ISSN 2518–2021 (Print) 2415–4474 (Electronic)

Fundamental and Applied Agriculture

Journal home page: https://www.f2ffoundation.org/faa/index.php/home

Vol. 9(3), pp. 232 – 239: 2024, doi: https://doi.org/10.5455/faa.225490

CROP SCIENCE | ORIGINAL ARTICLE

Enhancing Productivity of Aromatic Winter Rice Through Boron Management

Alok Kumar Mahato, Sabina Yeasmin, Babli Rani Deb, F M Jamil Uddin, Md Harun Rashid, Swapan Kumar Paul ✉

Department of Agronomy, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

ARTICLE INFO

Article history
Received: 03 Jul 2024
Accepted: 13 Sep 2024
Published online: 30 Sep 2024

Keywords
Micronutrient,
Yield components,
Grain yield,
Productivity

Correspondence
Swapan Kumar Paul
✉: skpaul@bau.edu.bd

ABSTRACT

Boron (B) is one of the most important micronutrients for plants which play vital role in various metabolic process. Boron deficiency in rice has been widely reported in many rice growing regions of the world including Bangladesh. Therefore, a field experiment was carried out at the Agronomy Field Laboratory of Bangladesh Agricultural University, Bangladesh during the period from November 2022 to May 2023 to study the effect of different levels of B on aromatic *Boro* (winter rice) rice (cv. BRRI dhan50. The experiment comprised ten treatments *viz.* control (0 kg B ha^{-1}), 2.0 kg B ha^{-1} (basal), 4.0 kg B ha^{-1} (basal), 6.0 kg B ha^{-1} (basal), 1.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 DAT), 2.0 kg B ha^{-1} (basal) + 2.0 kg B ha^{-1} (soil application at 30 DAT), 3.0 kg B ha^{-1} (basal) + 3.0 kg B ha^{-1} (soil application at 30 DAT), 1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage), 2.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 DAT) + 1.0 kg B ha^{-1} (foliar application at flag leaf stage) and 3.0 kg B ha^{-1} (basal) + 1.5 kg B ha^{-1} (soil application at 30 DAT) + 1.5 kg B ha^{-1} (foliar application at flag leaf stage). The experiment was laid out in Randomized Complete Block Design with three replications. The yield contributing characters and yield were significantly influenced by different levels of B. The highest number of total tillers hill^{-1} (14.65), effective tillers hill^{-1} (12.75) and grains panicle^{-1} (106.66) were obtained from 1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage). The highest grain (5.38 t ha^{-1}) and straw (6.27 t ha^{-1}) yields were also obtained from the same treatment which was at par with the treatment 2.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 DAT) + 1.0 kg B ha^{-1} (foliar application at flag leaf stage) whereas the lowest values were found in control. Results indicated that 1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage) appears as the promising practice in terms of grain yield of aromatic *Boro* rice (cv. BRRI dhan50).

1. Introduction

Rice (*Oryza sativa* L.) is the third major food grain worldwide and consumed as a staple food by more than half of the world's population (Sen et al., 2020). Most of the farmers prefer rice cultivation over other crops due to its wide adaptability to different ecosystems and low cultivation risk. The world population is increasing and it is estimated that 14,886 million tonnes (MT) of food will need to be produced in 2050 to meet food demand (Islam and Karim, 2019). Worldwide 503.17 MT rice is produced where China produces 29.5% of the total, followed by India (23.8%), Bangladesh (7.0%), Indonesia (6.9%), Vietnam (5.4%), and Thailand (3.7%) (Al Mamun et al., 2021). Rice is also the staple food of Bangladesh and accounts for about 78% of the country's total net cropped area cultivated (BBS, 2022). The production of rice is essential to Bangladesh's food security. Rice is cultivated in three seasons in Bangladesh namely *Aman* (monsoon rice), *Aus* (summer rice), and *Boro* (winter rice). Among them *Boro* is the leading one, heavily reliant on irrigation and fertilizers, followed by *Aman* and *Aus*. Over the past few decades, there has been a noticeable decrease in the amount of agricultural land due to increasing urbanization, industrialization, and population growth. Therefore, researchers are very much concern about maximization of productivity and quality of rice.

Micronutrient especially boron (B) plays a vital role in the crop productivity. Boron application in soil and foliar both are influences the production of field crops (Bithy et al., 2020; Hanifuzzaman et al., 2022; Dey, et al., 2023; Raku et al., 2023). Numerous researches have demonstrated that soils lacking in micronutrients, such as B, serve as a

Cite This Article
Mahato AK, Yeasmin S, Deb BR, Uddin FMJ, Rashid MH, Paul SK. 2024. Enhancing Productivity of Aromatic Winter Rice Through Boron Management. *Fundamental and Applied Agriculture*, 9(3): 232–239. https://doi.org/10.5455/faa.225490

