FOLIAR APPLICATION OF BORON AT DIFFERENT GROWTH STAGES FOR INCREASING BORO RICE PRODUCTION

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CERTIFICATE

This is to certify that the thesis entitled ***"FOLIAR APPLICATION OF BORON AT DIFFERENT GROWTH STAGES FOR INCREASING BORO RICE PRODUCTION"*** *submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGRONOMY,*** *embodies the result of a piece of bona fide research work carried out by* ***MD. HADISUR RAHMAN,*** *Registration No.* ***13-05281*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated:
Dhaka, Bangladesh

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Dedicated To

My Beloved Parents

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The author

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ABSTRACT

The field experiment was conducted at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from November, 2018 to May, 2019 to find out the influence of splitting of Boron as foliar application at different stages of boro rice. Two factors were used in the experiment, where two rice varieties *viz.* V_1: BRRI dhan28 and V_2: BRRI hybrid dhan5 and five levels of boron (B) application - B_0: 100% recommended B as basal dose, B_1: 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2: 75% of B as basal dose + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3: 50% of B as basal dose + 50% of B as foliar application at vegetative stage and B_4: 50% of B as basal dose + 25% of B as foliar application at vegetative stage + 25% of B as foliar application at panicle initiation stage. The experiment was laid out in a Split-plot design with three replications. Variety V_2 showed maximum plant height (100.73 cm), number of tillers hill^{-1} (12.55), leaf area index (7.21), dry weight of plant hill^{-1} (62.38 g), number of effective tillers hill^{-1} (11.59), panicle length (27.62 cm), number of filled grains panicle^{-1} (171.73), number of total grains panicle^{-1} (190.27), grain yield (6.66 t ha^{-1}), straw yield (7.36 t ha^{-1}), biological yield (14.03 t ha^{-1}) and harvest index (47.48%). In case of boron, B_4 influenced on number of tillers hill^{-1} (14.54), leaf area index (7.43), dry weight of plant hill^{-1} (70.68 g), number of effective tillers hill^{-1} (13.69), panicle length (27.68 cm), number of filled grains panicle^{-1} (176.17), number of total grains panicle^{-1} (189.00), grain yield (6.62 t ha^{-1}), straw yield (7.55 t ha^{-1}), biological yield (14.17 t ha^{-1}) and harvest index (46.55%). Interaction effect of variety and different levels boron splitting also showed significant influenced on different parameters. Results revealed that the number of effective tillers hill^{-1} (14.27), maximum leaf area index (8.05), highest dry weight of plant hill^{-1} (71.78 g), panicle length (29.60 cm), number of total grains panicle^{-1} (205.00), number of filled grains panicle^{-1} (193.00), 1000-grain weight (38.23 g), grain yield (7.64 t ha^{-1}), straw yield (8.27 t ha^{-1}), biological yield (15.91 t ha^{-1}) and harvest index (48.02%) were recorded from the treatment combination of V_2B_4. So, application of boron splitting at different stages of boro rice might be an option to improve its yield and yield attributes.

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
B	=	Boron
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centimeter
CS	=	Continuously saturated
CV%	=	Percentage of coefficient of variance
et al.	=	And others
FAO	=	Food and Agriculture Organization
g	=	Gram
GDP	=	Gross domestic product
ha	=	Hectare
ha^{-1}	=	Per hectare
HI	=	Harvest index
$Hill^{-1}$	=	Per hill
HYV	=	High yielding variety
IRRI	=	International Rice Research Institute
kg	=	Kilogram
LAI	=	Leaf area index
LCC	=	Leaf color chart
LSD	=	Least significant difference
m^{-2}	=	Per meter square
mg	=	Miligram
MoP	=	Muriate of potash
NPK	=	Nitrogen, Phosphorus and Potassium
NS	=	Non-significant
$Panicle^{-1}$	=	Per panicle
SCMR	=	SPAD Chlorophyll Meter Reading
SPAD	=	Soil Plant Analytical Development
SRDI	=	Soil Resources Development Institute
TSP	=	Triple super phosphate
$Unit^{-1}$	=	Per unit
Wt.	=	Weight

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) belongs to cereal crops under the Poaceae family which contains about 22 different species (Wopereis *et al*., 2009). In the world, Rice is the most dominant staple food in many countries (Mobasser *et al*., 2007). Rice ranked 2nd after wheat in the world crops (Abodolereza and Racionzer, 2009).

Rice is the 2nd most widely grown cereal crop and primary source of food for more than 50% the world population, and over 90% of the world's rice is grown in Asia which is carrying more than 60% of world population (Haque *et al*., 2015). Over 90% of the world's rice is grown in Asia (BBS, 2013)

Besides, based on the rice cultivation, Bangladesh is the 5th largest country of the world (BBS, 2016). In Bangladesh, rice covered an area of 11.53 million ha with a production of 35.56 million M tons while the average yield of rice in Bangladesh is around 2.98 t ha^{-1} (BRRI, 2017). Only rice covers about 82% of the total cropped land of Bangladesh. As per the estimation made by BBS (2011) consumption of rice in Bangladesh per capita is about 166 kg year^{-1}. Rice contributes 76% of the calorie intake and 66% of total protein intake (BNNC, 2008). More than 95% of the total cereal food supply shared by rice (Alam *et al*., 2012).

According to BBS (2019) Aus, Aman and Boro produced 2.92, 15.34 and 19.91 million metric tons of rice. In case of Boro rice, it covers the largest area of 4.86 million hectare with a production of 19.57 million M tons (BBS, 2018). Therefore, Boro rice is one of the most important rice crops for Bangladesh with respect to its high yield and contribution to rice production.

The population of Bangladesh is still growing and will require about 47.26 million tons of rice for the year 2020 (BBS, 2016). On the other hand, rice production area is decreasing day by day due to high population pressure as well as climate change. In any case, Bangladesh needs to build the rice yield further so as to satisfy the growing need. Rice cultivation is the major source of livelihood and about 72% of the agricultural production comes from rice. Moreover, rice is the major source of cash income to the average

Bangladesh farmers. Yearly increase of rice production in Bangladesh needs to be sustained to feed her ever increasing population. But there is a little scope to increase rice area (Sarkar *et al*., 2013). To ensure the food security for the increasing population, the cropping area under rice cultivation could hardly be increased. Therefore, it is an urgent need of time to increase rice production through increasing yield per unit area.

Hybrid rice varieties have 15- 30% yield advantage over modern inbred one (Julfiquar *et al*., 2009; Khalifa, 2009; Babu *et al.*, 2013). Slow senescence and more strong photosynthetic capability of flag leaf, higher LAI at grain filling period and higher post heading-CGR plays vital role for higher yield formation in hybrid rice (Gouk *et al.*, 1997). In Bangladesh, hybrid rice has been introduced through IRRI, BRRI and commercial seed companies of India and China during last 10 years and has already gained positive experience in Boro season and cultivated extensively (Islam *et al.*, 2010).

Variety plays an important role in increasing the yield of rice. Selection of potential variety, planting in suitable method and application of optimum amount of nutrient elements can play a vital role to increase the yield of rice as well as national income. The uses of HYV and hybrid varieties have been increased remarkably in recent years in Bangladesh. Thus the country has almost reached a level of self-sufficiency in food. National Commission of Agriculture projected that to remain self-sufficient Bangladesh, it is necessary to improve the production of rice.

The function of Boron is to enhance cell growth and panicle development in rice plants (Garg *et al*., 1979). Boron plays an important role for better pollination, seed setting and grain formation in different rice varieties (Aslam *et al*., 2002; Rehman *et al*., 2012). Boron is more important at the time of reproductive stage as contrast with vegetative stage of the crop and observed 90% of the boron in plants is localized in the cell walls (Loomis and Durst, 1992). A whitish discoloration and twisting of new leaves is the symptoms which begin in rice when boron deficiency (Yu and Bell, 1998). The severe deficiencies of boron symptom from rice include thinner stems, shorter and fewer tillers, shorter panicle length and failure to produce filled grains. Stems and leaves were found to be brittle while boron suffering leaves and stems are flaccid due to boron deficient. Decreasing productivity of rice in the rice growing countries is due to the deficiencies of micronutrient (Savithri *et* *al*., 1999). Boron deficiency is more important as it influences the flowering and plant reproductive process and therefore directly influences harvested yield (Bolanos *et al*., 2004). In boron deficient plants, the amount of protein and soluble nitrogenous compounds are lower (Gupta, 1993). So, boron can be satisfactorily applied to the soil to provide season long elevation of the boron status of a crop. So, it is essentially required to know the impact of variety and boron splitting at different stages of boro rice to study their influence on boro productivity.

From the above mentioned facts, this study was undertaken with following objectives:

i. To compare performance of different variety.
ii. To evaluate the effect of foliar application of boron on the grain set and yield of boro rice.
iii. To find out the optimum combination between variety and boron application on the growth and yield of boro rice.

CHAPTER 2

REVIEW OF LITERATURE

Fruitful production of any crop relies upon different activities have been done during crop cultivation. Variety is one of the most important basic ingredients of crop. Boron application is likewise a significant practice to achieve desired yield of crop. Some portions of the works identified with different rice varieties with splitting different rates of boron as foliar application are cited below.

2.1 Effect of variety

An experiment with three varieties (cv. BRRI dhan28, BRRI dhan29 and Binadhan-14) and four water management systems were directed to examine the impact of variety and water management system on the growth, development and yield execution of boro rice. At 100 DAT, the most elevated plant height, maximum number of tillers hill^{-1}, dry matter of shoot hill^{-1} and dry matter of root hill^{-1} were achieved from BRRI dhan29 and the least qualities were observed in Binadhan-14. Variety had significant influence on all the crop attributes under experiment with the exception of 1000-grain weight. The highest grain yield was found from BRRI dhan29 and the lowest grain yield was recorded from Binadhan-14 (Murshida *et al*., 2017).

Haque and Biswash (2014) conducted with five varieties of hybrid rice which were gathered from various private seed organizations and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In the experiment the highest plant height was 101.5 cm for BRRI dhan28 and the lowest plant height was for Richer (82.5 cm). In the event to 50% flowering, BRRI dhan29 required maximum days (116.3 days) and BRRI dhan28 required fewer days (95 days). In case of no. of effective tillers, Hira showed the best performance (17.7) and Sonarbangla-1 showed the least performance (13.3). Thinking about the days to development, Sonarbangla-1 required less days (118 days) and BRRI dhan29 required the maximum days (148 days). In panicle length status, Richer showed the best performance (27.7 cm) while BRRI dhan28 showed the least performance (26 cm). Number of filled grains panicle^{-1} was the most noteworthy for BRRI dhan29 (163.3), though, Jagoron produced grains panicle^{-1} was 118. Number of all out grains was most noteworthy in BRRI dhan29 (201.7) where Jagoron produced (133.7) of all out grains. Then again, for 1000-grain weight, Aloron was the best than other hybrids. In case of biological yield (g), BRRI dhan29 demonstrated best return (49.6 g) and Hira only 18 g. considering the performance of all the variety, the variety Aloron was the best than the respective varieties under the study.

An experiment with 24 trial hybrid rice varieties was conducted by Widyastuti *et al.* (2015). The outcomes demonstrated that grains yields were influenced by areas, seasons, and genotypes. The genotypes × areas × seasons cooperation impact was significant; along these, the best hybrid was different for each area and season. A7/PK36 hybrid has the best execution in Batang during the dry season, while A7/PK40 and A7/PK32 are the best hybrids in the rainy season. In Sukamandi, 9 hybrids were recognized as better yielder over that of the check variety in the dry season, but not so in the rainy season.

Chamely *et al*. (2015) carried out an experiment with three varieties *viz*., BRRI dhan28 (V_1), BRRI dhan29 (V_2) and BRRI dhan45 (V_3); and five rates of nitrogen *viz*., control (N_0), 50 kg (N_1), 100 kg (N_2), 150 kg (N_3) and 200 kg (N_4) N ha^{-1} to examine the impact of variety and rate of nitrogen on the performance of Boro rice. The growth and development investigation results demonstrate that the highest plant height (80.88 cm) and the most elevated number of effective tillers hill^{-1} (13.80) were achieved from BRRI dhan29 at 70 DATs and the maximum total dry matter (66.41 g) was obtained from BRRI dhan45. The shortest plant (78.15 cm) and the minimum number of effective tillers hill^{-1} (12.41) were achieved from BRRI dhan45 and the lowest dry matter (61.24 g) was found in BRRI dhan29. The harvest data indicates that variety had significant influence on total tillers hill^{-1}, effective tillers hill^{-1}, non-effective tillers hill^{-1}, panicle length, grain yield, straw yield and harvest index. The most elevated grain yield (4.84 t ha^{-1}) was observed from BRRI dhan29.

Siddique *et al.* (2002) reported the difference between hybrid and inbred rice in respect to their growth duration, yield and quality in boro season of 1999. Among the varieties, Aalok 6201 produced the highest grain yield followed by BRRI dhan29 and IR68877H however measurably they were comparative. BRRI dhan28 had the most reduced grain yield, which was measurably like Loknath503. BRRI dhan28 and the tested hybrid rice had shorter growth duration than BRRI dhan29.

Paul *et al*. (2014) conducted an experiment to examine the yield performance of some transplant aman rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties *viz*. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57. Among the varieties, BRRI dhan52 produced the tallest plant (117.20 cm), highest number of effective tillers hill^{-1} (11.28), grains panicle^{-1} (121.5) and 1000-grain weight (23.65 g) though the lowest values of these parameters were produced by BRRI dhan57. The highest grain yield (5.69 t ha^{-1}) was acquired from BRRI dhan52 followed by BRRI dhan49 (5.15 t ha^{-1}) and the lowest one (4.25 t ha^{-1}) was achieved from BRRI dhan57.

Yuan *et al.* (2005) considered the variety in the yield attributes of 75 high quality rice cultivars. Among the yield attributes, the best variety was recorded for number of grains panicle^{-1} in indica rice, and no. of panicles plant^{-1} in japonica rice.

Sarkar *et al*. (2014) conducted an experiment to examine the yield and quality of aromatic fine rice as influenced by variety and nutrient management. The experiment contained three aromatic fine rice varieties *viz*. BRRI dhan34, BRRI dhan37 and BRRI dhan38. The highest plant height (142.7 cm), the highest number of effective tillers hill^{-1} (10.02), grains number panicle^{-1} (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 t ha^{-1}) were achieved in BRRI dhan34.

Hossain *et al.* (2005) investigated the relationship between grain yield with the morphological parameters of five local and three modern aromatic rice varieties. Panicle length differed significantly in aromatic rice varieties. Maximum panicle length was found by BRRI dhan38 (24.14 cm) and minimum panicle length by Radhunipagal (20.65 cm).

Sarker *et al.* (2013) led a trial to study morphological, yield and yield contributing attributes of four *Boro* rice varieties of which three were local *viz.*, Bashful, Poshursail and Gosi; while another one was a high yielding variety (HYV) BRRI dhan28. The BRRI dhan28 were significantly predominant among the cultivars examined. The BRRI dhan28 was shorter in plant tallness, having more tillering capacity, higher leaf number which thus indicated prevalent growth character and yielded more than those of the local cultivars. The HYV BRRI dhan28 produced higher grains number panicle^{-1} and bolder grains brought about higher grain yield over the local cultivars. Along this, BRRI dhan28 had more total dry mass than those of local cultivars. The BRRI dhan28 delivered higher grain yield (7.41 t ha^{-1}) than Bashful, Poshurshail and Gosi, respectively. Among the local rice varieties, Gosi indicated the higher yielding capacity than Bashful and Poshursail.

Haque *et al.* (2013) carried out an investigation to assess some physiological attributes and yield of three hybrid rice varieties (BRRI hybrid dhan2, Heera 2, and Tia) in contrast with BRRI dhan48 in Aus season. Contrasted with BRRI dhan48, hybrid varieties aggregated more prominent shoot dry matter at the time of anthesis, higher flag leaf chlorophyll at 2, 9, 16 and 23 days after flowering (DAF), flag leaf photosynthetic rate at 2 DAF and longer panicles. Heera 2 and BRRI hybrid dhan 2 showed significantly higher chlorophyll a, b ratio over Tia and BRRI dhan 48 at 2, 9, 16 and 23 DAF in their flag leaf. Shoot hold remobilization to grain showed higher degree of sensitivity to rising of minimum temperature in the studied hybrids contrasted with the inbred. Inefficient photosynthetic activities of flag leaf and poor shoot hold translocation to grain came about poor grain filling percentage in the test hybrids. Thus the contemplated hybrids indicated significantly lower grain yield (36.7%) when contrasted with inbred BRRI dhan48, regardless of planting date in *Aus* season.

Khalifa (2009) conducted an experiment for physiological assessment of some hybrid rice varieties in different planting dates. Four hybrid rice H1, H2, GZ 6522 and GZ 6903 were used in that experiment. Results demonstrated that H1 hybrid rice variety outperformed other varieties for number of tillers m^{-2}, chlorophyll content, leaf area index, sink capacity, grains number panicle^{-1}, length of panicle (cm), weight of 1000-grains (g), panicles number m^{-1}, panicle weight (g) and grain yield (t ha^{-1}).

Srivastava and Tripathi (1998) found that the increase in grain yield in local check variety in comparison with hybrid might be attributed to the increased fertile grains panicle^{-1}.

Islam *et al*. (2009) led a pot experiments with hybrid variety Sonarbangla-1 and inbred modern variety BRRI dhan31 and BRRI hybrid dhanl to contrast the growth and yield behavior of hybrid and inbred rice varieties under controlled condition. BRRI dhan3l had around 10-15% higher plant height, very similar tillers plant^{-1}, 15-25% higher leaf area at all days after transplanting (DAT) contrasted with Sonarbangla-1. Sonarbangla-1 resulted about 40% higher dry matter production at 25 DAT but had very similar dry matter production at 50 and 75 DAT, 4-11% higher rooting depth at all DATs, about 22% higher root dry weight at 25 DAT, but 5-10% lower root dry weight at 50 and 75 DAT contrasted with BRRI dhan31. The photosynthetic rate was higher (20 μ mol m^{-2} sec^{-1}) in BRRI dhan3l at 35 DAT (highest tillering stage) but at 65 DAT, Sonarbangla-l showed higher photosynthetic rate of 19.5 μ mol m^{-2} sec^{-1}. BRRI dhan3l showed higher panicles plant^{-1} than Sonarbangla-1, but Sonarbangla-1 resulted higher grains number panicle^{-1}, 1000-grain weight and grain yield than BRRI dhan31.

Mante (2016) reported that similar to filled grains, the 1000 grains weight was significantly affected by land preparation, crop establishment and varieties tested. There was interaction between treatments still the significant differences possibly were due to the genetic characteristics of the varieties.

Ashrafuzzaman *et al.* (2008) conducted a field trial to assess the growth and yield of inbred and hybrid rice with tiller separation at different growth periods. The trial was led with two levels of treatments *viz.* (a) Variety: BRRI dhan32 and Sonarbangla-1; and (b) tiller separation days: 20, 25, 30, 35 and 40 days after mother plant transplantation. The highest number of filled grains panicle^{-1} (144.28) was seen from the tiller separation at 20 DAT. Total and effective tillers hill^{-1} was influenced by tiller separation beyond 30 DAT. Delayed tiller separation broadened the flowering and maturity duration. Accordingly, it was inferred that earlier tiller separation (20-30 DAT) showed higher grain yield in hybrid variety but no such difference was found in inbred variety.

Ahmed *et al.* (2007) carried out a field analysis to examine the impact of cultivation methods on inbred and hybrid rice in *Boro* season. The experiment comprised of two levels of treatment *viz*., variety and cultivation method. Interaction effects of variety and cultivation method showed that nursery seedlings of the inbred variety resulted the highest grain yield (8.88 t ha^{-1}) and sprouted seeds broadcast of the inbred variety showed the lowest grain yield (6.35 t ha^{-1}).

A field experiment was conducted by Amin *et al.* (2006) to examine the impacts of plant density on the yield and yield contributing characters of hybrids and conventional varieties of rice. Compared with conventional varieties, the hybrids showed larger panicles, heavier seeds and resulting in an average yield increase of 7.27%.

Bhuiyan *et al*. (2014) conducted an experiment with aimed to observe the adaptability and performances of different hybrid rice varieties and to find the best hybrid rice variety in terms of yield and yield components and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on yield. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced favorable yield.

Anwar and Begum (2010) revealed that time of tiller separation of rice significantly impacted on plant height, number of total tiller hill^{-1}, number of bearing tillers and panicle length but grain and straw yields were unaffected. Therefore, Sonarbangla-1 appeared to be tolerant to tiller separation and separation ought to be done between 20 to 40 DAT without hampering grain yield.

Geetha *et al.* (1994) studied six hybrids for grain characters. ADRH4 was the highest yielding (19.7 gm plant^{-1}). The increased yield in this hybrid was due to higher no. of grains plant^{-1}. Correlation analysis revealed that only grains plant^{-1} had a strong positive association with grain yield.

