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Response of Sulphur and Boron on Growth, Yield Traits and Yield of Boro Rice (BRRI dhan28) at High Ganges River Floodplain of Bangladesh

AKM Abdul BARI[1], Razita Jalil PROMI[1], Nahar SHUMSUN[1], Md. Kamrul HASAN[2]
Moaz Hosen PRAMANIK[3], Cihan DEMİR[4], Celaleddin BARUTÇULAR[5], 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]Cukurova University, Department of Field Crops, Faculty of Agriculture, Türkiye
[*]Sorumlu Yazar (Corresponding author): akmabari@gmail.com

Abstract

The experiment was conducted at the reaearch field of the Department of Crop Science and Technology, University of Rajshahi, Rajshahi-6205, during the Rabi season from November 2015 to April 2016 to study the effect of sulphur and boron on growth and yield performance of boro rice (cv. BRRI dhan28). The experimental area belongs to High Ganges River Floodplain under Agro Ecological Zone-11 (AEZ-11). The experiment was constructed with two factors viz., factor A (sulphur) and factor B (boron) with three level of doses of each, i.e., S_0: without sulphur (control), S_1: 20 kg S ha^{-1}, S_2: 30 kg S ha^{-1}, and B_0: without boron (control), B_1: 2 kg B ha^{-1}, B_2: 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 growth, yield contributing traits and yield of rice, and the treatment of S1B1 (20 kg S ha^{-1} with 2 kg B ha^{-1}) performed the best results of number of tillers $hill^{-1}$ (28.78), panicle length (26.94 cm), grains $panicle^{-1}$ (177.57), filled grains $panicle^{-1}$ (150.27), 1000-grain weight (29.75 g), highest grain (6.30 t ha^{-1}), straw (5.91 t ha^{-1}), and biological yield (12.21 t ha^{-1}) and HI (51.60%). 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 maximum yield of boro rice in calcareous soils of AEZ-11.

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1. Introduction

Food security is becoming serious concern due to increasing trends of global population, and it is in alarming situation in Asia and Africa continent. There is an urgent need to produce more food with an efficient and sustainable agricultural production systems to feed the rapidly growing population (Islam et al., 2021). Population pressure of Bangladesh creates remarkable stress on the natural resources. Rice (*Oryza sativa* L.) is the main source of energy among cereals alone that serves as major source of calories to the population in Asia, Africa and Latin America. Rice is one of the major staples, and is considered the primary nutrient source for more than 3 billion people. The crop is grown in more than 150 million hectares across the world, and is of critical importance to the economies of various nations, especially in South-East Asia, China and India.

Asian countries consume about 86.70% of the global rice production, and Bangladesh consumes 6.50% of the global rice production (Hussain, 2012). Per capita availability of rice per year in Bangladesh is about 160 kg which makes it the fourth highest consuming nation of the world (Hussain, 2012). Approximately 77% of the cropped area is devoted to rice production, with some 60-70% of the agricultural labour employed in rice production, marketing and distribution. Production of rice contributes 70% of the agricultural GDP, and one-sixth of the national income in Bangladesh (BBS, 2011). For improving food security, different strategies are aligned to increase the productivity of agricultural crops, and to stabilize of food prices. However, rice plays a pivotal role in all spheres of life in Bangladesh, and it is the most important commodity in terms of livelihood and food. So, it is imperative to increase rice production. Though Bangladesh has excellent sub-tropical climate for rice cultivation but its productivity is low compared with other Asian countries like Indonesia, Malaysia, etc. Therefore, to overcome this situation, increase in rice growth and production per unit area is the only alternative to bring self-sufficiency in food production. The desired results may be achieved by ensuring balanced quantities of essential nutrient elements to the soil, and by implementing good agricultural practices at field level.

Soil is a heterogeneous material which provides the nutritional requirements of crop plants. Due to continuous and intensive cropping the soils of Bangladesh are exhausted, and the nutrient stresses are increasing day by day. Depletion of soil fertility is a major constraint for sustainable crop production in Bangladesh. The problem has been doubled due to lack of interest in applying good agricultural practices by grower. Majority of soils are low in organic matter resulting in decreased macro- and micro-nutrients in some soils of Bangladesh (Khan et al., 1997; Islam, 2006). Supplement of all essential nutrients are the prime requirements for optimum growth and productivity of rice, and imbalance supply may hamper growth and ultimately the yield of the target crop (Jamil et al., 2012).