limiting factor in rice production (Ferdous et al., 2003; Hussain et al., 2012; Farooq et al., 2018; Nadeem et al., 2019). It was initially discovered that B was a necessary ingredient for plants. During the initial phases of plant growth and development, B was identified as an essential mineral that was engaged in numerous biological processes (Ahmad et al., 2009). Boron plays a crucial part in protein metabolism, pectin synthesis, regulating water balance within the plant, facilitating ATP synthesis, and facilitating the movement of sugars during the flowering and fruiting phases. Additionally, B affects a wide range of plant processes, including hormone production, active salt absorption, fruit and flowering development, pollen germination, carbohydrate metabolism, nitrogen metabolism, and water relations (Shireen et al., 2018). Boron is responsible for better pollination, seed setting and grain formation in rice (Lordkaew et al., 2013; Rehman et al., 2012), making it more important during the reproductive stage as compared to the vegetative stage of the crop and found 90% of the boron in plants is localized in the cell walls (Loomis and Durst, 1992). However, a number of studies have demonstrated that a B deficit in plants can result in male sterility and failure of the grain set (Rerkasem et al., 2004), inhibition of root growth and disrupts cell membranes (Mousavi et al., 2022). Boron application to rice fields (boron deficient soil) increased rice growth and grain yields (Rehman et al., 2015). Therefore, optimization of B levels for rice cultivation is necessary to increase its productivity. Therefore, this study was undertaken to find out the effect of B management on the yield performance of aromatic *Boro* rice (cv. BRRI dhan50).

2. Materials and Methods

2.1. Experimental location and experimentation

The study was conducted at the Agronomy Field Laboratory (latitude of 24° 75′ North and longitude of 90° 50′ East), Bangladesh Agricultural University, Mymensingh, Bangladesh. The research plot belongs to the Old Brahmaputra Flood plain soil (AEZ 9) having of pH 6.82 and low in organic matter content (1.19%). The study area is characterized by high temperature, high humidity and heavy precipitation in summer season and moderate rainfall associated with moderately low temperature during winter (Figure 1).

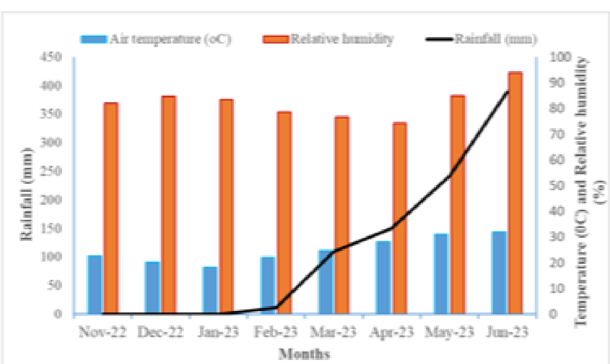

Figure 1. Distribution of monthly rainfall, temperature and relative humidity pattern of the experimental site during the crop growth period

2.2. Experimental treatments and design

The study comprises ten treatments including control *viz* T_0: 0 kg B ha^{-1} (control), T_1: 2.0 kg B ha^{-1} (basal),T_2: 4.0 kg B ha^{-1} (basal), T_3: 6.0 kg B ha^{-1} (basal), T_4: 1.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 days after transplanting), T_5: 2.0 kg B ha^{-1} (basal) + 2.0 kg B ha^{-1} (soil application at 30 DAT), T_6: 3.0 kg B ha^{-1} (basal) + 3.0 kg B ha^{-1} (soil application at 30 DAT), T_7: 1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage) , T_8: 2.0 kg B ha^{-1} (basal)+ 1.0 kg B ha^{-1} (soil application at 30 DAT) + 1.0 kg B ha^{-1} (foliar application at flag leaf stage), $T_{9:}$ 3.0 kg B ha^{-1} (basal) + 1.5 kg B ha^{-1} (soil application at 30 DAT) + 1.5 kg B ha^{-1} (foliar application at flag leaf stage). The study was structured using a Randomized Complete Block Design and replicated thrice. The research was conducted with 30 plots and all plots measured 2.5 m × 2.0 m. Plot to plot distance was 0.5 m and block to block distance was 1.0 m. The treatments were randomly distributed across the plots.

2.3. Crop husbandry

BRRI dhan50 was selected as test crops of the research which has long, slender grains and delightful aroma. Quality seeds of *Boro* rice cv. BRRI dhan50 was collected from the Bangladesh Rice Research Institute (BRRI), Gazipur. The gravity method is employed to choose robust and weighty seeds. Subsequently, the selected seeds were undergone a 24 hour soaking period in a water filled bucket. Afterward, they were taken out of the water and placed inside a jute bag. Seeds were begun to germinate after 48 hours and sown after 72 hours in the nursery bed. The experimental plots were fertilized with @ 150, 100, 100, 60 kg ha^{-1} of urea, triple super phosphate, muriate of potash and gypsum, respectively. Except urea, the entire amount of triple super phosphate, muriate of potash and gypsum were broadcast and incorporated into the soil at final land preparation. Urea was top dressed in three equal installments at 15, 30 and 45 days after transplanting (DAT). Nursery bed was made wet by application of water on the previous day before uprooting the seedlings. Seedlings of 45 days old were pulled out of the nursery in the early morning of transplanting day. The seedlings were arranged at intervals of 25 cm by 15 cm within each cluster with 2-3 seedlings per cluster. Irrigation was carried out as necessary to ensure that the field retains adequate moisture. Seedlings in some hills died off and those were replaced by gap filling after 15 DAT the seedlings from the same source. Weeding was done at 20 DAT followed by second one at 45 DAT. Excess water was removed from the field at 15 days before harvest. When the panicle emerged out the water was supplied at 5-7 cm depth to all the plots.

