ISPEC Tarım Bilimleri Dergisi, 7(1): 218-236, 2023
ISPEC Journal of Agricultural Sciences, 7(1): 218-236, 2023
DOI: https://doi.org/10.5281/zenodo.7771354

Sulphur and Boron Fertilization Increased Productivity of Boro Rice (BRRI dhan28) by Increasing Pollen Fertility and Agronomic Efficiency in Calcareous Soils

AKM Abdul BARI[1*], Razita Jalil PROMI[1], Imam MUHYIDIYN[2], Moaz Hosen PRAMANIK[3]
Cihan DEMİR[4], Murat ERMAN[5], Fatih ÇIĞ[6], Mohammad Sohidul ISLAM[2]
[1]University of Rajshahi, Department of Crop Science and Technology, Rajshahi, Bangladesh
[2]Hajee Mohammad Danesh Science and Technology University, Department of Agronomy, Dinajpur, Bangladesh
[3]Hajee Mohammad Danesh Science and Technology University, Department of Agricultural Chemistry, Dinajpur, Bangladesh
[4]University of Kırklareli, Department of Mechanical and Metal Technologies, Vocational School of Technical Sciences, Kırklareli, Türkiye
[5]Bursa Uludağ University, Faculty of Agriculture, Department of Field Crops, Türkiye
[6]Siirt University, Faculty of Agriculture, Department of Field Crops, Siirt, Türkiye
[*]Sorumlu yazar (Corresponding author): akmabari@gmail.com

Abstract
To study the effect of sulphur (S) and boron (B) on the performance of yield, agronomic efficiency, economic return of boro rice (cv. BRRI dhan28) was evaluated at the Reseahc Field of the Department of Crop Science and Technology, University of Rajshahi, Rajshahi-6205, during the Rabi season from November 2015 to April 2016 in High Ganges River Floodplain under AgroEcological Zone-11 (AEZ-11). The experiment was consisted three level of sulphur, viz., S_0: without sulphur (control), S_{20}: 20 kg S ha^{-1}, S_{30}: 30 kg S ha^{-1}, and three level of boron viz., B_0: without boron (control), B_2: 2 kg B ha^{-1}, B_3: 3 kg B ha^{-1}. The experiment was conducted in a Randomized Complete Block Design (RCBD) with three replications. The results revealed that S and B significantly influenced the yield straw yield, biomass yield, sterility percentage, agronomic efficiency and economic return of BRRI dhan28. The treatment combination of $S_{20}B_2$ (20 kg S ha^{-1} with 2 kg B ha^{-1}) performed the best results of the aforesaid traits. So, it can be suggested to apply S at 20 kg ha^{-1} and B at 2 kg ha^{-1} with recommended dose of NPK and Zn for maximizing yield, agronomic efficiency and economic point of view of boro rice in calcareous soils of AEZ-11.

Research Article

Article History
Received :20.12.2022
Accepted :25.01.2023

Keywords
Rice
sterility
yield
agronomic efficiency
economic performance

1.Introduction

Rice (*Oryza sativa* L.) is one of the most important food grain crops in the world (Islam et al., 2021), and the second most widely consumed in the world after wheat (Rajamoorthy et al., 2015), that provide food for more than half of the world population (Malik et al., 2008; Islam et al. 2008). The world population is projected to increase from 7.21 billion in 2015 to 8.27 billion in 2030, indicating a corresponding increase in food demand from 680 million tons in 2015 to 771 million tons in 2030 (FAO, 2016). There is a growing concern that current levels of rice and wheat production will not meet future demand (Islam et al., 2021). To meet this challenge of increased food demand, the productivity of rice should be increased efficiently. Though, rice is the staple food of Bangladesh and Bangladesh ranks 3rd position in the world both in acreage and production of rice after China and India (FAO, 2021), tut the average rice yield of Bangladesh is quite low (3.29 t ha^{-1}) as compared to other leading rice producing countries such as the USA (7.37 t ha^{-1}), Japan (6.58 t ha^{-1}), Korea (6.31 t ha^{-1}), and China (6.27 t ha^{-1}) (FAO, 2020).

Fertilizer management is an important aspect for lower yield of rice in Bangladesh. Higher crop yields naturally have higher requirement of nutrients. Thus, use of balanced fertilizers along with management practices can play a key role in sustaining higher yield of crops under different cropping patterns and also can preserve soil health on a long term basis (Islam et al., 2008; Sikdar et al., 2008). Nutrient stresses in Bangladesh soils are increasing day by day. The deficiency of NPK was a major problem before 1980's 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 deficiency has been recognized in many areas of Bangladesh, it is noted that current intensive use of agricultural land for crop production has extended the sulfur deficient areas to about 80% in the northern region (Khan et al., 2007) wherein soils are calcareous in nature with low organic matter, and deficiency of nutrients (especially sulphur and boron) is increasing day by day due to intensive cultivation (Rafique et al., 2006; 2008).

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). Insufficient availability of S 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; Islam et al., 2017a). 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 S 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 rice results in a reduction of growth, physiology, yield and quality (Jamal et al., 2005). Inadequate supply of S containing amino acids hampered nitrogen (N) assimilation resulting N 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), making it more important during the reproductive stage as compared to the vegetative stage of the crop. Boron is directly or indirectly involved in several physiological and bio-chemical processes during plant growth. It is involved in the synthesis and metabolism of protein, maintaining the correct water relations within the plant, synthesis of adenosine triphosphate (ATP), translocation of sugar, fruiting process, growth of pollen tube and development of the flowering and fruiting stages (Bolanos et al., 2004). Boron has been reported to be deficient in some soil and approximately, one million hectare of cultivable land in Bangladesh is suspected to have boron deficiency problem (Jahiruddin et al., 1995). B deficiency at the panicle initiation stage may lead to failure in panicle formation (Dobbermann and Fairhurst, 2000), and failure to produce viable seeds, and reduced rice productivity (David et al., 2005; Amer et al., 2020; Hanifuzzaman et al., 2022).

Application of S and B significantly increased the productivity of different crops like mungbean (Islam et al., 2017a, 2017b; Deep et al., 2022), soybean (Das et al., 2022), sesame (Islam et al., 2019), mustard (Basumatary et al., 2022), etc. Keeping this in view, the present investigation was carried out with to study the effect of sulphur and boron on sterility status, and yield of rice (BRRI dhan28) as well as agronomic efficiency and economic benefit of S and B.

2. Materials and Methods

2.1. Location and duration

To investigate the effect of sulphur and boron on the spikelet sterility and yield of boro rice (BRRI dhan28), an experiment was conducted at the Department of Crop Science and Technology, University of Rajshahi, Bangladesh. The experimental site is located at 24°22' N latitude and 88°38' E longitude with 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). The experiment was carried out during November 2015 to April 2016.

2.2. Soil characteristics

The soil of the experimental side was silty clay and calcareous dark grey floodplain (FAO and UNDP, 1988), having pH value of 8.4, low in organic matter content (1.25%). The soil of the experimental sites was analyzed before experimentation. The total soil nitrogen (N) was 0.10%, indicating a deficiency in soil N. Soil available P, S, B, and Zn were 16.2, 12.5, 0.23, and 0.11 ppm and available K, Ca, and Mg were 0.57, 15.35, and 4.30 meq $100g^{-1}$ soil, respectively. Based on the critical levels of these plant nutrients, N, S, and Zn were very low, P, K, and B were low; but Mg and Ca were optimum level. The physiological and chemical characteristics of the field soil have been presented in Table 1.