An experiment was conducted to study their impacts on the yield and yield contributing characters of rice varieties BR23 and Pajam with 2, 4 and 6 seedlings hill^{-1} during the *Aman* season. They revealed that the cv. BR23 demonstrated better performance over Pajam in regard of yield and yield components i.e. productive tillers number hill^{-1}, panicle length, l000-grain weight, grain yield and straw yield. On the other hand, the cultivar Pajam delivered significantly the highest plant height, number of total grains panicle^{-1}, number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1} (Kashem *et al*., 2005).

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers. They found that CNHR2 produced more number of effective tillers (413.4 m^{-2}) and filled grains $panicle^{-1}$ (111.0) than other tested varieties, whereas IR36 produced the highest 1000-grain weight (21.07 g) and number of panicles m^{-2} than other tested varieties.

A work was done by Myung (2005) with four different panicle types of rice varieties and saw that the primary rachis branches (PRBs) $panicle^{-1}$ and grains were higher on Sindongjinbyeo and Iksan467 varieties, but secondary rachis branches (SRBs) were lower than in Dongjin1 and Saegyehwa varieties.

Akbar (2004) revealed that variety, seedling age and their Interaction effect showed significant difference on almost all the crop characters. Among the varieties, BRRI dhan41 performed the best in regard of number of effective tillers $hill^{-1}$, panicle length, total spikelet's $panicle^{-1}$ and grains number $panicle^{-1}$. BRRI dhan41 also delivered the maximum grain and straw yields. Sonarbangla-1 positioned first in regard of total tillers $hill^{-1}$ and 1000-grain weight but produced highest number of non-effective tillers $hill^{-1}$ and sterile spikelet's $panicle^{-1}$. Grain, straw and biological yields were resulted highest in the combination of BRRI dhan41 with 15 day-old seedlings.

An experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti were conducted by Murthy *et al.* (2004) and they observed that Mukti (5.27 t ha^{-1}) out yielded the other genotypes and recorded the maximum number of filled grains and had lower spikelet sterility (25.85%) contrasted with the others.

Dongarwar *et al.* (2003) conducted an experiment to examine the response of hybrid rice KJTRH-1 in contrast with 2 traditional cultivars, Jaya and Swarna, to 4 fertilizer rates, i.e. 100:50:50, 75:37.5:37.5, 125:62.5:62.5 and 150:75:75 kg NPK ha^{-1} and revealed that KJTRH-1 showed significantly higher yield (49.24 q ha^{-1}) than Jaya (39.64 q ha^{-1}) and Swarna (46.06 q ha^{-1}).

Bisne *et al.* (2006) carried out an experiment with eight promising varieties using four CMS lines and observed that plant height, tiller number $hill^{-1}$ and grain yield differed significantly among the varieties and Pusa Basmati gave the highest plant height tiller number $hill^{-1}$ and grain yield in each line.

2.2 Effect of boron

Patil *et al*. (2017) conducted a field experiment to examine the impact of soil application of boron on growth, yield and soil properties of lowland paddy. The doses of borax were (0, 2.5, 5.0, 7.5 and 10) kg hectare^{-1} respectively. The soil available B (hot water soluble) was ranges between 0.292 to 0.412 ppm. The pooled analysis reported that treatment T_5 (Soil application of borax @10 kg ha^{-1}) produced significantly higher grain (43.45 q ha^{-1}) and straw yield (51.91 q ha^{-1}), however it was at par with treatment T_3 (Soil application of borax @ 5 kg ha^{-1}) and T_4 (Soil application of borax @ 7.5 kg ha^{-1}). It was recommended to apply 5 kg borax ha^{-1} in boron deficient soils at the time of transplanting to get higher yield and returns of paddy.

Tisdale *et al*. (1997) reported that boron is the main non-metal among the micronutrient elements which is required for various growth processes such as (i) new cell improvement in meristematic tissue, (ii) proper pollination and fruit or seed weight, (iii) translocation of sugars, starches, nitrogen and phosphorus and (iv) synthesis of amino acids and proteins.

Metwally *et al.* (2012) conducted an experiment to assess the fresh and dry matter yield of the test wheat cultivars and found marked decrease as the concentration of boron was increased. Increase in concentration of boron showed an inhibitory effect on the biosynthesis of pigments fractions in the test wheat cultivars as severely as dry matter gain. The adverse concentration effects of boron on some metabolic responses were clearly displayed by shoot and root systems, exhibited in the elevated rates of proline, hydrogen peroxide and malondialdehyde formation. Potassium leakage was severely affected by boron-stress in some cultivars at all tested concentrations, while in some others a moderate damage was manifested only at the higher boron concentrations. Results concluded that the Sakha 93 out of all the different cultivars investigated was found to display the lowest sensitivity to boron-stress, while Gemmeza 9 was the most sensitive one.

Ali *et al*. (2016) carried out an experiment to assess the effect of foliar application of B on yield and yield contributing characters of rice in calcareous soils with six B foliar application rates (0, 5, 10, 15, 20 and 25 mg L^{-1}). Boron (B) is an important micro nutrient and its deficiency caused a reduction in final crop harvest and quality of the yield. The outcome delineated a noteworthy impact of B as foliar application on grains number panicle^{-1}, number of filled grains and finally grain yield. The most noteworthy grain yield (352 g m^{-2}) was observed in 20 mg L^{-1} foliar application of B. On the other hand, an increase in B as foliar application to 25 mg L^{-1} reduces the grain yield significantly (313 g m^{-2}). Adverse impacts of the most noteworthy B application on yield contributing characters were also found. The decrease in the quantity and quality rice yield came about by increasing B application may be because of the harmful impact of higher concentration of B application.

Rahman *et al*. (2016) conducted a field experiment to evaluate the effect of foliar application of boron (B) on the grain set and yield of wheat (cv. Shatabdi). The different level of B treatments were (i) B as control, (ii) soil application of B, (iii) seed priming into boric acid solution, (iv) foliar application of B at primordial stage of crop, (v) foliar application of B at booting stage and (vi) foliar application of B at primordial and booting stages. The amount of B for soil application was 1.5 kg B ha^{-1} from boric acid (17% B) and the amount for each foliar application was 0.4% boric acid solution. The treatment getting foliar application of B at both primordial and booting stages of the crop resulted the highest yield (3.63 t ha^{-1}) which was statistically similar with the yield observed with foliar application of B at primordial or booting stage of crop and with soil application of B before crop (wheat) was sown; all the yields were significantly higher over the yield noted with seed priming or control treatment. The control treatment (no B application) had the least grain yield (2.60 t ha^{-1}).

A field study was initiated by Saleem *et al*. (2010) to evaluate the effectiveness of boron fertilizers borax and colemanite (powder and granular) in providing B to rice under flooded conditions. Boron application improved all the agronomic growth attributes and expanded the yield. Both B fertilizers fundamentally increased the plant height, effective panicles plant^{-1}, number of grains panicle^{-1} and 1000 grains weight. Both B sources were found similarly impactful in supplying B to rice crop. Borax gave significantly high yield at 2 kg B ha^{-1} and powder colemanite at 3 kg B ha^{-1}. Yield contrast between borax and powder colemanite was not significant at all three levels. Powder colemanite applied plots had significantly high residual B in contrast with borax at 0-15 and 15-30 cm and at 30-45 cm depth borax applied plots had high B content. Granular colemanite application did not significantly increase the crop growth and yield because of the large particle size B so that release was very slow.

A field experiment was conducted with two levels of boron *viz*., 1 and 2 kg ha^{-1} with control where basal dose of N, P2O5 and K2O were 120-90-60 kg ha^{-1} respectively. Wheat variety was Naseer-2000 and rice variety was IRRI-6. Boron application significantly influenced on wheat grain yield that ranged from 2.70 to 3.49 t ha^{-1} giving most elevated increase of 19.9% over control from 1.0 kg ha^{-1}. The numbers of effective tillers m^{-2}, spike m^{-2}, length of spike, plant height and weight of 1000-grain of wheat were also significantly dissimilar from control for the same treatment. Paddy yield was also significantly influenced by boron application, which ranged from 3.51 to 6.11 t ha^{-1}. The highest yield was obtained from 2 kg B ha^{-1} when applied to both crops. The number of spikes m^{-2}, spike length, plant height and 1000-grain weight of paddy were significantly influenced over control. The direct application of 1 and 2 kg B ha^{-1} result an increase of 59.6 and 62.1%, cumulative application of 1 and 2 kg B ha^{-1} increased the paddy yield by 61.1 and 74.1% while the residual application of B at the rate of 1 and 2 kg ha^{-1} increased the yield by 36.8 and 48.8% over control (Khan *et al.*, 2007).

Soil sampling and testing for Boron is currently not a typical practice for farmers in producing rice (*Oryza sativa* L.) in the southeastern United States and field research in Missouri observed that rice yields were best when soil boron levels were 0.25 to 0.35 ppm by the hot water extraction technique. In the year 2000, rice getting soil-applied Boron delivered greater yields than rice with foliar-applied boron and rice with no Boron applied. In 1999 and 2001, there was no significant variation between yields achieved with foliar or soil B applications (Dunn *et al*., 2005).

Tahir *et al.* (2009) carried out a field experiment to evaluate the yield response of wheat (*Triticum aestivum* L.) to boron application at different growth stages. Foliar application of boron was practiced in wheat at four different growth stages i.e at tillering, jointing, booting and anthesis. Results of the experimentation showed that number of grains $spike^{-1}$, weight of 1000 grain and grain yield was remarkably increased where boron was applied. Remarkably higher yield was achieved where boron was applied at booting stage. So, boron application at booting stage was observed to be the best time for obtaining higher grain yield of wheat. The results suggest that exogenous application of boron (0.5 kg ha^{-1}) at tillering stage influenced better yield and yield attributes of BARI Gom 24.

Shafiq and Maqsood (2010) conducted a field study to screen the response of rice crop to model based applied B fertilizer. Boron was applied as basal dose at the time of rice transplanting. The data showed that grains $panicle^{-1}$, weight of 1000-grains and paddy yield influenced positively to fertilizer B but vegetative growth *i.e.* plant height, tillering and total biomass did not influence significantly to B application. B rate of 1.74 kg $hectare^{-1}$ (T_4) demonstrated better for grains number $panicle^{-1}$ (164.7), 1000-grain weight (21.07 g) and paddy yield (3.2 t ha^{-1}). Boron concentration in both rice straw and paddy increased with B application but there was no impact of B on NPK concentration of straw and paddy.

An experiment was conducted by Pandey and Gupta (2013) to study the effect of foliar application of B on reproductive biology and seed quality of blackgram. Black gram (*V. mungo* L. var. DPU–88–31) was grown under controlled sand culture condition at deficient and sufficient B levels. After 32 days of sowing B deficient plants were sprayed with three concentrations of B (0.05%, 0.1% and 0.2% borax) at three different stages of reproductive development. Foliar spray at all the three concentrations and at all stages increased the yield parameters like number of pods, pod size and number of seeds formed $plant^{-1}$. Foliar B application also improved the seed yield of black gram.

Several experiments were conducted at Rangpur by BRRI researchers (1998) to examine the impact of B and FYM on four HYV rice varieties. They observed that application of FYM and B alone increased grain yield in all varieties with the exception of BRRI dhan27 than when NPK was applied. The combination of FYM and B increased vegetative growth and consequently lowering the harvest index. Vegetative growth of BRRI dhan27 was highly influenced by FYM and B applied together. They presumed that BRRI dhan27 might be less tolerant to B stress.

Islam *et al*. (1997) revealed that autumn rice influenced significantly to S, Zn and B applications. The highest grain yield (4.5 t ha^{-1}) was acquired in S+Zn+B treatment with a record of 41.8% yield advantage over control. On the other hand, the application of S, Zn or B alone result yield increase of 23.3, 21.7 and 14.6% respectively.

Jahiruddin *et al*. (1994) revealed that application of 2 Kg B ha^{-1} to BR2 rice significantly influenced on grains $panicle^{-1}$. Grain yield of BR2 rice was 7% increased over control.

Singh *et al*. (1990) led a field experiment during 1987-88 at Barapani, Meghalaya to evaluate the impacts of 3, 6 or 9 kg Zn ha^{-1}, 1.5 kg B ha^{-1} or application of Zn + B on yield of rainfed or submerged rice (cv. Nogoba). Zinc and boron application enhanced rice yield contrasted with the untreated control. The increase in yield because of B application and it was 31% higher in submerged than in rainfed conditions. The most noteworthy grain yield of 3.66 t ha^{-1} and straw yield of 4.81 t ha^{-1} were achieved from the application of B under submerged condition.

Mandal *et al*. (1987) conducted a field experiment with rice that an application of 16 kg borax ha^{-1} along with NPK increased the yield contributing characters and observed higher paddy yields.

A field experiment was conducted at Agricultural College Farm, Bapatla during *Kharif* season by Gowthami *et al.* (2018) to study the effect of foliar application of potassium, boron and zinc on quality p and seed yield in soybean. The experiment was carried out in clay loam soil in a randomized block design with eight treatments and three replications. Treatments consisted of T_1- Foliar applications of potassium nitrate @ 2% at 30 and 60 DAS, T_2- Foliar application of boric acid @ 50 ppm, T_3- Foliar application of zinc sulphate @ 1%, T_4- Foliar application of potassium nitrate @ 2% + boric acid @ 50 ppm, T_5- Foliar application of potassium nitrate @ 2% + zinc sulphate @ 1%, T_6- Foliar application of boric acid @ 50 ppm + zinc sulphate @ 1%, T_7- Foliar application of potassium nitrate @ 2% + boric acid @ 50 ppm + zinc sulphate @ 1% and T_8- Control (Water spray). The results revealed that foliar application of potassium nitrate @ 2% + boric acid @ 50 ppm + zinc sulphate @ 1% (T_7) at 30 and 60 DAS was found to be superior in increasing the quality parameters like SCMR (29.12% over control), total chlorophyll content (20.60% over control), protein (12.82% over control), oil content (26.24% over control) and yield (28.59% over control) followed by potassium nitrate @ 2% + boric acid @ 50 ppm at 30 and 60 DAS (T_4), boric acid @ 50 ppm + zinc sulphate

@ 1% at 30 and 60 DAS (T_6) and potassium nitrate @ 2% + zinc sulphate @ 1% at 30 and 60 DAS (T_5).

An experiment was conducted to evaluate the effects of four boron (B) doses (control, 0 kg B ha^{-1}, 1 kg B ha^{-1}, 3 kg B ha^{-1} and 6 kg B ha^{-1}) in soils deficient soil on yield and some yield components of chickpea (*Cicer arietinum* L.) like Plant height, pods per plant, grain yield, protein content, protein yield, thousand seed weight and leaf B concentration were measured. Grain yields were significantly increased by 1 kg ha-1 B application and increased the yield by an average of 5% (Ceyhan *et al.*, 2006).

El-Temsah (2017) conducted a field experiment to evaluate the effect of foliar application of silicon and boron on sakha 104 rice cultivar on yield, yield components and grain quality. The experiment conducted with 16 treatments which were the combinations of four Si rates (0, 1000, 2000 and 3000 ppm Si as silica fume 98% Si) and four B rates (0, 30, 60 and 90 ppm B, as boric acid 11.17% B). In a split-plot design with three replications, Si treatments occupied the main plots and B ones distributed in the sub plots. Application of 3000 ppm Si gave the highest values of panicle weight and filled grains %. Spraying 3000 ppm Si along with 2000 ppm Si recorded the highest panicle number m^{-2}, panicle length and filled grains number $panicle^{-1}$. All other applied Si rates statistically similar in spikelet numbers $panicle^{-1}$ and 1000 grain weight except for 0 ppm Si treatment. Thus, plots received 3000 ppm Si showed increases 13.4, 13.3, 13.4 and 19.0% in grain, straw, biological and grain crude protein yields, respectively, compared to the control (without Si). Rice plants fertilized with 90 ppm B possessed the highest yields surpassing other studied rates. Such treatment out yielded increases of 15.8 in grain yield, 14.1% in straw yield, 14.8% in biological yield and 23.5% in crude protein yield over the control (0 ppm B). The high performance of rice plants with 3000 ppm Si and 90 ppm B application in yield components was reflected on its yield parameters. The highest values of grain yield (4.37 t ha^{-1}) and biological yield (9.31t ha^{-1}) were obtained when rice plants foliar application with 3000 ppm Si + 90 ppm B. As a general trend, coupling high concentrations of Si with B caused the best impact on grain yield, straw yield, biological yield and harvest index where 3000 ppm Si x 90 ppm B was the effective combination in this respect.

In soils, the total B content ranges 20 to 200 ppm with the available (hot water soluble) B fraction ranging from 0.4 to 0.5 ppm. Under 5% of total soil B is available to plants. Plants assimilate B primarily in the form of H_3BO_3 and to a smaller extent as $B_4O_7^{2-}$, H_2BO_3, HBO_3^{2-}. The significant B containing mineral is tourmaline which containing 3-4% B. Boron for the most part happens in soil as undissociated H_3BO_3 and this might be the prime purpose behind which B is leached or drained so effectively from the soil (Gupta, 1979).

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2018 to May, 2019. This chapter deals with the materials and methods of the experiment with a brief description on experimental site, climate, soil, land preparation, planting materials, experimental design, land preparation, fertilizer application, transplanting, irrigation and drainage, intercultural operation, data collection, data recording and procedure of their analysis. The details of investigation for achieving stated objectives are described below.

3.1 Experimental site

The experiment was conducted at Sher-e-Bangla Agricultural University farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28. The experimental site was situated at 23°47′ North latitude and 90°35′ East longitude at an altitude of 8.2 meter above the sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.2 Climate and weather

The geographical location of the experimental area was under the sub-tropical climate 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). Information respect to monthly maximum and minimum temperature, rainfall, relative humidity and sunshine during the period of study of the experimental site was collected from Bangladesh Meteorological Department, Agargaon and is presented in Appendix II.

3.3 Soil characteristics

The experiment was done in a typical rice growing soil belonging to the Madhupur Tract. The experimental site belongs to the General soil type, Red Brown Terrace Soils under Tejgaon Series. Top soils were silty clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system. The experimental site was a medium high land. It was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resources and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

3.4 Treatments of the experiment

The following treatments were included in this experiment

Factor A: Two rice variety

V_1 = BRRI dhan28

V_2 = BRRI hybrid dhan 5

Factor B: Five levels of boron (B) application

B_0 = 100% recommended Boron (B) as basal dose

B_1 = 75% g of B as basal dose + 25% of B as foliar application at vegetative stage

B_2 = 75% g of B as basal dose + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation

B_3 = 50% of B as basal dose + 50% of B as foliar application at vegetative stage

B_4 = 50% of B as basal dose + 25% of B as foliar application at vegetative stage + 25% of B as foliar application at panicle initiation stage

3.5 Plant materials and collection of seeds and features

Two rice varieties *viz.*, BRRI dhan28 and BRRI hybrid dhan 5 were used as plant materials for the present study. The seeds of BRRI dhan28 and BRRI hybrid dhan 5 were collected from BRRI, Joydebpur, Gazipur, Bangladesh.

BRRI dhan28: BRRI dhan28 variety is grown in Boro season. This variety is recommended for cultivation in medium high land and medium low land. The life cycle of the variety is 140-145 days. It attains a plant height 95-100 cm. It gives an average yield of 6-6.5 t ha^{-1}.

BRRI hybrid dhan 5: BRRI hybrid dhan 5 variety is grown in Boro season. This variety is recommended for cultivation in medium high land and medium low land. The cultivar matures at 144 days of planting. It attains a plant height 110 cm. Average yield of the variety is 8.5-9 t ha^{-1}.

3.6 Sprouting of seed

Healthy seeds were chosen by specific gravity strategy and afterward submerged in water bucket for 24 hours and afterward it was kept tightly in plastic pot in the wake of disposing of the water in the bucket. The seeds began sprouting after 48 hours and were sown in nursery bed after 72 hours.

3.7 Preparation of nursery bed and seed sowing

According to BRRI recommendation seedbed was prepared with 1 m wide adding nutrients according to the requirements of soil. Sufficient amount of seeds were sown in the seed bed on 20 October, 2018 in order to have seedling of 35 days old and then transplant the seedlings in the main field.

3.8 Preparation of experimental land

The selected plot for the experiment was opened in the first week of October 2018 with a power tiller, and was exposed to the sun for a week. On 15 October, the selected land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilt. Weeds and stubble were removed and a desired tilt was obtained of soil finally for transplanting of seedlings.

3.9 Application of fertilizers

The following doses of fertilizer were applied for cultivation of crop as recommended by BRRI (2016).