2.4. Data collection

The harvesting was conducted at the point of full maturity marked by 90% of the seeds displaying a golden yellow in color. Excluding border hills, the data on various vegetation characteristics was documented through the random selection of five hills as of every plot. The produce harvested from each plot was individually grouped, appropriately tagged and dispatched to the place where it was threshed. The grains were threshed, cleaned, weighed, and the plot wise grain yield was documented. The straws were cleaned, dried and weighed to determine the yield. Subsequently, the paddy and straw production in plot $^{-1}$ were transformed into t ha^{-1}. Plant characters and yield components were collected from five randomly selected sample plants from each plot, and the grain yield, straw yield, biological yield and harvest index were recorded from the whole plot.

2.5. Statistical analysis

The data were compiled and tabulated in proper form for statistical analysis. The recorded data on various plant characters were statistically analyzed to find out the significance of variation resulting from the experimental treatments. Analysis of variance was done with the help of Statistix 10 computer package programme. The difference among treatment means was compared by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

3. Results

3.1. Plant height

The variation of plant height was remarkably subjective with the different level of B (Table 1). The experimental results showed that the tallest plant (84.36 cm) was recorded in T_7 [1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage)] which was identical to T_2 (83.62 cm), T_3 (83.07 cm), T_5 (80.67 cm), T_8 (82.33 cm) and T_9 (83.09 cm) while the shortest plant (79.24 cm) was recorded from control which was statistically identical to T_1 (79.62 cm) and T_4 (79.25 cm) (Table 1).

3.2. Number of total tillers hill^{-1}

Various treatments had a notable impact on number of total tillers hill^{-1} (Table 1). The findings showed that the highest number of total tillers hill^{-1} (14.65) was found in T_7 [1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage)] which was statistically identical with T_8 (14.10) [2.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 DAT) + 1.0 kg B ha^{-1} (foliar application at flag leaf stage)] whereas the lowest number of total tillers hill^{-1} (9.73) was recorded in control (Table 1).

3.3. Number of effective tillers hill^{-1}

Boron management on BRRI dhan50 demonstrated variability in the number of effective tillers hill^{-1} (Table 1). The highest number of effective tillers hill^{-1} (12.75) was recorded from T_7 [1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage)] followed by T_8 [2.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 DAT) + 1.0 kg B ha^{-1} (foliar application at flag leaf stage)] where the lowest number of effective tillers hill^{-1} (7.00) was recorded from control.

3.4. Number of non-effective tillers hill^{-1}

The diverse B treatments showed statistically significant impact on the overall count of non-effective tillers hill^{-1} of BRRI dhan50 (Table 1). The highest number of non-effective tillers hill^{-1} (2.73) was recorded from control which was identical to T_6 (2.24) [3.0 kg B ha^{-1} (basal) + 3.0 kg B ha^{-1} (soil application at 30 DAT)] while the lowest number of non-effective tillers hill^{-1} (1.16) was recorded from T_5 [2.0 kg B ha^{-1} (basal) + 2.0 kg B ha^{-1} (soil application at 30 DAT)] (Table 1).

3.5. Panicle length

The experimental findings showed that different B applications did not exhibit a statistically significant distinction in the panicle lengths of BRRI dhan50 (Table 1). The longest panicle length (22.30 cm) was found in T_3 [6.0 kg B ha^{-1} (basal)] while the shortest panicle length (21.22 cm) was recorded in T_0 (control) (Table 1).

3.6. Number of grains panicle^{-1}

Grains panicle^{-1} was significantly affected by application of B in BRRI dhan50 (Table 1). The highest number of grains panicle^{-1} (106.66) was recorded from T_7 [1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage)] followed by T_8 (104). where the lowest total grains panicle^{-1} (86.75) was recorded from control.

3.7. Number of sterile spikelets panicle^{-1}

The B fertilizer levels led to a notable influence on the number of sterile spikelets panicle^{-1} in BRRI dhan50 (Table 2). Result showed that the highest number of sterile spikelets panicle^{-1} (25.65) was recorded from control followed by T_1 (23.62) [2.0 kg B ha^{-1} (basal)] where the lowest number of sterile spikelets panicle^{-1} (13.57) was recorded from T_7 [1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage)] (Table 2).

3.8. 1000-grain weight

Significant variation was observed by the application of B in terms of 1000 seed weight of *Boro* rice BRRI dhan50 (Table 2). The highest 1000-grain weight (19.27 g) was found in T_7 [1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage)] which was statistically identical with T_3 (18.91g), T_5 (18.96 g), T_8 (19.17 g) and T_9 (18.90 g) where the lowest 1000-grain weight (17.22 g) was recorded from control (Table 2).

Table 1. Effect of boron on crop characters and yield contributing characters of Boro rice (BRRI dhan50)

Treatments	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)
T_0	79.24c	9.73e	7.00g	2.73a	21.22	86.75i
T_1	79.62c	11.49d	9.41f	2.08bc	21.56	90.11h
T_2	83.62ab	11.90cd	10.59de	1.31de	21.53	93.89f
T_3	83.07abc	13.75b	11.87c	1.88bcd	22.30	95.73e
T_4	79.25c	12.41c	10.92d	1.49cde	21.75	92.28g
T_5	80.67abc	11.67d	10.51e	1.16e	21.96	96.63d
T_6	80.33bc	13.92b	11.68c	2.24ab	22.03	98.30c
T_7	84.36a	14.65a	12.75a	1.90bcd	22.16	106.66a
T_8	82.33abc	14.10ab	12.35b	1.75bcde	21.76	104.00b
T_9	83.09abc	12.00cd	10.52e	1.48de	22.05	92.28g
$LSD_{(0.05)}$	3.95	0.56	0.39	0.59	1.48	0.55
Level of Sig.	**	**	**	**	NS	**
CV%	2.81	2.63	2.14	9.15	3.97	3.34

