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AGRONOMY | ORIGINAL ARTICLE

Foliar Supplementation of Boron Enhances the Performance of Inbred and Hybrid Boro Rice Varieties

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ABSTRACT

A field experiment was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University during November 2021 to April 2022 to investigate the effects of foliar supplementation of 0.1% aqueous solution of boron (B) to inbred and hybrid boro rice varieties. The experiment was laid out in completely randomized block design (RCBD) with two factors, viz. variety (inbred 'BRRI dhna29' and hybrid 'Lal Teer'), and foliar B supplementation in addition to the recommended basal dose (6 kg ha^{-1} boric acid) which was applied during the final land preparation. The later factor had four levels, viz. (i) no additional B supplementation (B1), foliar supplementation of B (ii) at tillering stage (B2), (iii) at panicle initiation stage (B3), and (iv) at both tillering and panicle initiation stages (B4). The experiment was replicated four times. The results revealed that hybrid (Lal Teer) variety outperformed the inbred variety (BRRI dhna29) in all yield related parameters, and grain and straw yields. All plant characters, yield contributing characters and yields were significantly affected by B supplementation. Although there were yield differences between inbred and hybrid cultivars, their response patterns to foliar supplementation of B were similar. In both varieties, the highest grain yield was recorded when the crops received foliar doses of B twice (tillering and panicle initiation stages) in addition to the recommended basal B fertilizer. However, a single foliar application of B at the tillering stage produced statistically similar results as two foliar applications. The control treatment (no boron application) produced the lowest grain yield and performed poorly in terms of both plant characters and yield related traits. Therefore, a single foliar application of B during tillering stage is recommended for both inbred and hybrid varieties.

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. Food security in Bangladesh is equivalent to rice security. Rice is cultivated in three seasons Aus, Aman and Boro throughout the year. Since independence, rice production has been increased three-fold from approximately 11 MT in 1971–72 to about 38.15 MT in 2021-2022 (BBS, 2022). This revolution has transformed the country from so called 'Bottomless Basket' to a 'Full of Food Basket' (Al Mamun et al., 2021). Boro rice has appeared as the central pillar for a resilient rice system with its rising yield and production. Boro rice contributes more than 55% of total rice production (BBS, 2019). With a good boro rice production in 2020, Bangladesh graduated to 3rd position in the rice world, sitting next to China and India (USDA, 2021). Aman produce the yield of 27.91 million metric tonnes in 5.5 million hectares. Boro cultivation area was 4.82 million hectare and production was 20.19 million tons in 2021-2022 (BBS, 2022). Therefore, boro rice is one of the most important rice crops

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for Bangladesh with respect to its high yield and contribution to rice production. Variety plays an important role in augmenting yield of rice. Selection of potential variety, planting in appropriate method and application of optimum amount of nutrient elements can play an important role to increase the rice yield and national income. Uses of modern inbred (also known as high yielding varieties – HYV) and hybrid varieties have been increased remarkably in recent years and the country has almost reached a level of self-sufficiency in food.

The micronutrients are essentially involved in metabolism of rice involved in chlorophyll synthesis, photosynthesis, enzyme activation and membrane integrity (Biesalski Hans and Jana, 2018; Gupta, 1993; Hänsch and Mendel, 2009). Boron plays a major role in plant vital activities such as cell division (Marschner, 2012). Boron is responsible for better pollination, seed setting and grain formation in different rice varieties (Lordkaew et al., 2013; Rehman and Farooq, 2013), 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). Due to deficiency of boron, several physiological functions, such as sugar transport, cell wall synthesis, lignification, cell wall structure, carbohydrate metabolism, RNA metabolism, respiration, indole acetic acid (IAA) metabolism, phenol metabolism, and membrane integrity hampered (Cakmak and Römheld, 1997; Hänsch and Mendel, 2009; Rehman et al., 2018). Boron deficiency in rice results in white and rolled tips of emerging leaves, reduced plant height, death of growing point and failure to produce panicles (Day and Aasim, 2020). Boron application to rice fields increased rice growth and grain yields in soils low in B (Rehman et al., 2015; Rehman et al., 2018); however, some problems with uptake of B in conditions of low moisture in soil and/ or application of B only upon evident B deficiency symptoms have been found (David et al., 2005; Rehman et al., 2018). Under such circumstances, foliar fertilization of micronutrients was found more effective and economical in many crops (Fageria et al., 2009; Islam et al., 2024; Rahman et al., 2023; Rashid et al., 2023) as this may instantly repair plant tissues damaged specifically from B deficiency (David et al., 2005; Hussain et al., 2012).

