GROWTH AND YIELD OF BORO RICE AS AFFECTED BY FERTILIZER MANAGEMENT

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CERTIFICATE

*This is to certify that the thesis entitled, "***GROWTH AND YIELD OF BORO RICE AS AFFECTED BY FERTILIZER MANAGEMENT***" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE IN AGRONOMY,*** *embodies the results of a piece of bona-fide research work carried out by* ***SATRATUN NESSA SAMIA****, Registration No.* ***15-06377*** *under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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DADICATED TO

MY BELOVED

PARENTS &

HUSBAND

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The Author

GROWTH AND YIELD OF BORO RICE AS AFFECTED BY FERTILIZER MANAGEMENT

ABSTRACT

The experiment was conducted in Boro season, 2020-21 to compare the performance of fortified rice variety BRRI dhan84 with non-fortified mega variety BRRI dhan89 and suitable fertilizer combination for maximum growth and yield. Treatments were: two rice variety viz., i) BRRI dhan84 (V_1) and ii) BRRI dhan89 (V_2) in the main plot and seven different fertilizer management viz., i) no fertilizer (F_1), ii) recommended NPKS (RFD) with Zn as basal (F_2), iii) RFD + Zn as foliar spray at anthesis (F_3), iv) RFD + Zn & B as foliar spray at anthesis (F_4), v) 50% RFD + 50% Cowdung as basal (F_5), vi) 50% RFD + 50% Cowdung + Zn & B as basal (F_6) and vii) 50% RFD + 50% Cowdung as basal + Zn & B as foliar at anthesis (F_7) in the sub-plot. The experiment was laid out in a Split-plot design having 3 replications. No significant variations observed between the two varieties for almost all the studied characters except filled grains panicle^{-1} where the variety BRRI dhan89 showed higher number of grains panicles^{-1} (116.14) than the other variety. RFD with foliar application of zinc and born (F_4) gave the highest plant height at harvest (102.54 cm), effective tillers hill^{-1} (12.83) that similar (13.00) with F_2 (RFD with Zn as basal), panicle length (25.91 cm), 1000-grain weight (23.58 g), grain yield (7.67 t ha^{-1}), biological yield (14.85 t ha^{-1}) and harvest index (51.69%). Irrespective of varieties, F_4 resulted superior response for almost all the studied parameters. Foliar application of zinc and boron at anthesis (F_4) along with RFD increased 8.79 and 27.45% yield in BRRI dhan89 compared to that of RFD with Zn as foliar (F_3) and RFD with Zn and B basal (F_2) application, respectively that was 17.11 and 26.77% for the other fortified rice variety BRRI dhan84. Foliar application of Zn and B along with recommended doses of NPKS can be recommended for Boro rice cultivation.

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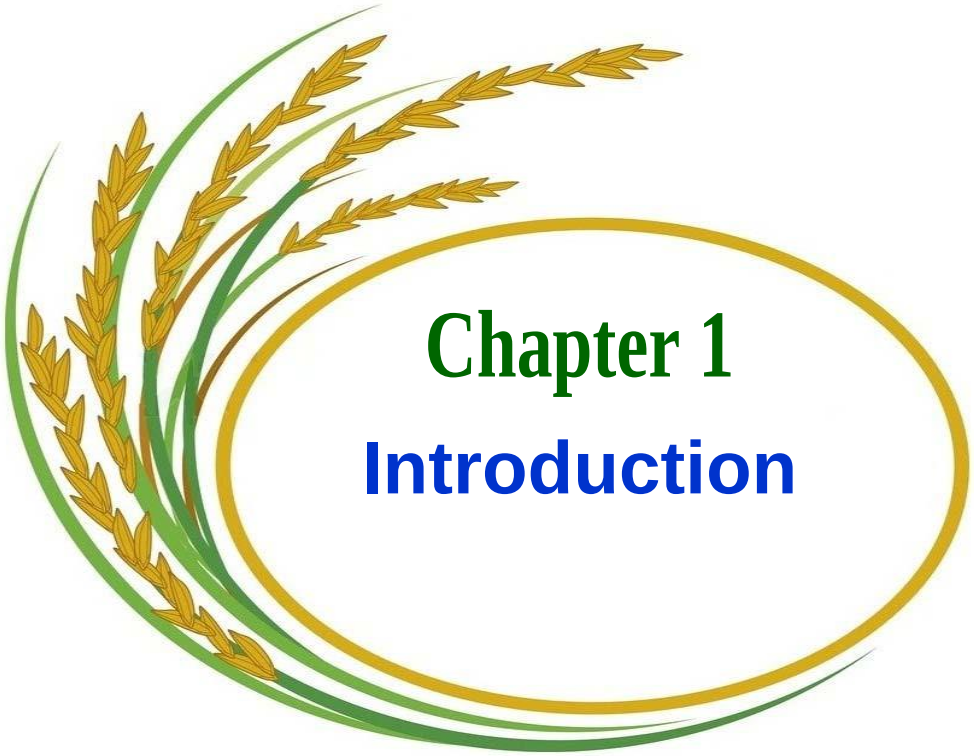
LIST OF ACRONYMS

AEZ	Agro ecological zone
B	Boron
BRRI	Bangladesh Rice Research Institute
BER	Bangladesh Economic Review
cm	Centimeter
CV	Coefficient of Variation
DAT	Days After Transplanting
et al.	And others (*et alibi*)
FAO	Food and Agriculture Organization
g	Gram
ha	Hectare
HI	Harvest Index
kg	Kilogram
LAI	Leaf Area Index
LSD	Least Significance Difference
m^2	Square Meter
MoP	Muriate of potash
N	Nitrogen
No.	Number
NPK	Nitrogen phosphorus potassium
NS	Non Significant
%	Percent
$panicle^{-1}$	per panicle
SPAD	Soil Plant Analysis Development
S	Sulphur
SRDI	Soil Resource Development Institute
$t\ ha^{-1}$	Ton (s) per hectare
TSP	Triple super phosphate
US	United States
Zn	Zinc



Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is the primary food for half the people in the world. In many reasons it is eaten with every meal and provides more calories than any other staple or single food. Rice, locally known as dhan is an annual aquatic grain that ranks second in respect of production concern worldwide after wheat. More than 50% of world population depends on rice as their staple food. Around 90% of cereal production in Bangladesh comes from rice. In respect of total acreage, India ranks first but in total production, China holds the top position but in respect of per unit production concern Australia, South Korea, Spain, Japan ranks superior position (Fukagawa and Ziska, 2019).

Bangladesh has a population of about 161.7 million with growth rate of 1.37% per annum, giving a population density of 1286 per square kilometer (FAO and World Bank population estimates, 2020). Rice is the staple food of Bangladesh, occupies nearly 90% of total net cropped area of the country and more than 99% of the people eat rice as their main food @ 416g /person/ day (HIES, 2010).

Nutrient value of per 100g edible portion of rice contains 77-79 g carbohydrate, 6.4-8.5 g protein, 0.4 – 1.5 g fat, 345 - 349 Kcal calorie, 9-10 mg calcium, 3-4 mg Fe (Iron). It is also most important crop in Bangladesh in respect of area, production and contribution to national economic development. Bangladesh has three rice producing season namely Aus, Aman and Boro. Among these seasons Aus, Aman and Boro covers 80% of total cultivated area of the country (AIS, 2011). The average yield of rice in Bangladesh is about 3.21 t ha^{-1} (BBS, 2021) which is very low comparison to other rice growing countries of the World, like Korea (6.87 t ha^{-1}), Japan (6.82 t ha^{-1}) and China (7.06 t ha^{-1}) (FAO, 2021). In Bangladesh Aus, Aman, Boro produced 2.75, 14.20 and 19.64 million metric tons of rice (BBS, 2021). Therefore, Boro rice is one of the most

important rice crops for Bangladesh with respect to its higher yield and contribution to rice production.

Nutrition sensitive agriculture is a food based approach to agricultural development that puts nutritionally rice foods, dietary diversity and food fortification at heart of overcoming malnutrition and micronutrient deficiencies. Micronutrients are essential plant nutrients that are found in trace amounts in tissue but play an imperative role in plant growth and development. Without these nutrients, plant nutrition would be compromised leading to potential declines in plant productivity.

Micronutrient deficiency is considered as one of the important emerging challenges to food and nutrition security in Bangladesh soil health is directly related to human health. Current estimate suggested that almost half of the world population suffers from mineral deficiencies, primarily in zinc and iron. Rice feeds almost 50-58% of the Worlds populations and considered as a global grain but it is deficient in micronutrient (Bouis and Welch, 2010). Therefore even a small increase in the nutritive value of rice can be highly significant for human nutrition (Zhang *et al*., 2015). According to the Soil Resource Development Institute (SRDI) in Bangladesh low to very low soil zinc (Zn) status was increased by 28.71% to 78.84% and Boron (B) increased by 25.99% to 30.78% in arable land since 2010-2020 (Hasan *et al*., 2020). In Bangladesh, children also suffer from high rate of micronutrient deficiencies, specifically vitamin A, iron, zinc and iodine deficiency. Improving nutrition through soils can have a significant impact on malnutrition in Bangladesh.

Zinc (Zn) is one of the most important micronutrient elements whose normal concentration range is 25 to 150 ppm in plant. The deficiencies of Zn cause multiple symptoms that usually appear 2 to three weeks after transplanting of rice seedlings; when leaves develops brown blotches and streaks that may fuse to cover older leaves entirely, plant remain stunted and in severe cases may die

while those that recover will show substantial delay in maturity and reduction in yield (Neue and Lantin, 1994). In rice, Zinc deficiency decreases tillering, increase spikelet sterility and time to crop maturity (IRRI, 2000).

Boron (B) is an important micronutrient element for plants to promote cell growth and development of the panicle (Garg *et al*., 1979). Boron (B) is responsible for better pollination and seeds setting, grain formation in different rice cultivars (Rahman *et al*., 2014; Aslam *et al*., 2002). The deficiency symptoms of B in rice start 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 fail to produce viable seeds. Boron deficiency is a particular important since it affects the flowering and plant reproductive process and hence directly affects harvested yield (Bolanos *et al*., 2004). Boron can be applied to the soil to provide the elevation of the Boron statues of a crop.

However, cultivation of MV and hybrid varieties of different crops is deteriorating soil fertility status of most Bangladesh soil day by day due to exhaustive nature of those varieties. As a consequence new nutrient deficiency in soil is emerging. Chronologically N, P, K, S, Zn and B deficiencies have arisen in Bangladesh soils (Islam, 2008). Some reasons of micronutrient deficiency in Bangladesh were highlighted by Jahiruddin and Islam (2014) and those are organic matter depletion, unbalanced use of fertilizers, minimum or no use of manure, high cropping intensity, high pH (e.g. calcareous soils), nutrient leaching and light textured soils (Jahiruddin and Islam, 2014). Rice bio-fortified with zinc (zinc rice) could help the critical gap by delivering up to 90% of their daily dietary requirements of zinc naturally (Bashar and Miah, 2016). Rice var. BRRI dhan84 composes of zinc which may scale up its potentially-competitive agronomic characteristics along with another non-fortified variety. Kader *et al*. (2020) also revealed that the zinc enriched BRRI dhan84 is a superb variety for cultivating in the dry (Boro) season and farmers

can be economically benefited. This experiment was conducted with the following objectives:

OBJECTIVES:

1. To find out the comparative performance of fortified rice var. BRRI dhan84 with BRRI dhan89
2. To determine the suitable fertilizer management of Boro rice
3. To identify the best combination of variety and fertilizer management in respect of growth and yield of Boro rice.

CHAPTER 2

REVIEW OF LITERATURE

Rice is the staple food crop for the people of Bangladesh. Many research works have been carried out extensively in many countries including Bangladesh and other countries for suitable fertilizer management and increase production of rice. Plant micronutrients play an important role on growth and yield of boro rice. Soil organic manure and inorganic fertilizer are the important factor for suitable soil fertility and crop productivity because organic matter is the store house of plant nutrients. Some literature related to the effect of fertilizer management on Boro rice are reviewed below-

2.1 Effect of variety

Latif *et al*. (2020) noticed that the maximum number of effective tillers hill^{-1} (17.64) was given by BRRI dhan29 whereas the lowest values of respective effective tillers were obtained from BR14. The number of effective tillers hill^{-1} reduction in BR14 was caused for tiller mortality in the vegetative stages. The probable reasons of these results might be due to the influence of variety. The experiment also indicated that among the varieties, BRRI dhan29 produced the highest number (111.0) of grain panicle^{-1} and the lowest one (93.0) was found in BR14. Due to the variety the number of grains panicle^{-1} differ significantly.

Rahman *et al*. (2020) found that among the varieties the highest 1000-grain weight (26.65 g) was obtained from BRRI hybrid dhan3 and the lowest (21.43 g) was obtained from BRRI dhan28 rice variety.

Afroz *et al*. (2019) revealed that the highest number (81.90) of grain panicle^{-1}, the highest grain yield (4.56 t ha^{-1}) and the lowest number (17.43) of sterile spikelet panicle^{-1} were recorded in BRRI dhan29. On the other hand, the lowest number (76.82) of grains panicle^{-1} was observed in BRRI dhan28 variety. This might be due to producing highest number of total effective tillers hill^{-1}, highest

number of grains panicle^{-1}, lowest number of sterile spikelet panicle^{-1} and maximum 1000-grain weight of the variety BRRI dhan29. The lowest grain yield (3.89 t ha^{-1}) was obtained from BRRI dhan28 due to the lowest number of effective tillers hill^{-1}, highest number of sterile spikelet panicle^{-1} and the lightest 1000-grain weight.

Chowhan *et al*. (2019) reported that Variety Shakti-2 (V_4) gave the highest biological yield (18.14 t ha^{-1}) and the lowest from BRRI dhan28 (V_1) (12.21 t ha^{-1}) and Binadhan-14 (V_2) (12.15 t ha^{-1}). It was noticed that, varieties which had higher grain and straw yield ultimately provided the highest biological yield. From their experiments, they noticed that Varieties Shakti-2 (V_4), Heera-1 (V_3) and BRRI dhan28 (V_1) had an identical harvest index of 50.9%, 48.5%, 47.9% respectively. 40.4% harvest index provided by Binadhan-14. It reveals that hybrid rice obtained higher harvest index.

The field experiment was conducted by Akter *et al*. (2018) to study the yield and yield contributing characters except number of sterile panicle^{-1}were significantly affected by the variety. The performance of BRRI dhan74 was better compared to BRRI dhan29 in terms of all parameters. BBRI dhan74 gave the taller plant (89.00 cm) than BBRI dhan29 (81.10 cm). The varietal dissimilarity might be due to heredity or varietal character. He also revealed that the higher number of tiller hill^{-1} (10.12) was obtained from BRRI dhan74 than (9.70) the number of tillers hill^{-1} reported by BRRI dhan29.

Murshida *et al*. (2017) conducted an field experiment with three varieties (var. BRRI dhan28, BRRI dhan29 and Binadhan-14) with four water management systems were studied to determine the impact of variety and water management system on the growth, development and yield execution of boro rice. At 100 DAT, the most desired plant height, highest number of tillers per hill, dry matter of shoot per hill and dry matter of root per hill were found from BRRI dhan29 and the lower qualities were observed in Binadhan-14. Variety had

noticeable influence on all the crop attributes under experiment with desire of 1000-grain weight. The maximum grain yield obtained from BRRI dhan29 and the minimum grain yield was obtained from Binadhan-14.

Ullah *et al*. (2016) revealed that among the varieties the highest dry matter was obtained from Heera (41.5 g/hill) where lowest from BRRI dhan29 (37.0 g/hill) at 105 DAT respectively. They presented among the cultivars the highest number of filled grain was for the Heera (98.8 /panicle) where the lowest for BRRI dhan58 (82.1/panicle) cultivar and the lowest number of unfilled grain obtained from BRRI dhan29 (7.7/panicle) while the highest obtained from BRRI dhan58 (13.7/panicle) variety.

Hossain *et al*. (2016) reported that dissimilar variety of rice and nutrient levels along with their interaction have significant effect on growth and yield of rice. It was noticed that panicle length of the crop influenced by variety. Binadhan-10 produced taller panicle (24.60 cm) compare to BRRI dhan28 (20.97 cm). They also revealed that due to dissimilarity in variety, the grain yield of rice varied significantly. The maximum grain yield (6.38 t ha^{-1}) gave by the variety Binadhan-10 whereas BRRI dhan28 gave 4.69 t ha^{-1}.

Chamely *et al*. (2015) noticed that plant height is a varietal character and it is the heredity constituent of the variety, therefore plant height was not similar among the varieties. They also reported that among dissimilar cultivars, BRRI dhan29 produced the highest number of tillers $hill^{-1}$ and the highest number of effective tillers $hill^{-1}$ (11.07) was recorded in the variety BRRI dhan29 and the lowest one was observed in BRRI dhan45. The reasons for dissimilarities among the varieties might be for their varietal characters. In this study among the varieties the higher dry matter (66.41 g m^{-2}) was obtained in BRRI dhan45 and the lower dry matter (61.24 g) was obtained in BRRI dhan29.

Rahman and Bulbul (2014) observed statistically significant effect on varieties was observed in plant height of boro rice and all the yield and yield

contributing characters were significantly influenced by the variety. The highest plant height (107.00 cm) was obtained in BRRI hybrid2 and the highest tiller number hill^{-1} (10.96) were found in BRRI hybrid2 and the lowest plant height (101.95 cm) sand the lowest number of tiller hill^{-1} (10. 63) were obtained from BRRI dhan29. The difference among the cultivars due to the varietal characters. Tyeb *et al*. (2013) founded that the variation in plant height due to its characters.

Alam *et al*. (2009) revealed the difference in total dry matter accumulation in different varietal characters. Kamal *et al*. (2007) obtained that there was significant dissimilarity on non-effective tillers among cultivars. Among different cultivars BRRI dhan28 had the minimum number of effective tillers hill^{-1} (6.44) and the lowest number of grains panicle^{-1} (134.89) hence the maximum number of non-effective tillers hill^{-1} (6.67) which was contributed to the worst performance of the variety. They found the maximum harvest index (45.35%) was obtained from BRRI dhan28 and the minimum one (41.18%) obtained from Binadhan-5.

Diaz *et al*. (2000) also revealed that panicle length varied among varieties. Shamsuddin *et al.* (1998) also revealed that a variable plant height existed among the varieties. Singh and Gangwar (1989) revealed that variable numbers of grain panicle^{-1} were found among the cultivars. Varietal differences regarding the number of grains panicle^{-1} might due to dissimilarities in their varietal characteristics.