Nutrient	Fertilizer	Recommended doses (kg ha^{-1})	
		For inbed	For hybrid
N (Nitrogen)	Urea	150	270
P (Phosphorus)	TSP	100	150
K (Potassium)	MoP	100	120
Zn (Zinc)	Zinc sulphate	10	10
S (Sulphur)	Gypsum	60	75
B (Boron)	Borax	10	10

Fertilizers like as Urea, TSP, MoP, Gypsum, Zinc sulphate and Borax were used as sources for N, P, K, S, Zn and B respectively. Fertilizers were applied to the each plot as recommended doses. The full basal doses of TSP, MoP, gypsum, zinc sulphate were applied during the final preparation of plot land. 15 days before the transplantation, mixture of cowdung and compost was applied at the rate of 10 t ha^{-1}. Urea was applied in three equal installments at after recovery, tillering and before panicle initiation. Boron was applied as foliar application as per treatment at different stages.

3.10 Experimental design and layout

The experiment was carried out in a Split-plot design with three replications (block) having variety in the main plots and level of boron application in the sub-plot. Each replication was first divided into 10 sub plots where treatment combinations were assigned. Thus the total number of unit plots was 10×3=30. The size of the unit plot was 2.5m × 2.5m (6.25 m^2). The distance maintained between two unit plots was 0.5m for drainage channel and that between blocks was 0.75m. The treatments were distributed to the plots within each replication. The layout of the experiment field is shown in Appendix IV.

3.11 Seedlings uprooting

Seedlings of 35 days old were uprooted carefully and were kept in soft mud in shade. The seed beds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots. The seedlings were uprooted on November 20, 2018 without causing much mechanical injury to the roots.

3.12 Seedlings transplanting in the field

The seedlings were transplanted as per the experimental treatment in the main field on 21th November, 2018 with a line to line distance was 25 cm and hill to hill distance was 15 cm.

3.13 Intercultural operations

After establishment of seedlings, different intercultural operations were performed during the course of experimentation for better growth and development of the rice seedlings.

3.13.1 Irrigation and drainage

The experimental field was irrigated with adequate water and was maintained a constant level of standing water upto 3 cm in the early stages to enhance tillering and 4-5cm in the later stage to discourage late tillering. A good drainage facility was also maintained for immediate release of excess rainwater from the field. The field was finally dried out at 15 days before harvesting.

3.13.2 Gap filling

Minor gap filling was done for all of the plots at 7-10 days after transplanting (DAT) by planting same aged seedlings.

3.13.3 Weeding

Experimental plots were infested with some common weeds, which were controlled by uprooting and remove them three times from the field during the period of experiment. Weeding was done after 20, 40 and 60 days of transplanting.

3.13.4 Top dressing

Top-dressed of urea fertilizer was done in 3 equal installments at 10 days after transplanting, at tillering stage and before panicle initiation stage.

3.14 Plant protection

In the experimental plots, some plants were infested with grasshopper, rice stem borer, rice ear cutting caterpillar, thrips, leaf roller and rice bug to some extent; which was successfully controlled by application of insecticides spraying (Virtako+ Advantage + Cypermethrine) and Curatter 5 G. Brown spot of rice was controlled by spraying Tilt 250 EC. Crop was protected from birds and rats during the grain-filling period. For controlling birds, scarecrow and net were given and watching was done properly; especially during morning and afternoon.

3.15 Harvesting, threshing and cleaning

The rice plant was harvested depending upon the maturity of plant and ranged between 140 to 145 days. Harvesting was done manually from $1m^2$ each of the plot. Maturity of crop was determined when 80% of the grains become golden yellow in color. The harvested crop of each plot was bundled separately, tagged properly and brought to the threshing floor. Proper care was taken for harvesting, threshing and cleaning of rice seed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and sun dried. Finally the weight was adjusted to a moisture content of 12%. The straw was also sun dried properly and the yields of grain and straw plot^{-1} were recorded and converted to t ha^{-1}.

3.16 Experimental field observation

The experimental field was observed time to time to detect visual difference among the treatment and detect any kind of infestation by weeds, insects and diseases so that considerable losses by pest was minimized.

3.17 Recording of data

The following data were collected during the experimentation:

3.17.1. Crop growth characters

1. Plant height
2. Number of leaves hill^{-1}
3. Number of tillers hill^{-1}

4. Leaf area index
5. Dry weight of plant hill^{-1}

3.17.2 Yield contributing parameters

1. Number of effective tillers hill^{-1}
2. Number of non-effective tillers hill^{-1}
3. Panicle length
4. Number of filled grains panicle^{-1}
5. Number of unfilled grains panicle^{-1}
6. Number of total grains panicle^{-1}
7. 1000-grains weight

3.17.3 Yield parameters

1. Grain yield
2. Straw yield
3. Biological yield
4. Harvest index

3.18 Procedures of recording data

A brief outline of the data recording procedure is given below:

3.18.1 Crop growth characters

3.18.1.1 Plant height

Plant height was recorded in centimeter at the time of 30, 60, 90 DAT and at harvest. Data were recorded as the average of same 5 plants pre-selected at random from the inner rows of each plot. The plant height was measured from the ground level to tip of the plant.

3.18.1.2 Number of leaves hill^{-1}

Number of leaves hill^{-1} was counted from the average of same 5 plants pre-selected at random from the inner rows of each plot.

3.18.1.3 Number of tillers hill^{-1}

The number of total tillers hill^{-1} was recorded at 30, 60, 90 DAT and at harvest by counting total tillers as the average of same 5 hills pre-selected at random from the inner rows of each plot.

3.18.1.4 Leaf area index

Leaf area index (LAI) was measured manually at the time of 30, 60, 90 DAT and at harvest. Data were counted as the average of 5 plants selected at random the inner rows of each plots. The final recorded data were calculated multiplying by a correction factor 0.75 as per Yoshida (1981).

3.18.1.5 Dry weight of plant

Dry matter hill^{-1} was recorded at 30, 60, 90 DAT and at harvest from 5 randomly collected hill of each plot from inner rows leaving the boarder row. Collected hill were oven dried at 70°C for 72 hours then transferred into desiccator and allowed to cool down at room temperature and final weight was recorded and converted into dry matter content hill^{-1}.

3.18.2 Yield contributing characters

3.18.2.1 Number of effective tillers hill^{-1}

The total no. of effective tillers hill^{-1} was counted from 5 selected hills at the time of harvest and average value was recorded.

3.18.2.2 Number of non-effective tillers hill^{-1}

The tillers having no panicle were regarded as non-effective tiller. The total number of non-effective tillers hill^{-1} was counted from 5 selected hills at the time of harvest and average value was recorded.

3.18.2.3 Panicle length

Measurement of panicle length was taken with a meter scale from 5 selected panicles and the average value was recorded.

3.18.2.4 Number of filled grains panicle^{-1}

Panicle was considered to be fertile if any kernel was present there in. The total no. of filled grains was collected randomly from selected 5 plants of a plot and then average number of filled grains panicle^{-1} was recorded.

3.18.2.5 Number of unfilled grains panicle^{-1}

Panicle was considered to be sterile if no kernel was present there in. The total no. of unfilled grains was collected randomly from selected 5 plants of a plot and then average number of unfilled grains panicle^{-1} was recorded.

3.18.2.6 Number of total grains panicle^{-1}

The total number of grains panicle^{-1} was counted from 5 selected panicles and average value was recorded.

3.18.2.7 Weight of 1000-grains

One thousand cleaned dried grains were counted randomly from each plot and weighed by using a digital electric balance at the stage the grains retained 12% moisture and the mean weight was expressed in gram.

3.18.3 Yield parameters

3.18.3.1 Grain yield

Grain yield was determined from the central 1m^2 area of each plot and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.18.3.2 Straw yield

Yield of straw was determined from the central 1 m^2 area of each plot, after separating the grains. The sub-samples were oven dried to a constant weight and finally converted to t ha^{-1}.

3.18.3.3 Biological yield

Biological yield is the summation of grain yield and straw yield. Biological yield was determined using the following formula:

Biological yield (t ha^{-1}) = Grain yield (t ha^{-1}) + Straw yield (t ha^{-1})

3.18.3.4 Harvest index

Harvest index denotes the ratio of grain yield to biological yield and was calculated with the following formula:

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

3.19 Statistical analysis

The collected data on different parameters were compiled and statistically analyzed with a Split-plot design using the MSTAT-C computer package program. Mean differences among the treatments were adjusted and done by using Least Significant Difference (LSD) technique at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

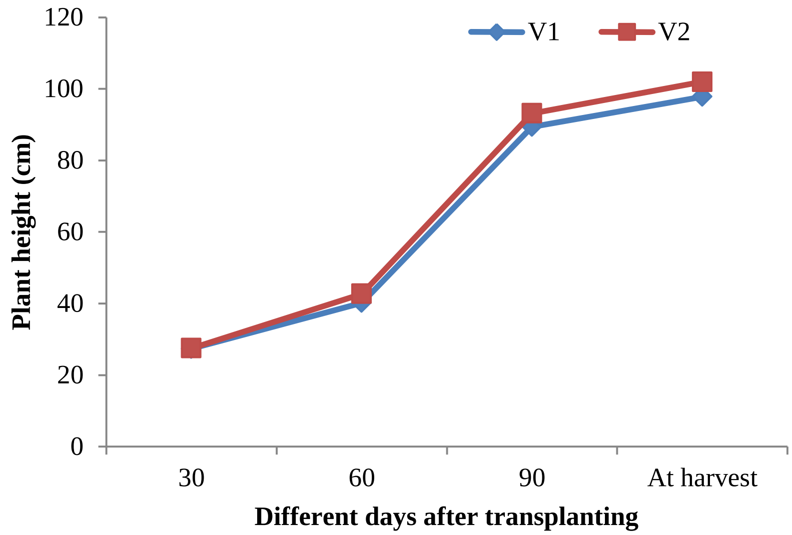
The experiment was conducted to study splitting of boron as foliar application at different stages of boro rice. The experiment was also conducted to reduce panicle sterility and improvement of grain set and yield of rice through foliar boron application. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

4.1.1.1 Effect of variety

Significant influenced was observed on plant height by different variety of rice at different growth stages (Figure 1 and Appendix V). At 30 DAT, the higher plant height was observed on V_1 (BRRI dhan28) and lower plant height was observed in V_2 (BRRI hybrid dhan 5). Results found that the higher plant height (36.40, 95.55 and 100.73 cm at 60, 90 DAT and at harvest respectively) was achieved from the variety V_2 (BRRI hybrid dhan 5) where the lower plant height (33.94, 94.60 and 99.07 cm at 60, 90 DAT and at harvest respectively) was observed from the variety V_1 (BRRI dhan28). This might be due to varietal differences. Similar results on plant height were also obtained by Murshida *et al*. (2017) and Sarkar *et al.* (2013) who revealed that plant height of rice significantly influenced by varietal differences.

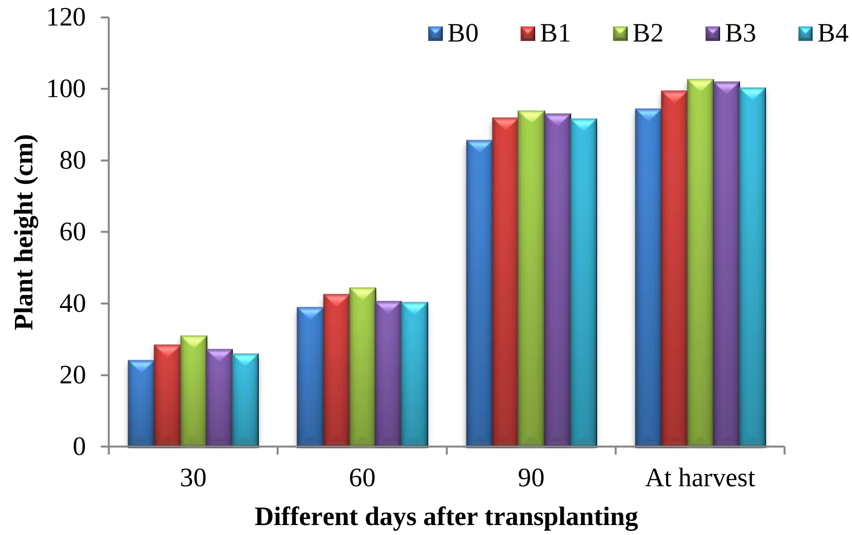


V_1 = BRRI dhan28 and V_2 = BRRI hybrid dhan 5

Figure 1. Effect of variety on plant height of boro rice at different days after transplanting ($LSD_{(0.05)}$ = NS, NS, 3.76 and 1.27 at 30, 60, 90 DAT and harvest, respectively)

4.1.1.2 Effect of boron

Plant height at different growth stages was significantly influenced by splitting different rates of boron in the study (Figure 2 and Appendix V). It was observed that the highest plant height (31.10, 44.45, 94.00, 102.72 cm at 30, 60, 90 DAT and at harvest respectively) was obtained from the treatment B_2 where the lowest plant height (24.23, 39.05, 85.65 and 94.51 cm at 30, 60, 90 DAT and at harvest respectively) was found from the treatment B_0. Ali *et al.* (2016) revealed that splitting boron as foliar application significantly enhanced plant height of rice. Because boron is essential in increasing 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. Crop up taken more nutrients and improved the crop vigor in splitting boron application treatment, healthy and vigorous plants will ultimately have great impact on crop growth. Similar trend of results on plant height were also achieved by Saleem *et al.* (2010), Shafiq and Maqsood (2010) and Khan *et al.* (2007).



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 2. Effect of different levels of boron splitting on the plant height of rice at different days after transplanting ($LSD_{(0.05)}$ = 1.26, 1.79, 3.39 and 6.09 at 30, 60, 90 DAT and harvest, respectively)

4.1.1.3 Interaction effect of variety and boron

Significant difference on plant height of rice at different growth stages was observed in the study. Interaction effect of variety and splitting different rates of boron showed significant differences (Table 1 and Appendix V). Results observed that the highest plant height (31.90, 46.83, 99.10 and 108.10 cm at 30, 60, 90 DAT and at harvest respectively) was found from the treatment combination of V_2B_2 which were statistically similar with V_1B_2, V_2B_1, V_1B_3 and V_1B_1 at 30 DAT, V_2B_1, V_1B_2 and V_1B_2 at 60 DAT, V_2B_1, V_1B_4, V_1B_3 and V_1B_1 at 90 DAT and V_2B_3 and V_2B_1 at harvest. The lowest plant height (23.73, 36.83, 83.53 and 92.20 cm at 30, 60, 90 DAT and at harvest respectively) was obtained from the treatment combination of V_1B_0 which was statistically at par with V_2B_0, V_1B_1 and V_1B_2 at harvest.

Table 1. Interaction effect of variety and different level of boron splitting on plant height at different days after transplanting (DAT) and harvest

Treatment combination	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	At Harvest
V_1B_0	23.73 e	36.83 c	83.53 c	92.20 c
V_1B_1	27.80 a-d	40.16 bc	90.46 a-c	97.50 bc
V_1B_2	30.30 ab	42.07 a-c	88.91 bc	98.01 bc
V_1B_3	28.38 a-d	41.77 a-c	91.05 a-c	100.15 a-c
V_1B_4	26.60 b-e	40.17 bc	92.92 a-c	101.10 a-c
V_2B_0	24.73 de	41.26 bc	87.76 bc	96.82 bc
V_2B_1	29.17 a-c	45.07 ab	93.29 ab	102.36 ab
V_2B_2	31.90 a	46.83 a	99.10 a	108.10 a
V_2B_3	26.20 b-e	39.80 bc	95.30 ab	103.80 ab
V_2B_4	25.53 c-e	40.58 bc	90.50 a-c	99.50 a-c
$LSD_{(0.05)}$	**3.78**	**5.36**	**10.18**	**8.96**
CV(%)	**7.97**	**7.47**	**6.44**	**5.17**

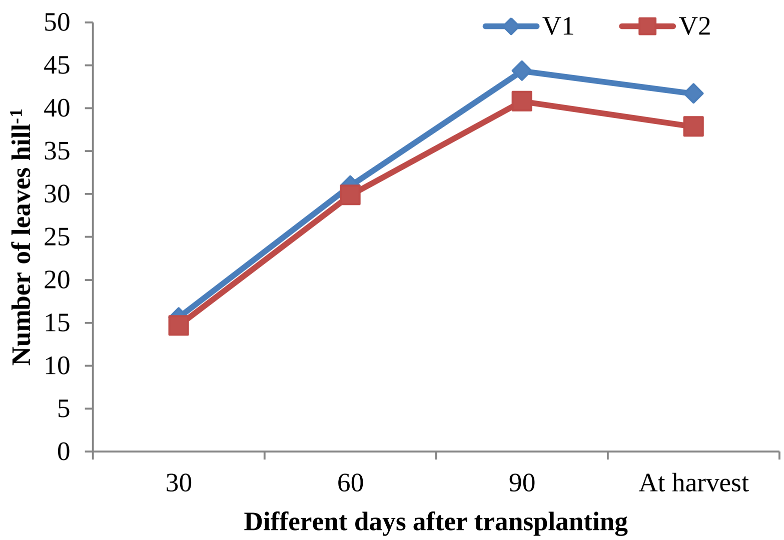
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5; B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

4.1.2 Number of leaves hill^{-1}

4.1.2.1 Effect of variety

Non-significantly influence on number of leaves hill^{-1} was exerted under the study due to different variety of rice at different growth stages (Figure 3 and Appendix VI). But the maximum number of leaves hill^{-1} (15.62, 30.95, 44.33 and 41.68 at 30, 60, 90 DAT and at harvest respectively) was observed from the variety V_1 (BRRI dhan28) and the minimum number of leaves hill^{-1} (14.68, 29.88, 40.80 and 37.85 at 30, 60, 90 DAT and at harvest respectively) was achieved from the variety V_2 (BRRI hybrid dhan 5). Similar trend of results was also obtained by Sarkar *et al.* (2013), Khalifa (2009) and Haque *et al.* (2013).

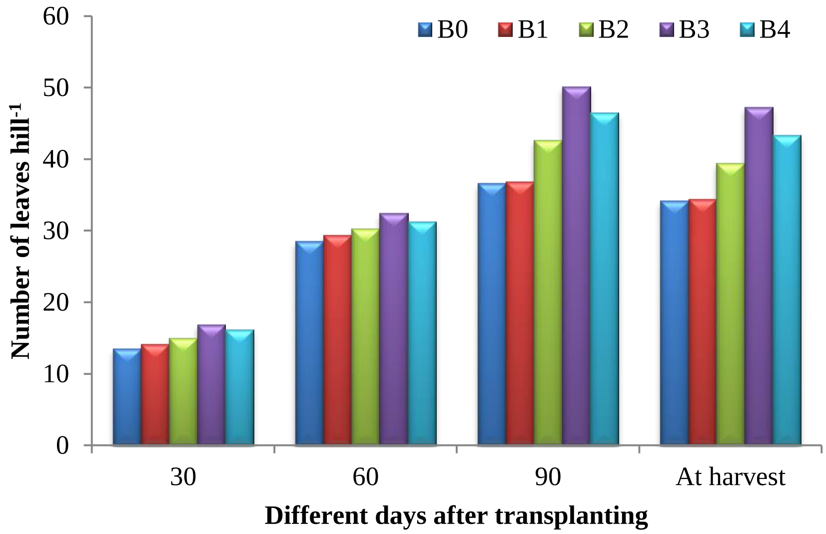


V1 = BRRI dhan28, V2 = BRRI hybrid dhan 5

Figure 3. Effect of variety on the number of leaves hill^{-1} of rice at different days after transplanting ($LSD_{(0.05)}$ = NS, NS, NS and NS at 30, 60, 90 DAT and at harvest, respectively)

4.1.2.2 Effect of boron

Significant variation was exerted on number of leaves hill^{-1} at different growth stages influenced by splitting different rates of boron application (Figure 4 and Appendix VI). Results showed that the maximum number of leaves hill^{-1} (16.87, 32.46, 50.16 and 47.33 at 30, 60, 90 DAT and at harvest respectively) was obtained from the treatment B_3. The minimum number of leaves hill^{-1} (13.52, 28.51, 36.67 and 34.19 at 30, 60, 90 DAT and at harvest respectively) was found from the treatment B_0. This result was coincided with the findings of Khan *et al*. (2007) and Shafiq and Maqsood (2010).



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 4. Effect of different levels of boron splitting on the number of leaves hill^{-1} of rice at different days after transplanting ($LSD_{(0.05)}$ = 2.29, 2.78, 5.55 and 5.63 at 30, 60, 90 DAT and harvest, respectively)

4.1.2.3 Interaction effect of variety and boron

Significant influenced on number of leaves hill^{-1} of rice at different growth stages was found by interaction effect of variety and splitting different rates of boron (Table 2 and Appendix VI). Results showed that the highest number of leaves hill^{-1} (18.47, 33.99, 52.67 and 49.85 at 30, 60, 90 DAT and at harvest respectively) was obtained from the treatment combination of V_1B_3 which was statistically similar with V_2B_4 at 30 DAT and 60 DAT, V_1B_4 and V_2B_3 at 90 DAT and V_1B_4 and V_2B_3 at harvest. The lowest number of leaves hill^{-1} (12.67, 27.52, 35.00 and 32.66 at 30, 60, 90 DAT and at harvest respectively) was achieved by the treatment combination of V_2B_0 which was statistically similar with V_2B_1, V_1B_0, V_1B_1 and V_2B_2 at harvest.

