitude at an elevation of 20 meter above the sea level. The experimental area belongs to High Ganges River Floodplain under Agro-Ecological Zone-11 (AEZ-11) (Appendix I).

2.2. Characteristics of Soil

The experimental field is of well-drained soil with moderately low permeability. The top soil is silty clay and slightly alkaline in reaction. The soil was medium fertile and pH value of the soil was 8.4. Physical and chemical characteristics of soil of the experimental field have been presented in Table 1.

Table 1. Physical and chemical characteristics of experimental initial field soil

SI. No	Properties	Value
1.	Sand (%)	20.8
2.	Silt (%)	60.3
3.	Clay (%)	20.9
4.	Textural class	Silty clay loam
5.	pH	8.4
6.	Organic Matter (%)	1.25
7.	Total Nitrogen (%)	0.10 (VL)
8.	Available phosphorus (ppm)	16.2 (L)
9.	Available Sulphur (ppm)	12.5 (VL)
10.	Zinc (ppm)	0.11 (VL)
11.	Boron (ppm)	0.23 (L)
12.	Potassium (meq/100g)	0.57 (L)
13.	Magnesium (meq/100g)	4.30 (OP)
14.	Calcium (meq/100g)	15.35 (OP)

Source: Soil Resource and Development Institute (SRDI), Regional Centre, Rajshahi, Bangladesh
Here, according to BARC (2005), VL = Very low, L = Low, M = Medium, OP = Optimum.

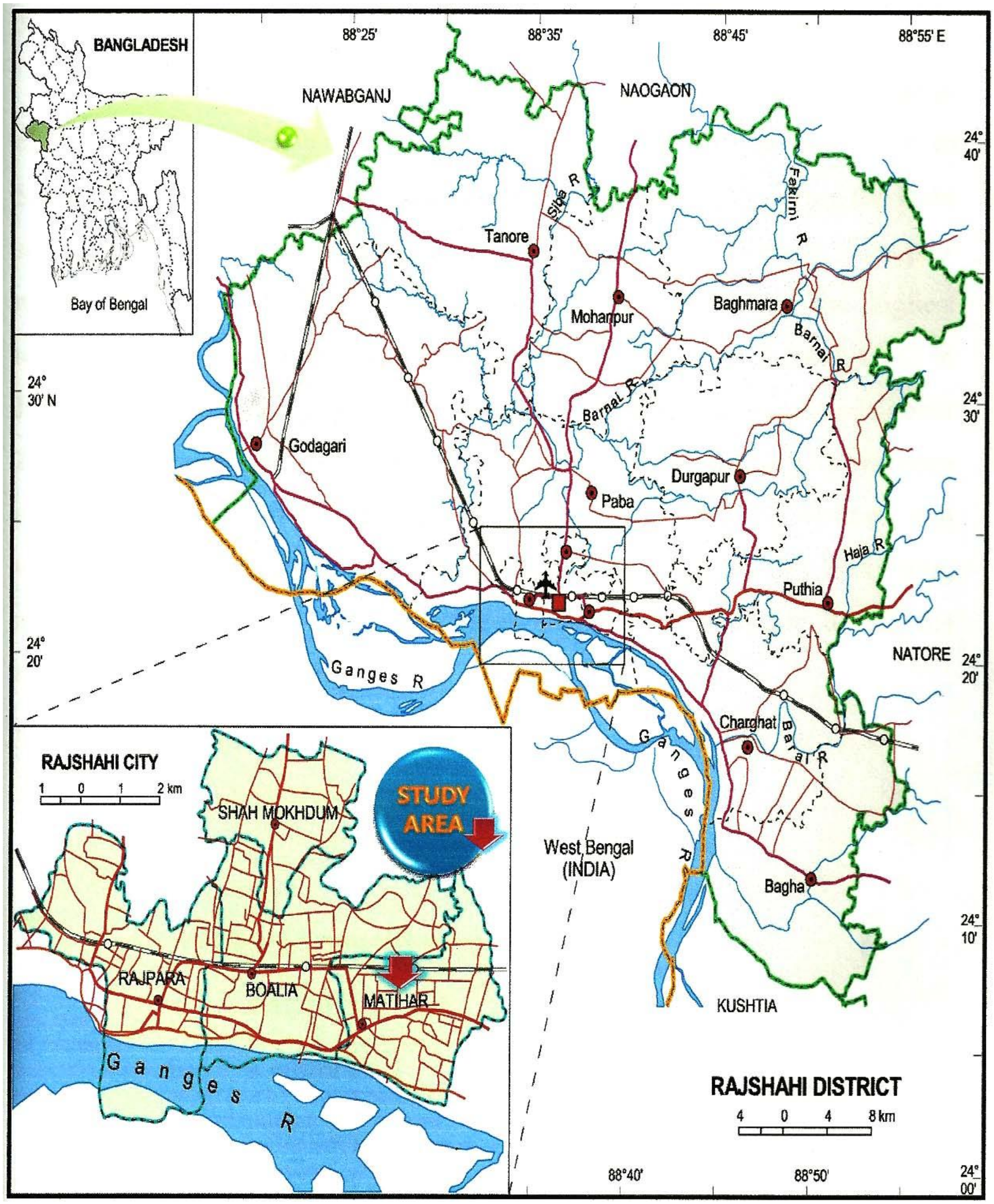

Figure 1. Location map of the study area

2.3. Climate

The experimental area was situated under subtropical climate, which is characterized by high temperature and moderate rainfall during kharif season (April to September) and low temperature during Robi season (October to March). The monthly total rainfall, average maximum and minimum temperature and relative humidity at the experimental site during the period of study have been presented in Appendix II.

2.4. Materials of the Experiment

2.4.1. Planting materials

BRRI Dhan-28 was selected as cultivating variety. This variety was developed by Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh. It is a popular variety and widely cultivated throughout the country. This is drought and cold tolerant rice variety and also moderately resistance to blast. BRRI dhan-28 was collected from Bangladesh Rice Research Institute (BRRI), Regional station, Shyampur, Rajshahi, Bangladesh.

2.4.2. Seed Sprouting

Healthy seeds were selected following standard method. Seed were immersed in water. Seeds were soaked in water in bucket and then taken out of water and spread thickly on polythene sheet and covered with wet gunny bags under dark condition for sprouting. The seeds started sprouting after 48 hours.

2.4.3. Raising of Seedling

A piece of medium high land was puddle well with country plough followed by cleaning and leveling with a ladder. The sprouted seeds were sown uniformly in a well prepared seed-bed on 29 November, 2015. Weeds were removed and irrigation was given in the seedbed as and when necessary. Due care was also taken to see that there was no infestation of pest and diseases and no damage by birds.

2.5. Experimental treatment

Experiment was constructed with two factors *viz.,* factor A (Sulphur) and factor B (Boron) with three levels dose of each. Here, Sulfur was used as gypsum ($CaSO_4.2H_2O$) and boron was used as Borax ($Na_2B_4O_7.10H_2O$). The detail of the treatment doses are given in the following Table 2.

Table 2. Treatment doses

Factor-A: Three Sulphur doses	Factor-B: Three Boron doses
1. S_0:0 kg S/ha	**1.** B_0: 0 kg B/ha
2. S_{20}:20 kg S/ha	**2.** B_2: 2 kg B/ha
3. S_{30}:30 kg S/ha	**3.** B_3: 3 kg B/ha

Therefore, the total nine treatment combinations were found which are as follows in Table 3.

Table 3. Treatment combinations

1. S_0B_0 (0 kg S/ha + 0 kg B/ha)	**6.** $S_{20}B_3$(20 kg S/ha + 3 kg B/ha)
2. S_0B_2 (0 kg S/ha + 2 kg B/ha)	**7.** $S_{30}B_0$(30 kg S/ha + 0 kg B/ha)
3. S_0B_3 (0 kg S/ha + 3 kg B/ha)	**8.** $S_{30}B_2$ (30 kg S/ha + 2 kg B/ha)
4. $S_{20}B_0$(20 kg S/ha + 0 kg B/ha)	**9.** $S_{30}B_3$(30 kg S/ha + 3 kg B/ha)
5. $S_{20}B_2$(20 kg S/ha + 2 kg B/ha)	

Urea was applied in three equal splits, as top dressing first split 10 days after transplanting (DAT), second at active tillering stage at 30 days after transplanting (DAT) and third split at panicle initiation stage at 60 days after transplanting (DAT).

2.6. Design and layout of the experiment

The experimental plots were laid out according to the requirement of the treatments and statistical design. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three blocks each representing replication. Again, each block replication was divided into nine unit plots where the treatment combinations were allocated at randomized. Therefore, total number of plots was 27 in the experiment. The size of unit plot was 10 m^2 (4 m × 2.5 m). The plot to plot distance was 1 m and between block was 1.5 m.

