INFLUENCE OF FOLIAR BORON APPLICATION ON IMPROVEMENT OF YIELD OF HYBRID RICE

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CERTIFICATE

This is to certify that the thesis entitled "INFLUENCE OF FOLIAR BORON APPLICATION ON IMPROVEMENT OF YIELD OF HYBRID RICE" 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 A. S. M. RASHEDUZZAMANBINHAFIZ, Registration No. 11-04519 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.

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Dedicated To

My Beloved Parents

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The author

INFLUENCE OF FOLIAR BORON APPLICATION ON IMPROVEMENT OF YIELD OF HYBRID RICE

ABSTRACT

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, 2016 to May, 2017 to find out the influence of foliar boron application on improvement of yield of hybrid rice. Two factors were used in the experiment, *viz*., three rice varieties - V_1 (ACI hybrid 1), V_2 (ACI Sera) and V_3 (BRRI hybrid dhan1) and five levels of boron application - B_0 (0%; Control), B_1 (1.2% B), B_2 (1.5% B), B_3 (1.8% B) and B_4 (2.1% B). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield and yield contributing parameters were recorded. Different variety and application of boron individually influenced plant height, number of leaves hill^{-1}, leaf area index, number of tillers hill^{-1}, dry weight of plant hill^{-1}, number of effective tillers hill^{-1}, number of panicles hill^{-1}, panicle length, number of filled grains panicle^{-1}, number of rachis panicle^{-1}, grain yield, straw yield, biological yield and harvest index. Combined effect of variety and application of boron also showed significant effect on different parameters. Results revealed that the number of effective tillers hill^{-1} (18.60), the highest dry weight of plant hill^{-1} (72.84 g), number of panicles hill^{-1} (18.48), panicle length (23.16 cm), number of rachis panicle^{-1} (9.78), number of filled grains panicle^{-1} (166.80), grain yield (7.88 t ha^{-1}), straw yield (8.42 t ha^{-1}), biological yield (16.30 t ha^{-1}) and harvest index (48.34%) were achieved from the treatment combination of V_2B_3. So foliar boron application improves the yield of hybrid rice.

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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
RCRD	=	Randomized Complete Block Design
S	=	Sulfur
SCMR	=	SPAD Chlorophyll Meter Reading
SPAD	=	Soil Plant Analytical Development
SRDI	=	Soil Resources Development Institute
SRI	=	System of Rice Intensification
TSP	=	Triple super phosphate
$Unit^{-1}$	=	Per unit
Wt.	=	Weight

CHAPTER I

INTRODUCTION

Rice belongs to the Poaceae family with the genus *Oryza* which contains about 22 different species (Wopereis *et al*., 2009). It is the dominant staple food for many countries of the world (Mobasser *et al*., 2007). It is also the most important food crop and a major food grain for more than a third of the world population and 50% of the global population (Zhao *et al*., 2011). Among the most cultivated cereals in the world, rice ranks as second to wheat (Abodolereza and Racionzer, 2009).

Rice is the second most widely grown cereal and primary source of food for more than half of the world population, and about 90% of the world rice is grown in Asia which is carrying about 60% of the world population (Haque *et al*., 2015).

In Bangladesh, rice covered an area of 11.53 million ha with a production of 33.54 million M tons while the average yield of rice in Bangladesh is around 2.92 t ha^{-1} (BBS, 2016). In case of Boro rice, it covers the largest area of 11788 hectare (41.38% of total rice cultivation area) with a production of 1.86 million tons (55.50%) and the average yield is about 2.91 t ha^{-1} during 2010–11 (BBS, 2016). Besides, based on the rice cultivation, Bangladesh is the 5th largest country of the world (BBS, 2016). Alam *el.al*. (2012) also reported that rice covers about 82% of the total cropped land of Bangladesh. It accounts for 92% of the total food grain production in the country and provides more than 50% of the agricultural value addition employing about 44% of total labour forces. According to the latest estimation made by BBS, per capita rice consumption is about 166 kg $year^{-1}$. Rice alone provides 76% of the calorie intake and 66% of total protein requirement and shares about 95% of the total cereal food supply Alam, *et.al*. (2012).

The population of Bangladesh is growing by two million every year and may increase by another 30 million over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020 (BRRI, 2011). During this time total rice area will also shrink to 10.28 million hectares. Rice yield therefore, needs to be increased by 53.3% (Mahamud *et al.*, 2013). However, Bangladesh has made commendable progress in reducing extreme poverty and food insecurity through productivity increase in agriculture. Rice is not only the foremost staple food but it also provides nearly 48% of the rural employment, about two-third of the total calories supply and about one-half of the protein intake of an average person in the country (Julfiquar *et al.*, 2009).

Yearly increment 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) rather agricultural land is declining @ 0.7% per annum (BBS, 2011).Despite the steady and significant progress made in rice production over the past 25 years, the recent yield level of modern rice varieties has been reached to a plateau (Bhuiyan, 2002). For breaking the yield ceiling of conventional varieties, hybrid rice is a viable option and appropriate strategy and also it is readily available (Longping, 2004 and Kumar *et al.*, 1998). FAO has considered hybrid rice technology as the key approach for increasing global rice production (Virmani, 2005).

Hybrid rice varieties have 15- 30% yield advantage over modern inbred one (Julfiquar *et al.*, 2009 and Khalifa, 2009). Slow senescence and more strong photosynthetic capability of flag leaf, higher LAI at grain filling period and higher post heading-CGR plays major role for higher yield formation in hybrid rice. Greater biomass accumulation before heading and higher shoot reserve translocation are the decisive factors of higher yield in hybrids (Haque *et al.*, 2015).

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 (Masum, 2009).

According to BBS, (2008) Aus, Aman and Boro produced 1.51, 9.66 and 17.76 million metric tons of rice. Therefore, Boro rice is one of the most important rice crops for Bangladesh with respect to its high yield and contribution to rice production.

Variety plays an important role in augmenting yield of rice. Selection of potential variety, planting in appropriate method and application of optimum amount of nutrient elements can play an important role to increase the rice yield and national income.

Uses of HYV and hybrid have been increased remarkably in recent years and the country has almost reached a level of self-sufficiency in food. National Commission of Agriculture projected that to remain self-sufficient Bangladesh will need to produce 47 million MT of paddy (31.6 million MT of rice) by the year 2020, implying a required rate of growth of production at 1.7% per year. An earlier Agricultural Research Strategy document prepared by the Bangladesh Agricultural Research Council projected the required paddy production by 2020 of 52 million MT (34.7 million MT of rice), which would require a production growth of 2.2% per year. The adoption of HYV rice technology, which enabled Bangladesh to double the yield rate during 1969-70 to 1998-99, was not however an unmixed blessing. Bangladesh Rice Research Institute (BRRI) released a number of cultivars to cultivate in Boro season with detailed study for their different agronomic traits to furnish worth information regarding yield and possibilities for varietal improvement.

The functions of B in rice plants are to promote cell growth and development of the panicle (Garg *et al*., 1979). Boron (B) is responsible for better pollination, seed setting and grain formation in different rice varieties (Aslam *et al*., 2002, and

Rehman *et al*., 2012), making it more important during the reproductive stage as compared to the vegetative stage of the crop and found 90% of the boron in plants is localized in the cell walls (Loomis and Durst, 1992). B deficiency symptoms in rice begin with a whitish discoloration and twisting of new leaves (Yu and Bell, 1998). Severe deficiency symptoms from rice include thinner stems, shorter and fewer tillers, and failure to produce viable seeds. Boron deficient stems and leaves were found to be brittle while boron sufficient leaves and stems are flaccid. Declining productivity trends in rice growing countries are due to the micronutrient deficiencies (Savithri *et al*., 1999). Boron (B) deficiency is of particular importance since it affects the flowering and plant reproductive process and therefore directly affects harvested yield (Bolanos *et al*., 2004). The amount of protein and soluble nitrogenous compounds are lower in B deficient plants (Gupta, 1993). Boron can be satisfactorily applied to the soil to provide season long elevation of the B status of a crop.

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

1. To identify the best variety in respect of panicle fertility in boro season
2. To determine the role of foliar boron application on panicle fertility of rice
3. To find out the optimum level of boron application for maximizing yield.

CHAPTER II

REVIEW OF LITERATURE

Successful production of any crop depends on various activities have been done during crop duration. The variety of crop is one of the important basic ingredients. Boron application is also an important practice to obtain desired yield. Some of the works related to different rice varieties with different rates of boron application are cited below.

2.1 Effect of variety

Murshida *et al*. (2017) conducted an experiment with three varieties (cv. BRRI dhan28, BRRI dhan29 and Binadhan-14) and four water management systems to examine the effect of variety and water management system on the growth and yield performance of boro rice. At 100 DAT, the highest plant height, maximum number of tillers hill^{-1}, dry matter of shoot hill^{-1} and dry matter of root hill^{-1} were obtained from BRRI dhan29 and the lowest values were found in Binadhan-14. Variety had significant effect on all the crop characters under study except 1000-grain weight. The highest grain yield was obtained from BRRI dhan29 and the lowest value was recorded from Binadhan-14.

Widyastuti *et al.* (2015) conducted a study with twenty-four experimental hybrid rice varieties. The results showed that grains yields were affected by locations, seasons, and genotypes. The genotypes × locations × seasons interaction effect was significant; therefore, the best hybrid was different for each location and season. A7/PK36 hybrid has the best performance in Batang during the dry season, while A7/PK40 and A7/PK32 are the best hybrids in the rainy season. In Sukamandi, nine hybrids were identified as better yielder than that of the check cultivar in the dry season, but not so in the rainy season.

Chamely *et al*. (2015) conducted 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 study the effect of variety and rate of nitrogen on the performance of Boro rice. The growth analysis results indicate that the tallest plant (80.88 cm) and the highest number of total tillers $hill^{-1}$ (13.80) were observed in BRRI dhan29 at 70 DATs and the highest total dry matter (66.41 g m^{-2}) was observed in BRRI dhan45. The shortest plant (78.15 cm) and the lowest number of tillers $hill^{-1}$ (12.41) were recorded from BRRI dhan45 and the lowest dry matter (61.24 g) was observed in BRRI dhan29. The harvest data reveal that variety had significant effect on total tillers $hill^{-1}$, effective tillers $hill^{-1}$, non-effective tillers $hill^{-1}$, panicle length, grain yield, straw yield and harvest index. The highest grain yield (4.84 t ha^{-1}) was recorded from BRRI dhan29.

Jisan *et al*. (2014) carried out 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) whereas the lowest values of these parameters were produced by BRRI dhan57. Highest grain yield (5.69 t ha^{-1}) was obtained from BRRI dhan52 followed by BRRI dhan49 (5.15 t ha^{-1}) and the lowest one (4.25 t ha^{-1}) was obtained from BRRI dhan57.

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

Sarkar *et al.* (2013) conducted an experiment to study morphological, yield and yield contributing characters 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 dhan 28. The BRRI dhan 28 were significantly superior among the cultivars studied. The BRRI dhan 28 was shorter in plant height, having more tillering capacity, higher leaf number which in turn showed superior growth character and yielded more than those of the local cultivars. The HYV BRRI dhan 28 produced higher number of grains panicle^{-1} and bolder grains resulted in higher grain yield over the local cultivars. Further, BRRI dhan28 had more total dry mass than those of local varieties. The BRRI dhan28 produced higher grain yield (7.41 t ha^{-1}) than Bashful, Poshurshail and Gosi, respectively. Among the local rice cultivars, Gosi showed the higher yielding ability than Bashful and Poshursail.

Haque *et al.* (2013) conducted an experiment to evaluate some physiological traits and yield of three hybrid rice varieties (BRRI hybrid dhan 2, Heera 2, and Tia) in comparison to BRRI dhan48 in *Aus* season. Compared to BRRI dhan 48, hybrid varieties accumulated greater shoot dry matter at 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 maintained significantly higher chlorophyll a, b ratio over Tia and BRRI dhan 48 at 2, 9, 16 and 23 DAF in their flag leaf. Shoot reserve remobilization to grain exhibited higher degree of sensitivity to rising of minimum temperature in the studied hybrids compared to the inbred. Inefficient photosynthetic activities of flag leaf and poor shoot reserve translocation to grain resulted poor grain filling percentage in the test hybrids. Consequently the studied hybrids showed significantly lower grain yield (36.7%) as compared to inbred BRRI dhan48, irrespective of planting date in *Aus* season.

Anwar and Begum (2010) reported that time of tiller separation of rice significantly influenced plant height, total number of 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 should be done between 20 to 40 DAT without hampering grain yield.

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

Islam *et al*. (2009) conducted a pot experiments with Hybrid variety Sonarbangla-1 and inbred modern variety BRRI dhan 31 and BRRI hybrid dhan-l to compare the growth and yield behavior of hybrid and inbred rice varieties under controlled condition. BRRI dhan 3l had about 10-15% higher plant height, very similar tillers/plant, 15-25% higher leaf area at all days after transplanting (DAT) compared to Sonarbangla-1. Sonarbangla-1 had 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 compared to BRRI dhan31. The photosynthetic rate was higher (20 μ mol m^{-2} sec^{-1}) in BRRI dhan3l at 35 DAT (maximum tillering stage) but at 65 DAT, Sonarbangla-l had higher photosynthetic rate of 19.5 μ mol m^{-2} sec^{-1}. BRRI dhan3l had higher panicles plant^{-1} than Sonarbangla-1, but Sonarbangla-1 had higher number of grains panicle^{-1}, 1000-grain weight and grain yield than BRRI dhan 31.

Obaidullah *et al*. (2009) conducted a field experiment to study the growth and yield of inbred and hybrid rice with clonal tillers different of age. They found highest grain yield (5.10 t ha^{-1}) from the clonal tiller of 25 days old and the lowest grain yield (4.31 t ha^{-1}) from 40 days old clonal tillers. Irrespective of variety 25 to 35 days old clonal tiller showed superior performance. Hybrid variety transplanted with 25 days old clonal tiller gave significantly higher grain yield.

Ashrafuzzaman *et al.* (2008) conducted a field experiment to study the growth and yield of inbred and hybrid rice with tiller separation at different growth periods. The experiment was conducted 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. Maximum filled grains $panicle^{-1}$ (144.28) was observed from the tiller separation at 20 DAT. Total and effective tillers $hill^{-1}$ was affected by tiller separation beyond 30 DAT. Delayed tiller separation extended the flowering and maturity duration. Therefore, it was concluded that earlier tiller separation (20-30 DAT) resulted higher grain yield in hybrid variety but no such variations was observed in inbred variety.

Ahmed *et al.* (2007) conducted a field experiment to study the influence of cultivation methods on inbred and hybrid rice in *Boro* season. The experiment consisted of two levels of treatment *viz*., variety and cultivation method. Interaction of variety and cultivation method revealed that nursery seedlings of the inbred variety produced the highest grain yield (8.88 t ha^{-1}) and sprouted seeds broadcast of the inbred variety gave the lowest grain yield (6.35 t ha^{-1}).

Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties *(viz.* Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (*viz.* KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

Wang *et al*. (2006) studied the effects of plant density on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27%.

Chowdhury *et al*. (2005) conducted an experiment to study their effect on the yield and yield components of rice varieties BR23 and Pajam with 2, 4 and 6 seedlings hill^{-1} during the *Aman* season. They reported that the cv. BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. number of productive tillers hill^{-1}, length of panicle, l000-grain weight, grain yield and straw yield. On the other hand, the cultivar Pajam produced significantly the tallest plant, total number of grains panicle^{-1}, number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1}.

Myung (2005) worked with four different panicle types of rice varieties and observed that the primary rachis branches (PRBs) panicle^{-1} and grains were more on Sindongjinbyeo and Iksan467 varieties, but secondary rachis branches (SRBs) were fewer than in Dongjin1 and Saegyehwa varieties.

Akbar (2004) reported that variety, seedling age and their interaction exerted significant influence on almost all the crop characters. Among the varieties, BRRI dhan41 performed the best in respect of number of bearing tillers hill^{-1}, panicle length, total spikelet's panicle^{-1} and number of grains panicle^{-1}. BRRI dhan41 also produced the maximum grain and straw yields. Sonarbangla-1 ranked first in respect of total tillers hill^{-1} and 1000-grain weight but produced highest number of non-bearing tillers hill^{-1} and sterile spikelet's panicle^{-1}. Grain, straw and biological yields were found highest in the combination of BRRI dhan41 with 15 day-old seedlings.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti and observed that Mukti (5268 kg ha^{-1}) out yielded the other genotypes and recorded the maximum number of filled grains and had lower spikelet sterility (25.85%) compared to the others.

Sumit *et al.* (2004) worked with newly released four commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar dhan1) and two high yielding cultivars (HYV) as controls (Pant dhan 4 and Pant dhan 12) and reported that KHR 2 gave the best yield (7.0 t/ha) among them.

2.2 Effect of boron

Among the micronutrient elements boron is the only non-metal which is required for a number of growth processes such as (i) new cell development 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 (Tisdale *et al*., 1997).

Patil *et al*. (2017) conducted a field experiment to study the effect of soil application of boron on growth, yield and soil properties of lowland paddy. The doses of borax were 0 kg, 2.5 kg, 5.0 kg, 7.5 kg and 10 kg per hectare respectively. The soil available B (hot water soluble) was ranges between 0.292 to 0.412 ppm. The pooled data revealed that treatment T_5 (Soil application of borax @10 $kgha^{-1}$) 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 for higher yield and returns of paddy.