Here in the column having similar letter does not differ significantly as per DMRT; ** = Significant at 1% level of probability; NS= Not Significant T0: 0 kg B ha^{-1} (control), T1: 2.0 kg B ha^{-1} (basal),T2: 4.0 kg B ha^{-1} (basal), T3: 6.0 kg B ha^{-1} (basal), T4: 1.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 days after transplanting), T5: 2.0 kg B ha^{-1} (basal) + 2.0 kg B ha^{-1} (soil application at 30 DAT), T6: 3.0 kg B ha^{-1} (basal) + 3.0 kg B ha^{-1} (soil application at 30 DAT), T7: 1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage) , T8: 2.0 kg B ha^{-1} (basal)+ 1.0 kg B ha^{-1} (soil application at 30 DAT) + 1.0 kg B ha^{-1} (foliar application at flag leaf stage), T9: 3.0 kg B ha^{-1} (basal) + 1.5 kg B ha^{-1} (soil application at 30 DAT) + 1.5 kg B ha^{-1} (foliar application at flag leaf stage).

Table 2. Effect of boron management on yield attributes, biological yield and harvest index of Boro rice (BRRI dhan50)

Treatments	Sterile spikelets panicle^{-1} (no.)	1000-grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
T_0	25.65a	17.22e	7.78f	39.96d
T_1	23.62b	17.79d	10.30bc	44.05abc
T_2	20.11c	18.33c	10.12bcd	42.53cd
T_3	19.97c	18.91ab	10.01cd	47.35a
T_4	22.35b	17.79d	10.62b	43.96bc
T_5	19.97c	18.96a	9.63de	43.92bc
T_6	19.04cd	18.56bc	10.28bc	43.82bc
T_7	13.57e	19.27a	11.65a	46.15ab
T_8	17.18d	19.17a	11.28a	45.64abc
T_9	18.59cd	18.90ab	9.24e	42.48cd
$LSD_{(0.05)}$	1.98	0.37	0.55	3.32
Level of Sig.	**	**	**	**
CV%	5.77	3.17	3.22	4.40

Here in the column having similar letter does not differ significantly as per DMRT; ** = Significant at 1% level of probability, NS= Not Significant; T0: 0 kg B ha^{-1} (control), T1: 2.0 kg B ha^{-1} (basal),T2: 4.0 kg B ha^{-1} (basal), T3: 6.0 kg B ha^{-1} (basal), T4: 1.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 days after transplanting), T5: 2.0 kg B ha^{-1} (basal) + 2.0 kg B ha^{-1} (soil application at 30 DAT), T6: 3.0 kg B ha^{-1} (basal) + 3.0 kg B ha^{-1} (soil application at 30 DAT), T7: 1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage) , T8: 2.0 kg B ha^{-1} (basal)+ 1.0 kg B ha^{-1} (soil application at 30 DAT) + 1.0 kg B ha^{-1} (foliar application at flag leaf stage), T9: 3.0 kg B ha^{-1} (basal) + 1.5 kg B ha^{-1} (soil application at 30 DAT) + 1.5 kg B ha^{-1} (foliar application at flag leaf stage).

3.9. Grain yield

Application of B led to a notable influence on the grain yield of *Boro* rice (BRRI dhan50). The highest grain yield (5.38 t ha^{-1}) was found in T_7 [1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage)] which was identical to T_8 (5.15 t ha^{-1}) [2.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 DAT) + 1.0 kg B ha^{-1} (foliar application at flag leaf stage] while the lowest grain yield (3.11 t ha^{-1}) was recorded from control (Figure 2).

3.10. Straw yield

Application of B led to a notable influence on straw yield of *Boro* rice, BRRI dhan50 (Figure 3). The highest straw yield (6.27 t ha^{-1}) was recorded in T_7 [1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage)] which was identical to T_8 (6.13 t ha^{-1}). where the lowest straw yield (4.67 t ha^{-1}) was recorded from control.

3.11. Biological yield

Application of B was significantly influenced the biological yield of BRRI dhan50. Result showed that the highest biological yield ha^{-1} (11.65 t) was found in T_7 [1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage)] which was identical to T_8 (11.28 t ha^{-1}) [2.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 DAT) + 1.0 kg B ha^{-1} (foliar application at flag leaf stage)] while the lowest biological yield (7.78 t ha^{-1}) was recorded from control (Table 2).

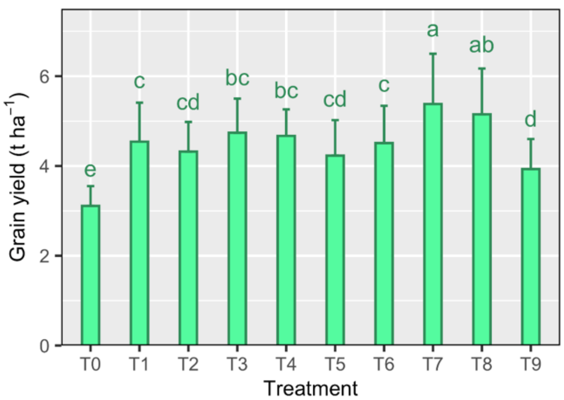

Figure 2. Effect of boron management on the grain yield of Boro rice. Bar represents standard errors of means. T0: 0 kg B ha^{-1} (control), T1: 2.0 kg B ha^{-1} (basal),T2: 4.0 kg B ha^{-1} (basal), T3: 6.0 kg B ha^{-1} (basal), T4: 1.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 days after transplanting), T5: 2.0 kg B ha^{-1} (basal) + 2.0 kg B ha^{-1} (soil application at 30 DAT), T6: 3.0 kg B ha^{-1} (basal) + 3.0 kg B ha^{-1} (soil application at 30 DAT), T7: 1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage) , T8: 2.0 kg B ha^{-1} (basal)+ 1.0 kg B ha^{-1} (soil application at 30 DAT) + 1.0 kg B ha^{-1} (foliar application at flag leaf stage), T9: 3.0 kg B ha^{-1} (basal) + 1.5 kg B ha^{-1} (soil application at 30 DAT) + 1.5 kg B ha^{-1} (foliar application at flag leaf stage).