2.2 Effect of chemical fertilizer on growth and yield of rice

The experiment was conducted by Wu-YuQiu *et al*. (2013) in Liaoning on Fuyou 33, a new rice variety derived from the cross Yanfeng 47xH1024 with 5 treatments [N application 135 (E_1), 187.5 (E_2), 240 (E_3), 242.5 (E_4) and 345 kg ha^{-1} (E_5)] replicated 3 times. To revealed the effect of nitrogen application on growth and yield of Fuyou 33. It was obtained that increasing nitrogen amounts

could enhance harvested panicles, leaf area index in the full heading stage, photosynthetic rates of flag leaf and dry weight accumulation in the maturity stage, but had a negative impact on productive panicle rates, high- efficiency leaf area rates and effective leaf rates in the full heading stages, accumulation in the rates of dry matter in the grain yield after heading and harvest index. The maximum rates were obtained from E_3 at 9.22 t ha^{-1}.

A series of experiments were conducted in 2001-2002, 2002-2003, 2003-2004 by Islam *et al*. (2008) to study the response and optimum rate of nutrients (NPK) for Chili- Fallow- T. Aman cropping pattern. They obtained that grain yield increased significantly due to application of different rates of nutrients and 60-19-36 kg ha^{-1} NPK increased the yield of T. Aman rice varieties in respect of yield and economics.

Ndaeyo *et al*. (2008) conducted a field experiment in Nigeria with 5 rice varieties (WAB340-8-82HI, WAB881-10-37-18-8-2-HI, WAB99-1-1, WAB224 -8-HB, WAB189-B-B-B-8-HB) and 4 rates of NPK (15:15:15) fertilizer (0, 200, 400, 600 kg ha^{-1}). The results revealed that 600 kg/ha NPK (15:15:15) fertilizer rate significantly ($P< 0.05$) enhanced plant height, number of leaves tiller $plant^{-1}$ in both years. This 400 kg /ha rate maximized the number of panicle per plant , length of central panicle per plant and the overall grain yield , straw yield over the other rates by 4-32% and 2-21% in 2005 and 2006 respectively.

Rahman *et al*. (2007) conducted a field experiment using rice cultivar BRRI dhan29 as a test crop and noticed that application of S had a significant positive effect on tiller/ha, plant height , panicle length and grain $panicle^{-1}$. They also revealed that application of S fertilizer at a recommended rate (20 kg S ha^{-1}) might be essential for obtaining maximum grain yield as well as straw yield of boro rice (var. BRRI dhan29).

Saleque *et al*. (2005) obtained a linear relation between P uptake and total system productivity which gives the idea that TSP depends to some level on P availability. Phosphorus application maximized rice yield in different seasons where the maximum response in P was in Aus and Boro than T. Aman.

A field experiment was conducted by Saha *et al*. (2004) in 2002-2003 to compare a suitable fertilizer recommendation model for lowland rice. Five different fertilizer recommendation models were tested and compared with one appropriate check plot. Results revealed that the application of different models were estimated by different fertilizer packages significantly enhanced panicle length, spikelet number per panicle, panicle numbers, grain per panicle, number of filled grain and unfilled grain per panicle . The combination of NPK revealed the maximum results (120-13-70-20 kg ha^{-1} NPKS).

Amin *et al*. (2004) conducted an experiment to estimate the effect of maximum plant density and fertilizer dose on yield of rice variety IR-6. They noticed that increased fertilizer dose of NPK maximized plant height.

Rasheed *et al*. (2003) conducted that the effect of different NP levels (0-0, 25-0, 50-25, 75-50, 100-75, 125-100 kg ha^{-1}) on yield and yield contributing characters of rice Bas-385. The yield contributing characters (number of effective tillers per hill, spikelets per panicle, grain per panicle, 1000-grain weight) were developed linearly with increasing NP levels up to 100 to 75 kg ha^{-1}. The level of NP 100-75 kg ha^{-1} obtained in the highest grain yield of 4.53 t ha^{-1} with lowest grain abnormalities (sterility, abortive grain) as against the lowest of 2.356 t ha^{-1} in the control (0-0) followed by 25-0 kg NP ha^{-1} with highest grain abnormalities.

Singh *et al*. (2003) noticed that crop growth rate and relative growth rate such as total dry matter production was enhanced by NPK fertilizers. The number of tiller and total dry matter production are closely correlated with yield

depending on the rice variety which can be greatly influenced by applying proper nutrient.

Pheav *et al*. (2003) reported that freshly applied P maximized rice grain yield by 95%. In the first and second crops using P fertilizer, yield increased by 62 and 33% relatively to the P-control plot. Cumulative removal of P in four successive rice crops estimated for 30 and 55% of the 16.5 kg/ha in the form of harvested grain and plants.

An experiment was conducted by Haq *et al*. (2002) with twelve treatments combinations of N, K, P, S, Zn and Diazinon. They noticed that all the treatments significantly maximized the grain and straw yield of BRRI dhan30 rice over no fertilizer (control), 90 kg N + 50 kg P_2O_5 + 40 kg K_2O + 10 kg S + 4 kg Zn ha^{-1} + Diazinon produce the highest grain and straw yields.

2.3 Combined effect of chemical fertilizer and cowdung on the growth and yield of rice

Rahman *et al*. (2009) conducted field experiment to determine the effect of urea N in combination with poultry manure and cowdung in rice and noticed application of manures and different doses of urea N fertilizer significantly maximized the yield and yield components and grain and straw yields.

Saleque *et al*. (2004) conducted an experiment to study the effect of different doses of inorganic fertilizers alone or in combination with cowdung and rice husk ash on the yield of low land rice-rice cropping pattern. Cowdung and ash were applied on dry season rice rice only and revealed the application of cowdung and ash maximized rice yield by about 1 t/ha per year over that obtained with inorganic fertilizer alone the treatments which revealed positive yield trend also showed positive P uptake and positive yield components were attributed to the maximized P supplying power of the soil. They also noticed that the application of one third of recommended chemical fertilizers with 5 t

cowdung maximized the low land rice yield than other treatments and produce yield 8.87 t ha^{-1}.

Tripathy *et al*. (2004) noticed significantly higher seed yield under the residual effects of the blended cowdung and NPK fertilizer compared with the control (No fertilizer).

Dao and Cavegelli (2003) conducted that animal manure had long been utilized as an organic source of plant nutrients and organic matter to develop the physical and fertility of soils.

Saitoh *et al*. (2001) determined the effect of organic fertilizer (cowdung and poultry manure) and pesticides on the growth and yield of rice and reported that yield treated with organic manure and pesticide free plots were 10% minimal than that of inorganic fertilizer and pesticide treated plot due to decreasing the number of panicle. Annually application of manure enhanced the carbon and nitrogen percentage of agricultural lands.

Mannan *et al*. (2000) found that manuring with cowdung improved grain and straw yields up to 10 t ha^{-1} in the addition to recommended doses of inorganic fertilizers with late application of N and also improved the quality of transplant aman rice over inorganic fertilizer.

2.4 Effect of micronutrients on rice

Singh *et al*. (2020) conducted an experiment to study the effect of zinc and silicon on growth and yield of aromatic rice which consisted of nine treatment combination viz. (T_1 – Control, T_2 –RFD 120:80:40, T_3 – RFD 120:60:40 + Two Zinc spray @ 0.5% , T_4 – RFD 120:60;40 + Two Silicon spray @ 0.2% , T_5 – RFD 120:60:40 + Two Silicon spray @ 0.3%, T_6 -NPK 150:80:40, T_7 – NPK 150:80:40 + Two Zinc spray @ 0.5%, T_8 – NPK 150:80:40 + Two Silicon spray @0.2%, T_9 – NPK 150 : 80 :40 + Two Silicon spray @0.3%) were tested.

Rice cultivar *Navya* (IMR 002) was taken as test crop. The result showed that application of Zn and Si significantly enhanced the growth and yield of aromatic rice. Plant height , dry weight, numbers of grain per panicles , number of tillers, LAI, 1000-grain weight were estimated the highest with the application of 120:80:40 kg/ha NPK + two Zn spray @0.5% at 30 and 50 DAT. Grain yield and straw yield along with biological yield also had the positive effect with the application of zinc and silicon and the highest grain yield was obtained from the application of 150:80:40 NPK+ two Zn spray @0.5% (65.88 q/ha) which was statistically similar to the treatment of NPK 150:80:40 + two Si spray @0.3% (63.46 q/ha). And the lowest was observed in T_1 (control) (30.12 q/ha). Harvest index was revealed as non significant.

Reddy *et al*. (2020) showed that the highest tillers and effective tillers were given by treatments T_9 (RDF + 20 kg Zn ha^{-1} + 1 kg B ha^{-1}) (10.07) was significantly highest among all treatments and statistically similar with T_5 (RDF + 10 kg Zn ha^{-1} + 0.5 kg B ha^{-1}), T_6 (RFD + 10 kg Zn ha^{-1} + 1 kg B ha^{-1}), T_7 (RFD + 20 kg Zn ha^{-1} + 0 kg B ha^{-1}), T_8 (RFD+20 kg Zn ha^{-1} +0.5 kg B ha^{-1}) and the lowest tiller obtained from T_1 (control). They also revealed that the highest dry matter (93.60 kg) obtained from T_9 (RDF + 20 kg Zn ha^{-1} + 1 kg B ha^{-1}) which was statistically similar with T_6 (RFD+10 kg Zn ha^{-1} + 1 kg B ha^{-1}), T_8 (RFD + 20 kg Zn ha^{-1} + 0.5 kg B ha^{-1}) and the lowest tiller obtained from T_1. This might be happened due to the application of zinc along with RFD of NPK influenced the yield attributes.

Moradi and Jahanban (2018) conducted a field experiment to study the Zinc (Zn) application effect (0, 10, 20 mg Zn kg^{-1} soil as foliar application) on growth and nutrients uptake under salinity stress (3, 7, 10 dS m^{-1}) in two varieties (Tarom and Daylamani) was tested in the experiments. The results revealed that Zn application under salinity stress promoted shoot and grain yield. The minimum and maximum protein percent in every salinity and Zn levels belonged to those tested varieties respectively. The results revealed that

the more Zn applied, the more Zn accumulated in the shoots and grain. Normally based on the results Daylamani variety showed more endurance to salinity as Zn application in low salinity levels than Tarom variety.

Kumar *et al*. (2017) conducted an experiment to study the effect of graded levels of zinc and boron on growth and yield of rice on Alfisols at Naganahalli village, Karnataka. The results revealed that the external application of zinc as $ZnSO_4$ @ 20 kg ha^{-1} and boron as borax @ 4 kg ha^{-1} had influenced on growth and yield of rice. The highest number of grain per panicle (130.05) and 1000-grain weight (26.96 g) were obtained from T_{12} (RFD + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}) than other treatments.

Hafiz (2017) conducted to study the influence of foliar boron application on improvement of yield of hybrid rice. Two factors used in this experiment with three rice varieties – V_1 (ACI hybrid 1), V_2 (ACI Sera), V_3 (BRRI hybrid dhan1) with 5 levels Boron applications B_0 (control), B_1 (1.2% B), B_2 (1.5% B), B_3 (1.8% B), B_4 (2.1% B). The results revealed that different variety and application of boron influenced on growth and yield and yield contributing characters. Even the interaction effect on variety and boron application also obtained the significant effect on different growth and yield parameters.

Mahmud (2017) conducted a field experiment to study the response of Zn, B, Cu on yield and quality of boro rice. In the experiment BRRI dhan28 was the tested crop. The experiment was conducted of one factor with 5 different combination of fertilizers *viz.*, i. T_1 = N (55) + P (35) + K (65) + S (18) + Zn (5) + B (4) + Cu (4), ii. T_2 = N (55) + P (35) + K (65) + S (18) + B (4) + Cu (4), iii. T_3 = N (55) + P (35) + K (65) + S (18) + Zn (5) + Cu (4), iv. T_4 = N (55) + P (35) + K (65) + S (18) + Zn (5) +B (4) and v. T_5 = N (55) + P (35) + K (65) + S (18) (control). The Zn, B, Cu along with NPK had significant influenced on growth, yield and yield components. The highest 1000-grain weight (23.82 g) obtained from T_1 and the lowest (20.31 g) was given by T_5.

17.28% more 1000-grain weight gave by T_1 over T_5. The highest grain yield (4.19 t ha^{-1}) was given by T_1 and the lowest grain yield was obtained from T_5. Considered above the findings T_1 fertilizer package could be the best fertilizer management for BRRI dhan28 in boro season.

Podder (2017) conducted in a field experiment to study the response of foliar spray of Zn, B on boro rice (BRRI dhan29). Treatments are- T_1 = Recommended dose of fertilizer (RDF), T_2 = RFD + Foliar spray (FS) with water at Tiller Initiation (TI), T_3 = RFD + FS with water at Flowering Initiation (FI), T_4 = Zn (0.2%) FS at TI + RFD, T_5 = Zn (0.5%) FS at TI + RFD, T_6 = Zn (0.8%) FS at TI +RFD, T_7 = Zn (0.2%) FS at FI +RFD, T_8 = Zn (0.5%) FS at FI + RFD, T_9 = Zn (0.8%) + FS at FI+RFD, T_{10} = B (0.5%) FS at TI + RFD, T_{11} = B (1.5%) FS at TI + RFD, T_{12} = B (0.2%) FS at TI + RFD, T_{13} = B (0.5%) FS at FI + RFD, T_{14} = B (1.5%) FS at FI + RFD, T_{15} = B (2.0%) FS at FI + RFD. The results showed that the highest plant (12.39, 31.12, 44.38, 59.47, 103.34 cm) was obtained T_{11} at 15, 30, 45, 60 and at harvest respectively. While the lowest plant height obtained from T_1 (13.18, 24.40, 33.53, 44.94, 78.59 cm) at 15, 30, 45, 60 and at harvest. The highest LAI (0.78, 0.85, 1.32, 3.00, 3.39 cm^2) and the highest effective tiller/hill (15.13), panicle length (27.86 cm) were obtained from T_{11}. The lowest LAI (0.74, 0.79, 1.10, 2.24, 2.58 cm^2), the lowest effective tillers /hill were obtained from $T_{1.}$ The higher grain yield, straw yield, biological yield and harvest index (7.10 t ha^{-1}, 7.61 t ha^{-1}, 14.71 t ha^{-1}, 48.26%) were obtained from T_{11} and the lowest obtained from T_1. Among all data T_{11} was the best combination than all other treatments.

Rahman *et al*. (2016) carried out an experiment to determine the effect of foliar application of Boron (B) on grain and yield of wheat (var. Shatabdi). The different levels of boron treatments were i. Control, ii. Soil application of B, iii. Seed priming into boric acid solution, iv. Foliar spray of boron at primordial stage of crop, v. foliar application of boron at booting stage, *viz*. Foliar application of boron at booting and primordial stage. The treatment foliar spray

of boron at booting and primordial stage gave the highest yield (3.63 t ha^{-1}) which was statistically similar with foliar application at booting or primordial stage and it was higher among all the treatments.

An experiment was conducted by Ali *et al.* (2016) to study the effect of foliar spray of B on yield and yield attributes of rice in calcareous soil. Six B foliar application rates (0, 5, 10, 15, 20, 25 mg L^{-1}). The results had significant effect of boron foliar application on the number of grain per panicle, number of filled grain per panicle, grain yield. The maximum grain yield (352 g m^{-2}) was found in 20 mg L^{-1} foliar application. But application of foliar spray with 25 mg L^{-1} reduced the grain yield (313 g m^{-2}). Reduction in the quantity and quality of rice was notable with the increasing B application which might have the toxic effect.

Shafiq and Maqsood (2010) conducted an experiment to determine the response of rice crop to model based B fertilizer. Boron was applied at transplanting time of rice as basal dose. The findings revealed that grains per panicle, 1000-grain weight, grain yield responded positive to boron fertilizer but at vegetative stage the effect of boron on rice plant was nit significantly positive. Concentration of B in both rice and straw increased with boron application but there was no effect of boron on NPK on grain and straw.

Islam (2015) noted that boron, zinc and their interaction had significant effect on unfilled grain of rice production. Among the different treatments the data showed the highest number of unfilled grain per panicle was obtained from control where the lowest number of unfilled grain per panicle was received by combination of boron and zinc application.

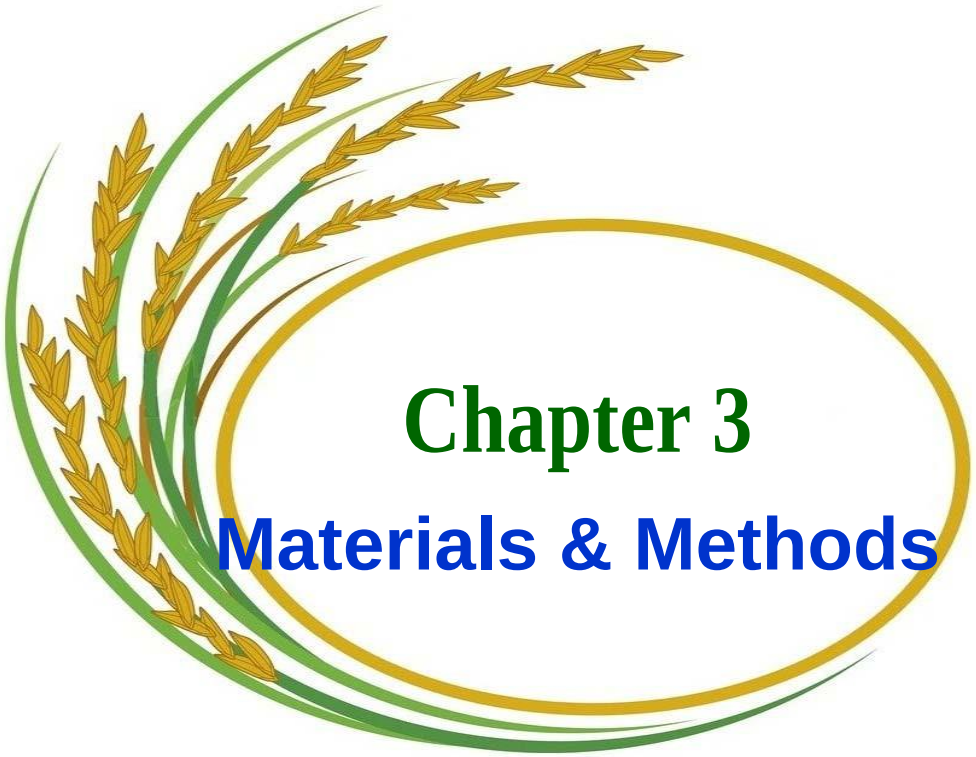
Hussain *et al.* (2012) conducted that the improvement in harvest index noted from boron treatment might be due to better starch utilization that obtain in higher seed setting to develop grains which increase the size of grain and

number of grains per panicle.