Table 2. Interaction effect of variety and different level of boron splitting on number of leaves $hill^{-1}$ at different days after transplanting (DAT) and harvest

Treatment combination	Number of leaves $hill^{-1}$			
	30 DAT	60 DAT	90 DAT	At Harvest
V_1B_0	14.37 bc	29.50 bc	38.33 c-e	35.72 c-e
V_1B_1	13.60 bc	29.00 bc	36.67 de	34.99 c-e
V_1B_2	15.98 a-c	31.54 a-c	45.67 a-c	42.88 a-c
V_1B_3	18.47 a	33.99 a	52.67 a	49.85 a
V_1B_4	15.67 a-c	30.72 a-c	48.33 ab	44.96 ab
V_2B_0	12.67 c	27.52 c	35.00 e	32.66 e
V_2B_1	14.73 bc	29.85 a-c	37.00 c-e	33.90 de
V_2B_2	14.07 bc	29.06 bc	39.67 b-e	36.05 b-e
V_2B_3	15.26 a-c	30.93 a-c	47.67 ab	44.81 ab
V_2B_4	16.67 ab	31.87 ab	44.67 a-d	41.81 a-d
$LSD_{(0.05)}$	**3.25**	**3.94**	**7.86**	**7.97**
CV(%)	**12.40**	**7.49**	**10.67**	**11.58**

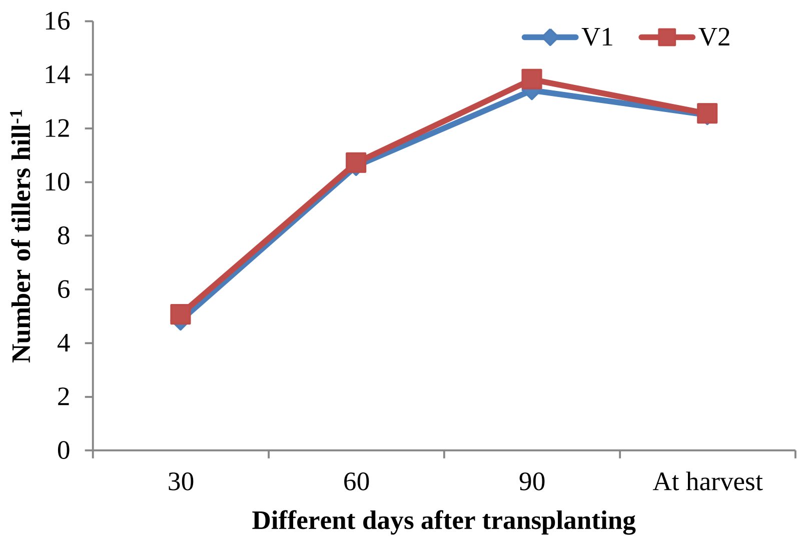
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5; B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

4.1.3 Number of tillers hill^{-1}

4.1.3.1 Effect of variety

Non-Significant variation was found on number of tillers hill^{-1} at different growth stages due to cause of different variety of rice (Figure 5 and Appendix VII). But result revealed that the highest number of tillers hill^{-1} (5.07, 10.72, 13.83 and 12.55 at 30, 60, 90 DAT and at harvest respectively) was obtained from the variety V_2 (BRRI hybrid dhan 5) where the lowest number of tillers hill^{-1} (4.84, 10.60, 13.42 and 12.50 at 30, 60, 90 DAT and at harvest respectively) was observed from the variety V_1 (BRRI dhan28). The result achieved from the present study was similar with the findings of Murshida *et al*. (2017), Chamely *et al*. (2015) and Paul *et al*. (2014).

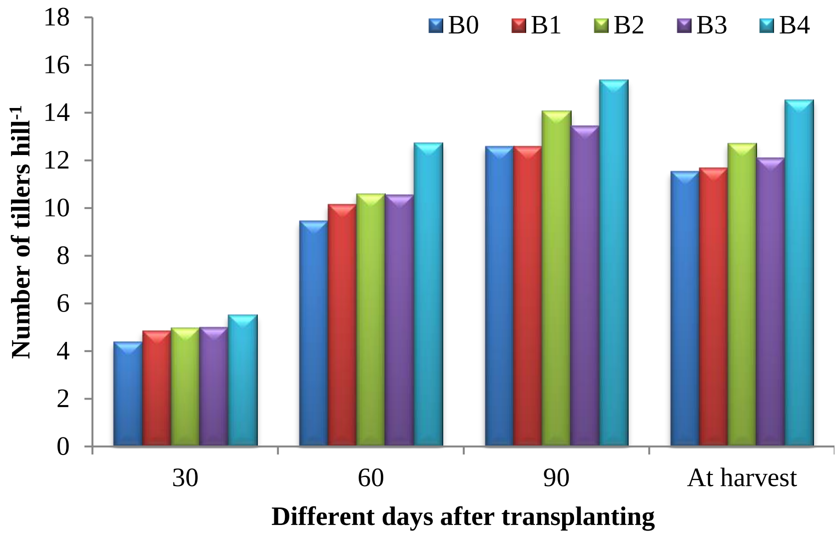


V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5

Figure 5. Effect of variety on the number of tillers hill^{-1} of rice at different days after transplanting ($LSD_{(0.05)}$ = NS, NS, NS and NS at 30, 60, 90 DAT and harvest, respectively)

4.1.3.2 Effect of boron

Number of tillers hill^{-1} at different growth stages of rice was significantly affected by splitting different rate of boron (Figure 6 and Appendix VII). Results showed that the highest number of tillers hill^{-1} (5.52, 12.75, 15.38 and 14.54 at 30, 60, 90 DAT and at harvest respectively) was achieved from the treatment B_4 where the lowest number of tillers hill^{-1} (4.39, 9.46, 12.60 and 11.54 at 30, 60, 90 DAT and at harvest respectively) was obtained from the treatment B_0. The findings were also similar with the findings of Khan *et al.* (2007) and Shafiq and Maqsood (2010).



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 6. Effect of different levels of boron splitting on the number of tillers hill^{-1} of rice at different days after transplanting ($LSD_{(0.05)}$ = 0.46, 1.03, 1.39 and 1.37 at 30, 60, 90 DAT and harvest, respectively)

4.1.3.3 Interaction effect of variety and boron

Statistically significant difference was exerted for number of tillers hill^{-1} at different growth stages of rice due to interaction effect of variety and splitting different rate of boron (Table 3 and Appendix VII). Results showed that the highest number of tillers hill^{-1} (6.04, 13.16, 16.00 and 15.00 at 30, 60, 90 DAT and at harvest respectively) was achieved from the treatment combination of V_2B_4 which was statistically similar with V_1B_4 at 60 DAT, 90 DAT and at harvest. The lowest number of tillers hill^{-1}(4.22, 9.44, 12.38 and 11.52 at 30, 60, 90 DAT and at harvest respectively) was revealed from the treatment combination of V_1B_0 which was statistically similar with V_2B_0, V_2B_3, V_2B_2, V_1B_3 and V_1B_1 at harvest.

Table 3: Interaction effect of variety and different level of boron splitting on number of tillers hill^{-1} at different days after transplanting (DAT) and harvest

Treatment combination	Number of tillers hill^{-1} at			
	30 DAT	60 DAT	90 DAT	At Harvest
V_1B_0	4.22 c	9.44 d	12.38 d	11.52 c
V_1B_1	4.76 bc	10.33 cd	12.60 b-d	11.67 c
V_1B_2	5.18 b	11.18 bc	14.49 a-c	13.33 a-c
V_1B_3	5.02 b	10.22 cd	12.89 b-d	11.89 c
V_1B_4	5.00 b	12.33 ab	14.77 ab	14.09 ab
V_2B_0	4.56 bc	9.48 d	12.59 cd	11.58 c
V_2B_1	4.97 b	9.99 cd	12.85 b-d	11.71 c
V_2B_2	4.78 bc	10.89 b-d	13.67 b-d	12.33 bc
V_2B_3	5.00 b	10.22 cd	14.00 b-d	12.11 bc
V_2B_4	6.04 a	13.16 a	16.00 a	15.00 a
$LSD_{(0.05)}$	**0.66**	**1.46**	**1.97**	**1.94**
CV(%)	**7.74**	**7.92**	**8.58**	**8.96**

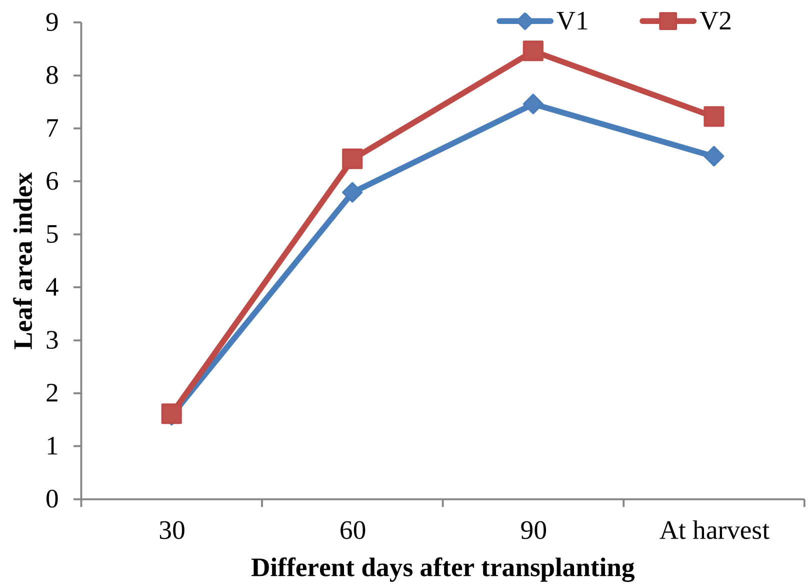
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5; B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

4.1.4 Leaf area index

4.1.4.1 Effect of variety

Significantly influenced on leaf area index was observed by different variety of rice at different growth stages except 30 DAT and 60 DAT (Figure 7 and Appendix VIII). The highest leaf area index (1.61, 6.42, 8.46 and 7.22 at 30, 60, 90 DAT and at harvest respectively) was obtained from the variety V_2 (BRRI hybrid dhan 5) where the lowest leaf area index (1.58, 5.79, 7.46 and 6.47 at 30, 60, 90 DAT and at harvest respectively) was observed from the variety V_1 (BRRI dhan28). Khalifa (2009) also obtained similar results regarding varietal differences.

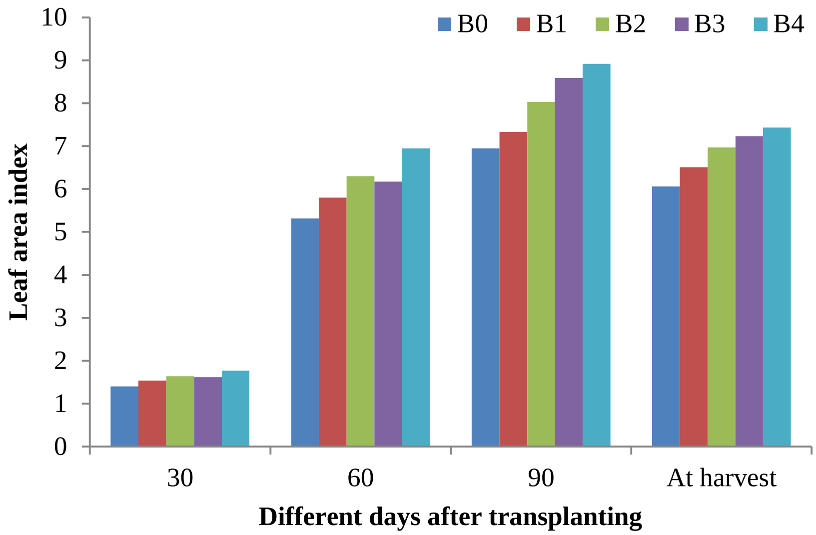


V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5

Figure 7. Effect of variety on the leaf area index of rice at different days after transplanting ($LSD_{(0.05)}$ = NS, NS, 0.20 and 0.30 at 30, 60, 90 DAT and harvest, respectively)

4.1.4.2 Effect of boron

Significant influenced was obtained in terms of leaf area index at different growth stages of rice influenced by splitting different rates of boron (Figure 8 and Appendix VIII). It was observed that the highest leaf area index (1.77, 6.95, 8.92 and 7.43 at 30, 60, 90 DAT and at harvest respectively) was obtained from the treatment B_4 where the lowest leaf area index (1.40, 5.32, 6.95 and 6.06 at 30, 60, 90 DAT and at harvest respectively) was found from the treatment B_0. The higher LAI was achieved by splitting boron foliar application B_4 which might be due to more cell division and elongation resulting vigorous leaf production and finally produced higher LAI than the treatment B_0. Similar result also reported by Hussain and Yasin (2004) also reported that application of B as foliar spraying in rice is highly attractive and produced higher LAI than control treatment.



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 8. Effect of different levels of boron splitting on the leaf area index of rice at different days after transplanting ($LSD_{(0.05)}$ = 0.08, 0.73, 0.56 and 0.59 at 30, 60, 90 DAT and harvest, respectively)

4.1.4.3 Interaction effect of variety and boron

Interaction effect of variety and splitting different rates of boron showed significant influence on leaf area index of rice at different growth stages (Table 4 and Appendix VIII). Results showed that the highest leaf area index (1.85, 7.23, 9.90 and 11.96 at 30, 60, 90 DAT and at harvest respectively) was obtained from the treatment combination of V_2B_4 which was statistically similar with V_2B_3 and V_1B_4 at 60 DAT. The lowest leaf area index (1.33, 5.04, 6.32 and 7.64 at 30, 60, 90 DAT and at harvest respectively) was achieved from the treatment combination of V_1B_0 which was statistically similar with V_1B_1 at 60, 90 DAT and at harvest.

Table 4. Interaction effect of variety and different level of boron splitting on leaf area index at different days after transplanting (DAT) and harvest

Treatment combination	Leaf area index			
	30 DAT	60 DAT	90 DAT	At Harvest
V_1B_0	1.33 f	5.04 e	6.32 f	5.46 d
V_1B_1	1.56 c-e	5.33 de	6.92 ef	6.07 cd
V_1B_2	1.63 b-d	6.29 a-d	7.80 cd	6.81 bc
V_1B_3	1.71 b	5.65 a-e	8.33 bc	7.17 b
V_1B_4	1.70 b	6.66 a-c	7.93 cd	6.80 bc
V_2B_0	1.47 e	5.59 c-e	7.58 de	6.67 bc
V_2B_1	1.52 de	6.27 a-e	7.73 cd	6.94 b
V_2B_2	1.65 bc	6.30 a-d	8.26 b-d	7.13 b
V_2B_3	1.54 c-e	6.69 ab	8.84 b	7.29 ab
V_2B_4	1.85 a	7.23 a	9.90 a	8.05 a
$LSD_{(0.05)}$	**0.10**	**1.04**	**0.78**	**0.83**
CV(%)	**4.25**	**9.80**	**5.72**	**7.05**

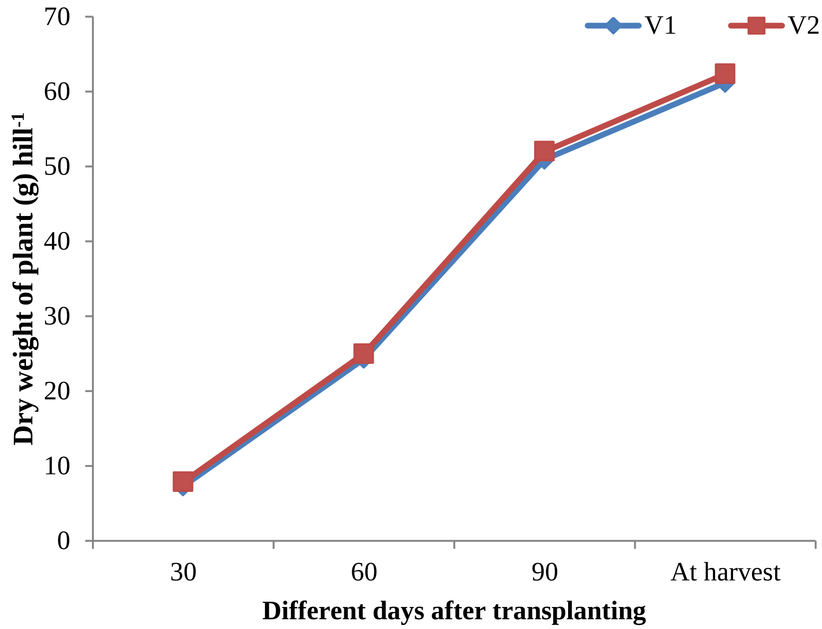
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5; B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

4.1.5 Dry weight (g) hill^{-1}

4.1.5.1 Effect of variety

Significantly influence on dry weight (g) hill^{-1} was found due to different variety of rice at different growth stages (Figure 9 and Appendix IX). Results achieved that the highest dry weight hill^{-1} (7.88, 25.00, 52.03 and 62.38 g at 30, 60, 90 DAT and at harvest respectively) was achieved from the variety V_2 (BRRI hybrid dhan 5) where the lowest dry weight (g) hill^{-1} (7.29, 24.33, 50.95 and 61.21 g at 30, 60, 90 DAT and at harvest respectively) was observed from the variety V_1 (BRRI dhan28). Similar results were also similar with the findings of Murshida *et al*. (2017), Chamely *et al.* (2015) and Sarkar *et al.* (2013).

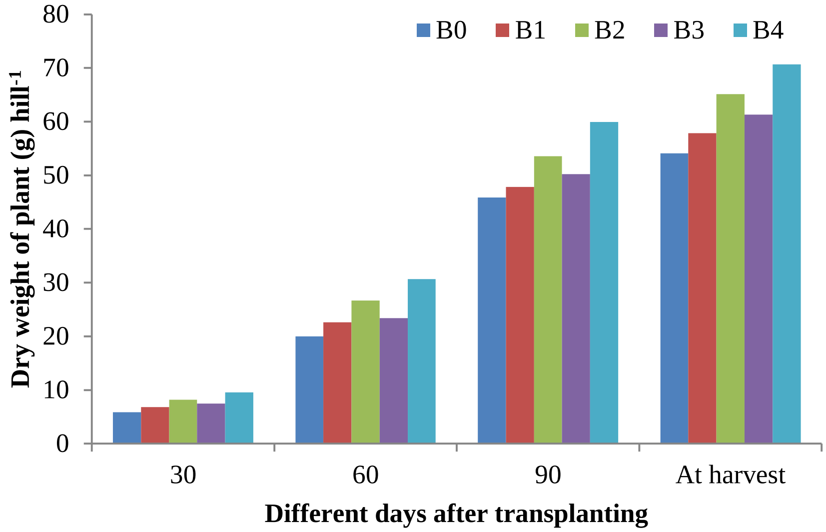


V_1 = BRRI dhan28 and V_2 = BRRI hybrid dhan 5

Figure 9. Effect of variety on the dry weight of plant of rice at different days after transplanting ($LSD_{(0.05)}$ = 0.04, NS, NS and NS at 30, 60, 90 DAT and harvest, respectively)

4.1.5.2 Effect of boron

Significant variation was observed in terms of dry weight (g) hill^{-1} at different growth stages influenced by splitting different rates of boron (Figure 10 and Appendix IX). Results showed that the highest dry weight (g) hill^{-1} (9.56, 30.67, 59.96 and 70.68 g at 30, 60, 90 DAT and at harvest respectively) was achieved from the treatment B_4 where the lowest dry weight (g) hill^{-1} (5.86, 20.00, 45.87 and 54.09 g at 30, 60, 90 DAT and at harvest respectively) was obtained from the treatment B_0 which was immediate lower than B_1 but significantly different. The vigorous expansion of leaves trigger the bigger assimilatory system which results in more photosynthesis. More photosynthates results in more dry matter accumulation. This result was also coincide with the result of Hussain and Yasin (2004) who reported that, foliar application of B produced vigorous plant resulting higher dry matter production than no B treated plot.



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 10. Effect of different levels of boron splitting on the dry weight of plant hill^{-1} of rice at different days after transplanting ($LSD_{(0.05)}$ = 0.31, 3.10, 3.06 and 3.74 at 30, 60, 90 DAT and harvest, respectively)

4.1.5.3 Interaction effect of variety and boron

Significantly influenced on dry weight (g) hill^{-1} of rice at different growth stages was observed by Interaction effect of variety and splitting different rates of boron (Table 5 and Appendix IX). Results observed that the highest dry weight (g) hill^{-1} (10.16, 32.35, 60.94 and 71.78 g at 30, 60, 90 DAT and at harvest respectively) was obtained from the treatment combination of V_2B_4 which was statistically similar with V_1B_4 and V_1B_2 at 60 DAT and at harvest. On the other hand, the lowest dry weight hill^{-1} (5.72, 19.45, 44.90 and 52.44 g at 30, 60, 90 DAT and at harvest respectively) was obtained from the treatment combination of V_1B_0 which was statistically similar with V_2B_0 at 30, 90 DAT and at harvest, V_1B_1 and V_2B_1 at 60 DAT.