Sulphur deficiency has been documented in different regions of Bangladesh soil which roughly covers 44% of the total cropped area. The deficiency of S along with NPK are frequently reported in Bangladesh soils (Hoque and Jahiruddin, 1994). The use of almost S free fertilizers may be an important reason for widespread occurrence of S deficiency problem, and the problem is increasing day by day due to intensive use of agricultural land for crop production in countries like Bangladesh. It is a severe problem in soils which are calcareous in nature with low organic matter content (Rafique et al., 2012). It plays a vital role in the synthesis of amino acids, proteins, and chlorophyll (Tiwari and

Gupta, 2006). Hence, deficiencyof S reduces chlorophyll content and photosynthetic CO_2fixation consequently reduces the growth, development and yield (Jamal et al., 2005; Islam et al., 2017a) as well as quality of crop products (Schonhof et al., 2007). Application of S significantly increased the grain yield of boro rice (Rahman et al., 2008). Majority of the farmers are applied nitrogen, phosphorus and potassium fertilizers but micronutrients are to not consider to increase yield of crops. Micronutrients are also essentially needed and playing specific role up to the maturity of crop plants. Application micronutrient such boron increased yield and quality of crops (David et al., 2005; Rehman et al., 2012; Islam et al., 2017b). It has been reported that application of B significantly increased the grain of rice in different countries like Bangladesh (Jahiruddin et al., 1992, 1995), Pakistan (Khan et al., 2006), USA (David et al., 2005). A marked increase of rice yield with the application of boron was estimated by 22% (Hyder et al., 2012), and 10% (Shorrocks, 1997). Therefore, keeping these points in view, the present investigation was undertaken to evaluate the effect of S and B on growth and yield of boro rice (BRRI dhan28).

2. Materials and Methods

2.1. Experimental site and duration

The experiment was carried out at the research field, Department of Crop Science and Technology, University of Rajshahi, Bangladesh during November 2015 to April 2016.Geographically the experimental site is located at 24°22'36" N latitude and 88°38'27" E longitude with an elevation of 20 meter above the sea level.

2.2. Soil

The experimental area belongs to High Ganges River Floodplain under Agro-Ecological Zone-11 (AEZ-11) and under clay, silty clay soil type and calcareous dark grey floodplain soil (FAO and UNDP, 1988), having pH value of 8.4, low in organic matter content (1.25%). The morphological, physiological and chemical characteristics of the field soil have been presented in Table 1.

Table 1. Physical and chemical characteristics of experimental initial soil and their interpretation according to fertilizer recommendation guide (BARC, 2012)

Properties	Analytical value	Critical level	Soil test values interpretation	Range of value used within the interpretation class
Physical properties				
Sand (%)	20.8	-	-	-
Silt (%)	60.3	-	-	-
Clay (%)	20.9	-	-	-
Textural class	Silty clay loam	-	-	-
Chemical properties				
pH	8.4	-	-	-
Organic matter (%)	1.25	-	-	-
Total nitrogen (%)	0.10	0.12	Very low	≤ 0.09
Available phosphorus (ppm)	16.2	10.00	Medium	7.51-15.0
Potassium (meq/l00g)	0.57	0.12	Very low	0.181-0.27
Available sulphur (ppm)	12.5	10.00	Very low	15.1-22.5
Zinc (ppm)	0.11	0.60	Very low	0.451-0.9
Boron (ppm)	0.23	0.20	Low	≤ 0.15
Magnesium (meq/l00g)	4.30	0.50	Optimum	0.751-1.125
Calcium (meq/l00g)	15.35	2.00	Optimum	≤ 1.5

Source: Soil Resource and Development Institute (SRDI), Regional Centre, Rajshahi (BARC, 2012).

2.3. Climate and weather

The research work was conducted during *Boro* season (November to May). 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 Table 2.

Table 2. Weather information (month wise) in the area of Rajshahi University, Rajshahi during experimentation

Months	Air temperature		Relative humidity (%)	Rainfall (mm)	Sunshine hour (day^{-1})
	Max. (^0C)	Min. (^0C)			
November/2015	29.20	17.97	89.13	3.20	7.43
December/2015	26.07	14.77	90.23	19.70	6.07
January/2016	25.03	11.10	83.67	0.43	6.53
February/2016	29.00	14.10	69.17	0.00	7.00
March/2016	31.20	18.60	74.70	12.67	6.37
April/2016	34.77	23.27	76.40	4.63	7.03
May/2016	35.07	25.10	81.00	2.43	7.23

2.4. Test crop

In this experiment aromatic rice named BRRI dhan28 was used as the test crop. It is a popular variety of boro rice. It takes 140 days for maturity.