Arif *et al.* (2012) recorded that the panicle length increased significantly and varied from 24 to 30.40 cm as a results of Zn, B and MT (Microtone) treatment. The plant treated with Zn + B at 3 + 1.5 kg/acre showed maximum response in panicle length of 30.40 cm as compared to the control (21.83 cm) followed by Zn + B at 6 + 3 kg/acre (29.70 cm) and B 11.33% at 1.5 kg/acre (29.67 cm).

Dunn *et al. (*2005) revealed that soil sampling and testing for boron was not common practice for the farmers for producing rice in the south eastern US and the field research was showed that rice yield were the maximum when boron of soil was 0.25 to 0.35 ppm by the hot water extraction practice. In 2000, rice was given the basal or soil application produce significantly highest yield than foliar spray application of boron. In 1999 and 2001 there was no significances difference between the yield received from foliar or soil applied.

Islam *et al.* (1997) conducted a field experiment that autumn rice responded significantly positive to S, Zn, B application. The maximum grain yield (4.5 t ha^{-1}) obtained in S + Zn + B application increase 41.80% yield over control while S, Zn, B single application gave 23.3, 21.7, 14.6% increased yield respectively.



Chapter 3

Materials & Methods

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the Boro season of December 2020 to June, 2021 to study the performance of fortified rice var. BRRI dhan84 with BRRI dhan89 and to determine the suitable fertilizer management. The materials used and methodology followed in the investigation have been presented details in this chapter.

Description of the experimental site

3.1.1 Geographical location

The experimental area was situated at $23^0$77'N latitude and $90^0$33'E longitude at an altitude of 9 meter above the sea level.

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain. The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3 Soil

The soil of the experimental site belongs to the general soil type, shallow red brown terrace soils under Tejgaon Series. Top soils were silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 6.2 and organic matter 1.14%.

3.1.4 **Climate**

The area has subtropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif

season (April-September) and minimal rainfall associated with moderately low temperature during the Rabi season (October-March).

3.1.5 Experimental treatments

There were two sets of factors included in the experiment; the first set comprised of two varieties and the second set consisted of seven treatments of fertilizer managements. Two sets of treatments were as follows:

A. Main plot (variety): 2

1. BRRI dhan84 (V_1)
2. BRRI dhan89 (V_2)

B. Sub-plot (fertilizer management): 7

1. Control (No fertilizer) (F_1)
2. Recommended Fertilizer Dose of NPKS (RFD) with Zn & B as basal (F_2)
3. RFD with Zn as foliar spray at anthesis (F_3)
4. RFD with Zn & B as foliar spray at anthesis (F_4)
5. 50% RFD+ 50% Organic manure (Cowdung) (F_5)
6. 50% RFD+ 50% Organic manure+Zn & B as foliar spray at anthesis (F_6)
7. 50% RFD+ 50% Organic manure + Zn & B as basal (F_7)

3.1.6 Experimental design and layout

The experiment was laid out into Split-plot design with three replications having variety viz., i) BRRI dhan84 (V_1) and ii) BRRI dhan89 (V_2) in the main plot and fertilizer management in the sub-plot. Each replication had fourteen unit plots to which the treatment combinations were assigned as per design. The total numbers of unit plots were forty two. The size of unit plot was 4.8m^2 (3 m x 1.6 m). The distance between replication to replication and plot to plot was 0.60 cm respectively. The layout of the experiment has been shown in Appendix II.

3.2 Growing of crop

3.2.1 Planting material

BRRI dhan84 and BRRI dhan89, the high yielding variety of boro rice were used as a test crop. BRRI dhan84 was developed by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The pedigree line (BR7831-59-1-1-4-5-1-9-P1) of the BRRI dhan84 was derived from a crops BRRI dhan29/IR68144//BRRI dhan28///BR11. BRRI released this variety in 2017 for cultivation in Boro season. The characterize of BRRI dhan84 variety is 96 cm in height, life cycle lasts for 140-145 days, average yield 6-6.5 t ha^{-1} and healthy thousand grains weight 22.8 gram.

Similarly, BRRI dhan89 was developed by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The pedigree line (BR9786-BC2-59-1-2) of the variety was derived from a cross BRRI dhan29/IRGC103404). BRRI released the variety in 2018 for cultivation in Boro season. The characterize of this rice variety is 106 cm in height, life cycle lasts for 154-158 days, average yield 8t ha^{-1} and healthy thousand grains weight 24.4 gram.

3.2.2 Seed collection and seed sprouting

Seeds of the BRRI dhan84 and BRRI dhan89 were collected from Bangladesh Rice Research Institute (BRRI), Gazipur. Healthy seeds were selected following standard method. Seeds were immersed in a bucket for 24 hours. Then these were taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

3.2.3 Raising of seedlings

Seedlings were raised in seedbed. The nursery bed prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation provided to the bed when needed. No fertilizer was applied to the nursery bed.

3.2.4 Preparation of nursery bed and seeds sowing

As per BRRI recommendation seedbed was prepared with 1.25 m wide adding nutrient as per the requirements of soil. Seeds were sown in the seed bed on December 3, 2020 in order to transplant the seedling in the main field.

Preparation of experimental land

The plot selected for the experiment was opened in the last week of December, 2020 with a power tiller, and was exposed to the sun for a week, later the land was irrigated and prepared by harrow, plough and cross-plough several times followed by laddering to obtain a good puddled field. Weeds and stubble were removed from the field. After the final land preparation the field layout was made on January 03, 2021 according to experimental plan. Individual plots were cleaned and finally leveled with the help of wooden plank so that water pocket would remain in the field.

3.2.5 Fertilizers and manure application

The recommended fertilizer used for the experiment was 260 kg ha^{-1}, 100 kg ha^{-1}, 120 kg ha^{-1}, 105 kg ha^{-1}, 10 kg ha^{-1}, 6 kg ha^{-1} and 10 t ha^{-1} N, P_2O_5, K_2O, S, Zn, B and organic matter in the form of Urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP), Gypsum, Zinc sulphate, Boric acid and Cowdung respectively as per treatment. The entire amount of TSP, MoP, Gypsum, Zinc sulphate and Boric acid, Cowdung were applied during the final preparation of land. Urea was applied as per treatment following the standard procedure. At anthesis zinc and boron was applied as foliar spray as per treatment.

3.2.6 Seedling transplanting

Land was prepared for transplanting of seedlings. Thirty days old seedlings were transplanted in the line following the spacing of 20 cm × 20 cm having two seedlings $hill^{-1}$ in the lines. The seedlings were transplanted on January 04, 2021.

3.3 Intercultural operations

3.3.1 Top dressing

The urea fertilizer was top-dressed in 3 equal installments in selected plots as per treatment.

3.3.2 Gap filling

First gap filling was done on January 19, 2021 and second gap filling was done one week after first gap filling on January 26, 2021.

3.3.3 Weeding

During plant growth period two hand weeding were done, first weeding was done at 15 DAT (days after transplanting) followed by second weeding at 21 DAT.

3.3.4 Application of irrigation water

Irrigation water was added to each plot, first irrigation was done as pre-sowing and other two irrigations were given 2-3 days before weeding. Supplemented irrigation water was also added to each plot during reproductive and ripening phase as and when necessary.

3.3.5 Drainage

Drainage channels were properly prepared to easy and quick drained out of excess water.

3.3.6 Plant protection measures

Rice plans were infested by rice stem borer and leaf hopper which was successfully controlled by applying Aktara on 03 March, Furadan on 19 March and Ripcord on 7 April, 2021 by following recommended produces.

3.4 General observation of the experimental field

The experimental field was observed time to time to detect visual difference

among the treatment and any kind of infestation by weeds, infests and diseases so that the considerable losses by pest should be minimize. Attack of rice stem borer, green leaf hopper, leaf roller was observed and controlled properly. But no bacterial and fungal disease was observed.

3.5 Harvesting and post-harvest operation

Maturity of crop was determined when 90% of the grains become golden yellow in color. Growth, yield and other crop data were recorded from 5 randomly selected hills of each plot. Five mid lines from each plot was separately harvested, bundled, properly tagged and brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 12 %. Straw was also sun dried properly. Finally grain and straw yield were recorded and converted to ton ha^{-1}.

3.6 Recording of data

The following data were collected during the study period:

A. Crop growth characters

i. Plant height from 25 DAT to harvest at 25 days interval
ii. Number of tillers $hill^{-1}$ from 25 DAT to harvest at 25 days interval
iii. Leaf area index (LAI) at 50 and 75 DAT
iv. SPAD value at 50 and 75 DAT

B. Yield contributing characters

i. Number of effective tillers $hill^{-1}$
ii. Number of in-effective tillers $hill^{-1}$
iii. Number of rachis branches $panicle^{-1}$
iv. Length of panicle
v. Filled grains $panicle^{-1}$
vi. Unfilled grains $panicle^{-1}$
vii. Weight of 1000 grains

viii. Grain yield

ix. Straw yield

x. Biological yield

xi. Harvest index

3.7 Detailed procedures of recording data

3.7.1 Crop growth characters

3.7.1.1 Plant height

The height of plant was recorded in centimeter (cm) at 25, 50, 75 DAT (days after transplanting) and at harvest. Data were recorded and averaged from 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.

3.7.1.2 Number of tillers hill^{-1}

The number of tillers hill^{-1} was recorded at 25, 50, 75 DAT (days after transplanting) and at harvest by counting total tillers and averaged from 5 hills pre-selected at random from the inner rows of each plot. Tillers having at least leaves were considered for counting.

3.7.1.3 Number of leaves hill^{-1}

The number of leaves hill^{-1} was recorded at 25, 50, 75 DAT (days after transplanting) and at harvest by counting total number of leaves and averaged from 5 hills pre-selected at random from the inner rows of each plot.

3.7.1.4 Leaf area index (LAI)

Leaf area index were estimated at 25, 50, 75 DAT (days after transplanting) and at harvest manually by the total number of leaves plant^{-1} and measuring the length and average width of leaf and multiplying by a factor of 0.75 .

3.7.1.5 SPAD value

The SPAD value of three leaves from five plants of each plot were measured

with the help of a chlorophyll meter (SPAD 502 plus) and the mean values were determined.

Yield and other crop characters

3.7.2.1 Number of effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted from the number of panicle bearing tillers hill^{-1}. Data on effective tillers hill^{-1} were counted from 5 selected hills at harvest and average value was recorded.

3.7.2.2 Number of in-effective tillers hill^{-1}

The total number of in-effective tillers hill^{-1} was counted from the number of non-panicle bearing tillers hill^{-1}. Data on in-effective tillers hill^{-1} were counted from 5 selected hills at harvest and average value was recorded.

3.7.2.3 Number of rachis branches panicle^{-1}

The number of rachis branches panicle^{-1} was calculated by counting rachis branches from 10 randomly selected panicles and the average value was recorded.

3.7.2.4 Length of panicle

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

3.7.2.5 Filled grains panicle^{-1}

The total number of filled grains was collected from randomly selected 10 panicles of a plot and then average number of filled grains panicle^{-1} was recorded.

3.7.2.6 Unfilled grains panicle^{-1}

The total number of unfilled grains was collected from randomly selected 10 panicles of a plot and then average number of unfilled grains panicle^{-1} was recorded.

3.7.2.7 Weight of 1000 grains

One thousand grains were counted randomly from the total cleaned harvested and dried grains of each individual plot and then weighed in grams and recorded.

3.7.2.8 Grain yield

Grains obtained from the central 5 lines from each plot were harvested, threshed and weighed carefully. Then grains were sun-dried and weighed again. The fresh and dry weight of grains (14% moisture) converted to t ha^{-1} basis.

3.7.2.9 Straw yield

Straws obtained of the central 5 lines from each plot were harvested, threshed and weighed carefully. Then grains were sun-dried and weighted again. Finally the fresh and dry weight of straws converted to t ha^{-1} basis.

3.7.2.10 Biological yield

Grain yield and straw yield together were regarded as biological yield. The biological yield was calculated with the following formula:

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

3.7.2.11 Harvest index

Harvest index was calculated from the grain and straw yield of rice for each plot and expressed in percentage.

$$\text{HI (\%)} = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.8 Statistical Analysis

The data collected on different characters were statistically analyzed to obtain the level of significance using the CropStat computer package program. The mean different among the treatment were compared by least significance difference test at 5% level of significance.

Chapter 4

Results& Discussion

CHAPTER 4
RESULTS AND DISCUSSION

The experiment was conducted to study the comparison between BRRI dhan84 which is a fortified rice variety with BRRI dhan89 to determine the suitable fertilizer management of Boro rice. Data on different growth and yield contributing characters were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix III-XI. The results have been presented with the help of Tables and Graphs and possible interpretations given under the following headings:

4.1 Crop growth characters

4.1.1 Plant height

4.1.1.1 Effect of variety

The effect of variety on the plant heights of rice are presented in Appendix III and Table 1. The plant height was observed non-significant variation between the two varieties at 25, 50, 75 DAT and at harvest. Though the numerically maximum plant height was given by BRRI dhan84 at 25, 50, 75 DAT compared to BRRI dhan89. At harvest, BRRI dhan89 gave the higher plant height (97.60 cm). The results were similar with the findings of Chamely *et al.* (2015), Tyeb *et al.* (2013) who observed that plant height influenced by varietal character.

Table 1. Effect of variety on plant height at different DAT of boro rice

Treatments	Plant height (cm) at			
	25 DAT	50 DAT	75 DAT	Harvest
V_1	18.14	40.21	76.24	96.05
V_2	17.63	36.71	67.21	97.60
$LSD_{(0.05)}$	NS	NS	NS	NS
CV (%)	16.68	6.38	11.09	5.38

CV = Coefficient of variation, $LSD_{(0.05)}$ = Least significant difference at 5% level, DAT = days after transplanting , NS = Non significant, V_1 = BRRI dhan84, V_2 = BRRI dhan89

4.1.1.2 Effect of fertilizer management

Rice plants showed non-significant variation by fertilizer management at 25 and 75 DAT but at 50 DAT and at harvest had significant variation (Table 2). The result revealed that at 50 DAT, the highest plant height (42.21 cm) was obtained

from F_4 (RFD with Zn & B as foliar spray) and the lowest plant height (32.28 cm) was recorded at F_1 (control – no fertilizer). At harvest, the highest plant height (102.54 cm) was recorded from F_4 (RFD with Zn & B as foliar spray) and the lowest plant height (86.74 cm) was obtained from F_1 (control-no fertilizer). Singh *et al*. (2020) observed that application of zinc as foliar spray with NPK enhanced plant height.

Table 2. Effect of fertilizer management on plant height of boro rice at different DAT

Treatments	Plant height (cm) at			
	25 DAT	50 DAT	75 DAT	Harvest
F_1	16.49	32.28 e	69.71	86.74 d
F_2	18.34	41.58 ab	72.19	99.40 abc
F_3	17.50	40.05 abc	69.05	99.73 ab
F_4	17.74	42.21 a	67.72	102.54 a
F_5	18.92	37.83 cd	71.58	97.67 bc
F_6	17.97	36.33 d	74.83	94.44 c
F_7	18.23	38.94 bcd	77.00	97.25 bc
$LSD_{(0.05)}$	NS	2.849	NS	4.297
CV (%)	12.32	6.22	13.22	3.72

In this column, the means having the same letter (s) do not differ significantly. CV = Coefficient of variation, $LSD_{(0.05)}$ = Least significant difference at 5% level, DAT = days after transplanting , NS = Non significant

F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD)with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis, F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

4.1.1.3 Interaction between variety and fertilizer management

Interaction between variety and fertilizer management had no significant effect on plant height at 25 DAT but at 50, 75 DAT and at harvest had significant effect on plant height. At 25 DAT, all the interaction between variety and fertilizer managements were statistically similar with no significant effect on plant height. At 50 DAT, the highest plant height (43.25 cm) obtained from V_1F_4 (BRRI dhan84 with RFD with Zn & B as foliar spray) and the lowest plant height (30.89 cm) was obtained from V_2F_1 (BRRI dhan89 with no fertilizer). At 75 DAT, the highest plant height (77.99 cm) was obtained from V_1F_1 (BRRI dhan84 with control) and the lowest plant height (61.44 cm) obtained from V_2F_1

(BRRI dhan89 with control). At harvest, the highest plant height (103.05 cm) was found in V_2F_4 (BRRI dhan89 and RFD with Zn & B as foliar spray) and the lowest plant height (84.19 cm) was found in V_1F_1 (BRRI dhan84 with control situation).

Table 3. Interaction effect of variety and fertilizer managements on plant height of Boro rice at different DAT

Treatments	Plant height (cm) at			
	25 DAT	50 DAT	75 DAT	Harvest
V_1F_1	17.18	33.67 de	77.99 a	84.19 e
V_1F_2	18.68	42.60 a	75.19 ab	100.14 ab
V_1F_3	18.81	42.90 a	74.50 ab	97.77 abc
V_1F_4	18.09	43.25 a	73.89 ab	102.02 ab
V_1F_5	18.77	39.68 abc	75.61 abc	98.23 abc
V_1F_6	17.26	37.53 bcd	77.15 ab	92.81 cd
V_1F_7	18.19	41.85 a	70.33 ab	97.20 abc
V_2F_1	15.81	30.89 e	61.44 b	89.29 de
V_2F_2	18.00	40.57 ab	69.19 ab	98.65 abc
V_2F_3	16.18	37.19 bcd	63.59 ab	101.70 ab
V_2F_4	17.38	41.17 ab	61.54 b	103.05 a
V_2F_5	19.07	35.99 cd	67.55 ab	97.11 abc
V_2F_6	18.68	35.13 d	72.51 ab	96.08 bc
V_2F_7	18.27	36.04 cd	74.66 ab	97.29 abc
$LSD_{(0.05)}$	NS	4.029	15.977	6.077
CV (%)	12.32	6.22	13.22	3.72

In this column, the means having the same letter (s) do not differ significantly. CV = Coefficient of variation, $LSD_{(0.05)}$ = Least significant difference at 5% level, DAT = days after transplanting, NS = Non significant

V_1 = BRRI dhan84, V_2 = BRRI dhan89, F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD) with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis, F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

4.1.2 Number of tillers hill^{-1}

4.1.2.1 Effect of variety

The effect of variety on the number of tillers hill^{-1} of rice presented in Table 4 (Appendix IV). The experimental results revealed that the number of tiller hill^{-1} noted as non significant variation between the two tested varieties at 25, 50, 75 DAT and at harvest. Though the maximum number of tillers hill^{-1} (2.71, 9.95,

12.52 and 13.67) was obtained from BRRI dhan84 at 25, 50, 75 DAT and at harvest respectively. And the lowest number of tillers hill^{-1} (2.29, 8.67, 12.38 and 11.10) was obtained from BRRI dhan89. The result achieved from the present study was similar with the findings of Murshida *et al*. (2017), Chamely *et al*. (2015), Paul *et al*. (2014).