2.3. Climate and weather

The research work was conducted during Boro season (November to April). The experimental area possesses subtropical climatic condition. The means of methodological information, like relative humidity, maximum temperature, minimum temperature and average temperature, rainfall of the experimental site during the crop growing period are presented in Figure 1.

2.4. Experimental design and layout

The experiment was consisted with two factors namely factor A: three levels of sulphur viz., i) S_0: 0 kg S ha^{-1}, ii) S_{20}: 20 kg S ha^{-1} and iii) S_{30}: 30 kg S ha^{-1}, and factor B: three levels of boron viz. i) B_0: 0 kg B ha^{-1}, ii) B_2: 2 kg B ha^{-1} and iii) B_3: 3 kg B ha^{-1}. It was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each block was divided into nine unit plots where nine treatment combinations were allocated at random. Therefore, the total number of plots of this experiment was 27. The size of unit plot was 4.0 m × 2.5 m

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

Properties	**Critical value**	**Value**	**Extraction methods**
Sand (%)	-	20.8	-
Silt (%)	-	60.3	-
Clay (%)	-	20.9	-
Textural class	-	Silty clay loam	Hydrometer method (Black, 1965). Determined by Marshall's triangular coordinates by
Soil pH (1:1.25, Soil:H_2O)	-	8.4	Glass-electrode pH meter with 1:1.25 soil-water ratio (Page et al., 1982).
Organic matter (%)	-	1.25	Wet oxidation method (Black, 1965). Calculated by Van Bemmelen factor 1.73 (Piper, 2019).
Total nitrogen (%)	0.10	0.10 (VL)	Micro-Kjeldahl method (Bremner and Mulvaney, 1982).
Available phosphorus (ppm)	10.00	16.2 (L)	Molybdate blue ascorbic acid (Bray and Kurtz, 1945).
Available sulphur (ppm)	10.00	12.5 (VL)	Turbidity method using $BaCl_2$ (Fox et al., 1964).
Available zinc (ppm)	0.60	0.11 (VL)	Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978).
Available boron (ppm)	0.20	0.23 (L)	Calcium chloride extraction method (Page et al., 1982).
Exchangeable potassium (meq l00g^{-1})	0.12	0.57 (L)	Determined by Flame photometer
Exchangeable magnesium (meq l00g^{-1})	0.50	4.30 (OP)	Extractable method (Hunter, 1974).
Exchangeable calcium (meq l00g^{-1})	2.00	15.35(OP)	Atomic absorption spectrophotometer (Knudsen et al., 1982)

Source: Soil Resource and Development Institute (SRDI), Regional Centre Rajshahi, Here, according to BARC (2012), VL = Very low, L = Low, M = Medium, OP = Optimum.

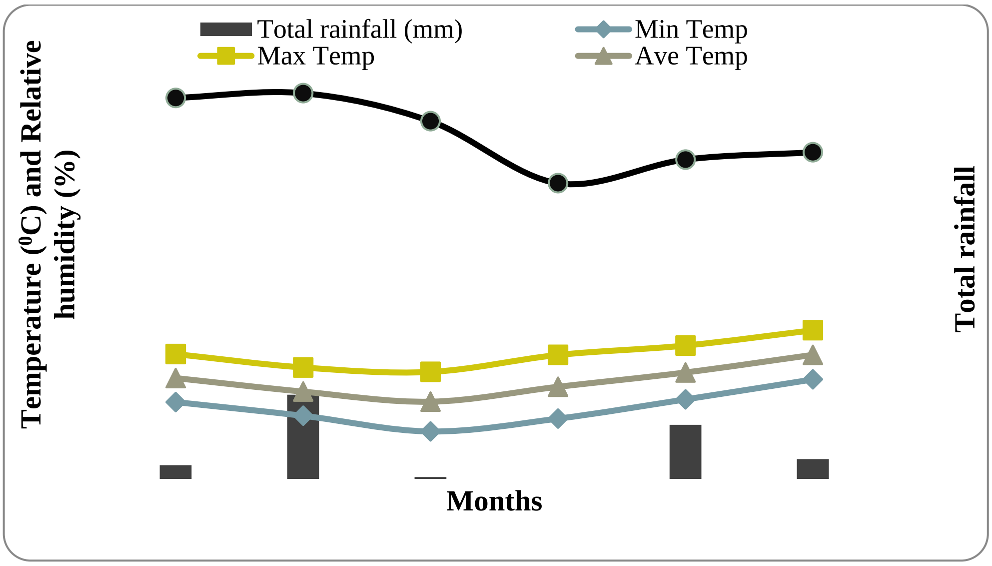

Figure 1. Monthly average temperature (minimum, maximum, and average), relative humidity (%), and rainfall (mm) during the experiment

2.5. Test crop

BRRI dhan28, a high yielding variety of *boro* rice was used as the test crop in this experiment. It is a popular variety of boro rice. Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, Bangladesh developed was this variety in 1994. The plant grows up to 90 cm height. Seed to seed duration is 140 days. The appropriate time for seed sowing is mid-December to 1st week of January and transplanting should be done within 20 January to 25 January. The variety is harvested from 1-25 May and approximate yield is 5.5-6.0 t ha^{-1} (BRRI, 2010).

2.6. Crop management

2.6.1. Seed collection, sprouting, nursery bed preparation and sowing

Seeds of BRRI dhan28 were collected from Genetic Resource and Seed Division, BRRI, Joydebpur, Gazipur, Bangladesh. Seeds were immersed into water in a bucket for 24 hours, then taken out of water, and kept tightly in gunny bags for 48 hours to sprout the seeds properly. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. Sprouted seeds weeds were broadcasted in the bed, and special cares were followed by providing irrigation and weeding for raising healthy seedlings in the seedbed.

2.6.2. Preparation of experimental land, and uprooting and transplanting of seedlings

The experimental field was prepared by three successive ploughings and cross ploughings with a tractor plough and subsequently leveled by laddering. The experimental plots were fertilized with recommended doses of 220, 80, 120, 100 and 5 kg ha^{-1} were applied as a source of urea, TSP, MoP, gypsum, and zinc sulphate, respectively.

The entire amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied as basal dose at final land preparation. Urea was applied as per the treatments in three equal installments. The first dose of urea was applied after seedling recovery, second during the vegetation stage i.e. 35 days of after transplanting (DAT), and third at 7 days before panicle initiation (BRRI, 2010). The seedlings of 35 days old were uprooted carefully from the nursery bed, and transplanted with 25 cm × 15 cm spacing on the well-puddled plots.

2.6.3. Intercultural operations

Gap filling was done as and where necessary using the seedling from the previous source. The crop was infested with some weeds during the early stage of crop establishment. Two hand weedings were done at 20 DAT followed by second weeding at 15 days after first weeding. Irrigation water was added to each plot according to the need.

All the plots were kept irrigated maintaining 3-5 cm stagnant water throughout the entire period up to 15 days before harvesting. Plants were infested with rice stem borer (*Scirphophaga incertolus*) and leaf hopper (*Nephotettix nigropictus*) which were controlled by applying Diazinon @ 10 ml/10 liter of water for 5 decimal lands when needed.

2.6.4. Harvesting and post-harvest operations

The crop was harvested when 90% of the grains become golden yellow in color. Ten pre-selected hills $plot^{-1}$ from which different crop growth data were collected, and 5 m^2 areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done using by pedal thresher. The grains were cleaned and sun dried to moisture content of about 12%. Straw was also sun dried properly. Finally grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}.