Ali *et al*. (2016) conducted to evaluate the effect of foliar application of B on yield and yield components 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 essential micro nutrient and its deficiency caused a reduction in final crop harvest and quality of the yield. The results illustrated a significant effect of B foliar application on number of grains panicle^{-1}, number of filled grains and final grain yield. The highest grain yield (352 g m^{-2}) was recorded in 20 mg L^{-1} foliar application, whereas an increase in B application to 25 mg L^{-1} reduces the final grain yield significantly (313 g m^{-2}). Detrimental effects of the highest B application on yield components were also observed. The decline in the quantity and quality rice yield resulted by increasing B application might be due to the toxic effect of higher concentration of B application.

Fakir *et al*. (2016) carried out from a field study to evaluate the effect of foliar application of boron (B) on the grain set and yield of wheat (cv. Shatabdi). The B treatments were (i) B control, (ii) soil application of B, (iii) seed priming into boric acid solution, (iv) foliar spray of B at primordial stage of crop, (v) foliar spray of B at booting stage and (vi) foliar spray of B at primordial and booting stages. The rate of B for soil application was 1.5 kg B ha^{-1} from boric acid (17% B) and the rate for each foliar spray was 0.4% boric acid solution. The treatment receiving foliar spray of B at both primordial and booting stages of the crop performed the highest yield (3630 kg ha^{-1}) which was statistically similar with the yield recorded with foliar spray of B at booting or primordial 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 lowest grain yield (2600 kg ha^{-1}).

Saleem *et al*. (2010) conducted a field study to evaluate the effectiveness of boron fertilizers borax and colemanite (powder and granular) in supplying B to rice under flooded conditions. Boron application improved all the agronomic growth parameters and increased the yield. Both B fertilizers significantly increased the plant height, panicles/plant, number of grains/panicle and weight of 1000 grains. Both B sources were found equally effective in supplying B to rice crop. Borax gave significantly high yield at 2 kg B/ha and powder colemanite at 3 kg B/ha. Yield difference between borax and powder colemanite was not significant at all three levels. Powder colemanite applied plots had significantly high residual B in compare to 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 due to the large particle size B so that release was very slow.

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

Khan *et al*. (2007) conducted a field experiment with two levels of boron *viz*., 1 and 2 kg ha^{-1} with control where basal dose of N, P_2O_5 and K_2O were 120-90-60 kg ha^{-1} respectively. Wheat variety was Naseer-2000 and rice variety was IRRI-6. Boron application significantly affected wheat grain yield that ranged from 2.70 to 3.49 t ha^{-1} giving highest increase of 19.9% over control from 1.0 kg ha^{-1}. The number of tillers m^{-2}, spike m^{-2}, spike length, plant height and 1000-grain weight of wheat were also significantly different from control for the same treatment. Paddy yield was also significantly affected 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 affected over control. The direct application of 1 and 2 kg B ha^{-1} gave 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 residual application of 1 and 2 kg B ha^{-1} increased the yield by 36.8 and 48.8% over control.

Dunn *et al*. (2005) found that soil sampling and testing for Boron is currently not a common practice for farmers producing rice (*Oryza sativa* L.) in the southeastern United States and field research in Missouri showed that rice yields were the greatest when soil B levels were 0.25 to0.35 ppm by the hot water extraction method. In 2000, rice receiving soil-applied Boron produced significantly greater yields than rice with foliar-applied B and rice with no Boron applied. In 1999 and 2001, there was no significant difference between yields obtained with foliar or soil B applications.

BRRI scientists (1998) conducted several experiments at Rangpur to study the effect of B and FYM on four HYV rice varieties. They found that application of FYM and B alone increased grain yield in all varieties except BRRI dhan27 than when NPK was applied. A combination of FYM and B encouraged vegetative growth and thereby lowering the harvest index. Vegetative growth of BRRI dhan27 was highly encouraged by FYM and B applied together. They suspected that BRRI dhan27 might be less tolerant to B stress.

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

BINA (1996) reported that under wheat-summer mungbean - T. aman cropping pattern the grain yield of third crop rice responded significantly to the micronutrient treatments. The highest grain yield (4.2 t ha^{-1}) was obtained by combined application of Zn, Cu, Mo and B which was statistically similar to the individual application of Zn or B. There was also considerable carry over effect of micronutrients on the succeeding crops.

Muralidharan and Jose (1995) carried out a field experiment and observed that rice grain yield increased due to application of B. They observed that rice grain yield was increased by 5% following the application of B to soil.

Muralidharan and Jose (1995) also conducted a field experiment and found that B application increased the yield of rice. The application of boron gave grain yield of 2.31 t ha^{-1} compared with the control yield of 2.07 t ha^{-1}.

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

Maharana *et al*. (1993) cited that the responses in respect of grain yield varied from 0.15 to 1.03 t ha^{-1}, percent yield response from 2.7 to 36.0, the maximum relative efficiency from 10 to 194 (kg yield/kg B applied) and benefit : cost ratio from 1.0 to 19.4 with applications of 5.15 kg of borax. In B deficient soils, borax increased B concentration in rice grain and straw.

Singh *et al*. (1990) conducted a field trial during 1987-88 at Barapani, Meghalaya to observe the effects 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 increased rice yield compared with the untreated control. The increase in yield due to B application was 31% higher in submerged than in rainfed conditions. The highest grain yield of 3.66 t ha^{-1} and straw yield of 4.81 t ha^{-1} were obtained from the application of B under submerged condition.

Misra *et al*. (1989) carried out laboratory and pot experiments in order to study the effects of flooding on the availability of Zn, Cu, B and Mo extracted by different reagents in relation to their contents and uptake of different growth stages of rice (cv. Jaya) grown in 10 soils belonging to alluvial, red, lateric and black soil groups. Flooding decreased extractable Zn, Cu, and B but increased Mo. The plant Zn, Cu, B and Mo contents were higher during vegetative growth period (30-40 days after transplanting) than at later growth stages. They found no significant correlation between extractable B and B contents in rice plants.

Mandal *et al*. (1987) carried out from a field trial with rice that an application of 16 kg borax ha-1 along with NPK increased the yield components and gave higher paddy yields.

Xiong (1987) carried out a pot trial of indica rice cv. Ginglian on different nitrogen doses with or without B. Application of 0.8-1.2 ppm B resulted in 1-5 days earlier heading and 1000-grain weight was increased with the application of B concentration.

The total B content in soils ranges between 20 and 200 ppm with the available (hot water soluble) B fraction ranging from 0.4 to 0.5 ppm (Gupta, 1979). Less than 5% of total soil B is available to plants. Plants absorb B principally in the from of H_3BO_3 and to a smaller extent as $B_4O_7^{2-}$, H_2BO_3, HBO_3^{2-}. The major B bearing mineral is tourmaline containing 3-4% B. Boron mainly occurs in soil as undissociated H_3BO_3 and this might be the prime reason for which B is leached so easily from the soil.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2016 to May, 2017. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses.

3.1 Site description

The experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28. The land area is situated at 23°41′N latitude and 90°22′E longitude at an altitude of 8.6 meter above sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.2 Climate

The experimental area is under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the Rabi season (October-March). The weather data during the study period of the experimental site is shown in Appendix II.

3.3 Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were 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 land 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

The following treatments were included in this experiment

Factor A: Three hybrid rice variety

1. V_1 = ACI hybrid 1
2. V_2 = ACI Sera
3. V_3 = BRRI hybrid dhan1

Factor B: Five levels of boron (B) application

1. B_1 = 0% (Control)
2. B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage
3. B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage
4. B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage
5. B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

3.5 Plant materials and collection of seeds

Three hybrid rice varieties *viz*., ACI hybrid 1, ACI Sera and BRRI hybrid dhan 1 were used as plant materials for the present study. The seeds of ACI hybrid 1 and ACI Sera were collected from local market (Siddik Bazar, Dhaka) and BRRI hybrid dhan1 was collected from BRRI, Joydebpur, Gazipur, Bangladesh.

3.6 Seed sprouting

Healthy seeds were kept in water bucket for 24 hours and then it was kept tightly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

3.7 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on October, 2016 in order to transplant the seedlings in the main field.

3.8 Preparation of experimental land

The plot selected for the experiment was opened in the first week of October 2016 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilt. Weeds and stubble were removed, and finally obtained a desirable tilt of soil for transplanting of seedlings.

3.9 Fertilizer application

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

Fertilizer	Recommended doses (kg ha^{-1})
Urea	150
TSP	100
MoP	100
Zinc sulphate	10
Gypsum	60
Borax	10

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MP, gypsum, zinc sulphate and borax, respectively were applied. The entire amount of TSP, MP, gypsum, zinc sulphate and borax were applied during the final preparation of plot land. Mixture of cowdung and compost was applied at the rate of 10 t ha^{-1} during 15 days before transplantation. Urea was applied in three equal installments at after recovery, tillering and before panicle initiation. Boron was applied as foliar application as per treatment at tillering, panicle initiation and flowering stage.

3.10 Experimental design and layout

The experiment was laid in a Randomized Complete Block Design (RCBD) with three replications (block). Each replication was first divided into 15 sub plots where treatment combinations were assigned. Thus the total number of unit plots was 15×3=45. The size of the unit plot was 2.5m × 2.3m. The distance maintained between two unit plots was 0.5m and that between blocks was 0.75m. The treatments were randomly assigned to the plots within each replication. The layout of the experiment field is shown in Appendix IV.

3.11 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on November 24, 2016 without causing much mechanical injury to the roots.

3.12 Transplanting of seedlings in the field

The seedlings were transplanted in the main field on 24 the November, 2016 with a spacing 15 cm from hill to hill and 20 cm from row to row.

3.13 Intercultural operations

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the rice seedlings.

3.13.1 Irrigation and drainage

Flood irrigation was given to maintain 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. The field was finally dried out at 15 days before harvesting.

3.13.2 Gap filling

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

3.13.3 Weeding

The crop was 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 15, 32 and 52 days of transplanting.

3.13.4 Top dressing

The urea fertilizer was top-dressed in 3 equal installments at 10 days after transplanting at tillering stage and before panicle initiation stage.

3.14 Plant protection

There were some incidence in insects specially grasshopper, stem borer, rice ear cutting caterpillar, thrips and rice bug which was controlled by spraying Curatter 5 G and Sumithion. Brown spot of rice was controlled by spraying Tilt.

3.15 Harvesting, threshing and cleaning

The rice plant was harvested depending upon the maturity of plant and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The straw was sun dried and the yields of grain and straw plot^{-1} were recorded and converted to t ha^{-1}.

3.16 General observation of the experimental field

The field was observed time to time to detect visual difference among the treatment and 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 study period:

3.17.1. Growth characters

1. Plant height (cm)
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 panicles hill^{-1}
3. Panicle length (cm)
4. Number of filled grains panicle^{-1}
5. Number of unfilled grains panicle^{-1}
6. Number of rachis panicle^{-1}
7. 1000-grains weight (g)

3.17.3 Yield parameters

1. Grain yield (t ha^{-1})
2. Straw yield (t ha^{-1})
3. Biological yield (t ha^{-1})

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

The height of plant was recorded in centimeter (cm) at the time of harvest. Data were recorded as the average of same 5 plants pre-selected at random from the inner rows of each plot. The height was measured from the ground level to the 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}

Total tillers which had at least one leaf visible were counted. It includes both productive and unproductive tillers. It was counted from the average of same 5 plants 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, 50, 70 DAT and at harvest. Data were recorded as the average of 5 plants selected at random the inner rows of each plots. The final 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, 50, 70 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, final weight was taken 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 number of effective tillers hill^{-1} was counted from 5 selected hills at harvest and average value was recorded.

3.18.2.2 Number of panicles hill^{-1}

The total number of panicles hill^{-1} was counted from 5 selected hills at harvest and average value was recorded.

3.18.2.3 Panicle length

The length of panicle was measured with a meter scale from 10 selected panicles and the average value was recorded.

3.18.2.4 Number of filled grains panicle^{-1}

The total number 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}

The total number 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 rachis panicle^{-1}

The total number of rachis panicle^{-1} was counted from 10 selected panicle 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 when 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 1 m^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

Straw yield 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 was determined using the following formula

Biological yield = Grain yield + Straw yield

3.18.3.4 Harvest index

It 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 data collected on different parameters were statistically analyzed with a Randomized Complete Block Design (RCBD) using the MSTAT computer package program. Mean separation among the treatments was done by using Least Significant Difference (LSD) technique at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

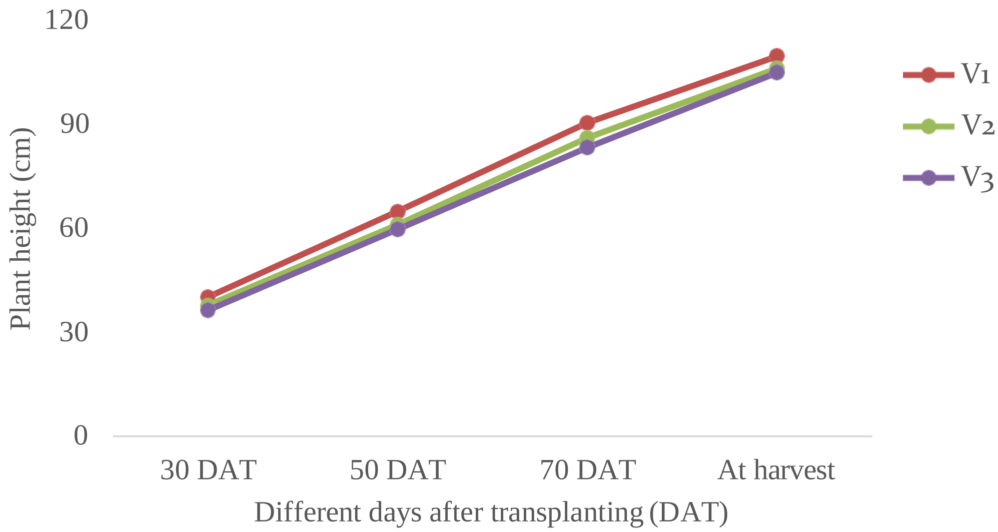
The experiment was conducted to study reduction of panicle sterility and improvement of yield of hybrid rice through foliar boron application. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

4.1.1.1 Effect of variety

Plant height was significantly influenced by different variety of rice at different growth stages (Figure 1 and Appendix V). Results revealed that the highest plant height (40.23, 64.88, 90.51 and 109.7 cm at 30, 50, 70 DAT and at harvest respectively) was achieved from the variety, V_1 (ACI hybrid 1) where the lowest plant height (36.44, 59.71, 83.40 and 105.0 cm at 30, 50, 70 DAT and at harvest respectively) was observed from the variety, V_3 (BRRI hybrid dhan 1) which was statistically similar with V_2 (ACI Sera). This might be due to varietal variation. Similar results on plant height were also achieved by Murshida *et al*. (2017), Sarkar *et al*. (2013), Anwar and Begum (2010) and Islam *et al*. (2009) who reported that plant height of rice significantly affected by varietal differences.

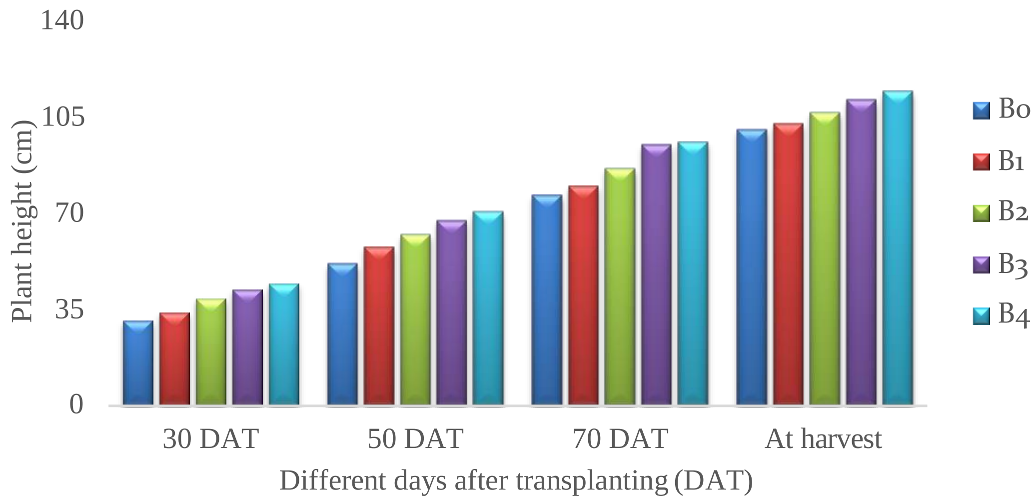


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 1. Effect of variety on the plant height of rice at different days after transplanting (LSD $_{(0.05)}$ = 1.69, 3.60, 2.45 and 1.90 at 30, 50, 70 DAT and harvest, respectively)

4.1.1.2 Effect of boron

Significant variation was observed in terms of plant height at different growth stages influenced by different rates of boron (Figure 2 and Appendix V). It was observed that the highest plant height (44.51, 70.47, 95.90 and 114.30 cm at 30, 50, 70 DAT and at harvest respectively) was obtained from the treatment, B_4 (2.1% B) followed by B_3 (1.8% B) where the lowest plant height (30.91, 51.69, 76.51 and 100.40 cm at 30, 50, 70 DAT and at harvest respectively) was found from the treatment, B_0 (0%; Control) which was immediate lower than B_1 (1.2% B) at harvest. Sarwar *et al.* (2016) investigated that boron application significantly enhanced plant height of rice. It is a well-known fact that boron is essential in enhancing carbohydrate metabolism, sugar transport, cell wall structure, protein metabolism, root growth and stimulating other physiological processes of plant that helped to trigger the plant height (Kumar *et al.*, 2017, Goldberg, 1997 and Ashour and Reda, 1972). Sarwar *et al.* (2016) reported that, poor performance in control (no boron) treatment might be due to imbalance nutrient application. In boron application treatment, crop up taken more nutrients and improved the crop vigor. 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_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 2. Effect of different levels of boron on the plant height of rice at different days after transplanting (LSD $_{(0.05)}$ = 2.93, 1.03, 1.05, 1.10 at 30, 50, 70 DAT and harvest)

4.1.1.3 Combined effect of variety and boron

Combined effect of variety and different rates of boron showed significant difference on plant height of rice at different growth stages (Table 1 and Appendix V). Results indicated that the highest plant height (46.52, 72.60, 99.70 and 117.60 cm at 30, 50, 70 DAT and at harvest respectively) was found from the treatment combination of V_1B_4 which was statistically similar with V_1B_3 at 70 DAS. The lowest plant height (31.21, 51.62, 77.07 and 100.40 cm at 30, 50, 70 DAT and at harvest respectively) was obtained from the treatment combination of V_3B_0 which was statistically similar with V_1B_0, V_2B_0, V_2B_1 and V_3B_1 and statistically similar with V_3B_2 at the time of harvest.