It was hypothesized that foliar applied B, in addition to the recommended basal dose, can meet the B requirement of rice and improves the grain yield, by decreasing the panicle sterility. The specific objectives of this study was- (i) to assess the performance of hybrid and inbred boro rice to foliar supplementation of B, and (ii) to find out the best physiological stages of hybrid and inbred boro rice for foliar B supplementation.

2. Materials and Methods

2.1. Experimental site and soil

The experiment was conducted in the Agronomy Field laboratory, Bangladesh Agricultural University, Mymensingh-2202 during the period from November 2021 to April 2022. The site is located at 24.75°N latitude and 90.50°E longitude, in the southwest part of the Old Brahmaputra River at an altitude of 18 m above the mean of sea level. The topography of the experimental site was classified as medium high land and site belongs to the Old Brahmaputra Floodplain (AEZ-9) agro-ecological region, which is characterized by non-calcareous dark grey floodplain soil. The experimental site was in tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in *kharif* season (April-September) and less rainfall associated with moderately low temperature during the *rabi* season (October-March). The soil type was silty loam with a pH around 6.5.

2.2. Experimental treatments and design

Two factors were included in the experiment, viz., variety, and foliar boro (0.1% aqeous solution) supplementation in addition to the recommended basal dose. Variety had two levels *viz.*, inbred - BRRI dhan29 (V1) and Hybrid variety-Lal Teer (V2), whereas boron application had four levels *viz.,* (i) no additional B supplementation (B1), foliar supplementation of B (ii) at tillering stage (B2), (iii) at panicle initiation stage (B3), and (iv) at both tillering and panicle initiation stages (B4). The experiment was laid out in a Randomized Complete Block Design with four replications. The recommended dose of B for both variety was 6 kg ha^{-1} boric acid which was applied during the final land preparation. The site was divided into four blocks. Each block was divided into 8 unit plots, where the 8 treatment combinations were allocated at random. Altogether there were 32 unit plots, each encompassing 4 m × 2.5 m. The spacing between block-to-block and individual plots within block were 1.0 m and 0.5 m, respectively.

2.3. Plant materials

Hybrid rice variety (Lal Teer hybrid dhan) and inbred high yielding variety (HYV) BRRI dhan29 were used as plant materials for the experiments. The seeds of hybrid variety were collected from local market (Borobazar, Mymensingh) and of BRRI dhan29 were collected from Agronomy Filed Laboratory, Bangladesh Agricultural University.

2.4. Crop husbandry and data collection

Land preparation was started on first week of November 2021 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross ploughed several times followed by laddering to obtain a good tilth. Spading was done at the corner of the field to break large clods. During the cultivation of boro crops, urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate, boric acid were applied at 150 kg ha^{-1}, 100 kg ha^{-1}, 100 kg ha^{-1}, 60 kg ha^{-1}, 10 kg ha^{-1}, 6 kg ha^{-1} for BRRI dhan29 (BARC, 2018), and 270 kg ha^{-1}, 130 kg ha^{-1}, 120 kg ha^{-1}, 70 kg ha^{1}, 10 kg ha^{-1}, 6 kg ha^{-1} for Lal Teer variety (BARC, 2018). The mixture of cow dung and compost was applied at the rate of 10 t ha^{-1} during 15 days before transplantation. Urea was applied in three equal installments at 21 days after transplanting, tillering and before panicle initiation. Supplemental dose(s) of B (boric acid) was applied as foliar application (0.1%) as per treatment at tillering and panicle initiation stages.

Healthy seeds were kept in water bucket for 24 hours and then it was kept tightly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours. Seeds were sown in the seed bed on November 2021 and seedlings were uprooted on December 28, 2021 without causing much mechanical injury to the roots. The uprooted seedlings were transplanted in the main field on 28 December, 2022 with a spacing 15 cm from hill to hill and 20 cm from row to row. After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the rice seedlings. Flood irrigation was given to maintain a constant level of standing water up to 3 cm in the early stages to enhance tillering and 4-5 cm in the later stage to discourage late tillering. The field was finally dried out at 15 days before harvesting. Gap filling was done for all of the plots at 10 days after transplanting (DAT) by planting same aged seedlings. Weeding was done after 15, 32 and 52 DAT by the help of Japanese Rice weeder. The urea fertilizer was top-dressed in 3 equal installments at 10 DAT at tillering stage and before panicle initiation stage. Due to infestation of some insects specially grasshopper, stem borer, rice ear cutting caterpillar, thrips and rice bug used insecticides Curatter 5G and Sumithion. Pesticides (Tilt) was applied to controlled Brown spot of rice disease in the field.