Table 5: Interaction effect of variety and different level of boron splitting on dry weight of plant (g) hill^{-1} at different days after transplanting (DAT) and harvest

Treatment combination	Dry weight of plant			
	30 DAT	60 DAT	90 DAT	At Harvest
V_1B_0	5.72 g	19.45 e	44.90 e	52.44 f
V_1B_1	6.44 f	22.07 de	48.29 de	58.95 de
V_1B_2	8.65 bc	28.67 a-c	55.44 bc	68.50 ab
V_1B_3	6.73 f	22.50 de	47.18 de	56.95 d-f
V_1B_4	8.95 b	29.00 ab	58.99 ab	69.58 ab
V_2B_0	6.01 g	20.54 cd	46.84 e	55.76 ef
V_2B_1	7.23 e	23.13 de	47.40 de	56.78 d-f
V_2B_2	7.72 d	24.69 b-d	51.65 cd	61.82 cd
V_2B_3	8.26 c	24.32 cd	53.29 c	65.74 bc
V_2B_4	10.16 a	32.35 a	60.94 a	71.78 a
$LSD_{(0.05)}$	**0.44**	**4.39**	**4.33**	**5.29**
CV(%)	**3.37**	**10.28**	**4.86**	**4.95**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

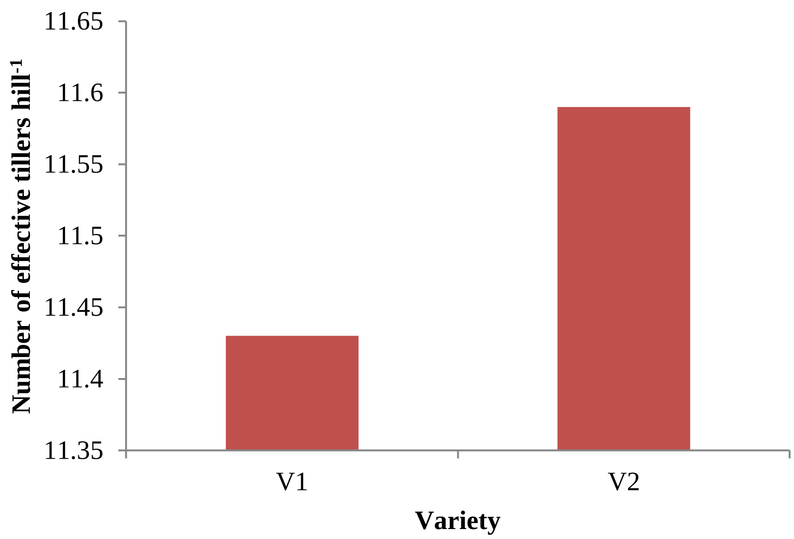
V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5; B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

4.2 Yield contributing parameters

4.2.1 Number of effective tillers hill^{-1}

4.2.1.1 Effect of variety

Non-significant difference was observed on number of effective tillers hill^{-1} due to different variety of rice (Figure 11 and Appendix X). Results revealed that the highest number of effective tillers hill^{-1} (11.59) was obtained from the variety V_2 (BRRI hybrid dhan 5) where the lowest number of effective tillers hill^{-1} (11.43) was observed from the variety V_1 (BRRI dhan28). The result achieved from the present study was similar with the findings of Chamely *et al.* (2015) and Paul *et al*. (2014).

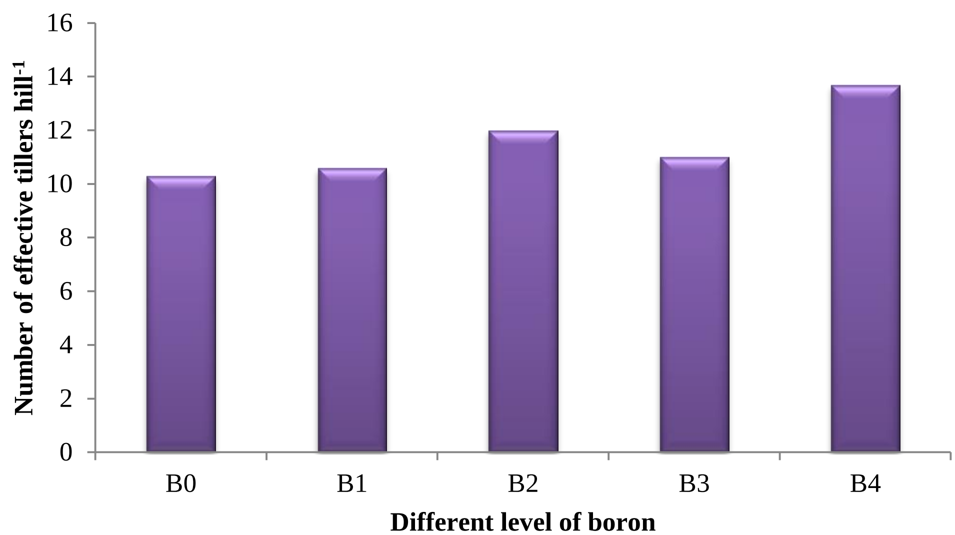


V_1 = BRRI dhan28 and V_2 = BRRI hybrid dhan 5

Figure 11. Effect of variety on the number of effective tillers hill^{-1} of boro rice (LSD $_{(0.05)}$ = NS)

4.2.1.2 Effect of boron

Number of effective tillers hill^{-1} of rice was significantly affected by splitting different rate of boron (Figure 12 and Appendix X). Results exposed that the highest number of effective tillers hill^{-1} (13.69) was observed from the treatment B_4. On the other hand, the lowest number of effective tillers hill^{-1} (10.29) was obtained from the treatment B_0 followed by B_1 (10.59). Saleem *et al.* (2011) reported that, the positive effect on plant effective tillers may be due to the proper development and differentiation of tissue as B affects the deposition of cell wall material by altering membrane properties. Costa *et al*. (2006) observed that appropriate boron availability in soils favors root growth and a sufficient supply of this micronutrient is very important for adequate rice plant development. So, appropriate foliar application of B resulting maximum production of effective tillers hill^{-1}. The result was consistent with the findings of Khan *et al.* (2007); Akbar *et al.* (2006) and Ashraf *et al*. (2004) who reported that B application significantly affected the plant growth.



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 12. Effect of different levels of boron splitting on the number of effective tillers hill^{-1} of rice ($LSD_{(0.05)}$ = 1.87)

4.2.1.3 Interaction effect of variety and boron

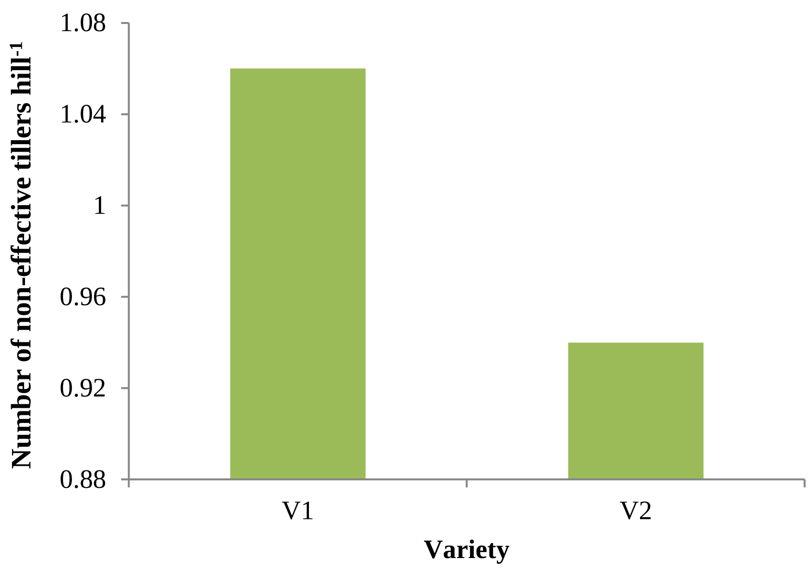
Significant difference was observed for number of effective tillers hill^{-1} of rice influenced by interaction effect of variety and splitting different rate of boron (Table 6 and Appendix X). It was remarked that the highest number of effective tillers hill^{-1} (14.27) was obtained from the treatment combination of V_2B_4 which was statistically similar with V_1B_4 treatment combination. On the other hand, the lowest number of effective tillers hill^{-1}

(10.26) was obtained from the treatment combination of V_1B_0 which was statistically similar with V_2B_0, V_1B_1, V_2B_1 and V_1B_3.

4.2.2 Number of non-effective tillers hill^{-1}

4.2.2.1 Effect of variety

Number of non-effective tillers hill^{-1} was remarkably influence by different variety of boro rice (Figure 13 and Appendix X). The highest number of non-effective tillers hill^{-1} (1.06) was obtained from the variety V_1 (BRRI dhan28) where the lowest number of non-effective tillers hill^{-1} (0.94) was observed from the variety V_2 (BRRI hybrid dhan 5). The present finding on number of non-effective tillers hill^{-1} was similar with the findings of Haque and Biswas (2014).

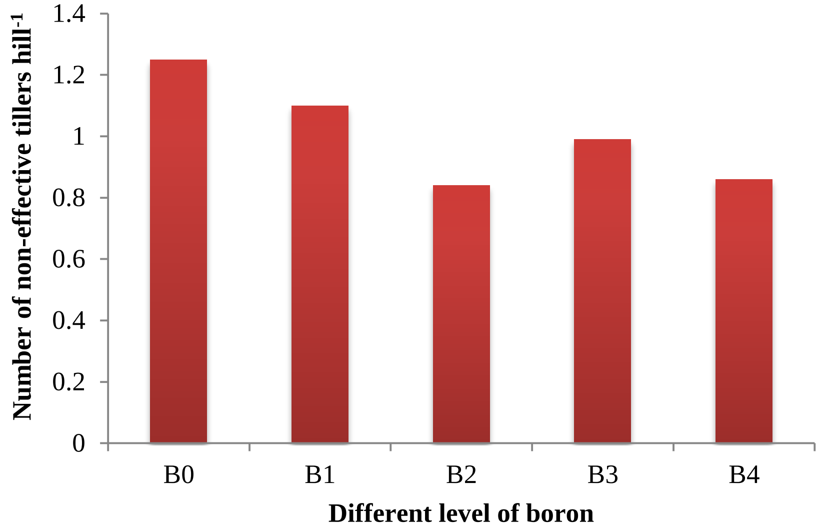


V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5

Figure 13. Effect of variety on the number of non-effective tillers hill^{-1} of rice at ($LSD_{(0.05)}$ = 0.08)

4.2.2.2 Effect of boron

Significant difference was found in terms of number of non-effective tillers hill^{-1} of rice influenced by splitting different rates of boron (Figure 14 and Appendix X). The highest number of non-effective tillers hill^{-1} (1.25) was obtained from the treatment B_0 followed by B_1 (1.10) where the lowest number of non-effective tillers hill^{-1} (0.84) was obtained from the treatment B_2 which was close to B_4 (0.86).



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 14. Effect of different levels of boron splitting on the number of non-effective tillers hill^{-1} of rice ($LSD_{(0.05)}$ = 0.15)

4.2.2.3 Interaction effect of variety and boron

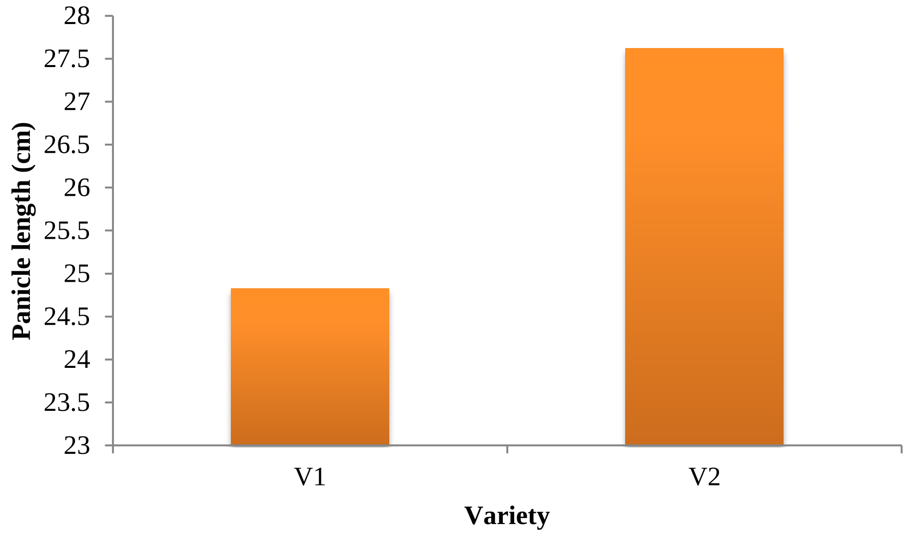
Interaction effect of variety and splitting different rates of boron showed significant variation on number of non-effective tillers hill^{-1} (Table 6 and Appendix X). It was found that the highest number of non-effective tillers hill^{-1} (1.27) was observed from the treatment combination of V_1B_0 followed by V_2B_0 and V_1B_1 where the lowest number of non-effective tillers hill^{-1} (0.73) was obtained from the treatment combination of V_2B_4 which was statistically identical with V_1B_2 and V_2B_3.

4.2.3 Panicle length

4.2.3.1 Effect of variety

Significant variation on panicle length was exerted due to different variety of rice (Figure 15 and Appendix X). It was revealed that the highest panicle length (27.62 cm) was observed from the variety V_2 (BRRI hybrid dhan 5) where the lowest panicle length (24.83

cm) was achieved from the variety V_1 (BRRI dhan28). Islam *et al*. (2010), Haque *et al.* (2013) and Khalifa (2009) also found similar results with the present study.

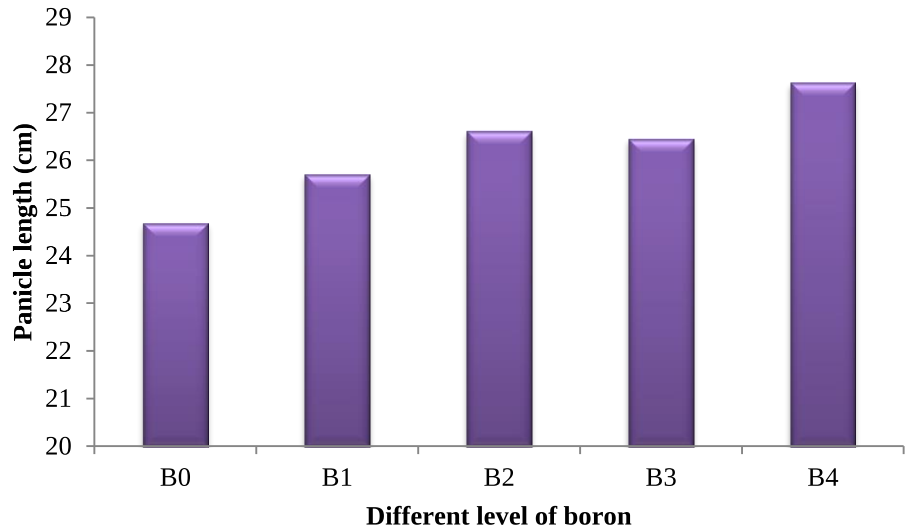


V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5

Figure 15. Effect of variety on the panicle length of rice ($LSD_{(0.05)}$ = 2.72)

4.2.3.2 Effect of boron

Significant variation was observed in terms of panicle length influenced by splitting different rates of boron (Figure 16 and Appendix X). It was achieved that the highest panicle length (27.68 cm) was obtained from the treatment B_4 which was statistically similar with B_2 (26.62) where the lowest panicle length (24.68 cm) was obtained from the treatment B_0 followed by B_1 (25.70 cm). Khan *et al.* (2007) also found similar results with the present study. Boron plays an important role in increasing the formation and elongation of panicles in rice plants (Omar *et al.*, 2012). Dobermann and Fairhurst (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.



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 16. Effect of different levels of boron splitting on the panicle length of rice ($LSD_{(0.05)}$ = 1.97)

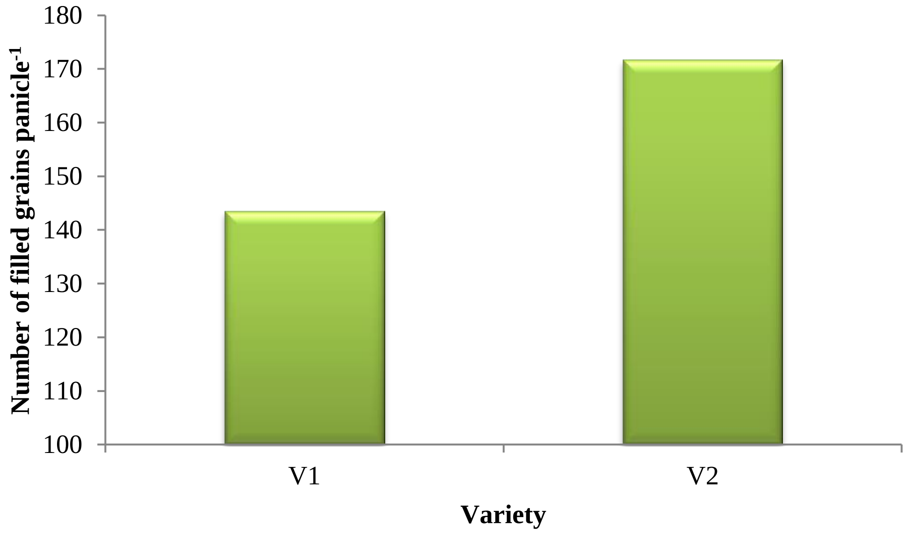
4.2.3.3 Interaction effect of variety and boron

Panicle length was statistically influenced by interaction effect of variety and splitting different rates of boron (Table 6 and Appendix X). Results showed that the highest panicle length (29.60 cm) was obtained from the treatment combination of V_2B_4 which was statistically identical with V_2B_2, V_2B_3 and V_2B_1. The lowest panicle length (23.57 cm) was achieved by the treatment combination of V_1B_0 which was statistically identical with V_2B_0, V_1B_1, V_1B_4 and V_1B_3.

4.2.4 Number of filled grains panicle^{-1}

4.2.4.1 Effect of variety

Significant difference was observed on number of filled grains panicle^{-1} due to different variety of rice (Figure 17 and Appendix X). Results stated that the highest number of filled grains panicle^{-1} (171.73) was obtained the variety V_2 (BRRI hybrid dhan 5) where the lowest number of filled grains panicle^{-1} (143.53) was achieved from the variety V_1 (BRRI dhan28). Paul *et al*. (2014), Islam *et al*. (2010) and Sarkar *et al.* (2013) also found similar results with the present study.

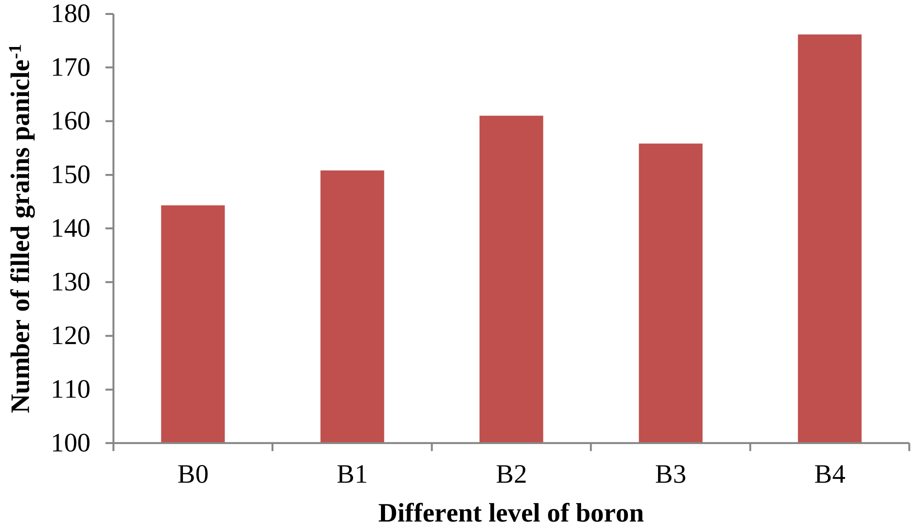


V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5

Figure 17. Effect of variety on the number of filled grains panicle^{-1} of rice ($LSD_{(0.05)}$ = 18.70)

4.2.4.2 Effect of boron

Number of filled grains panicle^{-1} of rice was significantly influenced by splitting different rate of boron (Figure 18 and Appendix X). It was found that the highest number of filled grains panicle^{-1} (176.17) was achieved from the treatment, B_4 followed by B_2 (161.00). The lowest number of filled grains panicle^{-1} (144.33) was observed from the treatment, B_0 which was statistically similar with B_1. More number of 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 (Farooq *et al*., 2012). 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. Maximum number of grains per panicle against control plots might be due to the reduction in pollen sterility of rice and proper grain filling (Rashid *et al.*, 2004). Ali *et al*. (2016), Saleem *et al*. (2010) and Shafiq and Maqsood (2010) also found similar trend of results with the present study.