Table 1. Combined effect of variety and boron on plant height of hybrid rice at different growth stages

Treatment combinations	Plant height (cm) at			
	30 DAT	**50 DAT**	**70 DAT**	**Harvest**
V_1B_0	30.75 h	52.56 i	77.80 ef	100.60 g
V_1B_1	35.86 f	60.48 f	84.18 d	105.30 f
V_1B_2	42.75 cd	67.40 cd	91.85 c	110.90cd
V_1B_3	45.28 b	71.36 ab	99.00 a	114.60 b
V_1B_4	46.52 a	72.60 a	99.70 a	117.60 a
V_2B_0	30.78 h	50.88 i	74.65 f	100.30 g
V_2B_1	33.36 g	56.92 gh	77.33 ef	101.20 g
V_2B_2	39.12 e	61.24 f	86.65 d	105.80 ef
V_2B_3	41.87 d	66.75 d	95.00 b	110.60 cd
V_2B_4	43.74 c	69.57 bc	96.85 ab	113.30 bc
V_3B_0	31.21 h	51.62 i	77.07 ef	100.40 g
V_3B_1	32.58 g	55.71 h	78.20 e	101.00 g
V_3B_2	35.24 f	57.78 gh	79.95 e	102.70 fg
V_3B_3	39.88 e	64.20 e	90.63 c	108.50 de
V_3B_4	43.27 c	59.25 fg	91.15 c	112.20 bc
$LSD_{(0.05)}$	**1.06**	**2.27**	**2.94**	**2.96**
CV (%)	**8.39**	**10.21**	**11.36**	**13.20**

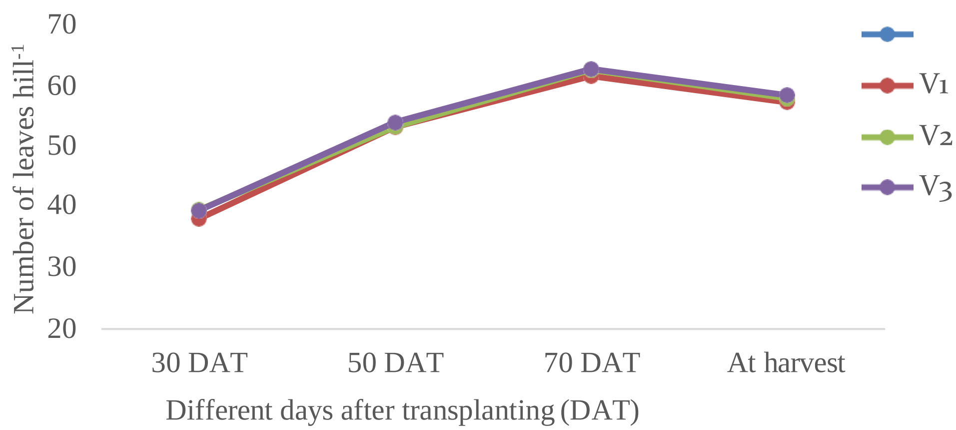
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1; B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering 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 observed due to different variety of rice at different growth stages (Figure 3 and Appendix VI). But the maximum number of leaves hill^{-1} (39.71, 54.06, 62.72 and 58.48 at 30, 50, 70 DAT and at harvest respectively) was achieved from the variety, V_3 (BRRI hybrid dhan 1) and the minimum number of leaves hill^{-1} (38.38, 53.28, 61.57 and 57.33 at 30, 50, 70 DAT and at harvest respectively) was observed from the variety, V_1 (ACI hybrid 1). Similar trend of results was also obtained by Sarkar *et al.* (2013), Haque *et al.* (2013) and Khalifa (2009).



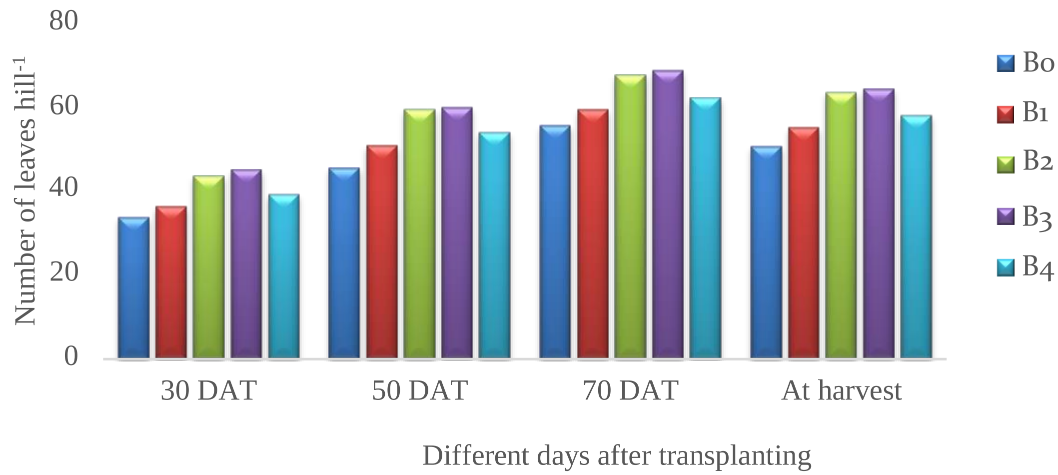
V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

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, 50, 70 DAT and harvest)

4.1.2.2 Effect of boron

Significant difference was found in terms of number of leaves hill^{-1} at different growth stages influenced by different rates of boron (Figure 4 and Appendix VI). Results signified that the highest number of leaves hill^{-1} (44.79, 59.50, 68.27 and

63.88 at 30, 50, 70 DAT and at harvest respectively) was obtained from the treatment, B_3 (1.8% B) which was statistically similar with B_2 (1.5% B) at 50, 70 DAT and at harvest respectively. The lowest number of leaves hill^{-1} (33.49, 45.20, 55.25 and 50.30 at 30, 50, 70 DAT and at harvest respectively) was found from the treatment, B_0 (0%; Control).



B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 4. Effect of different levels of boron on the number of leaves hill^{-1} of rice at different days after transplanting (LSD $_{(0.05)}$ = 1.33, 1.42, 1.73, 1.44 at 30, 50, 70 DAT and harvest)

4.1.2.3 Combined effect of variety and boron

Number of leaves hill^{-1} of rice at different growth stages was significantly influenced by combined effect of variety and different rates of boron (Table 2 and Appendix VI). Results indicated that the highest number of leaves hill^{-1} (46.60, 60.14, 70.24 and 65.64 at 30, 50, 70 DAT and at harvest respectively) was achieved from the treatment combination of V_3B_3 which was statistically similar with V_2B_2 at the time of harvest. The lowest number of leaves hill^{-1} (35.10, 47.74, 56.84 and 52.29 at 30, 50, 70 DAT and at harvest respectively) was obtained from the treatment combination of V_1B_0 which was statistically similar with V_1B_1 at the time of harvest.

Table 2. Combined effect of variety and boron on number of leaves hill^{-1} of hybrid rice at different growth stages

Treatment combinations	Number of leaves hill^{-1} at			
	30 DAT	**50 DAT**	**70 DAT**	**Harvest**
V_1B_0	35.10 g	47.74 e	56.84 gh	52.29 g
V_1B_1	35.28 g	49.67 de	58.20 fg	53.92 fg
V_1B_2	40.78 c	58.00 ab	65.28 cd	61.64 cd
V_1B_3	43.20 b	59.10 a	66.88 c	62.51 c
V_1B_4	37.56 e	51.88 cd	60.66 ef	56.27 e
V_2B_0	32.28 h	43.60 f	54.18 i	48.98 h
V_2B_1	37.34 ef	50.80 cd	60.12 ef	55.46 ef
V_2B_2	46.17 a	60.23 a	69.75 ab	64.99 ab
V_2B_3	44.56 ab	59.26 a	67.70 bc	63.48 bc
V_2B_4	38.66 de	52.62 c	61.18 e	56.90 e
V_3B_0	33.10 h	44.26 f	54.72 hi	49.62 h
V_3B_1	35.47 fg	51.00 cd	58.64 fg	54.80 ef
V_3B_2	42.88 b	58.82 a	66.52 c	62.64 c
V_3B_3	46.60 a	60.14 a	70.24 a	65.64 a
V_3B_4	40.52 cd	56.10 b	63.46 d	59.71 d
$LSD_{(0.05)}$	**1.95**	**2.11**	**2.27**	**2.05**
CV (%)	**9.21**	**10.37**	**12.54**	**11.37**

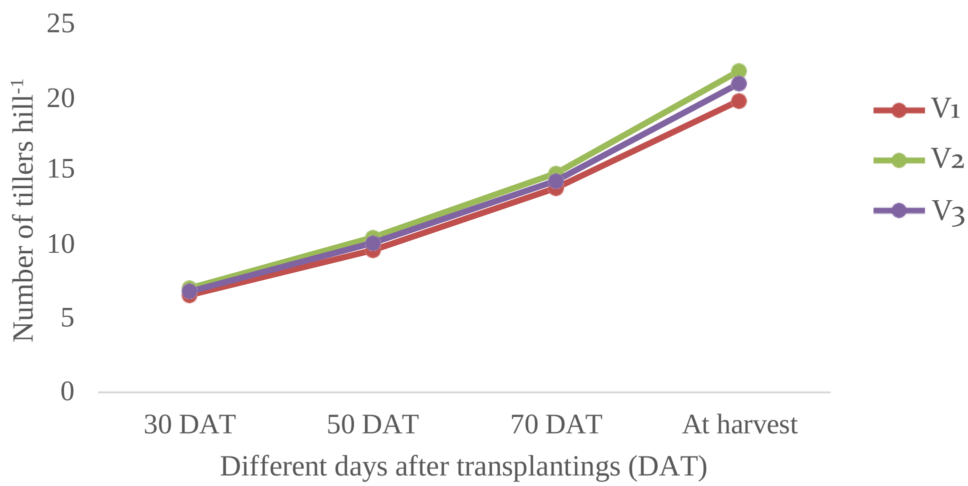
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1; B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

4.1.3 Number of tillers hill^{-1}

4.1.3.1 Effect of variety

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). Result revealed that the highest number of tillers hill^{-1} (7.19, 10.61, 14.93 and 21.85 at 30, 50, 70 DAT and at harvest respectively) was achieved from the variety, V_2 (ACI Sera) followed by V_3 (BRRI hybrid dhan1) where the lowest number of tillers hill^{-1} (6.72, 9.75, 13.94 and 19.84 at 30, 50, 70 DAT and at harvest respectively) was observed from the variety, V_1 (ACI hybrid 1). The result obtained from the present study was similar with the findings of Murshida *et al*. (2017), Chamely *et al*. (2015) and Jisan *et al*. (2014).

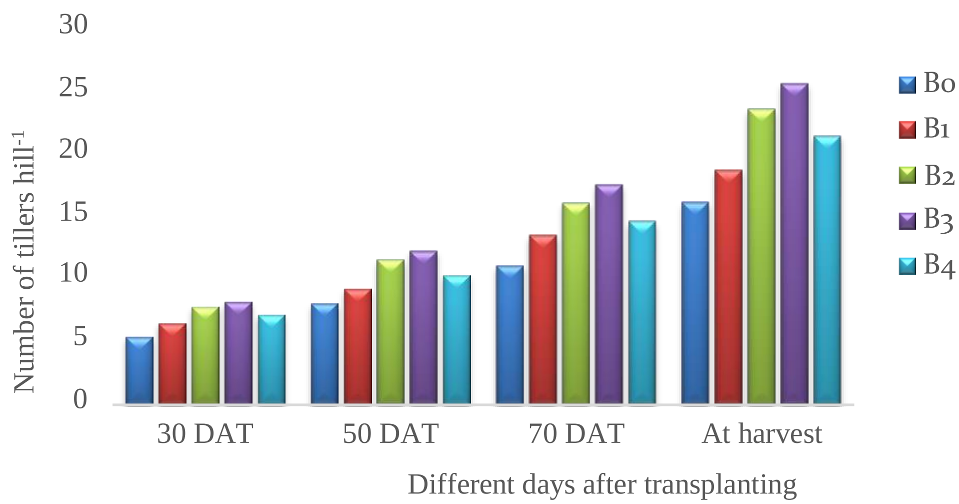


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 5. Effect of variety on the number of tillers hill^{-1} of rice at different days after transplanting (LSD $_{(0.05)}$ = 0.43, 0.37, 0.34, 0.32 at 30, 50, 70 DAT and harvest)

4.1.3.2 Effect of boron

Number of tillers hill^{-1} at different growth stages of rice was significantly affected by different rate of boron (Figure 6 and Appendix VII). Results showed that the highest number of tillers hill^{-1} (8.11, 12.15, 17.39 and 25.38 at 30, 50, 70 DAT and at harvest respectively) was obtained from the treatment, B_3 (1.8% B) followed by B_2 (1.5% B) where the lowest number of tillers hill^{-1} (5.39, 8.01, 11.00 and 16.00 at 30, 50, 70 DAT and at harvest respectively) was found from the treatment, B_0 (0%; Control). The findings was also similar with the findings of Khan *et al*. (2007) and Shafiq and Maqsood (2010).



B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 6. Effect of different levels of boron on the number of tillers hill^{-1} of rice at different days after transplanting (LSD $_{(0.05)}$ = 0.37, 0.39, 0.43, 0.48 at 30, 50, 70 DAT and harvest)

4.1.3.3 Combined effect of variety and boron

Significant variation was remarked for number of tillers hill^{-1} at different growth stages of rice due to combined effect of variety and different rate of boron (Table 3 and Appendix VII). Results exposed that the highest number of tillers hill^{-1} (8.32, 12.36, 18.48 and 26.72 at 30, 50, 70 DAT and at harvest respectively) was achieved from the treatment combination of V_2B_3 followed by V_3B_3 at harvest. The lowest number of tillers hill^{-1}(5.10, 7.62, 10.65 and 15.34 at 30, 50, 70 DAT and at harvest respectively) was obtained from the treatment combination of V_1B_0 which was statistically identical with V_2B_4 at the time of harvest.

Table 3. Combined effect of variety and boron on number of tillers hill^{-1} of hybrid rice at different growth stages

Treatment combinations	Number of tillers hill^{-1} at			
	30 DAT	**50 DAT**	**70 DAT**	**Harvest**
V_1B_0	5.10 j	7.62 g	10.65 i	15.34 i
V_1B_1	6.18 hi	8.75 f	13.12 g	17.34 h
V_1B_2	7.50 cd	10.88 cd	15.24 e	22.26 d
V_1B_3	7.86 bc	11.84 b	16.42 cd	23.77 c
V_1B_4	6.94 ef	9.66 e	14.26 f	20.48 ef
V_2B_0	5.80 i	8.62 f	11.47 h	17.10 h
V_2B_1	6.68 fg	9.48 e	13.58 g	19.76 f
V_2B_2	8.04 ab	12.15 ab	16.66 c	24.32 c
V_2B_3	8.32 a	12.36 a	18.48 a	26.72 a
V_2B_4	7.10 de	10.42 d	14.48 f	21.36 de
V_3B_0	5.28 j	7.78 g	10.88 hi	15.55 i
V_3B_1	6.44 gh	9.22 e	13.44 g	18.56 g
V_3B_2	7.72 bc	11.32 c	15.86 d	23.44 c
V_3B_3	8.14 ab	12.24 ab	17.28 b	25.66 b
V_3B_4	7.28 de	10.64 d	14.72 ef	21.86 d
$LSD_{(0.05)}$	**0.39**	**0.45**	**0.61**	**0.92**
CV (%)	**5.02**	**5.93**	**8.12**	**10.04**

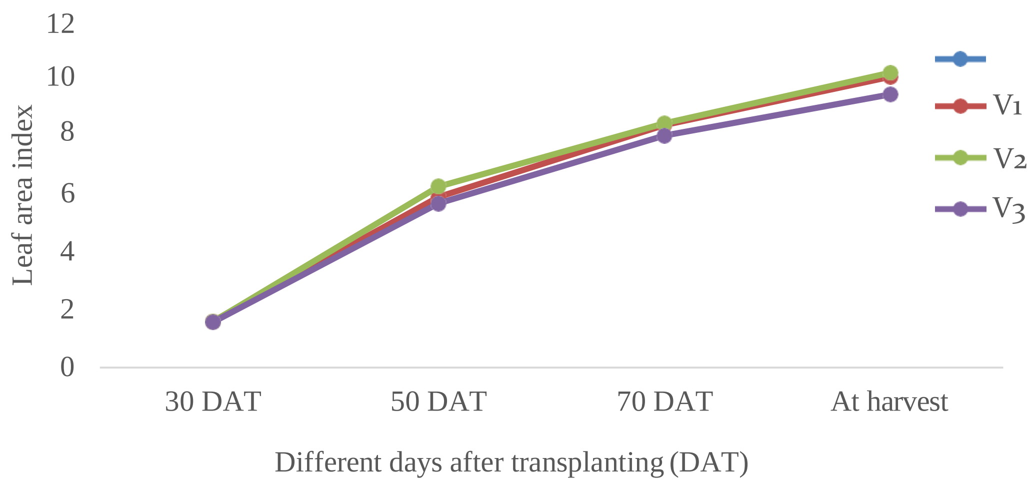
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1; B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

4.1.4 Leaf area index

4.1.4.1 Effect of variety

Leaf area index was significantly influenced by different variety of rice at different growth stages (Figure 7 and Appendix VIII). The highest leaf area index (1.73, 6.40, 8.58 and 10.33 at 30, 50, 70 DAT and at harvest respectively) was achieved from the variety, V_2 (ACI Sera) which was statistically identical with V_2 (ACI Sera) at harvest where the lowest leaf area index (1.71, 5.81, 8.15 and 9.58 at 30, 50, 70 DAT and at harvest respectively) was observed from the variety, V_3 (BRRI hybrid dhan 1). Khalifa (2009) and Islam *et al*. (2009) also obtained similar results regarding varietal performance.

