RESPONSE OF BORO RICE TO FOLIAR SPRAY OF ZINC AND BORON

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RESPONSE OF BORO RICE TO FOLIAR SPRAY OF ZINC AND BORON

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CERTIFICATE

This is to certify that the thesis entitled ***"RESPONSE OF BORO RICE TO FOLIAR SPRAY OF ZINC AND BORON "****submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGRONOMY,*** *embodies the result of a piece of bona fide research work carried out by* ***SUBROTA PODDER, Registration No. 16-07560*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:

Dhaka, Bangladesh

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Prof. Dr. Md. Fazlul Karim

Supervisor

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Abstract

The field experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from November 2016 to May, 2017 to find out the response of boro rice to foliar spray of zinc and boron. Treatment were T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF. The experiment was laid out in a Randomized complete Block Design (RCBD) with three replications. Data on different growth, yield and yield contributing parameters were recorded. The highest plant height (12.39, 31.12, 44.38, 59.47 and 103.34 cm at 15, 30, 45, 60 DAT and at harvest, respectively) was obtained from T_{11} [B (1.5%) FS at TI + RF] where the lowest plant height (13.18, 24.40, 33.53, 44.94 and 78.59 cm at 15, 30, 45, 60 DAT and at harvest, respectively) was found from T_1 (Recommended Fertilizer (RF)). The highest LAI (0.78, 0.85, 0.1.32, 3.00, 3.49 cm^2) and at harvest, respectively) was obtained from the treatment T_{11} [B (1.5%) FS at TI + RF] and the lowest was found in (0.74, 0.79, 1.10, 2.24, 2.58 cm^2) at 15, 30, 45, 60 DAT and at harvest, respectively) was found from T_1 (Recommended Fertilizer (RF)). The highest number of effective tillers $hill^{-1}$ (15.13), panicle length (27.86 cm) and filled grains $panicle^{-1}$ (155.52) was obtained from T_{11} [B (1.5%) FS at TI + RF] whereas the lowest was found from T_1 (Recommended Fertilizer (RF)). The maximum days to panicle initiation, days to flowering and days to maturity (79.67, 117.67 and 152.67 days) was obtained from T_{11} [B (1.5%) FS at TI + RF] the lowest was found from the treatment T_1 (Recommended Fertilizer (RF)). The highest grain yield, straw yield, biological yield and harvest Index (7.10 t ha^{-1}, 7.61 t ha^{-1}, 14.71 t ha^{-1} and 48.26) was obtained from the treatment T_{11} [B (1.5%) FS at TI + RF] where the lowest was found from the treatment T_1 (Recommended Fertilizer (RF)). From the above findings, it may be concluded that among the treatment T_{11} [B (1.5%) FS at TI + RF] performed the best results. So, the treatment T_{11} [B (1.5%) FS at TI + RF] showed the superior combination compared to other treatment combinations for rice production.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I
INTRODUCTION

Rice is the staple food of more than half of the world's population. More than 3.5 billion people depend on rice for more than 20% of their daily calories. Rice provided 19% of global human per capita energy and 13% of per capita protein. Rice production is one of the most important economic activities on Earth. Asia accounts for 90% of global rice consumption and total rice demand (GRiSP, 2013). Rice grain contains 80% carbohydrate, 7.1% protein, 0.66% fat, 0.12% sugar, 1.3% dietary fiber and sufficient amount of minerals for human diet. It is rich in potassium (115 mg 100^{-1} g), phosphorus (115 mg $100g^{-1}$), magnesium (25 mg $100g^{-1}$), calcium (28 mg $100g^{-1}$), iron (4.31 mg 100^{-} g^{1}), and other minerals (USDA, 2012). Rice is the single most important source of employment and income for rural people. Rice is grown on some 144 million farms, mostly smaller than 1 hectare holding by the marginal farmers (GRiSP, 2013).

In Bangladesh, rice covered an area of 11.53 million ha with a production of 33.54 million M tons while the average yield of rice in Bangladesh is around 2.92t ha^{-1} (BBS, 2014). In case of boro rice, it covers the largest area of 11788 hectare (41.38% of total rice cultivation area) with a production of 1.86 million tons (55.50%) and the average yield is about 2.91 t ha^{-1} during 2010–11 (BBS, 2011). Besides, based on the rice cultivation, Bangladesh is the 5th largest country of the world (BBS, 2014). Alam *et al.* (2012) reported that rice covers about 82% of the total cropped land of Bangladesh. It accounts for 92% of the total food grain production in the country and provides more than 50% of the agricultural value addition employing about 44% of total labour forces. According to the latest estimation made by BBS, per capita rice consumption is about 166 kg $year^{-1}$. Though the yield harvest from HYVs is greater than local verities still comparable lower than other rice growing countries. These might have many reasons behind. Of all the micro nutrients like zinc and boron deficiency field is to be considered deeply.

Zinc (Zn) is a micronutrient element whose normal concentration range is 25 to 150 ppm in plants. Deficiencies of Zn are usually associated with concentrations of less than 20 ppm, and toxicities will occur when the Zn leaf concentration exceeds 400 ppm (Tisdale *et al.*, 1997). Cultivars differ in their ability to take up Zn, which may be caused by differences in zinc translocation and utilization, differential accumulation of nutrients that interact with Zn and differences in plant roots to exploit for soil Zn (Tisdale *et al.,* 1997). Zinc interacts with both the macro and micro nutrients. Kumar *et al*. (1997) reported that application of 10 µg Zn/g soil along with 200 µg N/g soil increased the dry matter yield of pearl millet. They further reported that application of heavy doses of Zn (20µg Zn/g soil) might decrease the N content which in addition deteriorate the yield and quality of grains and fodder in pearl millet. Similar increases due to Zn application in dry matter and grain yields in different crops have also been reported by Kumar *et al.* (1981). The interaction of zinc (Zn) and phosphorous (P) is usually designated as a P-induced deficiency, the possible causes of which are: i. slower rate of translocation of zinc from the roots to the tops (Loneragan, 1951), ii. a simple dilution effect on the zinc concentration in the tops due to growth response of Phosphorus (Watanabe,1965), iii. difference in the distribution of zinc between roots and tops (Carroll and Loneragan, 1968), iv. physiological effects like phosphorus interference in the utilization of zinc by plant and v. precipitation of zinc by phosphorous in the venis and conducted tissues (Biddulph, 1953).

The functions of boron (B) in rice plants are to promote cell growth and development of the panicle (Garg *et al*., 1979). Boron (B) is responsible for better pollination, seed setting and grain formation in different rice varieties (Aslam *et al*., 2002, Rehman *et al*., 2012), making it more important during the reproductive stage as compared to the vegetative stage of the crop and found 90% of the boron in plants is localized in the cell walls (Loomis and Durst, 1992). B deficiency symptoms in rice begin with a whitish discoloration and twisting of new leaves (Yu and Bell, 1998). Severe deficiency symptoms from rice include thinner stems, shorter and fewer tillers, and failure to produce viable seeds. Boron deficient stems and leaves were found to be brittle while boron sufficient leaves and stems are flaccid. Declining productivity trends in rice growing countries are due to the micronutrient deficiencies (Savithri *et al*., 1999). Boron deficiency is of particular importance since it affects the flowering and plant reproductive process and therefore directly affects harvested yield (Bolanos *et al*., 2004). The amount of protein and soluble nitrogenous compounds are lower in B deficient plants (Gupta, 1993). Boron can be satisfactorily applied to the soil to provide season long elevation of the B status of a crop.

Furthermore, it is an economical way of supplementing the plant's nutrients when they are in short supply or unavailable form in the soils and it has been shown that the efficiency of foliar application is three to five folds greater than soil-applied fertilizers, and can thus significantly reduce the amount of fertilizer usage (Jamal *et al.,* 2006). Foliar application of rice could be an approach to improve rice yield which is vary scantly in our country. This the present experiment is taken with following objectives:

OBJECTIVES:

1. To study the effects of Zn and B as foliar spray on the growth and yield of boro rice.
2. To determine the spraying concentration of Zn and B in boro rice.

CHAPTER II

REVIEW OF LITERATURE

Successful production of any crop depends on various activities are done during is life cycle in sexual fertilization is particular. Some of the works related to micronutrient application in rice are noted here.

2.1Effect of Zinc

Debnath *et al*. (2015) was conducted a experiment to predict the responses of rice (*Oryza sativa*) to different levels of boron (B) and zinc (Zn) application. The result showed significance increase in grain and straw yield due to B fertilization. The highest yield response to the tune of 39.25 q/ha grain and 41.25 q/ha straw was recorded with 15 kg level of borax per hectare. Percent increase of grain and straw yield due to 15 kg borax alone over control was found to be 24.52 %and 17.78 % respectively. The soil also showed positive response to different levels of Zn fertilization but maximum response was observed upto 20 kg $ZnSO_4$/ha. Boron and Zn interacted synergistically to boost yield of rice crop resulting in additional yield of 7.1 q/ha of grain and 6.28 q/ha of straw. The increased percent of grain and straw yield of rice with Zn and interaction between B × Zn were 24.87 %,17.67 % and 47.04, 35.72 %, respectively. The boron concentration and uptake in grain and straw of rice also significantly increases with increase in level of borax upto 15 kg/ha and $ZnSO_4$ 10 kg/ha. However, a negative response was also observed in both grain and straw yield at level of 20kg/ha of borax and 30kg/ha of $ZnSO_4$.

Mustafa *et al.* (2011) noted a research to evaluate the effect of different methods and timing of zinc application on growth and yield of rice. Experiment was comprised of eight treatments viz., control, rice nursery root dipping in 0.5 % Zn solution, ZnSO4 application at the rate of 25 kg ha^{-1} as basal dose, foliar application of 0.5 % Zn solution at 15, 30, 45, 60 and 75 days after transplanting. Super Basmati, a promising variety of rice was used as a test crop. Remarkable effects were noted on yield components such as number of productive tillers per hill, kernel per panicle, 1000-kernel weight, biological yield, kernel yield and harvest index. Maximum productive tillers per m^{-2} (249.80) were noted with basal application at the rate 25 kg ha^{-1} 21 % ZnSO4 and minimum (220.28) were recorded with foliar application at 60 DAT @ 0.5 % Zn solution. Zinc application methods and timing had significantly pronounced effect on paddy yield. Maximum paddy yield (5.21 t ha^{-1}) was achieved in treatment Zn_2 (Basal application at the rate of 25 kg ha^{-1}, 21 % ZnSO4) and minimum paddy yield (4.17 t ha^{-1}) was noted in Zn (foliar application at 75 DAT @ 0.5% Zn solution). Zinc application increases the crop growth rate of rice.

Kulandaivel *et al.* (2004) reported that application of 30 kg $ZnSO_4$ along with 5 kg $FeSO_4$ ha^{-1} produced higher tiller m^{-2} and dry matter production on sandy clay loam soil.

Khan *et al.* (2003) was studied comparative effect of three different methods of zinc application aimed at alleviating Zn deficiency in transplanted flood rice (cv.IRRI.6) grown in alkaline calcareous soil. Three methods were tried i.e. nursery root dipping in 1.0% $ZnSO_4$, 0.20% $ZnSO_4$ solution spray after transplanting and 10 kg Zn ha^{-1} by field broad cast method. Zinc content of soil before flowering and after harvest was increased significantly for all the methods. The yield and yield parameters increased significantly by the application of Zn by any method. Among the methods the effect of Zn was non-significant on yield components like tillers m^{-2}, spikelets $panicle^{-1}$, % filled grains, 1000-grain weight and straw yield. However, soil application of Zn @ 10 kg ha^{-1} was rated superior because it produced significantly higher paddy yield.