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 18. Effect of different levels of boron splitting on the number of filled grains panicle^{-1} of rice ($LSD_{(0.05)}$ = 24.42)

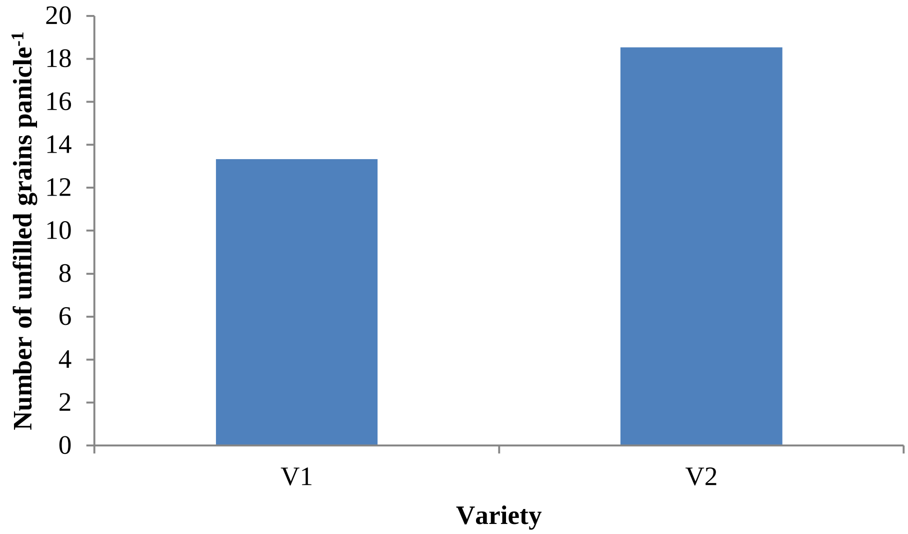
4.2.4.3 Interaction effect of variety and boron

Significant difference was exerted for number of filled grains panicle^{-1} of rice due to interaction effect of variety and splitting different rate of boron (Table 6 and Appendix X). Results showed that the highest number of filled grains panicle^{-1} (193.00) was obtained from the treatment combination of V_2B_4 followed by V_2B_2, V_2B_3 V_2B_1 and V_1B_4. The lowest number of filled grains panicle^{-1} (133.33) was revealed from the treatment combination of V_1B_0 which was statistically identical with V_1B_1, V_2B_0, V_1B_2 and V_1B_3.

4.2.5 Number of unfilled grains panicle^{-1}

4.2.5.1 Effect of variety

Significantly influenced by different variety of rice on number of unfilled grains panicle^{-1} was observed under the study (Figure 19 and Appendix X). It was revealed that the lowest number of unfilled grains panicle^{-1} (13.33) was found from the variety V_1 (BRRI dhan28) which was statistically dissimilar with V_2 (BRRI hybrid dhan 5) where the highest number of unfilled grains panicle^{-1} (18.53) was achieved from the variety V_2 (BRRI hybrid dhan 5).

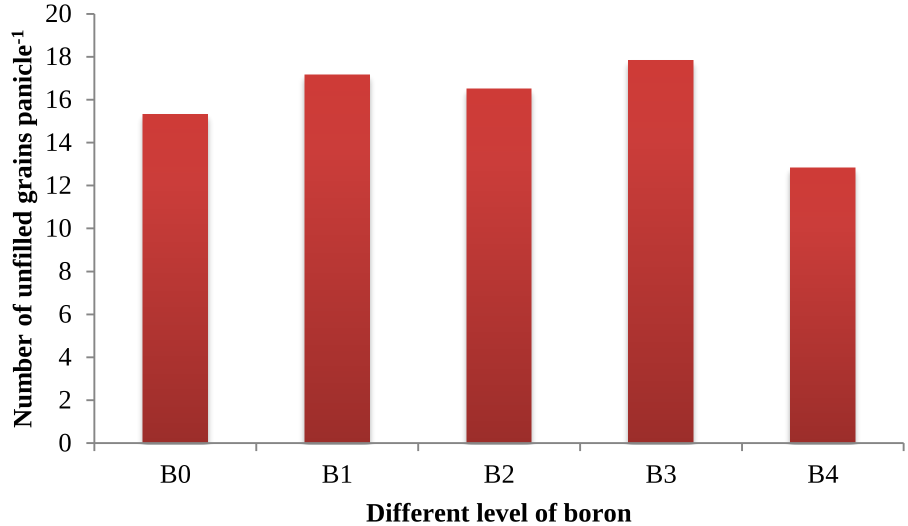


V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5

Figure 19. Effect of variety on the number of unfilled grains panicle^{-1} of rice (LSD $_{(0.05)}$ = 2.98)

4.2.5.2 Effect of boron

Significant difference was found in terms of number of unfilled grains panicle^{-1} of rice influenced by splitting different rates of boron (Figure 20 and Appendix X). Results showed that the lowest number of unfilled grains panicle^{-1} (12.83) was exhibited from the treatment B_4 where the highest number of unfilled grains panicle^{-1} (17.83) was found from the treatment B_3 which was statistically similar with B_1. This might be due to the supplemental foliar application of B which helped to reduce panicle sterility during panicle formation stage ultimately reduce the number of unfilled grain per panicle, on the other hand the control plot did not receive supplementary B during panicle formation stage, which may cause increasing the number of unfilled grain per panicle. This finding was in line with the findings of Ali *et al*. (2016) and Saleem *et al*. (2010) who revealed that the supplemental application of B during panicle formation stage increase the number of filled grain per panicle but lack of boron during this stage could increase the number of unfilled grain.



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 20. Effect of different levels of boron splitting on the number of unfilled grains panicle^{-1} of rice ($LSD_{(0.05)}$ = 2.83)

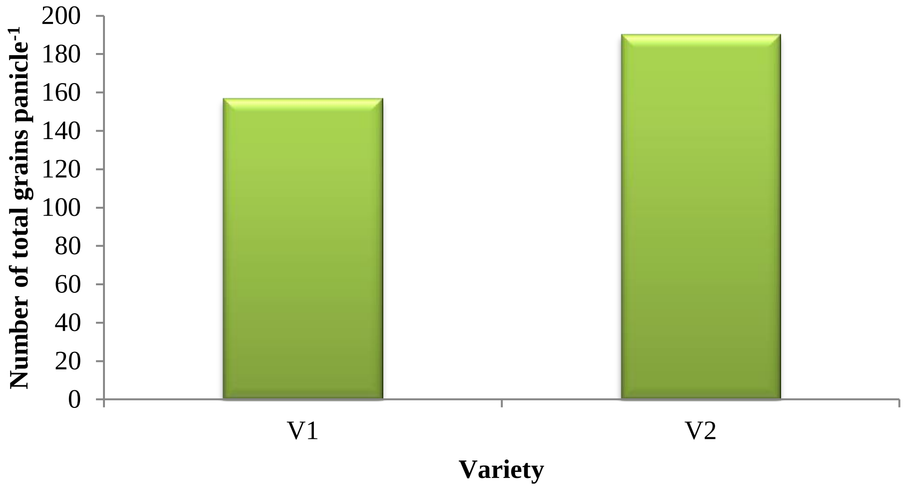
4.2.5.3 Interaction effect of variety and boron

Significant difference on number of unfilled grains panicle^{-1} was observed by interaction effect of variety and splitting different rates of boron (Table 6 and Appendix X). It was revealed that the lowest number of unfilled grains panicle^{-1} (12.00) was observed from the treatment combination of V_2B_4 which was statistically similar with V_1B_1, V_1B_2, V_1B_4 and V_1B_0. The highest number of unfilled grains panicle^{-1} (21.67) was achieved from the treatment combination of V_2B_3 which was statistically similar with V_2B_2 and V_2B_0.

4.2.4 Number of total grains panicle^{-1}

4.2.4.1 Effect of variety

There was marked variation observed on number of total grains panicle^{-1} due to different variety of rice (Figure 21 and Appendix X). Results exhibit that the highest number of total grains panicle^{-1} (190.27) was obtained the variety V_2 (BRRI hybrid dhan5) where the lowest number of total grains panicle^{-1} (156.87) was observed from the variety V_1 (BRRI dhan28). Paul *et al*. (2014), Islam *et al*. (2014) and Sarkar *et al.* (2013) also found similar results with the present study.

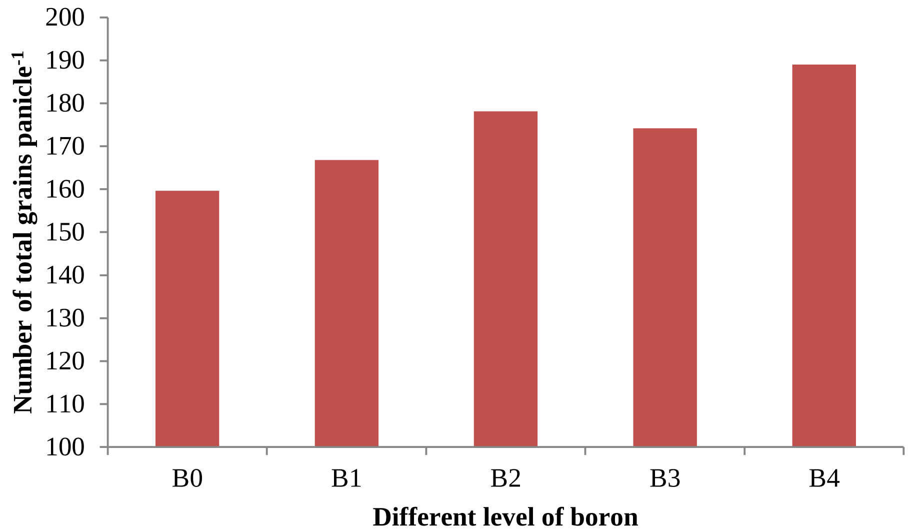


V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan5

Figure 21. Effect of variety on the number of total grains panicle^{-1} of rice ($LSD_{(0.05)}$ = 18.13)

4.2.4.2 Effect of boron

Number of total grains panicle^{-1} of rice was significantly affected by splitting different rate of boron (Figure 21 and Appendix X). It was observed that the highest number of total grains panicle^{-1} (189.00) was obtained from the treatment B_4 followed by B_2 (178.17). The lowest number of total grains panicle^{-1} (159.67) was obtained from the treatment B_0. Total number of 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 (Farooq *et al*., 2012). 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. Maximum number of grains per panicle against control plots might be due to the reduction in pollen sterility of rice and proper grain filling (Rashid *et al.*, 2004). Saleem *et al*. (2010), Shafiq and Maqsood (2010) and Ali *et al*. (2016) also found similar trend of results with the present study.



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 22. Effect of different levels of boron splitting on the number of total grains panicle^{-1} of rice ($LSD_{(0.05)}$ = 26.93)

4.2.6.3 Interaction effect of variety and boron

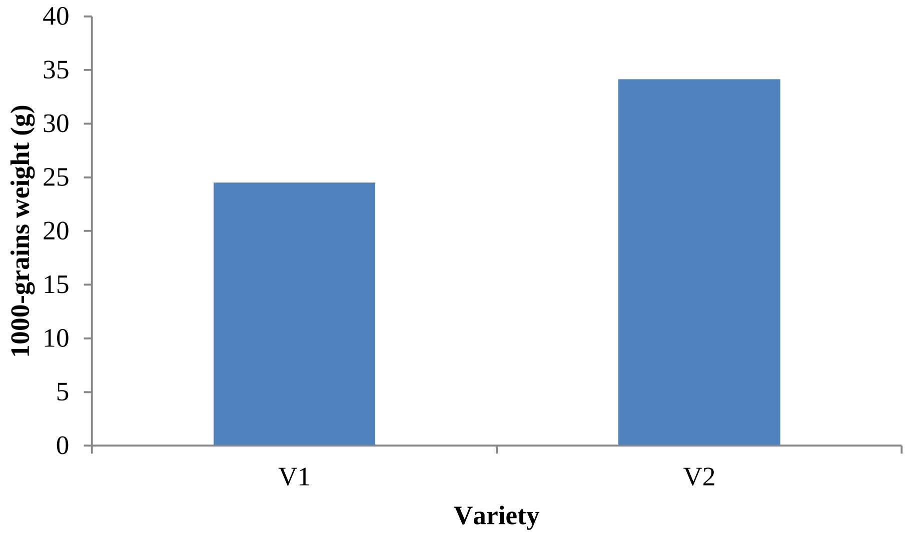
There was remarked variation was exerted for number of total grains panicle^{-1} of rice due to Interaction effect of variety and splitting different rate of boron (Table 6 and Appendix X). Among the different treatment combinations, the highest number of total grains panicle^{-1} (205.00) was achieved from the treatment combination of V_2B_4 which was statistically similar with V_2B_2 followed by V_2B_3, V_2B_1, V_2B_0 and V_1B_4. The lowest number of total grains panicle^{-1} (145.67) was obtained from the treatment combination of V_1B_0 which was statistically similar with V_1B_1, V_1B_2 and V_1B_3.

4.2.7 Weight of 1000-grains

4.2.7.1 Effect of variety

Weight of 1000-grains was remarkably influenced by different variety of rice (Figure 23 and Appendix X). It was remarked that the highest 1000-grains weight (34.15 g) was obtained from the variety V_2 (BRRI hybrid dhan 5) where the lowest 1000-grains weight

(24.52 g) was achieved from the variety V_1 (BRRI dhan28). Similar trend of result with the present study was also observed by Murshida *et al*. (2017), Paul *et al*. (2014) and Islam *et al*. (2014).

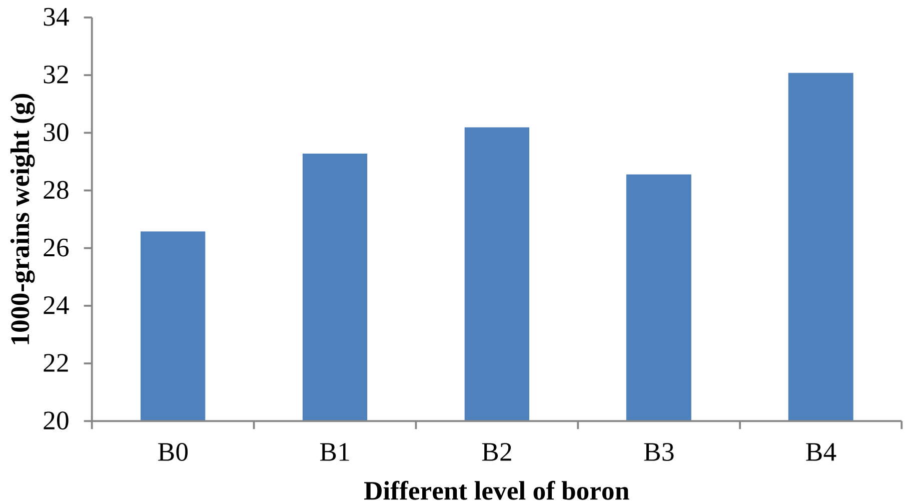


V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5

Figure 23. Effect of variety on the 1000-grains weight of rice ($LSD_{(0.05)}$ = 0.83)

4.2.7.2 Effect of boron

There was marked difference found in terms of 1000-grain weight of rice affected by splitting different rates of boron (Figure 24 and Appendix X). It was noted that the highest 1000-grains weight (32.08 g) was achieved from the treatment B_4 which was statistically similar with B_2. The lowest 1000 grain weight (26.58 g) was observed from the treatment B_0. It might be in case of more efficient participation of B in various metabolic processes which enhanced accumulation of assimilates in the grains and resulted in heavier grains weight. It is well established fact that B supply is imperative for obtaining high yields and good quality because of its fundamental part in the biochemical processes (Gupta, 1993). These results are supported by the findings of Saleem *et al*. (2010), Khan *et al.* (2007), Shafiq and Maqsood (2010), Suleimani (2006) and Ashraf *et al.* (2004). They concluded that 1000-grain weight of rice increased with the increasing level of B fertilizer.



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 24. Effect of different levels of boron splitting on the 1000-grains weight of rice ($LSD_{(0.05)}$ = 3.64)

4.2.7.3 Interaction effect of variety and boron

Significant variation on 1000-grains weight was influenced by Interaction effect of variety and splitting different rates of boron (Table 6 and Appendix X). Among the different treatment combinations, the highest 1000-grains weight (38.23 g) was obtained from the treatment combination of V_2B_4 which was statistically similar with V_2B_1, V_2B_2 followed by V_2B_3. The lowest 1000 grain weight (22.95 g) was achieved from the treatment combination of V_1B_0 which was statistically similar with the treatment combinations of V_1B_1, V_1B_2 and V_1B_3.

Table 6. Interaction effect of variety and different levels of boron splitting on effective, non-effective tillers hills^{-1}, panicle length, filled grains, unfilled grains, total grains panicle^{-1} and weight of 1000-grains

Treatment combination	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Panicle length (cm)	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Total grains panicle^{-1} (No.)	Weight of 1000-grains (g)
V_1B_0	10.26 c	1.27 a	23.57 d	133.33 d	11.33 e	145.67 c	22.95 d
V_1B_1	10.48 bc	1.19 a-c	24.33 cd	134.33 cd	12.00 e	146.33 c	24.50 d
V_1B_2	12.50 a-c	1.00 cd	25.27 b-d	148.33 b-d	13.67 de	162.00 bc	25.31 d
V_1B_3	10.83 bc	1.04 b-d	25.23 b-d	142.33 b-d	15.00 c-e	157.33 bc	23.90 d
V_1B_4	13.11 ab	0.99 cd	25.77 b-d	159.33 a-d	13.67 de	173.00 a-c	25.93 cd
V_2B_0	10.33 bc	1.22 ab	25.80 b-d	154.33 b-d	19.34 a-c	173.67 a-c	30.20 b
V_2B_1	10.70 bc	1.01 b-d	27.06 a-c	168.33 a-c	19.00 b-d	187.33 ab	34.03 ab
V_2B_2	11.49 bc	0.84 de	27.97 ab	173.67 ab	20.66 ab	194.33 ab	35.07 ab
V_2B_3	11.18 bc	0.93 de	27.67 a-c	169.33 ab	21.67 a	191.00 ab	33.20 ab
V_2B_4	14.27 a	0.73 e	29.60 a	193.00 a	12.00 e	205.00 a	38.23 a
LSD $_{(0.05)}$	**2.65**	**0.22**	**2.78**	**34.53**	**3.99**	**38.09**	**5.15**
CV(%)	**5.36**	**12.77**	**6.14**	**12.66**	**14.49**	**12.68**	**10.14**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

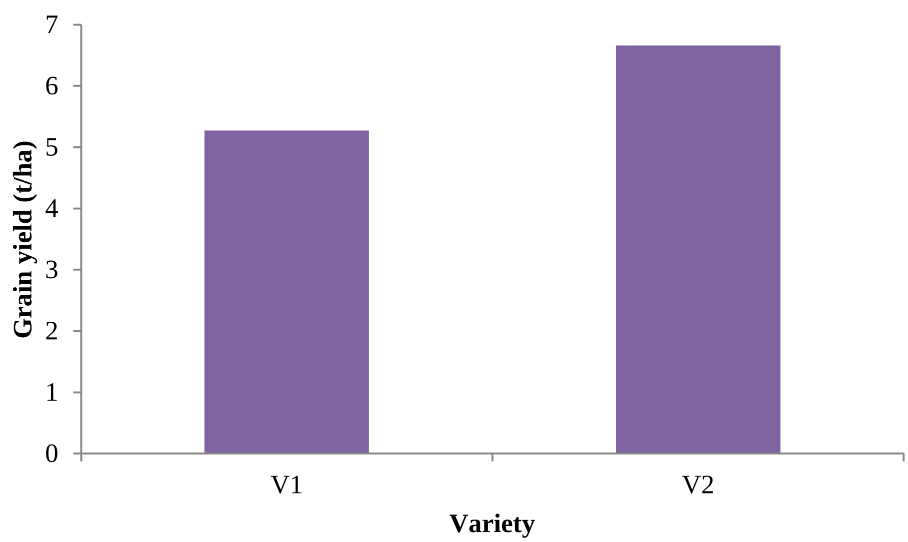
V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5; B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

4.3 Yield parameters

4.3.1 Grain yield

4.3.1.1 Effect of variety

Grain yield was significantly affected by different variety of rice (Figure 25 and Appendix XI). It was observed that the highest grain yield (6.66 t ha^{-1}) was obtained from the variety V_2 (BRRI hybrid dhan 5) where the lowest grain yield (5.27 t ha^{-1}) was found from the variety V_1 (BRRI dhan28). Varietal execution on grain yield might be a genetical attribute which influenced the grain yield of rice. The results on grain yield agreement with the findings of Murshida *et al*. (2017), Widyastuti *et al.* (2015), Chamely *et al.* (2015) and Paul *et al*. (2014) who reported that grain yield varied due to varietal differences.