Table 4. Effect of variety on number of tillers hill^{-1} at different DAT of boro rice

Treatments	Number of tillers hill^{-1} at			
	25 DAT	50 DAT	75 DAT	Harvest
V_1	2.71	9.95	12.52	13.67
V_2	2.29	8.67	12.38	11.10
$LSD_{(0.05)}$	NS	NS	NS	NS
CV (%)	10.69	18.83	5.68	18.44

In this column, the means having the same letter (s) do not differ significantly. CV=Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAT=days after transplanting , NS = Non significant

V_1= BRRI dhan84, V_2= BRRI dhan89

4.1.2.2 Effect of fertilizer management

Fertilizer management had significant effect on number of tillers at 25, 50 DAT and at harvest and non-significant effect at 75 DAT (Table 5). At 25 DAT, the maximum tiller numbers hill^{-1} (2.83) was obtained from F_2 (Recommended dose of fertilizer (RFD) with Zn & B basal application) while the minimum tiller numbers hill^{-1} (2.00) was obtained from F_7 (50% RFD + 50% Organic manure + Zn & B as basal) treatment. At 50 DAT, the maximum tiller numbers hill^{-1} (11.00) was obtained from F_2 (Recommended Dose of Fertilizer (RFD) with Zn & B basal application) while the minimum tiller numbers hill^{-1} at 50 DAT was (6.83) obtained from F_1 (control-no fertilizer). At 75 DAT, the maximum tiller numbers hill^{-1} (13.17) was obtained from F_4 (RFD with Zn & B as foliar spray at anthesis) treatment while the minimum tiller numbers at 75 DAT (11.33) was obtained from F_1 (control). At harvest, the maximum tiller numbers hill^{-1} (14.00) was obtained from F_2 (Recommended dose of fertilizer (RFD) with Zn & B basal application) while the minimum tiller numbers hill^{-1} (9.50) at harvesting

was obtained from control. The results were similar with the findings of Reddy *et al.* (2020) who observed that number of tiller hill^{-1} increased by maintaining the recommended dose of fertilizer with application of zinc.

Table 5. Effect of fertilizer management on number of tiller hill^{-1} at different DAT of boro rice

Treatments	Number of tiller hill^{-1} at			
	25 DAT	50 DAT	75 DAT	Harvest
F_1	2.50 abc	6.83 d	11.33	9.50 d
F_2	2.83 a	11.00 a	12.67	14.00 a
F_3	2.17 bc	10.00 ab	13.00	13.50 ab
F_4	2.67 ab	11.00 a	13.17	13.83 a
F_5	2.67 ab	8.83 b	11.83	12.83 abc
F_6	2.67 ab	8.33 c	12.67	11.67 bc
F_7	2.00 c	9.17 b	12.50	11.33 cd
$LSD_{(0.05)}$	0.536	1.368	NS	2.02
CV (%)	17.99	12.33	10.85	13.69

In this column, the means having the same letter (s) do not differ significantly. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT= days after transplanting, NS= Non significant

F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD)with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis, F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal.

4.1.2.3 Interaction effect of variety and fertilizer management

Interaction between variety and fertilizer managements had significant effect on tillers number observed at 25, 50, 75 DAT and at harvest (Appendix IV and Table 6). At 25 DAT, the maximum tiller number (3.00) was observed in V_1F_1 (BRRI dhan84 by control), V_1F_2 (BRRI dhan84 with RFD with Zn & B as basal), V_1F_5 (BRRI dhan84 with 50% RFD + 50% organic manure as cowdung) and the minimum tiller number was (1.67) observed in V_2F_7 (BRRI dhan89 and 50% RFD + 50% organic manure + Zn & B as basal). At 50 DAT, the maximum tiller number hill^{-1} was observed (11.33) in V_1F_2 (BRRI dhan84 with RFD with Zn & B as basal) which was statically similar with V_1F_3 (BRRI dhan84 and RFD with Zn as foliar spray at anthesis) treatments and the minimum tiller number hill^{-1} (6.33) was obtained from V_2F_1 (BRRI dhan89 and control-no fertilizer). But at 75 DAT, the maximum tiller number (14.00) inV_2F_7

(BRRI dhan89 and 50% RFD + 50% organic manure + Zn & B as basal) while the minimum tiller number was (9.67) observed in V_2F_1 (BRRI dhan89 and control-no fertilizer). At harvest, the maximum tiller number hill^{-1} (16.00) had found in V_1F_2 (BRRI dhan84 with RFD with Zn & B as basal), V_1F_5 (BRRI dhan84 with 50% RFD + 50% organic manure as cowdung) respectively and the minimum tiller number hill^{-1} (9.00) had found in V_2F_1 (BRRI dhan89 and control-no fertilize) respectively.

Table 6. Interaction effect of variety and fertilizer managements on number of tillers hill^{-1} of boro rice

Treatments	Number of tillers hill^{-1} at			
	25 DAT	50 DAT	75 DAT	Harvest
V_1F_1	3.00 a	7.33 de	13.00 ab	10.00 cde
V_1F_2	3.00 a	11.33 a	12.00 ab	16.00 a
V_1F_3	2.33 abc	11.00 a	13.67 ab	14.33 ab
V_1F_4	2.67 ab	10.67 ab	12.67 ab	14.33 ab
V_1F_5	3.00 a	10.33 ab	13.33 ab	16.00 a
V_1F_6	2.67 ab	9.00 bcd	12.00 ab	12.67 bc
V_1F_7	2.33 abc	10.00 abc	11.00 ab	12.33 bcd
V_2F_1	2.00 bc	6.33 e	9.67 b	9.00 e
V_2F_2	2.67 ab	10.67 ab	13.33 ab	12.00 abc
V_2F_3	2.00 bc	9.00 bcd	12.33 ab	12.67 bc
V_2F_4	2.67 ab	11.33 a	13.67 ab	13.33 ab
V_2F_5	2.33 abc	7.33 de	10.33 ab	9.67 de
V_2F_6	2.67 ab	7.67 de	13.33 ab	10.67 cde
V_2F_7	1.67 c	8.33 cd	14.00 a	10.33 cde
$LSD_{(0.05)}$	0.758	1.934	4.166	2.856
CV (%)	17.99	12.33	19.85	13.69

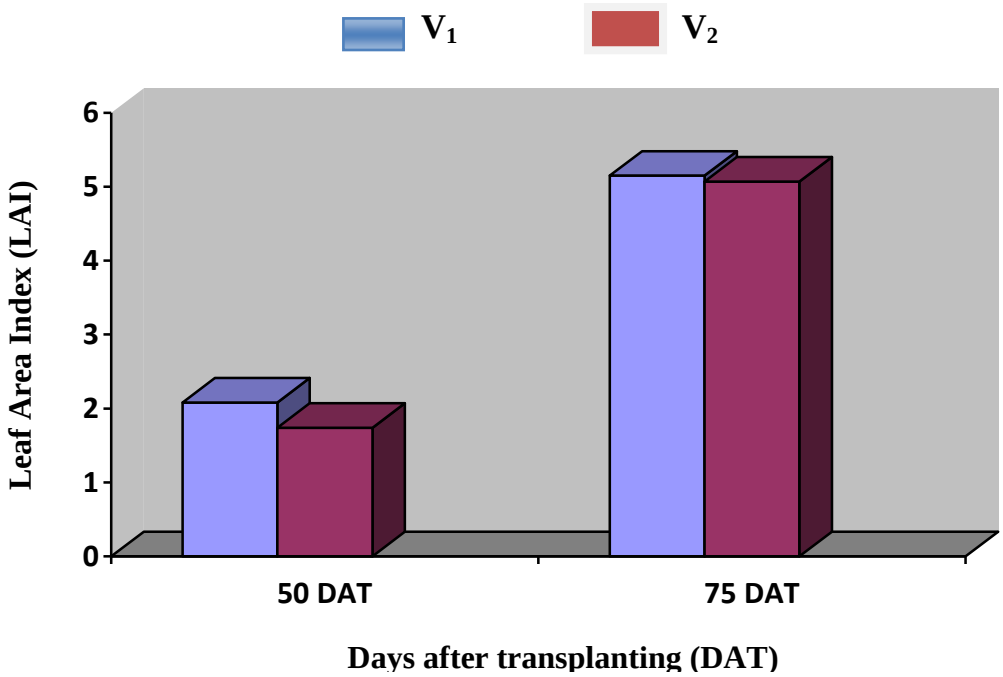
In this column, the means having the same letter (s) do not differ significantly. CV= Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT= days after transplanting , NS= Non significant

V_1= BRRI dhan84 , V_2= BRRI dhan89, F_1=Control (No fertilizer), F_2=Recommended Fertilizer Dose of NPKS (RFD)with Zn & B as basal, F_3=RFD with Zn as foliar spray at anthesis , F_4=RFD with Zn & B as foliar spray at anthesis, F_5=50% RFD+ 50% Organic manure (Cowdung), F_6= 50% RFD+ 50% Organic manure+Zn & B as foliar spray at anthesis, F_7=50% RFD+ 50% Organic manure + Zn & B as basal

4.1.3 Leaf area index

4.1.3.1 Effect of variety

Variety had non-significantly influenced on leaf area index (LAI) at 50 and 75 DAT (Appendix V and Figure 1). The result revealed that the higher leaf area index (2.08 and 5.15 respectively) at 50 and 75 DAT and from V_1 (BRRI dhan84) that followed by V_2 (BRRI dhan89) (1.74 and 5.07 respectively).

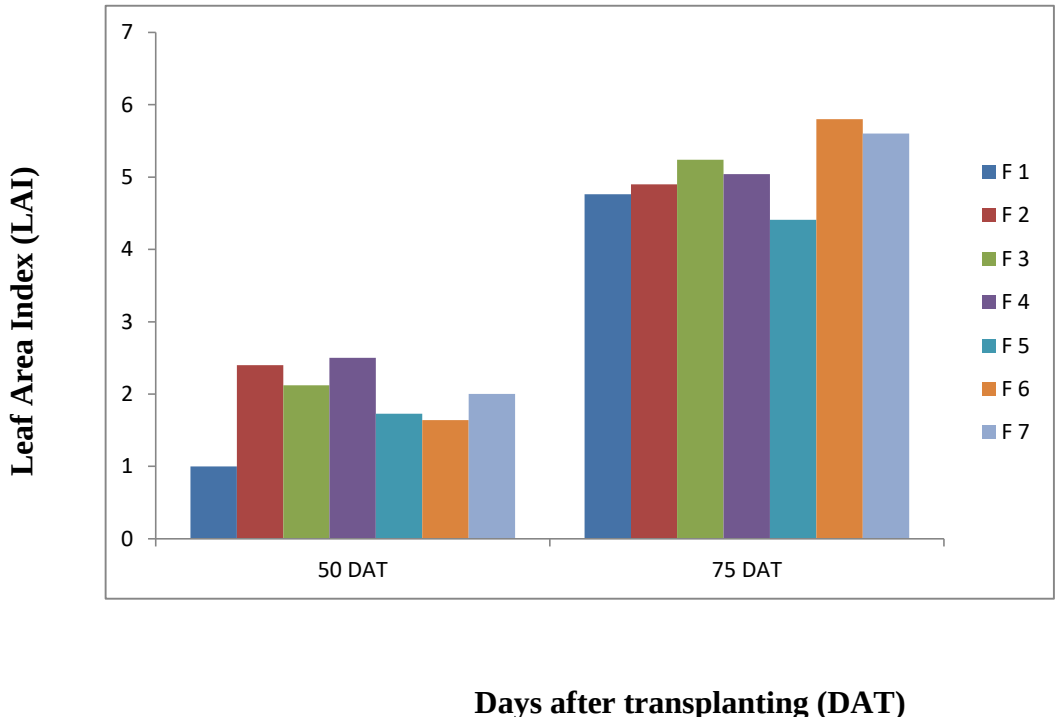


V_1= BRRI dhan84, V_2= BRRI dhan89

Figure 1. Leaf Area Index (LAI) of boro rice as influenced by variety ($LSD_{(0.05)}$= 0.222 and 1.523 at 50 and 75 DAT respectively).

4.1.3.2 Effect of fertilizer management

Fertilizer sources had significant and non significant effect on leaf area index (LAI) at 50 and 75 DAT respectively (Appendix V and figure 2). At 50 DAT, the highest leaf area index (2.40) was obtained from F_2 (RFD of NPKS with Zn & B as basal) while the lowest leaf area index (1.0) was obtained from F_1 (control). At 75 DAT the higher leaf area index (5.80) was obtained from F_6 (50% RFD + 50% organic manure + Zn & B as foliar spray at anthesis) and the lowest leaf area index (4.76) was also recorded in F_1 (control). The findings were also similar with the findings of Wu-YuQiu *et al.* (2013).



F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD)with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis , F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

Figure 2. Leaf Area Index (LAI) of boro rice as influenced by fertilizer management ($LSD_{(0.05)}$= 0.58 and 4.029 at 50 and 75 DAT respectively).

4.1.3.3 Interaction of variety and fertilizer management

Interaction between variety and fertilizer management had significant and non significant effect on leaf area index (LAI) observed at 50 and 75 DAT and (Appendix V and Table 7). At 50 DAT, the maximum leaf area index was (2.60) observed from in V_1F_2 (BRRI dhan84 with RFD with Zn & B as basal), while the minimum leaf area index was (0.93) obtained from V_2F_1 (BRRI dhan89 and control-no fertilizer). But at 75 DAT, the maximum leaf area index was also observed (6.42) from V_1F_6 (BRRI dhan84 and 50% RFD + 50% organic manure + Zn & B as foliar at anthesis) while the minimum leaf area index was (3.75) obtained from V_1F_5 (BRRI dhan84 and 50% RFD + 50% organic manure + Zn & B as basal).

Table 7. Interaction effect of variety and fertilizer managements on Leaf area index (LAI) of boro rice

Treatments	Leaf area index (LAI) at	
	50 DAT	75 DAT
V_1F_1	1.06 fg	5.18
V_1F_2	2.60 a	5.05
V_1F_3	2.50 a	4.88
V_1F_4	2.42 a	5.19
V_1F_5	2.08 a-d	3.75
V_1F_6	1.67 cde	6.42
V_1F_7	2.28 ab	5.58
V_2F_1	0.93 g	4.33
V_2F_2	2.24 abc	4.85
V_2F_3	1.78 b-c	5.6
V_2F_4	2.57 a	4.9
V_2F_5	1.38 efg	5.07
V_2F_6	1.62 def	5.17
V_2F_7	1.66 cde	5.56
$LSD_{(0.05)}$	0.587	NS
CV (%)	18.25	46.67

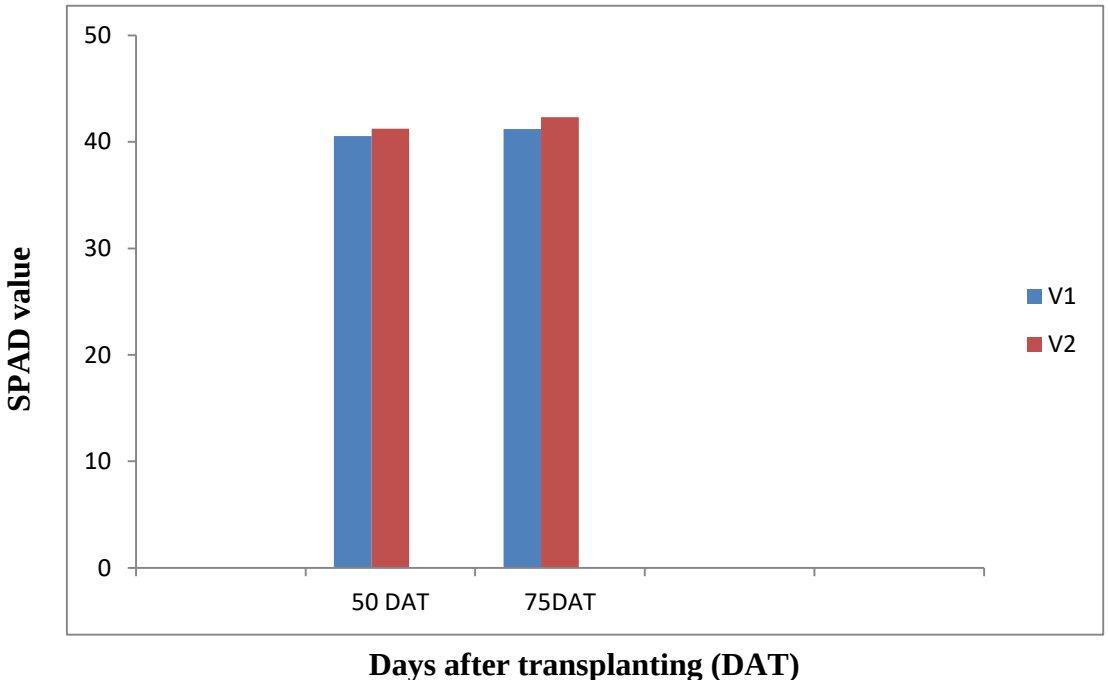
In this column, the means having the same letter (s) do not differ significantly. CV=Coefficient of variation, $LSD_{(0.05)}$ = Least significant difference at 5% level, DAT = days after transplanting, NS= Non significant

V_1= BRRI dhan84, V_2 = BRRI dhan89, F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD)with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis, F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

4.1.4 SPAD value

4.1.4.1 Effect of variety

Varieties had non-significant influence on SPAD value at 50 and 75 DAT (Appendix VI and Figure 3). The result revealed that at 50 DAT, the maximum SPAD value (41.22) was obtained from BRRI dhan89 (V_2) but the result was statistically similar with BRRI dhan84 (V_1). At 75 DAT, the maximum SPAD value (42.30) was also recorded from BRRI dhan89 (V_2) followed by BRRI dhan84 (V_1). The results were statistically similar in each case.