Karacal and Teceran (1986) reported increased milling recovery from 67 to 70% in rice grain with the application of 60 kg $ZnSO_4$ ha^{-1}. Application of $ZnSO_4$ @ 75 kg ha^{-1} was found to increase the protein content of rice grain significantly in vertisols (Nirmaladevi, 2001).

Saravanan and Ramanathan (1988) noticed significantly increased Zn uptake of rice with the application of $ZnSO_4$ @ 75 kg ha^{-1} in clay loam soil while, higher Zn uptake in rice grain was registered with application of $ZnSO_4$ @ 50 kg ha-1 in red loam soil (Sankaran *et al*., 2001).

Application of $ZnSO_4$ @ 20 kg ha^{-1} showed higher Zn uptake by rice grain and straw in lateritic soil (Das, 1986). But Ramadass *et al.* (1995) reported that with the application of 25 kg $ZnSO_4$ ha^{-1} also gave higher Zn uptake by rice crop in sandy loam soil. Kumar *et al* (1997) reported that two sprays of 0.5% $ZnSO_4$ solution at 3rd and 5th weeks after transplanting resulted in higher Zn uptake by rice. Application of $ZnSO_4$ @ 30 kg ha^{-1} along with 5 kg $FeSO_4$ ha^{-1} on sandy loam soil significantly increased the rice Zn uptake (Kulandaivel *et al.*, 2004).

Kumar *et al* (1997) reported significantly increased grain yield attributes and yield with two sprayings of 0.5% $ZnSO_4$ at 3rd and 5th weeks after transplanting. Significantly higher number of panicles m^{-2}, grains per panicle, panicle weight, grain and straw yields was registered by the application of 30 kg $ZnSO_4$ ha^{-1} along with 5 kg $FeSO_4$ ha^{-1} on sandy clay loam soil (Kulandaivel *et al*., 2004).

Babiker (1986) noted that number of panicles m^{-2}, panicle length, number of filled grains per panicle, 1000-grain weight, panicle weight and grain yield significantly increased with the application of $ZnSO_4$ @ 50 kg ha^{-1} while, significantly increased yield attributes and yield was registered with the application of $ZnSO_4$ @ 30 kg ha^{-1} in sandy loam soil (Pullarao and Shukla, 1996), in red loam soil (Sankaran *et al.*, 2001). Similar result was obtained with 60 kg $ZnSO_4$ ha^{-1} in silty loam soil (Karacal and Teceran, 1986). Application of $ZnSO_4$ @ 25 kg ha^{-1} significantly increased the grain and straw yield in sandy loam soil (Ramadass *et al*., 1995).

Singh *et al.* (1983) conducted similar results with 25 kg ZnSO4 ha^{-1} applied with poultry manure at 50 q ha^{-1}. Significantly increased grain yield was recorded with application of $ZnSO_4$ @ 20 kg ha^{-1} in coastal area of Bhuvaneswar (Katyal and Gangwar, 2000) and in medium black cotton soil (Raju *et al.* 1994).

Tomar *et al.* (1994) reported significantly increased dry matter production was recorded with the application of $ZnSO_4$ @ 7.5 kg ha^{-1} on clay loam soil. Significantly increased plant height was obtained with application of $ZnSO_4$ @ 15 kg ha^{-1} on silt clay loam soil (Chapahle and Badole, 1999).

2.2Effect of boron

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

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

Ali *et al*. (2016) noted an experiment to evaluate the effect of foliar application of B on yield and yield components of rice in calcareous soils with six B foliar application rates (0, 5, 10, 15, 20 and 25 mg L^{-1}). Boron (B) is an essential micro nutrient and its deficiency caused a reduction in final crop harvest and quality of the yield. The results illustrated a significant effect of B foliar application on number of grains $panicle^{-1}$, number of filled grains and final grain yield. The highest grain yield (352 g m^{-2}) was recorded in 20 mg L^{-1} foliar application, whereas an increase in B application to 25 mg L^{-1} reduces the final grain yield significantly (313 g m^{-2}). Detrimental effects of the highest B application on yield components were also observed. The decline in the quantity and quality rice yield resulted by increasing B application might be due to the toxic effect of higher concentration of B application.

Fakir *et al*. (2016) carried out a field study to evaluate the effect of foliar application of boron (B) on the grain set and yield of wheat (cv. Shatabdi). The B treatments were (i) B control, (ii) soil application of B, (iii) seed priming into boric acid solution, (iv) foliar spray of B at primordial stage of crop, (v) foliar spray of B at booting stage and (vi) foliar spray of B at primordial and booting stages. The rate of B for soil application was 1.5 kg B ha^{-1} from boric acid (17% B) and the rate for each foliar spray was 0.4% boric acid solution. The treatment receiving foliar spray of B at both primordial and booting stages of the crop performed the highest yield (3630 kg ha^{-1}) which was statistically similar with the yield recorded with foliar spray of B at booting or primordial stage of crop and with soil application of B before crop (wheat) was sown; all the yields were significantly higher over the yield noted with seed priming or control treatment. The control treatment (no B application) had the lowest grain yield (2600 kg ha^{-1}).

Saleem *et al*. (2010) conducted a field study to evaluate the effectiveness of boron fertilizers borax and colemanite (powder and granular) in supplying B to rice under flooded conditions. Boron application improved all the agronomic growth parameters and increased the yield. Both B fertilizers significantly increased the plant height, panicles/plant, number of grains/panicle and weight of 1000 grains. Both B sources were found equally effective in supplying B to rice crop. Borax gave significantly high yield at 2 kg B/ha and powder colemanite at 3 kg B/ha. Yield difference between borax and powder colemanite was not significant at all three levels. Powder colemanite applied plots had significantly high residual B in compare to borax at 0-15 and 15-30 cm and at 30-45 cm depth borax applied plots had high B content. Granular colemanite application did not significantly increase the crop growth and yield due to the large particle size B so that release was very slow.

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

Khan *et al*. (2007) conducted a field experiment with two treatments *viz*., 1 and 2 kg ha^{-1} with control where basal dose of N, P_2O_5 and K_2O were 120-90-60 kg ha^{-1} respectively. Wheat variety was Naseer-2000 and rice variety was IRRI-6. Boron application significantly affected wheat grain yield that ranged from 2.70 to 3.49 t ha^{-1} giving highest increase of 19.9% over control from 1.0 kg ha^{-1}. The number of tillers m^{-2}, spike m^{-2}, spike length, plant height and 1000-grain weight of wheat were also significantly different from control for the same treatment. Paddy yield was also significantly affected by boron application, which ranged from 3.51 to 6.11 t ha^{-1}. The highest yield was obtained from 2 kg B ha^{-1} when applied to both crops. The number of spikes m^{-2}, spike length, plant height and 1000-grain weight of paddy were significantly affected over control. The direct application of 1 and 2 kg B ha^{-1} gave an increase of 59.6 and 62.1%, cumulative application of 1 and 2 kg B ha^{-1} increased the paddy yield by 61.1 and 74.1%, while residual application of 1 and 2 kg B ha^{-1} increased the yield by 36.8 and 48.8% over control.

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

BRRI (2011) conducted several experiments at Rangpur to study the effect of B and FYM on four HYV rice varieties. They found that application of FYM and B alone increased grain yield in all varieties except BRRI dhan27 than when NPK was applied. A combination of FYM and B encouraged vegetative growth and thereby lowering the harvest index. Vegetative growth of BRRI dhan27 was highly encouraged by FYM and B applied together. They suspected that BRRI dhan27 might be less tolerant to B stress.

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

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

Muralidharan and Jose (1995) carried out a field experiment and observed that rice grain yield increased due to application of B. They observed that rice grain yield was increased by 5% following the application of B to soil and found that B application increased the yield of rice. The application of boron gave grain yield of 2.31 t ha-1 compared with the control yield of 2.07 t ha^{-1}.

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

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

Singh *et al*. (1990) conducted a field trial during 1987-88 at Barapani, Meghalaya to observe the effects of 3, 6 or 9 kg Zn ha^{-1}, 1.5 kg B ha^{-1} or application of Zn + B on yield of rainfed or submerged rice (cv. Nogoba). Zinc and boron application increased rice yield compared with the untreated control. The increase in yield due to B application was 31% higher in submerged than in rainfed conditions. The highest grain yield of 3.66 t ha^{-1} and straw yield of 4.81 t ha^{-1} were obtained from the application of B under submerged condition.

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

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

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

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

CHAPTER III

MATERIALS AND METHODS

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

3.1 Site description

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

3.2 Climate

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

3.3 Soil

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

3.4 Treatments

The following treatments were included in this experiment

T_1 : Recommended Fertilizer (RF)

T_2 : RF+ Foliar spray (FS) with water at tiller initiation (TI)

T_3 : RF + Foliar spray (FS) with water at flowering initiation (FI)

T_4 : Zn (0.2%) FS at TI + RF

T_5 : Zn (0.5%) FS at TI + RF

T_6 : Zn (0.8%) FS at TI + RF

T_7 : Zn (0.2%) FS at FI + RF

T_8 : Zn (0.5%) FS at FI + RF

T_9 : Zn (0.8%) FS at FI + RF

T_{10} : B (0.5%) FS at TI + RF

T_{11} : B (1.5%) FS at TI + RF

T_{12} : B (2.0%) FS at TI + RF

T_{13} : B (0.5%) FS at FI + RF

T_{14} : B (1.5%) FS at FI + RF

T_{15} : B (2.0%) FS at FI + RF

3.5 Plant materials

BRRI dhan29 was used a testing variety. It is a high yielding variety of *boro* rice, was developed by the Bangladesh Rice Research Institute (BRRI). This variety was developed by crossing of BG90-2 and BR 51-46-5 lines and released in 1994. The cultivar BRRI dhan29 matures in 155-160 days. It attains a height of 95-100 cm at maturity. The grain is medium sized and white in colour. The variety gives a grain yield of 7.5 t ha^{-1}. In terms of yield, this is the best modern cultivar so far released by BRRI (BRRI, 2015) and as mega variety seems from the farmers acceptance towards its popularity.

3.6 Seed sprouting

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

3.7 Preparation of nursery bed and seed sowing

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

3.8 Preparation of experimental land

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

3.9 Fertilizer application

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

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

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

3.10 Experimental design and layout

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

3.11 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on November 25, 2016 without causing much mechanical injury to the roots.

3.12 Transplanting of seedlings in the field

The seedlings were transplanted in the main field on 25th November, 2016 with a spacing 20×15 cm as row to row and hill to hill distance, respectively.

3.13 Intercultural operations

The following intercultural operations were done for maintaining the normal growth and development of the crop.

3.13.1 Gap filling

After one week of transplantation, seedlings of some of the hills died off and were replaced by gap filling with healthy seedlings by planting same aged seedlings.

3.13.2 Weeding

The crop was infested with some common weeds, which were controlled by uprooting and remove them three times from the field during the period of experiment. by hand.

The first weeding was done at 30 DAT. The second weeding was done at 50 DAT and the third one at 75 DAT.

3.13.3 Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water up to 6 cm in the early stages to enhance tillering and 10-12 cm in the later stage to discourage late tillering. The field was finally dried out 15 days before harvesting.