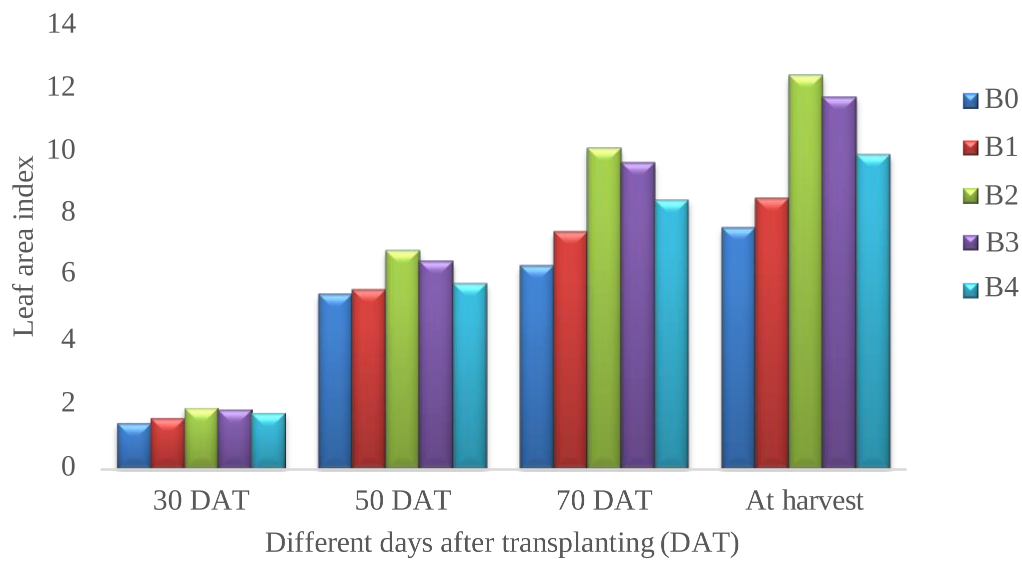


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan1

Figure 7. Effect of variety on the leaf area index of rice at different days after transplanting (LSD $_{(0.05)}$ = NS, 0.32, 0.30, 0.38 at 30, 50, 70 DAT and harvest)

4.1.4.2 Effect of boron

Significant variation was observed in terms of leaf area index at different growth stages of rice influenced by different rates of boron except at 30 DAT (Figure 8 and Appendix VIII). It was observed that the highest leaf area index (1.92, 6.88, 10.10 and 12.39 at 30, 50, 70 DAT and at harvest respectively) was obtained from the treatment, B_2 (1.5% B) followed by B_3 (1.8% B) where the lowest leaf area index (1.45, 5.50, 6.40 and 7.61 at 30, 50, 70 DAT and at harvest respectively) was found from the treatment, B_0 (0%; Control). The higher LAI was achieved by foliar application of B (1.5%) which might be due to more cell division and elongation resulting vigorous leaf production and finally produced higher LAI than the control treatment. Similar result also reported by Hussain and Yasin (2004) also concluded that application of B as foliar spraying in rice is highly attractive and produced higher LAI than control treatment.



B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 8. Effect of different levels of boron on the leaf area index of rice at different days after transplanting (LSD $_{(0.05)}$ = NS, 0.30, 0.39, 0.45 at 30, 50, 70 DAT and harvest)

4.1.4.3 Combined effect of variety and boron

Combined effect of variety and different rates of boron showed significant difference on leaf area index of rice at different growth stages (Table 4 and Appendix VIII). Results indicated that the highest leaf area index (1.93, 7.05, 10.21 and 12.71 at 30, 50, 70 DAT and at harvest respectively) was achieved from the treatment combination of V_2B_2 which was statistically identical with V_2B_3 and V_3B_3

and statistically similar with V_1B_3 at the time of harvest. The lowest leaf area index (1.47, 5.00, 6.30 and 7.51 at 30, 50, 70 DAT and at harvest respectively) was obtained from the treatment combination of V_3B_0 which was statistically identical with V_2B_0 and statistically similar with V_1B_0 and V_1B_1.

Table 4. Combined effect of variety and boron on leaf area index of hybrid rice at different growth stages

Treatment combinations	Leaf area index at			
	30 DAT	**50 DAT**	**70 DAT**	**Harvest**
V_1B_0	1.54	5.02 d	6.79 f	7.88 ef
V_1B_1	1.55	5.34 cd	7.20 ef	8.08 ef
V_1B_2	1.86	6.27 b	9.02 c	10.80 c
V_1B_3	1.88	6.78 a	9.82 ab	11.94 ab
V_1B_4	1.71	5.64 c	7.92 d	9.18 d
V_2B_0	1.33	6.87 a	6.12 g	7.44 f
V_2B_1	1.70	5.61 c	7.73 d	8.90 d
V_2B_2	1.93	7.05 a	10.21 a	12.71 a
V_2B_3	1.93	6.81 a	10.19 a	12.47 a
V_2B_4	1.75	5.64 c	8.67 c	10.11 c
V_3B_0	1.47	5.00 d	6.30 g	7.51 f
V_3B_1	1.58	5.54 c	7.51 de	8.59 de
V_3B_2	1.86	6.30 b	9.69 b	11.63 b
V_3B_3	1.94	7.06 a	10.29 a	12.77 a
V_3B_4	1.84	6.23 b	8.83 c	10.41 c
$LSD_{(0.05)}$	**NS**	**0.32**	**0.47**	**0.78**
CV (%)	**3.01**	**4.39**	**6.07**	**8.31**

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

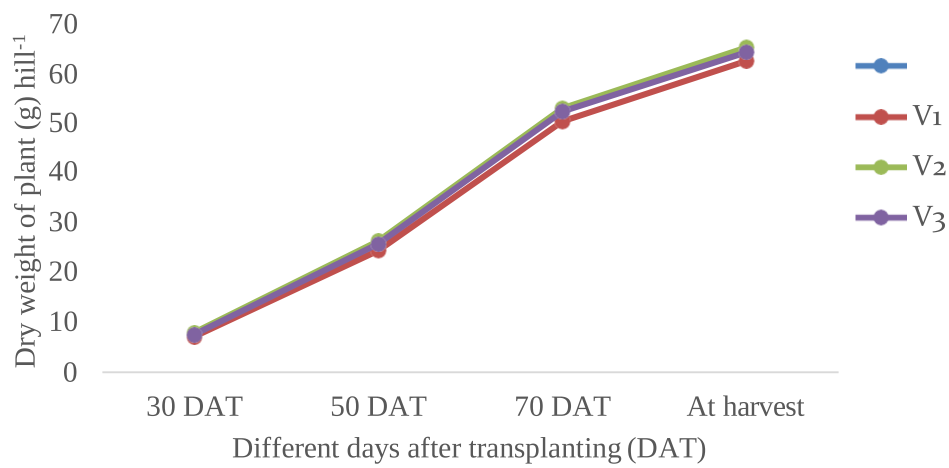
V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1; B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering 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 observed due to different variety of rice at different growth stages (Figure 9 and Appendix IX). Results showed that the highest dry weight hill^{-1} (8.68, 26.91, 53.30 and 65.35 g at 30, 50, 70 DAT and at harvest respectively) was achieved from the variety, V_2 (ACI Sera) followed by V_3 (BRRI hybrid dhan 1) where the lowest dry weight (g) hill^{-1} (78.80, 25.00, 50.67 and 62.68 g at 30, 50, 70 DAT and at harvest respectively) was observed from the variety, V_1 (ACI hybrid 1). Similar results were also similar with the findings of Murshida *et al*. (2017), Chamely *et al*. (2015), Sarkar *et al.* (2013) and Islam *et al*. (2009).



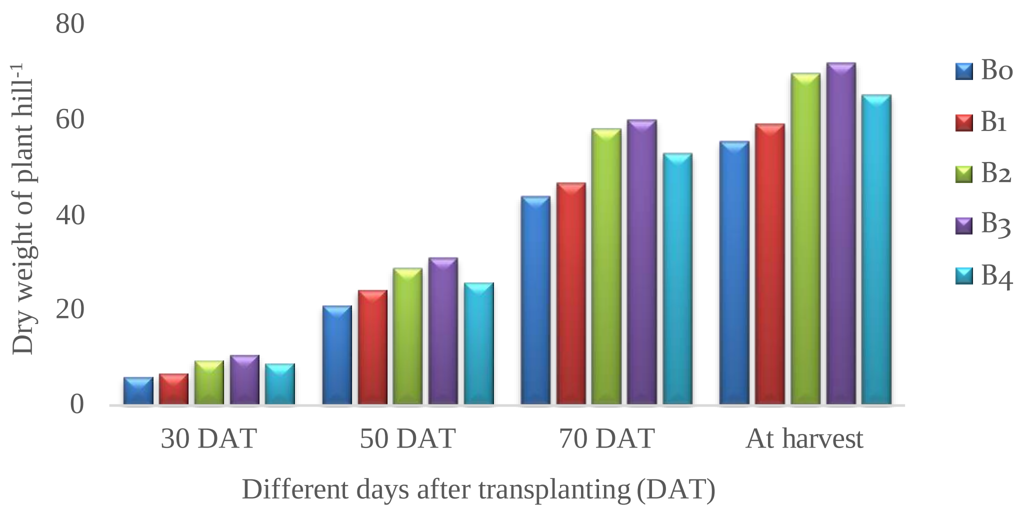
V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 9. Effect of variety on the dry weight of plant (g) hill^{-1} of rice at different days after transplanting (LSD $_{(0.05)}$ = 0.26, 0.30, 0.33, 0.39 at 30, 50, 70 DAT and harvest)

4.1.5.2 Effect of boron

Significant difference was found in terms of dry weight (g) hill^{-1} at different growth stages influenced by different rates of boron (Figure 10 and Appendix IX). It was found that the highest dry weight (g) hill^{-1} (10.60, 30.87, 59.87 and 71.76 g at 30, 50, 70 DAT and at harvest respectively) was obtained from the treatment, B_3(1.8%

B) followed by B_2 (1.5% B) where the lowest dry weight (g) hill^{-1} (5.91, 20.90, 43.73 and 55.36 g at 30, 50, 70 DAT and at harvest respectively) was found from the treatment, B_0 (0%; Control) which was immediate lower than B_1 (1.2% B) 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_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 10. Effect of different levels of boron on the dry weight (g) of plant hill^{-1} of rice at different days after transplanting (LSD $_{(0.05)}$ = 0.61, 0.93, 1.71, 1.74 at 30, 50, 70 DAT and harvest)

4.1.5.3 Combined effect of variety and boron

Dry weight (g) hill^{-1} of rice at different growth stages was significantly influenced by combined effect of variety and different rates of boron (Table 5 and Appendix IX). Results signified that the highest dry weight (g) hill^{-1} (11.60, 31.72, 61.60 and

72.84 g at 30, 50, 70 DAT and at harvest respectively) was achieved from the treatment combination of V_2B_3 which was significantly different from all other treatment combinations followed by V_3B_3 and V_2B_2. The lowest dry weight hill^{-1} (5.72, 19.66, 43.25 and 54.77 g at 30, 50, 70 DAT and at harvest respectively) was obtained from the treatment combination of V_1B_0 which was statistically similar with V_3B_0 at the time of harvest.

Table 5. Combined effect of variety and boron on dry weight (g) of plant hill^{-1} of hybrid rice at different growth stages

Treatment combinations	Dry weight (g) hill^{-1} at			
	30 DAT	**50 DAT**	**70 DAT**	**Harvest**
V_1B_0	5.72 e	19.66 i	43.25 i	54.77 i
V_1B_1	6.44 de	23.20 h	45.14 h	57.68 g
V_1B_2	9.14 bc	27.52 d	56.42 d	68.52 d
V_1B_3	9.48 bc	29.42 bc	57.96 c	70.67 c
V_1B_4	8.64 c	25.21 fg	50.58 f	61.78 f
V_2B_0	6.14 de	22.49 h	44.09 hi	55.88 h
V_2B_1	6.93 d	24.88 fg	48.11 g	60.82 f
V_2B_2	9.77 b	29.80 b	59.39 b	71.48 bc
V_2B_3	11.60 a	31.72 a	61.60 a	72.84 a
V_2B_4	8.90 bc	25.67 ef	53.29 e	65.74 e
V_3B_0	5.88 e	20.54 i	43.85 hi	55.42 hi
V_3B_1	6.58 de	24.36 g	46.76 g	58.44 g
V_3B_2	9.32 bc	28.66 c	57.96 c	68.83 d
V_3B_3	10.80 a	31.46 a	60.04 b	71.78 b
V_3B_4	8.98 bc	26.52 e	54.57 e	67.80 d
$LSD_{(0.05)}$	**0.92**	**0.93**	**1.35**	**1.03**
CV (%)	**5.73**	**10.52**	**8.32**	**11.05**

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.

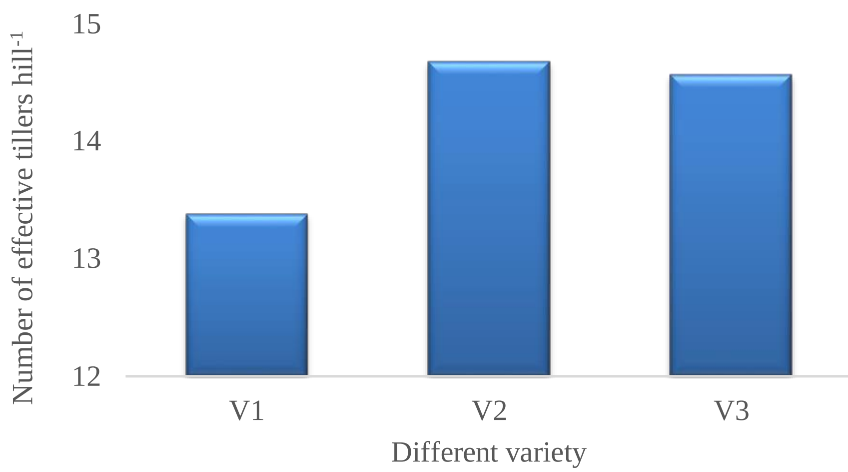
V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1; B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

4.2 Yield contributing parameters

4.2.1 Number of effective tillers hill^{-1}

4.2.1.1 Effect of variety

Significant variation was found on number of effective tillers hill^{-1} due to cause of different variety of rice (Figure 11 and Appendix X). Results exposed that the highest number of effective tillers hill^{-1} (14.68) was achieved from the variety, V_2 (ACI Sera) which was statistically similar with V_3 (BRRI hybrid dhan 1) where the lowest number of effective tillers hill^{-1} (13.38) was observed from the variety, V_1 (ACI hybrid 1). The result obtained from the present study was similar with the findings of Chamely *et al*. (2015) and Jisan *et al*. (2014).

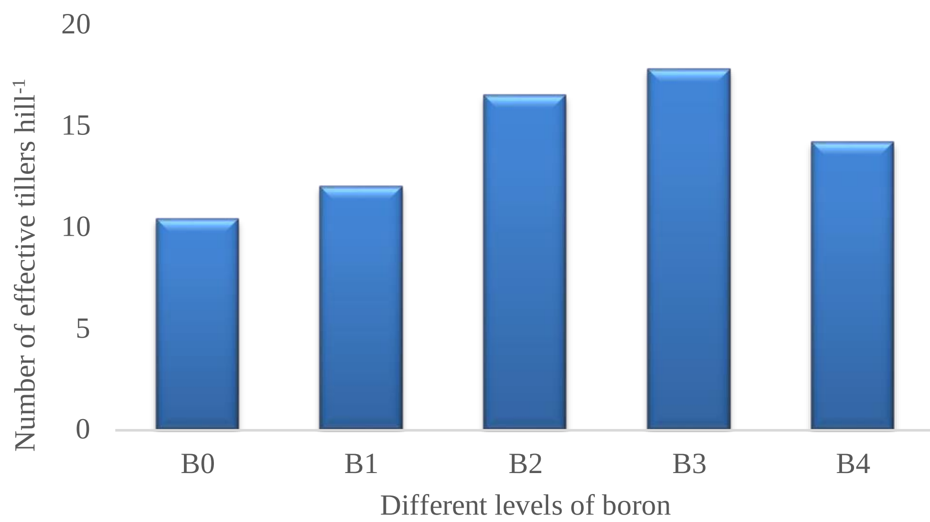


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 11. Effect of variety on the number of effective tillers hill^{-1} of rice (LSD $_{(0.05)}$ = 0.34)

4.2.1.2 Effect of boron

Number of effective tillers hill^{-1} of rice was significantly affected by different rate of boron (Figure 12 and Appendix X). Results revealed that the highest number of effective tillers hill^{-1} (17.84) was obtained from the treatment, B_3 (1.8% B) followed by B_2 (1.5% B) where the lowest number of effective tillers hill^{-1} (10.41) was found from the treatment, B_0 (0%; Control) followed by B_1 (1.2% B). Saleem *et al.* (2011); Dell and Huang (1997) and Marschner (1995) 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. Correa *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); Rahmatullah *et al.* (2006) and Ashraf *et al*. (2004) who reported that B application significantly affected the plant growth. Rerkasem *et al.* (2004) also reported that low B availability could reduce tiller numbers in wheat.