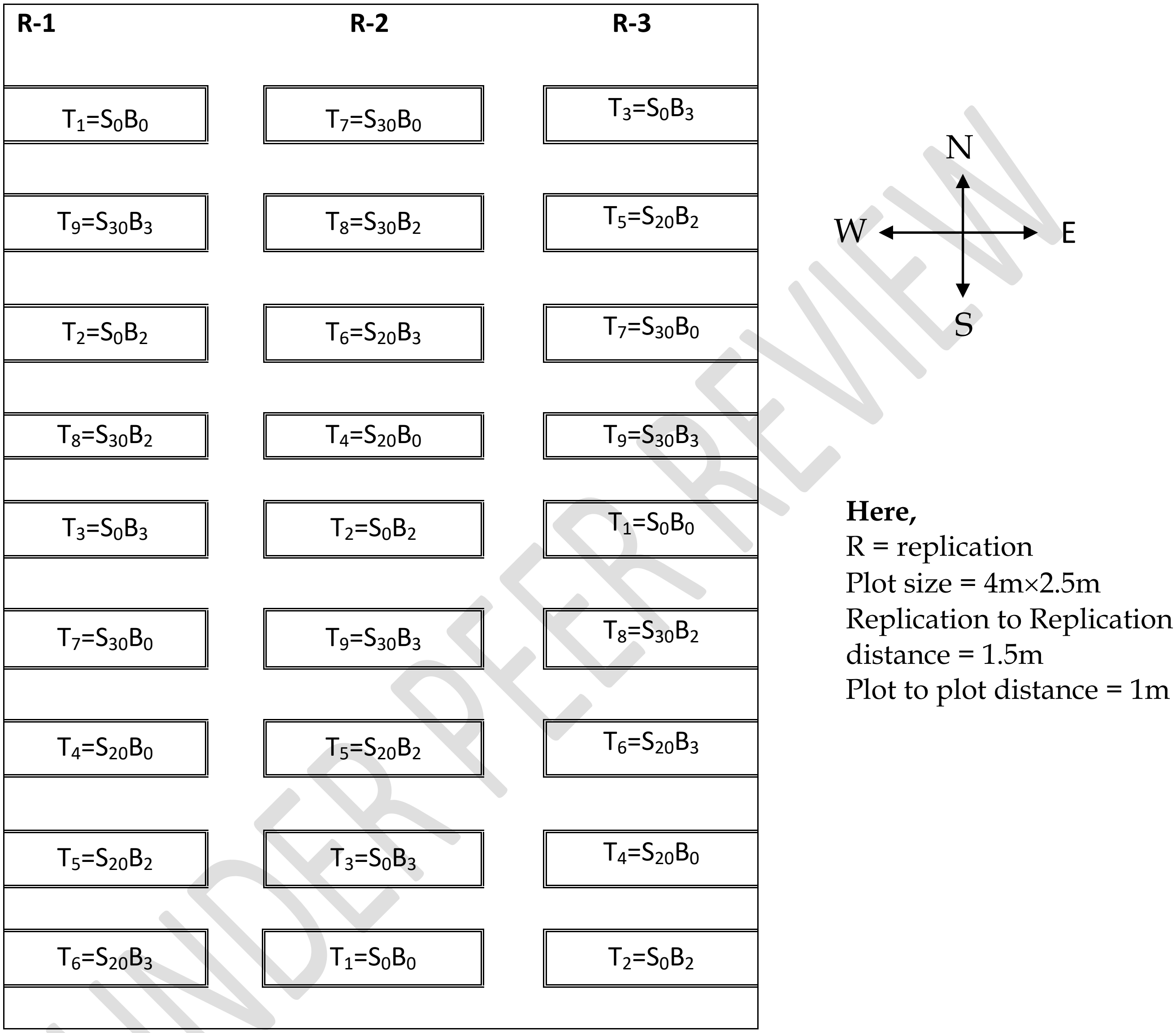

Figure 2. Layout of the experimental field

2.7. Preparation of main land for transplanting

At first, required amount of water was preserved in the field for rotting weeds before 10 days of ploughing. After that the land was opened by power tiller. Then it was ploughed and cross ploughed three times with bullock drawn country plough followed by laddering to obtain a desirable puddle condition. The corners of the land were spaded well. Weeds and stubbles were removed from the field prior to transplanting of seedlings. The experimental plot was finally made ready for transplantation on 31 December, 2015.

The layout of the experimental field was made according to the design adopted. The layout of the experimental field was done on 03 January, 2016 according to the design adopted. Individual plots were leveled with a wooden plank. The bunds around the individual plot were spread before transplantation. Finally the total experimental area was isolated from nearby fields through the formation of a big and raised ail (bunds).

2.8. Uprooting of seedling

The seedbed was made wet by application of water both in the morning and evening on the previous day before uprooting the seedling to reduce the mechanical injury of the root. The seedling were uprooted and kept on soft mud in shade and they were transplanted. The seedlings were similar and the having no injury were used for transplanting.

2.9. Transplanting of seedling

Forty days old seedlings were transplanted in the well-puddled plots, three seedlings hill^{-1} on 08 January, 2016.

2.10. Intercultural operation

The following intercultural operation was done for ensuring and maintaining the normal growth of crop.

2.10.1. Fertilizer management

The experimental field was fertilized with Urea, TSP, MP and Gypsum at the rate of 150 kg ha^{-1}, 100 kg ha^{-1}, 70 kg ha^{-1} and 60 kg ha^{-1} respectively. One third of Urea and whole TSP, MP and Gypsum were applied during the final land preparation and were thoroughly mixed to the soil. The remaining urea was top dressed in two equal split.

2.10.2. Gap filling

After one week of transplanting, gap filling was done where it was necessary using the seedling from the same source.

2.10.3. Weeding

Weeding was done manually. The first weeding was done at 15 days after transplanting (DAT), the second and third weeding was done at 30 and 50 DAT, respectively.

2.10.4. Irrigation and drainage

The crop was irrigated by flood irrigation up to a level of 6 cm at early stage to enhance tillering and 10-12 cm at the later stage to discourage later tillering. The filled was finally drained out before 15 days of harvest to enhance maturity.

2.10.5. Plant protection measures

During the growth period, some plants were attacked by stem borer (*Scirpophagaincertulas*), and green leaf hopper which were successfully controlled by Furadan 5 G @ 12 kg/ha and Sumithion 100 SCW @ 1 liter/ha.

2.10.6. General observation

Regular observations were done to see the growth stages of the crops. In general the field looked nice with normal green plants. They were vigorous and luxuriant. Tiller growth of all treatments combination was satisfactory. The plant did not lodge in any of the plot.

2.10.7. Sampling, harvesting, threshing, cleaning and processing

Maturity of crops was determined when about 80-85 percent grains becomes golden yellow. Five hills (excluding border hill) were randomly selected from each plot and tagged for recording necessary data. After sampling the whole plot was harvested at maturity.

2.11. Data collection

2.11.1. Plant height (cm)

Plant height was measured after harvest. The height of the plant measured from the ground level to the tip of the longer panicle.

2.11.2. Total number of tillers

The tillers which had at least one leaf visible were counted. If included both effective and non-effective tillers.

2.11.3. Panicle length (cm)

Lengths were measured from the first node of the rachis to the tip of each panicle.

2.11.4. Number of grain/panicle

Total number of filled grain and unfilled grain were counted as total grain/panicle.

2.11.5. Number of filled grain/panicle

Presences of food material in the panicle were considered as grain and total number of grains present on each panicle were counted as number of filled grain/panicle.

2.11.6. Number of unfilled grain/panicle

Grains having no food materials inside were considered as sterile spikelet and the number of such spikelet present on each panicle were counted as number of unfilled grain/panicle.

2.11.7. 1000-grain weight (g)

One thousand clean dried grains from the seed stock of each plot were counted separately and weight was taken by an electrical balance at 14% moisture.

2.11.8. Grain yield (t/ha)

The grain was separated by threshing plot wise than sun dried and weighed. The grain weight was finally converted into (t/ha).

2.11.9. Straw yield (t/ha)

Straw obtained from each unit plot was sun dried and weighted and then converted into (t/ha).

2.11.10. Biological yield (t/ha)

Grain yield and straw yield were altogether regarded as biological yield. Biological yield was calculated with the following formal-

Biological yield (t/ha) = Grain yield (t/ha) + straw yield (t/ha)

2.11.11. Harvest index (%)

It is the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

2.12. Statistical analysis

Recorded data for different parameters were compiled and tabulated in proper form for statistical analysis. The “Analysis of variance” (ANOVA) was done with the help of computer package program “MSTAT-C”.The mean differences were adjudged by Duncan’s Multiple Range Test. Simple correlation coefficient was done to determine the relationships between grain yield and its components with the help of computer package SPSS.