3.13.4 Top dressing

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

3.14.5 Plant protection

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

3.14 Sampling, harvesting and processing

The crop was harvested at full maturity. This was the time when about 80% of the seeds became golden yellow in colour. Five hills (excluding border hills) were randomly selected in each plot and uprooted before harvesting for recording the necessary data on various plant characters. The crops were harvested on 25May to 30 May at ripening stage from each plot manually to record the yields of grain and straw. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. The crops were threshed by manually. Grains were sun dried and cleaned. Straws were also sun dried properly. Finally, grain and straw yields were adjusted to 14% moisture and converted to ton per hectare.

3.15 Data collection on growth parameters

Data on plant growth parameters (plant height, tiller hill^{-1}, leaf area and leaf area index) were taken at 15, 30, 45, 60 DAT through destructive sampling in both locations. For growth analysis and estimation of dry matter production, five plants or hills were selected randomly from each treatment plot at various stages of crops and harvested at ground level. The sample plants were collected from three rows in the side of the plot leaving rest of the rows undisturbed at the center of the plot for final harvest. The computations were made as per procedure described by Ratford (1967); Hunt (1981); Brown (1984); Gardner *et al*, (1985).

3.16 General observation of the experimental field

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

3.17 Recording of data

The following data were collected during the study period:

3.17.1. Growth characters

1. Plant height (cm)
2. Tillers hill^{-1} (no.)
3. Leaf area index
4. Days to panicle initiation
5. Days to flowering
6. Days to maturity

3.17.2 Yield contributing parameters

1. Effective tillers hill^{-1} (no.)
2. Non-effective tillers hill^{-1} (no.)
3. Panicle length (cm)
4. Filled grains panicle^{-1} (no.)
5. Unfilled grains panicle^{-1}(no.)
6. 1000-grains weight (g)

3.17.3 Yield parameters

1. Grain yield (t ha^{-1})

2. Straw yield (t ha^{-1})
3. Biological yield (t ha^{-1})
4. Harvest index (%)

3.18 Procedures of recording data

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

3.18.1 Crop growth characters

3.18.1.1 Plant height

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

3.18.1.2Tillers $hill^{-1}$

Total tillers which had at least one leaf visible were counted. It includes both productive and unproductive tillers. It was counted from the average of same 5 plants pre-selected at random from the inner rows of each plot.

3.18.1.3 Leaves $hill^{-1}$

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

3.18.1.4 Leaf area index (LAI) measurement during the crop cycles

The leaf area index (LAI) is the ratio of leaf area to the soil area it occupies. Leaf area was measured at 15-day intervals starting from 15 DAT up to 60 DAT at harvest. Leaf area was measured from the functional leaves of five plants while five hills that were randomly selected for destructive sampling in each plot excluding border plants or hills. Every time destructive samples were uprooted and washed with water. Leaf blades were separated from the leaf sheath. Leaf area was measured by a Leaf Area Meter (LI-3100, LI-COR, Inc, Lincoln, NE 68504, USA) at the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka. Leaf areas (cm^2) per square meter of the land were computed by calculating the leaf area of the test plants. Leaf area index (LAI) was calculated following the standard formula (Hunt, 1981 and Gardner *et al.* 1985) as mentioned below:

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area (cm}^2)}{\text{Ground area (cm}^2)}$$

3.18.2 Yield contributing characters

3.18.2.1 Effective tillers hill^{-1}

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

3.18.2.2 Non-effective tillers hill^{-1}

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

3.18.2.3 Panicle length

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

3.18.2.4 Panicles hill^{-1}

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

3.18.2.4 Filled grains panicle^{-1}

The total number of filled grains was collected randomly from selected 5 panicles of a plot and then average number of filled grains panicle^{-1} was recorded.

3.18.2.5 Unfilled grains panicle^{-1}

The total number of unfilled grains was collected randomly from selected 5 panicles of a plot and then average number of unfilled grains panicle^{-1} was recorded.

3.18.2.6 Weight of 1000-grains

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

3.18.3 Yield parameters

3.18.3.1 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central $1m^2$ area and five sample plants were added to the respective unit plot yield to record the final grain yield $plot^{-1}$ and finally converted to t ha^{-1} in both locations.

3.18.3.2 Straw yield

Straw yield was determined from the central 1 m^2 area of each plot, after separating the grains. The sub-samples were sun dried to a constant weight and finally converted to t/ha-1.

3.18.3.3 Biological yield

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

Biological yield = Grain yield + straw yield.

3.18.3.4 Harvest Index

Straw of the 1 m^2 harvested area were dried in sunlight to a constant weight and dry weight was taken. It indicates the ratio of economic yield (grain yield) to biological yield (grain yield + straw yield) and was calculated by the following formula (Gardner *et al.*, 1985):

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

3.19 Statistical analysis

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

CHAPTER IV
RESULTS AND DISCUSSION

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

4.1 Growth parameters

4.1.1 Plant height

Different treatments had significant variation in terms of plant height at different growth stages of plant (Fig.1 and Appendix V). It was observed that the highest plant height (12.39, 31.12, 44.38, 59.47 and 103.34 cm at 15, 30, 45, 60 DAT and at harvest, respectively) was obtained from the treatment, T_{11} (B (1.5%) FS at TI + RF) followed by B_{14} (B (1.5%) FS at FI + RF) where the lowest plant height (13.18, 24.40, 33.53, 44.94 and 78.59 cm at 15, 30, 45, 60 DAT and at harvest, respectively) was found from the treatment, T_1(Recommended Fertilizer (RF)). Ali *et al.* (2016) investigated that boron application significantly enhanced plant height of rice. It is a well-known fact that boron is essential in enhancing carbohydrate metabolism, sugar transport, cell wall structure, protein metabolism, root growth and stimulating other physiological processes of plant that helped to trigger the plant height (Goldberg, 1997 and Ashour and Reda, 1972). Ali *et al.* (2016) reported that, poor performance in control (no boron) treatment might be due to imbalance nutrient application. In boron application treatment, crop up taken more nutrients and improved the crop vigor. Healthy and vigorous plants will ultimately have great impact on crop growth. Similar trend of results on plant height were also achieved by Saleem *et al*. (2010), Shafiq and Maqsood (2010) and Khan *et al*. (2007).

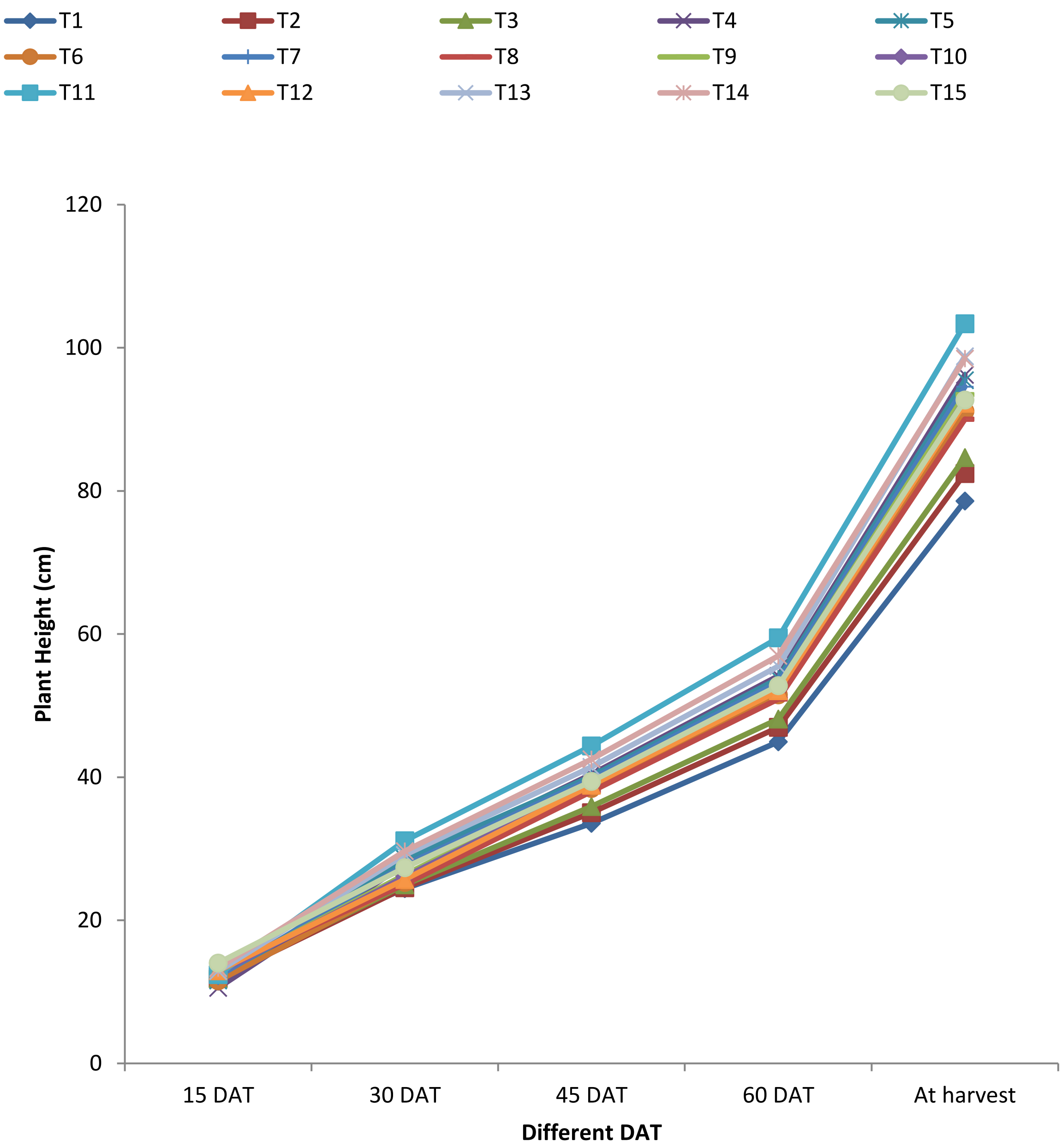

Figure 1. Effect of foliar spray of zinc and boron on the plant height of rice at different days after transplanting (LSD $_{(0.05)}$ = NS, 1.932, 3.191, 4.279, 7.993 at 15, 30, 45, 60 DAT and harvest, respectively)

T1= Recommended Fertilizer (RF), T2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T3= RF + Foliar spray (FS) with water at flowering initiation (FI), T4= Zn (0.2%) FS at TI + RF, T5=Zn (0.5%) FS at TI + RF, T6=Zn (0.8%) FS at TI + RF, T7= Zn (0.2%) FS at FI + RF, T8=Zn (0.5%) FS at FI + RF, T9= Zn (0.8%) FS at FI + RF, T10= B (0.5%) FS at TI + RF, T11= B (1.5%) FS at TI + RF, T12= B (2.0%) FS at TI + RF, T13= B (0.5%) FS at FI + RF, T14= B (1.5%) FS at FI + RF, T15= B (2.0%) FS at FI + RF.

4.1.2 Leaf area (cm^2)

Leaf area at different growth stages of rice was significantly affected by different treatments (Fig.2 and Appendix VI). It was observed that the highest leaf area (50.69, 75.66, 249.66, 881.39 and 1066.48 cm^2 at 15, 30, 45, 60 DAT and at harvest, respectively) was obtained from the treatment, T_{11} (B (1.5%) FS at TI + RF) followed by T_{14} (B (1.5%) FS at FI + RF) ,where the lowest leaf area (34.34, 51.26, 169.15, 597.16 and 722.57 cm^2 at 15, 30, 45, 60 DAT and at harvest, respectively) was found from the treatment, T_1(Recommended Fertilizer, RF) followed by T_2 and T_3 treatment. So the largest leaf area of rice was found in T_{11} treatment compared to T_1 treatment. The findings were also similar with the findings of Khan *et al*. (2007) and Shafiq and Maqsood (2010).