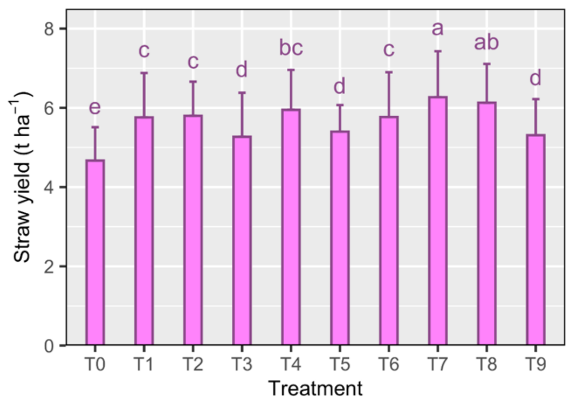

Figure 3. Effect of boron management on the straw yield of Boro rice. Bar represents standard errors of means. T0: 0 kg B ha^{-1} (control), T1: 2.0 kg B ha^{-1} (basal),T2: 4.0 kg B ha^{-1} (basal), T3: 6.0 kg B ha^{-1} (basal), T4: 1.0 kg B ha^{-1} (basal) + 1.0 kg B ha^{-1} (soil application at 30 days after transplanting), T5: 2.0 kg B ha^{-1} (basal) + 2.0 kg B ha^{-1} (soil application at 30 DAT), T6: 3.0 kg B ha^{-1} (basal) + 3.0 kg B ha^{-1} (soil application at 30 DAT), T7: 1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage) , T8: 2.0 kg B ha^{-1} (basal)+ 1.0 kg B ha^{-1} (soil application at 30 DAT) + 1.0 kg B ha^{-1} (foliar application at flag leaf stage), T9: 3.0 kg B ha^{-1} (basal) + 1.5 kg B ha^{-1} (soil application at 30 DAT) + 1.5 kg B ha^{-1} (foliar application at flag leaf stage).

3.12. Harvest index

Application of B led to a notable influence on harvest index of *Boro* rice (BRRI dhan50). The highest harvest index (47.35%) was recorded from T_3 [6.0 kg B ha^{-1} (basal)] which was statistically similar with T_1 (44.05 %), T_7 (46.15%) and T_8 (45.64%) where the lowest harvest index (39.96%) was achieved from control which was identical to T_2 (42.53%) and T_9 (42.48%) (Table 2).

4. Discussion

This study indicates that B application significantly influences on yield and yield related traits of BRRI dhan50. Boron application exhibited that superior grain yields and yield contributing characters and harvest index when compared to control. The study reveals that the basal application of B @ 1.0 kg ha^{-1} + soil application at 30 DAT @ 0.5 kg ha^{-1} + foliar application at flag leaf stage @ 0.5 kg B ha^{-1} resulted tallest plant, number of total tillers hill^{-1}, effective tillers hill^{-1}, grains panicle^{-1}, 1000-grain weight, grain yield, straw yield and biological yield (Tables 1, 2 and Figures 2, 3). Conversely the highest non-effective tillers hill^{-1} and sterile spikelets panicle^{-1} recorded from control. Boron is an essential micronutrient that supports various physiological functions, including cell wall formation, pollen tube growth, and seed setting. Boron application improved plant height and tillering intensity in rice, which can be explained by the active involvement of B in meristematic growth of plant (Bohnsack and Albert, 1977). This may have resulted increased cell division and elongation (Mouhtaridou et al., 2004), resulting in taller plants and improved tillering of rice.

Previous studies documented that plant height increased significantly in terms of foliar and basally applied B fertilizer. It is a well-known fact that B is essential in enhancing carbohydrate metabolism, sugar transport, cell wall structure, protein metabolism, root growth and stimulating other physiological processes of plant that helped to trigger the plant height (Kumar et al., 2015). Similar trend of results on plant height were also achieved by Saleem et al. (2010), Shafiq and Maqsood (2010) and Khan et al. (2007). Positive effect on effective tillers hill^{-1} was reported by Saleem et al. (2011) which was explained by the proper development and differentiation of tissue as B affects the deposition of cell wall material by altering membrane properties. Corrêa et al. (2006) observed that appropriate B availability in soils favors root growth and a sufficient supply of this micronutrient is very important for adequate rice plant development. The result was consistent with the findings of Khan et al. (2007); Rashid et al., (2004) who reported that B application significantly affected the plant growth. We observed that B application improved the panicle fertility while more panicle sterility was observed in B control plots (Table 2). Sterility is induced by B deficiency in many species of monocots and dicots, especially in cereals (Dell and Huang, 1997), which reduces pollen viability (Subedi et al.,1998; Shahid et al.,

2018) and resulted an empty, misshaped, shriveled pollen grains, or maybe normal in shape but lack reserves of storage materials such as starch (Dell and Huang, 1997; Lordkaew et al*.,* 2010). Rashid et al*.* (2004) observed that there was a substantial increase in grain yield of rice varieties due to reduced panicle sterility after B application. Ali et al*.* (2016) and Saleem et al*.* (2010) reported that the supplemental application of B during panicle formation stage increase the number of filled grains panicle^{-1} while lack of B during this stage could increase the number of unfilled grains.