Two varieties were harvested depending upon their maturity, BRRI dhan29 was harvested in April 24, 2022 and the hybrid was harvested April 30, 2022. And harvesting was done manually from each plot. Data collection on various parameters, such as Plant height, panicle length, number of effective tillers hill^{-1}, number of filled grains panicle^{-1}, and 1000-grain weight, was done by randomly selected five hills from each unit of plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The straw was sun dried and the yields of grain and straw plot^{-1} were recorded and converted to t ha^{-1}.

2.5. Data analysis

The data recorded for various parameters were compiled and organized into a structured table and subjected to statistical analysis utilizing the statistical package 'R.' Analysis of Variance (ANOVA) was conducted using 'agricolae' package of 'R' (R Core Team, 2021). Tukey's post hoc test was employed to assess and determine the differences among the means of different treatments.

3. Results and Discussion

3.1. Plant height

Plant height of boro rice was non-significantly influenced by variety (Table 1). The higher plant height was achieved from the variety V1 (87.08 ± 3.7 cm) and the lower plant height was achieved from the variety V2 (86.87 ± 2.48 cm). Significant variation was observed in plant height of boro rice due to different time of foliar application of boron (Table 1). It was observed that the highest plant height was obtained from the treatment, B4, which was 90.16 ± 3.29 cm, whereas the lowest plant height was found from the treatment B1 which was 84.16 ± 1.82 cm. Treatment B4 produced 7.12% taller plant than the treatment B1. Rehman et al. (2018) investigated that B application significantly enhanced plant height of rice. Sarwar et al. (2016) reported that, poor performance in control (no B application) treatment might be due to imbalance nutrient application. In B application treatment, crop up taken more nutrients and improved the crop vigor. Healthy and vigorous plants will ultimately have great impact on crop growth. Interaction effect of variety and different rates of boron showed non-significant difference on plant height of boro rice (Table 1). Results indicated that the highest plant height was found from the treatment combination of V1B4 which was 91.33 ± 4.55 cm. The lowest plant height was obtained from the treatment combination of V2B1 and which is 83.92 ± 2.2 cm.

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

Number of effective tillers plant^{-1} varied significantly between the inbred and hybrid varieties (Table 1). Hybrid variety Lal Teer gave higher number (9.62 ± 0.7) of effective tillers hill^{-1} than that of the inbred variety BRRI dhan29 (8.37 ± 0.7). Number of effective tillers hill^{-1} was significantly influenced by different time of foliar application of boron in both varieties (Table 1). It was observed that the highest number of effective tillers hill^{-1} was obtained from the treatment B4, which was 9.5 ± 0.96 and it was statistically similar to the treatments B2 and B3. The lowest number of effective tillers hill^{-1} was found from the treatment B1, which was 8.46 ± 0.87. Foliar B supplemented twice (B4) produced 12.29% higher number of effective tillers hill^{-1} than the control treatment B1. Binhafiz (2017) reported that B application significantly affected the plant growth. Interaction effect of variety and different time of foliar application of B showed non-significant difference on number of effective tillers hill^{-1} of boro rice (Table 1). Results indicated that the highest number of effective tillers hill^{-1} was found from the treatment combination of V2B4 which was 10.25 ± 0.42. The lowest number of effective tillers hill^{-1} was obtained from the treatment combination of V1B1 and which was 7.91 ± 0.69.