2.7. Data collection

Five hills were randomly selected from each plot at maturity to record the yield contributing characters like number of effective tillers $hill^{-1}$, panicle length, number of grains $panicle^{-1}$, number of fertile and sterile grains panicle^{-1}, and 1000-grains weight were measured.

2.7.1 Sterility percentage

Filled and unfilled (sterile) grains were counted separately from the selected panicles, and spikelet sterility percentage was calculated by using the following formula (Islam et al., 2021).

$$\text{Spikelet sterility percentage} = \frac{\text{Number of sterile spikelets panicle}^{-1}}{\text{Total number of spikelets panicle}^{-1}\ (\text{filled + non-filled grains})} \times 100$$

2.7.2 Agronomic Efficiency (AE)

Calculation of AE was done by using the following formulae developed by Shah et al. (2001).

AE of N fertilizer (AE) = GYNA-GYN0/NR

Where, GYNA= Grain yield (kg ha^{-1}) with addition of nutrient,

GYN0= Grain yield (kg ha^{-1}) without addition of nutrient,

NR= Rate of added nutrient (kg ha^{-1}).

2.7.3 Economic analysis

A partial budget analysis was done to calculate the changes of benefit for a proposed change in the farm input and operation. It is useful to think of partial budgeting as a type of marginal analysis as it is the best adapted to analyzing relatively small changes in the whole farm plan (Kay, 1981). To compare the different treatments combination with one control treatment the following equation was applied.

$$\text{MBCR (over control)} = \frac{\text{Gross return } (T_1) - \text{Gross return } (T_0)}{\text{VC } (T_i) - \text{VC } (T_0)}$$

Where, Ti = T_2, T_3, ……. T_9, T_{10}

T1 = Control treatment

VC= Variable cost

Gross return = Yield x Price

2.8. Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) using a computer operated program namely, MSTATC.

3. Results and Discussion

3.1. Sterility percentage

The sterility percentage (SP) of rice grain is an important yield parameter which directly associated with the grain yield. Application of S and B significantly influenced the SP of rice (BRRI dhan28). The SP reduced to 22.92% from 31.28% with the addition of S, while the value reduced to 23.68% with the addition of B in rice field. The lowest SP (15.34%) was recorded at S_2B_2 treatment which was at par with S_2B_1 treatment (15.47%). Both fertilizers individually or in combination remarkably reduced the SP in this study. These results were adheres to the findings of Inal et al. (2004) who reported that S fertilization decreased the SP of wheat. The results of the effect of boron are in agreement with the findings of Subedi and Budhathoki (1995) and Subedi et al. (1997), who reported that B significantly reduced the SP of rice. Micronutrients like zinc plays an important role on the SP of rice, and SP significantly reduced with the addition of zinc fertilization in rice (Islam et al., 2021).

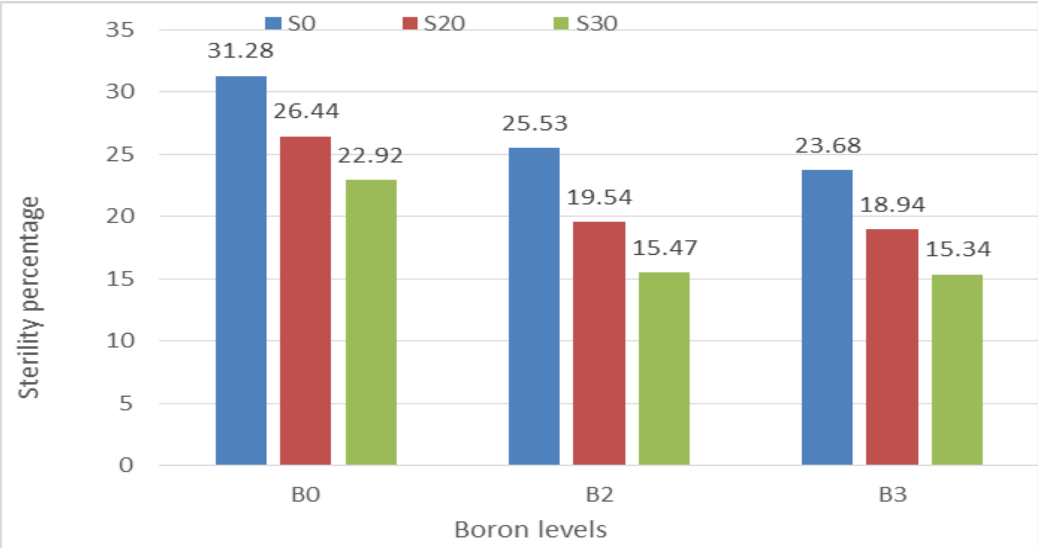

Figure 2. Effect of S and B on the sterility percentage of rice (BRRI dhan28)

3.2. Grain and straw yield

The grain yield was significantly influenced by the application of S and B (Table 3). The grain yield varied from 3. 30 to 4.80 t ha^{-1}, and 3.72 to 4.84 due to t ha^{-1} due to S and B fertilization, respectively. S and B fertilization increased the grain yield over control by 32.42 to 45.45%, and 25.00 to 30.11%, respectively. The highest grain yield was achieved in S_{20} over S_0 and S_{30}, and this might be due to higher production of effective tillers hill^{-1} and increased number of grains panicle^{-1}. Application of S significantly increased the grain yield as reported by many researchers (Mondal et al., 2004; Saha et al., 2007; Rahman et al., 2008; Singh et al., 2012; Ram et al., 2014). It has been reported earlier that application of 20kg S ha^{-1} increased grain yield of BR11 rice by 34% (Islam et al., 1997). The grain yield of BRRI dhan28 due to application of B followed the similar trend as like S. Application of B fertilizer with recommended doses of other fertilizers significantly increased the yield attributes and yield of rice (Amin et al., 2004). Boron enhanced the fertilization of cereals and oilseeds and reduced the sterility of reproductive organ by enhancing the pollination by creating the stigma receptive and sticky that helps in grain fertility as well as increased the number of grains per panicle increased due to reduction of flower sterility (Garg et al., 1979), which might have upsurge the grain yield of rice. The increasing evidence of rice grain yield through B fertilization has been reported by David et al. (2005), Hussain et al. (2012), Shukla et al. (2020), and Phonglosa et al. (2018). In earlier study, Singh et al. (1990) also reported that application of B in rice field increased the grain yield by 31% over without B. In many studies reported that B application in rice crop resulted in increased rice grain yield due to number of grains per panicle (Lin and Zhu, 2000; Ramanathan et al., 2002), reduced panicle sterility (Jana et al., 2005; Rashid, 2006) and higher grain filling (Rashid et al., 2004). Nonetheless, combined application of S and B in addition of N, P, K, and Zn significantly increased the grain yield of rice cv. BRRI dhan30 (Afroz, 2011).