Plate 1. Seed bed preparation

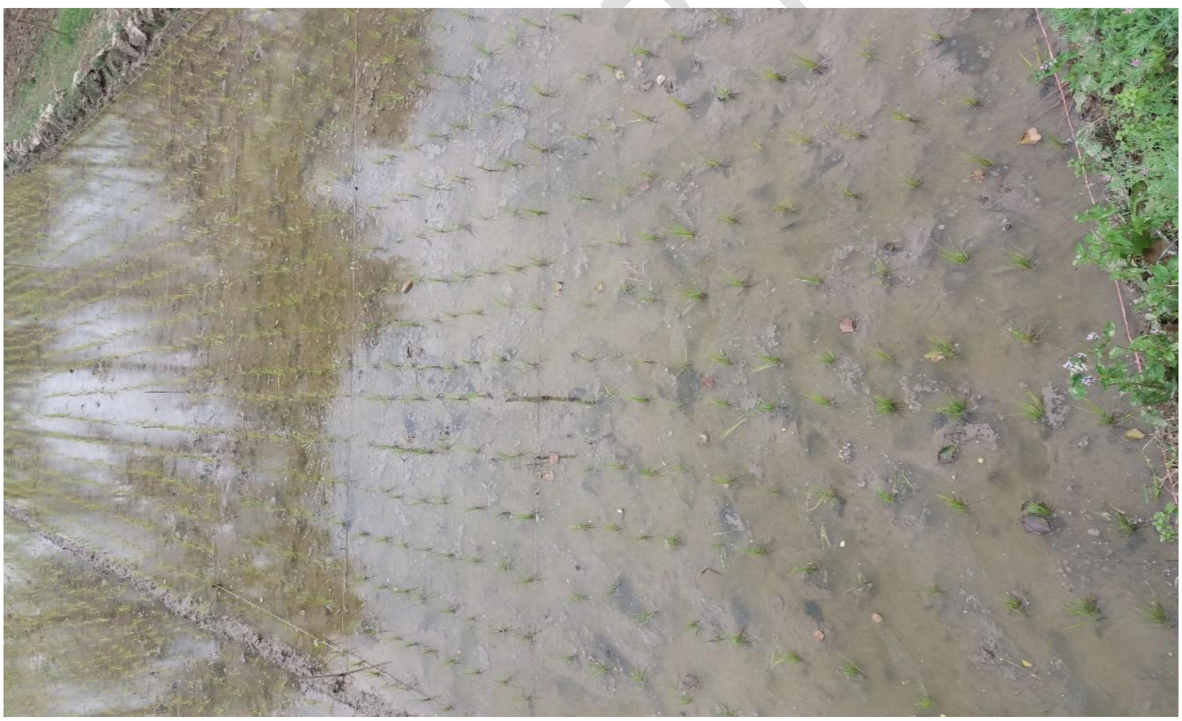

Plate 2. Initial stage

Plate 3. Booting stage

Plate 4. Flower initiation stage

Plate 5. Maturity stage

Plate 6. Final field inspection

3. RESULTS AND DISCUSSION

The present research work was undertaken to investigate the effect of Sulphur (S) and Boron (B) on growth and yield of Boro rice in calcareous soils of Bangladesh. The results on growth, yield and yield contributing characters of BRRI dhan-28 have been presented. Among the studied characters, plant height (cm) and total number of tillers were recorded at 30, 50, 70 DAT and at harvest, while number of grains/panicle, number of filled and unfilled grains/panicle, 1000–grains weight (g), grain yield (t/ha), straw yield (t/ha), biological yield (t/ha) and harvest index (%) were recorded at the time of harvest and their detailed results described under the following subheadings.

3.1. Main and combined effect of Sulphur and Boron on the growth of plant height (cm)

3.1.1. Effect of Sulphur

Plant height is one of the most efficient characters among the yield and yield contributing characters for getting the higher yield of rice due to the plant height is a key of higher straw yield. Plant height differed significantly due to the application of various level of Sulphur at 30, 50, 70 DAT and at harvest (Figure 3 and Appendix III). Among the different levels of Sulphur, the maximum plant height (38.289 cm at 30 DAT, 68.378 cm at 50 DAT, 92.922 cm at 70 DAT and 97.811 cm at harvest) was recorded in S_{20} (20 kg S/ha) and the lowest plant height (35.522 cm at 30 DAT, 54.990 cm at 50 DAT, 88.00 cm at 70 DAT and 90.778 cm at harvest) was recorded in S_0 (control). Similar result was also observed by Islam *et al.,* (2009) who conducted an experiment to evaluate the effects of different rates and sources of Sulphur on the yield and yield components, nutrient content and nutrient uptake of rice and the longest plant was found from 16kg S/ha applied as gypsum while the shortest plant was noticed with control treatment Sulphur.

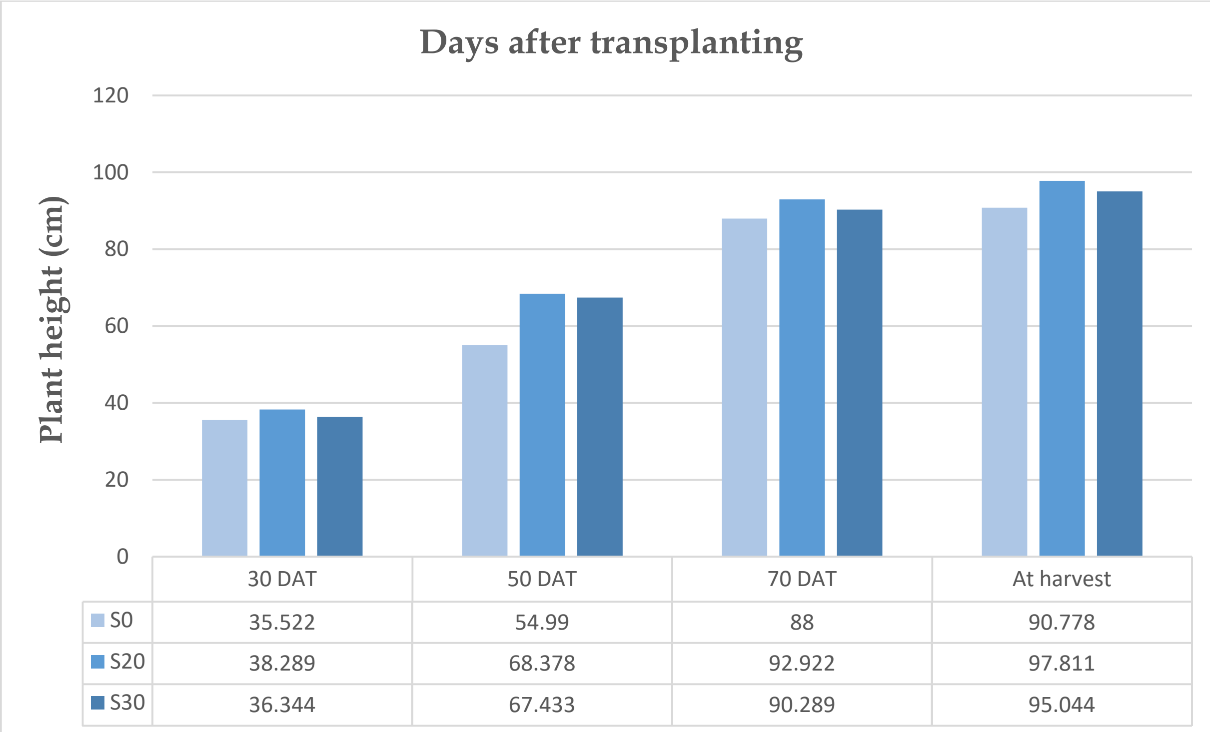

Figure 3. Effect of Sulphur (S) on plant height at 30, 50, 70 DAT and at harvest

3.1.2. Effect of Boron

Application of Boron significantly influenced the plant height of Boro rice (Figure 4 and Appendix III). The findings showed that the longest plant height (37.422 cm) was found in B_2 (2 kg/ha) followed by B_3 (3 kg/ha), whereas the shortest plant height (35.589 cm) was recorded from B_0 (control) at 30 DAT. At 50 DAT, the longest plant height (64.70cm) was found in B_2 (2 kg/ha) whereas the shortest plant height (62.546cm) was recorded from B_0 (control). At 70 DAT, the longest plant (91.867cm) was found in B_3 (3 kg/ha) and the shortest plant height (89.444 cm) was found in no Boron application followed by B_2 (2 kg/ha). Again, at harvest stage, the longest plant height (96.378 cm) was found in B_3 (3kg/ha), whereas the shortest plant height (93.022 cm) was found in B_0 (control) followed by B_2 (2 kg/ha). Another study shows that plant height was significantly influenced by B application with the range from 3.51 to 6.11 t/ha (Khan *et al.*, 2011).