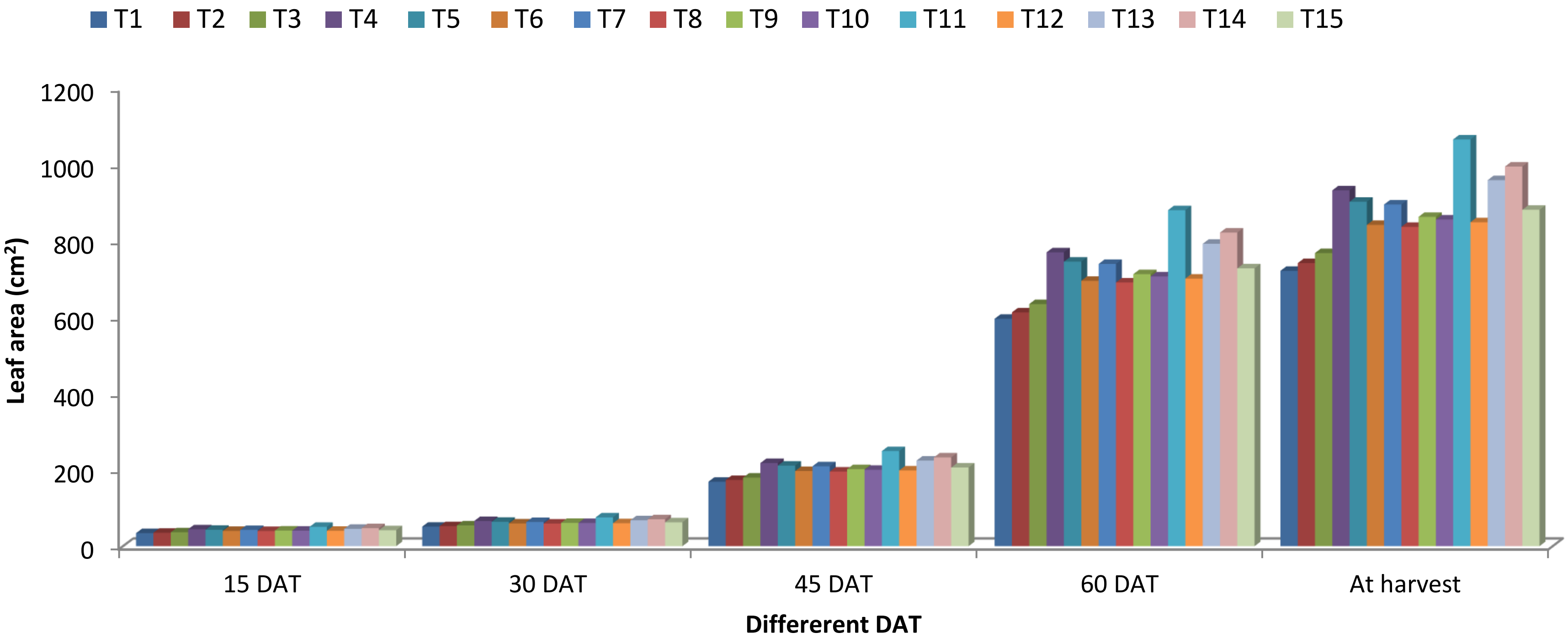

Figure 2. Effect of foliar spray of zinc and boron on the leaf area of rice at different days after transplanting (LSD $_{(0.05)}$ = 3.706, 5.529, 18.45, 64.43, 77.96 at 15, 30, 45, 60 DAT and harvest, respectively)

T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF.

4.1.3 Leaf area index

Significant variation was observed in terms of leaf area index at different growth stages of rice influenced by different treatments (Table 1 and Appendix VII). It was observed that the highest leaf area index (0.78, .85, 1.32, 3.00 and 3.49 cm) at 15, 30, 45, 60 DAT and at harvest, respectively) was obtained from the treatment T_{11} (B (1.5%) FS at TI + RF) followed by T_{14} [B (1.5%) FS at FI + RF] where the lowest leaf area index (0.74, 0.79, 1.10, 2.24 and 2.58 cm) at 15, 30, 45, 60 DAT and at harvest, respectively) was found from the treatment T_1 (Recommended Fertilizer (RF)). The higher LAI was achieved by foliar application of B (1.5% Foliar Spray at TI + RF) which might be due to more cell division and elongation resulting vigorous leaf production and finally produced higher LAI than the control treatment. Similar result also reported by Hussain and Yasin (2004) also concluded that application of B as foliar spraying in rice is highly attractive and produced higher LAI than control treatment.

Table 1. Effect of foliar spray of zinc and boron on leaf area Index (LAI) of rice at different growth stages

Treatments	Leaf Area Index				
	15 DAT	30 DAT	45 DAT	60 DAT	At harvest
T_1	0.74e	0.79g	1.10g	2.24g	2.58g
T_2	0.74e	0.79g	1.11g	2.29g	2.63g
T_3	0.75de	0.80e-g	1.13g	2.34g	2.70fg
T_4	0.77a-c	0.83a-d	1.23b-d	2.71b-d	3.14b-d
T_5	0.76b-d	0.82b-d	1.22c-e	2.64c-e	3.06c-e
T_6	0.76b-e	0.81c-g	1.18ef	2.51ef	2.90ef
T_7	0.76b-e	0.82b-e	1.21c-e	2.63c-e	3.04c-e
T_8	0.76c-e	0.81d-g	1.17ef	2.50ef	2.88ef
T_9	0.76b-e	0.81c-g	1.19de	2.55de	2.96de
T_{10}	0.76b-e	0.81b-f	1.19de	2.54de	2.93de
T_{11}	0.78a	0.85a	1.32a	3.00a	3.49a
T_{12}	0.76c-e	0.81b-f	1.18ef	2.52e	2.92e
T_{13}	0.77a-c	0.83a-c	1.25bc	2.76bc	3.21bc
T_{14}	0.78ab	0.84ab	1.27ab	2.84ab	3.31ab
T_{15}	0.76b-d	0.82b-f	1.20c-e	2.59c-e	3.00de
LSD $_{(0.05)}$	0.016	0.023	0.052	0.175	0.204
CV (%)	6.17	5.78	5.37	5.32	5.32

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

T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF.

4.1.4 Days to panicle initiation

Significant variation was observed in terms of days to panicle initiation of rice influenced by different treatments (Table 2 and Appendix IX). Result showed that the maximum days to panicle initiation(79.67 days) was obtained from the treatment, T_{11} (B (1.5%) FS at TI + RF) followed by T_{14} [B (1.5%) FS at FI + RF] which was statistically similar with T_{13} (B (0.5%) FS at FI + RF) where the minimum days to panicle initiation (74.33 days) was found from the treatment T_1 (Recommended Fertilizer (RF)) which was statistically similar with T_2 (RF+ Foliar spray (FS) with water at tiller initiation (TI)) and T_3 [RF + Foliar spray (FS) with water at flowering initiation (FI)].

4.1.5 Days to flowering

Significant variation was observed in terms of days to flowering of rice influenced by different treatments (Table 2 and Appendix IX). Result showed that the maximum days to flowering (117.67 days) was obtained from the treatment, T_{11} [B (1.5%) FS at TI + RF)]which was statistically similar with T_{14} [B (1.5%) FS at FI + RF] and T_{13} [B (0.5%) FS at FI + RF] where the minimum days to flowering(112.33 days) was found from the treatment T_1 (Recommended Fertilizer (RF)) which was statistically similar with T_2 (RF+ Foliar spray (FS) with water at tiller initiation (TI)).

4.1.6 Days to maturity

Significant variation was observed in terms of days to maturity of rice influenced by different treatments (Table 2 and Appendix IX). Result showed that the maximum days to maturity (152.67 days) was obtained from the treatment, T_{11} (B (1.5%) FS at TI + RF) which was statistically similar with T_{14} (B [1.5%) FS at FI + RF] and T_{13} [B (0.5%) FS at FI + RF] where the minimum days to maturity (147.33) was found from the treatment T_1 (Recommended Fertilizer (RF)) which was statistically similar with T_2 [RF+ Foliar spray (FS) with water at tiller initiation (TI)].

Table 2. Effect of foliar spray of zinc and boron on growth contributing parameters of rice

Treatments	Days to panicle initiation	Days to flowering	Days to maturity
T_1	74.33g	112.33g	147.33g
T_2	75.00fg	113.00fg	148.00fg
T_3	75.00fg	113.33e-g	148.33e-g
T_4	77.67b-d	115.67bc	150.67bc
T_5	77.33c-e	115.33b-d	150.33b-d
T_6	75.67f-g	113.67e-g	148.67e-g
T_7	77.67b-d	115.67bc	150.67bc
T_8	75.33fg	113.33e-g	148.33e-g
T_9	76.67d-f	114.67c-e	149.67c-e
T_{10}	76.33d-f	114.33c-f	149.33c-f
T_{11}	79.67a	117.67a	152.67a
T_{12}	76.00d-g	114.00d-f	149.00d-f
T_{13}	78.67a-c	116.67ab	151.67ab
T_{14}	79.33ab	117.33a	152.33a
T_{15}	77.33c-e	115.33b-d	150.33b-d
$LSD_{(0.05)}$	1.893	1.624	1.534
CV(%)	3.79	3.03	3.10

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

T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF.

4.2 Yield contributing parameters

4.2.1 Number of effective tillers $hill^{-1}$

Number of effective tillers $hill^{-1}$ of rice was significantly affected by different treatments (Fig.3 and Appendix viii). Results revealed that the highest number of effective tillers $hill^{-1}$ (15.13) was obtained from the treatment T_{11}[B (1.5%) FS at TI + RF] followed by T_{14}[B (1.5%) FS at FI + RF] where the lowest number of effective tillers $hill^{-1}$ (10.25) was found from the treatment T_1(Recommended Fertilizer (RF)) which was statistically similar withT_2(RF+ Foliar spray (FS) with water at tiller initiation (TI)) and T_3(RF + Foliar spray (FS) with water at flowering initiation (FI)). Saleem *et al.* (2011); Dell and Huang (1997) and Marschner (1995) reported that, the positive effect on effective tillers may be due to the proper development and differentiation of tissue as B affects the deposition of cell wall material by altering membrane properties. Correa *et al*. (2006) observed that appropriate boron availability in soils favors root growth and a sufficient supply of this micronutrient is very important for adequate rice plant development. So, appropriate foliar application of B resulting maximum production of effective tillers $hill^{-1}$. The result was consistent with the findings of Khan *et al*. (2007); Rahmatullah *et al.* (2006) and Ashraf *et al*. (2004) reported that B application significantly affected the plant growth. Rerkasem *et al.* (2004) reported that low B availability could reduce tiller numbers in wheat.