Table 2. Effect of S and B on the grain, straw and biological yield, and harvest index of rice (BRRI dhan28)

Treatments	Grain yield (t ha^{-1})	% Increase grain yield over control	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S levels					
S_0	3.30 b	-	4.79 b	8.09 b	40.79 b
S_{20}	4.80 a	45.45	5.71 a	10.51 a	45.67 a
S_{30}	4.37 a	32.42	5.48 a	9.85 a	44.36 a
LSD (0.05)	0.672	-	0.642	1.038	2.596
CV (%)	8.01	-	6.92	5.86	4.24
B levels					
B_0	3.72 b	-	4.61 b	8.33 b	44.66 b
B_2	4.84 a	30.11	5.43 a	10.27 a	47.13 a
B_3	4.65 a	25.00	5.31 a	9.96 a	46.69 a
LSD (0.05)	1.367	-	1.532	2.111	0.955
CV (%)	8.01	-	6.92	5.86	4.24

There was a significant and positive effect of S and B on the straw yield of rice as like grain yield (Table 2). The highest straw yield (5.71 t ha^{-1}) was noticed from S_1 (20 kg S t ha^{-1}) treatment which was statistically identical (5.48 t ha^{-1}) with S_2 (30 kg S t ha^{-1}), and the lowest straw yield (4.79 t ha^{-1}) was recorded from S_0 (control) treatment. On the other hand, B also remarkably increased the straw yield of rice but no statistical difference was recorded B_1 and B_2 treatment. The result obtained in the straw yield is in accordance with the findings of Afroz (2011) concluded that combined application of S and B along with N, P and K increased the straw yield of rice. Similar result was obtained by Shah et al. (2009). A significant increase in the straw yield of BR 11 rice due to application of S was noticed by Islam et al. (1997). There is increasing evidence that improved biomass weight through S fertilization along without B or with B in many crops including rice (Ziaeyan and Rajaie, 2009; Singh et al., 2012; Rumi, 2017; Shukla et al., 2020; Amer et al., 2020; Hanifuzzaman et al., 2022), mungbean (Islam et al., 2017a, 2017b; Deep et al., 2022), mustard (Basumatary et al., 2022), soybean (Das et al., 2022), and sesame (Islam et al., 2019). Boron application in rice-wheat cropping system significantly increased the straw yield of rice (Rahmatullah et al., 2006).

3.3. Relationship between grain and yield attributes

3.3.1. Grain yield and effective tiller hill^{-1}

A direct significant and positive relationship between the grain yield and effective tillers hill^{-1} was observed of BRRI dhan28 which has been confirmed with correlation co-efficient R^2 = 0.906* (Figure 3). The line regression of Y (grain yield) on X (panicle length) having equation Y = 2.328 X + 15.15 which show gradual increase in grain yield with the increase of effective tillers hill^{-1}. Similar result was observed by Afroz (2011) with the application of S and B in BRRI dhan30. The findings of this character agree with the result obtained by Shah et al. (2009).

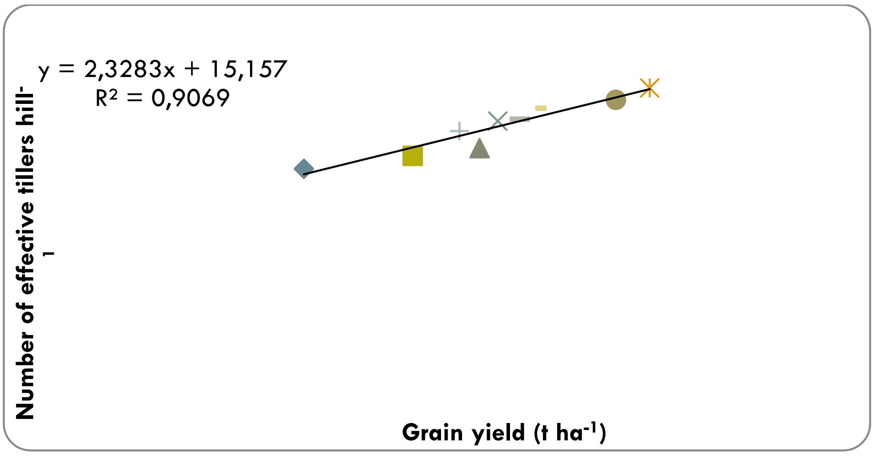

Figure 3. Relationship between grain yield and number of effective tiller hill^{-1} of BRRI dhan28 under different levels of S and B fertilization

3.3.2. Grain yield and panicle length

There was a significant and positive relationship between the grain yield and panicle length of BRRI dhan28 has been found out. The correlation co-efficient (R^2 =0.857*) was significant at 5% level of probability. The relationship was more evident when the equation Y =2.270 X + 14.19 is shown in Fig. 4. The positive gradient indicates that the grain yield and panicle length is directly correlated i.e. the grain yield is increased with the increment of the panicle length. This result is in agreement with the findings of Afroz (2011) who reported significant positive correlation with the addition of S and B in BRRI dhan30. Rahman et al. (2007) reported that the grain yield increased with the increase of panicle length of BRRI dhan29 under S fertilized condition.

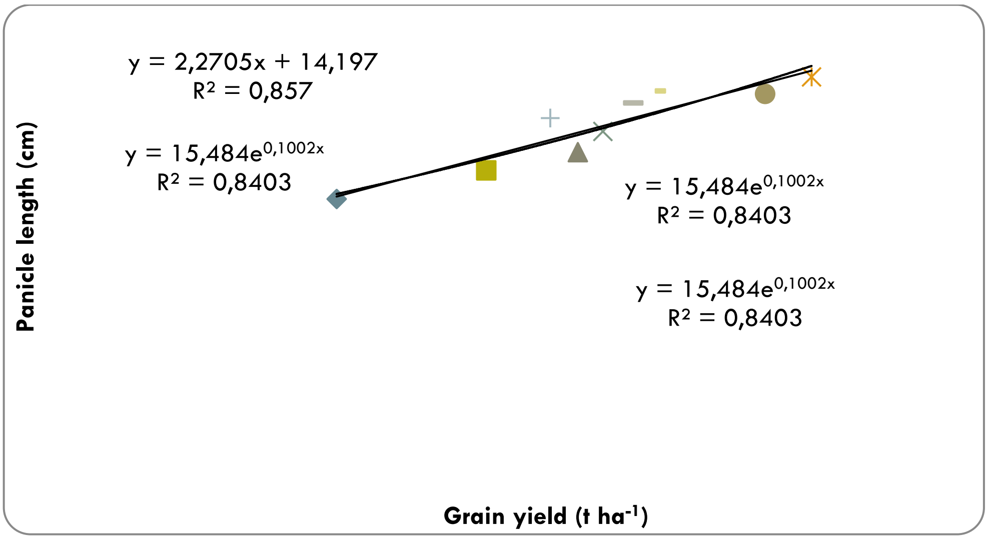

Figure 4. Relationship between grain yield and panicle length of BRRI dhan28 under different levels of S and B fertilization

3.3.3. Grain yield and weight of 1000-grains

The relationship between the grain yield and weight of 1000-grains of rice cv. BRRI dhan28 was positively correlated, and the correlation coefficient $R^2 = 0.803$* indicates strong relationship (Fig. 5). The relationship was more evident when the equation Y = 1.875X + 16.93 which shows that the grain yield gradually increased with the increase of weight of 1000-grains i.e. increase in grain yield result in increase in S and B levels, and vise-versa. Similar result was also noticed by Afroz (2011) in BRRI dhan30, Rahman et al. (2007) in BRRI dhan29. Hasegawa (2003) reported positive correlation between 1000-grain weight and grain yield of rice.