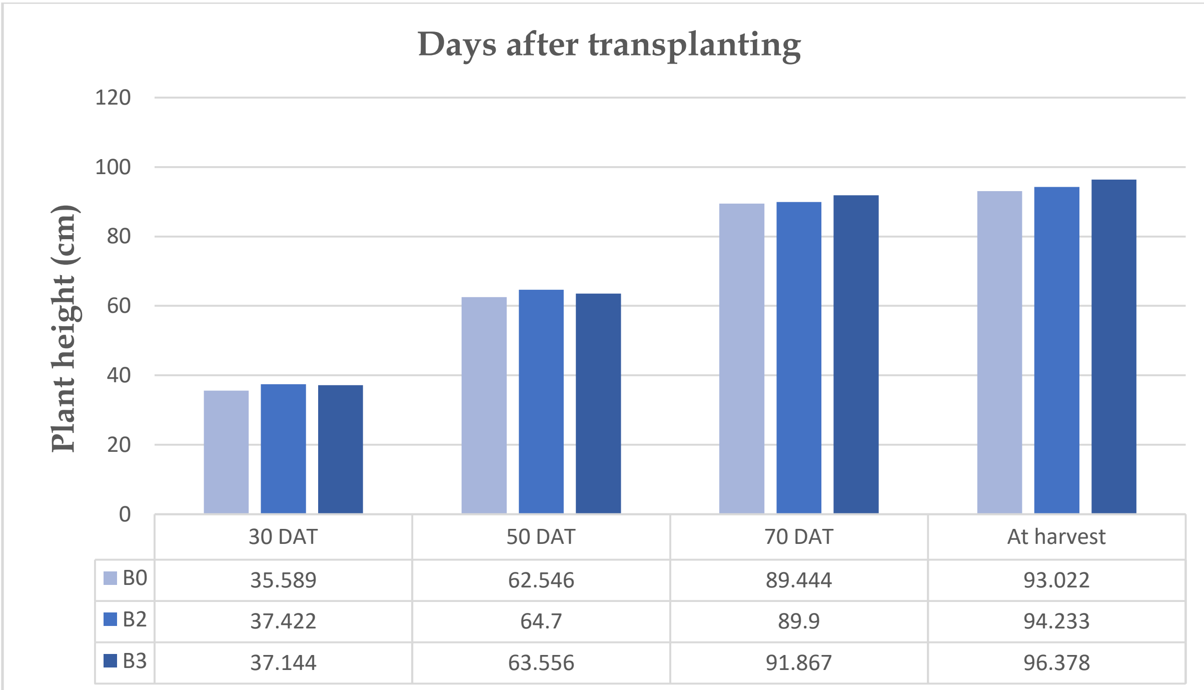

Figure 4. Effect of Boron (B) on plant height at 30, 50, 70 DAT and at harvest

Table 4. Interaction effect of sulphur and boron on plant height (cm) at different days after transplanting

Treatment	Plant height (cm)			
	30 DAT	**50 DAT**	**70 DAT**	**At harvest**
S_0B_0	33.87e	53.17d	86.33f	89.53f
S_0B_2	37.77b	58.43c	88.47e	90.47e
S_0B_3	34.93d	53.37d	89.20de	92.33cd
$S_{20}B_0$	37.80b	67.70ab	91.23bc	95.67bc
$S_{20}B_2$	38.27ab	68.30ab	92.77b	97.47b
$S_{20}B_3$	38.80a	69.13a	94.77a	100.30a
$S_{30}B_0$	35.10d	66.77b	90.77cd	93.87c
$S_{30}B_2$	36.23c	67.37ab	88.47e	94.77c
$S_{30}B_3$	37.70b	68.17ab	91.63bc	96.50b
LSD (0.5)	0.9916	1.870	1.641	-
Level of significance	**	**	**	NS
CV (%)	4.19%	3.30%	6.80%	4.36%

In a column, means followed by a similar letter(s) or without letter are not significantly different whereas, means followed by a dissimilar letter(s) are significantly different as per DMRT at 5%. Here, ** indicates significant at 1% level of probability, NS = Non-significant, CV (%) = Co-efficient of variation, DAT = Days after transplanting.
S_0 = 0 kg Sulphur (control), S_{20} = Sulphur 20kg/ha, S_{30} = Sulphur 30kg/ha.
Again, B_0 = 0kg Boron (control), B_2 = Boron 2kg/ha, B_3 = Boron 3kg/ha

3.1.3. Combined effect of Sulphur and Boron

A significant variation was found during the growth period of plant height due to interaction effect between Sulphur and Boron fertilizers, whereas at harvest the treatment combination was non-significant (Table 4 and Appendix III). Among the interaction effects, 20 kg S/ha with the combination of 3 kg B/ha ($S_{20}B_3$) recorded the longest plant height (38.80cm at 30 DAT, 69.13 cm at 50 DAT, 94.77cm at 70 DAT and 100.30 cm at harvest). Similarly, the shortest plant height (33.87cm at 30 DAT, 53.17 cm at 50 DAT, 86.33 cm at 70 DAT and 89.53 cm at harvest) was found from both of the control fertilizers, S_0B_0 (without Sulphur and Boron).

3.2. Main and combined effect of Sulphur and Boron on the growth and yield of total number of tillers

3.2.1. Effect of Sulphur

Tiller production are directly related to grain and straw yield in case of the more tillers produced more panicle, more grains which ultimately increase the grain and straw yield of rice. Analysis of variance of data regarding to tiller production was affected significantly due to the various levels of Sulphur application at 30, 50, 70 DAT and at harvest. Among the Sulphur levels, the maximum total tillers (11.52, 21.152, 26.89 and 26.184) were recorded in 20 kg S/ha (S_{20}) at 30, 50, 70 DAT and at harvest respectively, which was significantly differed from others (Figure 5 and Appendix IV). The minimum total tillers (7.593, 17.78, 22.963 and 21.593) were recorded in 0 kg S/ha at 30, 50, 70 DAT and at harvest respectively.Islam *et al*. (1996) reported a significant increase in tillers of BR11 rice at BAU farm and at farmer's field in Melandha by applying 20kg S/ha.Haque and Chowdhury (2004) also reported that number of effective tillers/hill of rice was increased by S application.

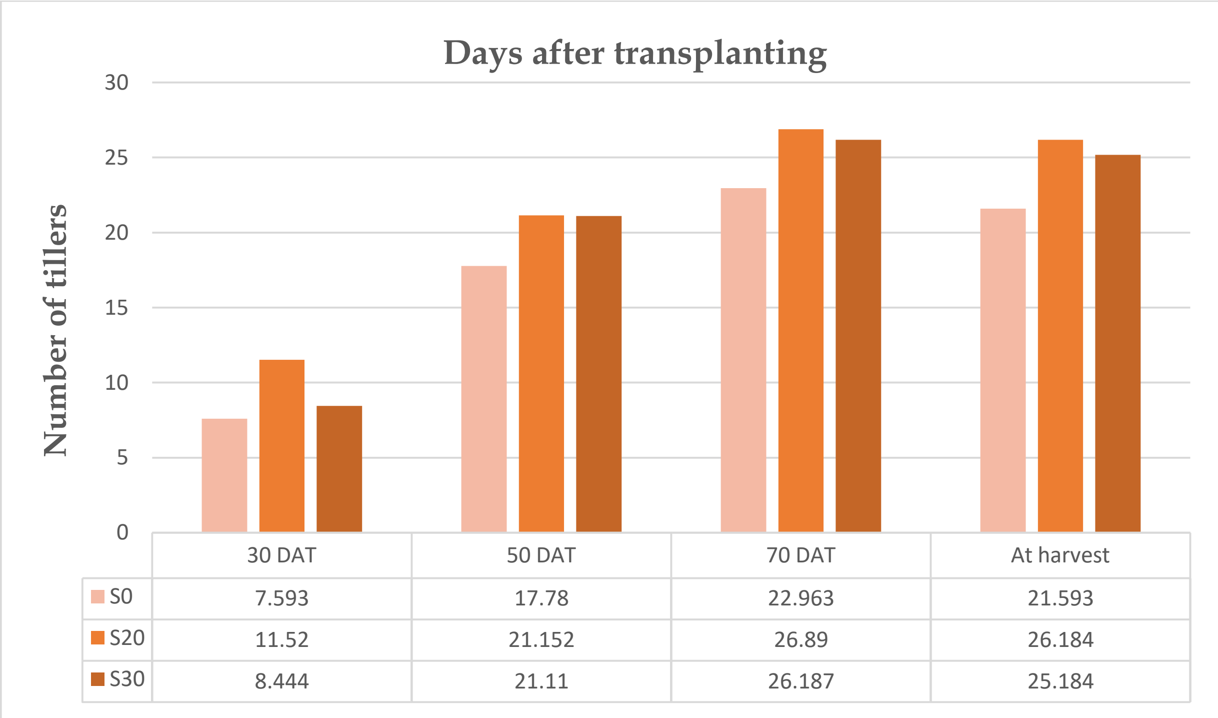

Figure 5. Effect of Sulphur (S) on total number of tillers at 30, 50, 70 DAT and at harvest

3.2.2. Effect of Boron

Number of total tillers showed significant difference due to the different level of Boron application at 30, 50, 70 days after transplanting and at harvest. The findings showed that the highest number of total tiller (10.038) was found in B_2 (2 kg/ha) followed by B_3 (3 kg/ha) whereas the lowest number of total tiller (8.112) was recorded from B_0 (control) at 30 DAT. At 50 DAT, the highest number of total tiller (20.594) was found in B_2 (2 kg/ha) followed by B_3 (3 kg/ha) whereas the lowest number of total tiller (18.483) was recorded from B_0 (control). Similarly, at 70 DAT, the highest tiller number was found in B_2 dose, followed by B_3 and lowest was found in no Boron application. Again, at harvest stage, the highest number of total tiller (25.149) was found in B_2 (2 kg/ha) followed by B_0 (control), whereas the lowest number of total tiller (23.888) was recorded from B_3 (3 kg/ha) (Figure 6 and Appendix IV).Singh and Ram (2007) studied on effects of zinc and boron on T. aman rice and found that application of zinc and boron had significant positive effects on the tiller/hill.