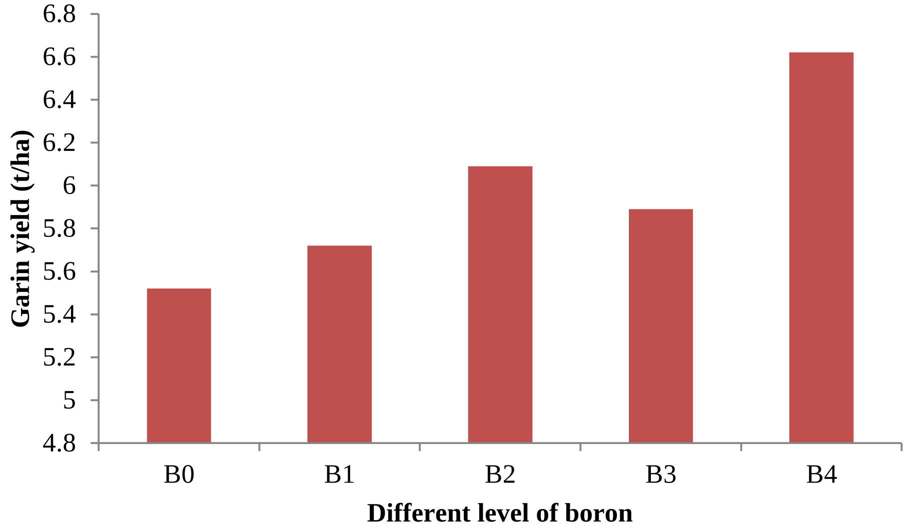


V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5

Figure 25. Effect of variety on the grain yield of rice ($LSD_{(0.05)}$ = 0.66)

4.3.1.2 Effect of boron

Statistically marked difference was found in terms of grain yield affected by splitting different rates of boron (Figure 26 and Appendix XI). Results showed that the highest grain yield (6.62 t ha^{-1}) was obtained from the treatment B_4 followed by B_2 (6.09 t ha^{-1}) where the lowest grain yield (5.52 t ha^{-1}) was found from the treatment, B_0 which was statistically identical with B_1 (5.72 t ha^{-1}). The yield increase was because of the role of B in plant physiological functions very remarkably during plant reproductive stage so its growth attributes such as tillers number, panicle length, number of filled grains panicle^{-1} and 1000-grains weight improved which attributed the higher grain yield. Boron is basically embroils in several biochemical processes such as carbohydrate metabolism, sugar transport, lignification, nucleotide synthesis, respiration and pollen viability therefore its deficiency directly influences panicle production and hence the rice yield (Dobermann and Fairhurst, 2000). Hussain *et al*. (2012) revealed that, maximum grain yield by foliage application of B at the flowering stage might be the direct impact of higher number of grains panicle^{-1} and 1000-grain weight. Many reports concluded that B applied at the heading or flowering phase in rice resulted in increased rice grain yield and grains number panicle^{-1} (Ramanthan *et al*., 2002; Lin and Zhu, 2000). Along this, by supplying plants with micronutrients especially B, either through soil application, foliar application, or seed treatment, increases yield and quality as well as macronutrient use efficiency (Imtiaz *et al*., 2006). B has remarkably identified as one of the important elements for the grain crop production in the world. Jana *et al*. (2005) and Rashid *et al*. (2006) reported that, B application enhanced rice yield due to reduced panicle sterility appreciably. On the other hand, the reason for the lowest grain yield in boron deficient plots might be the higher pollen infertility and lower grain filling as it plays very essential role in both processes (Rashid *et al*., 2004; Rerkasem *et al*., 1993). Again, Cheng and Rerkasem (1993) opined that, B deficiency reduces pollen germination and the fertilization process. The soil application of boron is stated to be as effective as its Interaction use with NPK or other micronutrients (Timmer *et al.,* 2007 and Dunn *et al.*, 2005). Farooq *et al.* (2012) also revealed that, decrease in panicle sterility and increases in grain size are the principal reasons of increase in grain yield by B as foliage application. Adequate B supply may also help maintain the assimilate supply to the developing grains (Sharma *et al*., 2002) and increase the grain size. The trend of on grain yield from the present study was similar with the findings of Patil *et al*. (2017), Rahman *et al*. (2016), Shafiq and Maqsood (2010) and Islam *et al*. (1997). Micronutrient malnutrition is a major human health problem in the developing world (Yang *et al.*, 2007; Khan *et al*., 2007; Farooq *et al*., 2012); so, considering the human sound health, biofortification of B offers an attractive and economical solution of this important issue (Mao *et al*., 2014).



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 26. Effect of different levels of boron splitting on the Grain yield of rice ($LSD_{(0.05)}$ = 0.58)

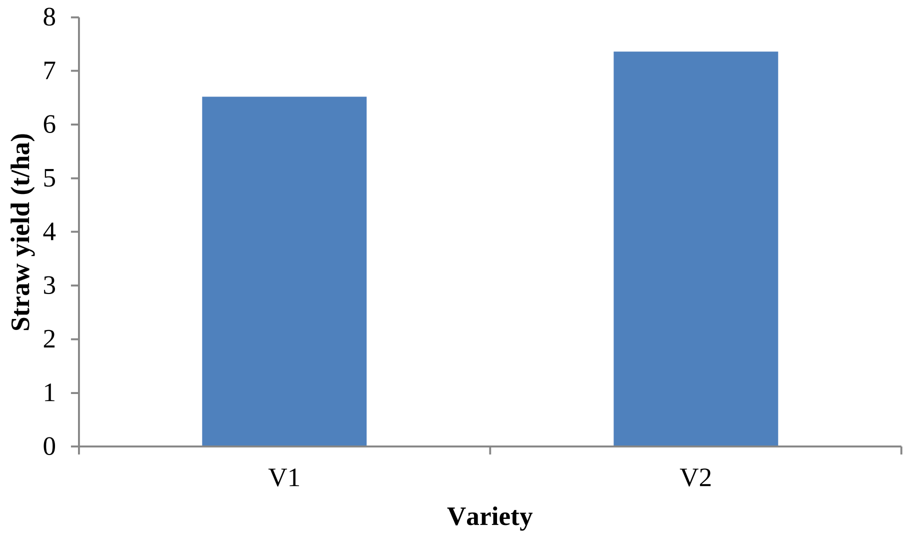
4.3.1.3 Interaction effect of variety and boron

There was marked variation on grain yield of rice was observed by interaction effect of variety and splitting different rates of boron (Table 7 and Appendix XI). It was noted that the highest grain yield (7.64 t ha^{-1}) was obtained from the treatment combination of V_2B_4 which was statistically dissimilar with the other treatment combination where the lowest grain yield (5.00 t ha^{-1}) was obtained from the treatment combination of V_1B_0 which was statistically identical with V_1B_1, V_1B_2, V_1B_3 and V_1B_4.

4.3.2 Straw yield

4.3.2.1 Effect of variety

Significant influence on straw yield was found because of different variety of rice (Figure 27 and Appendix XI). Considering varietal variation, the highest straw yield (7.36 t ha^{-1}) was observed from the variety V_2 (BRRI hybrid dhan 5) which was statistically dissimilar with V_1 (BRRI dhan28) where the lowest straw yield (6.52 t ha^{-1}) was obtained from the variety V_1 (BRRI dhan28).

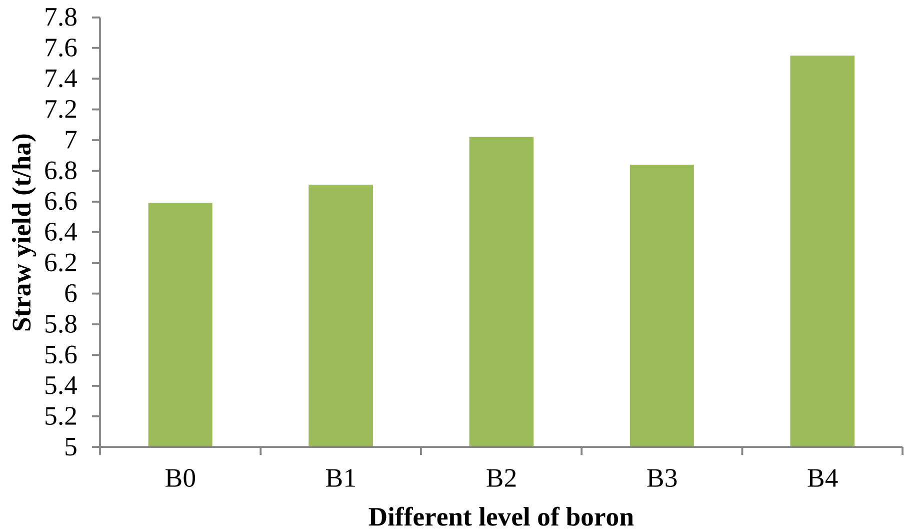


V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5

Figure 27. Effect of variety on the straw yield of rice ($LSD_{(0.05)}$ = 0.56)

4.3.2.2 Effect of boron

Significant impact was observed in terms of straw yield influenced by splitting different rates of boron under the study (Figure 28 and Appendix XI). Among the different boron treatment, the highest straw yield (7.55 t ha^{-1}) was noted from the treatment B_4 which was statistically similar with B_2 (7.02 t ha^{-1}) where the lowest straw yield (6.59 t ha^{-1}) was observed from the treatment B_0 which was statistically similar with B_1 (6.71 t ha^{-1}). Application of B increased rice straw yield because boron improved the membranes function which directly affect the transport of all metabolites that required for the 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. This result was in agreement with the findings of Rashid *et al*. (2007).



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 28. Effect of different levels of boron splitting on the straw yield of rice ($LSD_{(0.05)}$ = 0.78)

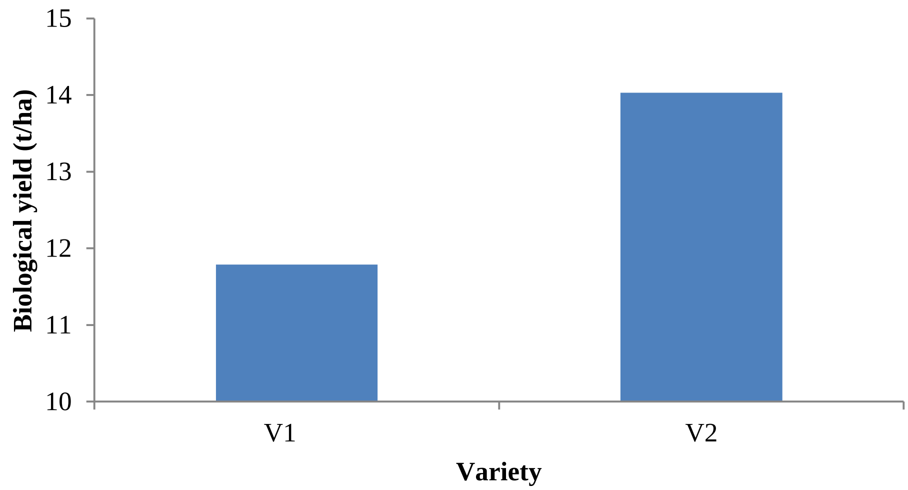
4.3.2.3 Interaction effect of variety and boron

There was marked variation was observed on straw yield of rice by interaction effect of variety and splitting different rates of boron (Table 7 and Appendix XI). Among the different treatment combinations, the highest straw yield (8.27 t ha^{-1}) was found from the treatment combination of V_2B_4 which was statistically similar with V_2B_2 and V_2B_3. On the other hand, the lowest straw yield (6.26 t ha^{-1}) was achieved from the treatment combination of V_1B_0 which was statistically similar with V_1B_1, V_1B_2, V_1B_3, V_1B_4, V_2B_0 and V_2B_1.

4.3.3 Biological yield

4.3.3.1 Effect of variety

Significant difference was observed on biological yield because of different variety of rice (Figure 29 and Appendix XI). It was found that the highest biological yield (14.03 t ha^{-1}) was obtained from the variety V_2 (BRRI hybrid dhan 5) where the lowest biological yield (11.79 t ha^{-1}) was observed from the variety V_1 (BRRI dhan28).

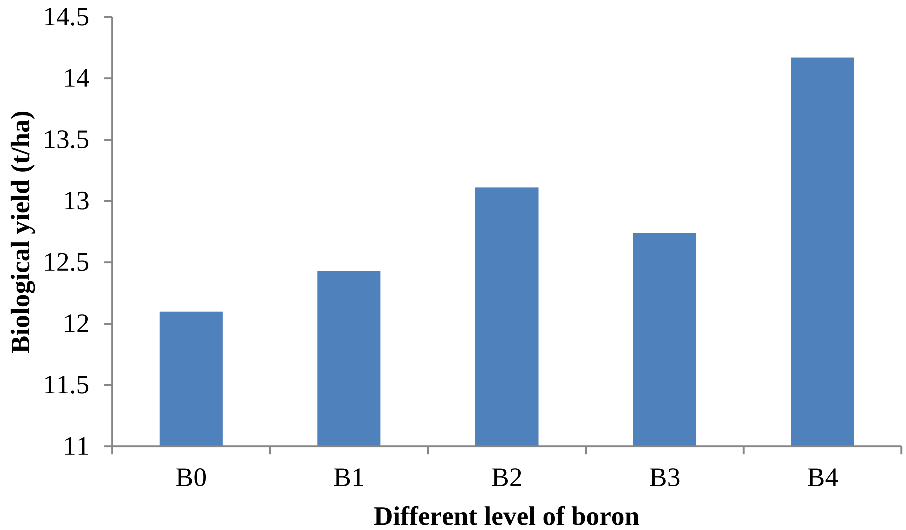


V_1 = BRRI dhan28 and V_2 = BRRI hybrid dhan 5

Figure 29. Effect of variety on the biological yield of rice ($LSD_{(0.05)}$ = 0.64)

4.3.3.2 Effect of boron

Biological yield of rice was significantly influenced by splitting different rate of boron (Figure 30 and Appendix XI). Results showed that the highest biological yield (14.17 t ha^{-1}) was achieved from the treatment B_4 which was statistically similar with the treatment B_2 where the lowest biological yield (12.10 t ha^{-1}) was observed from the treatment B_0 which was statistically similar with treatment B_1 and B_3.



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 30. Effect of different levels of boron splitting on the biological yield of rice ($LSD_{(0.05)}$ = 1.16)

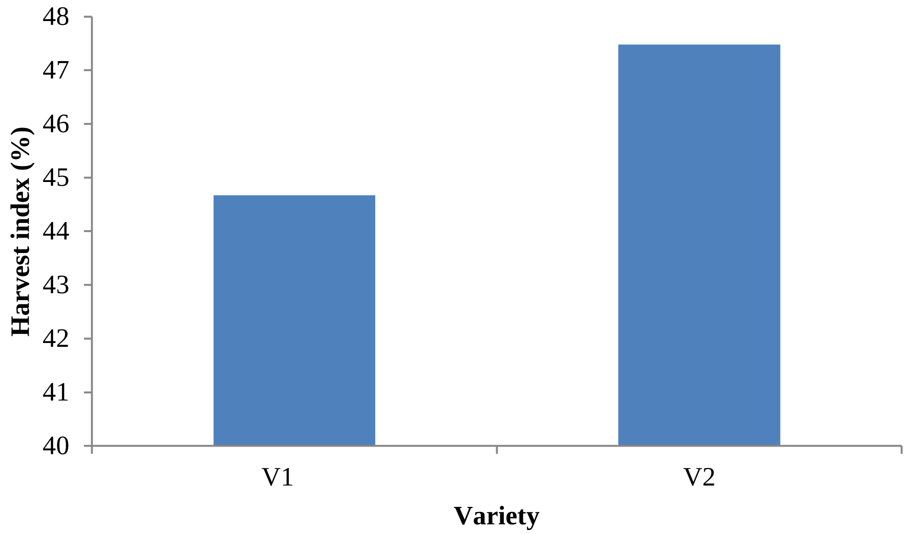
4.3.3.3 Interaction effect of variety and boron

Significant difference was notable for biological yield of rice because of Interaction effect of variety and splitting different rates of boron (Table 7 and Appendix XI). It was remarked that the highest biological yield (15.91 t ha^{-1}) was achieved from the treatment combination of V_2B_4 which was statistically dissimilar with other treatment combinations. On the other hand, the lowest biological yield (12.20 t ha^{-1}) was achieved from the treatment combination of V_1B_0 which was statistically similar with V_1B_1, V_1B_3, V_1B_2 and V_1B_4.

4.3.4 Harvest index

4.3.4.1 Effect of variety

Harvest index was significantly affected by different variety of rice (Figure 31 and Appendix XI). It was expressed that the highest harvest index (47.48%) was obtained from the variety V_2 (BRRI hybrid dhan 5) where the lowest harvest index (44.67%) was achieved from the variety V_1 (BRRI dhan28).

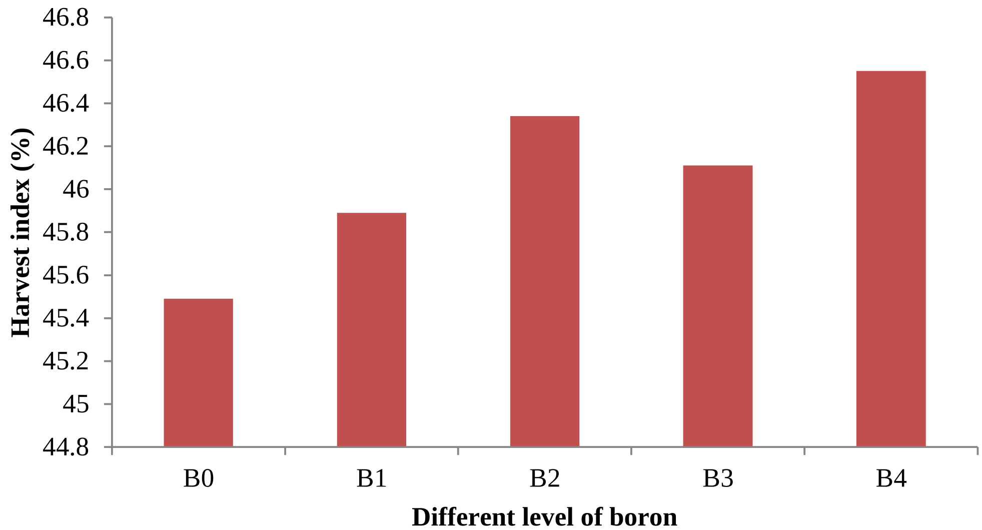


V_1 = BRRI dhan28 and V_2 = BRRI hybrid dhan 5

Figure 31. Effect of variety on the harvest index of rice ($LSD_{(0.05)}$ = 1.99)

4.3.4.2 Effect of boron

Marked variation was exerted in terms of harvest index of rice influenced by splitting different rates of boron (Figure 32 and Appendix XI). Results showed that the highest harvest index (46.55%) was achieved from the treatment B_4 followed by B_2 (46.34%) where the lowest harvest index (45.49%) was obtained from the treatment B_0 followed by B_1 (45.89%). Boron nutrition is more crucial during the reproductive phase as compared to the vegetative phase of the crop in cereals (Rerkasem and Jamjod, 2004). Harvest index improved in case of B application might be because of better starch utilization that results in more seed setting and translocation of assimilates to developing grains, that increases the grain size and grains number per panicle (Hussain *et al*., 2012).



B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

Figure 32. Effect of different levels of boron splitting on the harvest index of rice ($LSD_{(0.05)}$ = 0.93)

4.3.4.3 Interaction effect of variety and boron

Interaction effect of variety and splitting different rates of boron showed remarkable impact on harvest index of boro rice (Table 7 and Appendix XI). It was indicated that the highest harvest index (48.02%) was obtained from the treatment combination of V_2B_4 followed by V_2B_2 and V_2B_3. The lowest harvest index (44.40%) was achieved from the treatment combination of V_1B_0 which was statistically similar with V_1B_1, V_1B_2 and V_1B_3.