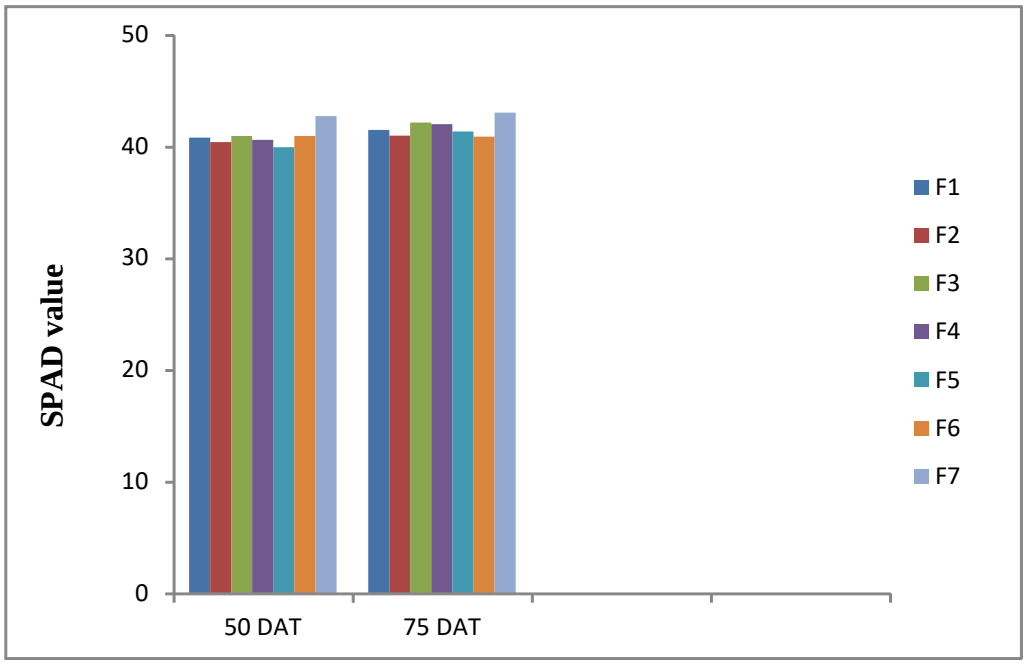


V_1= BRRI dhan84, V_2= BRRI dhan89

Figure 3. SPAD value of boro rice as influenced by variety ($LSD_{(0.05)}$= NS and NS at 50 and 75 DAT respectively).

4.1.4.2 Effect of fertilizer management

Fertilizer management had significant effect on SPAD value at 50 and 75 DAT (Appendix VI and Figure 4). At 50 DAT, the highest SPAD value (42.68) was obtained from F_7 (50% RFD + 50% organic manure + Zn & B as basal) which was different from other treatments and the lowest SPAD value (39.91) was obtained from F_5 (50% RFD + 50% organic manure (cowdung)). At 75 DAT, the highest SPAD value (43.58) was obtained from F_7 (50% RFD + 50% organic manure + Zn & B as basal). The lowest SPAD value (40.84) was obtained from F_6 (50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis).



Days after transplanting (DAT)

F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD) with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis , F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

Figure 4. SPAD value of boro rice as influenced by fertilizer management ($LSD_{(0.05)}$= 2.439 and 2.123 at 50 and 75 DAT respectively).

4.1.4.3 Interaction of variety and fertilizer management

Interaction between variety and fertilizer management had significant effect on SPAD value observed at 50 and 75 DAT (Appendix VI and Table 8). At 50 DAT, the highest SPAD value (42.9) observed in V_2F_7 (BRRI dhan89 and 50% RFD + 50% organic manure + Zn & B as basal) and the lowest SPAD value (38.81) obtained in V_1F_5 (BRRI dhan84 and 50% RFD + 50% organic manure). At 75 DAT, the highest SPAD value observed (44.32) in V_2F_7 (BRRI dhan89 and 50% RFD + 50% organic manure + Zn & B as basal) and the lowest SPAD value (39.92) obtained in V_1F_5 (BRRI dhan84 and 50% RFD + 50% organic manure) which were statistically similar with V_1F_1 (BRRI dhan84 and control), V_1F_2 (BRRI dhan84 and RFD with Zn & B as basal), V_1F_6 (BRRI dhan84 and 50% RFD + 50% organic manure + Zn & B as foliar spray at anthesis), V_2F_2 (BRRI dhan89 and RFD of NPKS with Zn & B as basal), V_2F_6 (BRRI dhan89

and 50% RFD + 50% organic manure + Zn & B.

Table 8. Interaction effect of variety and fertilizer management on SPAD value of boro rice at different growth stages

Treatments	SPAD value at	
	50 DAT	75 DAT
V_1F_1	39.36 bc	40.22 b
V_1F_2	39.79 abc	41.09 b
V_1F_3	41.18 abc	41.73 ab
V_1F_4	40.11 abc	41.47 ab
V_1F_5	38.81 c	39.92 b
V_1F_6	40.98 abc	41.09 b
V_1F_7	42.45 ab	42.84 ab
V_2F_1	42.18 abc	42.71 ab
V_2F_2	39.96 abc	40.78 b
V_2F_3	40.65 abc	42.51 ab
V_2F_4	41.05 abc	42.48 ab
V_2F_5	41 abc	42.71 ab
V_2F_6	40.83 abc	40.60 b
V_2F_7	42.9 a	44.32 a
$LSD_{(0.05)}$	3.4486	3.002
CV (%)	5.006	4.27

In this column, the means having the same letter (s) do not differ significantly. CV=Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAT=days after transplanting , NS= Non significant

V_1= BRRI dhan84 , V_2= BRRI dhan89, F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD)with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis , F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD+ 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

4.2 Yield contributing characters

4.2.1 Number of effective tillers hill^{-1}

4.2.1.1 Effect of variety

Variety had not significant effect on number of effective tillers hill^{-1} at harvest (Appendix VII and Table 9). The maximum number of effective tillers hill^{-1} (12.14) was recorded from BRRI dhan84 (V_1) but the result was statistically

similar with other treatments. So number of effective tillers hill^{-1} at harvest of boro rice was not affected by variety. The similar trend of results on effective tillers were also achieved by Latif *et al.* (2020), Afroz *et al.* (2019).

Table 9. Effect of variety and fertilizer management on no. of effective tillers, ineffective tillers of boro rice

Treatments	No. of effective tillers hill^{-1}	No. of ineffective tillers hill^{-1}
Variety		
V_1	12.14	1.29
V_2	10.86	1.0
$LSD_{(0.05)}$	NS	NS
CV (%)	14.51	191.07
Fertilizer management		
F_1	9.17 c	0.33
F_2	13 a	1.17
F_3	12.83 a	0.67
F_4	12.83 a	0.5
F_5	11.5 ab	1.33
F_6	10.33 bc	0.5
F_7	10.83 abc	0.33
$LSD_{(0.05)}$	2.183	NS
CV (%)	15.93	57.07

In this column, the means having the same letter (s) do not differ significantly. CV=Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAT=days after transplanting , NS= Non significant

V_1 = BRRI dhan84, V_2 = BRRI dhan89, F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD)with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis , F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD+ 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

4.2.1.2 Effect of fertilizer management

Fertilizer management had significant effect on number of effective tillers hill^{-1} at harvest (Appendix VII and Table 9). The highest number of effective tillers hill^{-1} (13.0) was recorded from recommended fertilizer doses of NPKS with Zn & B as basal (F_2) which was statistically similar with RFD with Zn as foliar spray at anthesis (F_3) and RFD with Zn & B as foliar at anthesis (F_4). Whereas

the lowest number of effective tillers hill^{-1} (9.17) from control (no fertilizer) (F_1). Similar results on effective tillers were recorded by Reddy *et al.* (2020).

4.2.1.3 Interaction of variety and fertilizer management

Interaction between variety and fertilizer management had significant effect on number of effective tillers hill^{-1} at harvest (Appendix VII and Table 10). The highest number of effective tiller hill^{-1} (14.0) was observed in V_1F_2 (BRRI dhan84 with RFD of NPKS with Zn & B as basal) which was statistically similar with V_1F_5. The lowest number of effective tillers hill^{-1} (8.67) was observed in BRRI dhan89 with control (V_2F_1). The results were in agreement with the findings of Singh *et al*. (2020).

Table 10. Interaction effect of variety and fertilizer managements on number of effective tillers and ineffective tillers hill^{-1} of boro rice

Treatments	Number of effective tillers hill^{-1}	Number of ineffective tillers hill^{-1}
V_1F_1	9.67 cde	0.33
V_1F_2	14 a	2.33
V_1F_3	13 ab	1.0
V_1F_4	12.67 abc	1.0
V_1F_5	13.67 a	2.67
V_1F_6	10.33 b-e	1.0
V_1F_7	11.67 a-e	0.67
V_2F_1	8.67 e	0.33
V_2F_2	12 a-d	0
V_2F_3	12.67 abc	0.33
V_2F_4	13 ab	0
V_2F_5	9.33 d	0
V_2F_6	10.33 b-e	0
V_2F_7	10 b-e	0
$LSD_{(0.05)}$	3.088	NS
CV (%)	15.93	157.07

In this column, the means having the same letter (s) do not differ significantly. CV=Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAT=days after transplanting , NS= Non significant, V_1 = BRRI dhan84, V_2 = BRRI dhan89, F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD) with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis, F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

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

4.2.2.1 Effect of variety

Variety had no significant effect on number of in-effective tillers hill^{-1} at harvest (Appendix VII and Table 9). The maximum number of in-effective tillers hill^{-1} (1.29) was recorded from BRRI dhan84 (V_1) which was statically similar with other treatments. So number of in-effective tillers hill^{-1} at harvest of boro rice was not affected by varieties. Rahman and Bulbul (2014) also found similar result was supported the present finding.

4.2.2.2 Effect of fertilizer management

Fertilizer management was not significantly effected on number of in-effective tillers hill^{-1} at harvest (Appendix VII and Table 9). The maximum number of in-effective tillers hill^{-1} (1.33) was recorded from F_5 (50% RFD + 50% organic (cowdung). So, the effect of fertilizer management showed non-significant effect on number of in-effective tillers hill^{-1}.

4.2.2.3 Interaction effect of variety and fertilizer management

Interaction between variety and fertilizer management had no significant effect on number of in-effective tillers hill^{-1} at harvest (Appendix VII and Table 10). The maximum number of in-effective tillers hill^{-1} (2.67) was observed in V_1F_5 (BRRI dhan84 and 50% RFD + 50% organic manure) which was statistically similar with other treatments. So, interaction effect of variety and fertilizer management on number of in-effective tillers hill^{-1} was non-significant and statistically similar.

4.2.4 Number of rachis branches panicle^{-1}

4.2.4.1 Effect of variety

Variety had significant effect on number of rachis branches panicle^{-1} (Appendix VIII and Table 11). The higher number of rachis branches panicle^{-1} (10.48) was recorded from BRRI dhan89 (V_2) and the lower rachis branches panicle^{-1} which was recorded from BRRI dhan84 (V_1). The result showed the effect of variety on number of rachis branches panicle^{-1} was not statistically similar.

4.2.4.2 Effect of fertilizer management

Fertilizer management had significant effect on number of rachis branches panicle^{-1} (Appendix VIII and Table 11). The maximum number of rachis branches panicle^{-1} (9.50) was recorded from F_7 (50% RFD + 50% organic manure + Zn & B as basal) which was statistically similar with F_2 (RFD with Zn & B as basal), F_3 (RFD with Zn as foliar spray at anthesis), F_4 (RFD with Zn & B as foliar spray at anthesis). Whereas the minimum number of rachis branches panicle^{-1} (8.00) from F_1 (control).

Table 11. Effect of variety and fertilizer management on rachis branch panicle^{-1} and panicle length of boro rice

Treatments	Rachis branch panicle^{-1} (No.)	Panicle length (cm)
V_1	7.38 b	25.36
V_2	10.48 a	26.09
$LSD_{(0.05)}$	0.8809	NS
CV (%)	10.51	4.92
F_1	8.0 b	24.75 b
F_2	9.0 a	25.49 ab
F_3	9.17 a	25.75 a
F_4	9.33 a	25.91 a
F_5	8.83 ab	25.93 a
F_6	8.67 ab	26.14 a
F_7	9.50 a	25.91 a
$LSD_{(0.05)}$	0.955	1.02
CV (%)	8.98	3.33

In this column, the means having the same letter (s) do not differ significantly. CV=Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAT=days after transplanting , NS= Non significant

V_1= BRRI dhan84 , V_2= BRRI dhan89, F_1=Control (No fertilizer), F_2=Recommended Fertilizer Dose of NPKS (RFD)with Zn & B as basal, F_3=RFD with Zn as foliar spray at anthesis , F_4=RFD with Zn & B as foliar spray at anthesis, F_5=50% RFD+ 50% Organic manure (Cowdung), F_6= 50% RFD+ 50% Organic manure+Zn & B as foliar spray at anthesis, F_7=50% RFD+ 50% Organic manure + Zn & B as basal

4.2.4.3 Interaction of variety and fertilizer management

Interaction between variety and fertilizer management had significant effect on number of rachis branches panicle^{-1} (Appendix VIII and Table 12). The maximum number of rachis branches panicle^{-1} (11.33) was observed in combination of BRRI dhan89 and 50% RFD + 50% organic manure + Zn & B as basal (V_2F_7). The minimum number of rachis branches panicle^{-1} (6.33) was observed in the combination of BRRI dhan84 and control (V_1F_1) which was statistically similar with other treatments.

Table 12. Interaction effect of variety and fertilizer managements on rachis branch panicle^{-1} and panicle length of boro rice

Treatments	Rachis branch Panicle^{-1} (No.)	Panicle length (cm)
V_1F_1	6.33 c	24.25 c
V_1F_2	7.33 c	25.24 abc
V_1F_3	7.67 c	25.58 ab
V_1F_4	7.67 c	26.09 ab
V_1F_5	7.67 c	25.71 ab
V_1F_6	7.33 c	25.43 abc
V_1F_7	7.67 c	25.22 bc
V_2F_1	9.67 b	25.66 abc
V_2F_2	10.67 ab	25.73 ab
V_2F_3	10.67 ab	25.92 ab
V_2F_4	11 ab	25.73 ab
V_2F_5	10 ab	26.15 ab
V_2F_6	10 ab	26.84 a
V_2F_7	11.33 a	26.59 ab
$LSD_{(0.05)}$	1.351	1.442
CV (%)	8.98	3.33

In this column, the means having the same letter (s) do not differ significantly. CV=Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAT=days after transplanting , NS= Non significant

V_1= BRRI dhan84 , V_2= BRRI dhan89, F_1=Control (No fertilizer), F_2=Recommended Fertilizer Dose of NPKS (RFD)with Zn & B as basal, F_3=RFD with Zn as foliar spray at anthesis , F_4=RFD with Zn & B as foliar spray at anthesis, F_5=50% RFD+ 50% Organic manure (Cowdung), F_6= 50% RFD+ 50% Organic manure+Zn & B as foliar spray at anthesis, F_7=50% RFD+ 50% Organic manure + Zn & B as basal

4.2.5 Length of panicle

4.2.5.1 Effect of variety

Variety had no significant effect on length of panicle (Appendix VIII and Table 11). The maximum length of panicle (26.09 cm) was recorded from BRRI dhan89 (V_2) and the minimum panicle length was (25.36 cm) observed from BRRI dhan84 (V_1). Different rice varieties have different panicle length due to genetic makeup of the variety and higher panicle length is achieved from high yielding varieties compare to low yielding varieties. Hossain *et al.* (2016); Chamely *et al*. (2015) and Diaz *et al.* (2000) were found similar result which supported the present study and reported that panicle length differ among varieties.

4.2.5.2 Effect of fertilizer management

Fertilizer management had significant effect on length of panicle (Appendix VIII and Table 11). The highest length of panicle (26.14 cm) was recorded from 50% RFD + 50% organic manure + Zn & B as foliar spray at anthesis (F_6) which was statistically similar with other treatments. Whereas the lowest (24.75 cm) from control (F_1). Arif *et al.* (2012) recorded that the panicle length increased significantly and varied from 24 to 30.40 cm as a results of Zn, B and MT (Microtone) treatment

4.2.5.3 Interaction of variety and fertilizer management

Interaction between variety and fertilizer management had significant effect on length of panicle (Appendix VIII and Table 12). The highest length of panicle (26.84 cm) was observed in the combination of BRRI dhan89 and 50% RFD + 50% organic manure + Zn & B as foliar spray at anthesis (V_2F_6). The lowest length of panicle (24.25 cm) was observed in combination of BRRI dhan84 with control (V_1F_1).

4.2.6 Filled grains panicle^{-1}

4.2.6.1 Effect of variety

Variety had significant effect on filled grains panicle^{-1} (Appendix IX and Table 13). The maximum number of filled grains panicle^{-1} (116.14) was recorded from V_2 (BRRI dhan89) whereas the minimum number of filled grains panicle^{-1} (89.47) from BRRI dhan84 (V_1). The BRRI dhan89 resulted 29.82% higher number of filled grain panicle^{-1} than BRRI dhan84. Similar variation of filled grains panicle^{-1} among varieties was also revealed by Khatun *et al.* (2020) and Ullah *et al.* (2016).

Table 13. Effect of variety and fertilizer management on number of filled grains and unfilled grains panicle^{-1} and 1000-grain weight of boro rice

Treatments	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}	1000-grain weight (g)
Variety			
V_1	89.47 b	18.43	21.64
V_2	116.14 a	16.71	22.34
$LSD_{(0.05)}$	10.85	NS	NS
CV (%)	9.81	17.54	7.90
Fertilizer management			
F_1	96.50 ab	13.83 c	20.57 d
F_2	98.83 ab	21.17 ab	20.98 cd
F_3	108.17 ab	18.50 abc	21.42 cd
F_4	105.67 ab	22.83 a	23.58 a
F_5	105.33 ab	16.17 bc	23.33 ab
F_6	92.33 b	14.83 c	22.13 abc
F_7	112.83 a	15.67 c	21.92 bcd
$LSD_{(0.05)}$	20.307	6.284	1.474
CV (%)	16.58	30.01	5.62

In this column, the means having the same letter (s) do not differ significantly. CV=Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAT=days after transplanting , NS= Non significant, V_1 = BRRI dhan84, V_2 = BRRI dhan89, F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD) with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis, F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

4.2.6.2 Effect of fertilizer management

Fertilizer management had significant effect on number of filled grains panicle^{-1} (Appendix IX and Table 13). The highest number of filled grains panicle^{-1} (112.83) was recorded from 50 % RFD + 50% organic manure + Zn & B as basal (F_7). Whereas the lowest number of filled grains panicle^{-1} (92.33) obtained from 50% RFD + 50% organic manure + Zn & B as foliar spray at anthesis (F_6)

4.2.6.3 Interaction of variety and fertilizer management

Interaction between variety and fertilizer management had significant effect on number of filled grains panicle^{-1} (Appendix IX and Table 14).