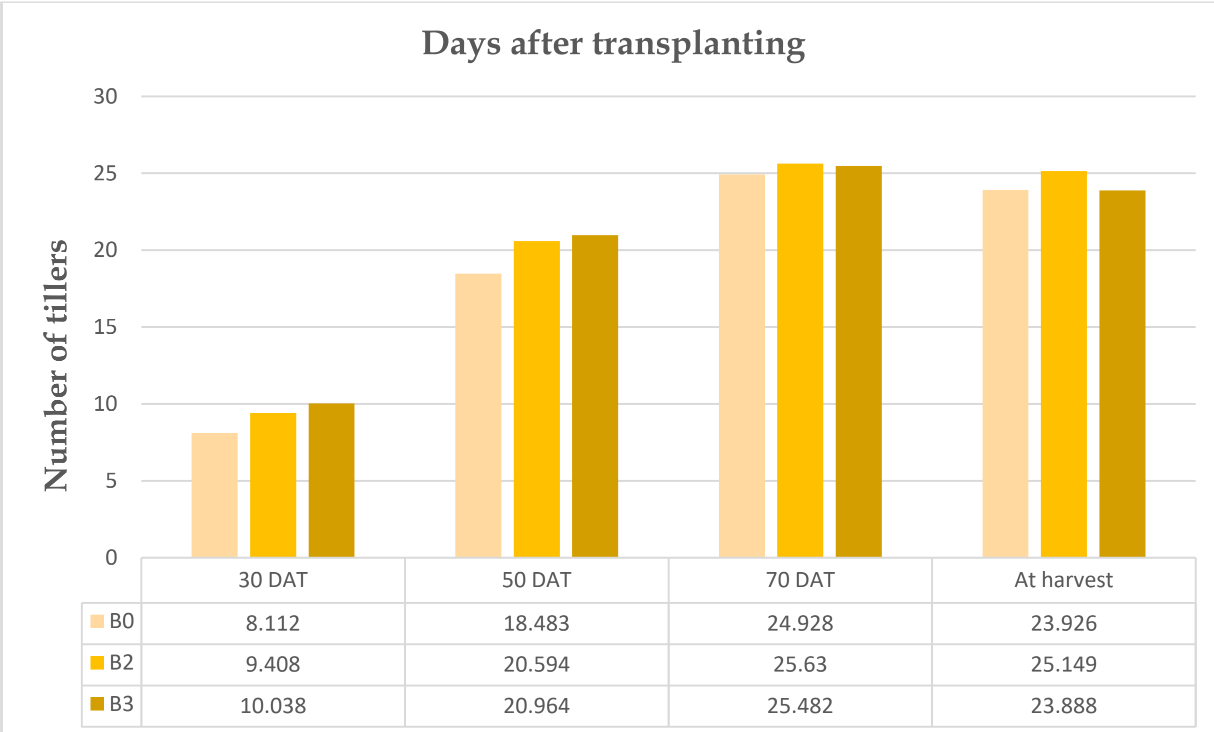

Figure 6. Effect of Boron (B) on total number of tillers at 30, 50, 70 DAT and at harvest

3.2.3. Combined effect of Sulphur and Boron

A significant variation was also found during the growth period due to interaction effect between Sulphur and Boron fertilizers regarding number of tillers whereas at 50 DAT the treatment combination was non-significant (Table 5 and Appendix IV). Among the interaction effects, 20 kg S/ha with the combination of 2 kg B/ha ($S_{20}B_2$) recorded the maximum tillers (22.56, 28.89 and 28.78) at 50, 70 DAT and at harvest respectively, which was statistically differed from other interactions of both fertilizers at every data recording stages. But at 30 DAT the highest number of tiller (12.11) was found in $S_{20}B_3$ combination. On the other hand, the lowest number of tillers (5.78, 15.67, 22.56, and 20.44) was observed from the interaction effect of control S_0B_0 fertilizers at 30, 50, 70 DAT and at harvest respectively (Table 5). These results revealed that all the interaction treatments showed increment tillers production up to 70 DAT, thereafter it decrease at harvest which might be due to the tillers mortality for maturity at harvest. The interaction treatment of $S_{20}B_2$ (20 kg S/ha and 2 kg B/ha) obtained the maximum tillers due to the proper nutrient supply to the plant which ultimately reduced the tillers mortality at harvest. Such results indicate that interaction of Sulphur and Boron promoted the number of effective tillers. Saliva and Castilla (2004) also reported that effective tillers hill^{-1}increased up to 5% by the application of Sulphur and Boron.

Table 5. Interaction effect of Sulphur and Boronon total number of tillers at different days after transplanting

Treatment	Number of tiller			
	30 DAT	**50DAT**	**70DAT**	**At harvest**
S_0B_0	5.78f	15.67e	22.56e	20.44e
S_0B_2	8.33de	18.11d	22.03e	21.78de
S_0B_3	8.67cd	19.56cd	24.33d	22.56cd
$S_{20}B_0$	10.89b	19.67cd	25.45cd	25.36b
$S_{20}B_2$	11.56ab	22.56a	28.89a	28.78a
$S_{20}B_3$	12.11a	21.11bc	26.33bc	25.55b
$S_{30}B_0$	7.67e	20.11c	26.78b	26.33b
$S_{30}B_2$	8.33de	21.11bc	26.48bc	25.67b
$S_{30}B_3$	9.33c	22.22bc	25.78bc	23.55c
LSD (0.5)	0.9269	-	1.283	1.428
Level of significance	*	NS	**	**
CV (%)	6.01%	6.18%	2.23%	8.59%

In a column, means followed by a similar letter(s) or without letter are not significantly different whereas, means followed by a dissimilar letter(s) are significantly different as per DMRT at 5%. Here, * indicates significant at 5% level of probability, ** indicates significant at 1% level of probability, NS = Non-significant, CV (%) = Co-efficient of variation, DAT = Days after transplanting.

3.3. Main and combined effect of Sulphur and Boron on the growth of panicle length (cm)

3.3.1. Effect of Sulphur

Similar to plant height and tillering of Boro rice (*cv*. BRII dhan-28), the panicle length responded significantly to Sulphur application (Table 6 and Appendix V).The panicle length varied from 20.34 cm to 24.98 cm due to different rates of S applications. The treatment S_{20} (20kg S/ha) produced the highest result (24.98cm) and the control treatment (S_0) did the lowest (20.34cm).Rahman *et al.,* (2007) conducted a field experiment and reported that application of S had a significant positive effect on panicle length.

3.3.2. Effect of Boron

The panicle length of Boro rice was significantly affected due to application of Boron (Table 7 and Appendix V). Apparently the longest panicle (24.17cm) was observed in B_2 treatment (2kg/ha) and the shortest panicle (22.33 cm) was recorded in B_0 treatment (control).Singh and Ram (2007) reported positive effect of B on panicle length.

3.3.3. Combined effect of Sulphur and Boron

The interaction effect of S and B treatment on the panicle length of Boro rice was significant (Table 8 and Appendix V). Panicle length due to different rates of S and B application varied from 18.62cm to 26.94cm. The maximum panicle length (26.94cm) was found in $S_{20}B_2$ treatment (20 kg S/ha with 2 kg B/ha) and the minimum panicle length (18.62cm) was noted with control treatment, S_0B_0 (without Sulphur and Boron).

3.4. Main and combined effect of Sulphur and Boron on number of grains panicle^{-1}

3.4.1. Effect of Sulphur

The number of grains panicle^{-1} was appreciably increased due to the addition of Sulphur (Table 6 and Appendix V).The grains per panicle due to different rates of S applications varied from 140.11 to 167.37. The highest number of grains panicle^{-1} (167.37) was observed in S_{20} treatment (S 20 kg/ha), followed by S_{30} treatment (30 kg/ha) (165.26) and the lowest number of grains panicle^{-1} (140.11) was observed in S_0 treatment (control).Jahiruddin*et al.,* (1994) conducted a field experiment on Sonatala silt loam soil at BAU farm during the boro season and reported that 25 kg S/ha increased the number of grains/panicle and grain yield of rice.

3.4.2. Effect of Boron

The number of grains panicle^{-1} increased significantly with the different rates of Boron application, compared to B_0 (control) (Table 7 and Appendix V). The grains per panicle due to different rates of B applications varied from 150.26 to 165.78. The highest number of grains panicle^{-1} (165.78) was observed in B_2 treatment (2 kg/ha) and the lowest number of grains panicle^{-1} (150.26) was observed in B_0 treatment (control). Singh and Ram (2007) reported positive effect of B on grains^{-1}.