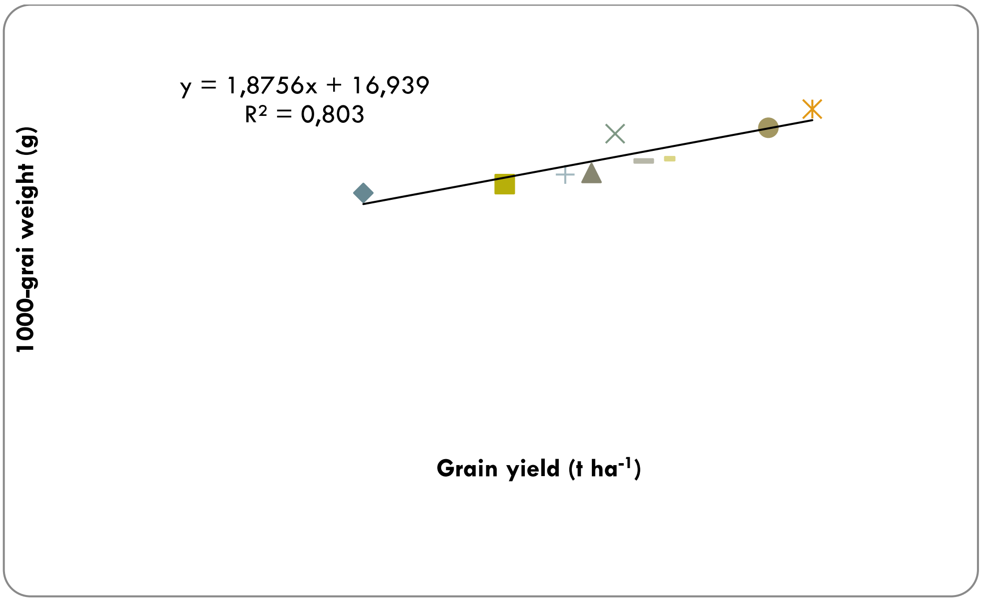

Figure 5. Relationship between grain yield and 1000-grains weight of BRRI dhan28 under different levels of S and B fertilization

3.3.4. Grain yield and sterility percentage

There is a direct significant and negative relationship between the grain yield and sterility percentage of rice cv. BRRI dhan28 which have been confirmed with correlation co-efficient r = 0.566* (Fig. 6). The relationship was more evident when the equation Y = -3.525 X + 36.69 which indicates gradual reduction of grain weight with the increment of sterility percentage in BRRI dhan28. A similar conclusion was drawn by Islam et al. (2021) who reported that the grain yield gradually decreased with increase of sterility percentage under addition of zinc micronutrient. Spikelet sterility had significant negative association with the grain yield (Fageria et al., 2013). In another previous study, Fageria et al. (2004) reported significant negative association between grain yield and spikelet sterility in upland rice genotypes grown on a Brazilian Oxisol.

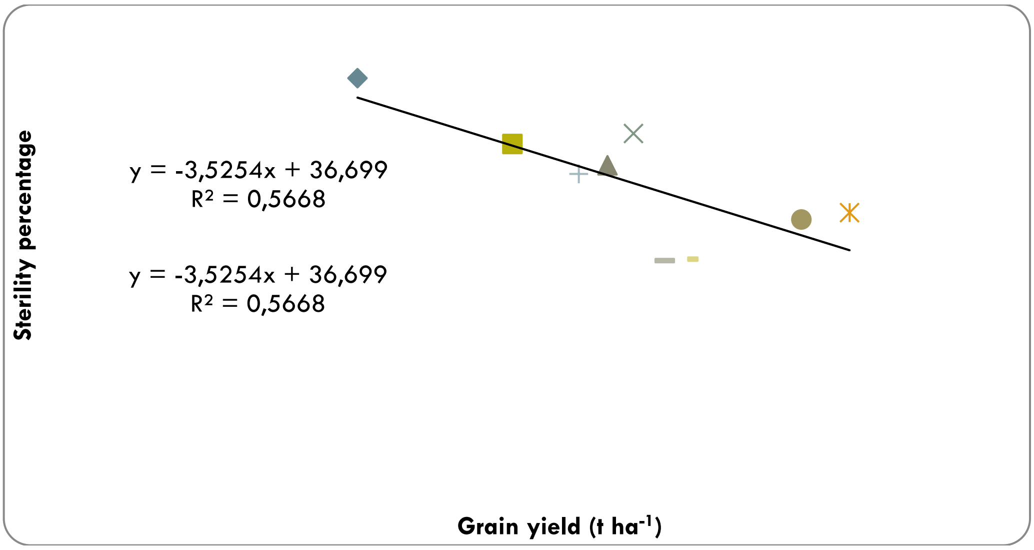

Figure 6. Relationship between grain yield and sterility of BRRI dhan28 under different levels of S and B fertilization

3.3.5. Agronomic efficiency

Agronomic efficiency (AE) determines the strength of certain inputs on per unit basis in quantitative terms (Tandon, 1987). AE is achieved by the yield gained over control per unit of added input (fertilizer) that reflects the competence of an input. However, sulphur use efficiency (SUE) was substantially influenced by application of different levels of S (Table 3).

Generally, the SUE increased up to a certain level S and thereafter decreased with the increase of S levels. Higher value of SUE (78%) was recorded in S_{20} and the lower value (36%) in S_{30}. Higher value of SUE with the lower level of S application might be the results of intense competition of root and efficient S uptake. On the other hand, the lower value of SUE with higher S fertilized soil this might be due to smaller proportion of applied S is taken up by plants and the rest part of available S might be lost via leaching or other pathways. The SUE depends on the S dose, fertilizer source and the application time (Aula et al., 2019). S becomes available to make it more effective when applied at right dose and right time (Chien et al., 2011). Higher AE indicates that the application of nutrients minimizes the loss as well as properly uses that results in increased grain yield of rice (Table 2) as compared to control treatment.

Eriksen (2009) reported that the SUE is nearly 25% for agricultural crops. The average SUE is 34.2% in rice when the application rate of S is 15-45 kg ha^{-1}, whereas the SUE value is 29.8% when the

S rates is 45 kg ha^{-1} (Singh Shivay et al., 2014). The higher SUE in our study was observed which might be due to crop and site specificity of SUE (Aula et al., 2019). Application B tremendously increased the grain yield boron use efficiency (BUE) over control but no significant difference of BUE was observed between B_2 and B_3 that means AE of boron fertilization between two and three kg of boron application was statistically analogous.

Table 3. Agronomic efficiency of S and B for growing BRRI dhan28 under S and B fertilization

Treatments	**GYNA (Kg ha^{-1})**	**GYNO (Kg ha^{-1})**	**NR (Kg ha^{-1})**	**AE of fertilizer (%)**
		S levels		
S_0	3300	3300	0	-
S_{20}	4860	3300	20	78 a
S_{30}	4370	3300	30	36 b
LSD (0.05)	-	-	-	-
CV (%)	-	-	-	-
		B levels		
B_0	3720	3720	0	-
B_2	4840	3720	2	560 a
B_3	4650	3720	3	465 a
LSD (0.05)	-	-	-	2.351
CV (%)	-	-	-	41.21

GYNA= Grain yield (kg ha^{-1}) with addition of nutrient, GYN0= Grain yield (kg ha^{-1}) without addition of nutrient, NR= Rate of added nutrient (kg ha^{-1})

3.5. Economic analysis

The economic performance of S and B fertilization was evaluated in this study (Table 4). The outcome revealed that S and B fertilizer application showed superior performance regarding gross return (GR), gross margin (GM), marginal gross margin (MGM) and marginal benefit cost ratio (MBCR) over their corresponding control treatment. However, the highest values of GR (Tk. 145,800), GM (Tk. 129,600), MGM (Tk. 45800) and MBCR (45.8) were recorded at S_{20} treatment. On the other hand, application of B @2kg ha^{-1} the values were GR (Tk. 145,200), GM (Tk. 144,700), MGM (Tk. 33100) and MBCR (66.2). The results revealed that the S was more responsive than B fertilization. Our results are certified by Chowdhury et al. (2020), and Tarafder et al. (2020) who reported that application of inorganic S fertilizer significantly increased the GR, GM and BCR in crops. Hussain et al. (2012) concluded that B fertilization increased the net economic income and ratio of benefit to cost compared to control treatment. The results indicated that application of S (20 kg ha^{-1}) and B (20 kg ha^{-1}) is highly profitable to the rice growers.