Table 14. Interaction effect of variety and fertilizer managements on number of filled grains and unfilled grains panicle^{-1} and 1000-grain weight of boro rice

Treatments	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}	1000-grain weight (g)
V_1F_1	85.33 cde	11.33 d	19.80 e
V_1F_2	76. 0 de	26.67 a	21.70 b-e
V_1F_3	96.67 a-e	17.0 bcd	20.63 de
V_1F_4	92.0 b-e	24.33 ab	23.47 ab
V_1F_5	97.0 a-e	15.0 cd	23.33 abc
V_1F_6	75.0 e	16.33 bcd	20.43 de
V_1F_7	104.33 a-d	18.33 a-d	22.13 a-d
V_2F_1	107.68 abc	16.33 bcd	21.33 cde
V_2F_2	121.67 a	15.67 bcd	20.26 de
V_2F_3	119.67 ab	20.0 a-d	22.20 a-d
V_2F_4	119.33 ab	21.33 abc	23.70 ab
V_2F_5	113.67 abc	17.33 bcd	23.33 abc
V_2F_6	109.67 abc	13.33 cd	23.83 a
V_2F_7	121.33 a	13.0 cd	21.70 b-e
$LSD_{(0.05)}$	28.719	8.887	2.084
CV (%)	16.58	30.01	5.62

In this column, the means having the same letter (s) do not differ significantly. CV=Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAT=days after transplanting , NS= Non significant, V_1 = BRRI dhan84, V_2 = BRRI dhan89, F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD)with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis , F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

The highest number of filled grains panicle^{-1} (121.67) was observed in combination of BRRI dhan89 and RFD of NPKS with Zn & B as basal (V_2F_2) and the lowest number of filled grains panicle^{-1} (75) was observed in combination of BRRI dhan84 and 50% RFD + 50% organic manure + Zn & B as foliar at anthesis (V_1F_6).

4.2.7 Unfilled grains panicle^{-1}

4.2.7.1 Effect of variety

Variety had no significant effect on number of unfilled grains panicle^{-1} (Appendix IX and Table 13). The numerically maximum number of unfilled grains panicle^{-1} (18.43) was recorded from BRRI dhan84 (V_1) which was similar with other treatment. The result shown the effect of variety was non-significant and statistically similar. Afroz *et al*. (2019) also found similar result which supported the present finding and revealed that different variety had different varietal characteristics which influenced the unfilled grains panicle^{-1} and among different rice varieties the highest number (81.90) of grain panicle^{-1}, the highest grain yield (4.56 t ha^{-1}) and the lowest number (17.43) of sterile spikelet panicle^{-1} were recorded in BRRI dhan29. On the other hand, the lowest number (76.82) of grains panicle^{-1} was observed in BRRI dhan28 variety.

4.2.7.2 Effect of fertilizer management

Fertilizer management had significant effect on number of unfilled grains panicle^{-1} (Appendix IX and Table 13). The maximum number of unfilled grains panicle^{-1} (22.83) was recorded from F_4 (RFD with Zn & B as foliar spray at anthesis). Whereas the minimum number of unfilled grains panicle^{-1} (13.83) from control (F_1) which was statistically similar with 50% RFD + 50 % organic manure + Zn & B as foliar spray at anthesis (F_6) and 50% RFD + 50% organic manure + Zn & B as basal (F_7).

4.2.7.3 Interaction of variety and fertilizer management

Interaction between variety and fertilizer management had significant effect on number of unfilled grains panicle^{-1} (Appendix IX and Table 14). The highest

number of unfilled grains panicle^{-1} (26.67) was observed in combination of BRRI dhan84 and RFD of NPKS with Zn & B as basal (V_1F_2). The minimum number of unfilled grains panicle^{-1} (11.33) was observed in BRRI dhan84 by control (V_1F_1).

4.2.9 Weight of 1000 grains

4.2.9.1 Effect of variety

Variety had no significant effect on weight of 1000 grains of boro rice (Appendix IX and Table 13). The maximum weight of 1000 grains (22.34 g) was recorded from BRRI dhan89 (V_2) which was different from other treatment. The result was shown the effect of variety on weight of 1000-grain was non-significant and similar.

4.2.9.2 Effect of fertilizer management

Fertilizer management had significant effect on weight of 1000 grains of boro rice (Appendix IX and table 13). The maximum weight of 1000 grains (23.58 g) was recorded from RFD with Zn & B as foliar spray at anthesis (F_4). Whereas the minimum weight of 1000-grain was (20.57 g) from control (F_1).

4.2.9.3 Interaction of variety and fertilizer management

Interaction between variety and fertilizer management had significant effect on weight of 1000-grains (Appendix IX and Table 14). The maximum weight of 1000 grains (23.83 g) was observed in BRRI dhan89 by 50% RFD + 50 % organic manure + Zn & B as foliar spray(V_2F_6) whereas the minimum weight of 1000 grains (19.8 g) was observed in BRRI dhan84 with control (V_1F_1).

4.2.10 Grain yield

4.2.10.1 Effect of variety

Variety had non significant effect on grain yield of boro rice (Appendix X and Table 15). The numerically maximum grain yield (6.42 t ha^{-1}) was recorded from BRRI dhan89 (V_2) whereas the minimum grain yield (5.98 t ha^{-1}) was from BRRI dhan84 (V_1). The result showed the effect of variety on grain yield

was non significant. Latif *et al.* (2020) also found the similar result as the present study.

4.2.10.2 Effect of fertilizer management

Fertilizer management had significant effect on grain yield of boro rice (Appendix X and Table 15). The highest grain yield (7.67 t ha^{-1}) was recorded from RFD with Zn & B as foliar spray at anthesis (F_4) which was statistically different from other treatments.

Table 15. Effect of variety and fertilizer management on grain yield, straw yield, biological yield and harvest index of boro rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Variety				
V_1	5.98	6.72	12.70	46.88
V_2	6.42	7.25	13.66	46.79
$LSD_{(0.05)}$	NS	NS	NS	NS
CV (%)	9.21	26.19	7.66	10.09
Fertilizer management				
F_1	4.40 e	6.92 abc	11.32 e	39.05 d
F_2	6.03 c	7.31 a	13.34 cd	45.34 c
F_3	6.80 b	7.48 a	14.28 ab	47.81 bc
F_4	7.67 a	7.19 ab	14.85 a	51.69 a
F_5	6.86 b	7.10 abc	13.87 bc	49.45 ab
F_6	6.10 c	6.63 bc	12.73 d	47.91 bc
F_7	5.54 d	6.37 c	11.91 e	46.61 bc
$LSD_{(0.05)}$	0.402	0.636	0.664	2.924
CV (%)	5.45	7.65	4.23	5.24

In this column, the means having the same letter (s) do not differ significantly. CV=Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAT=days after transplanting , NS= Non significant, V_1 = BRRI dhan84, V_2 = BRRI dhan89, F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD) with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis, F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

Whereas the lowest grain yield (4.40 t ha^{-1}) was from control (F_1). The result showed the effect of fertilizer management on grain yield was statistically significant. Arif *et al.* (2012) reported that the micronutrients required in minute quantity and their deficiency leads to decreasing growth and yield of crops

4.2.10.3 Interaction of variety and fertilizer management

Interaction between variety and fertilizer management had significant effect on grain yield of boro rice (Appendix X and Table 16). The highest grain yield (7.80 t ha^{-1}) was observed in BRRI dhan89 by RFD with Zn as foliar spray at anthesis (V_2F_4).

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Table 16. Interaction effect of variety and fertilizer managements on grain yield, straw yield, biological yield and harvest index of boro rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index
V_1F_1	4.36 h	6.86 bc	11.22 g	39.02 e
V_1F_2	5.94 ef	6.97 bc	12.91 de	46.04 cd
V_1F_3	6.43 d	6.85 bc	13.27 d	48.45 a-d
V_1F_4	7.53 ab	6.87 bc	14.40 ab	52.36 a
V_1F_5	6.60 cd	6.83 bc	13.42 cd	49.11 abc
V_1F_6	5.73 fg	6.40 c	12.12 efg	47.30 bcd
V_1F_7	5.29 g	6.28 c	11.57 fg	45.86 cd
V_2F_1	4.43 h	6.98 bc	11.41 fg	39.07 e
V_2F_2	6.12 def	7.65 ab	13.77 bcd	44.63 d
V_2F_3	7.17 bc	8.11 a	15.28 a	47.17 bcd
V_2F_4	7.80 a	7.50 ab	15.31 a	51.02 ab
V_2F_5	7.13 bc	7.18 bc	14.32 bc	49.78 abc
V_2F_6	6.47 de	6.86 bc	13.33 d	48.52 a-d
V_2F_7	5.79 fg	6.45 c	12.24 ef	47.35 bcd
$LSD_{(0.05)}$	0.569	0.9	0.940	4.136
CV (%)	5.45	7.65	4.23	5.24

In this column, the means having the same letter (s) do not differ significantly. CV=Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAT=days after transplanting , NS= Non significant, V_1 = BRRI dhan84, V_2 = BRRI dhan89, F_1 = Control (No fertilizer), F_2 = Recommended Fertilizer Dose of NPKS (RFD) with Zn & B as basal, F_3 = RFD with Zn as foliar spray at anthesis , F_4 = RFD with Zn & B as foliar spray at anthesis, F_5 = 50% RFD + 50% Organic manure (Cowdung), F_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis, F_7 = 50% RFD + 50% Organic manure + Zn & B as basal

The lowest grain yield (4.36 t ha^{-1}) was observed in BRRI dhan84 with control (V_1F_1) which was statistically similar with V_2F_1 (BRRI dhan89 with control).

4.2.11 Straw yield

4.2.11.1 Effect of variety

Variety had no significant effect on straw yield of boro rice (Appendix X and Table 15). The numerically maximum straw yield (7.25 t ha^{-1}) was recorded from BRRI dhan89 (V_2). Whereas the minimum straw yield (6.72 t ha^{-1}) was recorded from BRRI dhan84 (V_1). The result shown the effect of variety on straw yield was non-significant. Chamely *et al*. (2015) also found similar result with the present study and revealed that straw yield varied among varieties.

4.2.11.2 Effect of fertilizer management

Fertilizer management had significant effect on straw yield of boro rice (Appendix X and Table 15). The highest straw yield (7.48 t ha^{-1}) was recorded from RFD with Zn as foliar spray (F_3) which was statistically similar with F_2 (RFD of NPKS with Zn & B as basal). Whereas the lowest straw yield (6.37 t ha^{-1}) was from 50% RFD + 50% organic manure + Zn & B as basal (F_7). The result shown the effect of fertilizer sources on straw yield was statistically significant.

4.2.11.3 Interaction of variety and fertilizer management

Interaction between variety and fertilizer management had significant effect on straw yield of boro rice (Appendix X and Table 16). The maximum straw yield (8.11 t ha^{-1}) was observed in combination of BRRI dhan89 and RFD with Zn as foliar spray at anthesis (V_2F_3). The minimum straw yield (6.28 t ha^{-1}) was observed in BRRI dhan84 by 50% RFD + 50% organic manure + Zn & B as basal (V_1F_7). The result showed that the interaction effect of variety and fertilizer management on straw yield was statistically significant.

4.2.12 Biological yield

4.2.12.1 Effect of variety

Variety had non significant effect on biological yield of boro rice (Appendix XI and Table 15). The numerically maximum biological yield (13.66 t ha^{-1}) was recorded from BRRI dhan89 (V_2). Whereas the minimum biological yield (12.70 t ha^{-1}) was recorded from BRRI dhan84 (V_1). The result showed the effect of variety on biological yield was non significant. Chowan *et al*. (2019) found similar results with the present study and revealed that varieties which had higher grain and straw yield achieved the highest biological yield.

4.2.12.2 Effect of fertilizer management

Fertilizer managements had significant effect on biological yield of boro rice (Appendix XI and Table 15). The highest biological yield (14.28 t ha^{-1}) was recorded from RFD with Zn & B as foliar spray at anthesis (F_4) which was statistically different from other treatments. Whereas the lowest biological yield (11.32 t ha^{-1}) was from control (F_1). So, the result shown the effect of fertilizer management on biological yield was statistically significant

4.2.12.3 Interaction effect of variety and fertilizer management

Interaction between variety and fertilizer management had significant effect on biological yield (Appendix XI and Table 16). The maximum biological yield (15.31 t ha^{-1}) was observed in BRRI dhan89 and RFD with Zn & B as foliar spray at anthesis (V_2F_4) that statistically similar with V_2F_3. The lowest biological yield (11.22 t ha^{-1}) was observed in BRRI dhan84 with control (V_1F_1). So, the interaction effect of variety and fertilizer management on biological yield was significant.

4.2.13 Harvest index

4.2.13.1 Effect of variety

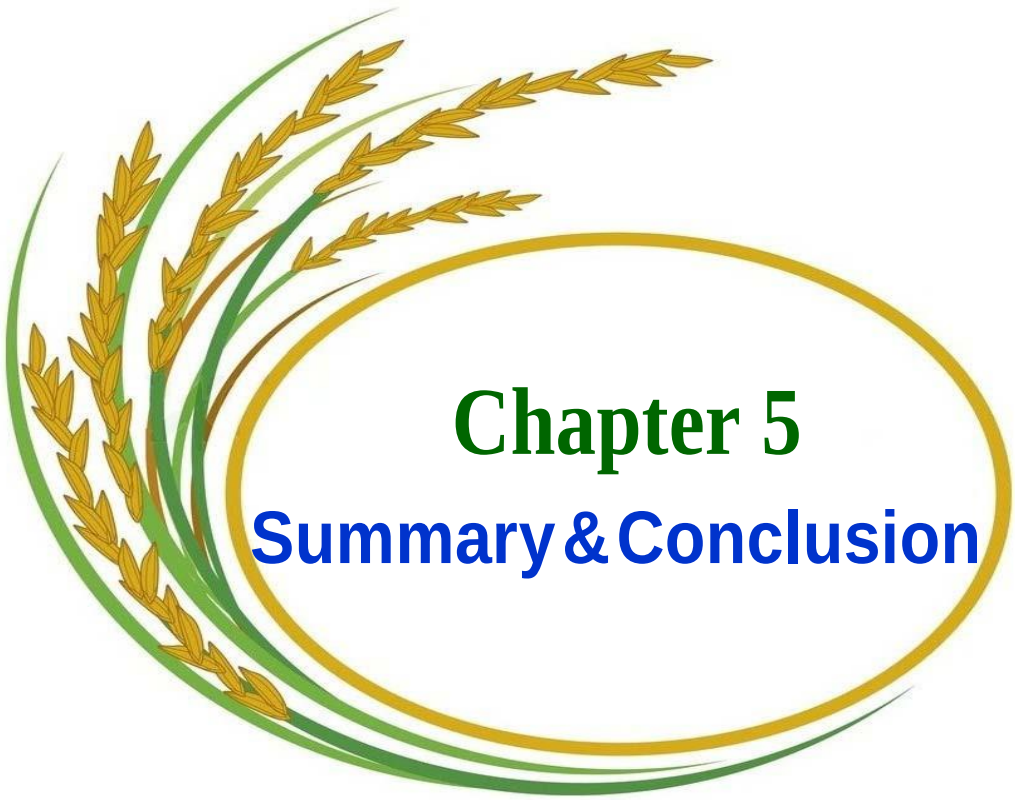
Variety had no significant effect on harvest index of boro rice (Appendix XI and Table 15). The numerically maximum harvest index (46.88 %) was recorded from BRRI dhan84 (V_1) whereas the minimum harvest index (46.79 %) from BRRI dhan89 (V_2). But the result shown the effect of variety on harvest index was statistically similar. The findings were similar with the findings of Chowhan *et al.* (2019) and Akter *et al.* (2018).

4.2.13.2 Effect of fertilizer management

Fertilizer management had significant effect on harvest index (Appendix XI and Table 15). The maximum harvest index (51.69 %) was recorded from RFD with Zn & B as foliar spray at anthesis (F_4). Whereas the minimum harvest index (39.05 %) was from control (F_1). The result shown the effect of fertilizer management on harvest index was statistically significant.

4.2.13.3 Interaction of variety and fertilizer management

Interaction between variety and fertilizer management had significant effect on harvest index of boro rice (Appendix XI and Table 16). The maximum harvest index (52.36 %) was observed in BRRI dhan84 and RFD with Zn & B as foliar spray at anthesis (V_1F_4). The minimum harvest index (39.02 %) was observed in BRRI dhan84 by control (V_1F_1) which was statistically similar with V_2F_1 (BRRI dhan89 with control). So, the interaction effect of variety and fertilizer management on harvest index was statistically significant.



Chapter 5

Summary & Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from December, 2020 to June, 2021 to study the suitable fertilizer management of boro rice under the Modhupur Tract (AEZ-28). The experiment comprised as two factors A) Factor A: Variety: 2 levels- 1) BRRI dhan84 (V_1) and 2) BRRI dhan89 (V_2); B) Factor B: Fertilizer management: 7 levels-1. Control (No fertilizer) (F_1), 2. Recommended Fertilizer Dose of NPKS (RFD) with Zn & B as basal (F_2), 3. RFD with Zn as foliar spray at anthesis (F_3), 4. RFD with Zn & B as foliar spray at anthesis (F_4), 5. 50% RFD + 50% Organic manure (Cowdung) (F_5), 6. 50% RFD + 50% Organic manure + Zn & B as foliar spray at anthesis (F_6), 7. 50% RFD + 50% Organic manure + Zn & B as basal (F_7).

The experiment was laid out in Split plot design with three replications having variety in the main plot and fertilizer management in sub-plots. The data on crop growth characters (plant height, number of tillers hill^{-1}, leaf area index, SPAD value) were recorded from five plants which were randomly selected from each unit plot for taking observations with 25 days interval at 25, 50, 75 days after transplanting and at harvest and yield as well as yield contributing characters (number of effective and ineffective tillers hill^{-1}, panicle length, number of rachis branches panicle^{-1}, number of filled and unfilled grains panicle^{-1}, 1000-grain weight, grain and straw yield, biological yield and harvest index) were recorded after harvest and analyzed using the CropStat package. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

Variety showed no significant influence on most of the growth and yield parameters except filled grains, rachis branch panicle^{-1}, leaf area index at 50 DAT.

The higher plant height (18.14 cm, 40.21 cm, 76.24 cm and 96.05 cm) was obtained from BRRI dhan84 (V_1) at 25, 50, 75 DAT and at harvest respectively, and the lower plant height (17.63 cm, 36.71 cm, 67.21 cm and 97.60 cm, respectively) at BRRI dhan89 (V_2). The maximum number of tillers hill^{-1} at 25, 50, 75 DAT and at harvest (2.71, 9.95, 12.52, 13.67 respectively) was obtained from BRRI dhan84 (V_1) and the minimum (2.29, 8.67, 12.38, 11.10 respectively) from BRRI dhan84 (V_1). The higher panicle length (26.09 cm) was found from BRRI dhan89 (V_2) and lower panicle length (25.36 cm) was found from BRRI dhan84 (V_1).