3.4.3. Combined effect of Sulphur and Boron

Unlike other parameters, there was a significant effect of Sulphur and Boron applications on the number of grains panicle^{-1}(Table 8 and Appendix V). The number of grains panicle^{-1} was found to be 126.78 to 177.57. The highest number of grains panicle^{-1} (177.57) was observed in $S_{20}B_2$ treatment and the lowest number of grains panicle^{-1} (126.78) was noted with control treatment, S_0B_0.

3.5. Main and combined effect of Sulphur and Boron on number of filled grains panicle^{-1}

3.5.1. Effect of Sulphur:

Number of filled grainspanicle^{-1} significantly varied due to application of Sulphur (Table 6 and Appendix V). The highest number of filled grains (147.37) was found when the crop was fertilized with 30 kg S/ha (S_{30} treatment), followed by S_{20} treatment (20 kg/ha) (140.78) and the lowest (108.81) was in S_0 treatment (control). From the study of Rahman *et al.,* (2009) found that filled grain/panicle significantly responded to different levels of applied S.

3.5.2. Effect of Boron

Application of Boron increased the production of filled grains per panicle. This increase was statistically significant (Table 7 and Appendix V). The highest number of filled grains panicle^{-1}(144.04) was found from B_2 treatment (2 kg/ha) and lowest number (121.48) was found in B_0 treatment (control).Sheudzhen (1991) reported that application of B decreased spikelet sterility.

3.5.3. Combined effect of Sulphur and Boron

Interaction effect of Sulphur and Boron showed significant variation in the number of filled grainspanicle^{-1} (Table 8 and Appendix V).The treatment combination $S_{20}B_2$ produced the highest number (150.27) of filled grainspanicle^{-1}. The lowest number of filled grainspanicle^{-1}(89.18) was noted with control treatment (S_0B_0), which was followed by the treatment combination ofS_0B_3 (0 kg S/ha with 3 kg B/ha) (102.27) and S_0B_2 (0 kg S/ha with 2 kg B/ha) (104.67).

3.6. Main and combined effect of Sulphur and Boron on number of unfilled grains panicle^{-1}

3.6.1. Effect of Sulphur

Number of unfilled grainspanicle^{-1} differed significantly due to the effect of Sulphur (Table 6 and Appendix V). The maximum number of unfilled grainspanicle^{-1} (31.30) was recorded in S_0 treatment (control) and minimum number of unfilled grainspanicle^{-1} (17.89) was recorded from S_{30} treatment (30 kg/ha).

3.6.2. Effect of Boron

Number of unfilled grainspanicle^{-1} differed significantly due to the effect of Boron (Table 7 and Appendix V). Among the Boron treatments, the maximum number of unfilled grainspanicle^{-1} (28.78) was recorded in B_0 treatment (control), followed by B_3 treatment (3 kg/ha) (27.93) and minimum number of unfilled grainspanicle^{-1} (21.74) was recorded from B_2 treatment (2 kg/ha).

3.6.3. Combined effect of Sulphur and Boron

The data on unfilled grainspanicle^{-1} showed significant difference among the interaction effect between Sulphur and Boron application levels (Table 8 and Appendix V). The unfilled grains panicle^{-1} varied from 26.21 to 51.21 due to interaction effect of Sulphur and Boron fertilizers. The maximum number of unfilled grains panicle^{-1} (51.21) was found in interaction of S_0B_3 treatment (0 kg S/ha with 3 kg B/ha), which was followed by the treatment combination of $S_{20}B_0$ (20 kg S/ha with 0 kg B/ha) (49.22). The minimum number of unfilled grains panicle^{-1} (26.21) found in interaction of $S_{30}B_3$ treatment (S 30 kg/ha with 3 kg B/ha), followed by the treatment combination of $S_{20}B_2$ (20 kg S/ha with 2 kg B/ha) (27.30).

3.7. Main and combined effect of Sulphur and Boron on 1000-grain weight (g)

3.7.1. Effect of Sulphur

1000-grain weight also differed significantly due to the application of different level of Sulphur (table 6 and Appendix V). The highest weight of 1000-grain (27.57 g) was observed in S_{20} treatment (20 kg/ha) and the lowest weight of 1000-grain (22.49 g) was observed in S_0 treatment (control), followed by S_{30} (30 kg/ha) (23.72 g).Sarfaraz*et al.,* (2002) field experiment showed that effect of S fertilizers significantly increased 1000-grain weight.

3.7.2. Effect of Boron

Application of Boron for 1000-grain weight was statistically significant (Table 7 and Appendix V). The highest weight of 1000-grain (25.24 g) was found from B_2 treatment (2 kg/ha) and the lowest weight of 1000-grain (24.01 g) was observed in B_0treatment (control), followed by B_3 treatment (3 kg/ha) (24.53 g).Xiong (1987) reported that 1000-grain weight increased with B application.

3.7.3. Combined effect of Sulphur and Boron

The combined effect of Sulphur and Boron on 1000-grain weight was significant (table 8 and Appendix V). In values the maximum weight (29.75 g) was noted in the treatment combination $S_{20}B_2$ (20 kg S/ha with 2 kg B/ha) and the minimum weight (21.68 g) was noted S_0B_0 treatment combination (control), followed by the treatment combination of $S_{30}B_3$ (30 kg S/ha with 3 kg B/ha) (22.37 g) and S_0B_2 (0 kg S/ha with 2 kg B/ha) (22.42 g).

Table 6. Effect of Sulphur on panicle length, grains panicle^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, 1000-grain weight (g) at harvest

Treatment	Panicle length (cm)	Grains panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000-grain weight (g)
S_0	20.34b	140.11b	108.81b	31.30a	22.49b
S_{20}	24.98a	167.37a	140.78a	26.59b	27.57a
S_{30}	24.76a	165.26a	147.37a	17.89c	23.72b
LSD (0.5)	0.5902	2.01	11.91	3.127	1.494
Level of significance	**	**	**	**	**
CV (%)	4.93	15.95	7.43	6.77	4.64

In a column, means followed by a similar letter(s) or without letter are not significantly different where-as, means followed by a dissimilar letter(s) are significantly different as per DMRT at 5%. Here, ** indicates significant at 1% level of probability, CV (%) = Co-efficient of variation

Table 7. Effect of Boron on panicle length, grains panicle^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, 1000-grain weight (g) at harvest

Treatment	Panicle length (cm)	Grains panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000-grain weight (g)
B_0	22.33b	150.26b	121.48b	28.78a	24.01b
B_2	24.17a	165.78a	144.04a	21.74b	25.24a
B_3	23.59a	162.37a	134.44a	27.93a	24.53b
LSD (0.5)	0.5902	2.01	11.91	3.127	1.494
Level of significance	**	**	**	**	**
CV (%)	4.93	15.95	7.43	6.77	4.64

In a column, means followed by a similar letter(s) or without letter are not significantly different whereas, means followed by a dissimilar letter(s) are significantly different as per DMRT at 5%. Here, ** indicates significant at 1% level of probability, CV (%) = Co-efficient of variation.

Table 8. Interaction effect of Sulphur and Boron on panicle length, grains panicle^{-1}, filled grainspanicle^{-1}, unfill d grains panicle^{-1}, 1000-grain weight (g) at harvest

Treatment	Panicle length (cm)	Grains panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000-grain weight (g)
S_0B_0	18.62f	126.78d	89.18d	37.60b	21.68d
S_0B_2	20.58e	140.56cd	104.67cd	35.89b	22.42d
S_0B_3	21.82d	153.48cd	102.27cd	51.21a	23.37cd
$S_{20}B_0$	23.22c	158.33c	109.11c	49.22a	26.67b
$S_{20}B_2$	26.94a	177.57a	150.27a	27.30c	29.75a
$S_{20}B_3$	24.78b	168.78ab	133.30ab	35.48b	26.28b
$S_{30}B_0$	25.14b	165.67ab	135.55ab	30.12c	25.23bc
$S_{30}B_2$	24.98b	164.78ab	138.44ab	26.34c	23.55cd
$S_{30}B_3$	24.16bc	165.33ab	139.12ab	26.21c	22.37d
LSD (0.5)	1.022	2.01	15.25	5.416	2.588
Level of significance	**	**	*	**	**
CV (%)	4.93	15.95	7.43	6.77	4.64

In a column, means followed by a similar letter(s) or without letter are not significantly different whereas, means followed by a dissimilar letter(s) are significantly different as per DMRT at 5%. Here, * indicates significant at 5% level of probability, ** indicates significant at 1% level of probability, CV (%) = Co-efficient of variation

3.8. Main and combined effect of Sulphur and Boron on grain yield (t/ha)

3.8.1. Effect of Sulphur

Grain yield varied significantly due to different levels of Sulphur, where significant grain yield varied from 3.30 to 5.46 t/ha (Table 9 and Appendix VI). The highest grain yield (5.46 t/ha) was recorded from S_{20} treatment (20 kg/ha) and the lowest grain yield (3.30 t/ha) was observed in S_0 treatment (control). The pattern of grain yield was similar to that of panicle length. The result obtained in grain yield is in accordance with the findings of Islam *et al*. (2009).Jawahar and Vaiyapuri (2010) carried out a field experiment to study the effect of Sulphur on grain and straw yield of rice. Jena and Kabi (2012) observed that application of S significantly increased the grain and straw yield.