Table 4. Economic analysis of sulphur and boron fertilization on rice (BRRI dhan28) production

Treatments	GR (Tk ha^{-1}) 1	TVC (Tk ha^{-1}) 2	GM (Tk ha^{-1}) 3=(1-2)	MGM (Tk ha^{-1}) 4=(3-T1)	MBCR 5=(4/2)
S_0	99000	-	99000	-	-
S_{20}	145800	1000	144800	45800	45.8
S_{30}	131100	1500	129600	30600	20.4
B_0	111600	-	111600	-	-
B_2	145200	500	144700	33100	66.2
B_3	139500	750	138750	27150	36.2

GR: Gross return, TVC: Total variable cost; GM: Gross margin, MGM: Marginal gross margin, MBCR: Marginal benefit cost ratio, Gypsum fertilizer @50 Tk kg^{-1}, Boric acid @ 250 Tk kg^{-1} Rice @ 30.0 Tk kg^{-1}

4. Conclusion

The overall results indicated that application of S and B significantly influenced the sterility percentage, grain yield, biomass yield, harvest index, agronomic efficiency and economic aspects. The effect of S was especially remarkable over B for achieving higher yield of BRRI dhan28 and in the economic point of view. Addition of S @20kg ha^{-1} and B @ 2 kg ha^{-1} showed the best results of the aforesaid parameters. Overall, combined application of S and B is advocated for increasing rice yield, agronomic efficiency and maximizing the net economic returns of BRRI dhan28.

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

Acknowledgements

The authors thank to the Chairman, Department of Crop Science and Technology, Faculty of Agriculture, University of Rajshahi, Rajshahi for his valuable contribution to accomplish the present study.

References

Afroz, T., 2011. Effects of sulphur and boron on growth, yield and nutrient content of T. aman rice. MS. Thesis, Sher-e-Bangla Agricultural University, Bangladesh.

Amer, M., Ali, M., Iqbal, R., Ahmad, S., Aslam, M.U., Haider, I., Mehmood, H., Rafique, M.A., Uddin, S.Z., Rehman, M.A., 2020. Growth and yield response of rice varieties to foliar application of boron. *Journal of Biodiversity and Environmental Science*, 17(1): 66-72.

Amin, M., Ayaz, M.K., Ejaz, A.K., Ramzan, M., 2004. Effect of increased plant intensity and fertilizer doze on yield of rice variety (IRRI-6). J. Res Sci., 15: 9-16.

Aula, L., Dhillon, J.S., Omara, P., Wehmeyer, G.B., Freeman, K.W., Raun, W.R., 2019. World sulfur use efficiency for cereal crops. *Agronomy Journal*, 111(5): 2485-2492.

Badruddin, M., 1999. The effect of sulphur deficiency on ionaccumulation with special reference to 15N and 35S transport and metabolism in chickpea (*Cicer arietinum* L.). Ph.D. Thesis, Dhaka University, Bangladesh.

BARC (Bangladesh Agricultural Research Council), 2012. Fertilizer Recommendation Guide-2012. Bangladesh Agricultural Research Council, Farmgate, Dhaka-1215, Bangladesh.

Basumatary, A., Bhupenchandra, I., Chauhan, S., Choudhary, A.K., Goswami, K., 2022. Synergistic influence of sulphur and boron fertilization on enhancing the productivity of rapeseed (*Brassica napus* L.) and nutrient status in subtropical acidic soil of Assam, India. *Communications in Soil Science and Plant Analysis*, 53(12): 1498-1517.

Black, C.A., 1965. Methods of soil analysis, Part1. Agronomy Monograph 9. ASA Madison, Wisconsin, USA.

Bolanos, L., Lukaszewski, K., Bonilla, I., Blevins, D., 2004. Why boron? *Plant Physiology and Biochemistry*, 42: 907-912.

Bray, R.H., Kurtz, L.T., 1945. Determination of total, organic, and available forms of phosphorus in soils. *Soil Science*, 59: 39-45.

Bremner, J.M., Mulvaney, C.S., 1982. Methods of soil analysis, part 2 Chemical and Microbiological Properties. pp. 595-624.

BRRI (Bangladesh Rice Research Institute), 2010. Adhunik Dhaner Chash (In Bengali). 15th Edition. Bangladesh Rice Research Institure, Gazipur, Bangladesh. pp. 10-18.

Chien, S.H., Gearhart, M.M., Villagarcía, S., 2011. Comparison of ammonium sulfate with other nitrogen and sulfur fertilizers in increasing crop production and minimizing environmental impact: a review. *Soil Science*, 176(7): 327-335.

Chowdhury, T., Chowdhury, M.A., Rahman, M.A., Nahar, K., Islam, M.T., 2020. Response of *Aloe vera*. to inorganic and organic fertilization in relation to leaf biomass yield and post-harvest fertility of soil. *Bulgarian Journal of Agricultural Science*, 26(2): 346-354.

Das, S., Paul, S.K., Rahman, M.R., Roy, S., Uddin, F.M.J., Rashid, M.H., 2022. Growth and yield response of soybean to sulphur and boron application. *Journal of the Bangladesh Agricultural University*, 19(4): 12-19.

David, D., Gene, S., Andy, K., 2005. Boron fertilization of rice with soil and foliar application. *Crop Manage*, 4(1): 1-7.

Deep, C.G., Singh, V., George, S.G., 2022. Effect of sulphur and boron on growth and yield of greengram (*Vigna radiata* L.). *International Journal of Plant Soil Science*, 34(13): 93-98.

Dobbermann, A., Fairhurst, T., 2000. Rice-nutrient disorder &nutrient management. 1st edi. Potash & Phosphate Institute of Canada and International Rice Research Institute. pp. 40-117.

Eriksen, J., 2009. Soil sulfur cycling in temperate agricultural systems. *Advances in Agronomy*, 102: 55-89.

Fageria, N.K., Barbosa Filho, M.P., Stone, L.F., 2004. Phosphorus nutrition for bean production. Phosphorus in Brazilian agriculture, 435-455.

Fageria, N.K., Knupp, A.M., Moraes, M.F., 2013. Phosphorus nutrition of lowland rice in tropical lowland soil. *Communications in Soil Science and Plant Analysis*, 44(20): 2932-2940.

FAO (Food and Agriculture Organization) 2020. Production Year Book of 2020. No. 79. Published by Food and Agriculture Organization, Rome, Italy. pp: 76-77.

FAO (Food and Agriculture Organization) 2021. Production Year Book of 2021. No. 80. Published by Food and Agriculture Organization, Rome, Italy. pp. 54-55.

FAO (Food and Agriculture Organization), 2016. Food and agricultural organization of the United Nations (FAO), FAO Statistical Database; 2016. Available: http://faostat.fao.org

FAO-UNDP (Food and Agriculture Organization-United Nations Development Programme), 1988. Land Resources Appraisal of Bangladesh for Agricultural Development: Agroecological Regions of Bangladesh. Technical Report No. 2, FAO, Rome, Italy.