B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 12. Effect of different levels of boron on the number of effective tillers hill^{-1} of rice (LSD $_{(0.05)}$ = 0.93)

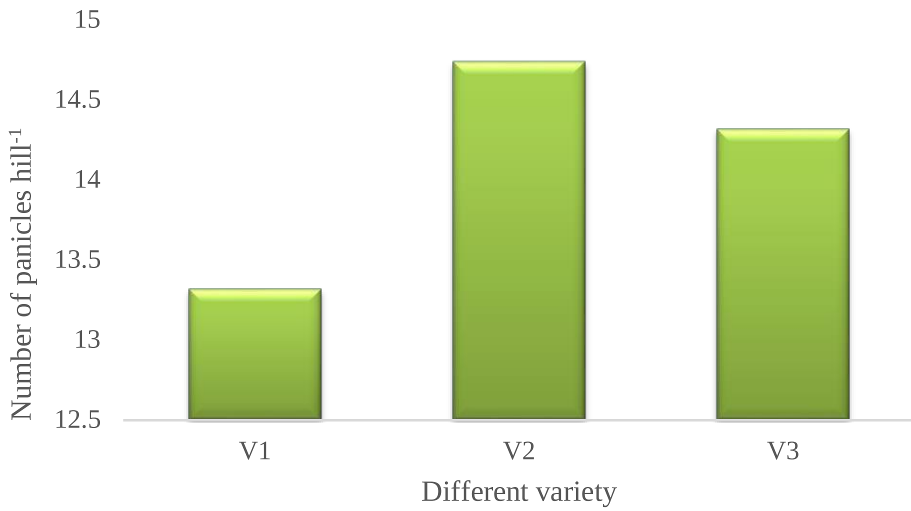
4.2.1.3 Combined effect of variety and boron

Significant variation was remarked for number of effective tillers hill^{-1} of rice due to combined effect of variety and different rate of boron (Table 6 and Appendix X). It was indicated that the highest number of effective tillers hill^{-1} (18.60) was achieved from the treatment combination of V_2B_3 followed by V_3B_3 and V_2B_2. The lowest number of effective tillers hill^{-1} (9.90) was obtained from the treatment combination of V_1B_0 which was statistically similar with V_3B_0 followed by V_1B_1 and V_2B_0.

4.2.2 Number of panicles hill^{-1}

4.2.2.1 Effect of variety

Number of panicles hill^{-1} was significantly influenced by different variety of rice (Figure 13 and Appendix X). The highest number of panicles hill^{-1} (14.74) was achieved from the variety, V_2 (ACI Sera) followed by V_3 (BRRI hybrid dhan 1) where the lowest number of panicles hill^{-1} (13.32) was observed from the variety, V_1 (ACI hybrid 1). The present finding on number of panicles hill^{-1} was similar with the findings of Islam *et al*. (2009).

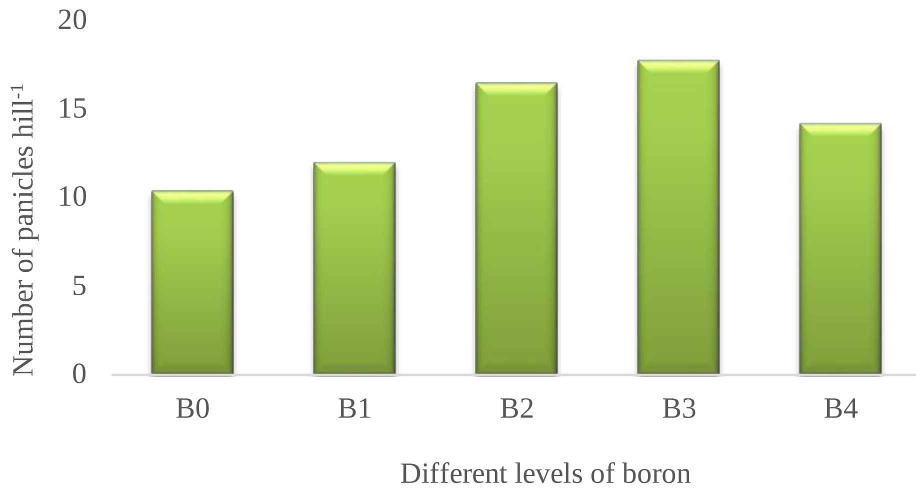


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 13. Effect of variety on the number of panicles hill^{-1} of rice at (LSD $_{(0.05)}$ = 0.32)

4.2.2.2 Effect of boron

Significant variation was observed in terms of number of panicles hill^{-1} of rice influenced by different rates of boron (Figure 14 and Appendix X). The highest number of panicles hill^{-1} (17.74) was obtained from the treatment, B_3 (1.8% B) followed by B_2 (1.5% B) where the lowest number of panicles hill^{-1} (10.34) was found from the treatment, B_0 (0%; Control) which was close to B_1 (1.2% B).



B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 14. Effect of different levels of boron on the number of panicles hill^{-1} of rice (LSD $_{(0.05)}$ = 0.98)

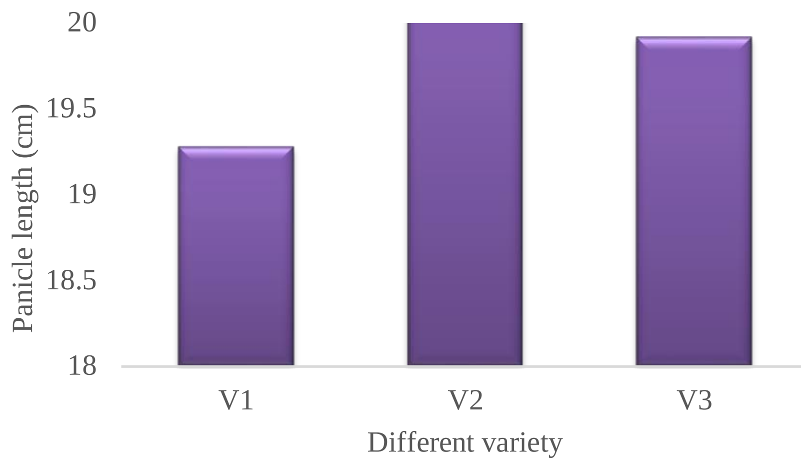
4.2.2.3 Combined effect of variety and boron

Combined effect of variety and different rates of boron showed significant difference on number of panicles hill^{-1} (Table 6 and Appendix X). It was found that the highest number of panicles hill^{-1} (18.48) was achieved from the treatment combination of V_2B_3 followed by V_3B_3 where the lowest number of panicles hill^{-1} (9.86) was obtained from the treatment combination of V_1B_0 which was statistically identical with V_3B_0 followed by V_1B_1 and V_2B_0.

4.2.3 Panicle length

4.2.3.1 Effect of variety

Significant influence on panicle length was observed due to different variety of rice (Figure 15 and Appendix X). It was found that the highest panicle length (20.30 cm) was achieved from the variety, V_2 (ACI Sera) which was statistically similar with V_3 (BRRI hybrid dhan1) where the lowest panicle length (19.28 cm) was observed from the variety, V_1 (ACI hybrid 1). Sarkar *et al*. (2014), Haque *et al.* (2013) and Khalifa (2009) also found similar results with the present study.

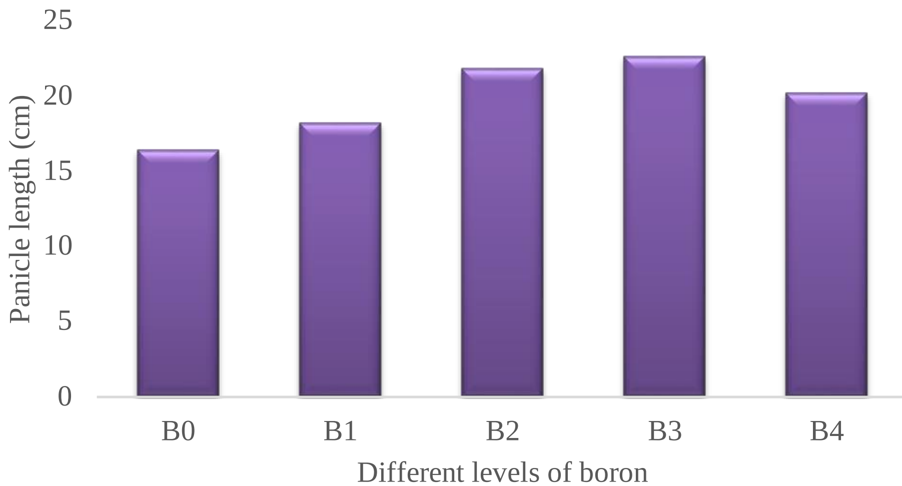


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 15. Effect of variety on the panicle length (cm) of rice (LSD $_{(0.05)}$ = 0.39)

4.2.3.2 Effect of boron

Significant difference was found in terms of panicle length influenced by different rates of boron (Figure 16 and Appendix X). It was shown that the highest panicle length (22.60 cm) was obtained from the treatment, B_3 (1.8% B) which was statistically similar with B_2 (1.5% B) where the lowest panicle length (16.40 cm) was found from the treatment, B_0 (0%; Control) followed by B_1 (1.2% B). Khan *et al*. (2007) also found similar results with the present study. Boron plays an important role in accelerating the formation and elongation of panicles in rice plants (Liew *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_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 16. Effect of different levels of boron on the panicle length (cm) of rice (LSD $_{(0.05)}$ = 1.03)

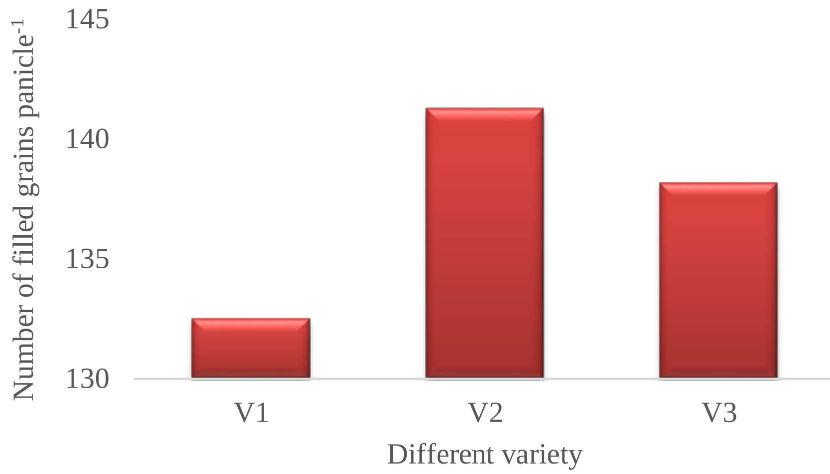
4.2.3.3 Combined effect of variety and boron

Panicle length was significantly influenced by combined effect of variety and different rates of boron (Table 6 and Appendix X). Results indicated that the highest panicle length (23.16 cm) was achieved from the treatment combination of V_2B_3 which was statistically identical with V_3B_3 and statistically similar with V_2B_2. The lowest panicle length (16.42 cm) was similar from the treatment combination of V_1B_0 which was statistically similar with V_2B_0 and V_3B_0.

4.2.4 Number of filled grains panicle^{-1}

4.2.4.1 Effect of variety

Significant variation was found on number of filled grains panicle^{-1} due to cause of different variety of rice (Figure 17 and Appendix X). Results showed that the highest number of filled grains panicle^{-1} (141.30) was achieved from the variety, V_2 (ACI Sera) followed by V_3 (BRRI hybrid dhan 1) where the lowest number of filled grains panicle^{-1} (a132.50) was observed from the variety, V_1 (ACI hybrid 1). Jisan *et al*. (2014), Sarkar *et al*. (2014) and Sarkar *et al.* (2013) also found similar results with the present study.

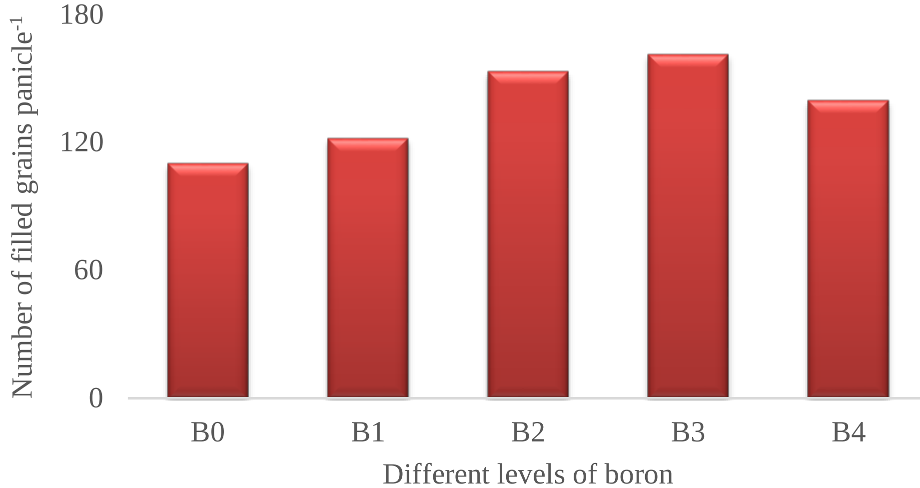


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 17. Effect of variety on the number of filled grains panicle^{-1} of rice (LSD $_{(0.05)}$ = 1.34)

4.2.4.2 Effect of boron

Number of filled grains panicle^{-1} of rice was significantly affected by different rate of boron (Figure 18 and Appendix X). It was observed that the highest number of filled grains panicle^{-1} (161.40) was obtained from the treatment, B_3 (1.8% B) followed by B_2 (1.5% B). The lowest number of filled grains panicle^{-1} (a110.30) was found from the treatment, B_0 (0%; Control). 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 (Rehman *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_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 18. Effect of different levels of boron on the number of filled grains panicle^{-1} of rice (LSD $_{(0.05)}$ = 3.22)

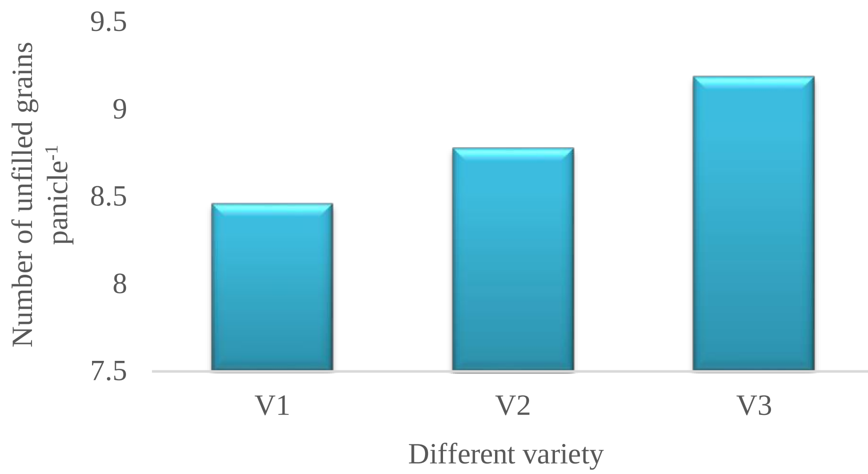
4.2.4.3 Combined effect of variety and boron

Significant variation was remarked for number of filled grains panicle^{-1} of rice due to combined effect of variety and different rate of boron (Table 6 and Appendix X). Results revealed that the highest number of filled grains panicle^{-1} (166.80) was found from the treatment combination of V_2B_3 followed by V_2B_2 and V_3B_3. The lowest number of filled grains panicle^{-1} (106.60) was obtained from the treatment combination of V_1B_0 followed by V_3B_0.

4.2.5 Number of unfilled grains panicle^{-1}

4.2.5.1 Effect of variety

Number of unfilled grains panicle^{-1} was significantly influenced by different variety of rice (Figure 19 and Appendix X). It was found that the the lowest number of unfilled grains panicle^{-1} (8.46) was achieved from the variety, V_1 (ACI hybrid 1) which was statistically dissimilar with V_2 (ACI Sera) where the highest number of unfilled grains panicle^{-1} (9.19) was observed from the variety, V_3 (BRRI hybrid dhan1).