Table 7: Interaction effect of variety and different levels of boron splitting on grain yield, straw yield, biological yield and harvest index of boro rice

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
V_1B_0	5.00 e	6.26 c	11.26 f	44.40 d
V_1B_1	5.12 e	6.39 bc	11.51 ef	44.48 d
V_1B_2	5.37 de	6.61 bc	11.98 d-f	44.82 b-d
V_1B_3	5.26 de	6.50 bc	11.76 ef	44.72 cd
V_1B_4	5.60 c-e	6.82 bc	12.42 c-f	45.08 a-d
V_2B_0	6.03 b-d	6.91 bc	12.94 b-e	46.59 a-d
V_2B_1	6.31 b-d	7.03 bc	13.34 b-d	47.30 a-d
V_2B_2	6.81 b	7.42 ab	14.23 b	47.86 ab
V_2B_3	6.53 b	7.18 a-c	13.71 bc	47.63 a-c
V_2B_4	7.64 a	8.27 a	15.91 a	48.02 a
$LSD_{(0.05)}$	**0.82**	**1.10**	**1.64**	**2.88**
CV(%)	**7.93**	**9.19**	**7.36**	**3.61**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

V_1 = BRRI dhan28, V_2 = BRRI hybrid dhan 5; B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage

CHAPTER 5

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from November 2018 to May, 2019 to find out the effect of foliar application of boron at different growth stages for increasing boro rice production. Two factors were used in the experiment, *viz*. two rice varieties - V_1 (BRRI dhan28) and V_2 (BRRI hybrid dhan 5) and five levels of boron application - B_0 = 100% of recommended Boron (B) as basal dose, B_1 = 75% of B as basal dose + 25% of B as foliar application at vegetative stage, B_2 = 75% of B as basal application + 12.5% of B as foliar application at vegetative stage + 12.5% of B at panicle initiation, B_3 = 50% of B as basal application + 50% of B as foliar application at vegetative stage and B_4 = 50% of B as basal application + 25% of B at vegetative stage as foliar application + 25% B as foliar application at panicle initiation stage. The experiment was laid out in a Split-plot design with three replications. Data on different growth, yield and yield contributing parameters were recorded.

Different variety had significant influenced on growth, yield and yield contributing parameters. Considering the growth parameters, the highest plant height (100.73 cm) was obtained from the variety V_2 (BRRI hybrid dhan 5) where the highest number of leaves hill^{-1} (41.68) was observed from the variety V_1 (BRRI dhan28). But the highest number of tillers hill^{-1} (12.55), leaf area index (7.21) and dry weight of plant hill^{-1} (62.38 g) were obtained from the variety V_2 (BRRI hybrid dhan 5). Again, the lowest plant height (99.07 cm) and leaf area index (6.46) were found from the variety V_1 (BRRI dhan28) and the lowest number of leaves hill^{-1} (37.85) was achieved from the variety V_2 (BRRI hybrid dhan 5). On the other hand, the lowest number of tillers hill^{-1} (12.50) and dry weight of plant hill^{-1} (61.21 g) were observed from the variety V_1 (BRRI dhan28). In case of yield and yield contributing parameters, the highest number of effective tillers hill^{-1} (11.59), panicle length (27.62 cm), number of filled grains panicle^{-1} (171.73), number of unfilled grains panicle^{-1} (18.53), number of total grains panicle^{-1} (190.27), 1000-grains weight (34.15 g), grain yield (6.66 t ha^{-1}), straw yield (7.36 t ha^{-1}), biological yield (14.03 t ha^{-1})

and harvest index (47.48%) were achieved from the variety V_2 (BRRI hybrid dhan 5). The lowest number of non-effective tillers hill^{-1} (0.94) was achieved from the variety V_2 (BRRI hybrid dhan 5) respectively. The lowest number of effective tillers hill^{-1} (11.43), panicle length (24.83 cm), number of filled grains panicle^{-1} (143.53), number of total grains panicle^{-1} (156.87), 1000-grains weight (24.52 g), grain yield (5.27 t ha^{-1}), straw yield (6.52 t ha^{-1}), biological yield (11.79 t ha^{-1}) and harvest index (44.67%) were achieved from the variety V_1 (BRRI dhan28) but the highest number of non-effective tillers hill^{-1} (1.14) was observed from the variety V_1 (BRRI dhan28).

Splitting different rates of boron application had also significant influenced on growth, yield and yield contributing parameters. Considering growth parameters, the highest plant height (102.72 cm) was achieved from the treatment, B_2 where the highest leaf area index (10.74) was obtained from B_4 but the highest number of leaves hill^{-1} (47.33) was achieved from B_3. The highest number of tillers hill^{-1} (14.54) and highest dry weight of plant hill^{-1} (70.68 g) were obtained from the treatment B_4. The lowest plant height (94.51 cm), number of leaves hill^{-1} (34.19), number of tillers hill^{-1} (11.54), leaf area index (7.42) and lowest dry of plant (54.09 g) were found from the treatment B_0. In terms of yield and yield contributing parameters, the highest number of effective tillers hill^{-1} (13.69), panicle length (27.68 cm), number of filled grains panicle^{-1} (176.17), number of total grains panicle^{-1} (189.00), 1000-grains weight (32.08 g), grain yield (6.62 t ha^{-1}), straw yield (7.55 t ha^{-1}), biological yield (14.17 t ha^{-1}) and harvest index (46.55 %) were obtained from the treatment B_4 where the lowest number of non-effective tillers hill^{-1} (0.83) was obtained from B_2 and number of unfilled grains panicle^{-1} (12.83) were achieved from the treatment B_4. On the other hand, the lowest number of effective tillers hill^{-1} (10.29), panicle length (24.68 cm), number of filled grains panicle^{-1} (144.33), number of total grains panicle^{-1} (159.67), 1000-grains weight (26.58 g), grain yield (5.52 t ha^{-1}), straw yield (6.59 t ha^{-1}), biological yield (12.10 t ha^{-1}) and harvest index (45.49%) were achieved from the treatment B_0. The highest number of non-effective tillers hill^{-1} (1.29) was also found from the treatment B_0. But the highest number of unfilled grains panicle^{-1} (17.83) was achieved from the treatment B_3.

Interaction effect of variety and splitting different rates of boron as foliar application had also significant influenced on growth, yield and yield contributing characters of boro rice.

Considering growth parameters, the highest plant height (108.10 cm) was obtained from the treatment combination of V_2B_2 where the highest number of leaves hill^{-1} (49.85) was achieved from the treatment combination of V_1B_3 but the highest leaf area index (8.05), the highest number of tillers hill^{-1} (15.00) and dry weight of plant hill^{-1} (71.78 g) were achieved from the treatment combination of V_2B_4. The lowest plant height (92.20 cm), leaf area index (5.46), number of tillers hill^{-1} (11.52) and dry weight of plant hill^{-1} (52.44 g) were obtained from the treatment combination of V_1B_0 but the lowest number of leaves hill^{-1} (32.66) was achieved from the treatment combination of V_2B_0. In terms of yield and yield contributing characters, the highest number of effective tillers hill^{-1} (14.27), panicle length (29.60 cm), number of filled grains panicle^{-1} (193.00), number of total grains panicle^{-1} (205.00), 1000-grains weight (38.23 g), grain yield (7.64 t ha^{-1}), straw yield (8.27 t ha^{-1}), biological yield (15.91 t ha^{-1}) and harvest index (48.02%) were achieved from the treatment combination of V_2B_4 but the highest unfilled grains panicle^{-1} (21.67) was achieved from the treatment combination of V_2B_3 where the lowest number of effective tillers hill^{-1} (10.26), panicle length (23.57 cm), number of filled grains panicle^{-1} (133.33), number of total grains panicle^{-1} (145.67), 1000 grain weight (22.95 g), grain yield (5.00 t ha^{-1}), straw yield (6.26 t ha^{-1}), biological yield (12.20 t ha^{-1}) and harvest index (44.40%) were achieved from the treatment combination of V_1B_0 but the lowest number of unfilled grains panicle^{-1} (12.00) was observed from the treatment combination of V_2B_4.

CONCLUSION

From the above findings, it may be concluded that the variety V_2 (BRRI hybrid dhan 5 performed as the better variety in respect of panicle fertility and yield. Boron treatment B_4 (50% of B as basal dose + 25% of B as foliar application at vegetative stage + 25% of B as foliar application at panicle initiation stage) performed better results on grain set and panicle fertility. So, the treatment combination of V_2 (BRRI hybrid dhan 5) and B_4 (50% of B as basal dose + 25% of B as foliar application at vegetative stage + 25% of B as foliar application at panicle initiation stage) proved to be superior treatment for maximizing boro rice production.

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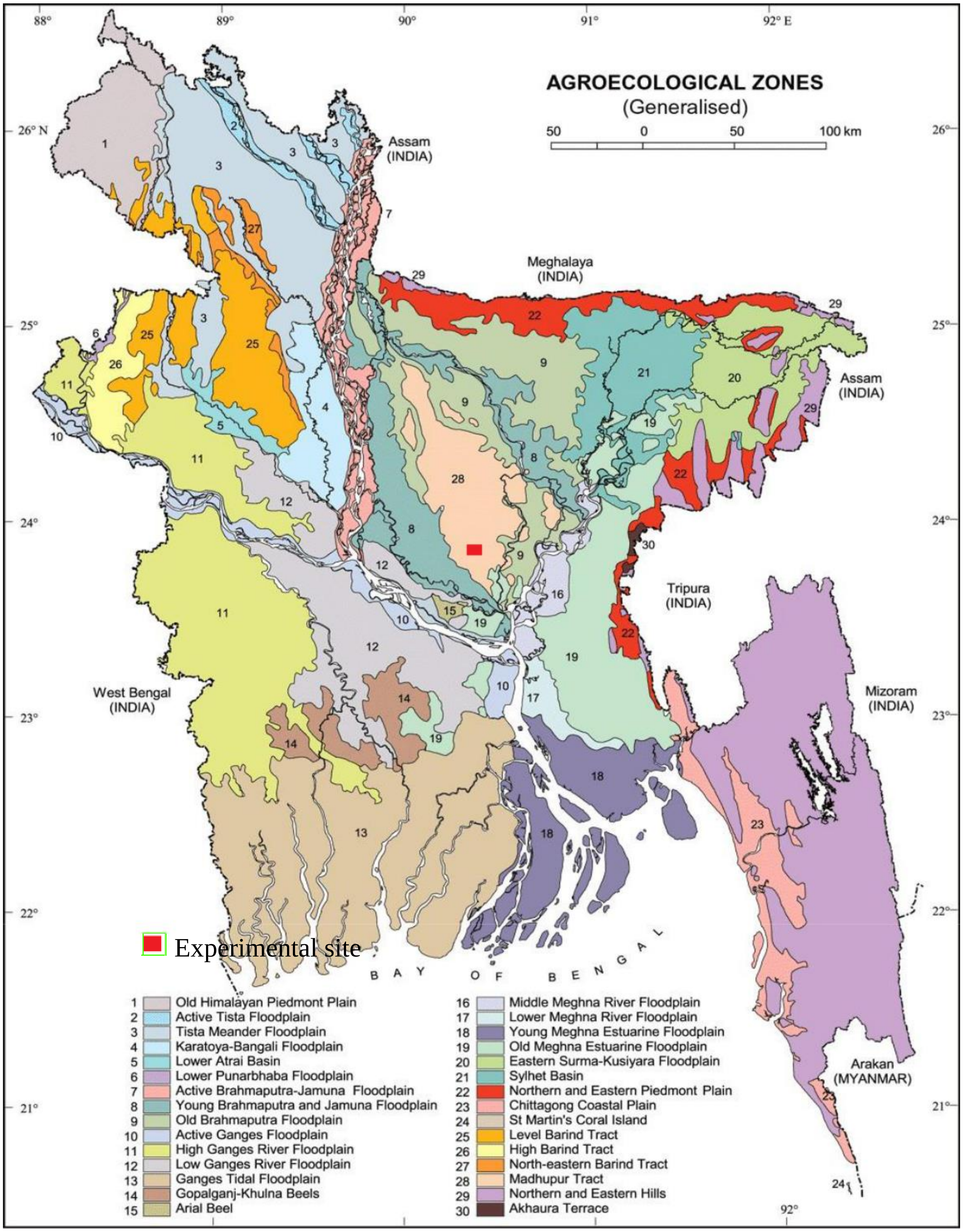
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from November 2018 to May, 2019

Month and year	RH (%)	Air temperature (C)			Rainfall
		Max.	*Min.*	*Mean*	(mm)
November, 2018	56.25	28.70	8.62	18.66	14.5
December, 2018	50.64	27.15	8.55	18.25	14
January, 2019	46.20	23.70	11.55	17.62	0.0
February, 2019	37.95	22.85	14.15	18.50	0.0
March, 2019	52.50	35.30	21.10	28.20	21.7
April, 2019	65.20	34.75	24.70	29.72	160.0
May, 2019	68.40	32.60	23.85	28.22	187.2

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

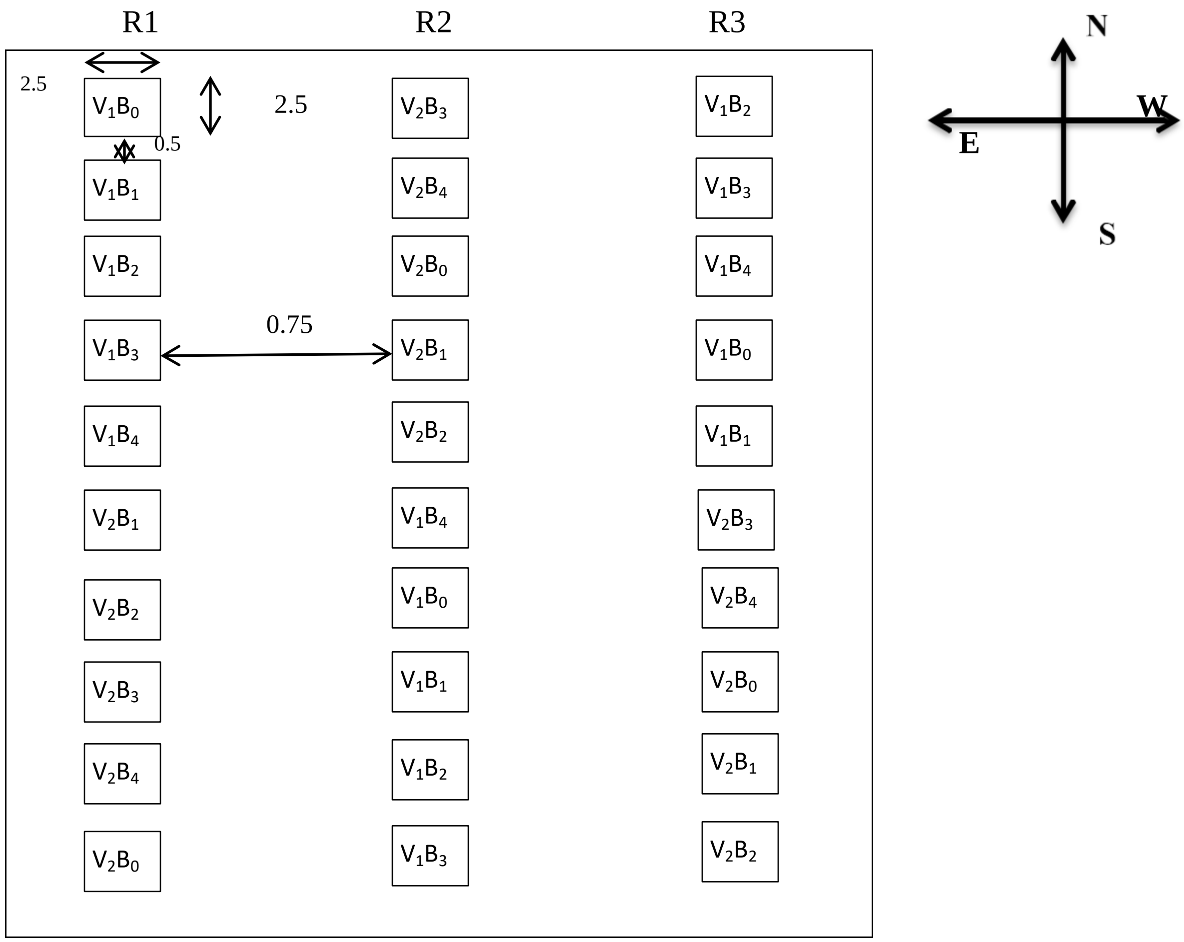
Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field



Length of plot: 2.5 m
Width of plot: 2.5 m
Replication to replication distance: 0.75 m
Plot to plot distance: 0.5 m
Unit plot size: 2.5 m × 2.5 m (6.25 m^2)

Appendix V. Mean square values of plant height of different rice varieties through foliar boron application

Sources of variation	Degrees of freedom	Mean square of plant height			
		30 DAT	60 DAT	90 DAT	At harvest
Replication	2	1.693	0.575	2293.57	2144.09
Factor A	1	0.154^{NS}	47.175^{NS}	109.10*	131.71*
Error	2	4.494	2.744	5.74	3.44
Factor B	4	40.012*	26.571*	64.95*	62.20*
AB	4	4.211*	14.631*	30.34*	23.22*
Error	16	4.777	9.598	34.59	26.66

*Significant at 5% level
NS=Non-significant

Appendix VI. Mean square values of number of leaves hill^{-1} of different rice varieties through foliar boron application

Sources of variation	Degrees of freedom	Mean square of number of leaves hill^{-1}			
		30 DAT	60 DAT	90 DAT	At harvest
Replication	2	6.032	7.176	10.533	17.975
Factor A	1	6.580^{NS}	9.141^{NS}	93.633^{NS}	110.323^{NS}
Error	2	1.931	3.035	16.133	15.402
Factor B	4	11.446*	14.385*	211.383*	194.662*
AB	4	5.513*	5.748*	8.717*	7.126*
Error	16	3.527	5.185	20.625	21.195

*Significant at 5% level
NS=Non-significant

Appendix VII. Mean square values of number of tillers hill^{-1} of different rice varieties through foliar boron application

Sources of variation	Degrees of freedom	Mean square of number of tillers hill^{-1}			
		30 DAT	60 DAT	90 DAT	At harvest
Replication	2	0.082	0.0284	2.064	0.743
Factor A	1	0.411^{NS}	0.0007^{NS}	0.720^{NS}	0.012^{NS}
Error	2	0.089	0.4408	1.805	1.335
Factor B	4	0.980*	9.0873*	8.207*	8.944*
AB	4	0.428*	0.9588*	1.139*	0.943*
Error	16	0.147	0.7189	1.367	1.259

*Significant at 5% level, NS = Non-significant

Appendix VIII. Mean square values of leaf area index of different hybrid rice varieties through foliar boron application

Sources of variation	Degrees of freedom	Mean square of leaf area index			
		30 DAT	60 DAT	90 DAT	At harvest
Replication	2	0.1173	0.0038	4.102	5.609
Factor A	1	0.0030^NS	2.9328^NS	7.530*	4.248*
Error	2	0.0017	0.3582	0.016	0.037
Factor B	4	0.1150*	2.2006*	4.103*	1.828*
AB	4	0.0267*	0.2531*	0.585*	0.398*
Error	16	0.0046	0.3584	0.207	0.232

*Significant at 5% level
NS =Non-significant

Appendix IX. Mean square values of dry weight hill^{-1} of different rice varieties through foliar boron application

Sources of variation	Degrees of freedom	Mean square of dry weight hill^{-1}			
		30 DAT	60 DAT	90 DAT	At harvest
Replication	2	7.5540	74.175	162.533	448.933
Factor A	1	2.5638*	3.360^NS	8.533^NS	8.943^NS
Error	2	0.0007	2.403	4.170	5.200
Factor B	4	11.7017*	101.693*	183.814*	247.769*
AB	4	1.3716*	11.406*	20.403*	51.191*
Error	16	0.0654	6.436	6.272	9.358

*Significant at 5% level
^NS Non-significant

Appendix X. Mean square values of yield contributing parameters of different rice varieties through foliar boron application

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters						
		Number of effective tillers $hill^{-1}$	Number of non-effective tillers $hill^{-1}$	Panicle length	Number of filled grains $panicle^{-1}$	Number of unfilled grains $panicle^{-1}$	Number of total grains $panicle^{-1}$	1000-grains weight
Replication	2	11.940	0.264	4.257	323.43	1.733	326.53	4.100
Factor A	1	0.187^{NS}	0.104*	58.241*	5964.30*	202.800*	8366.70*	695.142*
Error	2	2.596	0.002	3.017	141.70	3.600	133.20	0.282
Factor B	4	11.335*	0.175*	7.474*	871.78*	23.133*	717.13*	24.784*
AB	4	0.905*	0.0169*	0.576*	57.38*	31.133*	64.03*	4.848*
Error	16	2.348	0.0169	2.596	398.11	5.333	484.28	8.847

*Significant at 5% level

**Significant at 1% level

Appendix XI. Mean square values of yield parameters of different rice varieties through foliar boron application

Sources of variation	Degrees of freedom	Mean square of yield parameters			
		Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	0.023	0.007	0.044	186.032
Factor A	1	14.560*	5.326*	37.498*	57.963*
Error	2	0.179	0.128	0.167	1.616
Factor B	4	1.074*	0.838*	3.802*	1.013^{NS}
AB	4	0.226*	0.180*	0.797*	0.172*
Error	16	0.224	0.407	0.901	2.776

*Significant at 5% level

**Significant at 1% level

Pictorial view of research work

Plate 1. Seed soaking for germination

Plate 2. Seedbed with seedling

Plate 3. plot preparation

Plate 4. After transplanting rice

Plate 5. Panicle initiation stage

Plate 6. During weighing of Boron (B)

Pictorial view of research work

Plate 7: Preparation of Boron for foliar application

Plate 8. Panical emergence satge

Plate 9. Overview of experimental field

Plate 10. During harvesting

Plate 11. Data collection and sun drying

Plate 12. Dry weight measurement