EFFECT OF Zn, B AND Cu ON THE YIELD AND QUALITY OF BORO RICE (BRRI Dhan 28)

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CERTIFICATE

*This is to certify that the thesis entitled " **Effect of Zn, B and Cu on the Yield and Quality of Boro Rice (BRRI Dhan 28)**" 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 (MS)** in **SOIL SCIENCE,** embodies the results of a piece of bona fide research work carried out by **ANISUL HAQUE MAHMUD**, Registration. No.* **11-04601** *under my supervision and guidance. No part of this 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.

Dated:

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Dhaka, Bangladesh

Supervisor

DEDICATED TO

MY

BELOVED PARENTS

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The Author

EFFECT OF Zn, B AND Cu ON THE YIELD AND QUALITY OF BORO RICE

ABSTRACT

A field experiment was carried out to evaluate the response of Zn, B and Cu on the yield and quality of boro rice at the research farm of Sher–e–Bangla Agricultural University, Dhaka, Bangladesh during the period from January to May, 2016. The experiment consisted of single 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 experiment was laid out following Randomized Complete Block Design (RCBD) with four replications. The micronutrients (Zn, B and Cu) along with recommended doses of NPK had significant influence on the growth, yield and yield contributing characters of rice. The maximum weight of 1000 grain (23.82 g) was gained by T_1 and the minimum weight of 1000 grain (20.31 g) was gained by T_5. T_1 gave 17.28 % more weight of 1000 grain over treatment T_5. The maximum rice yield (4.19 t ha^{-1}) was produced when the plot treated with T_1 ($N_{55}+P_{35}+K_{65}+S_{18}+Zn_5+B_4+Cu_4$) fertilizer package while the minimum grain yield (3.35 t ha^{-1}) was produced when the plot treated with T_5. T_1 which gave 25.08% more grain yield over T_5. Considering the above fact, fertilizer package T_1 ($N_{55}+P_{35}+K_{65}+S_{18}+Zn_5+B_4+Cu_4$) could be the best fertilizer management practice for optimizing the production of BRRI dhan 28 during boro season.

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LIST OF ACRONYMS

%	= Percent
^0C	= Degree Celsius
AEZ	= Agro-Ecological Zone
BARI	= Bangladesh Agricultural Research Institute
BAU	= Bangladesh Agricultural University
BBS	= Bangladesh Bureau of Statistics
Co	= Cobalt
CV%	= Percentage of coefficient of variance
cv.	= Cultivar
DAE	= Department of Agricultural Extension
DAS	= Days after sowing
et al.	=And others
FAO	= Food and Agriculture Organization
g	= gram(s)
ha^{-1}	= Per hectare
HI	= Harvest Index
kg	= Kilogram
LSD	= Least Significant Difference
Max	= Maximum
mg	= milligram
Min	= Minimum
MoP	= Muriate of Potash
N	= Nitrogen
No.	= Number
NPK	= Nitrogen, Phosphorus and Potassium
NS	= Not significant
SAU	= Sher-e-Bangla Agricultural University
SRDI	= Soil Resources and Development Institute
TSP	= Triple Super Phosphate
Wt.	= Weight

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) a semi aquatic annual grass plant belongs to the Gramineae family and it is the vital food for 2.4 billion people in Asia, nearly 90% of the world's rice is produced and consumed in this region and more than four hundred millions of people in Africa and Latin America (IRRI, 2011). In worldwide, 474.86 million metric tons of rice was produced from 159.64 million hectares of land with an average yield of 4.43 t ha^{-1} during the year of 2014-15 (USDA, 2015). It is estimated that by the year 2025, the world's farmers should be producing about 60% more rice than at present to meet the food demands of the expected world population at that time. Global rice production has tripled in the last five decades from 150 million tons in 1960 to 450 million tons in 2011, due to the rice Green Revolution in Asia.

Bangladesh is an agro-based developing country where agriculture is the single largest sector of the economy and this sector is largely dominated by rice production (Awal and Siddique, 2011).Rice is the staple dietary item for the people in Bangladesh which contributes more than 80 percent to the total food supply (BBS, 2011). It is not only the main source of carbohydrate but also provides 69.61% of calories and 56.15% of the proteins in the average daily diet of the people (FAO, 2011). Food security is a major concern in our country because food requirement is increasing at an alarming rate due to increasing population.It is necessary to enhance rice production to meet the increasing food demand for the vast growing population of the country which increases at the rate of 1.32 percent per annum (BER, 2010) and the increase in rice production can be achieved by efficient and good agricultural practices, water and nutrient inputs (Liew *et al*., 2010). Rice alone constitute of 97% of the food grain production in Bangladesh (BBS, 2013). It dominates over all other crops and covers 75% of the total cropped area (Rekabdar, 2004). Boro rice covers about 48.97% of total rice area and contributes to 38.14% of total rice production in the country (BBS, 2012). It covers 47, 60,055 ha of land and the production was 1, 87, 78,154 t with an average yield of 3.95 t ha $^{-1}$.But the main problem is that in Bangladesh the yield of rice is low compare to the other rice growing countries like Japan, South Korea where the average yield is 6.22 and 7.00 ton per hectare respectively (Islam *et al*., 2013).

Rice-rice cropping system is the most important cropping system in Bangladesh. Long-term intensive cropping on the same piece of land with high-yielding varieties often exhausts the availability of soil micronutrients. The continuous depleted soil fertility and poor management of plant micronutrients are major constraints has become hurdle in the effort to increase rice production in Bangladesh. The increasing land use intensity has resulted in a great exhaustion of nutrients in soils. Micronutrient malnutrition affects nearly one-third of the world populations, particularly in developing and under-developed countries (Alloway, 2004). It is also becoming an alarming issue in the context of balance plant nutrition in Bangladesh. Before 1980's, deficiency of NPK was a major problem in Bangladesh soils, and thereafter along with NPK, deficiency of S, B Zn and Cu are frequently reported (Islam *et al*., 1986, Islam and Hossain, 1993 and Hoque and Jahiruddin, 1994). So, deficiencies of these micronutrients become major concern, not only in sustainable crop production point of view but also in animal and human nutrition. Micronutrients are needed in trace amounts but their adequate supply improves nutrient availability and positively affects the cell physiology that is reflected in yield as well (Taiwo *et al*., 2001). Soils deficient in micronutrients are not capable of nourishing crop plant successfully and therefore low yield and quality of crops are obtained (Zia *et al.,* 2004). Farmers apply N, P, K and S fertilizers widely and application of micronutrients such as Zn, Cu, Mn and B is not a usual practice. Soils deficient in their supply of micronutrients are alarmingly widespread across the globe due to intensive cropping, loss of fertile topsoil and losses of nutrients through leaching (Somani, 2008).

Zinc is one of the most important essential nutrients required for the biosynthesis of the plant growth regulator such as indole-3-acetic acid (IAA) (Fang *et al.,* 2008) and for carbohydrate and nitrogen metabolism which leads to high yield and yield components. Plants take up zinc in the form of Zn^{2+} ions. Diffusion is believed to be the dominant mechanism for Zn^{2+} transport to plant roots (Rashid, 2001). The critical index of effective zinc in the soil suitable for rice growth is 1.5 mg kg^{-1} (Yan, 2003). Average up take of zinc is 0.05 kg t^{-1} of grain, of which 60 % remains in the straw at maturity (IRRI, 2000). Boron can influence photosynthesis and respiration and activate number of enzymatic systems of protein and nucleic acid metabolism in plants (Chowdhury *et al.,* 2010). It is also involved in keeping cell wall structure and maintaining membrane function (Marschner, 1995). It is believed to improve the strength of the membrane and cell wall with the cross-linked polymer and strengthen the plants vascular bundles which hold back the biotic invasion (Stangoulis and Graham, 2007).