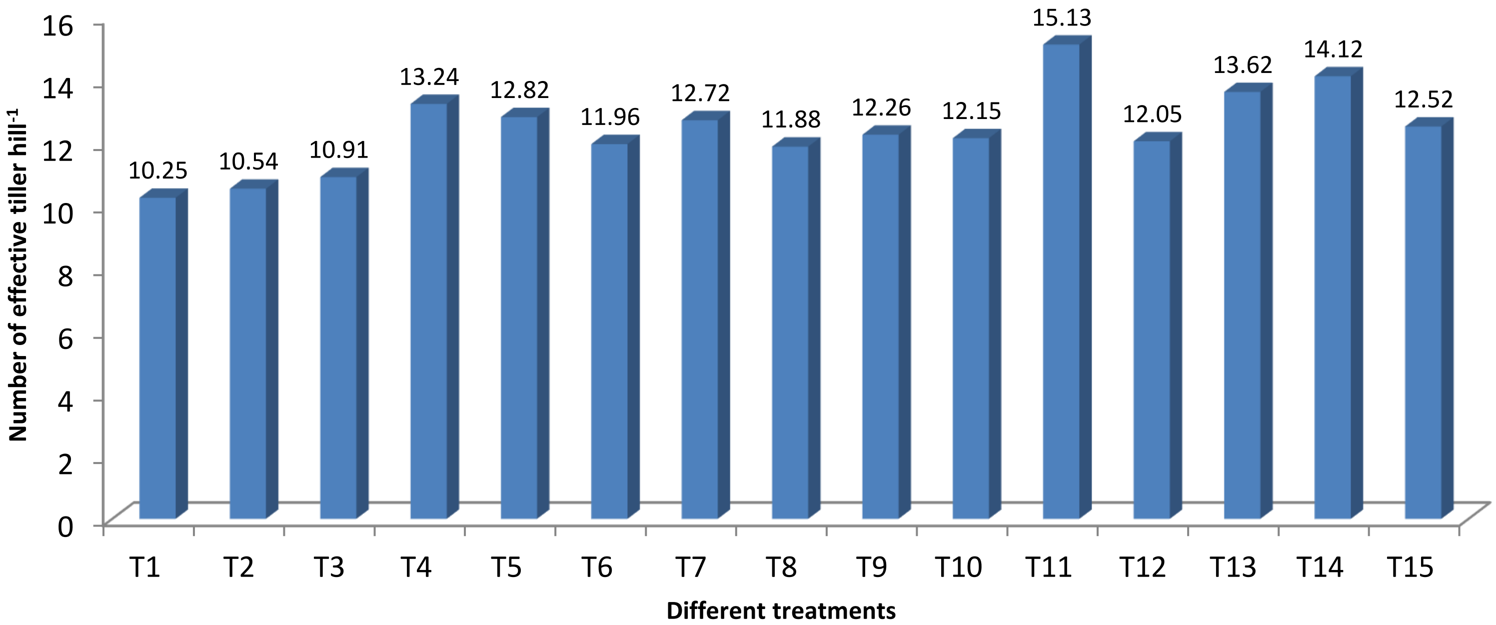

Figure 3. Effect of foliar spray of zinc and boron on the number of effective tillers hill^{-1}of rice (LSD $_{(0.05)}$ = 1.107)

T_1: Recommended Fertilizer (RF), T_2: RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3: RF + Foliar spray (FS) with water at flowering initiation (FI), T_4: Zn (0.2%) FS at TI + RF, T_5: Zn (0.5%) FS at TI + RF, T_6: Zn (0.8%) FS at TI + RF, T_7: Zn (0.2%) FS at FI + RF, T_8: Zn (0.5%) FS at FI + RF, T_9: Zn (0.8%) FS at FI + RF, T_{10}: B (0.5%) FS at TI + RF, T_{11}: B (1.5%) FS at TI + RF, T_{12}: B (2.0%) FS at TI + RF, T_{13}: B (0.5%) FS at FI + RF, T_{14}: B (1.5%) FS at FI + RF, T_{15}: B (2.0%) FS at FI + RF

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

Significant variation was observed in terms of number of non effective tiller hill^{-1} of rice influenced by different treatments (Table 3 and Appendix viii). The highest number of non effective tiller hill^{-1} (3.46) was found from the treatment, T_1 (Recommended Fertilizer (RF)) where the lowest number of non effective tillers hill^{-1} (0.76) was found from T_{11} [B (1.5%) FS at TI + RF].

4.2.3 Panicle length

Significant difference was found in terms of panicle length influenced by different treatments (Table 3 and Appendix viii). Result showed that the highest panicle length (27.86) was obtained from the treatment, T_{11} (B (1.5%) FS at TI + RF) followed by T_{14} [B (1.5%) FS at FI + RF] where the lowest panicle length (19.41) was found from the treatment T_1 (Recommended Fertilizer (RF)) which was statistically similar with T_2 (RF+ Foliar spray (FS) with water at tiller initiation (TI)) and T_3 (RF + Foliar spray (FS) with water at flowering initiation (FI)). Khan *et al*. (2007) also found similar results with the present study. Boron plays an important role in accelerating the formation and elongation of panicles in rice plants (Liew *et al.*, 2012). Dobermann and Fairhurst (2000) reported that B deficiency, particularly at the panicle formation stage, would greatly reduce the formation of panicles in rice plant ultimately reduced the panicle length.

Table 3. Effect of foliar spray of zinc and boron on yield contributing parameters of rice

Treatments	Non effective tillers $hill^{-1}$	Panicle length (cm)
T_1	3.46a	19.41j
T_2	3.18b	19.52j
T_3	3.04b	19.61j
T_4	1.53ij	24.49cd
T_5	1.68hi	24.06de
T_6	2.36cd	21.28hi
T_7	1.74gh	23.32ef
T_8	2.56c	21.08i
T_9	1.96f	22.18gh
T_{10}	2.09ef	21.93hi
T_{11}	0.76l	27.86a
T_{12}	2.23de	21.61hi
T_{13}	1.34j	25.33bc
T_{14}	1.10k	25.80b
T_{15}	1.90fg	23.00fg
$LSD_{(0.05)}$	0.2048	1.010
CV(%)	7.46	7.66

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

T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF.

4.2.4 Number of filled grains panicle^{-1}

Number of filled grains panicle^{-1} of rice was significantly affected by different treatments (Fig.4 and Appendix viii). Result showed that the highest number of filled grains panicle^{-1} (155.52) was obtained from the treatment, T_{11} [B (1.5%) FS at TI + RF] followed by T_{14} [B (1.5%) FS at FI + RF] and T_{13}[B (0.5%) FS at FI + RF] where the lowest number of filled grains panicle^{-1} (108.40) was found from the treatment T_1 (Recommended Fertilizer (RF)) which was statistically similar with T_2 (RF+ Foliar spray (FS) with water at tiller initiation (TI)) and T_3 (RF + Foliar spray (FS) with water at flowering initiation (FI)).More number of grains per panicle and higher grain weight by B application might be due to involvement of B in reproductive growth as B improves the panicle fertility in rice (Rehman *et al*., 2012). Rashid *et al.* (2004) observed that there was a substantial increase in grain yield of rice varieties due to reduced panicle sterility after B application. Maximum number of grains per panicle against control plots might be due to the reduction in pollen sterility of rice and proper grain filling (Rashid *et al.*, 2004). Ali *et al*. (2016), Saleem *et al*. (2010) and Shafiq and Maqsood (2010) also found similar trend of results with the present study.

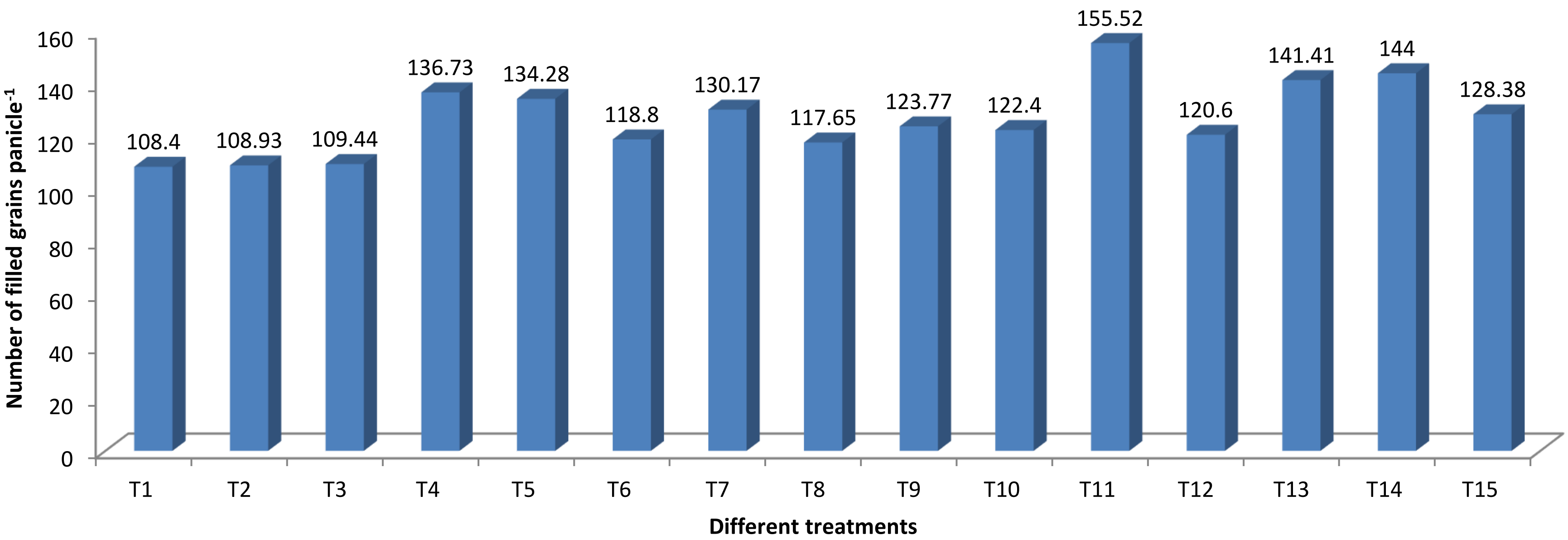

Figure 4. Effect of foliar spray of zinc and boron on the number of filled grains panicle^{-1} of rice (LSD $_{(0.05)}$ = 4.117)

T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF.

4.2.5 Number of unfilled grains panicle^{-1}

Significant variation was observed in terms of number of unfilled grains panicle^{-1} of rice influenced by different treatments (Table 4 and Appendix viii). Result showed that the highest number of unfilled grains panicle^{-1} (22.45) was obtained from the treatment T_1 (Recommended Fertilizer (RF)) where the lowest number of unfilled grains panicle^{-1} (7.85) was found from the treatment T_{11} [B (1.5%) FS at TI + RF].This might be due to the supplemental foliar application of B which helped to reduce panicle sterility during panicle formation stage ultimately reduce the number of unfilled grain per panicle, on the other hand the control plot did not receive supplementary B during panicle formation stage, which may cause increasing the number of unfilled grain per panicle. This findings was in line with the findings of Ali *et al*. (2016) and Saleem *et al*. (2010) who reported that the supplemental application of B during panicle formation stage increase the number of filled grain per panicle but lack of boron during this stage could increase the number of unfilled grain.

4.2.6 Weight of 1000-grain

Non significant variation was observed in terms of 1000-grain weight of rice influenced by different treatments (Table 4 and Appendix X). It was found from the result that, numerically the highest 1000-grain weight (28.92 g) was obtained from the treatment, T_{11} (B (1.5%) FS at TI + RF) followed by T_{14} (B (1.5%) FS at FI + RF) where the lowest 1000-grain weight (27.08) was found from the treatment T_1 (Recommended Fertilizer (RF)). It might be due to more efficient participation of B in various metabolic processes which enhanced accumulation of assimilates in the grains and resulted in heavier grains weight. It is well established fact that B supply is imperative for obtaining high yields and good quality because of its fundamental part in the biochemical processes (Gupta, 1993). These results are supported by the findings of Saleem *et al*. (2010), Shafiq and Maqsood (2010), Khan *et al*. (2007), Soleimani (2006) and Ashraf *et al.* (2004). They concluded that 1000-grain weight of rice increased with the increasing level of B fertilizer. In other cereals such as wheat, boron has also improved 1000-grain weight when it was sprayed on foliage at three growth stages *i.e*. tillering, booting and milking (Hussain *et al*., 2005).