3.3. Number of filled grains panicle^{-1}

There was no varietal difference in number of filled grains panicle^{-1} between the hybrid and inbred varieties (Table 1). Both varieties produced ~100 filled grains panicle^{-1}. Number of filled grains panicle^{-1} was significantly influenced by different time of foliar application of boron in both varieties (Table 1). It was found that the highest number of filled grains panicle^{-1} was obtained from the treatment B4, which was statistically similar with treatment B2 and B3 (Table 1). The lowest number of filled grains panicle^{-1} was found from the treatment B1, which was 90.90 ± 8.46. Treatment B4 produced 17.27% higher number of filled grains panicle^{-1} than the treatment B1. More number of effective grains per panicle and higher grain weight by B application might be due to involvement of B in reproductive growth as B improves the panicle fertility in rice (Rehman and Farooq, 2013). Rashid et al. (2004) and Rehman et al. (2014) observed that there was a substantial increase in grain yield of rice varieties due to reduced panicle sterility after B application. Maximum number of effective grains panicle^{-1} against control plots might be due to the reduction in pollen sterility of rice and proper grain filling (Rashid et al., 2004). Interaction effect of variety and boron fertilizer management showed significant difference on number of filled grains panicle^{-1} of boro rice (Table 1). Results indicated that the highest number of grains panicle^{-1} was found from the treatment combination of V1B4 which was 107.22 ± 8.90. The lowest number of grains panicle^{-1} was obtained from the treatment combination of V2B1 and which was 88.68 ± 10.33.

3.4. Panicle length

Panicle length was significantly influenced by varieties (Table 1). Larger panicle (21.96 ± 1.1 cm) was recored in the hybrid variety than that of the inred one (20.61 ± 0.56 cm). Hybrid variety produced 6.55% longer penicle than the inbred variety. Foliar B supplementation also had significant influence on panice length of rice. Plots which received foliar B supplementary spray twice (B4) produced larger panicle (22.04 ± 1.55) followed by treatment B3, which was statistically similar. Boron plays an important role in accelerating the formation and elongation of panicles in rice plants (Liew et al., 2012). Dobermann (2000) reported that B deficiency, particularly at the panicle formation stage, would greatly reduce the formation of panicles in rice plant ultimately reduced the panicle length. Interaction effect of variety and different rates of boron showed non-significant difference on panicle length of Boro rice (Table 1). Results indicated that the highest panicle length was found from the treatment combination of V2B4 which was 23.11 ± 1.51 cm. The lowest panicle was obtained from the treatment combination of V1B1 and which was 20.13 ± 0.50 cm.

3.5. Weight of 1000 grains

Seed size varied significantly between the varieties. The hybrid variety had coarser grain with an average weight of 1000 seeds of grain weight of 33.24 ± 0.99 g in comparison to inbred rice BRRI dhan29 with WTS of 23.32 ± 0.95 g.

Weight of 1000 grains varied due to foliar B supplementation (Table 1). The highest weight of 1000 grains was obtained from the treatment B4 which was 29.36 ± 5.32 g, statistically similar with treatment B3 where the lowest weight of 1000 grains was found from the treatment, B1 which was 27.33 ± 5.21 g. Treatment B4 produced 7.43% higher weight of 1000 grains than the treatment B1. It is well established fact that B supply is imperative for obtaining high yields and good quality grains because of its fundamental part in the biochemical processes (Gupta, 1980). Boron plays an important role in preventing spikelet sterility and grain filling in cereals (Galeriani et al., 2022; Rerkasem et al., 2020). Similar functions of boron in the reproductive and grain filling stages have been reported by other researchers (Hanifuzzaman et al., 2022; Rehman et al., 2015; Rehman et al., 2018). They concluded that 1000-grain weight of rice increased with the increasing level of B fertilizer. In other cereals such as wheat, boron has also improved 1000-grain weight when it was sprayed on foliage at three growth stages i.e. tillering, booting and milking (Hussain et al., 2012).

Interaction effect of variety and different times of foliar application of B showed non-significant difference on weight of 1000 grains of boro rice (Table 1). Results indicated that the highest 1000-grain weight was found from the treatment combination of V2B4 which was 34.33 ± 0.22 g. The lowest weight of 1000 grains was obtained from the treatment combination of V1B1 and which was 22.47 ± 0.14 g.