Zinc deficiency in lowland rice fields occurred due to its chemical precipitation with sesquioxides and rendering it unavailable to plants (Mandal *et al*., 1992). Hence, lowland rice fields having marginal or medium status of available Zn could become Zn deficient under waterlogged conditions (Dobermann and Fairhurst, 2000). Response of rice crop to applied Zn towards yield increments as well as grain Zn enrichment was observed in India (Singh, 2009), Bangladesh (Rahman *et al*., 2008) and Turkey (Cakmak, 2008). Zn deficiency causes multiple symptoms that usually appear 2 to 3 weeks after transplanting of rice seedlings; when leaves develop brown blotches and streaks that may fuse to cover older leaves entirely, plants 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). Zinc deficiency in rice decreases tillering, increases spikelet sterility and time to crop maturity (IRRI, 2000).

Boron (B) deficiency is of particular importance since it affects the vegetative growth, flowering and plant reproductive process for a consequence stunted growth and reduction in the number of panicles 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 deficiencies occur over a much wider range of soils and crops in comparison to any other micronutrient deficiency. Boron deficiency has been reported in 80 countries and for 132 crops around the world. Boron deficiency in rice results in white and rolled tips of emerging leaves, reduced plant height, death of growing point and failure to produce panicles (Dobermann and Fairhurst 2000).

Cu deficiency causing restricted emergence of new leaves in rice reduced tillering and promoted pollen sterility reported by Dobermann and Fairhurst (2000). For proper growth and development of crop plants, micronutrients especially Zn, B and Cu are essential micronutrients to improve the economic yield and quality of several crop plants (Sinha *et al.*, 2000).Fertilizers particularly Zn, B and Cu in addition to recommended dose of major nutrients is needed to increase yield, uptake and total content of essential nutrients in rice (Abbas *et al.,* 2013). So, from the above discussion it may be concluded that, if plant micronutrients (Zn, B and Cu) are not supplied in an adequate amount with an appropriate proportion, high yielding crop variety (BRRI dhan28) under intensive cropping may fail to express their full potential. With a view to reveal the efficacy of micronutrients (Zn, B and Cu) the experiment was undertaken with the following objectives:

1. To study the effect of Zn, B and Cu on the yield of boro rice (BRRI Dhan 28)

2. To determine the optimum level of Zn, B and Cu for potential yield of boro rice (BRRI Dhan 28)

3. To determine the chemical composition in the grain and straw on boro rice (BRRI Dhan 28)

CHAPTER II

REVIEW OF LITERATURE

Among essential plant nutrients micro nutrients (Zn, B and Cu) are also important factor which influence optimum plant growth and development of the crops for boosting the crop production.In nutritional point of view fertilizer management especially micro nutrition for modern rice cultivation has become an important issue. Considering the above points, available literature was reviewed under different fertilizer management(micro nutrients) of rice.

2.1 Effect of zinc on the growth parameters and yield of boro rice

Field experiment was conducted Kumar *et al.* (2017) on farmer's field at Naganahalli village, Mysore district, Karnataka during summer season, to study the effect of graded levels of zinc and boron on growth, yield and chemical properties of soils under paddy.The experiment was laid out in randomised complete block design (RCBD) with sixteen treatments (16) and replicated thrice (3) with using Jaya variety of paddy.Zinc and boron were added through $ZnSO_4$ and borax respectively at three levels *viz.*, 10, 20 and 30 kg $ZnSO_4$ ha^{-1} and 2, 4 and 6 kg borax ha^{-1}. The result indicated that application of recommended levels of major nutrient fertilizers (NPK) along with $ZnSO_4$ @ 20 kg ha^{-1} and Borax @ 4 kg ha^{-1} has significantly enhanced the plant height (87.21 cm) and was superior over all other treatments. Lower plant height of 64.67 cm was recorded in T_1 treatment (RDF + FYM). The highest number of effective tillers $hill^{-1}$ (26.88) was recorded in T_{12} treatment which received RDF + ZnSO4 @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1} which was superior over all other treatments. The lowest number of effective tillers $hill^{-1}$ (12.61) was recorded in T_1 treatment which received RDF + FYM as compared to other treatments.The result indicated that significantly highest 1000 grain weight (26.96 g) was recorded in T_{12} treatment which received RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1} which was superior over all other treatments. The lowest 1000 grain weight (21.87 g) was recorded in T_1 treatment which received RDF + FYM as compared to other treatments. In case of grain yield, a significant increase in grain yield of rice was noticed over the RDF+FYM due to application of different levels of $ZnSO_4$ and borax. The highest grain (62.21 q ha^{-1}) yield was recorded in the T_{12} treatment which received RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1} which was significantly superior over all other treatments. The lowest grain (49.89 q ha^{-1}) yield was recorded in T_1 (RDF+FYM) treatment.The highest straw (88.33 q ha^{-1}) yield was recorded in the T_{12} treatment which received RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1} which was significantly superior over all other treatments. The lowest straw yield (64.40 q ha^{-1}) was recorded in T_1 (RDF+FYM) treatment.

The field experiments were conducted by Alam and Kumar (2015) at the Agricultural Farm in Newaji Tola in Saran district of Bihar, India to evaluate the effect of Zinc on growth and yield of rice var. Pusa Basmati-1.Seeds were sown in field in a randomized complete block design (RCBD) with four treatments (0 kg ha^{-1} $ZnSO_4$, 5 kg ha^{-1} $ZnSO_4$, 10 kg ha^{-1} $ZnSO_4$ and 20 kg ha^{-1} $ZnSO_4$) and four replications. The result exerted that, the maximum plant height (101.53 cm) was given when the field received 10 kg ha^{-1} $ZnSO_4$ and the minimum plant height (89.80 cm) was given when the field received 0 kg ha^{-1} $ZnSO_4$. The maximum panicle length (23.39 cm) was given when the field received 10 kg ha^{-1} $ZnSO_4$ and the minimum panicle length (16.57 cm) was given when the field received 0 kg ha^{-1} $ZnSO_4$. The maximum number of effective tillers m^{-2} (317) was given when the field received 10 kg ha^{-1} $ZnSO_4$ and the minimum number of effective tillers m^{-2} (225) was given when the field received 0 kg ha^{-1} $ZnSO_4$. The maximum 1000 grain weight (24.97 g) was given when the field received 10 kg ha^{-1} $ZnSO_4$ and the minimum 1000 grain weight (22.25 g) was given when the field received 0 kg ha^{-1} $ZnSO_4$.
The maximum grain yield (32.45 q ha^{-1}) was given when the field received 10 kg ha^{-1} $ZnSO_4$ and the minimum grain yield (24.32 q ha^{-1}) was given when the field received 0 kg ha^{-1} $ZnSO_4$.The field experiments were conducted by Alam and Kumar (2015) at the Agricultural Farm in Newaji Tola in Saran district of Bihar, India to evaluate the effect of Zinc on growth and yield of rice var. Pusa

Basmati-1.Seeds were sown in field in a randomized complete block design (RCBD) with four treatments (0 kg ha^{-1} $ZnSO_4$, 5 kg ha^{-1} $ZnSO_4$, 10 kg ha^{-1} $ZnSO_4$ and 20 kg ha^{-1} $ZnSO_4$) and four replications. The result exerted that, the maximum straw yield (69.25 q ha^{-1}) was given when the field received 10 kg ha^{-1} $ZnSO_4$ and the minimum straw yield (46.37 q ha^{-1}) was given when the field received 0 kg ha^{-1} $ZnSO_4$. The maximum harvest index (34.50 %) was given when the field received 0 kg ha^{-1} $ZnSO_4$ and the minimum harvest index (31.94 %) was given when the field received 10 kg ha^{-1} $ZnSO_4$.