Fox, R.L., Olson, R.A., Rhoades, H.F., 1964. Evaluating the sulfur status of soils by plant and soil tests. *Soil Science Society of America Journal*, 28(2): 243-246.

Garg, O., Sharma, A., Kona, G., 1979. Effect of boron on the pollen vitality and yield of rice plants (*Oryza stativa* L. var. Jaya). *Plant Soil*, 52: 951-594.

Gomez, K.A., Gomez, A.A., 1984. Statistical Procedures for Agricultural Research. edn 2, John Wiley & Sons, New York, USA.

Hanifuzzaman, M., Jamil Uddin, F.M., Golam Mostofa, M., Sarkar, S.K., Paul, S.K., Rashid, M.H., 2022. Effect of zinc and boron management on yield and yield contributing characters of Aus rice (*Oryza sativa*). *Research on Crops*, 23(1): 1-10.

Haque, M.S., Jahiruddin, M., 1999. Effect of single and multiple applications of sulphur and zinc in a continuous rice cropping pattern. *Indian Journal of Agricultural Research*, 28(1): 9-14.

Hasegawa, H., 2003. High-yielding rice cultivars perform best even at reduced nitrogen fertilizer rate. *Crop Science*, 43: 921-926.

Havlin, J.L., Beaton, J.D., Tisdale, S.L., Nelson, W.L., 2004. Soil fertility and fertilizers, an introduction to nutrient management. Singapore: Pearson Education. pp: 25-28.

Hawkesford, M.J., 2000. Plant responses to sulphur deficiency and the genetic manipulation of sulphate transporters to improve S utilization efficiency. *Journal of Experimental Botany*, 51: 131-138.

Hunter, A.H., 1974. Tentative ISFEJ soil extractant procedure: International soil fertility evaluation and improvement project. Raleigh: North Carolina State University, USA.

Hussain, M., Khan, M.A., Khan, M.B., Farooq, M., Farooq, S., 2012. Boron application improves growth, yield and net economy return of rice. *Rice Science*, 19(3): 259-262.

Inal, A., Günes, A., Alpaslan, M., Adak, M.S., Taban, S., Eraslan, F., 2006. Diagnosis of sulfur deficiency and effects of sulfur on yield and yield components of wheat grown in central Anatolia, Turkey. *Journal of Plant Nutrition*, 26(7): 1483-1498.

Islam, M.R., Hossain, A., 1998. Influence of additive nutrients on the yield of BR 11 rice. *Thai Journal of Agricultural Science*, 26: 195-199.

Islam, M.R., Alam, M.N., Hashem, M.A., 1995. Enhancement ofblue green algal growth and yield of BR 11 rice under different levels of soil fertility. *Progressive Agriculture*, 6(2): 83-89.

Islam, M.R., Hoque, M.S., Islam, M.R., 1997. Distribution of different forms of sulphur in some selected soils of Bangladesh. *Progressive Agriculture*, 8(1&2): 129-132.

Islam, M.R., Shah, M.S., Jahiruddin. M., 2009. Effects of different rates and sources of sulphur on the growth and yield of BRRI dhan30. *Bangladesh Research Publications Journal*, 2(1): 397-405.

Islam, M.S., Akhter, M.M., Rahman, M.SQ., Banu, M.B., Khalequzzaman, K.M., 2008b. Effect of nitrogen and number of seedlings per hill on the yield and yield components of T. Aman rice (BRRI dhan33). *International Journal of Sustainable Crop Production*, 3(3): 61-65.

Islam, M.S., Ali, M.T., Hasan M.K., Wais, A.H., Hakim M.A., Hafeez, A., Bari, A., Chowdhury, M.K., 2019. Response of sulphur and zinc on the growth and yield traits of sesame (*Sesamum indicum* L.) at Old Himalayan Piedmont Plain soil. *ISPEC Journal of Agricultural Sciences*, 3(1): 98-115.

Islam, M.S., EL Sabagh, A., Hasan, K., Akhter, K., Barutçular, C., 2017a. Growth and yield response of mungbean (*Vigna radiata* L.) as influenced by sulphur and boron application. *Scientific Journal of Crop Science*, 6(1): 153-160.

Islam, M.S., Hasan, K., Sarkar, N., EL Sabagh, A., Rashwan, E., Barutçular, C., 2017b. Yield and yield contributing characters of mungbean as influenced by zinc and boron. *Agricultural Advances*, 6(1): 391-397.

Islam, M.S., Khatun, K.M., Hafeez, A., Chowdhury, M.K., Konuşkan, Ö., Barutcular, C., Erman, M., Çiğ, F., EL Sabagh, A., 2021. The effect of zinc fertilization and cow dung on sterility and quantitative traits of rice. *Journal of Aridland Agriculture*, 7: 60-67.

Jahiruddin, M., Ali, M.S., Hossain, M.A., Ahmed, M.U., Hoque, M.M., 1995. Effect of boron on grain set, yield and some others of paddy cultivars. *Bangladesh Journal of Agricultural Research*, 22: 179-184.

Jamal, A., Fazli, I.S., Ahmad, S., Abdin, M.Z., Yun, S.J., 2005. Effect of sulphur and nitrogen application on growth characteristics, seed and oil yield of soybean cultivars. *Korean journal of crop science*, 50(5): 340-345.

Jana, P.K., Ghatak, R., Sounda, G., Ghosh, R.K., Bandyopadhyay, P., 2005. Effect of boron on yield, content and uptake on NPK by transplanted rice at farmer's field on red and laterite soils of West Bengal. *Journal of International Academic Research*, 9: 341-344.

Kay, R.D., 1981. Farm management: Planning, Control and Implementation. McGraw-Hill Book Company, No:631, New York, USA.

Khan, H.R., Blume, H.P., Kabir, S.M., Bhuiyan, M.M.A., Ahmed, F., Syeed, S.M.A. 2007. Quantification of the severity, reserve and extent of acidity in the twenty profiles of acid sulfate soils and their threats to environment. *Soil and Environment*, 26: 45-55.

Knudsen, D., Peterson, G.A., Pratt, P.F., 1982. Lithium, sodium and potassium determination. In: A.L., Miller, R.H., Keeney, D.R. (Eds), *Methods of Soil Analysis*, 2nd edn., American Society of Agronomy, Madison, USA, pp. 228-239.

Lin, X.Q., Zhu, D.F., 2000. Effects of regent on growth and yield in rice. *Acta Agriculturae Zhejiangensis*, 12: 70-73.

Lindsay, W.L., Norvell, W.A., 1978. Development of a DTPA soil test for Zn, Fe, Mn, and Cu. *Soil Science Society of America Journal*, 42: 421-428.

Malik, A.R., Zahida, H.P., Muhammad, S.M., 2008. Genetic diversity analysis of traditional and improved cultivars of Pakistani rice (*Oryza sativa* L.) using RAPD markers. *Electronic Journal of Biotechnology*, 11(3): 1-10.

Mondal, S.S., Arup, G., Debabrata, A., Maiti, D., 2004. Production potential and economics of different rainfed rice (*Oryza sativa*)-based utera cropping systems and its effect on fertility buildup of soil. *International Journal of Agronomy*, 49(1): 6-9.

Page, A.L., Miller, R.H., Keeney, D.R., 1982. Methods of soil analysis. Part 2, 2nded., American Society of Agronomy, Wisconsin, USA.