Maximum yield-related parameters were improved by B application (Table 1 and 2) which might be due to role of B in reproductive growth, especially flowering, better fruit and seed set resulting in better yields (Noppakoonwong et al., 1997). Improvement in yield contributing parameters due to B application resulted in improved grain yield which might be the result of a greater number of productive tillers, increased grain weight and reduced panicle sterility. The 1000-grain weight was increased by B application (Table 2) which was in line with the findings of other researchers (Rashid et al*.*, 2004; Soleimani, 2006; Khan et al*.*, 2007; Saleem et al*.*, 2010; Shafiq and Maqsood, 2010). This increased 1000-grain weight of rice with the increasing level of B fertilizer was explained as the B addition influenced pollination process which ultimately increased seed production in panicle. Grain yield also increased by B application (Figure 2) and these outcomes are correlated with Shafiq and Maqsood (2010), Murralidharan and Jose, 2013, Fakir et al*.* (2016) and Patil et al*.* (2017) who obtained maximum grain yield in rice crop with B addition.

Boron is essentially involved in a number of biochemical processes, such as respiration, pollen viability, lignification, sugar transport, carbohydrate metabolism, and nucleotide synthesis, its directly impacts panicle production and, consequently, rice yield (Dobermann and Fairhurst, 2000). According to Hussain et al*.* (2012), a higher number of grains panicle^{-1} and a 1000-grain weight may have a direct impact on the maximum grain production achieved by applying B to the leaves during the blooming stage. Numerous researches suggest that applying boron to rice at the heading or blooming stage improved the number of grains panicle^{-1} and the yield of rice grains (Ramanathan et al*.,* 2002; Hussain et al*.*, 2012; Shukla et al*.*, 2020; Bodeerath et al., 2024).

Application of B also positively influenced the biological and straw yield of rice (Table 2 and Figure 3). This is consistent with findings by Saleem et al. (2011), who reported the highest straw yield at 3 kg B ha^{-1} compared to the control. These results align with the study by Rashid et al. (2007). The increase in rice straw yield can be attributed to the role of B in improving membrane function, which enhances the transport of essential metabolites for growth and development, as well as the activity of membrane-bound enzymes, leading to a higher straw yield. Harvest index was too influenced positively with boron application (basal) (Table 2) which is correlated with the outcomes of Tahir et al*.* (2009) who mentioned that applying B significantly enhanced the harvest index. Boron nutrition is more important during the reproductive stage as compared to the vegetative stage of the crop in cereals (Poza-viejo et al*.*, 2018). Improvement in harvest index resulted from B application might be due to better starch utilization that results in higher seed setting and translocation of assimilates to developing grains, which increases the grain size and number of grains per panicle (Hussain et al*.*, 2012). The combination of basal application, soil application at 30 DAT, and foliar application at the flag leaf stage ensures that boron is available during critical growth stages, maximizing its beneficial effects on crop characters, yield components and rice yield.

5. Conclusion

Application of B at various level significantly improved the growth and yield of *Boro* rice (BRRI dhan50). The highest plant height, total grains panicle^{-1}, effective tillers, 1000-grain weight, grain yield, straw yield, and biological yield were recorded in when B was applied @ 1.0 kg B ha^{-1} (basal) + 0.5 kg B ha^{-1} (soil application at 30 DAT) + 0.5 kg B ha^{-1} (foliar application at flag leaf stage). This approach not only enhances yield but also improves plant characteristics and yield-related traits compared to no additional boron supplementation. So, it should be concluded that applied B @1.0 kg ha^{-1} (basal) + 0.5 kg ha^{-1} (soil application at 30 DAT) + 0.5 kg ha^{-1} (foliar application at flag leaf stage) increases yield and yield contributing characters of rice crop under B deficient soils. Foliar application of B should be recommended as effective management strategy to improve the yield of *Boro* rice. For justifying the recent findings further study can be conducted in different Agroecological Zones (AEZ) of Bangladesh.

Acknowledgments

The authors thankfully acknowledge the Ministry of Science and Technology of the Government of People's Republic of Bangladesh for funding this research.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Ahmad W, Niaz A, Kanwal S, Rahmatullah, Rasheed MK. 2009. Role of boron in plant growth: A review. Journal of Agricultural Research, 47 (3): 329-338.