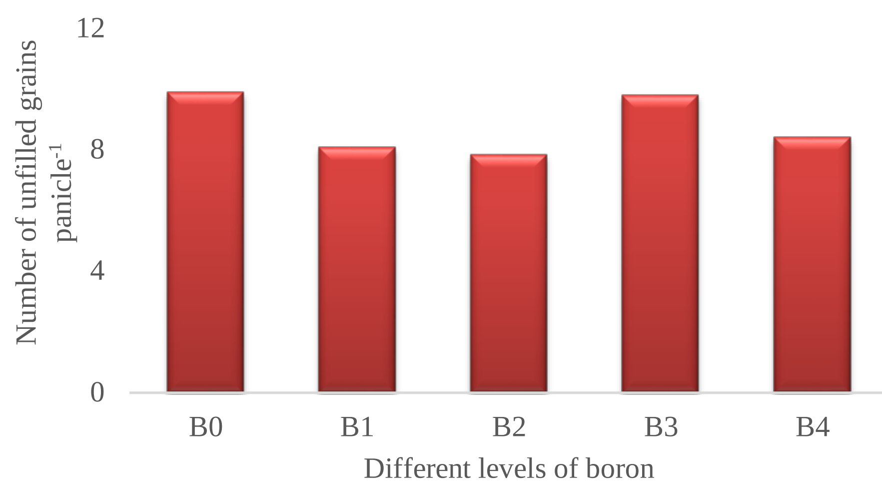
V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 19. Effect of variety on the number of unfilled grains panicle^{-1} of rice (LSD $_{(0.05)}$ = 0.34)

4.2.5.2 Effect of boron

Significant variation was observed in terms of number of unfilled grains panicle^{-1} of rice influenced by different rates of boron (Figure 20 and Appendix X). Results exhibited that the lowest number of unfilled grains panicle^{-1} (7.84) was obtained from the treatment, B_2 (1.5% B) which was statistically similar with B_1 (1.2% B) and B_4 (2.1% B) where the highest number of unfilled grains panicle^{-1} (9.90) was found from the treatment, B_0 (0%; Control) which was statistically similar with B_3

(1.8% B). 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 findings was in line with the findings of Ali *et al*. (2016) and Saleem *et al*. (2010) who reported 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_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 20. Effect of different levels of boron on the number of unfilled grains panicle^{-1} of rice (LSD $_{(0.05)}$ = 0.59)

4.2.5.3 Combined effect of variety and boron

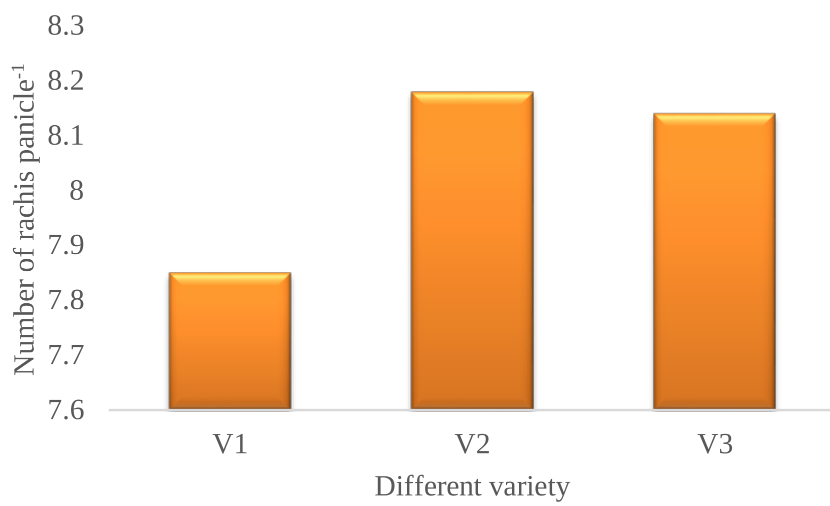
Combined effect of variety and different rates of boron showed significant difference on number of unfilled grains panicle^{-1} (Table 6 and Appendix X). It was found that the lowest number of unfilled grains panicle^{-1} (7.28) was achieved from the treatment combination of V_1B_2 which was statistically similar with V_2B_0 and

V_2B_4. The highest number of unfilled grains panicle^{-1} (10.60) was obtained from the treatment combination of V_3B_0 which was statistically similar with V_3B_3 followed by V_2B_3.

4.2.6 Number of rachis panicle^{-1}

4.2.6.1 Effect of variety

Non-significant variation was found in terms of number of rachis panicle^{-1} due to cause of varietal performance of rice (Figure 21 and Appendix X). But it was found that the highest number of rachis panicle^{-1} (8.18) was achieved from the variety, V_2 (ACI Sera) and the lowest number of rachis panicle^{-1} (7.85) was observed from the variety, V_1 (ACI hybrid 1). Myung (2005) also found similar results which supported the present study.

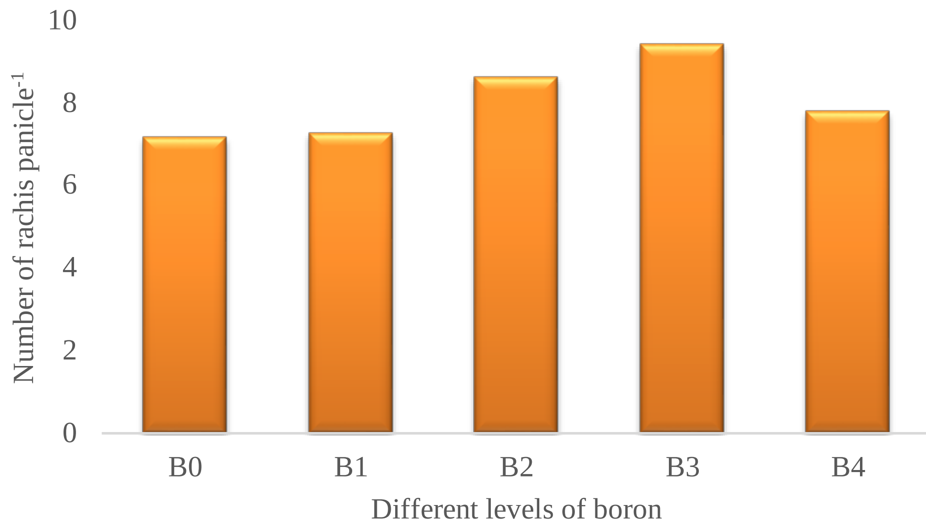


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 21. Effect of variety on the number of rachis panicle^{-1} of rice at (LSD $_{(0.05)}$ = NS)

4.2.6.2 Effect of boron

Number of rachis panicle^{-1} of rice was significantly affected by different rate of boron (Figure 22 and Appendix X). It was expressed that the highest number of rachis panicle^{-1} (9.43) was obtained from the treatment, B_3 (1.8% B) followed by B_2 (1.5% B) where the lowest number of rachis panicle^{-1} (7.17) was found from the treatment, B_0 (0%; Control) which was statistically similar with B_1 (1.2% B).



B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 22. Effect of different levels of boron on the number of rachis panicle^{-1} of rice (LSD $_{(0.05)}$ = 0.39)

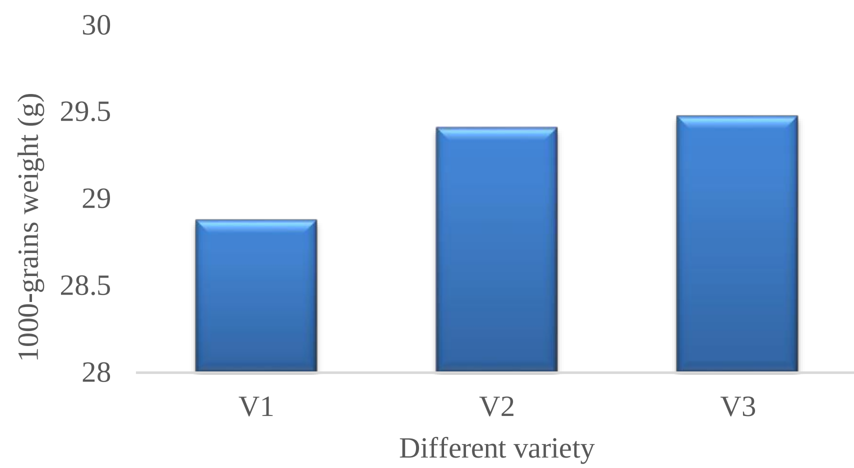
4.2.6.3 Combined effect of variety and boron

Significant variation was remarked for number of rachis panicle^{-1} of rice due to combined effect of variety and different rate of boron (Table 6 and Appendix X). Among the different treatment combinations, the highest number of rachis panicle^{-1} (9.78) was achieved from the treatment combination of V_2B_3 which was statistically similar with V_3B_3 followed by V_1B_3, V_2B_1 and V_2B_2. The lowest number of rachis panicle^{-1} (6.78) was obtained from the treatment combination of V_1B_0 which was statistically similar with V_1B_1 that was also close to the treatment combination of V_2B_0, V_2B_1, V_3B_0 and V_3B_1.

4.2.7 Weight of 1000-grains

4.2.7.1 Effect of variety

Weight of 1000-grains was significantly influenced by different variety of rice (Figure 23 and Appendix X). It was noted that the highest 1000-grains weight (29.48 g) was achieved from the variety, V_3 (BRRI hybrid dhan 1) which was statistically similar with V_2 (ACI Sera) where the lowest 1000-grains weight (28.88 g) was observed from the variety, V_1 (ACI hybrid 1). Similar trend of result with the present study was also found by Murshida *et al*. (2017), Jisan *et al*. (2014) and Sarkar *et al*. (2014).

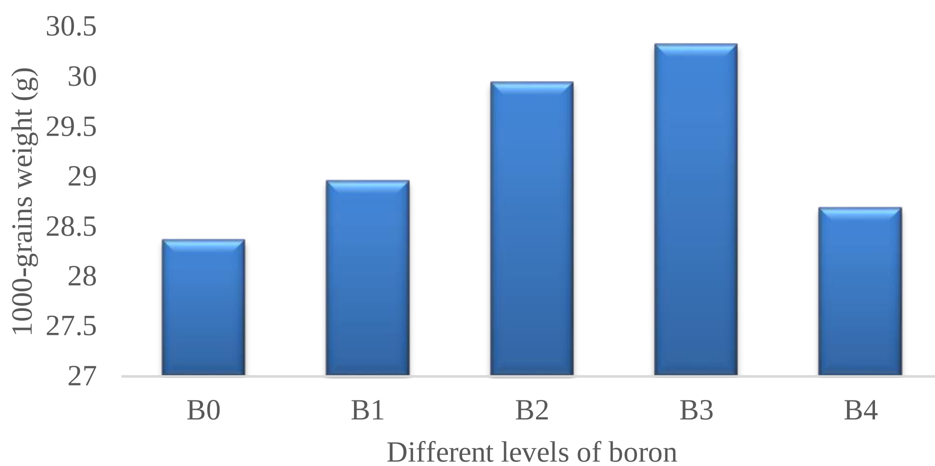


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 23. Effect of variety on the 1000-grains weight (g) of rice (LSD $_{(0.05)}$ = 0.34)

4.2.7.2 Effect of boron

Significant variation was observed in terms of 1000-grain weight of rice influenced by different rates of boron (Figure 24 and Appendix X). It was found that the the highest 1000-grains weight (30.33 g) was obtained from the treatment, B_3 (1.8% B) which was statistically similar with B_2 (1.5% B). The lowest 1000 grain weight (28.37 g) was found from the treatment, B_0 (0%; Control) which was statistically similar with B_1 (1.2% B) and B_4 (2.1% B). It might be due to 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), Shafiq and Maqsood (2010), Khan *et al*. (2007), Soleimani (2006) and Ashraf *et al.* (2004). They concluded that 1000-grain weight of rice increased with the increasing level of B fertilizer. In other cereals such as wheat, boron has also improved 1000-grain weight when it was sprayed on foliage at three growth stages *i.e*. tillering, booting and milking (Hussain *et al*., 2005).



B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 24. Effect of different levels of boron on the 1000-grains weight (g) of rice (LSD $_{(0.05)}$ = 0.93)

4.2.7.3 Combined effect of variety and boron

Combined effect of variety and different rates of boron showed significant difference on 1000-grains weight (Table 6 and Appendix X). Among the different treatment combinations, the highest 1000-grains weight (30.57 g) was achieved from the treatment combination of V_3B_3 which was statistically similar with V_2B_3 followed by V_2B_2. The lowest 1000 grain weight (26.83 g) was obtained from the treatment combination of V_1B_0 which was significantly different from all other treatment combinations followed by V_1B_0.

Table 6. Combined effect of variety and boron on yield contributing parameters of hybrid rice

Treatment combinations	Number of effective tillers hill^{-1}	Number of panicles hill^{-1}	Panicle length (cm)	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Number of rachis panicle^{-1}	1000 grain weight (g)
V_1B_0	9.90 i	9.86 k	16.42 g	106.60 m	9.48 de	6.78 h	26.83 j
V_1B_1	11.36 h	11.31 j	17.78 f	116.30 k	8.22 f-h	7.08 gh	28.26 h
V_1B_2	15.75 e	15.71 e	21.26 cd	148.40 e	7.28 j	8.10 d	29.76 de
V_1B_3	17.04 cd	16.96 c	21.80 bc	155.70 c	9.18 e	9.08 b	30.01 cd
V_1B_4	12.87 g	12.78 h	19.14 e	135.50 h	8.14 gh	7.77 de	27.59 i
V_2B_0	11.06 h	11.00 j	16.68 g	113.70 k	7.52 ij	7.24 g	27.98 h
V_2B_1	12.56 g	12.50 hi	18.44 ef	128.20 i	8.36 fg	7.40 e-g	29.34 fg
V_2B_2	17.32 bc	17.22 c	22.66 ab	158.90 b	9.36 de	9.27 b	30.14 bc
V_2B_3	18.60 a	18.48 a	23.16 a	166.80 a	10.10 bc	9.78 a	30.40 ab
V_2B_4	14.60 f	14.52 g	20.56 d	138.70 g	7.33 ij	7.68 d-f	29.56 e-g
V_3B_0	10.28 i	10.15 k	16.10 g	110.40 l	10.60 a	7.48 e-g	29.53 e-g
V_3B_1	12.22 g	12.10 i	18.36 ef	121.40 j	8.64 f	7.32 fg	29.27 g
V_3B_2	16.56 d	16.42 d	21.48 cd	152.80 d	7.78 hi	8.52 c	29.95 cd
V_3B_3	17.88 b	17.78 b	22.84 a	161.50 b	10.40 ab	9.43 ab	30.57 a
V_3B_4	15.18 ef	15.15 f	20.84 cd	144.90 f	9.78 cd	7.96 d	29.68 d-f
LSD $_{(0.05)}$	**0.63**	**0.48**	**0.93**	**3.21**	**0.45**	**0.39**	**0.34**
CV (%)	**7.05**	**8.31**	**6.14**	**12.39**	**5.21**	**5.07**	**10.39**

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.

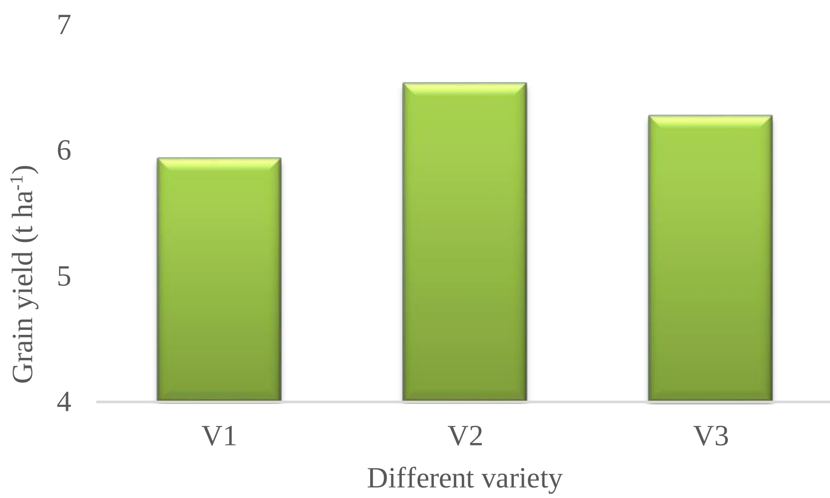
V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan1; B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

4.3 Yield parameters

4.3.1 Grain yield

4.3.1.1 Effect of variety

Grain yield was significantly influenced by different variety of rice (Figure 25 and Appendix XI). It was noted that the highest grain yield (6.54 t ha^{-1}) was achieved from the variety, V_2 (ACI Sera) followed by V_3 (BRRI hybrid dhan 1) where the lowest grain yield (5.94 t ha^{-1}) was observed from the variety, V_1 (ACI hybrid 1). Varietal performance on grain yield might be a genetical character which affected 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 Jisan *et al*. (2014) who reported that grain yield varied due to varietal variation.