3.8.2. Effect of Boron

The grain yield of Boro rice (BRRI dhan-28) responded significantly to the application of Boron (Table 10 and Appendix VI). The highest grain yield (4.84 t/ha) was recorded from B_2 treatment (2 kg/ha) and the lowest grain yield (3.72 t/ha) was observed in B_0 (control). In a field study, the BRRI scientists also observed significant yield increase with B application in the Boro rice (Anonymous, 1998).Singh *et al.,* (1990) also reported that the increase in yield due to B application was 31% higher over control.Sharif *et al*. (2006) also showed that grain yield increased by Boron application.

3.8.3. Combined effect of Sulphur and Boron

Combined application of Sulphur and Boron showed a significant variation in grain yield. The highest grain yield (6.30 t/ha) and the lowest grain yield (2.02 t/ha) were found from $S_{20}B_2$ (20 kg S/ha with 2 kg B/ha) treatment and S_0B_0 treatment (control) respectively (Table 11and Appendix VI).

3.9. Main and combined effect of Sulphur and Boron on straw yield (t/ha)

3.9.1. Effect of Sulphur

Sulphur showed a significant variation in straw yield (Table 9 andAppendix VI). The highest straw yield (5.71 t/ha) was recorded from S_{20} treatment (20 kg/ha) and the lowest straw yield (4.79 t/ha) was observed in S_0 treatment (control), followed by S_{30} treatment (30 kg/ha) (4.81 t/ha). Yield of straw in S_0 and S_{30} treatment were statistically similar. The findings of this character agree with the result obtained by Saha *et al.,* (2009). Jena and Kabi (2012) reported that application of S significantly increased the grain and straw yield.

3.9.2. Effect of Boron

Boron also showed significant effect on straw yield (Table 10 and Appendix VI). The highest straw yield (5.43 t/ha) was found from B_2 treatment (2 kg/ha). The lowest straw yield (4.61 t/ha) was observed in B_0 (control). The second highest straw yield (5.31 t/ha) was found from B_3 treatment (3 kg/ha).Singh*et al.,* (1990) conducted a field trial and observed that B application increase straw yield.Rahmatullah*et al.,* (2006) reported that straw yield was increased by Boron application.

3.9.3. Combined effect of Sulphur and Boron

Result presented in Table 11 and Appendix VI showed that interaction effect of Sulphur and boron were significantly influenced on the straw yield. The highest straw yield (5.91 t/ha) was noticed from $S_{20}B_2$ (20 kg S/ha with 2 kg B/ha) treatment and lowest straw yield (4.09 t/ha) was recorded from $S_{30}B_0$ (30 kg S/ha with 0 kg B/ha) treatment.

3.10. Main and combined effect of Sulphur and Boron on biological yield (t/ha)

3.10.1. Effect of Sulphur

A significant variation was found due to the effect of Sulphur application in respect of biological yield (Table 9 and Appendix VI). It was found that the biological yield was highest (11.17 t/ha) in S_{20} treatment (20 kg/ha). Similarly, the lowest biological yield (8.09 t/ha) was observed in S_0 treatment (control). While S_{30} treatment (30 kg/ha) produced statistically similar lower biological yield (8.18 t/ha). The variation result on biological yield was found due to the variation in Sulphur which result supported by Khan *et al.,* (2007).Rahman *et al.,* (2009) reported that biological yield of BRRI dhan-41 significantly responded to different levels of applied S.

3.10.2. Effect of Boron

Boron also showed significant effect on biological yield (Table 10 and Appendix VI). The highest biological yield (10.27 t/ha) was found from B_2 treatment (2 kg/ha) and the lowest biological yield (8.33 t/ha) was observed in B_0 (control). The second highest biological yield (9.96 t/ha) was found from B_3 treatment (3 kg/ha).

3.10.3. Combined effect of Sulphur and Boron

Combined application of Sulphur and Boron showed a significant variation in biological yield (Table 11 and Appendix VI).The highest biological yield (12.21 t/ha) was recorded from $S_{20}B_2$ (20 kg S/ha with 2 kg B/ha) treatment and the lowest biological yield (6.98 t/ha) was observed from S_0B_0 treatment (control).

Table 9. Effect of Sulphur on yield characters and HI at harvest

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
S_0	3.30b	4.79b	8.09b	40.79b
S_{20}	5.46a	5.71a	11.17a	48.88a
S_{30}	3.37b	4.81b	8.18b	41.19b
LSD (0.5)	0.6718	0.6457	1.038	2.596
Level of significance	**	**	**	**
CV (%)	8.01	6.92	5.86	4.24

In a column, means followed by a similar letter(s) or without letter are not significantly different where-as, means followed by a dissimilar letter(s) are significantly different as per DMRT at 5%. Here, ** indicates significant at 1% level of probability, CV (%) = Co-efficient of variation

Table 10. Effect of Boron on yield characters and HI at harvest

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
B_0	3.72b	4.61b	8.33b	44.66b
B_2	4.84a	5.43a	10.27a	47.13a
B_3	4.65a	5.31a	9.96a	46.69a
LSD (0.5)	0.6718	0.6457	1.038	2.596
Level of significance	**	**	**	**
CV (%)	8.01	6.92	5.86	4.24

In a column, means followed by a similar letter(s) or without letter are not significantly different whereas, means followed by a dissimilar letter(s) are significantly different as per DMRT at 5%. Here, ** indicates significant at 1% level of probability, CV (%) = Co-efficient of variation.

Table 11. Interaction effect of Sulphur and Boron on yield characters and HI at harvest

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
S_0B_0	2.02g	4.96c	6.98g	28.94d
S_0B_2	3.21ef	4.61cd	7.82ef	41.05c
S_0B_3	3.94cd	5.21bc	9.15cd	43.06ab
$S_{20}B_0$	5.33ab	5.77ab	11.10ab	48.02ab
$S_{20}B_2$	6.30a	5.91a	12.21a	51.60a
$S_{20}B_3$	4.74bc	5.46bc	10.20bc	46.47ab
$S_{30}B_0$	3.02fg	4.09d	7.11fg	42.48b
$S_{30}B_2$	3.56de	5.75ab	9.31cd	38.24cd
$S_{30}B_3$	3.18ef	5.58bc	8.76de	36.30cd
LSD (0.5)	1.164	1.118	1.798	4.497
Level of significance	**	**	**	**
CV (%)	8.01	6.92	5.86	4.24

In a column, means followed by a similar letter(s) or without letter are not significantly different whereas, means followed by a dissimilar letter(s) are significantly different as per DMRT at 5%. Here, ** indicates significant at 1% level of probability, CV (%) = Co-efficient of variation.

3.11. Main and combined effect of Sulphur and Boron on harvest index (%)

3.11.1. Effect of Sulphur

Harvest index present comparative yield performance between grain and straw yield. It also indicates the percent grain yield on the basis of biological yield. The data on harvest index was significantly influenced by the Sulphur application (Table 9 and Appendix VI). It was recorded that the harvest index was highest (48.88%) in S_{20} treatment (20 kg/ha). The lowest harvest index (40.79%) was observed in S_0 treatment (control), while S_{30} treatment (30 kg/ha) also produced statistically similar lower harvest index (41.19%).

3.11.2. Effect of Boron

The data on harvest index was significant by the application of Boron (Table 10 and Appendix VI). However, the highest harvest index (47.13%) was found from B_2 treatment (2 kg/ha) and the lowest harvest index (44.66%) was observed in B_0 (control). The second highest harvest index (46.69%) was found from B_3 treatment (3 kg/ha).

3.11.3. Combined effect of Sulphur and Boron

Analysis of variance data regarding to harvest index was significantly influenced by the interaction effect of Sulphur and Boron (Table 11 and Appendix VI). The highest harvest index (51.60%) was recorded from $S_{20}B_2$ treatment and lowest harvest index (28.94%) was observed from S_0B_0 treatment (control).