2.5. Experimental design and layout

In this study BRRI dhan28 is imposed with three sulphur **(**S_0: 0 kg S ha^{-1}**,** S_1: 20 kg S ha^{-1} and S_2: 30 kg S ha^{-1}), and three boron doses (B_0: 0 kg B ha^{-1}, B_1: 2 kg B ha^{-1} and B_2: 3 kg B ha^{-1}). It was designed by Randomized Complete Block Design (RCBD) having three replications. Recommended doses of other inorganic fertilizers of urea, TSP, and MoP were applied at the rate of 150, 120, and 100 kg ha^{-1}, respectively. 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 29. The size of unit plot was 4.0 m × 2.5 m. The distance between plots, and blocks were 50 and 25cm, respectively.

2.6. Experimentation

Healthy seeds were selected by specific gravity method. Seeds were then immersed in water in a bucket for 24 hours. Then seeds were taken out of water and kept thickly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours of steeping. A piece of high land was selected at the Crop Science and Technology Research Field, University of Rajshahi, for raising seedlings. The land was puddled with country plough, cleaned and leveled with ladder. Then the sprouted seeds were sown in the nursery beds on November, 2015. Weeds were removed and irrigation was provided in the seedling nursery as and when necessary. The experimental land was first opened with a tractor drawn disc plough. The land was then puddled thoroughly by repeated ploughing and cross ploughing with a country plough and subsequently leveled by laddering. Weeds and stubble were cleared off from individual plots and finally plots were leveled so properly by wooden plank that no water pocket could remain in the puddled field. The land was fertilized as per treatment specifications. Well decomposed cow dung was applied 10 days before transplanting. Full dose of TSP and MP as well as gypsum and boric acid as per treatment were applied one day before transplanting. Nitrogen from urea was applied per treatments in three equal splits. The first split of urea was applied as top dressing at 20 days after transplanting (DAT). The second split of urea was applied after 35 DAT, and the third split of urea was applied at 55 DAT. The nursery beds were made wet by application of water one day ahead of uprooting the seedlings. Thirty five days old seedlings were uprooted carefully without causing any mechanical injury to the root and transplanted in the well puddled plot. Three seedlings were transplanted in each hill with a spacing of 25 cm × 15 cm. The intercultural operations were done for ensuring and maintaining normal growth of the crop as per necessary.

2.7. Data collection

Five hills were randomly selected from each plot at maturity to record the yield contributing characters. Plant height, number of total tillers hill^{-1}, panicle length, number of grains panicle^{-1}, number of fertile grains panicle^{-1}, number of sterile grains panicle^{-1}, 1000-grains weight, grain yield (t ha^{-1}) (adjusted to 14% moisture content), straw yield, biological yield and harvest index (%) were measured.

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, MSTAT.

3. Results and Discussion

3.1. Plant height

A significant variation of the plant height was found during the growth stages except harvesting stage due to combined application of S and B fertilizers (Table 3). The application of 20 kg S ha^{-1} + 3 kg B ha^{-1} (S_1B_2) produced the longest plant (38.80, 69.13, 94.77 and 100.30 cm) at 30, 50 and 70 DAT and harvest, respectively. On the other hand, the shortest plant (33.87, 53.17, 86.33 and 89.53 cm, respectively) was found at control condition (S_0B_0). Application of S significantly increased the plant height of rice as reported by Chandel et al. (2002), Samaraweera (2009), Singh et al. (2012), Singh Shivay et al. (2014), Ram et al. (2014), and Amgain et al. (2021). The longest plant of rice was found from 16 kg S/ha applied as gypsum while the shortest plant was noticed without sulphur (Islam et al., 2009). In several studies it has been reported that 20 kg S/ha applied as gypsum produced the highest plant height of rice (Rahman et al., 2008), and 18 kg S/ha applied as gypsum exhibited highest plant height of sesame (Islam et al., 2019).