Table 1. Varietal differences of Boro rice in plant characters, yield contributing characters

Treatments	Plant height (cm)	No. of effective tillers hill^{-1}	No. of filled grains panicle^{-1}	Panicle length (cm)	Weight of 1000 seeds (g)
Variety (V)					
V1	87.08 ± 3.7	8.37 ± 0.7 b	101.26 ± 8.45	20.61 ± 0.56 b	23.32 ± 0.95 b
V2	86.87 ± 2.48	9.62 ± 0.7 a	99.00 ± 8.57	21.96 ± 1.1 a	33.24 ± 0.99 a
Sig. level	NS	**	NS	**	**
Boron (B)					
B1	84.16 ± 1.82 c	8.46 ± 0.87 b	90.90 ± 8.46 b	20.68 ± 0.71 b	27.33 ± 5.21 b
B2	86.08 ± 1.68 bc	8.83 ± 0.78 ab	99.87 ± 4.44 ab	20.98 ± 0.68 b	27.57 ± 5.4 b
B3	87.5 ± 1.95 ab	9.20 ± 0.94 ab	103.17 ± 5.11 a	21.45 ± 0.88 ab	28.86 ± 5.35 a
B4	90.16 ± 3.29 a	9.50 ± 0.96 a	106.58 ± 6.57 a	22.04 ± 1.55 a	29.36 ± 5.32 a
Sig. level	**	*	**	**	**
Interaction (V × B)					
V1 × B1	84.41 ± 1.66	7.91 ± 0.69	93.12 ± 6.86 c	20.13 ± 0.50	22.47 ± 0.14 d
V1 × B2	85.67 ± 1.68	8.33 ± 0.72	100.58 ± 6.15 b	20.44 ± 0.29	22.55 ± 0.07 d
V1 × B3	86.91 ± 2.47	8.50 ± 0.69	104.13 ± 6.74 ab	20.91 ± 0.54	23.88 ± 0.86 c
V1 × B4	91.33 ± 4.55	8.75 ± 0.68	107.22 ± 8.90 a	20.98 ± 0.53	24.39 ± 0.02 c
V2 × B1	83.92 ± 2.2	9.00 ± 0.72	88.68 ± 10.33 d	21.23 ± 0.36	32.20 ± 0.24 b
V2 × B2	86.5 ± 1.81	9.33 ± 0.47	99.15 ± 2.60 b	21.52 ± 0.46	32.60 ± 0.85 ab
V2 × B3	88.08 ± 1.34	9.91 ± 0.50	102.21 ± 3.62 b	21.99 ± 0.85	33.84 ± 0.06 a
V2 × B4	89.00 ± 0.98	10.25 ± 0.42	105.95 ± 4.52 a	23.11 ± 1.51	34.33 ± 0.22 a
Sig. level	NS	NS	*	NS	*
CV (%)	2.67	6.93	6.67	3.42	1.58

V1 = BRRI dhan29, V2 = Lal Teer hybrid rice; B1 = no B application, B1 = foliar application of B (0.1%) at tillering stage. B3 = foliar application of B (0.1%) at panicle initiation stage, B4 = foliar application of B (0.1%) at both tillering and panicle initiation stages; WTS = weight of 1000 seeds; values in columns are mean ± SD; columns with similar letter or without any letter do not differ significantly at P = 0.05. ** and * designate significant at 1% and 5% levels of significance, NS = not significant at P = 0.05; CV = co-efficient of variation

3.6. Grain yield

Significant variation on grain yield was found due to the variety of rice (Figure 1). Result revealed that higher grain yield (5.82 t ha^{-1}) was achieved from the hybrid variety (Lal Teer) than the inbred variety BRRI dhan29, which gave the yield of 4.78 t ha^{-1} (Figure 1). The hybrid variety produced 21.75% more grain yield than the BRRI dhan29. Though the yield performance of a genotypes is the function of its genotype and envrionement (management), hybrid varities are developed to outperform inbred varieties. Other researchers (Chen et al., 2018; Huang et al., 2018; Xu et al., 2021) also reported higher grain grain yield in hybrid in comparison to inbred varieties.

Grain yield was significantly influenced by different rates of boron (Figure 1). It was observed that the highest grain yield (6.19 t ha^{-1}) was obtained from B supplementation to the crop twice, during tillering and panicle initiation stages (B4). Statistically similar result grain yield was recorded in treatment B3, i.e. when boron was foliar applied during panicle initiation only (Figure 1). No additional B supplement (B1) treatment produced the lowest grain yield (4.89 t ha^{-1}).