Al Mamun MA, Nihad SAI, Sarkar MAR, Aziz MA, Qayum MA, Ahmed R, Rahman NMF, Hossain MI, Kabir MS. 2021. Growth and trend analysis of area, production and yield of rice: A scenario of rice security in Bangladesh. PloS One, 16: 12 e0261128. https://doi.org/10.1371/journal.pone.0261128

Ali S, Raza SA, Butt SJ, Sarwar Z. 2016. Effect of foliar boron application on rice (*Oryza Sativa* L.) growth and final crop harvest. Agriculture and Food Sciences Research, 3: 49-52. https://doi.org/10.20448/journal.512/2016.3.2/512.2.49.52

Atique-ur-Rehman, Farooq M, Cheema ZA, Wahid A. 2012. Seed priming with boron improves growth and yield of fine grain aromatic rice. Plant Growth Regulation, 68: 189–201. https://doi.org/10.1007/s10725-012-9706-2

Atique-ur-Rehman, Farooq M, Nawaz A, Rehman A, Iqbal S. 2015. Soil application of boron improves the tillering, leaf elongation, panicle fertility, yield and its grain enrichment in fine-grain aromatic rice. Journal of Plant Nutrition, 38: 338-354. https://doi.org/10.1080/01904167.2014.963120

BBS. 2022. Statistical Yearbook of Bangladesh 2021. Bangladesh Bureau of Statistics, Dhaka, Bangladesh.

Bithy S, Paul SK, Kader MA, Sarkar SK, Mahapatra CK, Islam AKMR. 2020. Foliar application of boron boosts the performance of tropical sugar beet. Journal of Bangladesh Agricultural University, 18: 537–544. https://doi.org/10.5455/JBAU.121026

Bodeerath S, Veeradittakit J, Jamjod S, Prom-U-Thai C. 2024. Applying boron fertilizer at different growth stages promotes boron uptake and productivity in rice. Rice Science, 2024. https://doi.org/10.1016/j.rsci.2024.08.007.

Bohnsack CW, Albert LS. 1977. Early effects of boron deficiency on indoleacetic acid oxidase levels of squash root tips. Plant Physiology, 59: 1047-1050. https://doi.org/10.1104/pp.59.6.1047

Corrêa JC, Costa ADM, Crusciol CAC, Mauad M. 2006. Influence of boron addition on growth of roots and shoot of upland rice crops. Revista Brasileira De Ciencia Do Solo, 30: 1077-1082. https://doi.org/10.1590/S0100-06832006000600017

Dell B, Huang L. 1997. Physiological response of plants to low boron. Plant and soil, 193. https://doi.org/10.1023/A:1004264009230

Dey A, Begum M, Kobiraj MS, Rashid MH, Paul SK. 2023. Influence of foliar application of boron on the growth, yield and quality of sesame (cv. BARI Til-4). Turkish Journal of Agriculture-Food Science and Technology, 11: 2356-2364. https://doi.org/10.24925/turjaf.v11i12.2355-2363.6364

Dobermann A, Fairhurst TH. 2000. Nutrient disorders and nutrient management. Potash and Phosphate Institute, Potash and Phosphate Institute of Canada and International Rice Research Institute, Singapore, 191.

Fakir O, Rahman M, Jahiruddin M. 2016. Effects of foliar application of boron (B) on the grain set and yield of wheat (*Triticum aestivum* L.). American Journal of Experimental Agriculture, 12: 21-8. https://doi.org/10.9734/AJEA/2016/24286

Farooq M, Rashid A, Nadeem F, Stuerz S, Asch F, Bell RW, Siddique KH. 2018. Boron nutrition of rice in different production systems. A review. Agronomy for Sustainable Development, 38: 1-24. https://doi.org/10.1007/s13593-018-0504-8

Ferdous J, Jahiruddin M, Islam M. 2003. Response of wheat to micronutrient in Old Brahmaputra Flood plain soil. Bangladesh Journal of Seed Science and Technology, 7: 35-38.

Gomez KA, Gomez AA. 1984. Statistical Procedures for Agricultural Research, 2nd edn. John Willey and Sons., New York, pp. 97-111.

Hanifuzzaman M, Jamil Uddin FM, Mostofa MG, Sarkar SK, Paul SK, Rashid MH. 2022. Effect of zinc and boron management on yield and yield cotributing characters of Aus rice (*Oryza sativa*). Research on Crops, 23: 1-10 . https://doi.org/10.31830/2348-7542.2022.001

Hussain M, Khan MA, Khan MB, Farooq M, Farooq S. 2012. Boron application improves growth, yield and net economic return of rice. Rice Science, 19: 259-262.

Islam SMF, Karim Z. 2019. World's demand for food and water: The consequences of climate change. Desalination-challenges and Opportunities 2019. https://doi.org/10.5772/intechopen.85919

Khan R, Gurmani AH, Gurmani AR, Zia MS. 2007. Effects of boron application on rice yield under wheat rice system. International Journal of Agriculture and Biology, 8: 805-808.

Kumar N, Misra R, Shankhdhar SC. 2015. Effect of foliar application of boron on growth, yield, chlorophyll, amylose and nitrate reductase activity in rice. ORYZA-An International Journal on Rice, 52: 123-130.

Loomis WD, Durst RW. 1992. Chemistry and biology of boron. BioFactors (Oxford, England) 3: 229-239.

Lordkaew S, Dell B, Jamjod S, Rerkasem B. 2010. Boron deficiency in maize. Plant and Soil, 342(1):207-220. https://doi.org/10.1007/s11104-010-0685-7

Lordkaew S, Konsaeng S, Jongjaidee J, Dell B, Rerkasem B, Jamjod S. 2013. Variation in responses to boron in rice. Plant and Soil, 363: 287-295. https://doi.org/10.1007/s11104-012-1323-3

Mouhtaridou GN, Sotiropoulos TE, Dimassi KN, Therios IN. 2004. Effects of boron on growth, and chlorophyll and mineral contents of shoots of the apple rootstock MM 106 cultured in vitro. Biologia plantarum, 48: 617-619. https://doi.org/10.1023/B:BIOP.0000047169.13304.67

Mousavi SM, Nejad SAG, Nourgholipour F, Zoshkey SA. 2022. Agronomic aspects of boron: fertilizers, agronomical strategy, and interaction with other nutrients. In Boron in Plants and Agriculture, 249-270. https://doi.org/10.1016/B978-0-323-90857-3.00011-4

Murralidharan P, Jose AI. 2013. Effects of boron and molybdenum on the uptake of NPK in rice. Journal of Tropical Agriculture, 32**:** 157-158.