Sulphur might be greatly increased the plant height through chlorophyll formation which enhance vegetative growth. This result is in agreement with the findings of Kaisher et al. (2010) who reported that sulphur significantly increased the plant height through chlorophyll formation which enhance vegetative growth. B enhanced the differentiation of tissue, cell division and nitrogen absorption from the soil which augment the plant growth, ultimately increased the plant height. Addition of boron remarkably increased the plant height of rice (Shah et al., 2011; Hyder et al., 2012; Amer et al., 2020), seedling height of mung bean plant (Singh et al., 2014; Islam et al., 2017a, 2017b).

Significant effect of S and B on the plant height has also been observed by many researchers in the past for different crops of rice (Uddin et al., 1997; Singh et al., 2011), and mung bean (Islam et al., 2017a). Sulphur has the strong buffering capacity of organic soils (Kaler et al., 2016), which might enhanced the plant growth.

Table 3. Interaction effect of sulphur and boron on the plant height at different DAT

Treatment	Plant height (cm)			
	30 DAT	50 DAT	70 DAT	At harvest
S_0B_0	33.87e	53.17d	86.33 f	89.53 f
S_0B_1	37.77 b	58.43c	88.47e	90.47e
S_0B_2	34.93d	53.37d	89.20de	92.33cd
S_1B_0	37.80b	67.70ab	91.23bc	95.68 c
S_1B_1	38.27ab	68.30ab	92.77 b	97.47 b
S_1B_2	38.80a	69.13a	94.77a	100.30a
S_2B_0	35.l0d	66.77	90.77cd	93.87c
S_2B_1	36.23c	67.37ab	88.47e	94.77c
S_2B_2	37.70b	68.17ab	91.63bc	96.50b
LSD(0.5)	0.9916	1.870	1.641	-
LS	**	**	**	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, 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%. LS: level of significance, ** 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_1= sulphur 20 kg ha^{-1}, S_2= sulphur 30 kg ha^{-1}. Again, B_0= 0 kg boron (control), B_1 = boron 2 kg ha^{-1}, B_2 = boron 3 kg ha^{-1}

3.2. Total number of tillers

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 harvesting. The application of S @ 20 kg ha^{-1} produced the maximum total tillers (11.52, 21.152, 26.89 and 26.184) at 30, 50, 70 DAT and at harvest, respectively, which was significantly differed from others (Table 4). The minimum total tillers (7.593, 17.78, 22.963 and 21.593) were recorded in 0 kg S ha^{-1} at 30, 50, 70 DAT and at harvest, respectively. Tillering is the product of expanding auxiliary buds which is directly connected with the nutritional status of the mother plant during early vegetative growth period. It has been reported that application of sulphur significantly increased the number of total tillers in rice (Chandel et al., 2002; Samaraweera, 2009), wheat (Dewal and Pareek, 2004; Inal et al., 2006). The results indicate that interaction of S and B promoted the number of effective tillers. The results confirm the findings of Haque and Chowdhury (2004), Islam et al. (2009), Ram et al. (2014), who reported that S application significantly increased the number of tillers over the control. Combined application of sulphur and boron increased the effective tillers hill^{-1} of rice by 5% and 144% (Afroz, 2011).

3.3. Panicle length

The combination of S and B application significantly influenced the panicle length of boro rice (Table 5). Panicle length due to different rates of S and B application varied from 18.62 cm to 26.94 cm. However, the maximum panicle length (26.94 cm) was produced by the application of S 20 kg ha^{-1} + B 2 kg ha^{-1}), whereas the minimum panicle length (18.62 cm) was noted with control treatment (without S and B). The Increase in growth and straw yield might be ascribed to cell division, enlargement and elongation resulting in overall improvement in plant organs associated with faster and uniform vegetative growth of the crop under the influence of S implementation. Application of the S up to 30 kg S ha^{-1} significantly increased the panicle length of rice (Chandel et al., 2002; Ram et al., 2014). Application of S increased the plant characteristics like plant height, number of effective tillers which might have enhanced the panicle length. Boron plays a major role in cell division which increases the panicle length. B promotes cell growth and development of the panicle (Garg et al., 1979) which encouraged the panicle length of rice plants. These are in conformity with those reported earlier by Rashid et al. (2004), Ahmad and Irshad (2011), Shukla et al. (2020) who reported that B is beneficial for improving the panicle length of rice. Our results confirm the findings of Mehmood et al. (2009) and Phonglosa et al. (2018).