Table 4. Effect of foliar spray of zinc and boron on unfilled grains panicle^{-1} and 1000-seed weight of rice

Treatments	Unfilled grain panicle^{-1}	1000 seed weight (g)
T_1	22.45a	27.08
T_2	20.95b	27.20
T_3	20.21b	27.30
T_4	12.01ij	27.79
T_5	12.84hi	28.60
T_6	16.55cd	27.97
T_7	13.17gh	27.72
T_8	17.64c	27.39
T_9	14.35f	27.36
T_{10}	15.06ef	27.73
T_{11}	7.85l	28.92
T_{12}	15.83de	27.35
T_{13}	11.03j	29.12
T_{14}	9.73k	29.00
T_{15}	14.01fg	27.34
LSD $_{(0.05)}$	1.116	NS
CV(%)	4.47	2.97

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

T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF.

4.3 Yield parameters

4.3.1 Grain yield

Significant variation was observed in terms of grain yield influenced by different treatments (Fig. 5 and Appendix XI). Results exhibited that the highest grain yield (7.10 t ha^{-1}) was obtained from the treatment T_{11}[B (1.5%) FS at TI + RF] followed by T_{14}[B (1.5%) FS at FI] and T_{13}[B (0.5%) FS at FI + RF] where the lowest grain yield (5.02 t ha^{-1}) was found from the treatment, T_1(Recommended Fertilizer (RF)) which was statistically similar with T_2(RF+ Foliar spray (FS) with water at tiller initiation (TI)) and T_3 (RF + Foliar spray (FS) with water at flowering initiation (FI)).The yield increase was due to the role of B in plant physiological functions especially during plant reproductive phase so its growth parameters such as number of tillers, length of panicle, number of filled grains per panicle and 1000-weight of grain improved which attributed the higher grain yield. Boron is basically involves in several biochemical processes including carbohydrate metabolism, sugar transport, lignification, nucleotide synthesis, respiration and pollen viability therefore its deficiency directly affects panicle production and hence the rice yield (Dobermann and Fairhurst, 2000). Hussain *et al*. (2012) concluded that, maximum grain yield by foliage application of B at the flowering stage might be the direct effect of higher number of grains per panicle and 1000-grain weight. Many reports indicate that B applied at the heading or flowering stage in rice resulted in increased rice grain yield and number of grains per panicle (Ramanthan *et al*., 2002 and Lin and Zhu, 2000). Moreover, by supplying plants with micronutrients especially B, either through soil application, foliar spray, or seed treatment, increases yield and quality as well as macronutrient use efficiency (Imtiaz *et al*., 2006). B has long been identified as one of the major constraints for grain crop production in the world. Jana *et al*. (2005) and Rashid *et al*. (2006) reported enhanced rice yield due to reduced panicle sterility by B application appreciably. On the other hand, the reason for the lowest grain yield in boron deprived plots might be the higher pollen infertility and lower grain filling as it plays very active role in both processes (Rashid *et al*., 2004 and Rerkasem *et al*., 1993). Again, Cheng and Rerkasem (1993) reported that, B deficiency depresses pollen germination and the fertilization process. The sole application of boron is reported to be as effective as its combined use with NPK or other micronutrients Chaudry *et al.* (2007) and Dunn *et al.* (2005), Rehman *et al.* (2014) also reported that, substantial decrease in panicle sterility and increase in grain size are the principal reasons of increase in grain yield by foliage application of B. Although primary role of B is to cross-link rhamnogalacturonan II monomers by a borate bridge, providing stability to the cell wall matrix (O'Neill *et al.*, 1997) nonetheless, applied in small amounts is a critical component of membranes in pollen tubes (Bolanos *et al.*, 2004 and Jackson, 1989). As growth of pollen tubes requires rapid synthesis of cell wall and plasma membrane (Taiz and Zeiger, 2010). Adequate B supply may also help maintain the assimilate supply to the developing grains (Dixit *et al*., 2002) and increase the grain size. The trend of on grain yield from the present study was similar with the findings of Patil *et al*. (2017), Fakir *et al*. (2016), Shafiq and Maqsood (2010) and Islam *et al*. (1997). Micronutrient malnutrition is a major human health problem in the developing world (Yang *et al.*, 2007; Khan *et al*., 2010; Farooq *et al*., 2012); so, considering the human sound health, biofortification of B offers an attractive and economical solution of this important issue (Mao *et al*., 2014).

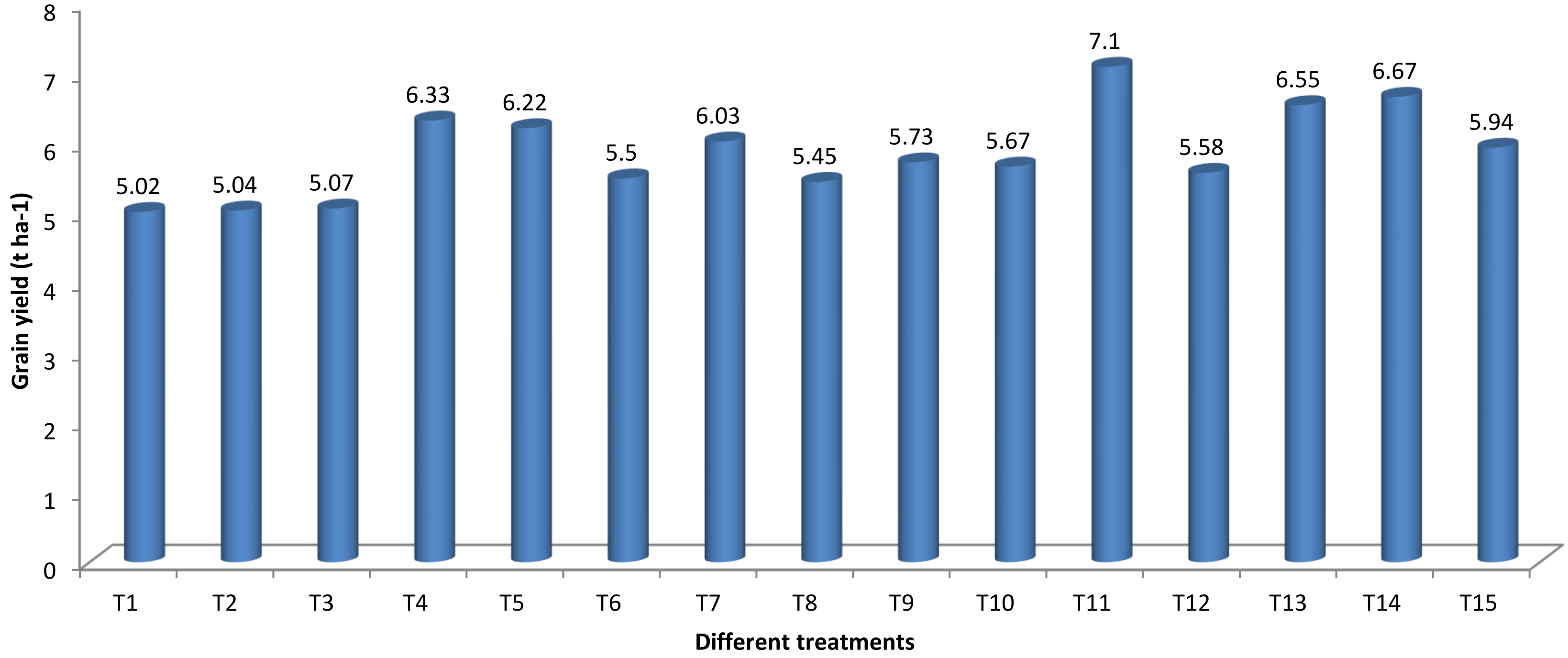

Figure 5. Effect of foliar spray of zinc and boron on the grain yield (t ha^{-1}) of rice (LSD $_{(0.05)}$ = 0.158)

T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF

4.3.2 Straw yield

Significant difference was found in terms of straw yield influenced by different treatments (Fig. 6 and Appendix XI). Among the different B treatment, the highest straw yield (7.61 t ha^{-1}) was obtained from the treatment, T_{11} [B (1.5%) FS at TI + RF] followed by T_{14} [B (1.5%) FS at FI] where the lowest grain yield (6.38 t ha^{-1}) was found from the treatment, T_2 (RF+ Foliar spray (FS) with water at tiller initiation (TI)) which was statistically identical with T_3 (RF + Foliar spray (FS) with water at flowering initiation (FI)). Rice straw yield increased because B improved the membranes function which could positively affect the transport of all metabolites required for normal growth and development, as well as the activities of membrane bound enzymes which attributed to higher straw yield of rice (Gupta, 1993). Saleem *et al*. (2011) reported that, the highest straw yield was Rashid recorded at 3 kg B ha^{-1} over control. This result was in agreement with the findings of Rashid *et al*. (2007).

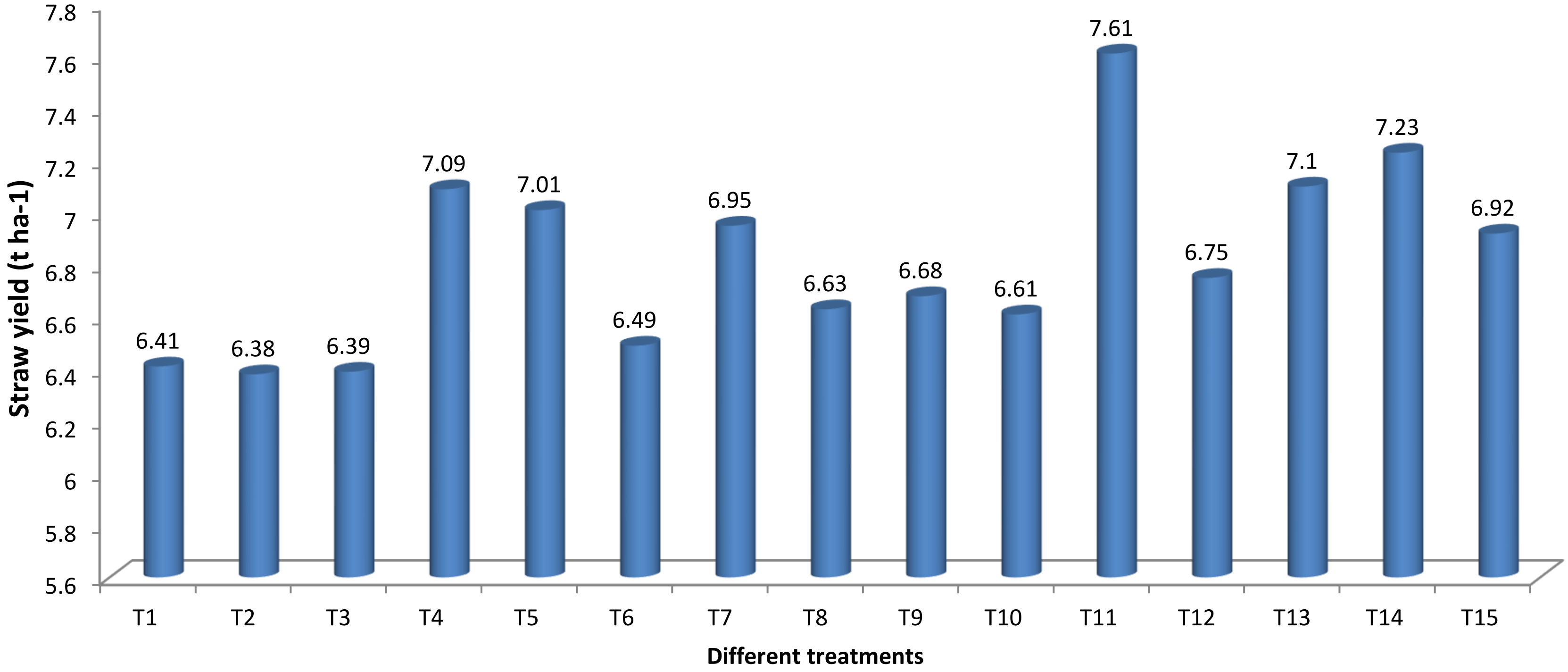

Figure 6. Effect of foliar spray of zinc and boron on the straw yield (t ha^{-1}) of rice (LSD $_{(0.05)}$ = 0.218)