The grain yield was increased due to the role of boron in plant physiological functions especially during plant reproductive phase so its growth parameters such as number of effective tillers, length of panicle, number of filled grains per panicle and 1000-weight of grain improved which attributed the higher grain yield. Boron is basically involves in several biochemical processes including carbohydrate metabolism, sugar transport, lignification, nucleotide synthesis, respiration and pollen viability therefore its deficiency directly affects panicle production and hence the rice yield (Dobermann, 2000; Rehman et al., 2018). Hussain et al. (2012) concluded that maximum grain yield by foliage application of boron at the flowering stage might be the direct effect of higher number of effective grains per panicle and 1000-grain weight. Jana et al. (2009) and Rashid et al. (2004) reported that, rice yield increased due to reduced panicle sterility by boron application appreciably. Rehman et al. (2014) also reported that, substantial decrease in panicle sterility and increase in grain size are the principal reasons of increase in grain yield by foliage application of boron. Adequate boron supply may also help maintain the assimilate supply to the developing grains (Day and Aasim, 2020; Kohli et al., 2023) and increase the grain size. Interaction effect of variety and different rates of B showed slightly significant difference on grain yield (t ha^{-1}) of boro rice (Figure 1). Results indicated that the highest grain yield was found from the treatment combination of V2B4 which was 6.73 (t ha^{-1}). The lowest grain yield was obtained from the treatment combination of V1B1 and which was 3.64 (t ha^{-1}).

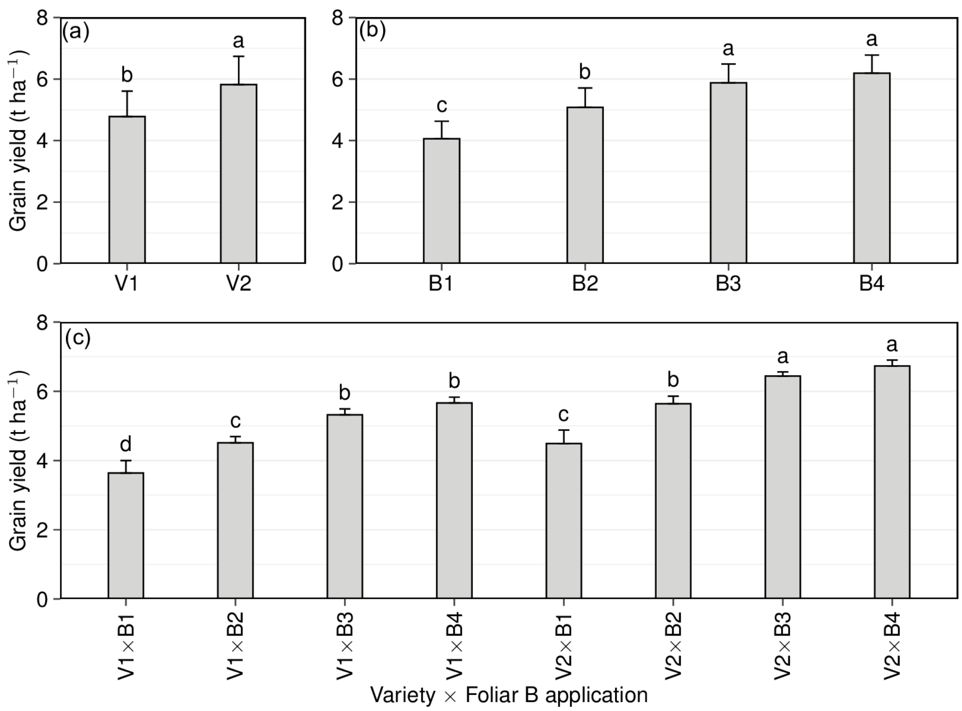

Figure 1. Effect of (a) variety, (b) foliar application of B, and (c) their interaction on grain yield of *Boro* rice.V1 = BRRI dhan29, V2 = Lal Teer hybrid rice, B1 = no B application, B1 = foliar application of B (0.1%) at tillering stage. B3 = foliar application of B (0.1%) at panicle initiation stage, B4 = foliar application of B (0.1%) at both tillering and panicle initiation stages; vertical bars and error bars represent mean and standard deviation, respectively; bars with similar letter do not differ significantly at P = 0.05.

3.7. Straw yield

There was significant difference of straw yield between the inbred and hybrid varities (Figure 2). Result revealed that higher straw yield (6.84 t ha^{-1}) was achieved from the variety the hybrid variety Lal Teer than that of inbred BRRI dhan29 which was 5.82 t ha^{-1}. Hybrid variety produced 17.53% more straw than the inbred variety BRRI dhan29.