Table 4. Interaction effect of S and B on total number of tillers at different days after transplanting

Treatments	Number of tillers			
	30 DAT	50 DAT	70 DAT	At harvest
S_0B_0	5.78 f	15.67 e	20.56 e	20.44 e
S_0B_1	8.33 de	18.11 d	22.03 d	21.78d d
S_0B_2	8.67 cd	19.56 cd	24.33 c	22.56 cd
S_1B_0	10.89 b	19.67 cd	25.45 bc	25.36 b
S_1B_1	11.56 ab	22.56 a	28.89 a	28.78 a
S_1B_2	12.11 a	21.31 ab	27.33 ab	27.55 a
S_2B_0	7.67 e	20.11 c	25.38 bc	25.83 b
S_2B_1	8.33 de	21.11 bc	26.78 b	26.67 b
S_2B_2	9.33 c	22.22 bc	25.78 bc	26.55 b
LSD(0.5)	0.927	-	1.283	1.428
LS	*	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%. LS= level of significance, ** 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_1= sulphur 20 kg ha^{-1}, S_2= sulphur 30 kg ha^{-1}; Again, B_0= 0 kg boron (control), B_1 = boron 2 kg ha^{-1}, B_2 = boron 3 kg ha^{-1}

3.4. Grains panicle^{-1}

The number of grains panicle-1increased significantly with the different rates of boron application. Application of S@20 kg ha^{-1} + 3 kg B ha^{-1} (S_1B_2) produced the maximum number of grains panicle^{-1} (176.78) which was at par with the treatment combination of S_1B_1 (20 kg S ha^{-1} + 2 kg B ha^{-1}) (175.57), while the lowest number of grains panicle^{-1} (129.78) was noted with control treatment (S_0B_0). Sulphur nutrient might have given metabolic energy to the plant, which enhanced the grain panicle^{-1} with increasing S fertilization. Chandel et al. (2002) reported that increasing sulphur levels up to 30 kg S ha^{-1} in rice significantly improved grains panicle^{-1}. It has been reported earlier that B is responsible for better pollination, seed setting and grain formation in different rice varieties (Aslam et al., 2002; Rehman et al., 2012). The number of grains panicle^{-1} in rice is increased due to application of B at heading or flowering stage (Hussain et al., 2012). Our results are also certified by Ramanathan et al. (2002), Ziaeyan and Rajaie (2009), Phonglosa et al. (2018), who concluded that B fertilization considerably increased the number of grains panicle^{-1}.

3.5. Fertile grains panicle^{-1}

Interaction effect of sulphur and boron showed significant variation in the number of fertile grains panicle^{-1} (Table 5). The treatment combination of 20 Kg S ha^{-1} + 3 kg B ha^{-1} (S_1B_2) produced the highest number of fertile grains panicle^{-1}

(143.30) which was followed by the treatment combination of S_1B_1 (20 kg S ha^{-1} + 2 kg B ha^{-1}) (141.27). The lowest number of fertile grains $panicle^{-1}$ (89.18) was noted with control treatment (S_0B_0). These results are in conformity with those already reported by Ram et al. (2014), who depicted that S application increased the grains $panicle^{-1}$ and panicle weight due to enhanced shoot growth and dry-matter accumulation. Shukla et al. (2020) concluded that B application in rice significantly increased the filled grains $panicle^{-1}$, and both soil + foliar applied B produced superior results over soil applied alone. This may be attributed to the reason that B is responsible for better seed setting and illustrated significant effect on number of filled grains. The result of the present findings corroborates with the results of Ali et al. (2016), and Rani and Latha (2017), who declared that B increased the number of filled grains $panicle^{-1}$.

3.6. Sterile grains $panicle^{-1}$

The data on sterile grains $panicle^{-1}$ showed significant variance of interaction effect between S and B application levels (Table 5). The sterile grains $panicle^{-1}$ varied from 26.21 to 51.21 due to interaction effect of S and B fertilizers. The maximum number of sterile grains $panicle^{-1}$ (51.21) was found in interaction of S_0B_2 treatment (0 kg S ha^{-1} + 3 kg B ha^{-1}), which was followed by the treatment combination of S_1B_0 (20 kg S ha^{-1} + 0 kg B ha^{-1}) (49.22). The minimum number of sterile grains $panicle^{-1}$ (26.21) found in interaction of S_2B_2 treatment (S 30 kg ha^{-1} + 3 kg B ha^{-1}), followed by the treatment combination of S_1B_1 (20 kg S ha^{-1} with 2 kg B ha^{-1}) (27.30). Afroz (2011) reported that combined application of S and B significantly reduced the number of sterile grains $panicle^{-1}$. It has been reported that B deficiency limits reproductive growth. B induces panicle numbers $plant^{-1}$ and reduces poor grain fertility. These results are in conformity with the findings reported by Ramanathan et al. (2002), and Rashid et al. (2009).