The higher number of filled grains panicle^{-1} (116.14) was recorded from BRRI dhan89 (V_2) whereas the lower number of filled grains panicle^{-1} (89.47) was from BRRI dhan84. The higher number of unfilled grains panicle^{-1} (18.63) was recorded from BRRI dhan84 (V_1) whereas the lower number of unfilled grains panicle^{-1} (16.71) was from BRRI dhan89 (V_1). The higher number of rachis branch panicle^{-1} (10.48) was recorded from BRRI dhan89 (V_2) whereas the lower number of rachis branch panicle^{-1} (7.38) was from BRRI dhan84 (V_1).

The higher SPAD value (41.22 and 42.30) was recorded from BRRI dhan89 (V_2) at 50 and 75 DAT whereas the lower SPAD value (40.53 and 41.19) was from BRRI dhan84 (V_1). The higher 1000-grain weight (22.34 g) was recorded from BRRI dhan89 (V_2) whereas the lower 1000-grain weight (21.64 g) was from BRRI dhan84 (V_1). The higher grain yield (6.42 t ha^{-1}) was recorded from BRRI dhan89 (V_2) whereas the lower grain yield (5.98 t ha^{-1}) was from BRRI dhan84 (V_1). The higher straw yield (7.25 t ha^{-1}) was recorded from BRRI dhan89 (V_2) whereas the lower straw yield (6.72 t ha^{-1}) was from BRRI dhan84 (V_1). The higher biological yield (13.66 t ha^{-1}) was recorded from BRRI dhan89 (V_2) whereas the lower grain yield (12.70 t ha^{-1}) was from BRRI dhan84 (V_1). The higher harvest index (46.88%) was recorded from BRRI dhan84 (V_1) whereas the lower harvest index (46.79%) was from BRRI dhan89 (V_2). The maximum effective tiller hill^{-1} (12.14) was recorded from BRRI

dhan84 (V_1 treatment) whereas the minimum effective tiller hill^{-1} (10.86) from BRRI dhan89 (V_2 treatment). The maximum ineffective tiller hill^{-1} (1.29) was recorded from BRRI dhan84 (V_1) and the minimum ineffective tiller hill^{-1} (1.00) was recorded from BRRI dhan89 (V_2).

Significant variation was recorded for fertilizer management on most of the growth and yield parameters except plant height at 25 DAT and 75 DAT, number of tiller hill^{-1} at 75 DAT, ineffective tiller hill^{-1} and leaf area index at 75 DAT.

The maximum plant height (18.92 cm) was recorded at 25 DAT from F_5 (50% RFD + 50% organic manure). At 50 DAT, the highest plant height (42.21 cm) obtained from F_4 (RFD with Zn & B foliar spray). At 75 DAT, the highest plant height (77 cm) was from F_7 (50% RFD + 50% organic manure + Zn & B as basal).

At harvest, the highest plant height (102.54 cm) was obtained from RFD with Zn & B as foliar spray at anthesis (F_4). The minimum plant height (16.49 cm, 32.28 cm, 69.71 cm and 86.74 cm, respectively) at 25, 50, 75 DAT and at harvest respectively was obtained from (F_1) control. The maximum number of tillers hill^{-1} (2.83) at 25 DAT and was obtained from RFD of NPKS with Zn & B as basal (F_2) and the minimum (2.00) was from F_7 (50% RFD + 50% organic manure + Zn & B as basal). At 50, 75 DAT the maximum tiller number (11.00, 13.17) was obtained from RFD with Zn & B as foliar spray (F_4) respectively. At harvest, the maximum number of tiller hill^{-1} (14.0) was obtained from F_2 (RFD of NPKS with Zn & B as basal). The minimum tiller number hill^{-1} (6.63, 11.33 and 9.50) was at 50, 75 DAT and harvesting respectively obtained from control situation (F_1). The maximum leaf area index (2.50 and 5.8) at 50 and 75 DAT respectively was obtained from RFD with Zn & B as foliar spray at anthesis (F_4) and 50% RFD + 50% organic manure + Zn & B as foliar spray at

anthesis (F_6). The minimum leaf area index (1.0 and 4.41) from control (F_1) and 50% RFD + 50% organic manure (cowdung) (F_5) respectively. The higher number of effective tillers hill^{-1} (13.0) was recorded from RFD of NPKS with Zn & B as basal (F_2) which was statistically similar with RFD with Zn as foliar spray (F_3) and RFD with Zn & B spray at anthesis (F_4) respectively. Whereas the lower number of effective tillers hill^{-1} (9.17) from control (no fertilizer) (F_1). The maximum number of filled grains panicle^{-1} (112.83) was recorded from 50% RFD + 50% organic manure + Zn & B as basal (F_7). Whereas the minimum number of filled grains panicle^{-1}(92.33) from 50 % RFD + 50% organic manure + Zn & B as foliar spray (F_6). The higher weight of 1000 grains (23.58 g) was recorded from RFD with Zn & B as foliar spray at anthesis (F_4). Whereas the minimum weight of 1000 grains was (20.57 g) from control (no fertilizer) (F_1). The maximum grain yield (7.67 t/ha) was recorded from RFD with Zn & B as foliar spray at anthesis (F_4). Whereas the minimum grain yield was (4.40 t ha^{-1}) from control (F_1). The maximum straw yield (7.48 t ha^{-1}) was recorded from RFD with Zn as foliar spray at anthesis (F_3) which was statistically similar with RFD of NPKS with Zn & B as basal and minimum straw yield (6.37 t ha^{-1}) was recorded from 50% RFD + 50% organic manure + Zn & B as basal (F_7). The maximim biological yield (14.85 t ha^{-1}) was obtained from RFD with Zn & B spray at anthesis (F_4) and minimum biological yield (11.91 t ha^{-1}) was recorded from 50% RFD + 50% organic manure + Zn & B as basal. The highest harvest index (51.69 %) was recorded from RFD with Zn & B as foliar spray at anthesis (F_4) and the minimum harvest index (39.05 %) was recorded in control (F_1).

The interaction of variety and fertilizer managements had significant effect on all growth and yield contributing characters except number of ineffective tillers hill^{-1} and leaf area index (LAI) at 50 DAT. At 25 DAT, the highest plant height (19.07 cm) was obtained from BRRI dhan89 by 50% RFD + 50% organic manure (cowdung) (V_2F_5). At 50 DAT, the highest plant height (43.25 cm) from BRRI dhan84 by RFD with Zn & B as foliar spray at anthesis (V_1F_4). At

75 DAT, the highest plant height (77.99 cm) from BRRI dhan84 with control (V_1F_1). At harvest, the highest plant height (103.05 cm) from BRRI dhan89 with RFD with Zn & B as foliar spray at anthesis (V_2F_4) . The lowest plant height (15.81 cm, 30.89 cm, 61.44 cm) at 25, 50, 75 DAT respectively was obtained from BRRI dhan89 with control (V_2F_1) and at harvest the lowest plant height was obtained from BRRI dhan84 with control (V_1F_1). The highest number of tillers hill^{-1} (16.00) at harvest was obtained from BRRI dhan84 by 50% RFD + 50% organic manure (V_1F_5) which statistically similar with V_1F_2 (BRRI dhan84 by RFD of NPKS with Zn & B as basal) but at 25 DAT, the highest tiller number (3) was obtained from BRRI dhan84 with (V_1F_5) which was statistically similar with V_1F_1 and V_1F_2 . The lowest tiller number hill^{-1} (1.67, 6.33) was at 25 and 75 DAT obtained from V_2F_7 (BRRI dhan89 by 50% RFD + 50% organic manure + Zn & B as basal) and (V_2F_1) BRRI dhan89 with control respectively. The higher number of effective tillers hill^{-1} (14.00) was recorded from BRRI dhan84 with RFD of NPKS with Zn & B as basal (V_1F_2) which was statistically similar with BRRI dhan89 by control (V_2F_1). The higher 1000-grain weight (23.83 g) recorded from BRRI dhan89 by 50% RFD + 50% organic manure + Zn & B as foliar spray (V_1F_6) and lowest 1000-grain weight 19.80 g) recorded from BRRI dhan84 by control (V_1F_1). The higher grain yield (7.80 t ha^{-1}) was recorded from BRRI dhan89 by RFD with Zn & B as foliar spray at anthesis (V_2F_4). Whereas the lowest grain yield (4.36 t ha^{-1}) was from BRRI dhan84 by control (V_1F_1) which was statistically similar with BRRI dhan89 with control (V_2F_1).

Considering the facts of the present experiment, the following conclusions may be drawn-

- BRRI dhan89 performed better and recorded the higher filled grains per panicle (116.14), rachis branch panicle^{-1} (10.78), 1000-grain weight (22.34 g), grain yield (6.42 t ha^{-1}), straw yield (7.25 t ha^{-1}) and biological yield (13.66 t ha^{-1}).

- In case of fertilizer management, foliar spray of zinc and boron at anthesis with recommended doses of NPKS showed the best performance having the highest rachis branch panicle^{-1} (9.33), grain yield (7.67 t ha^{-1}), 1000-grain weight (23.58 g), biological yield (14.85 t ha^{-1}) and harvest index (51.29%).

- Foliar application of Zn & B along with recommended doses of NPKS (V_2F_4) as basal dose in BRRI dhan89 resulted the best performance having grain yield of 7.8 t ha^{-1}.

However, to reach a specific conclusion and recommendation, experiments with different levels of other micronutrients needed to be repeat with more varieties and in different Agro- ecological zones of Bangladesh.

REFERENCES

Afroz, R., Salam, M. and Begum, M. (2019). Effect of weeding regime on the performance of boro rice cultivars. *J. Bangladesh Agric. Univ*. **17**(3): 265-273.

AIS (Agricultural Information Service). (2011). Krishi Diary (In Bangladesh). Agril. Inform. Ser. Khamarbari, Farmgate, Dhaka, Bangladesh. p. 23.

Akter, M. S., Yeasmin, S. and Hasan, A. (2018). Effect of integrated nitrogen application on the yield of two Boro rice varieties: BRRI dhan29 and BRRI dhan74. *Arc. Agric. Environ. Sci*. **3**(4): 410-415.

Alam, M. M., Ali, M. H., Hasanuzzaman, M., Nahar, K. and Islam, M. R. (2009). Dry matter partitioning in hybrid and inbred rice varieties under variable doses of phosphorus. *Int. J. Sust. Agric*. **1**: 10-19.

Ali, S., Raza, S. A., Butt, S. J. and Sarwar, Z. (2016). Effect of foliar boron application on rice growth and final crop harvest. *Agric. Food Sci. Res*. **3**(2): 49–52.

Amin, M., Ayaz, M. K., Ejaz, A. K. and Ramzan, M. (2004). Effect of increased plant intensity and fertilizer doze on yield of rice variety (IRRI-6). *J. Res. Sci*. **15**: 9- 16.

Arif, M., Shehzad, M. A. Bashir, F., Tasneem, M., Yasin, G. and Iqbal. M. (2012). Boron, zinc and microtone effects on growth, chlorophyll contents and yield attributes in rice (*Oryza sativa* L.) cultivar. *African J. Biotech*. **11**(48): 10851- 10858.

Aslam, M., Mahmood, I. H., Qureshi, R. H., Nawaz, S. and Akhtar, J. (2002). Salinity tolerance of rice as affected by boron nutrition. *Pakistan J. Soil Sci*. **21**: 110- 118

Bashar, M. K. and Miah, M. A. H. (2016). Nutritional security through biofortified zinc rice. The Daily Star Newspaper, 04 February, 2016.

BBS. (2021). Statistical yearbook of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Govt. of Peoples Republic of Bangladesh. pp. 33-43.

BER. (2016). Bangladesh Economic Review, Department of Finance, Ministry of Finance, Government of Bangladesh, Dhaka, Bangladesh.

Bolanos, L., Lukaszewski, K., Bonilla, I. and Blevins, D. (2004). Why Boron? *Plant Physiol. Biochem*. **42**: 907-912.

Bouis, H. E. and Welch, R. M. (2010). Biofortification – A sustainable agricultural strategy for reducing micronutrient malnutrition in the global South. *Crop Sci*. **50**(S1): S-20–S-32.

Chamely, S. G., Islam, N., Hoshain, S. Rabbani, M. G., Kader, M. A. and Salam, M. A. (2015). Effect of variety and nitrogen rate on the yield performance of boro rice. *Prog. Agric*. **26**(1): 6-14.

Chowhan, S., Hoque, M. I., Rani, G. S., Islam, M. and Akter, M. B. (2019). Effect of variety and seedling number on the rowth and yield of Boro rice in Bangladesh. *J. Exp. Agric. Int*. **41**(6): 1-15.

Dao, T. H. and Cavegelli, M. A. (2003). Mineralization carbon, nitrogen and water extractable phosphorous release from composted manure and manure amended soils. *Agron. J*. **95**: 405-413.

Diaz, S. H., Castro, R. and Morejon, R. (2000). Morpho-agronomic characterization of varieties of rice. Instituto Nacional de ciencias Agricolas, Gaveta Postall, San Jose, De las, Lajsa, La Habna. **21**(3): 81-86.

Dunn, D., Stevens, G. and Kendig, A. (2005). Boron fertilization of rice with soil and foliar applications. *Plant Manag. Network*. **1**: 1-7.

FAO and World Bank population Estimates. (2020). Population density- Bangladesh. https://data.worldbank.org/

FAO (Food and Agriculture Organization). (2021). Retrieved from: http://www.fao.org/faostat/en/#data/QCL.

Fukagawa, N. K. and Ziska, L. H. (2019). Rice: Importance for global nutrition. *J. Nutr. Sci. Vitaminol* (Tokyo). **65**: S_2-S_3. doi: 10. 3177/ jnsv. 65.S_2.. PMID: 31619630

Garg, O., Sharma, A. and Kona, G. (1979). Effect of boron on the pollen vitality and yield of rice plants (*Oryza stativa* L. var. Jaya). *Plant Soil*. **52**: 951– 594.

Hafiz, A. S. M. R. B. (2017). Influence of foliar boron application on improvement of yield of hybrid rice. M.S. Thesis, Dept. Agronomy, Sher-e-Bangla Agril. Univ., Dhaka, Bangladesh.

Haq, M. T., Sattar, M. A., Hossain, M. M. and Hasan, M. M. (2002). Effects of fertilizers and pesticides on growth and yield of rice. *Online J. Biol. Sci.* **2**(2): 84-88.

Hasan, M.N., Bari, M.A. and Lutfar, M.R. (2020). Soil Fertility Trends in Bangladesh 2010 to 2020. SRSRF project. Soil Resource Development Institute, Ministry of Agriculture, Dhaka, Bangladesh. pp. 58-66.

HIES (Household Income and Expenditure Survey). (2010). Bangladesh Bureau of Statistics, Government of Bangladesh, Dhaka.

Hossain, M. E., Haque, A. N. A., Haque, M. E. and Lee, H. (2016). Performance and productivity of boro rice varieties cultivated in saline area of Satkhira. *J. Biosci. Agric. Res*. **8**(2): 726-733.

Hussain, M., Khan, M. A., Khan, M. B., Farooq, M. and Farooq, S. (2012). Boron application improves the growth, yield and net economic return of rice. *Rice Sci*. **19**: 259–262.

IRRI (International Rice Research Institute). (2000). Nutritional disorders and nutrient management in rice. Int. Rice Res. Ins. Manila, Philippines.

Islam M. S., Howlader M. I. A., Rafiquzzaman S., Bashar H. M. K. and Al-Mamun M. H. (2008). Yield response of chilli and T. Aman Rice to NPK fertilizers in Ganges Tidal Floodplain. *J. Soil. Nature*. **2**(1): 07-13.

Islam, M. R. (2015). Effect of boron and zinc on the growth and yield of t. Aman rice (BRRI dhan34). M. S. Thesis, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka− 207, Bangladesh.

Islam, M. R., Riasat, T. M. and Jahiruddin, M. (1997). Direct and residual effects of S, Zn and B on yield, nutrient uptake in a rice-mustard cropping system. *J. Indian Soc. Soil Sci*. **45**(10): 126-129.

Islam, M. S. (2008). The Status of Soil fertility in Bangladesh: Past, Present and Future Scenario. Presentation at the IPI-BFA-BRRI International Workshop. 30 March-01 April, 2008.

Jahiruddin, M. and Islam, M.R. (2014). Project Report (2011-2014). Requirement of micronutrients for crops and cropping patterns. PIU-BARC (NATP Phase-I) project. Project ID No. 339.

Kader, M. A., Biswas, P. S., Aditya, T. L., Anisuzzaman, M., Hore, T. K. and Haq, M. E. (2020). Zinc enriched high yielding rice variety BRRI dhan84 for dry season rice growing areas of Bangladesh. *Asian Plant Res. J.* **6**(1): 6-13.

Kamal, M. M. Anwar, M. P., Alam, F. and Hossain, S. M. A. (2007). Performance of modern boro rice varieties under different planting methods. *J. Bangladesh Agril. Univ*. **5**(1): 43-47.

Khatun, S., Mondal, M. M. A., Khalil, M. I., Roknuzzaman, M. and Mollah, M. M. I. (2020). Growth and yield performance of six aman rice varieties of Bangladesh. *Asian Res. J. Agric*. **12**(2): 1-7.

Kumar, M. B. M., Subbarayappa, C. T. and Ramamurthy, V. (2017). Effect of Graded Levels of Zinc and Boron on Growth, Yield and Chemical Properties of Soils under Paddy. *Int. J. Cur. Micro. App. Sci*. **6**(10): 1185-1196.

Latif, A., Islam, M., Hasan, A., Salam, M., Rahman, A. and Zaman, F. (2020). Effect of source of irrigation water on yield performance of Boro rice. *Arc. Agric. Environ. Sci*. **5**(3): 254-260.

Mahmud, A. H. (2017). Effect of Zn, B and Cu on the yield and quality of boro rice (BRRI dhan28). M. S. Thesis, Dept. Soil sci., Sher-e-Bangla Agril. Univ., Dhaka, Bangladesh.

Mannan, M. A., Kamal, A. M. A. and Islam, M. R. (2000). Effect of manure and fertilizer on growth, yield and protein content of transplant aman rice. Bangladesh *J. Train. Dev*. **13**(1-2): 203-210.

Moradi, S. and Jahanban, L. (2018). Salinity stress alleviation by Zn as soil and foliar applications in two rice cultivars. *Comm. Soil Sci. Plant Analysis*. **49**(20): 2517–2526.

Murshida, S., Uddin, M. R., Anwar, M. P., Sarker, U. K., Islam, M. M. and Haque, M. M. I. (2017). Effect of variety and water management on the growth and yield of Boro rice. *Progress. Agric*. **28**(1): 26-35.

Ndaeyo, N. U., Iboko, K. U., Harry, G. I. and Edem, S. O. (2008). Growth and yield performances of some upland rice (*Oryza sativa* L.) cultivars as influenced by varied rates of NPK (15:15:15) fertilizer on an ultisol. *J. Trop. Agric. Food. Env. Ext*. **7**(3): 249-255.