Straw yield was also significantly influenced by foliar B supplement (Figure 2). It was observed that treatment B4 (foliar supplementation twice) exhibited the highest straw yield (7.51 t ha^{-1}) which was statistically identical to the B3. Conversely, B1 (no foliar B supplementation) gave the lowest straw yield (4.89 t ha^{-1}). Boron supplementation tiwce, especially at the later growth stage of the crop boosted vegetative growth since boron improved the membranes function which could positively affect the transport of all metabolites required for normal growth and development, as well as the activities of membrane bound enzymes which attributed to higher straw yield of rice (Gupta, 1993). Saleem et al. (2011) reported that, the highest straw yield was recorded at 3 kg B ha^{-1} over control.

Interaction effect of variety and different rates of B showed slightly significant difference on straw yield of boro rice (Figure 2). Results indicated that the highest straw yield was found from the treatment combination of V2B4 which was 8.08 (t ha^{-1}). The lowest straw yield was obtained from the treatment combination of V1B1 and which was 4.54 t ha^{-1}.

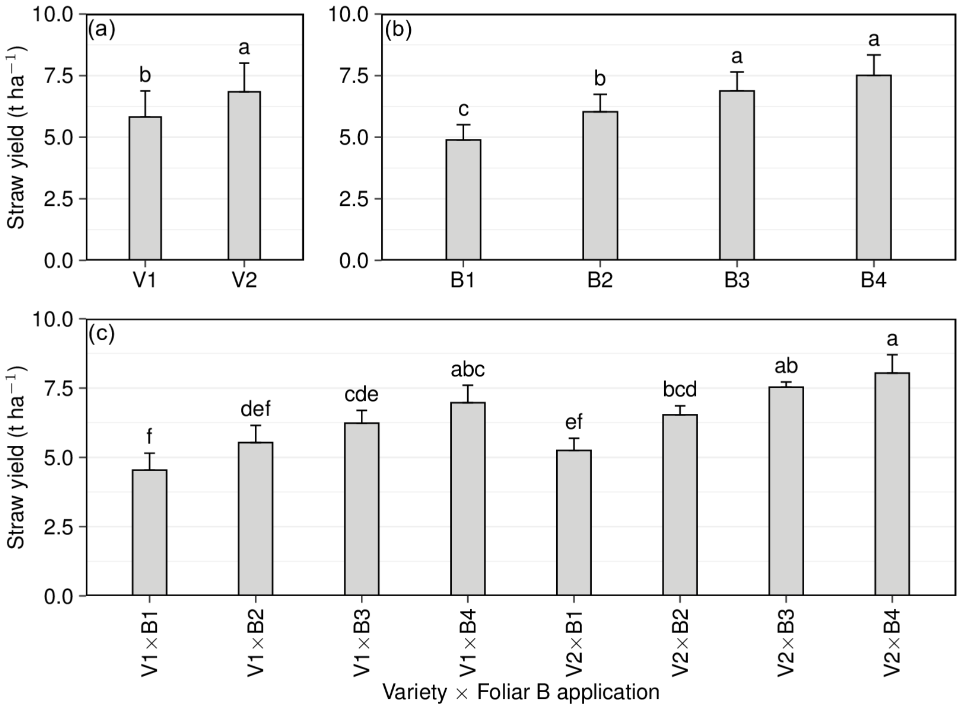

Figure 2. Effect of (a) variety, (b) foliar application of B, and (c) their interaction on straw yield of *Boro* rice.V1 = BRRI dhan29, V2 = Lal Teer hybrid rice, B1 = no B application, B1 = foliar application of B (0.1%) at tillering stage. B3 = foliar application of B (0.1%) at panicle initiation stage, B4 = foliar application of B (0.1%) at both tillering and panicle initiation stages; vertical bars and error bars represent mean and standard deviation, respectively; bars with similar letter do not differ significantly at P = 0.05.

4. Conclusion

For both inbred and hybrid varieties, the highest grain yields were observed when foliar boron was supplemented twice: at the tillering and panicle initiation stages, in addition to the basal dose. However, a single foliar application of boron at the tillering stage produced statistically similar yields compared to two applications. Based on the results, it is recommended to apply a single foliar dose of boron (0.1% aqueous solution) during the tillering stage for both inbred and hybrid boro rice varieties to optimize grain yields and overall plant performance. This approach not only enhances yield but also improves plant characteristics and yield-related traits compared to no additional boron supplementation.

Conflict of Interests

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

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