A field study was carried out by Mustafa *et al.* (2011) at agronomic research area, University of Agriculture, Faisalabad, during kharif 2008 to evaluate the effect of different methods and timing of zinc application on growth and yield of rice. Experiment was laid out in a randomized complete block design with three replications. The experiment comprised of eight treatments *viz.*, control, rice nursery root dipping in 0.5 % Zn solution, $ZnSO_4$ 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. The results of the experiment revealed that, maximum plant height (104.5 cm) was recorded in treatment Zn_1 (Nursery root dipping at the rate of 0.5 % Zn solution) while minimum plant height (103.1 cm) was recorded in treatment Zn_5 when foliar application was done 45 days after transplanting. Foliar application 15 days after transplanting (DAT) produced panicle length of 26.64 cm as compared with control which gave 24.15 cm panicle length. In control 8.27 % less number of total tillers m^{-2} were produced as compared to basal application of zinc at the rate of 25 kg ha^{-1} 21 % $ZnSO_4$. The maximum effective tillers m^{-2} (249.80) was recorded from basal application @ 25 kg ha^{-1} 21 % $ZnSO_4$where as the minimum one (237.02) was recorded from no zinc application plot. The maximum 1000 grain weight (21.00 g) was recorded from foliar application at 15 DAT @ 0.5 % Zn solution where as the minimum one (18.52 g) was recorded from no zinc application plot. The maximum grain yield (5.21 t ha^{-1}) was recorded from basal application @ 25 kg ha^{-1} 21 % $ZnSO_4$ where as the minimum grain yield (4.17 t ha^{-1}) was recorded from foliar application at 75 DAT @ 0.5 % Zn solution. The maximum biological yield (11.87 t ha^{-1}) was recorded from foliar application at 15 DAT @ 0.5 % Zn solution where as the minimum grain yield (10.56 t ha^{-1}) was recorded from foliar application at 60 DAT @ 0.5 % Zn solution.

Field trials were conducted by Zayed *et al.* (2011)in El Serw Agricultural Research Station, Agriculture Research Center, Egypt during 2009 and 2010 summer seasons to study the effect of Zn^{+2}, Fe^{+2} and Mn^{+2} as single or combined application in soil to the rice (Sakha101 as moderately salt tolerant rice variety) growth and yield. The trials were laid out in a randomized complete block design with four replications. The treatments included Zn^{+2}, Mn^{+2}, Fe^{+2} application as soil single treatments or Zn + Mn , Zn + Fe , Mn + Fe and Zn +Mn + Fe as a combined applications through soil as well as a comparative treatment of commercial compound (14%Mn +12%Fe +16%Zn) was applied twice at 20 and 45 days after transplanting (DAT) as foliar spray. They found that, the tallest plant (97.00 cm) was attained by Zn^{+2} + Fe^{+2}+ Mn^{+2} combined treatment and the shortest plant (86.87 cm) was attained by control treatment (no micronutrients). The maximum panicle length (21.30 cm) was attained by foliar (comparative treatment) and the shortest plant (19.35 cm) was attained by control treatment (no micronutrients). The maximum number of effective tillers $hill^{-1}$ (17.00) was attained by Zn^{+2} + Fe^{+2}+ Mn^{+2} combined treatments and the minimum one (15.00) was attained by control treatment (no micronutrients). The maximum 1000 grain weight (28.50 g) was attained by foliar (comparative treatment) and the minimum 1000 grain weight (26.35 g) was attained by control treatment (no micronutrients). The highest grain yield (2.27 t fed^{-1}) was attained by Zn^{+2} + Fe^{+2}+ Mn^{+2} combined treatment and the lowest grain yield (1.77 t fed^{-1}) was attained by control treatment (no micronutrients). The highest straw yield (3.31 t fed^{-1}) was attained by Zn^{+2} + Fe^{+2}+ Mn^{+2} combined treatment and the lowest straw yield (2.92 t fed^{-1}) was attained by control treatment (no micronutrients). The highest harvest index

(42.00 %) was attained by foliar (comparative treatment) and the lowest harvest index (37.80 %) was attained by control treatment (no micronutrients).

An experiment was carried out by Rahman *et al.* (2008) at Bangladesh Agricultural University, Mymensingh farm during 2004 Boro season to evaluate the effect of S and Zn on rice (cv. BRRI dhan29). The experiment was laid out in a randomized complete block design (RCBD) with four replications. There were seven treatments viz. T_1: S_0Zn_0 (control), T_2: $S_{10}Zn_0$, T_3: $S_{20}Zn_0$, T_4: $S_0Zn_{1.5}$, T_5: S_0Zn_3, T_6: $S_{10}Zn_{1.5}$, T_7: $S_{20}Zn_3$. The investigation result revealed that, the height of Boro rice plant was significantly affected due to application S and Zn. Apparently, the tallest plant was observed in $S_{20}Zn_3$, the recommended dose of S and Zn (BARC, 1997), which was superior to all other treatments. The shortest plant was recorded in S_0Zn_0 (control). Plant height due to different treatments varied from 84.95 to 96.58 cm. Panicle length responded significantly to S and Zn application. The treatment containing 100% of the recommended dose of S and Zn produced the highest result (25.26 cm) and the control did the lowest (22.73 cm). Panicle length was approximately similar among treatments except the control.The number of effective tillers hill^{-1} due to different treatments varied from 7.6 to 12.1. The maximum tiller (12.1) was recorded in $S_{20}Zn_3$ which was superior to all other treatments and the lowest (7.60) in control receiving neither S nor Zn. The weight of 1000 grains did not vary significantly with various treatments. The 1000-grain weight followed the order $T_4>T_2>T_7>T_5>T_3>T_6>T_1$. The grain weight varied from 23.56 to 24.89 g over the treatments.The highest grain yield (5.76 t ha^{-1})was obtained in $S_{20}Zn_3$. The $S_{10}Zn_{1.5}$ which is the 50% of recommended dose produced the intermediate grain yield (4.95 t ha^{-1}). The lowest grain yield (4.35 t ha^{-1}) was obtained in control receiving neither S nor Zn.A significant and positive effects of S and Zn on straw yield of Boro rice was observed. The straw yield varied between 5.47 and 7.32 t ha^{-1} with the highest yield (7.32 t ha^{-1}) obtained in $S_{20}Zn_3$, the second highest in $S_{20}Zn_0$ (7.25 t ha^{-1}) and the lowest (5.47 t ha^{-1}) in S_0Zn_0.

A field experiment was conducted by Suresh and Salakinkop (2016) during *kharif* 2014 in Main Agricultural Research Station (MARS), Dharwad to study the biofortification of zinc and iron on growth and yield of rice. The experiment consisted of two factors *viz.,* soil and foliar application of zinc sulphate and ferrous sulphate. Factor-1 consisted of six soil applications *viz.,* S_1: Control (No application of $ZnSO_4$ and $FeSO_4$), S_2: $ZnSO_4$ and $FeSO_4$ application each @ 10 kg ha^{-1}, S_3: $ZnSO_4$ and $FeSO_4$ application each @ 15 kg ha^{-1}, S_4: $ZnSO_4$ and $FeSO_4$ application each @ 20 kg ha^{-1}, S_5: $ZnSO_4$ and $FeSO_4$ application each @ 25 kg ha^{-1}, S_6: $ZnSO_4$ and $FeSO_4$ application each @ 30 kg ha^{-1} and factor-2 consisted of foliar applications *viz.*, F_1: No spray of $ZnSO_4$ and $FeSO_4$, F_2: Foliar spray of $ZnSO_4$ and $FeSO_4$ each @ 0.5 %. The experiment was laid out in factorial RCBD with three replications. They reported that, the maximum number of effective tillers (66.66) was recorded from S_5 treatment while the minimum one (49.56) was recorded from S_1 treatment. The maximum 1000 grain weight (18.42 g) was recorded from S_6 treatment while the minimum one (17.00 g) was recorded from S_1 treatment. The maximum grain yield (3575 kg ha^{-1}) was recorded from S_5 treatment while the minimum grain yield (2878 kg ha^{-1}) was recorded from S_1 treatment. The maximum straw yield (5299 kg ha^{-1}) was recorded from S_5 treatment while the minimum straw yield (3718 kg ha^{-1}) was recorded from S_1 treatment.