Neue, H. U. and Lantin, R. S. (1994). Micronutrient toxicities and deficiencies in rice. In. AR Yeo, T.J. Flowers, (Ed), Soil Mineral Stresses: Approaches to Crop Improvement. Springer-Verlag, Berlin. pp. 175–200.

Paul, S. K., Jisan, M. T. and Salim, M. (2014). Yield performance of some transplant aman rice varieties as influenced by different levels of nitrogen. *J. Bangladesh Agril. Univ*. **12**(2): 321-324.

Phaev, S., Bell, R. W., White, P. F. and Kirk, G. J. D. (2003). Fate of applied fertilizer phosphorous in a highly weathered sandy soil under lowland rice cropping and its residual effect. *Field Crops Res*. **81**: 1-16.

Podder, S. (2017). Response of boro rice to foliar spray of zinc and boron. M.S. Thesis, Dept. Agronomy, Sher-e-Bangla Agril. Univ., Dhaka, Bangladesh.

Rahman, M. N., Islam, M. B., Sayem, S. M., Rahman, M. A. and Masud, M. M. (2007). Effect of different rates of sulphur on the yield and yield attributes of rice in old Brahmaputra floodplain soil. *J. Soil. Nature*. **1**(1): 22-26.

Rahman, M. S., Islam, M. R., Rahman, M. M. and Hossain, M. I. (2009). Effect of cowdung, poultry manure and urea-N on the yield and nutrient uptake of BRRI dhan29. *Bangladesh Res. Pub. J.* **2**: 552-558.

Rahman, M. R. and Bulbul, S.H. (2014). Effect of alternate wetting and drying (AWD) irrigation for Boro rice cultivation in Bangladesh. *Agric. Forest. Fish*. **3**(2): 86.

Rahman, A., Farooq, M., Cheema, A., Nawaz, A. and Wahid, A. (2014). Foliage applied boron improves the panicle fertility, yield and biofortification of fine grain aromatic rice. *J. Soil Sci. Plant Nutr*. **14**(3): 723-733.

Rahman, S., T. Ahmed, R. Ahmed, N. Alam, A.M.S. Ahmed, S. Ireen, I. Chowdhury, F. Chowdhury and S.M. Rahman. (2016). Status of zinc nutrition in Bangladesh: The underlying associations, *J. Nutr. Sci*. **5**. 1-9. doi. 10.1017.jns.2016.17.

Rahman, A., Salam, M., Kader, M., Islam, M. and Perveen, S. (2020). Growth and yield of boro rice (Oryza sativa L.) in response to crop establishment methods and varieties. *Arc. Agric. Environ. Sci*. **5**(2): 137-143.

Rasheed, M., Asif, M. and Ghafoor, A. (2003). Yield and yield attributes of fine rice BAS-385 as affected by different NP levels on farmer's field. *Pak. J. Agric. Sci*. **40**: 1-2.

Reddy, B., Umesha, C., kiran, P. and Reddy, D. (2020). Effect of Zinc and Boron levels on growth, yield and economics of Rice (*Oryza sativa* L.) var. Shiats dhan-1. *Int. J. Curr. Micro. App. Sci*. **9**(12): 826-832.

Saha, P. K., Saleque, M. A., Panaullah, G. M. and Miah, M. M. A. (2004). Comparison of the fertilizer recommendation models for low land rice. *Bangladesh J. Soil Sci*. **30**(1-2): 31-37.

Saitoh, K., Kuroda,T. and Kumano, S. (2001). Effect of organic fertilization and pesticide application on growth and yield of field- grown rice for 10 years. *Japanese J. Sci*. **70**(4): 530-540.

Saleque, M. A., Abedin, M. J., Bhuiyan, N. I., Zaman, S. K. and Panaullah, G. M. (2004). Long-term effects of inorganic and organic fertilizer sources on yield and nutrient accumulation of low land rice. *Field Crops Res*. **86**(1): 53-56.

Saleque, M. A., Choudhury, N. N., Karim, S. M. R. and Panaullah, G. M. (2005). Mineral nutrition and yield of four rice genotypes in the farmers' fields of salt affected soils. *J. Plant Nutri*. **28**(5): 865–875.

Shafiq, M. and Maqsood, T. (2010). Response of rice to model based applied boron fertilizer. *J. Agric. Res*. **48**(3): 37-48.

Shamsuddin, A. M., Islam, M. A. and Hossain, A. (1998). Comparative studies on the yield and agronomic characters of nine cultivars of Aus rice. *Bangladesh J. Agril*. **15**(1): 121-124.

Singh, S. and Gangwar, B. (1989). Comparative studies on production potentials in traditional tall and improved rice cultivars. *J. Andaman Sci. Assoc*. **5**(1): 81- 82.

Singh, V. K., Dwivedi, B. S., Shukla, A. K. and Yadav, R. L. (2003). Effects of nitrogen and phosphorus fertilization on the growth and yield of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) as influenced by the inclusion of forage cowpea (*Vigna unguiculata*) in rice-wheat system. *Indian J. Agril. Sci*. **73**(9): 482-489.

Singh, V., Singh, V., Singh, S. and Khanna, R. (2020). Effect of zinc and silicon on growth and yield of aromatic rice (*Oryza sativa*) in north-western plains of India. *J. Rice Res. Dev*. **3**(1): 82–86.

Tyeb, A., Paul, S. K. and Samad, M. A. (2013). Performance of variety and spacing on the yield and yield contributing characters of transplanted aman rice. *J. Agro. Environ*. **7**(1): 57–60.

Tripathy, R. K., Pandey, N., Mishra, P. K. and Rajput, R. S. (2004). Branching behavior and production of chickpea as influenced by residual effect of cowdung blended nutrients applied to hybrid rice and direct application of nutrients to chickpea under hybrid rice- chickpea cropping system. *Indian J. Agril. Sci*. **79**(5): 262-269.

Ullah, S. S., Amin, R. A. K. M., Roy, T. S., Mandal, M. S. H. and Mehraj, H. (2016). Effect of nitrogen sources for spikelet sterility and yield of boro rice varieties. *Adv. Plants Agric. Res*. **5**(5): 614-622.

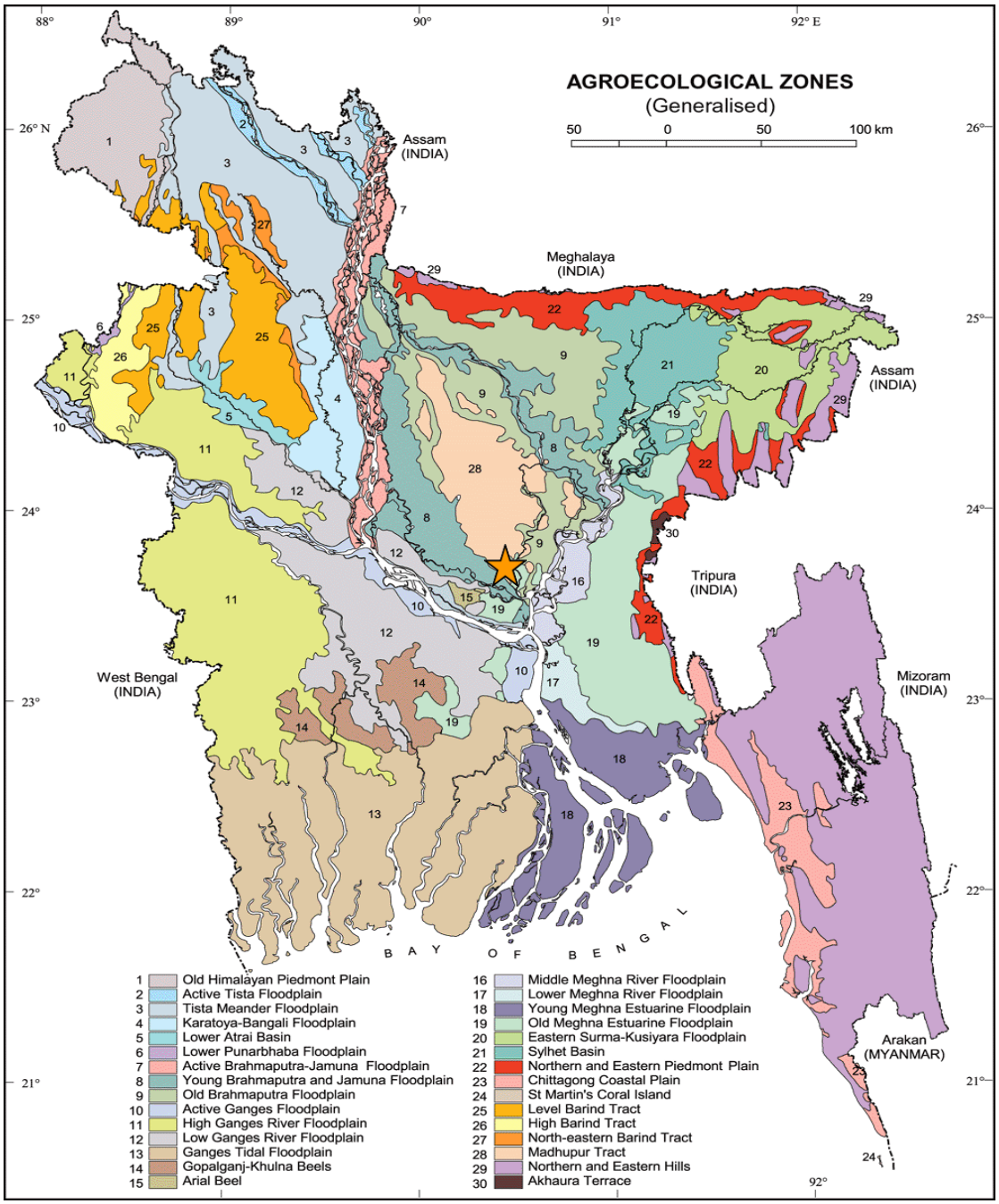
Wu-YuQiu, Fu-LiDong, Zhao-Li and Zhang-LiYun (2013). Effect of nitrogen application on growth characters and yield of new rice variety Fuyou 33. Liaoning, China. *J. North Rice Office*. **43**(3): 25-28.

Yu, X. and Bell, P. F. (1998). Nutrient deficiency symptoms and boron uptake mechanisms of rice. *J. Plant Nutr*. **21**: 2077-2088.

Zhang, W., Liu, D. Y., Li, C., Cui, Z. L., Chen, X. P., Russell Y. and Zou, C. Q. (2015). Zinc accumulation and remobilization in winter wheat as affected by phosphorus application. *Field Crops Res*. **184**: 155-161.

APPENDICES

Appendix I. Map showing the experimental sites under study



★ **The experimental site under study**

Appendix II. Layout of the experiment

R1

V_2F_1	V_2F_5	V_2F_2	V_2F_4	V_2F_6	V_2F_3	V_2F_7
V_1F_5	V_1F_6	V_1F_7	V_1F_3	V_1F_2	V_1F_4	V_1F_1

0.6 m

R2

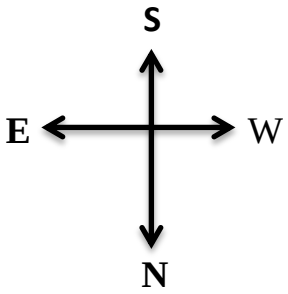
V_2F_4	V_2F_3	V_2F_5	V_2F_1	V_2F_7	V_2F_2	V_2F_6
V_1F_2	V_1F_1	V_1F_4	V_1F_7	V_1F_3	V_1F_6	V_1F_5

R3

V_1F_6	V_1F_4	V_1F_3	V_1F_5	V_1F_1	V_1F_7	V_1F_2
V_2F_3	V_2F_7	V_2F_6	V_2F_2	V_2F_4	V_2F_1	V_2F_5

Plot to plot 0.6 m

plat size = 3x1.6 m^2



Appendix III. Means square values for plant height of boro rice at different days after transplanting

Sources of variation	Degrees of freedom	Mean square values at			
		25 DAT	50 DAT	75 DAT	At harvest
Replication	2	7.44	5.15	36.2618	6.45056
Variety (VAR)	1	2.78^{NS}	129.485^{NS}	855.638^{NS}	25.0252^{NS}
Error(I)	2	8.89	6.01	63.3133	27.1761
Fertilizer Management (FM)	6	3.511^{NS}	69.732*	64.9403^{NS}	155.968*
VAR × FM	6	2.51^{NS}	4.03*	29.8384*	9.99780*
Error(II)	24	4.58	5.71	89.8911	13.0069

NS = Non significant
* Significant at 5% level

Appendix IV. Means square values for number of tillers hill^{-1} of boro rice at different days after transplanting

Sources of variation	Degrees of freedom	Mean square values at			
		25 DAT	50 DAT	75 DAT	At Harvest
Replication	2	1.50000	1.45238	6.16667	20.3095
Variety (VAR)	1	1.92857^{NS}	17.3571^{NS}	0.214286^{NS}	69.4286^{NS}
Error(I)	2	0.714286	3.07143	0.500000	5.21429
Fertilizer Management (FM)	6	0.555555*	13.5238*	2.53968^{NS}	16.0952*
VAR × FM	6	0.206349*	1.96825*	8.82540*	5.65079*
Error(II)	24	0.202381	1.31746	6.11111	2.87302

NS = Non significant
* Significant at 5% level

Appendix V. Means square values for leaves area index (LAI) of boro rice at different days after transplanting

Sources of variation	Degrees of freedom	Mean square values at	
		50 DAT	75 DAT
Replication	2	0.310550	0.164531
Variety (VAR)	1	1.18339 ^{NS}	0.737525 ^{NS}
Error(I)	2	0.115786	2.74136
Fertilizer Management (FM)	6	1.57034*	1.33317 ^{NS}
VAR × FM	6	0.172754*	1.15469 ^{NS}
Error(II)	24	0.121512	5.71597

NS = Non significant
* Significant at 5% level

Appendix VI. Means square values for SPAD value of boro rice at different growth stages

Sources of variation	Degrees of freedom	Mean square values at	
		50 DAT	75 DAT
Replication	2	1.36	0.49
Variety	1	5.11 ^{NS}	12.92 ^{NS}
Error(I)	2	2.60	2.19
Fertilizer management (FM)	6	4.53*	5.3*
VAR × FM	6	2.84*	2.38*
Error(II)	24	4.18	3.17

NS = Non significant
* Significant at 5% level

Appendix VII. Means square values for effective tiller numbers hill^{-1} of boro rice

Sources of variation	Degrees of freedom	Mean square values	
		No. of effective tillers hill^{-1}	No. of ineffective tillers hill^{-1}
Replication	2	9.92857	2.16667
Variety (VAR)	1	17.3571 ^{NS}	14.8810 ^{NS}
Error(I)	2	2.78571	1.73810
Fertilizer Management (FM	6	13.0556 ^{NS}	0.968254 *
VAR × FM	6	3.80159 *	1.38095 ^{NS}
Error(II)	24	3.35714	1.17460

NS = Non significant
* Significant at 5% level

Appendix VIII. Means square values for number of rachis branches panicle^{-1} and panicle length of boro rice at harvest

Sources of variation	Degrees Of freedom	No. of rachis branches panicle^{-1}	Panicle length
Replication	2	0.714	1.31
Variety	1	100.59 *	5.61 ^{NS}
Error(I)	2	0.88	1.59
Fertilizer Management (FM)	6	1.49 *	0.93*
VAR × FM	6	0.31*	0.70*
Error(II)	24	0.642	0.73

NS = Non significant
* Significant at 5% level

Appendix IX. Means square values for number of filled grain, unfilled grains panicle^{-1} and 1000-grain weight of boro rice

Sources of variation	Degrees of freedom	No. of fi 71 grains panicle^{-1}	No. of unfilled grains panicle^{-1}	1000-grain weight
Replication	2	360.16	24.07	1.36
Variety	1	7466.67 *	30.85 ^{NS}	5.07 ^{NS}
Error(I)	2	101.73	9.5	3.01
Fertilizer Management (FM)	4	309.07*	68.54*	7.73*
VAR× FM	4	162.77*	46.57*	3.82*
Error(II)	16	290.45	27.81	1.52

NS = Non significant
* Significant at 5% level

Appendix X. Means square values for grain and straw yield of boro rice

Sources of variation	Degrees of freedom	Grain yield	Straw yield
Replication	2	0.32	1.35
Variety	1	1.98 ^{NS}	2.91 ^{NS}
Error(I)	2	0.326	3.34
Fertilizer Management (FM)	6	6.67*	0.90*
VAR × FM	6	0.107*	0.224*
Error(II)	24	0.114	0.285

NS = Non significant
* Significant at 5% level

Appendix XI. Analysis of variance of the data on biological yield and harvesting index of boro rice

Sources of variation	Degrees of freedom	Biological yield	Harvest Index
Replication	2	1.73	13.43
Variety	1	9.71 ^{NS}	0.74 ^{NS}
Error(I)	2	5.41	22.33
Fertilizer Management (FM)	6	9.8*	95.47*
VAR × FM	6	0.46*	2.38*
Error(II)	24	0.31	6.02

NS = Non significant
* Significant at 5% level

PLATES

Plate-1: Rice seeds soaked into water

BRRI dhan84 BRRI dhan89

Plate-2: Rice seed germination

Plate-3: Seedling stage of tested crops

Plate-4: Final land preparation of experiment field

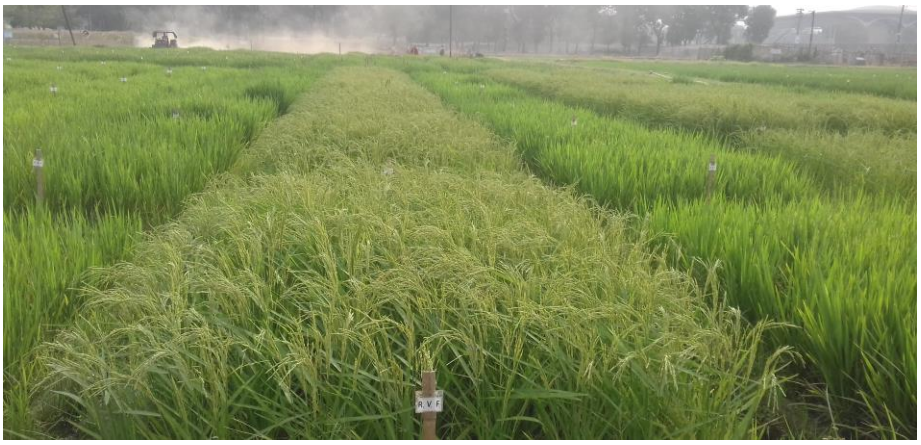


Plate-5: Panicle emergence of boro rice

Plate-6: Experimental field under study at harvest