4. CONCLUSION

All the studied characters were statistically significant due to Sulphur application where 20 kg S/ha showed superior performance on them. However, treatment S_{20} (20 kg S/ha) obtained the tallest height of plant (97.811 cm) at harvest, maximum number of total tillers hill^{-1} (26.184), highest length of panicle (24.98 cm), maximum number of grains panicle^{-1} (167.37), maximum weight of 1000-grains (27.57 g), maximum yield of grain (5.46 t/ha), maximum yield of straw (5.71 t/ha), maximum biological yield (11.17 t/ha) and HI (48.88%). In terms of Boron application at different levels, significant variation was found for the most of the parameters, where 2 kg B/ha showed superior performance. Results indicated that the highest height of plant (96.378 cm) was found in B_3 (3 kg B/ha). Maximum number of total tillers hill^{-1} (25.149), highest length of panicle (24.17 cm), maximum number of grains panicle^{-1} (165.78), maximum number of filled grains panicle^{-1} (144.04), minimum number of unfilled grains panicle^{-1} (21.74), maximum weight of 1000-grains (25.24 g), highest yield of grain, straw and biological (4.84, 5.43 and 10.27 t/ha, respectively) and highest HI (47.13%) were found in B_2 (2 kg B/ha). Almost all the growth, yield and yield contributing characters were significantly affected by the interaction effect of Sulphur and Boron fertilizers at all the growth stages and at harvest whereas the combination of $S_{20}B_2$ (20 kg S/ha with 2 kg B/ha) comparatively performed the best than that of other combinations. Plant height was highest (100.30 cm) in $S_{20}B_3$ (20 kg S/ha with 3 kg B/ha) and the lowest (89.53 cm) in S_0B_0 (without S and B) at harvest. However, number of tillers hill^{-1} increased with the advancement of time but decreased at harvest. As a result, the maximum number of total tillers hill^{-1} (28.78), highest length of panicle (26.94 cm), maximum number of grains panicle^{1} (177.57), maximum number of filled grains panicle^{1} (150.27) and minimum number of unfilled grains panicle^{1} (27.30), maximum weight of 1000-grains (29.75 g), maximum yield of grain, straw and biological (6.30, 5.91 and 12.21 t/ha, respectively) and higher HI (51.60%) was obtained from the combination of $S_{20}B_2$ (20 kg S/ha with 2 kg B/ha). From the above results, It was observed that 20 kg S/ha and 2 kg B/ha treatment and treatment combination singly or their interactions showed the superior performance concerning to growth, yield and yield contributing traits of BRRI dhan-28. Finally, it could be concluded and recommended that the use of 20 kg S/ha and 2 kg B/ha as singly or their interaction with recommended dose of NPK and Zn would be highly effective for higher production of BRRI dhan-28 under the regional condition of AEZ-11. Further study may be needed for ensuring the performance of the present study in different AEZs of Bangladesh.

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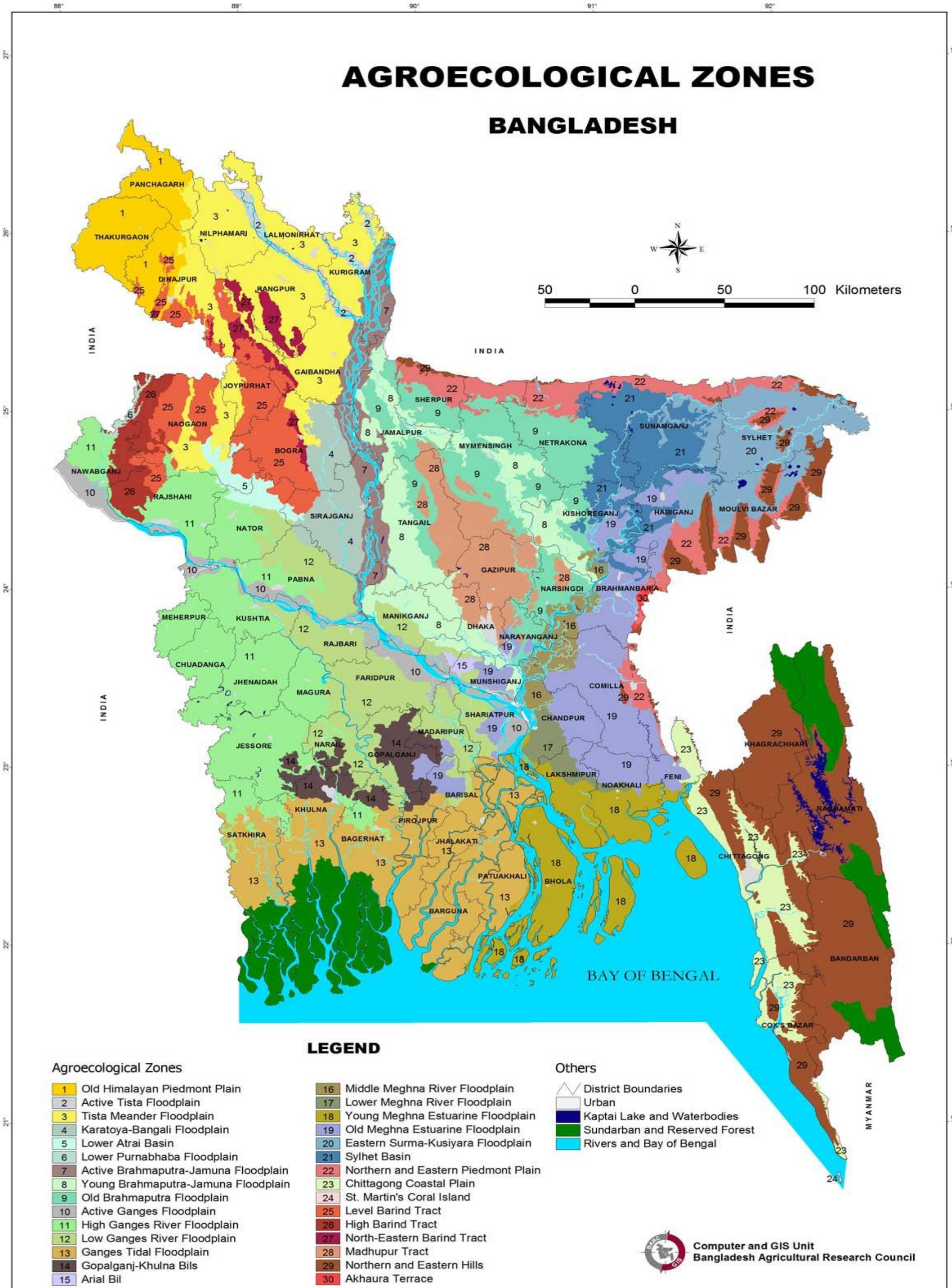
Appendices

Appendix I. Map showing the Agro-Ecological Zones of Bangladesh



Appendix II. Record of Monthly average, maximum and minimum air temperature, average humidity and rainfall during the study period (November2015 to April 2016)

Month	Year	** Air temperature (°C)			** Relative Humidity (%)	* Rainfall (mm)
		Maximum	Minimum	Average		
November	2015	29.1	16.3	21.8	77	Nil
December	2015	25.0	13.1	18.1	81	Nil
January	2016	22.5	11.5	16.2	83	2.0
February	2016	25.5	13.1	18.6	77	27.0
March	2016	32.1	17.7	24.4	67	12.3
April	2016	37.6	23.0	29.8	64	50.8

Source: Regional Meteorological Station,Shaympur,Rajshahi, Bangladesh.

Here,

**=Monthly Average

* =Monthly total

Appendix III. Analysis of variance for plant height (cm) of Boro rice (Mean Square)

Source of variation	Degrees of Freedom	Mean square			
		Plant Height (cm)			
		30 DAT	50 DAT	70 DAT	At harvest
Replication	2	2.467	2.140	2.179	5.970
Factor A	2	18.167**	502.442**	54.603**	112.990**
Factor B	2	8.787**	10.457**	14.914**	25.988**
AB	4	4.625**	9.642**	4.596**	0.926NS
Error	16	0.191	0.679	0.523	1.662

Here, * indicates significant at 5% level of probability, ** indicates significant at 1% level of probability,NS = Non-significant, variation, DAT = Days after transplanting

Appendix IV. Analysis of variance for number of tiller of Boro rice (Mean Square)

Source of variation	Degrees of Freedom	Mean square			
		Number of Tiller			
		30 DAT	50 DAT	70 DAT	At harvest
Replication	2	0.703	0.863	0.176	0.017
Factor A	2	38.403**	33.693**	39.455**	52.462**
Factor B	2	8.675**	16.124**	1.234**	4.633**
AB	4	1.022*	2.531NS	6.820**	6.381**
Error	16	0.305	1.532	0.320	0.396

Here, * indicates significant at 5% level of probability, ** indicates significant at 1% level of probability,NS = Non-significant, DAT = Days after transplanting

Appendix V. Analysis of variance for panicle length (cm), grains panicle^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, 1000-grain weight (g) of Boro rice at harvest (Mean Square)

Source of variation	Degrees of Freedom	Mean square				
		Panicle length (cm)	Grains panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000-grain weight (g)
Replication	2	0.989	10217.745	18.074	0.080	3.060
Factor A	2	61.641**	17515.091**	3853.000**	451.985**	63.111**
Factor B	2	7.991**	11993.721**	890.867**	208.291**	3.451**
AB	4	5.588**	11807.757**	284.855*	184.344**	7.882**
Error	16	0.203	9817.443	82.606	5.698	1.301

Here, * indicates significant at 5% level of probability, ** indicates significant at 1% level of probability

Appendix VI. Analysis of variance for grain yield, straw yield, biological yield and harvest index of Boro rice at harvest (Mean Square)

Source of variation	Degrees of Freedom	Mean square			
		Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Replication	2	0.026	0.039	0.002	0.954
Factor A	2	28.430**	2.412**	47.404**	200.059**
Factor B	2	3.207**	1.771**	9.743**	8.595**
AB	4	3.092**	2.591**	5.958**	91.230**
Error	16	0.263	0.243	0.628	3.928

Here, ** indicates significant at 1% level of probability