A glass house experiment was conducted by Muthukumararaja and Sriramachandrasekharan (2012) at Department o Soil Science and Agricultural Chemistry, Faculty of Agriculture, Annamalai University, Tamilnadu, India, during 2010-2011. Four rates of zinc were applied to rate different levels of soil Zn. These zinc rates of 0. 2.5, 5.0, 7.5 mg Zn kg^{-1} were applied using zinc sulfate. Recommended dose of 150 N kg ha^{-1}, 50 P_2O_5 kg ha^{-1} and 50 KCl kg ha^{-1} were applied through 1.63 g pot^{-1} urea, 1.56 g pot^{-1} superphosphate and 0.4 g pot^{-1} muriate of potash, respectively. The experimental design was performed using Completely Randomized Design (CRD) with four replications. They found that, the grain yield ranged from 18.70 to 37.53 g pot^{-1} with graded dose of zinc application. The grain yield response due to 2.5, 5.0 and 7.5 mg Zn kg^{-1} over no zinc was 12.47, 18.83 and 18.13 g pot^{-1}, respectively. The highest grain yield (37.53 g pot^{-1}) was noticed at 5 mg Zn kg^{-1} which was about 10% greater than control (no zinc).The grain yield ranged from 18.70 to 37.53 g pot^{-1} with graded dose of zinc application. The grain yield response due to 2.5, 5.0 and 7.5 mg Zn kg^{-1} over no zinc was 12.47, 18.83 and 18.13 g pot^{-1}, respectively. The highest grain yield (37.53 g pot^{-1}) was noticed at 5 mg Zn kg^{-1} which was about 10% greater than control (no zinc).

Kulhare *et al.* (2016) carried out an experiment during *Kharif* 2009 under All India Co-ordinated Research Project on Micro, Secondary Nutrients, Pollutants Elements in Soil and Plants, of Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidhyalya, Jabalpur, Madhya Pradesh, India to find out the suitable genotype for Zn deficient soil condition and to optimize the dose of Zn for sustainable production of rice. Treatments comprised of twenty rice varieties *viz.*, Chandra Hasini, Pusa Basmati, Safari-17, Swarna, Purnima, Danteshwari, Indira Sona, Indira Sugandhit Dhan-1, IR-36, Bamleshwari, Samleshwari, Dubraj, Mahamaya, PKV-HMT, Shyamla, MTU-1010, Vandana, Kranti, Madhuri and Karma Masuri and five levels of Zn *viz.*, 0.0, 10, 20, 20 kg Zn +0.5% spray of $ZnSO_4$ and 0.5% spray of $ZnSO_4$. The treatments were replicated thrice in a factorial randomized block design. They reported that, application of Zn @10, 20, 20+0.5% foliar spray of$ZnSO_4$ and 0.5% foliar spray of $ZnSO_4$ significantly increased the straw yield of rice over control. While the application of Zn @ 10, 20 and 20+0.5% foliar spray of ZnSO4 were also found significantly superior to 0.5% foliar spray of ZnSO4 for straw yield. However, Zn @ 20 kg Zn and 20 kg Zn+0.5% foliar spray of ZnSO4 gave significantly higher straw yield than that of 10 kg Zn ha^{-1} but the levels were found on par. Application of Zn @10, 20, 20+0.5% foliar spray of$ZnSO_4$ and 0.5% foliar spray of $ZnSO_4$ significantly increased the grain yield of rice over control. While the application of Zn @ 10, 20 and 20+0.5% foliar spray of $ZnSO_4$ were also found significantly superior to 0.5% foliar spray of

$ZnSO_4$ for grain yield. However, Zn @ 20 kg Zn and 20 kg Zn+0.5% foliar spray of $ZnSO_4$ gave significantly higher grain yield than that of 10 kg Zn ha^{-1} but the levels were found on par.

2.2 Effect of boron on the growth parameters and yield of boro rice

Sarwar *et al*. (2016) conducted an experiment at agronomic research farm, Department of agronomy BZU Multan (71.43 E^o, 30.2 N^o) Pakistan, during kharif season 2013to study the effect of boron nutrition under intermittent flooding and drying condition seems sustainable nutrient management technique in rice.Rice cultivar Super Basmati was used as experimental material. Experiment was layout under RCBD split plot arrangement and replicated thrice.The experiment was composed of two factors. First factor included different rice cultivation systems, like aerobic rice (direct seeded), flooded rice and alternate wetting and drying. In second factor, there were different boron application methods (basal and foliar). Boronfertilization treatments were: B_0 (no application), B_1 (basal), B_2 (2% foliar application at seedling), B_3 (foliar (2%) at tillering) and B_4 (foliar at panicle initiation). They found that, the tallest plant (113.2 cm) was recorded from B_1 and the shortest pant (94.00 cm) was recorded from B_0 treatment. The maximum panicle length (36.60 cm) was recorded from B_4 and the minimum panicle length (18.70 cm) was recorded from B_0 treatment. The maximum number of effective tillers m^{-2} (442.80) was recorded from B_4 and the minimum number of effective tillers m^{-2} (240.90) was recorded from B_0 treatment. The maximum 1000 grain weight (27.60 g) was recorded from B_4 and the minimum 1000 grain weight (12.00 g) was recorded from B_0 treatment. The maximum grain yield (3599 kg ha^{-1}) was recorded from B_4 and the minimum grain yield (2119 kg ha^{-1}) was recorded from B_0 treatment.

Effect of different B levels (0.5, 1.0, 1.5 and 2.0 kg ha^{-1}) on growth, yield and ionic concentration of fine rice (Supper Basmati) under saline sodic soil at SSRI, Pindi Bhattian was studied by Hyder (2012) during 2009 and 2010. The treatments were arranged in randomized complete block design (RCBD) with three replications. The treatments under investigation were: control, 0.5, 1.0, 1.5 and 2.0 kg B ha^{-1}. They reported that, the maximum plant height (155.7 cm) was recorded in treatment receiving 1 kg B ha^{-1}. The lowest height (147 cm) was recorded in control treatment. The maximum panicle length (31 cm) was produced in treatment receiving 2 kg B ha^{-1} followed by treatment receiving 1.50 kg B ha^{-1} and the minimum one (27.70 cm) was produced by control treatment. The maximum number of tillers (28) was produced in treatment receiving 1.5 kg B ha^{-1} followed by treatment receiving 1 kg B ha^{-1} and the minimum one (19.00) was produced by control treatment. The maximum 1000 grain weight (31.70 g) was produced in treatment receiving 2.00 kg B ha^{-1} followed by treatment receiving 1.50 kg B ha^{-1} and the minimum one (29.30 g) was produced by control treatment. The maximum grain yield (5.00 t ha^{-1}) was produced in treatment receiving 2 kg B ha^{-1} followed by treatment receiving 1.50 kg B ha^{-1} and the minimum grain yield (4.10 t ha^{-1}) was produced by control treatment. The maximum straw yield (17.90 t ha^{-1}) was produced in treatment receiving 1.50 kg B ha^{-1} followed by treatment receiving 2 kg B ha^{-1} and the minimum straw yield (12.20 t ha^{-1}) was produced by control treatment.

Rehman *et al*. (2014) conducted a field study to investigate the efficiency of foliage applied boron on the panicle fertility, yield and biofortification of fine grain aromatic rice. The boron levels were 0 (control), 0.16, 0.24, 0.32, 0.40 and 0.48 M B solution. The result of the investigation revealed that, the highest number of tillers $hill^{-1}$ (20.50) was gained when the plot treated with 0.24 M B solution and the lowest number of tillers $hill^{-1}$ (16.70) was gained when the plot treated with 0 M B solution. The highest 1000 grain weight (19.88 g) was gained when the plot treated with 0.32 M B solution and the lowest 1000 grain weight (16.89 g) was gained when the plot treated with 0 M B solution.The highest grain yield (43.57 g $plant^{-1}$) was gained when the plot treated with 0.32 M B solution and the lowest grain yield (36.28 g $plant^{-1}$) was gained when the plot treated with 0 M B solution.