T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF

4.3.3 Biological yield

Biological yield of rice was significantly affected by different treatments (Fig.7 and Appendix XI). Results exhibited that the highest biological yield (14.71 t ha^{-1}) was obtained from the treatment, T_{11} [B (1.5%) FS at TI + RF] followed by T_{14} [B (1.5%) FS at FI] where the lowest grain yield (11.43 t ha^{-1}) was found from the treatment, T_1 (Recommended Fertilizer (RF)) which was statistically identical with T_2 (RF+ Foliar spray (FS) with water at tiller initiation (TI)) and T_3 (RF + Foliar spray (FS) with water at flowering initiation (FI)).

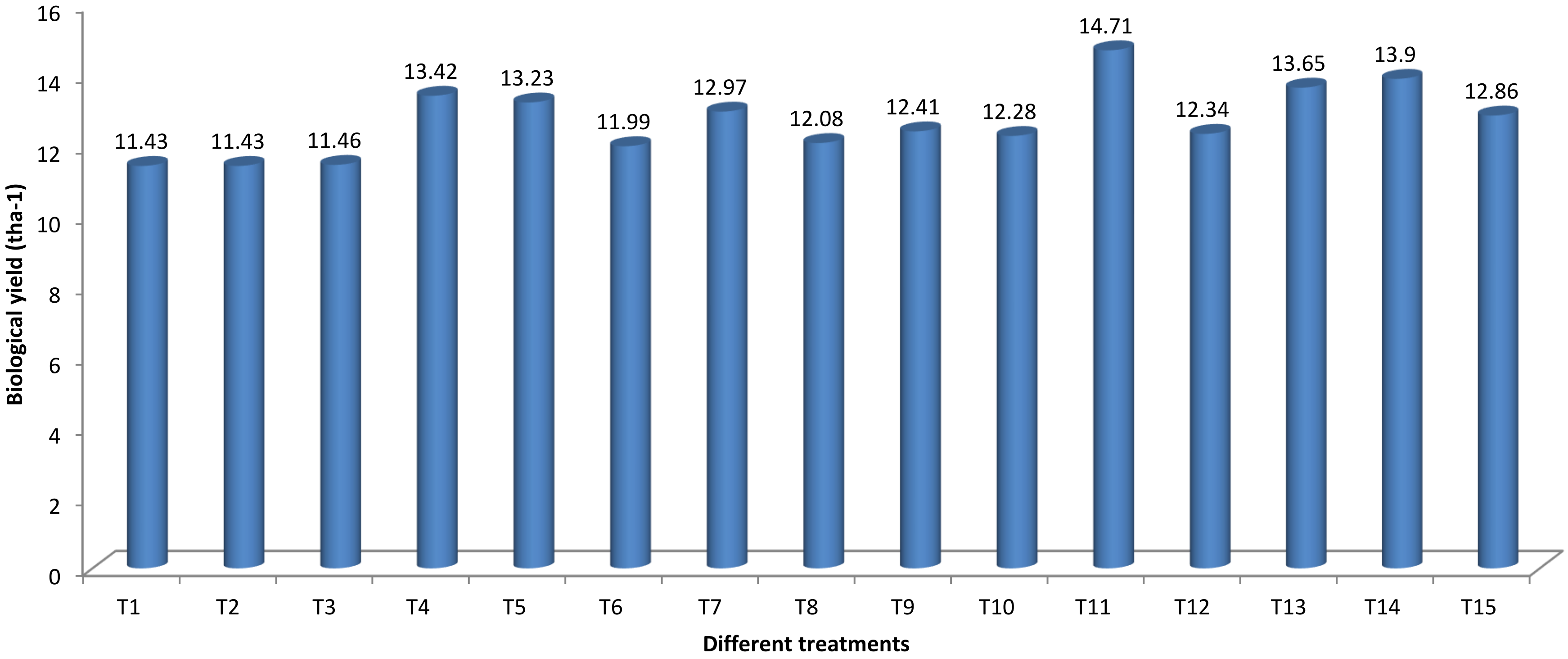

Figure 7. Effect of foliar spray of zinc and boron on the biological yield (t ha^{-1}) of rice (LSD $_{(0.05)}$ =0.423)

T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF

4.3.4 Harvest index

Significant variation was observed in terms of harvest index of rice influenced by different treatments (Fig.8 and Appendix XI). Results indicated that the highest harvest index (48.26) was obtained from the treatment, T_{11} (B (1.5%) FS at TI + RF) followed by T_{13} [B (0.5%) FS at FI + RF] and T_{14} [B (1.5%) FS at FI] where the lowest harvest index (43.88) was found from the treatment, T_1 (Recommended Fertilizer (RF)) which was statistically identical with T_2 (RF+ Foliar spray (FS) with water at tiller initiation (TI)) and T_3 (RF + Foliar spray (FS) with water at flowering initiation (FI)).Boron nutrition is more important during the reproductive stage as compared to the vegetative stage of the crop in cereals (Rerkasem and Jamjod, 2004). Improvement in harvest index resulted from B application might be due to better starch utilization that results in higher seed setting and translocation of assimilates to developing grains, which increases the grain size and number of grains per panicle (Hussain *et al*., 2012).

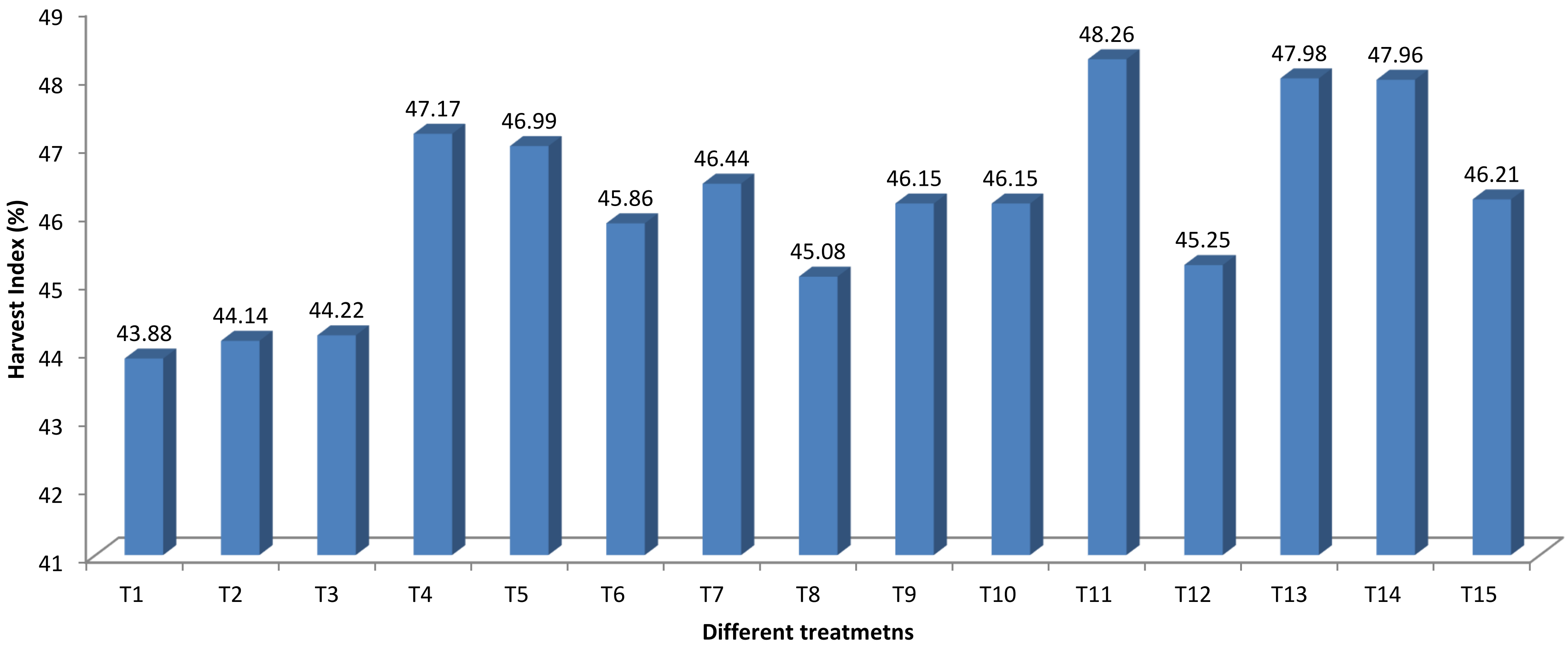

Figure 8. Effect of foliar spray of zinc and boron on the harvest index (%) of rice (LSD $_{(0.05)}$ =0.564)

T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF

CHAPTER V
SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from November 2016 to May, 2017 to find out the improvement of yield of rice through foliar boron and zinc. One factors were used in the experiment, *viz*. T_1= Recommended Fertilizer (RF), T_2= RF+ Foliar spray (FS) with water at tiller initiation (TI), T_3= RF + Foliar spray (FS) with water at flowering initiation (FI), T_4= Zn (0.2%) FS at TI + RF, T_5=Zn (0.5%) FS at TI + RF, T_6=Zn (0.8%) FS at TI + RF, T_7= Zn (0.2%) FS at FI + RF, T_8=Zn (0.5%) FS at FI + RF, T_9= Zn (0.8%) FS at FI + RF, T_{10}= B (0.5%) FS at TI + RF, T_{11}= B (1.5%) FS at TI + RF, T_{12}= B (2.0%) FS at TI + RF, T_{13}= B (0.5%) FS at FI + RF, T_{14}= B (1.5%) FS at FI + RF, T_{15}= B (2.0%) FS at FI + RF. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on different growth, and yield contributing parameters were recorded.

The highest plant height (12.39, 31.12, 44.38, 59.47 and 103.34 cm at 15, 30, 45, 60 DAT and at harvest, respectively) was obtained from T_{11} (B (1.5%) FS at TI + RF) where the lowest plant height (13.18, 24.40, 33.53, 44.94 and 78.59 cm at 15, 30, 45, 60 DAT and at harvest, respectively) was found from T_1 (Recommended Fertilizer (RF)). The highest leaf area and LAI (0.78, 0.85, 1.32, 3.00 and 3.49) at 15, 30, 45, 60 DAT and at harvest, respectively) was obtained from the treatment T_{11} (B (1.5%) FS at TI + RF) and the lowest leaf area index (0.74, 0.79, 0.1.10, 2.24 and 2.58) at 15, 30, 45, 60 DAT and at harvest, respectively) was found from T_1 (Recommended Fertilizer, RF).