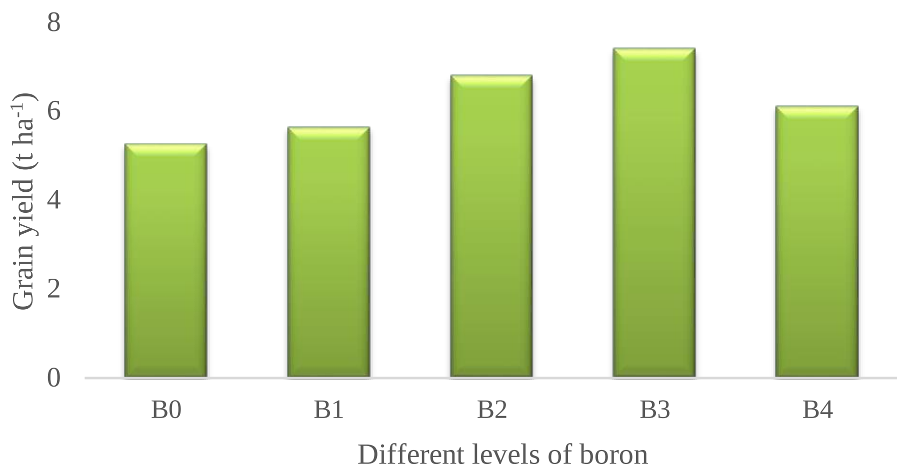
V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 25. Effect of variety on the Grain yield (t ha^{-1}) of rice (LSD $_{(0.05)}$ = 0.18)

4.3.1.2 Effect of boron

Significant variation was observed in terms of grain yield influenced by different rates of boron (Figure 26 and Appendix XI). Results exhibited that the highest grain yield (7.42 t ha^{-1}) was obtained from the treatment, B_3 (1.8% B) followed by B_2

(1.5% B) where the lowest grain yield (5.27 t ha^{-1}) was found from the treatment, B_0 (0%; Control) which was statistically identical with B_1 (1.2% B). The yield increase was due to the role of B in plant physiological functions especially during plant reproductive phase so its growth parameters such as number of tillers, length of panicle, number of filled grains per panicle and 1000-weight of grain improved which attributed the higher grain yield. Boron is basically involves in several biochemical processes including carbohydrate metabolism, sugar transport, lignification, nucleotide synthesis, respiration and pollen viability therefore its deficiency directly affects panicle production and hence the rice yield (Dobermann and Fairhurst, 2000). Hussain *et al*. (2012) concluded that, maximum grain yield by foliage application of B at the flowering stage might be the direct effect of higher number of grains per panicle and 1000-grain weight. Many reports indicate that B applied at the heading or flowering stage in rice resulted in increased rice grain yield and number of grains per panicle (Ramanthan *et al*., 2002 and Lin and Zhu, 2000). Moreover, by supplying plants with micronutrients especially B, either through soil application, foliar spray, or seed treatment, increases yield and quality as well as macronutrient use efficiency (Imtiaz *et al*., 2006). B has long been identified as one of the major constraints for grain crop production in the world. Jana *et al*. (2005) and Rashid *et al*. (2006) reported enhanced rice yield due to reduced panicle sterility by B application appreciably. On the other hand, the reason for the lowest grain yield in boron deprived plots might be the higher pollen infertility and lower grain filling as it plays very active role in both processes (Rashid *et al*., 2004 and Rerkasem *et al*., 1993). Again, Cheng and Rerkasem (1993) reported that, B deficiency depresses pollen germination and the fertilization process. The sole application of boron is reported to be as effective as its combined use with NPK or other micronutrients Chaudry *et al.* (2007) and Dunn *et al.* (2005). Rehman *et al.* (2014) also reported that, substantial decrease in panicle sterility and increase in grain size are the principal reasons of increase in grain yield by foliage application of B. Although primary role of B is to cross-link rhamnogalacturonan II monomers by a borate bridge, providing stability to the cell wall matrix (O'Neill *et al.*, 1997) nonetheless, applied in small amounts is a critical component of membranes in pollen tubes (Bolanos *et al.*, 2004 and Jackson, 1989). As growth of pollen tubes requires rapid synthesis of cell wall and plasma membrane (Taiz and Zeiger, 2010). Adequate B supply may also help maintain the assimilate supply to the developing grains (Dixit *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), Fakir *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*., 2010; 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_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 26. Effect of different levels of boron on the Grain yield (t ha^{-1}) of rice (LSD $_{(0.05)}$ = 0.45)

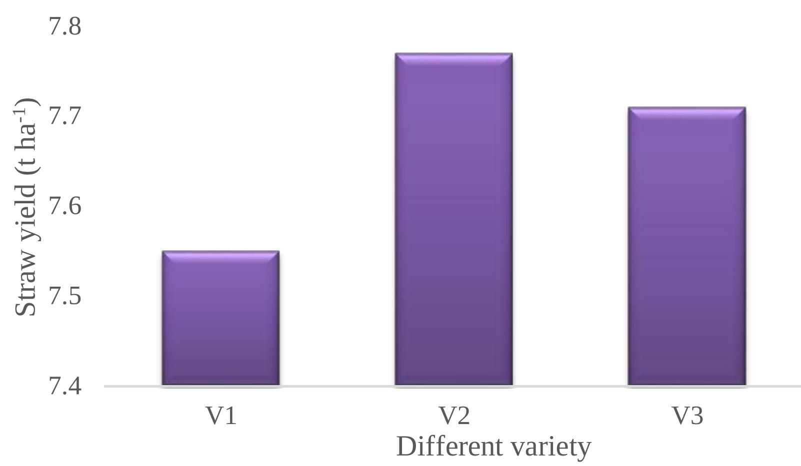
4.3.1.3 Combined effect of variety and boron

Combined effect of variety and different rates of boron showed significant difference on grain yield of rice (Table 7 and Appendix XI). It was eminent that the highest grain yield (7.88 t ha^{-1}) was achieved from the treatment combination of V_2B_3 which was statistically similar with V_3B_3 followed by V_2B_2 where the lowest grain yield (5.18 t ha^{-1}) was obtained from the treatment combination of V_1B_0 which was statistically similar with V_2B_0, V_3B_0 and V_1B_1.

4.3.2 Straw yield

4.3.2.1 Effect of variety

Significant influence on straw yield was observed due to different variety of rice (Figure 27 and Appendix XI). Considering varietal performance, the highest straw yield (7.77 t ha^{-1}) was achieved from the variety, V_2 (ACI Sera) which was statistically similar with V_3 (BRRI hybrid dhan 1) where the lowest straw yield (7.55 t ha^{-1}) was observed from the variety, V_1 (ACI hybrid 1).

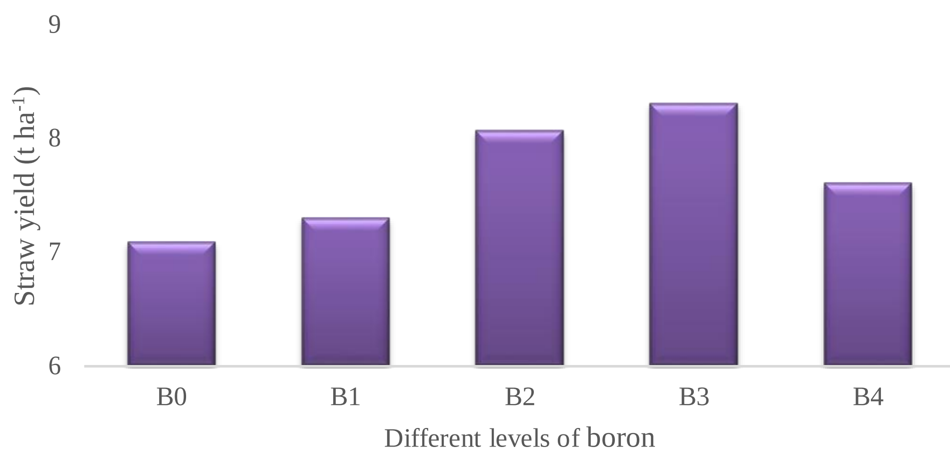


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 27. Effect of variety on the straw yield (t ha^{-1}) of rice (LSD $_{(0.05)}$ = 0.10)

4.3.2.2 Effect of boron

Significant difference was found in terms of straw yield influenced by different rates of boron (Figure 28 and Appendix XI). Among the different B treatment, the highest straw yield (8.31 t ha^{-1}) was obtained from the treatment, B_3 (1.8% B) which was statistically similar with B_2 (1.5% B) where the lowest straw yield (7.09 t ha^{-1}) was found from the treatment, B_0 (0%; Control) which was statistically similar with B_1 (1.2% B). Rice straw yield increased because B improved the membranes function which could positively affect the transport of all metabolites required for normal growth and development, as well as the activities of membrane bound enzymes which attributed to higher straw yield of rice (Gupta, 1993). Saleem *et al*. (2011) reported that, the highest straw yield was recorded at 3 kg B ha^{-1} over control. This result was in agreement with the findings of Rashid *et al*. (2007).



B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 28. Effect of different levels of boron on the straw yield (t ha^{-1}) of rice ($LSD_{(0.05)}$ = 0.43)

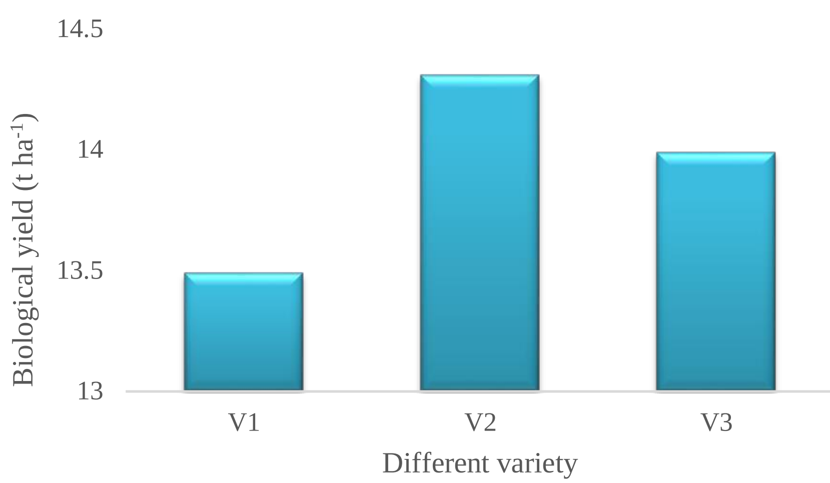
4.3.2.3 Combined effect of variety and boron

Straw yield of rice was significantly influenced by combined effect of variety and different rates of boron (Table 7 and Appendix XI). Among the different treatment combinations, the highest straw yield (8.42 t ha^{-1}) was achieved from the treatment combination of V_2B_3 which was statistically similar with V_3B_3, V_1B_3, V_2B_2 and V_3B_2. The lowest straw yield (7.02 t ha^{-1}) was obtained from the treatment combination of V_1B_0 which was statistically similar with V_1B_1, V_2B_0, V_3B_0 and V_3B_1.

4.3.3 Biological yield

4.3.3.1 Effect of variety

Significant variation was found on biological yield due to cause of different variety of rice (Figure 29 and Appendix XI). It was observed that the highest biological yield (14.31 t ha^{-1}) was achieved from the variety, V_2 (ACI Sera) followed by V_3 (BRRI hybrid dhan 1) where the lowest biological yield (13.49 t ha^{-1}) was observed from the variety, V_1 (ACI hybrid 1).

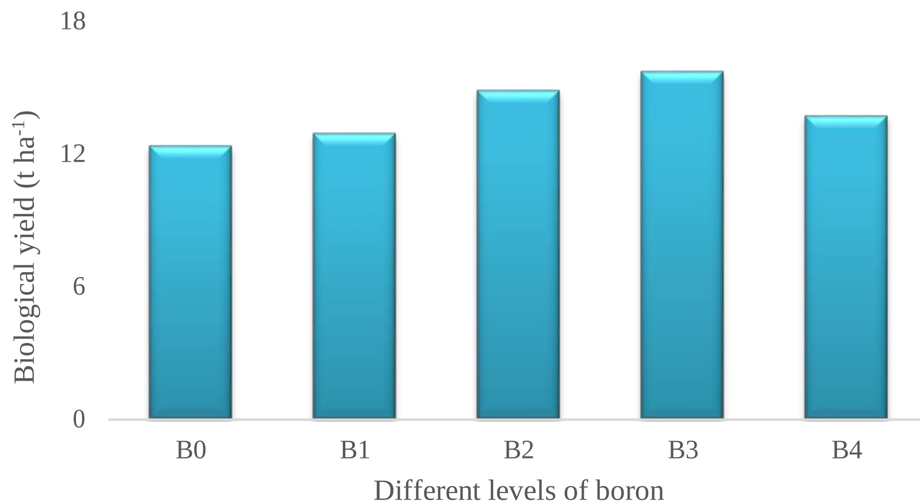


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 29. Effect of variety on the biological yield (t ha^{-1}) of rice (LSD $_{(0.05)}$ = 0.32)

4.3.3.2 Effect of boron

Biological yield of rice was significantly affected by different rate of boron (Figure 30 and Appendix XI). Results exhibited that the the highest biological yield (15.73 t ha^{-1}) was obtained from the treatment, B_3 (1.8% B) which was significantly different from all other treatment followed by B_2 (1.5% B) where the lowest biological yield (12.36 t ha^{-1}) was found from the treatment, B_0 (0%; Control).



B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 30. Effect of different levels of boron on the biological yield (t ha^{-1}) of rice (LSD $_{(0.05)}$ = 0.32)

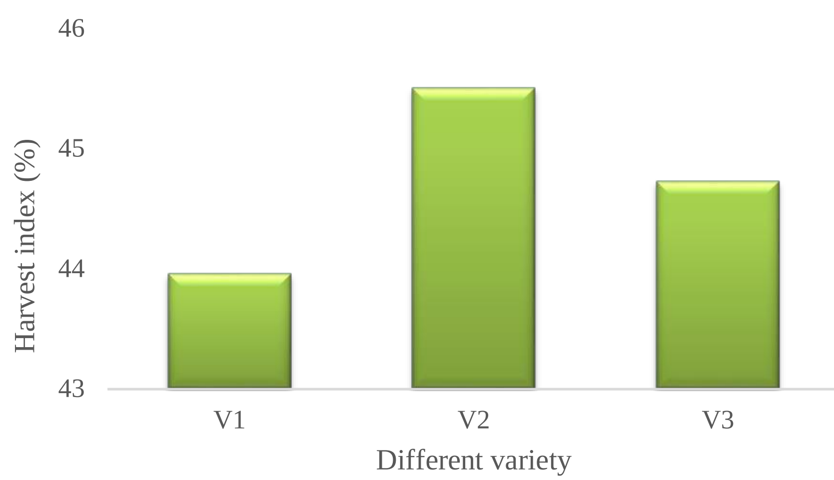
4.3.3.3 Combined effect of variety and boron

Significant variation was remarked for biological yield of rice due to combined effect of variety and different rate of boron (Table 7 and Appendix XI). It was expressed that the highest biological yield (16.30 t ha^{-1}) was achieved from the treatment combination of V_2B_3 which was statistically similar with V_3B_3 followed by V_2B_2. The lowest biological yield (12.20 t ha^{-1}) was obtained from the treatment combination of V_1B_0 which was statistically similar with V_1B_1, V_2B_0 and V_3B_0.

4.3.4 Harvest index

4.3.4.1 Effect of variety

Harvest index was significantly influenced by different variety of rice (Figure 31 and Appendix XI). It was observed that the highest harvest index (45.51%) was achieved from the variety, V_2 (ACI Sera) followed by V_3 (BRRI hybrid dhan1) where the lowest harvest index (43.96%) was observed from the variety, V_1 (ACI hybrid 1).

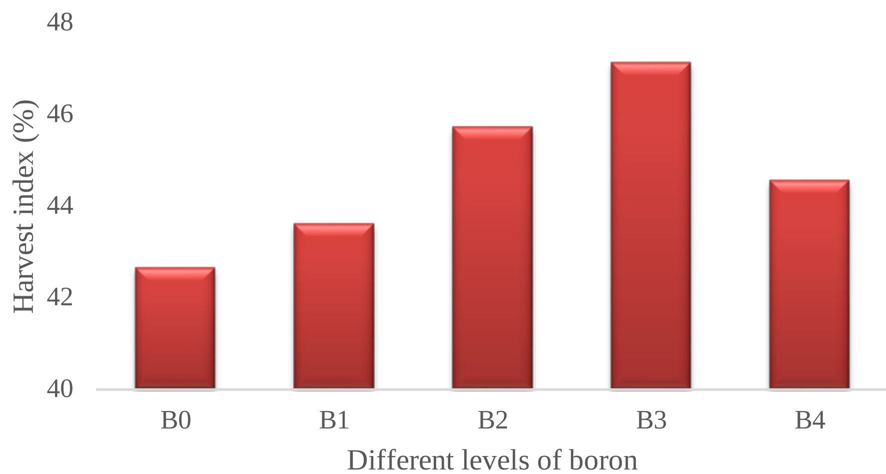


V_1 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1

Figure 31. Effect of variety on the harvest index of rice (LSD $_{(0.05)}$ = 0.45)

4.3.4.2 Effect of boron

Significant variation was observed in terms of harvest index of rice influenced by different rates of boron (Figure 32 and Appendix XI). Results indicated that the highest harvest index (47.13%) was obtained from the treatment, B_3 (1.8% B) followed by B_2 (1.5% B) where the lowest harvest index (42.65%) was found from the treatment, B_0 (0%; Control) followed by B_1 (1.2% B). Boron nutrition is more important during the reproductive stage as compared to the vegetative stage of the crop in cereals (Rerkasem and Jamjod, 1997). Improvement in harvest index resulted from B application might be due to better starch utilization that results in higher seed setting and translocation of assimilates to developing grains, which increases the grain size and number of grains per panicle (Hussain *et al*., 2012).



B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

Figure 32. Effect of different levels of boron on the harvest index (%) of rice (LSD $_{(0.05)}$ = 0.34)

4.3.4.3 Combined effect of variety and boron

Combined effect of variety and different rates of boron showed significant difference on harvest index of rice (Table 7 and Appendix XI). It was signified that the highest harvest index (48.34%) was achieved from the treatment combination of V_2B_3 followed by V_2B_2 and V_3B_3. The lowest harvest index (42.46%) was obtained from from the treatment combination of V_1B_0 which was statistically similar with V_2B_0 and V_3B_0.