3.7. 1000-grain weight

The interaction effect of S and B on 1000-grain weight of rice was significant (Table 5). Sulphur application @20kg S ha^{-1} along with 2 kg B ha^{-1} provided the maximum 1000-grain weight (29.75g), while the minimum weight (21.68 g) was recorded S_0B_0 treatment combination (control), followed by the treatment combination of S_2B_2 (30 kg S ha^{-1} with 3 kg B ha^{-1}) (22.37 g) and S_0B_1 (0 kg S ha^{-1} with 2 kg B ha^{-1}) (22.42 g). Carbohydrate metabolism, sugar and starch formation greatly influenced by boron, which increased the size and weight of grain. Yield attributes like grains/panicle and test weight were significantly increased by the application of S in rice field, and the highest 1000-grains weight was recorded up to 30 kg S ha^{-1} (Chandel et al., 2002). Boron application significantly increased the 1000-grains weight of rice (Shukla et al., 2018). Reduction of sterile grains $panicle^{-1}$due to addition of B might be the reason for increasing 1000-grains weight. Similar result was confirmed by Rashid (2006), Rahmatullah et al. (2006), Patel et al. (2020), Shukla and Singh (2020), wherein it was concluded that foliar application of B increased the 1000-grains weight.

3.8. Grain yield

The grain yield of rice showed a significant variation due to the combined application of S and B. The highest grain yield (6.30 t ha^{-1}) was recorded from the application of S@20 kg S t ha^{-1} + 2 kg B t ha^{-1} (S_1B_1), while the lowest grain yield (2.02 t ha^{-1}) were found from S_0B_0 treatment (control) (Table 6). Boron enhanced the pollination by creating the stigma receptive and sticky that helps in grain fertility. Number of grains $panicle^{-1}$ increased due to reduction of flower sterility. Afroz (2011) have reported that application of S and B in addition of N, P, K, and Zn significantly increased the grain yield of rice (BRRI dhan30). Application of S with other fertilizers significantly increased the grain yield of rice (Mondal et al., 2004; Saha et al., 2007; Rahman et al., 2008; Singh et al., 2012; Ram et al., 2014). Amin et al. (2004) reported that application of B fertilizers in addition to N, P and K showed significant increase the yield contributing attributes and yield of rice. The pattern of grain yield was similar to that of yield contributing traits. Application of S and B might be promoted growth of plants which directly produced longer panicle, higher number of grains panicle^{-1} and 1000-grain weight (Table 5). The result obtained in grain yield is in accordance with the findings of Hussain et al. (2012), Shukla et al. (2018), and Phonglosa et al. (2018). It has been reported earlier that boron encourages fertilization in grain crops like cereals and oilseeds (Garg et al., 1979; Subedi et al., 1997; Hanifuzzaman et al., 2022), which might have increased the grain yield of rice due to lower sterility percentage (Fig. 1). 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. The higher pollen infertility and lower grain filling due to lack of B might be responsible for lower grain yield of rice (Rashid et al., 2004).

Table 5. Effect of S and B on panicle length, grains panicle^{-1}, fertile grains panicle^{-1}, sterile grains panicle^{-1}, and 1000-grains weight

Treatments	Panicle length (cm)	Grains panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000-grain weight (g)
S_0B_0	18.62 f	129.78 d	89.18 d	40.60 a	21.68 d
S_0B_1	20.58 e	140.56 c	104.67 c	35.89 b	22.42 d
S_0B_2	21.82 d	144.48 c	110.27 c	34.21 b	23.37 cd
S_1B_0	23.22 c	148.33 c	109.11 c	39.22 a	26.67 b
S_1B_1	26.94 a	175.57 a	141.27 a	34.30 b	28.75 a
S_1B_2	25.78 ab	176.78 a	143.30 a	33.48 b	27.18 ab
S_2B_0	25.14 b	170.67 ab	131.55 b	39.12 a	25.23 bc
S_2B_1	24.98 b	163.78 b	138.44 b	25.34 c	23.55 cd
S_2B_2	24.16 bc	164.33 b	139.12 b	25.21 c	22.37 d
LSD(0.5)	1.022	2.01	15.25	5.416	2.588
LS	**	**	*	**	**
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%. LS: level of significance, ** indicates significant at 1 % level of probability, CV (%) = Co-efficient of variation, DAT = Days after transplanting; S_0= 0 kg sulphur (control), S_1= sulphur 20 kg ha^{-1}, S_2= sulphur 30 kg ha^{-1}; Again, B_0= 0 kg boron (control), B_1 = boron 2 kg ha^{-1}, B_2 = boron 3 kg ha^{-1}