Saleem *et al*. (2011) investigated a field study during 2008-2009 at traditional rice growing area in the northern part of Malaysia to evaluate the effectiveness of boron fertilizers borax and colemanite (powder and granular) in supplying B to rice under flooded conditions. Boron levels were 0 kg B ha^{-1}, 1 kg B ha^{-1}, 2 kg B $ha^{-1}$and 3 kg B ha^{-1}; it was applied at the time of planting by broadcasting. Nitrogen (N), phosphorus (P) and potassium (K) fertilizers were given according to the recommendations of Malaysian Agriculture Development Authority (MADA). They found that, the highest number of effective tillers $hill^{-1}$ (14.30) was recorded from 3 kg B ha^{-1} and the lowest number of effective tillers $hill^{-1}$ (8.00) was recorded from 0 kg B ha^{-1}. The highest 1000 grain weight (23.80 g) was recorded from 3 kg B ha^{-1} and the lowest 1000 grain weight (19.00 g) was recorded from 0 kg B ha^{-1}. The highest grain yield (7.40 kg $plot^{-1}$) was recorded from 3 kg B ha^{-1} and the lowest grain yield (5.70 kg $plot^{-1}$) was recorded from 0 kg B ha^{-1}. Boron also significantly increased the straw yield of the rice at 3 kg B ha^{-1} applied as borax and CP.

2.3 Effect of copper on the growth parameters and yield of boro rice

The study was carried out by Siddika *et al*. (2016) at the Soil Science Field laboratory of Bangladesh AgriculturalUniversity, Mymensingh during the boro season of 2014-2015.There were five treatments as follows: T_1: Control (NPKS), T_2 : NPKS + Zn, T_3 : NPKS +Zn + Cu, T_4 : NPKS +Zn + Cu+ Mn T_5 : NPKS + Zn + Cu +Mn +B.The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.The doses of micronutrients were 1 kg Zn ha^{-1}, 2 kg Cu ha^{-1}, 3 kg Mn ha^{-1} and 1 kg B ha^{-1} which were supplied from librel zinc, $CuSO_4.5H_2O$, $MnCl_2.H_2O$ and librel boron. The data of the experiment revealed that, for plant height at 30, 45 and 60 DAT, the highest values of 44.67, 61.00 and 72.07 cm, respectively were obtained from T_3 which were statistically similar with the values of 43.20, 58.73 and 69.33 cm found in T_4. The shortest plants at all these three stages

(39.60, 51.73 and 59.93 cm) were observed in T_1 (control NPKS).The tallest plant of 92.13 cm was found in T_3, which was identical with treatment T_4. The shortest plant of 85.67 cm was observed in T_1 (Control NPKS). The panicle length varied from 20.60 cm to 25 cm due to different treatments. The highest panicle length (25 cm) was found in T_3 which was identical with T_2, T_4, and T_5 and the lowest panicle length (20.60 cm) was observed in T_1. For number of effective tillers hill^{-1} at 30, 45 and 60 DAT, the highest values of 10.80, 20.90 and 21.67 were obtained from T_3 and the lowest values of 9.07, 17.00 and 17.73 were observed in T_1.The highest number of effective tillers hill^{-1} of 18.40 was found in T_3 and the lowest value of 12.10 was observed in T_1. The 1000-grain weight remained unaffected by the treatments under study. The grain yield ranged from 4.55 to 6.13 t ha^{-1} where the lowest and the highest grain yields were obtained in the T_1 (Control NPKS) and T_3 (NPKS+Zn+Cu), respectively. The highest grain yield as found in T_3 was statistically similar to T_4 (NPKS+Zn+Cu+Mn) and T2 (NPKS+Zn) treatments. The straw yield ranged from 5.56 to 7.23 t ha^{-1}. It was observed that the treatment T_3 produced the highest straw yield which was statistically identical with T_4 and T_2. The lowest straw yield obtained in T_1 (Control NPKS) was not statistically different from T_5.

A study was conducted by Mhoro *et al*. (2015)in selected physiographic units of Mbeya Region Tanzania, to investigate the levels of soil macro- and micronutrients effect on crops (rice, wheat and beans) performance. Screen-house experiments with three levels of Zn (0, 7.5 and 15 mg kg^{-1} soil) and Cu (0, 5 and 10 mg kg^{-1} soil) in combination with N and P treatment in completely randomized design with three replications was conducted. The result of the experiment revealed that, the maximum plant height (100.33 cm) was recorded from (NP + Zn_{15} + Cu_5) and the minimum plant height (38.67 cm) was recorded from control treatment. The maximum grain yield (9.05 g pot^{-1}) was recorded from NP + Zn_{15} + Cu_5 treatment and the minimum grain yield (0.93 g pot^{-1}) was recorded from control treatment.The maximum biomass weight

(3.35 g pot^{-1}) was recorded from NP + Zn_{15} + Cu_5 treatment and the minimum biomass weight (0.57 g pot^{-1}) was recorded from control treatment.

Pot experiments were conducted by Jia-kuan *et al.* (2005) in 2002 and 2003 to investigate the effects of soil copper (Cu) concentration on growth, development and yield formation of rice by using the japonica cultivar Wu xiangjing 14 and hybrid rice combination Shanyou 63. The soil for pot experiment was a silty loam with the alkali-hydrolysable N, P_2O_5, K_2O and total Cu contents 80.5, 10.2, 82.1 and 37.4 mg kg^{-1}, respectively. $CuCl_2 \cdot 3H_2O$ was added to the soil to obtain a series of soil Cu levels of 100, 150, 300, 500 and 1000 mg kg^{-1}, with 20 replicates. Their investigation showed that, compared to the control, the plant height at maturity was decreased by 4.1, 6.6, 20.6, 27.4, 37.2 and 48.4% at soil Cu levels of 100, 200, 400, 600, 800 and 1000 mg kg^{-1}, respectively. The plant height was decreased significantly with the increase of soil Cu levels. The maximum number effective tillers pot^{-1}(22.00) were obtained from when the pot treated with 100 mg kg^{-1} Cu, on the other hand the minimum number effective tillers pot^{-1}(2.00) were obtained from when the pot treated with 1000 mg kg^{-1} Cu. They farther inferred that, increasing the Cu concentration in soil from 100 mg kg^{-1} to 1000 decreased the number effective tillers pot^{-1}. The maximum 1000 grain weight (24.10 g) were obtained from when the pot treated with 100 mg kg^{-1} Cu, on the other hand the minimum 1000 grain weight (20.60 g) were obtained from when the pot treated with 1000 mg kg^{-1} Cu. The maximum grain yield (74.90 g pot^{-1}) were obtained from when the pot treated with 75.40 mg kg^{-1} Cu, on the other hand the minimum grain yield (2.80 g pot^{-1}) were obtained from when the pot treated with 1000 mg kg^{-1} Cu. The grain yields were decreased by 10.1, 15.4, 37.0, 83.9, 89.3 and 96.2% at soil Cu levels of 100, 200, 400, 600, 800 and 1000 mg kg^{-1}, respectively. The total biomass under different soil Cu treatments from 100 to 1000 mg kg^{-1} were all significantly lower ($P < 0.01$ or $P < 0.05$) as compared to the control. No difference existed in the total biomass between soil Cu treatments of 100 and 200 mg kg^{-1}, but both of them were significantly higher than those under the other soil Cu treatments (above 400 mg kg^{-1}). The total biomass at soil Cu level of 400 mg $kg^{-1}$was significantly higher than that under soil Cu levels of 600, 800, 1000 mg kg^{-1}. No significant difference was detected for total biomass between soil Cu treatment of 600 and 800 mg kg^{-1}, but both of them were significantly higher than those at soil Cu level of 1000 mg kg^{-1}. The results indicated that the total biomass was significantly influenced at soil Cu level of 100 mg kg^{-1}, and decreased with the increasing levels of Cu application.