The highest number of effective and tillers hill^{-1} (15.13) was obtained from T_{11} (B (1.5%) FS at TI + RF) whereas the lowest (10.25) was found from T_1 (Recommended Fertilizer (RF)). The highest number of non effective tiller hill^{-1} (3.46) was found from T_1 (Recommended Fertilizer (RF)) where the lowest (0.76) was found from T_{11} (B (1.5%) FS at TI + RF). The highest panicle length (27.86) was obtained from T_{11} (B (1.5%) FS at TI + RF) where the lowest panicle length (19.41) was found from the treatment T_1 (Recommended Fertilizer (RF)). Numerically the highest 1000-grain weight (28.92 g) was obtained from the treatment, T_{11} (B (1.5%) FS at TI + RF) and the lowest 1000-grain weight (27.08) was found from the treatment T_1 (Recommended Fertilizer (RF)). The highest number of filled grains panicle^{-1} (155.52) was obtained from T_{11} (B (1.5%) FS at TI + RF) whereas the lowest number of filled grains panicle^{-1} (108.40) was found T_1 (Recommended Fertilizer (RF)). The highest number of unfilled grains panicle^{-1} (22.45) was obtained from T_1 (Recommended Fertilizer (RF)) whereas the lowest number of unfilled grains panicle^{-1} (7.85) was found from the treatment T_{11} (B (1.5%) FS at TI + RF). The maximum days to panicle initiation, days to flowering and days to maturity (79.67, 117.67 and 152.67 days) was obtained from T_{11} (B (1.5%) FS at TI + RF) the lowest days to flowering and days to maturity (74.33, 112.33 and 147.33 days) was found from the treatment T_1 (Recommended Fertilizer, RF).

The highest grain yield (7.10 t ha^{-1}) was obtained from the treatment, T_{11} (B (1.5%) FS at TI + RF) followed by T_{14} (B (1.5%) FS at FI) and T_{13} (B (0.5%) FS at FI + RF)where the lowest grain yield (5.02 t ha^{-1}) was found from the treatment, T_1 (Recommended Fertilizer (RF)). The highest straw yield (7.61 t ha^{-1}) was obtained from the treatment T_{11} (B (1.5%) FS at TI + RF) where the lowest grain yield (6.38 t ha^{-1}) was found from the treatment T_2 (RF+ Foliar spray (FS) with water at tiller initiation (TI)). The highest biological yield and harvest index (14.71 t ha^{-1} and 48.26)) was obtained from the treatment, T_{11} (B (1.5%) FS at TI + RF) where the lowest was (11.43 t ha^{-1} and 43.88) found in the treatment T_1 (Recommended Fertilizer (RF)).

From the above findings, it may be concluded that among the treatment T_{11} (B (1.5%) FS at TI + RF) performed the best results. So, the treatment T_{11} (B (1.5%) FS at TI + RF) is the superior combination compared to other treatment combinations for rice production (BRRI dhan 29).

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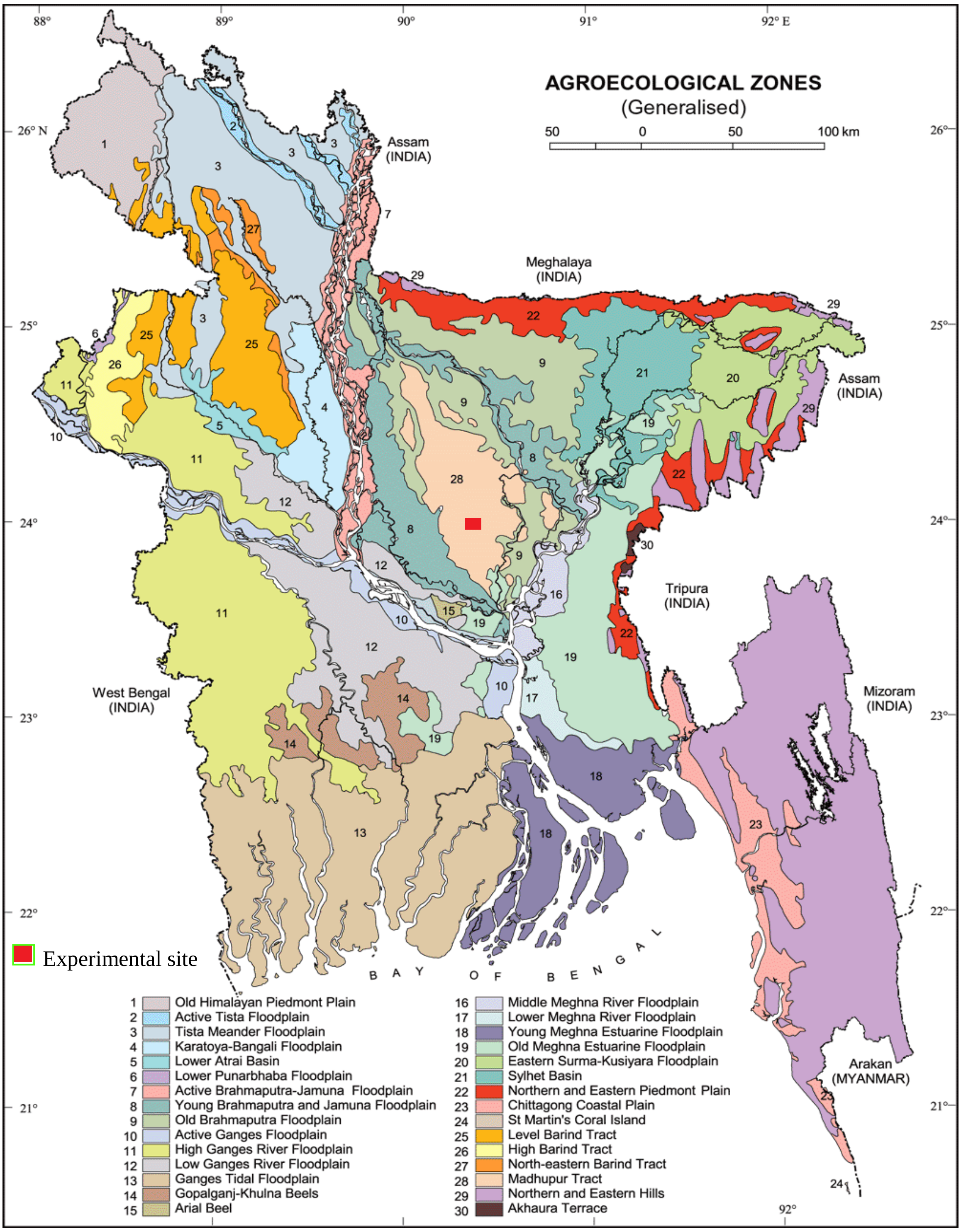
APPENDICES

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



Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from November 2016 to May, 2017

Month and year	RH (%)	Air temperature (^{0}C)			Rainfall (mm)
		Max.	*Min.*	*Mean*	
November, 2016	56.75	28.60	8.52	18.56	14.40
January, 2017	46.20	23.80	11.70	17.75	0.0
February, 2017	37.90	22.75	14.26	18.51	0.0
March, 2017	52.44	35.20	21.00	28.10	20.4
April, 2017	65.40	34.70	24.60	29.65	165.0
May, 2017	68.30	32.64	23.85	28.25	182.2

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

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

A. Morphological characteristics of the experimental field

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

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

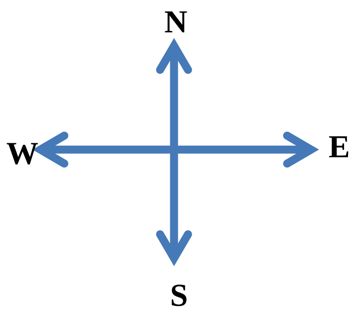
Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field

R_1				R_2				R_3		
T_1	T_6	T_{11}		T_1	T_6	T_{11}		T_1	T_6	T_{11}
T_2	T_7	T_{12}		T_2	T_7	T_{12}		T_2	T_7	T_{12}
T_3	T_8	T_{13}	**Replication**	T_3	T_8	T_{13}	**Replication**	T_3	T_8	T_{13}
T_4	T_9	T_{14}		T_4	T_9	T_{14}		T_4	T_9	T_{14}
T_5	T_{10}	T_{15}		T_5	T_{10}	T_{15}		T_5	T_{10}	T_{15}

Total Number of Plot: 45
Length of plot: 2.5m
Width of plot: 2.3m
Replication to replication distance: 0.75 m
Plot to plot distance: 0.5 m
Unit plot size: 2.5 m × 2.3 m (5.75 m^2)



Appendix V. Mean square values of plant height of different treatment

Sources of variation	Degrees of freedom	Mean square of plant height				
		15 DAT	30 DAT	45 DAT	60 DAT	At harvest
Replication	2	0.340	0.157	9.982	17.884	10.851
Treatments	14	2.308^{NS}	12.618**	23.056**	41.392**	125.279**
Error	28	0.590	1.334	3.641	6.546	22.649
Total	44					

**Significant at 1% level

$^{NS=}$Not significant

Appendix VI. Mean square values of number of leaf area of different treatment

Sources of variation	Degrees of freedom	Mean square of leaf area				
		15 DAT	30 DAT	45DAT	60 DAT	At harvest
Replication	2	8.595	19.040	207.737	2588.535	3790.126
Treatments	14	57.359**	127.794**	1391.706**	17344.65**	25394.16**
Error	28	4.910	10.937	119.066	1483.890	2172.579
Total	44					

**Significant at 1% level

Appendix VII. Mean square values of leaf area index of different treatment

Sources of variation	Degrees of freedom	Mean square of leaf area index				
		15 DAT	30 DAT	45DAT	60 DAT	At harvest
Replication	2	0.000	0.000	0.001	0.019	0.027
Treatments	14	0.000**	0.001**	0.000**	0.123**	0.181**
Error	28	0.000	0.000	0.001	0.011	0.015
Total	44					

**Significant at 1% level

Appendix VIII. Mean square values of yield contributing parameters of different treatment

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters				
		Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}
Replication	2	0.770	0.004	0.151	3.804	0.104
Treatment	14	5.112**	1.765**	18.401**	573.838**	51.647**
Error	28	0.438	0.015	0.365	6.059	0.445
Total	44					

**Significant at 1% level

Appendix ix. Mean square of growth contributing parameters of rice

Sources of variation	Degrees of freedom	Mean square of growth contributing parameters of rice		
		Days to panicle initiation	Days to flowering	Days to maturity
Replication	2	0.067	0.089	0.089
Treatment	14	7.943**	7.708**	7.708**
Error	28	1.281	0.303	0.303
Total	44			

** Significant at 1% level

Appendix X. Mean square values of yield contributing parameters of rice

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters	
		Number of panicle^{-1}	1000- grains weight
Replication	2	0.797	0.596
Treatment	14	97.404**	2.328^{NS}
Error	28	1.924	0.688
Total	44		

** Significant at 1% level

^{NS} =Not significant

Appendix Xi. Mean square values of yield parameters of different treatment

Sources of variation	Degrees of freedom	Mean square of yield parameters			
		Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	0.526	0.226	1.114	0.312
Treatment	14	7.36**	8.34**	10.29**	14.117**
Error	28	1.023	1.312	1.514	1.072
Total	44				

**Significant at 1% level