3.9. Straw yield

Result presented in Table 6 showed that interaction effect of S and B were significantly influenced the straw yield. The highest straw yield (6.41 t ha^{-1}) was noticed from S_1B_1 (20 kg S t ha^{-1} with 2 kg B t ha^{-1}) treatment, and the lowest straw yield (3.96 t ha^{-1}) was recorded from S_0B_0 (control) treatment. Hossain et al. (1997), Afroz (2011) concluded that combined application of S and B along with N, P and K increased the straw yield of rice. The findings of this character agree with the result obtained by Shah et al. (2009). Rahmatullah et al. (2006) reported that the straw yield was increased by boron application.

3.10. Biological yield

Combined application of sulphur and boron showed a significant variation in biological yield (Table 6). The highest biological yield (12.71 t ha^{-1}) was recorded from S_1B_1 (20 kg S t ha^{-1} with 2 kg B t ha^{-1}) treatment, and the lowest biological yield (5.98 t ha^{-1}) was observed from S_0B_0 treatment (control). The variation result on the biological yield of rice was found due to the variation in sulphur which result supported by Zayed et al. (2017). Remarkable increase of biological yield of rice owing to application of S was also noted by Singh et al. (2012). B also showed the better result for enhancing the biological yield of rice. The same findings also reported by Ziaeyan and Rajaie (2009), and Shukla et al. (2018). Greater biological yield may be attributed due to the higher values of grain and straw yields under S and B fertilization.

3.11. Harvest index

Analysis of variance data regarding to harvest index was significantly influenced by the interaction effect of S and B (Table 6). The highest harvest index (49.57%) was recorded from S_1B_1 treatment, which was statistically identical with the S_1B_1 treatment, and the lowest harvest index (33.78%) was observed from S_0B_0 treatment (control). S and B fertilizers played an important role for increasing the grain yield and consequently increased the harvest index. These results were at par with that of Hussain et al. (2012), Kumar et al. (2015), and Islam et al. (2017a) who reported that S and B significantly increased the harvest index of crops.

Table 6. Interaction effect of sulphur and boron on yield characters and HI at harvest

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_0B_0	2.02 e	3.96 c	5.98 d	33.78 d
S_0B_1	3.21 d	4.61 cd	7.82 c	41.05 c
S_0B_2	3.94 cd	5.51 bc	9.45 b	41.59 c
S_1B_0	4.74 bc	5.66 bc	10.40 b	45.58 b
S_1B_1	6.30 a	6.41 a	12.71 a	49.57 a
S_1B_2	5.33 ab	5.86 ab	11.19 ab	47.63 ab
S_2B_0	3.02 d	4.59 cd	7.6l c	39.68 c
S_2B_1	4.56 bc	5.75 ab	10.31 b	44.23 b
S_2B_2	4.18 cd	5.38 bc	9.56 b	43.72 bc
LSD(0.5)	1.164	1.118	1.798	4.497
LS	**	**	**	**
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%. LS: level of significance, ** indicates significant at 1 % level of probability, CV (%) = Co-efficient of variation, DAT = Days after transplanting; S_0= 0 kg sulphur (control), S_1= sulphur 20 kg ha^{-1}, S_2= sulphur 30 kg ha^{-1}. Again, B_0= 0 kg boron (control), B_1 = boron 2 kg ha^{-1}, B_2 = boron 3 kg ha^{-1}

4. Conclusion

Application of and S and B improved the panicle length, number of grains panicle-1, filled grains panicle^{-1}, 1000-grain weight, grain yield, straw yield and harvest index. The results revealed that the addition of S @20 kg S t ha^{-1} + 2 kg B t ha^{-1} (S_1B_1) produced the highest grain yield and harvest index followed by S @20 kg S t ha^{-1} + 2 kg B t ha^{-1} (S_1B_2). Therefore, 20 kg S t ha^{-1} + 2 kg B t ha^{-1} can be applied in the soil to harvest higher grain yield of BRRI dhan28 in calcareous soil.

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.

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