Two seasons field experiments were conducted by Liew *et al.* (2012) at Sawah Sempadan, Kampung Seri Tiram Jaya, Tanjong Karang (3° 28’ 0” North, 101° 13’ 0” East) during the off season of 2007 (July 2007 – November 2007) and in the main season of 2008 (January 2008 – May 2008) using high yielding cultivar (MR219). The experiments were carried out in randomized complete block design (RCBD) with three replications. Copper and B stock solutions were prepared from the laboratory grade of copper sulphate pentahydrate ($CuSO_4.5H_2O$) with 99% purity and sodium pentaborate ($Na_2B_{10}O_{16}.10H_2O$) with 99% purity. There were nine combination of Cu and B treatment, namely control or T_1 (0 ppm Cu + 0 ppm B), T_2 (0 ppm Cu + 10 ppm B), T_3 (0 ppm Cu + 20 ppm B), T_4 (10 ppm Cu + 0 ppm B), T_5 (10 ppm Cu + 10 ppm B), T_6 (10 ppm Cu + 20 ppm B), T_7 (20 ppm Cu + 0 ppm B), T_8 (20 ppm Cu + 10 ppm B) and T_9 (20 ppm Cu + 20 ppm B). the researcher reported that, the treatments with 20 ppm Cu and 20 ppm B produced significantly higher number of productive tillers m^{-2} (672.0)($P > 0.05$) during the 1st season of the field experiment as compared with the control plot (589.33) (0 ppm Cu and 0 ppm B).The response of rice cultivar MR219 to the Cu and B treatments with respect to 1000-grain weight was significantly higher in T9 (25.82 g) as compared to the other treatments. High concentrations of Cu and B (T_9, T_8, T_7 and T_6) significantly influenced the 1000-grain weight of rice planted in the 1st season of the field experiment.Significant increase grain yield was recorded during the 1st season (off season 2007). Treatments with T_7 (7.53 t ha^{-1}), T_9

(7.33 t ha^{-1}), T_8 (7.28 t ha^{-1}) and T_6 (7.06 t ha^{-1}) produced significantly higher ($P > 0.05$) rice yield as compared with the control, T_1 (5.75 t ha^{-1}). However, rice yield in the 2nd season of the field experiment showed no significant difference.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from January, 2016 to May, 2016 to study the effect of Zn, B and Cu on the yield and quality of *boro* Rice. This chapter includes materials and methods that were used in conducting the experiment. The details are presented below under the following headings:

3.1 Experimental Site and Soil

The experiment was conducted in typical rice growing silt loam soil at the Sher-e-Bangla Agricultural University Farm, Dhaka during the *Boro* season of 2016. The morphological, physical and chemical characteristics of the soil are shown in the Table 1 and 2

Table 1. Morphological Characteristics of the Experimental Field

Morphology	Characteristics
Location	SAU Farm, Dhaka
Agro-ecological zone	Madhupur Tract (AEZ- 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur clay
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

3.2 Climate

The climate of the experimental area is characterized by high temperature, high humidity and medium rainfall with occasional gusty winds during the *kharif* season (March-September) and a scanty rainfall associated with moderately low temperature in the R*abi* season (October-March). The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season January 2016 has been presented in Appendix I.

Table 2. Initial Physical and Chemical Characteristics of the Soil

Characteristics		Value
Mechanical fractions:	% Sand (2.0-0.02 mm)	22.53
	% Silt (0.02-0.002 mm)	56.72
	% Clay (<0.002 mm)	20.75
Textural class		Silt Loam
pH (1: 2.5 soil- water)		5.9
Organic Matter (%)		1.09
Total N (%)		0.06
Available K (ppm)		15.63
Available P (ppm)		10.99
Available S (ppm)		6.07

3.3 Planting Material

BRRI dhan 28 was used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute originated from BR 601-3-3-4-2-5 in 1994. It is recommended for *Boro* season. Average plant height of the variety is 90 cm at the ripening stage. The grains are medium fine and white. It requires about 155-160 days completing its life cycle with an average grain yield of 5.00-6.00 ton ha^{-1}.

3.4 Land Preparation

The land was first opened by a tractor and prepared thoroughly by ploughing and cross ploughing with a power tiller followed by country plough. Laddering helped breaking the clods and leveling the land followed every ploughing. Before transplanting each unit of plot was cleaned by removing the weeds, stubbles and crop residues. Finally each plot was prepared by puddling.

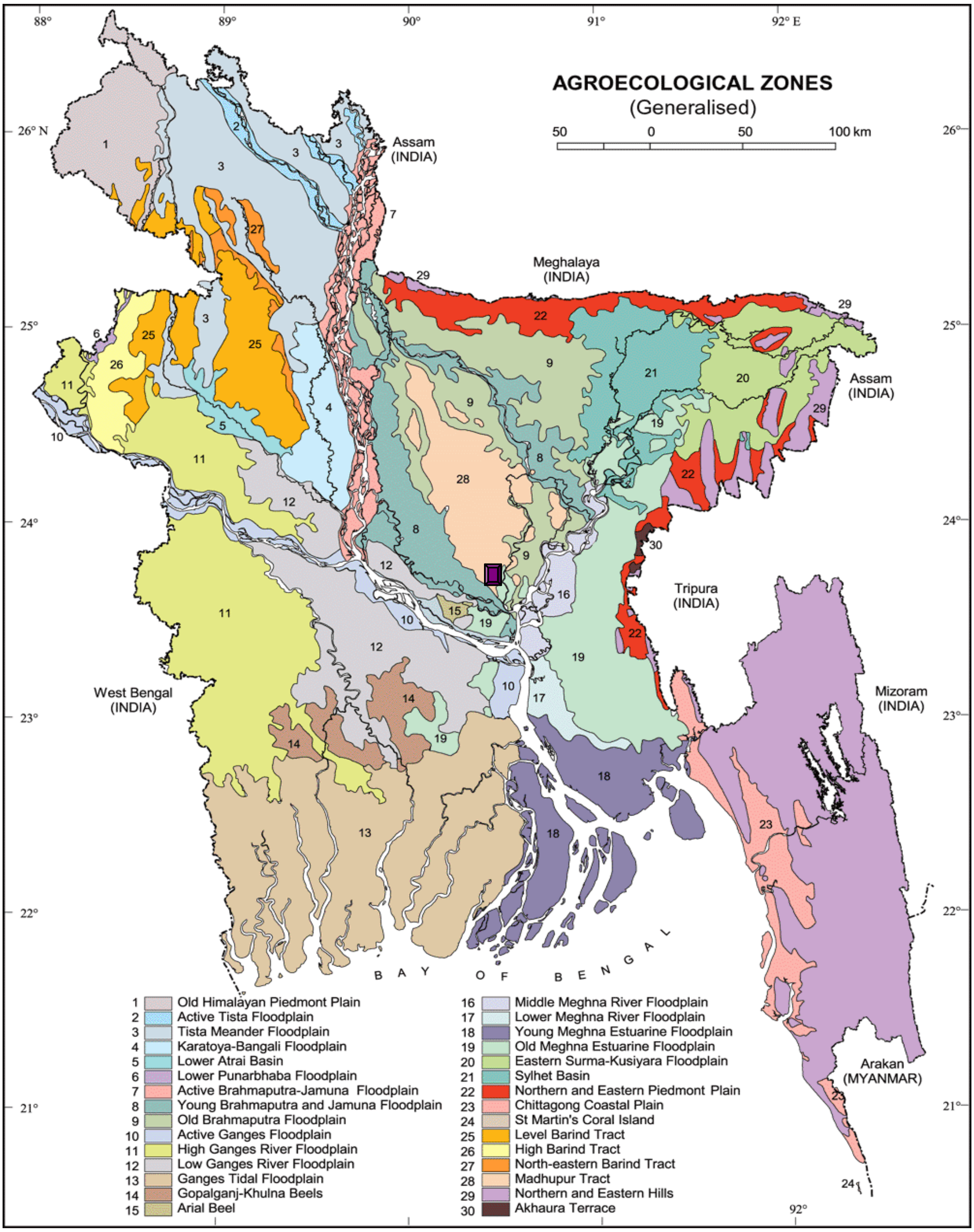


Figure 1: Map showing the experimental sites under study

3.5 Experimental Design and Layout

The experiment was laid out in a Randomize Complete Block Design (RCBD) with four replications. The total number of plots was 20; measuring 5.00 m × 2.60 m and ailes separated plots from each other. The distance maintained between replication was 1 m and plot to plot distance was 0.5m.