Table 7. Combined effect of variety and boron on yield parameters of hybrid rice

Treatment combinations	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1B_0	5.18 i	7.02 i	12.20 j	42.46 h
V_1B_1	5.42 hi	7.18 g-i	12.60 j	43.02 g
V_1B_2	6.36 de	7.92 b-d	14.28 de	44.54 de
V_1B_3	6.78 c	8.14 ab	14.92 c	45.44 c
V_1B_4	5.96 fg	7.48 e-g	13.44 gh	44.35 e
V_2B_0	5.36 i	7.15 g-i	12.51 j	42.85 gh
V_2B_1	5.84 fg	7.40 e-h	13.24 hi	44.11 ef
V_2B_2	7.52 b	8.22 ab	15.74 b	47.78 b
V_2B_3	7.88 a	8.42 a	16.30 a	48.34 a
V_2B_4	6.12 ef	7.64 d-f	13.76 fg	44.48 de
V_3B_0	5.28 i	7.10 hi	12.38 j	42.65 gh
V_3B_1	5.68 gh	7.32 f-i	13.00 i	43.69 f
V_3B_2	6.55 cd	8.06 a-c	14.61 cd	44.83 d
V_3B_3	7.60 ab	8.36 a	15.96 ab	47.62 b
V_3B_4	6.28 de	7.72 c-e	14.00 ef	44.86 d
$LSD_{(0.05)}$	**0.29**	**0.33**	**0.39**	**0.43**
CV (%)	**8.52**	**6.51**	**7.53**	**6.22**

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 = ACI hybrid 1, V_2 = ACI Sera and V_3 = BRRI hybrid dhan 1; B_1 = 0% (Control), B_2 = 1.2% foliar application of B at tillering, panicle initiation and flowering stage, B_3 = 1.5% foliar application of B at tillering, panicle initiation and flowering stage, B_4 = 1.8% foliar application of B at tillering, panicle initiation and flowering stage and B_5 = 2.1% foliar application of B at tillering, panicle initiation and flowering stage

CHAPTER V

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 2016 to May, 2017 to find out the improvement of yield of hybrid rice through foliar boron application. Two factors were used in the experiment, *viz*. three rice varieties - V_1 (ACI hybrid 1), V_2 (ACI Sera) and V_3 (BRRI hybrid dha1) and five levels of boron application - B_0 (0%; Control), B_1 (1.2% B), B_2 (1.5% B), B_3 (1.8% B) and B_4 (2.1% B). The experiment was laid out in a Randomized complete Block Design (RCBD) with three replications. Data on different growth, yield and yield contributing parameters were recorded.

Different variety had significant influence on growth, yield and yield contributing parameters. Considering growth parameters, the highest plant height (109.7 cm) was achieved from the variety, V_1 (ACI hybrid 1) where the highest number of leaves hill^{-1} (58.48) was achieved from the variety, V_3 (BRRI hybrid dhan1). But the highest number of tillers hill^{-1} (21.85) leaf area index (10.33) and dry weight of plant hill^{-1} (65.35 g) were achieved from the variety, V_2 (ACI Sera). Again, the lowest plant height (105.0 cm) and leaf area index (9.58) were observed from the variety, V_3 (BRRI hybrid dhan 1) and the lowest number of leaves hill^{-1} (57.33), number of tillers hill^{-1} (19.84) and dry weight of plant hill^{-1} (62.68 g) were observed from the variety, V_1 (ACI hybrid 1). In terms of yield and yield contributing parameters, the highest number of effective tillers hill^{-1} (14.68), number of panicles hill^{-1} (14.74), panicle length (20.30 cm), number of filled grains panicle^{-1} (141.30), number of rachis panicle^{-1} (8.18), grain yield (6.54 t ha^{-1}), straw yield (7.77 t ha^{-1}), biological yield (14.31 t ha^{-1}) and harvest index (45.51%) were achieved from the variety, V_2 (ACI Sera). The lowest number of unfilled grains panicle^{-1} (8.46) and highest 1000-grains weight (29.48 g) were achieved from the variety, V_1 (ACI hybrid 1) and V_3

(BRRI hybrid dhan 1) respectively. The lowest number of effective tillers hill^{-1} (13.38), number of panicles hill^{-1} (13.32), panicle length (19.28 cm), number of filled grains panicle^{-1} (132.50), number of rachis panicle^{-1} (7.85), 1000-grains weight (28.88 g), grain yield (5.94 t ha^{-1}), straw yield (7.55 t ha^{-1}), biological yield (13.49 t ha^{-1}) and harvest index (43.96%) were observed from the variety, V_1 (ACI hybrid 1) but the highest number of unfilled grains panicle^{-1} (9.19) was observed from the variety, V_3 (BRRI hybrid dhan 1).

Different rates of boron application had also significant influence on growth, yield and yield contributing parameters. Considering growth parameters, the highest plant height (114.30 cm) was obtained from the treatment, B_4 (2.1% B) where the highest leaf area index (12.39) was obtained from B_2 (1.5% B) but the highest number of leaves hill^{-1} (63.88), number of tillers hill^{-1} (25.38) and highest dry weight of plant hill^{-1} (71.76 g) were obtained from the treatment, B_3 (1.8% B). The lowest plant height (100.40 cm), number of leaves hill^{-1} (50.30), number of tillers hill^{-1} (16.00), leaf area index (7.61) and lowest dry weight of plant hill^{-1} (55.36 g) were found from the treatment, B_0 (0%; Control). In terms of yield and yield contributing parameters, the highest number of effective tillers hill^{-1} (17.84), number of panicles hill^{-1} (17.74), panicle length (22.60 cm), number of filled grains panicle^{-1} (161.40), number of rachis panicle^{-1} (9.43), 1000-grains weight (30.33 g), grain yield (7.42 t ha^{-1}), straw yield (8.31 t ha^{-1}), biological yield (15.73 t ha^{-1}) and harvest index (47.13%) were obtained from the treatment, B_3 (1.8% B) where the lowest number of effective tillers hill^{-1} (10.41), number of panicles hill^{-1} (10.34), panicle length (16.40 cm), number of filled grains panicle^{-1} (110.30), number of rachis panicle^{-1} (7.17), 1000-grains weight (28.37 g), grain yield (5.27 t ha^{-1}), straw yield (7.09 t ha^{-1}), biological yield (12.36 t ha^{-1}) and harvest index (42.65%) were found from the treatment, B_0 (0%; Control). The highest number of unfilled grains panicle^{-1} (9.90) was also found from the treatment, B_0 (0%; Control) where the lowest number of unfilled grains panicle^{-1} (7.84) was obtained from the treatment, B_2 (1.5% B).

Combined effect of variety and different rates of boron application had also significant influence on growth, yield and yield contributing parameters of rice. Considering growth parameters, the highest The highest plant height (117.60 cm) was achieved from the treatment combination of V_1B_4 where the highest number of leaves hill^{-1} (65.64) was achieved from the treatment combination of V_3B_3 but the highest leaf area index (12.71) was achieved from the treatment combination of V_2B_2 and the highest number of tillers hill^{-1} (26.72) and dry weight of plant hill^{-1} (72.84 g) were achieved from the treatment combination of V_2B_3. The lowest plant height (100.40 cm) and leaf area index (7.51) were obtained from the treatment combination of V_3B_0 where the lowest number of leaves hill^{-1} (52.29), number of tillers hill^{-1} (15.34) and dry weight of plant hill^{-1} (54.77 g) were obtained from the treatment combination of V_1B_0. In terms of yield and yield contributing parameters, the highest number of effective tillers hill^{-1} (18.60), number of panicles hill^{-1} (18.48), panicle length (23.16 cm), number of filled grains panicle^{-1} (166.80), number of rachis panicle^{-1} (9.78), grain yield (7.88 t ha^{-1}), straw yield (8.42 t ha^{-1}), biological yield (16.30 t ha^{-1}) and harvest index (48.34%) were achieved from the treatment combination of V_2B_3 but the highest 1000-grains weight (30.57 g) was achieved from the treatment combination of V_3B_3 where the lowest number of effective tillers hill^{-1} (9.90), number of panicles hill^{-1} (9.86), panicle length (16.42 cm), number of filled grains panicle^{-1} (106.60), number of rachis panicle^{-1} (6.78), 1000 grain weight (27.59 g), grain yield (5.18 t ha^{-1}), straw yield (7.02 t ha^{-1}), biological yield (12.20 t ha^{-1}) and harvest index (42.46%) were obtained from the treatment combination of V_1B_0. The lowest and highest number of unfilled grains panicle^{-1} (7.28 and 10.60 respectively) was achieved from the treatment combination of V_1B_2 and V_3B_0 respectively.

From the above findings, it may be concluded that the treatment combination of variety, V_2 (ACI Sera) and boron treatment, B_3 (1.8% B) performed the best results. So, the treatment combination of variety, V_2 (ACI Sera) with boron treatment, B_3 (1.8% B) is the superior combination compared to other treatment combinations for rice production.

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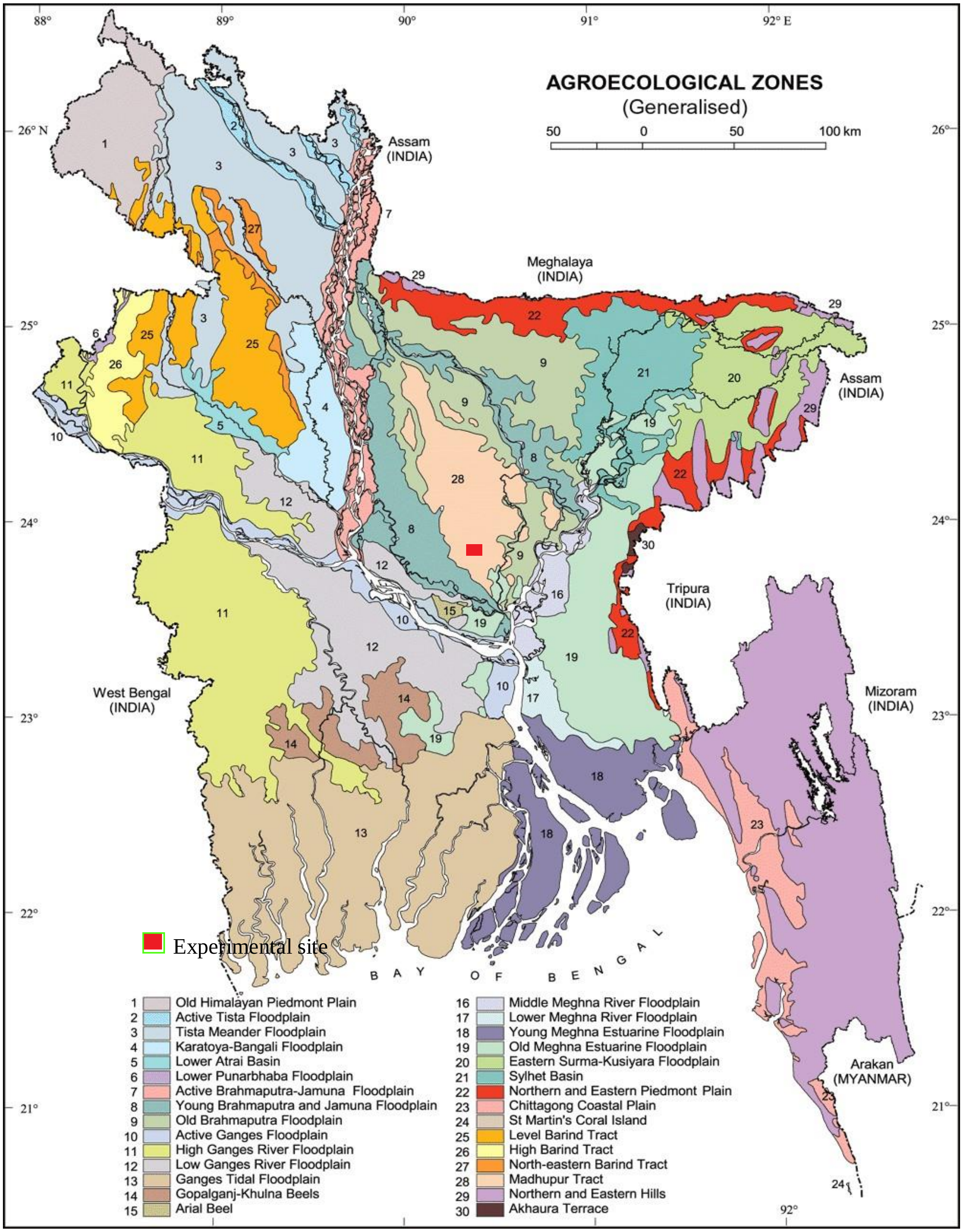
APPENDICES

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 2016 to May, 2017

Month and year	RH (%)	Air temperature (C)			Rainfall (mm)
		Max.	*Min.*	*Mean*	
November, 2016	56.75	28.60	8.52	18.56	14.40
January, 2017	46.20	23.80	11.70	17.75	0.0
February, 2017	37.90	22.75	14.26	18.51	0.0
March, 2017	52.44	35.20	21.00	28.10	20.4
April, 2017	65.40	34.70	24.60	29.65	165.0
May, 2017	68.30	32.64	23.85	28.25	182.2

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)

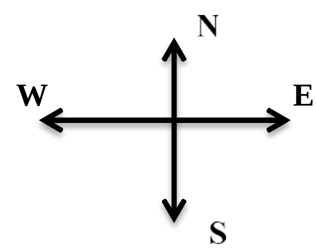
B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
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

V_2B_3	**V_2B_2**	**V_1B_4**		**V_1B_4**	**V_2B_3**	**V_2B_2**		**V_2B_2**	**V_1B_4**	**V_2B_3**
V_1B_0	**V_3B_1**	**V_2B_1**		**V_2B_1**	**V_1B_0**	**V_3B_1**		**V_3B_1**	**V_2B_1**	**V_1B_0**
V_1B_3	**V_2B_0**	**V_1B_2**	**Replication**	**V_1B_2**	**V_1B_3**	**V_2B_0**	**Replication**	**V_2B_0**	**V_1B_2**	**V_1B_3**
V_3B_1	**V_3B_0**	**V_2B_4**		**V_2B_4**	**V_3B_1**	**V_3B_0**		**V_3B_0**	**V_2B_4**	**V_3B_1**
V_1B_1	**V_3B_4**	**V_3B_3**		**V_3B_3**	**V_1B_1**	**V_3B_4**		**V_3B_4**	**V_3B_3**	**V_1B_1**
	R_1				**R_2**				**R_3**	



Length of plot: 2.5 m
Width of plot: 2.3 m
Replication to replication distance: 0.75 m
Plot to plot distance: 0.5 m
Unit plot size: 2.5 m × 2.3 m (5.75 m^2)

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

Sources of variation	Degrees of freedom	Mean square of plant height			
		30 DAT	50 DAT	70 DAT	At harvest
Replication	2	1.266	1.311	3.621	2.744
Factor A	2	8.214**	25.36*	39.27*	36.523**
Factor B	4	15.329*	46.18*	32.52*	51.344*
AB	8	7.117**	16.75**	14.76**	14.581**
Error	28	1.122	2.276	3.334	3.634

*Significant at 5% level
**Significant at 1% level

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

Sources of variation	Degrees of freedom	Mean square of number of leaves hill^{-1}			
		30 DAT	50 DAT	70 DAT	At harvest
Replication	2	1.048	1.106	2.304	1.056
Factor A	2	16.186*	18.317**	22.036*	26.174*
Factor B	4	24.439*	31.255*	38.527*	34.462*
AB	8	8.286**	9.279**	11.298**	12.231**
Error	28	0.259	0.386	1.073	2.264

*Significant at 5% level
**Significant at 1% level

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

Sources of variation	Degrees of freedom	Mean square of number of tillers $hill^{-1}$			
		30 DAT	50 DAT	70 DAT	At harvest
Replication	2	0.036	0.058	0.072	0.086
Factor A	2	0.786**	5.247**	7.319**	8.627**
Factor B	4	4.023**	8.076*	10.573*	6.014**
AB	8	1.152**	2.272**	4.044**	4.113**
Error	28	0.056	0.126	0.358	1.053

*Significant at 5% level

**Significant at 1% level

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	50 DAT	70 DAT	At harvest
Replication	2	0.017	0.102	0.132	0.156
Factor A	2	NS	7.541*	8.579*	8.388*
Factor B	4	NS	6.386*	12.37*	11.342*
AB	8	NS	3.227**	7.114**	8.511**
Error	28	0.136	0.512	1.108	1.126

*Significant at 5% level

**Significant at 1% level

^{NS}Nonsignificant

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

Sources of variation	Degrees of freedom	Mean square of dry weight hill^{-1}			
		30 DAT	50 DAT	70 DAT	At harvest
Replication	2	0.106	0.286	0.388	0.504
Factor A	2	6.246*	17.661*	28.863*	25.241*
Factor B	4	8.365*	12.428*	40.28*	46.268*
AB	8	3.181**	8.139**	14.32**	12.117**
Error	28	0.146	1.375	1.107	1.287

*Significant at 5% level

**Significant at 1% level

Appendix X. Mean square values of yield contributing parameters of different hybrid 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 panicles hill^{-1}	Panicle length	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Number of rachis panicle^{-1}	1000-grains weight
Replication	2	0.132	0.118	0.533	1.116	0.081	0.106	0.212
Factor A	2	5.263*	4.569*	7.038	47.041**	3.263*	5.569*	8.034
Factor B	4	11.31*	8.74*	16.16*	69.117*	6.31*	10.74*	15.72*
AB	8	4.841*	3.336**	6.752*	23.056*	1.841*	4.336**	7.728*
Error	28	0.346	0.314	0.436	2.148	0.138	0.286	0.376

*Significant at 5% level

**Significant at 1% level

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

Sources of variation	DF	Mean square of yield parameters			
		Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	0.526	0.226	1.114	0.312
Factor A	2	7.36*	8.34*	10.29*	14.117*
Factor B	4	15.38*	26.18*	28.36*	26.315*
A x B	8	6.52*	7.731*	8.85**	11.831**
Error	28	1.023	1.312	1.514	1.072

*Significant at 5% level

**Significant at 1% level

PICTURES

Picture 1. Rice seedlings at seedbed

Picture 2. Rice seedlings transplantation

Picture 3. Field condition at 12 DAT

Picture 4. Irrigated condition at 30 DAT

Picture 5. Weeding from the field

Picture 6. Data collection from the field

Picture 7. Flowering condition at 85 DAT

Picture 8. Foliar boron application at flowering stage

A **B**

Picture 9. Difference between the plots after boron application (A: Without foliar application of Boron and B: Plot with foliar application of boron)

Picture 10. Net was given to protect rice crop from birds