Phonglosa, A., Dalei, B.B., Senapati, N., Pattanayak, S.K., Saren, S., Ray, K., 2018. Effect of boron on growth, yield and economics of rice under eastern ghat high land zone of Odisha. *International Journal of Agricultural Science*, 10(7): 5660-5662.

Piper, C.S., 2019. Soil and plant analysis. Scientific Publishers.

Rafique, E., Mahmood-ul-hassan, M., Khokar, K.M., Nabi, G., Tabassam, T., 2008. Zinc nutrition of onion: Proposed diagonistic criteria. *Journal of Plant Nutrition*, 31: 307-316.

Rafique, E., Rashid, A., Ryan, J., Bhatti, A.U., 2006. Zinc deficiency in rain fed wheat in Pakistan: Magnitude, spatial variability, management and plant analysis diagnostics norms. *Communications in Soil Science and Plant Analysis*, 37: 181-197.

Rahman, M.N., Islam, M.B., Sayem, S.M., Rahman, M.A., Masud, M., 2007. M. Effect of different rates of sulphur on the yield and yield attributes of rice in old Brahmaputra floodplain soil. *Journal of Soil and Nature*, 1(1): 22-26.

Rahman, M.T., Jahiruddin, M., Humauan, M.R., Alam, M.J., Khan, A.A., 2008. Effect of sulphur and zinc on growth, yield and nutrient uptake of boro rice (cv. BRRI dhan29). *Journal of Soil and Nature*, 2(3): 10-15.

Rahmatullah, K., Gurmani, A.H., All, R.G., Zia, M.S., 2006. Effect of boron application on rice yield under wheat rice system. *International Journal of Agriculture And Biology*, 8(6): 805-808.

Rajamoorthy, Y., Rahim, K., Munusamy, S., 2015. Rice industry in Malaysia: challenges, policies and implications. *Procedia Economics and Finance*, 31: 861-867.

Ram, A., Kumar, D., Singh, N., Anand, A., 2014. Effect of sulphur on growth, productivity and economics of aerobic rice (*Oryza sativa*). *International Journal of Agronomy*, 59(3): 404-409.

Ramanathan, S., Stalin, P., Thilagavathi, T., Natarajan, K., Ankorion, Y., 2002. Foliar nutrition of peak on rice. *In 17. World congress of soil science,* Conference Proceedings Book, 14-21 August, Thailand, pp. 2231-2242.

Rashid, A., 2006. Boron deficiency in soils and crops of Pakistan: Diagnosis and management. Pakistan Agricultural Research Council, Islamabad, Pakistan.

Rashid, A., Yaseen, M., Ashraf, M., Mann, R.A., 2004. Boron deficiency in calcareous soil reduces rice yield and impairs grain quality. *International Rice Research Notes*, 29(1): 58-60.

Rehman, A., Farooq, M., Cheema, Z.A., Wahid, A., 2012. Seed priming with boron improves growth and yield of fine rice. *Plant Growth Regulation*, 68(2): 189-201.

Rumi, M.S., 2017. Effect of cowdung and sulphur on the growth and yield of aromatic rice cv. Tulshimala. MS Thesis, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.

Saha, P.K., Ishaque, M., Saleque, M.A., Miah, M.A.M., Panaullah, G.M., Bhuiyan, N.I., 2007. Long-Term Integrated Nutrient Management for Rice-Based Cropping Pattern: Effect on Growth, Yield, Nutrient Uptake, Nutrient Balance Sheet, and Soil Fertility. *Communications in Soil Science and Plant Analysis*, 38(5-6): 579-610.

Schonhof, I., Blankenburg, D., Muller, S., Krumbein, A., 2007. Sulfur and nitrogen supply influence growth, product appearance, and glucosinolate on centration of broccoli. *Journal of Plant Nutrition and Soil Science*, 170: 65-72.

Shah, K.H., Memon, M.Y., Siddiqui, S.H., Aslam, M., 2001. Response of wheat to broadcast and fertigation technique or P application. *Pakistan Journal of Biological Sciences*, 4: 543-545.

Shah, M.S., Islam. M.R., Jahiruddin, M., 2009. Effects of different rates and sources of sulphur on the growth and yield of BRRI dhan30. *Bangladesh Research Publications Journal*, 2(1): 397-405.

Shukla, A., Singh, R., Singh, S.K., Shivanand, Shukla, D.V., Singh, R., 2020. Study the effect of boron levels on yield attributes of rice crop. *Journal of Pharmacognosy and Phytochemistry*, 9(6): 730-733.

Sikdar, M.S.I., Rahman, M.M., Islam, M.S., Yeasmin, M.S., Akhter, M.M., 2008. Effect of nitrogen level on aromatic rice varieties and soil fertility status. *International Journal of Sustainable Crop Production*, 3(3): 49-54.

Singh Shivay, Y., Prasad, R., Pal, M., 2014. Effect of levels and sources of sulfur on yield, sulfur and nitrogen concentration and uptake and S-use efficiency in basmati rice. *Communications in Soil Science and Plant Analysis*, 45(18): 2468-2479.

Singh, A.K., Manibhushan, Meena, M.K., Upadhyaya, A., 2012. Effect of sulphur and zinc on rice performance and nutrient dynamics in plants and soil of Indo Gangetic plains. *Journal of Agricultural Science*, 4(11): 162-170.

Singh, B.P., Singh, A., Singh, B.N., 1990. Response of rice (*Oryza sativa* L.) to zinc sulfate under mid-altitude conditions of Meghalaya. *Indian Journal of Agricultural Sciences*, 60: 70-71.

Subedi, K.D., Budhathoki, C.B., 1995. Wheat sterility problem in Nepal: Research at Lumle Agricultural Research Centre. In Causes of Sterility in Wheat. In: R.W. Bell, B. Rerkasem (Ed), *Environmental Science Report*, Western Australia, pp. 44-55.

Subedi, K.D., Budhathoki, C.B., Subedi, M., Yubak, D., 1997. Response of wheat genotypes to sowing date and boron fertilization aimed at controlling sterility in a rice-wheat rotation in Nepal. *Plant Soil*, 188: 249-256.

Tanaka, M., Fujiwara, T., 2007. Physiological roles and transport mechanisms of boron: perspectives from plants. *Pflugers Archiv European Journal of Physiology*, 456: 671-677.

Tandon, L., 1987. Phosphorus research and agricultural production in India. Fertilizer Development and Consultation Organization, New Delhi, India.

Tarafder, S., Rahman, M.A., Hossain, M.A., Chowdhury, M.A., 2020. Yield of *Vigna radiata* L. and post-harvest soil fertility in response to integrated nutrient management. *Agricultural and Biological Sciences Journal*, 6(1): 32-43.

Tiwari, K.N., Gupta, B.R., 2006. Sulphur for sustainable high yield agriculture in Uttar Pradesh. *Indian Journal of Fertilisers*, 1: 37-52.

Ziaeyan, A.H., Rajaie, M., 2009. Combined effect of zinc and boron on yield and nutrients accumulation in corn. *International Journal of Plant Production*, 3: 33-45.

To Cite	Bari, A., Promi, R.J., Muhyidin, I., Pramanik, M.H., Demir, C., Erman, M., Çığ, F., Islam, M.S., 2023. Sulphur and Boron Fertilization Increased Productivity of Boro Rice (BRRI dhan28) by Increasing Pollen Fertility and Agronomic Efficiency in Calcareous Soils of Bangladesh. *ISPEC Journal of Agricultural Sciences*, 7(1): 218-236. DOI: https://doi.org/10.5281/zenodo.7771354.