3.6 Initial Soil Sampling

Before land preparation, initial soil samples at 0-15 cm depth were collected from different spots of the experimental field. The composite soil sample were air-dried, crushed and passed through a 2 mm (8 meshes) sieve. After sieving, the soil samples were kept in a plastic container for physical and chemical analysis of the soil.

3.7 Treatments

The experiment consists of single factor *i.e.*different doses of fertilizers. Detail of treatments is given bellow:

Different level of fertilizers (kg ha^{-1})

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
v. T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

3.8 Fertilizer Application

The amounts of Zn, B and Cu fertilizers required per plot were calculated as per the treatments.Full amount of Zinc Sulphate, Boric acid and Copper Sulphate were applied with basal dose of TSP, MP and Gypsum before transplanting of rice seedling. Guti urea was applied once at 7 DAT.One guti for each 4 plants had been applied.

3.9 Raising of Seedlings

The seedlings of rice were raised wet-bed methods. Seeds (95% germination) @ 5 kg ha^{-1} were soaked and incubated for 48 hour and sown on a well-prepared seedbed. During seedling growing, no fertilizers were used. Proper water and pest management practices were followed whenever required.

3.10 Transplanting

Forty days old seedlings of BRRI dhan 28 were carefully uprooted from the seedling nursery and transplanted in 06 February, 2016 in well puddle plot. Two seedlings per hill were used following a spacing of 20 cm × 20 cm. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings whenever required.

3.11 Intercultural Operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.11.1 Irrigation

Irrigations were provided to the plots as and when required during the growing period of rice crop.

3.11.2 Weeding

The plots were infested with some common weeds, which were removed by uprooting them from the field with hand weeding three times during the period of the cropping season.

3.11.3 Insect and Pest Control

There were moderate infestation of leaf roller and rice hispa in the experimental field and for control measure Marshal and Diazinon @ 2ml L^{-1} were applied two times with one week interval.

3.12 Crop Harvest

The crop was harvested at full maturity when 80-90% of the grains were turned into straw colored on May, 2016. The crop was cut at the ground level and plot wise crop was bundled separately and brought to the threshing floor. Ten hills of rice plant were selected randomly from the plants for measuring yield contributing characters.

3.13 Plant characters:

3.13.1 Plant Height

The height of plant was recorded in centimeter (cm) at harvesting stage. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle.

3.13.2 Length of Panicle (cm)

The length of panicle was measured with a meter scale from 10 selected plants and the average value was recorded as per plant.

3.13.3 Total Number of Effective Tiller $Hill^{-1}$

The total number of effective tillers per hill was counted as the number of panicle bearing hill per plant. Data on effective tillers per hill were counted from 10 selected hills and average value was recorded.

3.13.4 Total Number of Non Effective Tiller Hill^{-1}

The total number of non effective tillers per hill was counted as the number of non-panicle bearing plant per hill. Data on non effective tillers per hill were counted from 10 randomly selected hills and average value was recorded.

3.13.5 Weight of 1000 Seeds (g)

One thousand seeds were counted randomly from the total cleaned harvested seeds and then weighed in grams and recorded.

3.13.6 Grain Yield (t ha^{-1})

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of the respective unit plot yield was converted to ton per ha.

3.13.7 Straw yield (t ha^{-1})

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of the respective unit plot yield was converted to t ha^{-1}.

3.13.8 Biological yield (t ha^{-1})

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

3.13.9 Harvest index(%)

Harvest index is the relationship between grain yield and biological yield. It was calculated by using the following formula:

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

3.14 Chemical Analysis of Plant Samples:

3.14.1 Collection and Preparation of Plant Samples

Grain and straw samples were collected after threshing for P, K and S analysis. The plant samples were dried in an oven at 70 ^{0}C for 72 hours and then ground by a grinding machine (Wiley-mill) to pass through a 20-mesh sieve. The samples were stored in plastic vial for analyses of P, K and S. The grain and straw samples were analyzed for determination of P, K and S concentrations.

3.14.3 Digestion of Plant Samples with Nitric-Perchloric Acid for P, K and S Analysis

A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^{0}C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The contents of the flask were boiled until they were become clean and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water and P, K and S were determined from this digest by using different standard methods.

3.14.4 Determination of P, K and S from Plant Samples:

3.14.4.1 Phosphorus

Plant samples (grain and straw) were digested by di-acid (Nitric acid and Perchloric acid) mixture and P content in the digest was measured by blue color development (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 1 ml for grain sample and 2 ml for straw sample from 100 ml digest by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrical at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.15.4.2 Potassium

Ten milliliters of digest sample for the grain and five ml for the straw were taken and diluted 50 ml volume to make desired concentration so that the flame photometer reading of samples were measured within the range of standard solutions. The concentrations were measured by using standard curves.

3.15.4.3 Sulphur

Sulphur content was determined from the digest of the plant samples (grain and straw) as described by Page *et al*., 1982. The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter *et al*., 1984).

3.16 Statisticalanalysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and the mean differences were adjusted by Least Significance Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

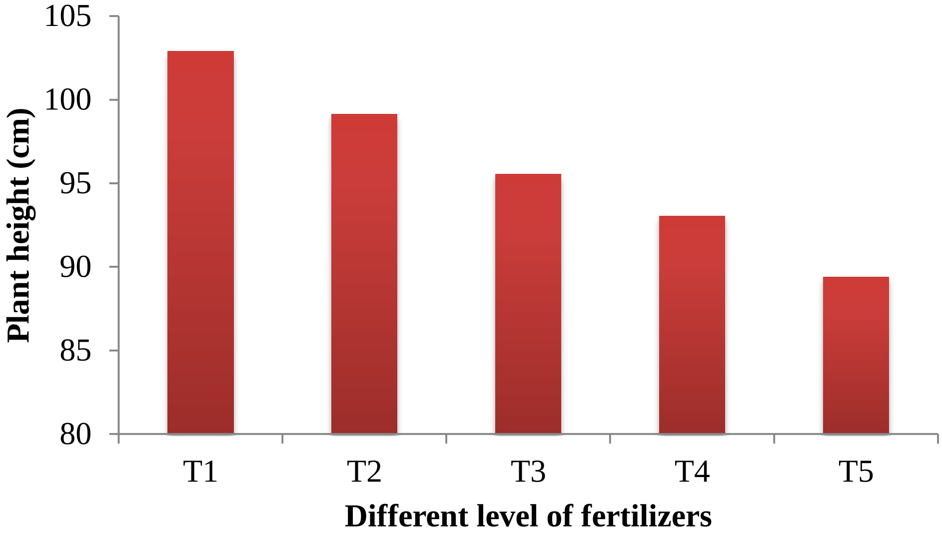
CHAPTER IV

RESULTS AND DISCUSSION

Results obtained from the study of Zn, B and Cu on the yield and quality of *boro* rice have been presented and discussed in this chapter. Treatments effect of fertilizer management on all the studied parameters have been presented in figures and discussed below under the following sub-headings.