Nadeem F, Farooq M. 2019. Application of micronutrients in rice-wheat cropping system of South Asia. Rice Science, 26: 356-371. https://doi.org/10.1016/j.rsci.2019.02.002

Noppakoonwong RN, Rerkasem B, Bell RW, Dell B, Loneragan JF. 1997. Diagnosis and prognosis of boron deficiency in black gram (*Vigna mungo* L. Hepper) in the field by using plant analysis. In: Boron in Soils and Plants: Proceedings of the International Symposium on Boron in Soils and Plants held at Chiang Mai, Thailand, 7–11 September, 1997, Springer Netherlands, pp. 89-93. https://doi.org/10.1007/978-94-011-5564-9_17

Patil YJ, Patil HM, Bodake PS, Lende NS, Patil VS. 2017. Effect of soil application of *v* on growth, yield and soil properties of lowland paddy. International Journal of Chemical Studies 5: 972-975.

Poza-Viejo L, Abreu I, González-García MP, Allauca P, Bonilla I, Bolaños L, Reguera M. 2018. Boron deficiency inhibits root growth by controlling meristem activity under cytokinin regulation. Plant Science, 270**:** 176-189. https://doi.org/10.1016/j.plantsci.2018.02.005

Ramanathan S, Stalin P, Thilagavathi T, Natarajan K, Ankorion Y. 2002. Foliar nutrition of PeaK on rice. In: Proceeding of the 17th WCSS, 14-21 August, Thailand, pp. 2231-2242.

Rashid A, Yasin M, Ali MA, Ahmad Z, Ullah R. 2007. An alarming boron deficiency in calcareous rice soils of Pakistan: boron use improves yield and cooking quality. Advances in plant and animal boron nutrition, 103-116.

Rashid A, Yasin M, Ashraf M, Mann RA. 2004. Boron deficiency in calcareous soil reduces rice yield and impairs grain quality. International Rice Research Notes, 29: 58-60.

Rerkasem B, Jamjod S. 2004. Boron deficiency in wheat: a review. Field crops research, 89: 173-186. https://doi.org/10.1016/j.fcr.2004.01.022

Raku RJ, Shivanand Jha S, Rahman MM, Sarker MS, Rashid MH, Paul SK. 2023. Effect of rate and method of zinc and boron application on the yield performance of mustard. Journal of Agroforestry and Environment, 16: 36-41. https://doi.org/10.55706/jae1625

Saleem M, Khanif YM, Fauziah C, Samsuri AW, Hafeez B. 2011. Effectiveness of borax and colemanite as boron sources for rice grown in flooded acidic soil. Soil Science and Plant Nutrition, 57**:** 403-410. https://doi.org/10.1080/00380768.2011.582589

Saleem M, Khanif YM, Fauziah C, Samsuri AW, Hafeez B. 2010., Effectiveness of borax and colemanite as boron sources for rice grown in flooded acidic soil. In Proceedings of the 19th World Congress of Soil Science, 9-11.

Sen S, Chakraborty R, Kalita P. 2020. Rice-not just a staple food: A comprehensive review on its phytochemicals and therapeutic potential. Trends in Food Science & Technology, 97: 265-285. https://doi.org/10.1016/j.tifs.2020.01.022

Shafiq M, Maqsood T. 2010. Response of rice to model based applied boron fertilizer. Journal of Agricultural Research (03681157), 48: 1-10.

Shahid M, Nayak AK, Tripathi R, Katara JL, Bihari P, Lal B, Gautam P. 2018. Boron application improves yield of rice cultivars under high temperature stress during vegetative and reproductive stages. International Journal of Biometeorology, 62:1375–1387. https://doi.org/10.1007/s00484-018-1537-z

Shireen F, Nawaz MA, Chen C, Zhang Q, Zheng Z, Sohail H, Bie Z. 2018. Boron: functions and approaches to enhance its availability in plants for sustainable agriculture. International Journal of Molecular Sciences, 19: 1856. https://doi.org/10.3390/ijms19071856

Soleimani R. 2006. The effects of integrated application of micronutrient on wheat in low organic carbon conditions of alkaline soils of western Iran. In: 18th world congress of soil science, Vol. 22.

Subedi KD, Gregory PJ, Summerfield RJ, Gooding MJ. 1998. Cold temperatures and boron deficiency caused grain set failure in spring wheat (*Triticum aestivum* L.). Field Crops Research, 57: 277-288. https://doi.org/10.1016/S0378-4290(97)00148-2

Shukla A, Raghvendra Singh R, Singh SK, Shivanand, Shukla DM, Ram Singh, R. 2020. Study the effect of boron levels on yield attributes of rice crop. Journal of Pharmacognosy and Phytochemistry, 9(6): 730-733.

Tahir M, Tanveer A, Shah TH, Fiaz N, Wasaya A. 2009. Yield response of wheat (Triticum aestivum L.) to boron application at different growth stages. Pakistan Journal of Life and Social Sciences, 7: 39-42.