4.1 Effect of different level of fertilizers on plant height

Plant height is an important morphological attribute; it is a function of combined effects of genetic makeup of a plant, soil nutrient status, seedling vigor and the environmental conditions under which it is grown. Plant height was significantly influenced by different level of fertilizer of rice (Figure 1). The result of the study revealed that, the tallest plant height (102.90 cm) was recorded from T_1 (N_{55}+P_{35}+K_{65}+S_{18}+Zn_5+B_4+Cu_4) treatment which was statistically similar with T_2 (N_{55}+P_{35}+K_{65}+S_{18}+B_4+Cu_4) and T_3 (N_{55}+P_{35}+K_{65}+S_{18}+Zn_5+Cu_4). On the other hand the shortest plant height (89.40 cm) was recorded from T_5 (N_{55}+P_{35}+K_{65}+S_{18} (control)) which was statistically similar with T_4 (N_{55}+P_{35}+K_{65}+S_{18}+Zn_5+B_4) treatment. In this study, there was a synergistic effect of Zn, B and Cu found in increasing plant height of rice. Improvement in plant growth was due to proper nourishment of crop with nutrient supply and also increased activity of meristematic cells and cell elongation with supplemental application of Zn as it is known to have favorable effect on metabolic process which attributed to longer plant height than control treatment (Suresh and Salakinkop, 2016 and Pooniya and Shivay, 2013). Similar result regarding plant height of rice has also been observed by many other researchers in the past (Uddin *et al.,* 1997, Salam and Subramanian, 1993 andTejasarwana, 1991). Sarwar *et al.* (2016) investigated that boron application significantly enhanced plant height of rice. It is a well-known fact that boron is essential in enhancing carbohydrate metabolism, sugar transport, cell wall structure, protein metabolism, root growth and stimulating other physiological processes of plant that helped to trigger the plant height (Kumar *et al.*, 2017, Goldberg, 1997 and Ashour and Reda, 1972). Sarwar *et al.* (2016) reported that, poor performance in control (no boron) treatment might be due to imbalance nutrient application. In boron application treatment, crop up taken more nutrients and improved the crop vigor. Healthy and vigorous plants will ultimately have great impact on crop growth.Saleem *et al.* (2011) reported that effect of 2 and 3 kg B ha^{-1} recorded taller plants, followed by 1 kg B ha^{-1}. The untreated control recorded lower plant height. These results were supported by the findings of Mehdi *et al.* (2006). He reported that B increased the plant height of both rice and wheat. Cu had also significant influence on plant height which was aimed at supplying nutrients is invariably important in promoting plant growth (Liew *et al.*, 2012 and Dobermann and Fairhurst, 2000). Similar results were reported by Siddika *et al*. (2016) and El-Nahhal *et al.* (2013).

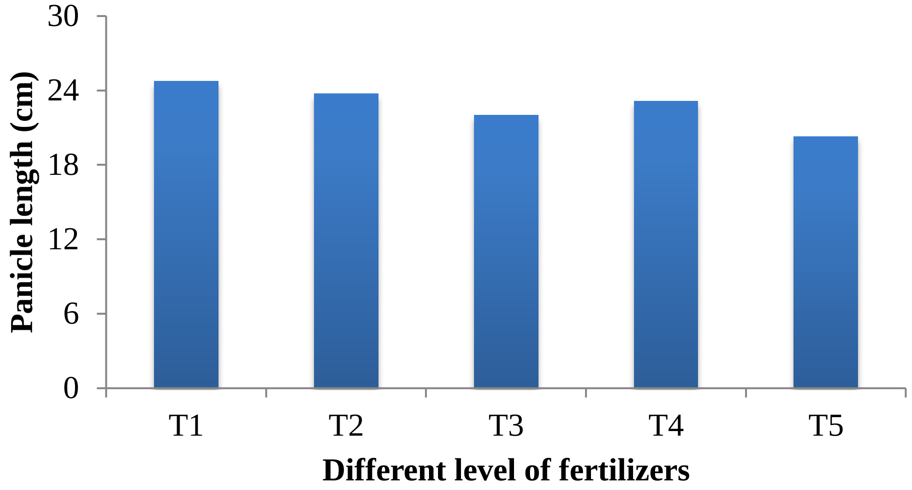


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 1. Effect of different level of fertilizers on the plant height of rice (LSD $_{(0.05)}$ = 9.12)

4.2 Effect of different level of fertilizers on panicle length

Panicle length of rice was significantly differed by different level of fertilizer (Figure 2). The result of the experiment revealed that, the maximum panicle length (24.74 cm) was recorded from T_1 treatment which was statistically similar with all the treatments except T_5 and the minimum panicle length (20.30cm) was recorded from T_5 treatment which was statistically similar with T_3. These results are in line with the findings of Mustafa *et al.* (2011), Rahman *et al.* (2008), Maqsood *et al.* (1999), Hung *et al.* (1990) and Balakrishnar and Natarajaratnam (1986) who reported that adequate supply of Zn to rice increased its panicle length. 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.



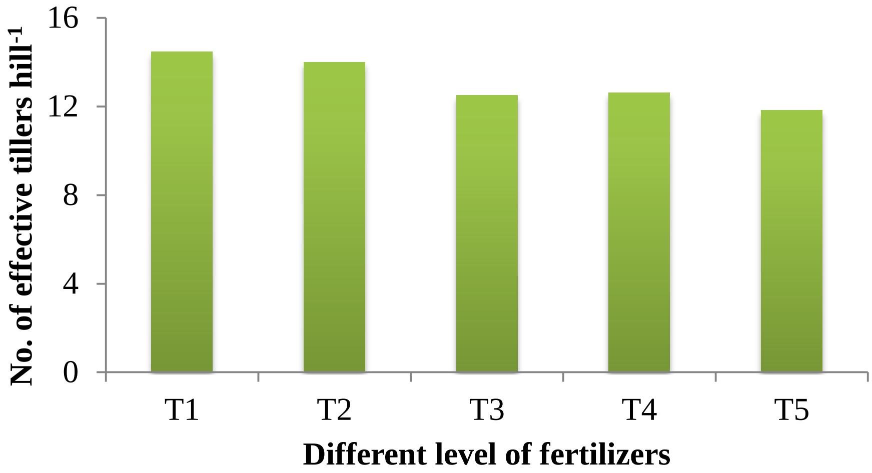
T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 2. Effect of different level of fertilizers on the panicle length of rice (LSD $_{(0.05)}$ = 2.78)

4.3 Effect of different level of fertilizers on no. of effective tillers hill^{-1}

No. of effective tillers hill^{-1} of rice was significantly varied due to fertilizer variation (Figure 3). The result exerted that, the maximum no. of effective tillers hill^{-1} (14.46) was given by treatment T_1 which was statistically at par with rest of the treatments except T_3 and T_5, on the other hand the minimum no. of effective tillers hill^{-1} (11.82) was given by treatment T_5 which was statistically at par with T_3 and T_4. Higher zinc concentration in the grain maintained by the application of zinc in the rhizosphere with constant supply coupled with more number of productive tillers hill^{-1} (Muthukumararaja and Sriramachandrasekharan, 2012 and Jena *et al*., 2006). Mustafa *et al*. (2011) also reported that, increase in productive tillers hill^{-1} might be ascribed to adequate supply of zinc that might had increased the uptake and availability of other essential nutrients, which resulted in improvement of plant metabolic process and finally increased the number effective tillers hill^{-1}. This result was in accordance with that of Kumar *et al.* (2017) and Arif *et al.*, (2012), Naik and Das (2007) and Slaton *et al*. (2005a). Saleem *et al.* (2011) and Marschner

(1995) reported that, the positive effect on plant effective tillers may be due to the proper development and differentiation of tissue as B affects the deposition of cell wall material by altering membrane properties. The result of our present piece of work was consistent with the findings of Rahmatullah *et al.* (2006) and Ashraf *et al*. (2004) who reported that B application significantly affected the plant growth. Rerkasem and Jamjod (2004) also reported that low B availability could reduce tiller numbers in wheat. Siddika *et al*. (2016) and Liew *et al.* (2012) reported that, **t**iller production is greatly affected by the availability of Cu and the higher effective tillers hill^{-1} was produced with adequate supply of Cu. Similar result also reported by Narimani *et al.* (2010) who observed higher number of fertile tillers plant^{-1} in durum wheat due to application of Cu. Copper deficient plant always shows a decrease in the numbers of tillers formed (Dobermann and Fairhurst, 2000).

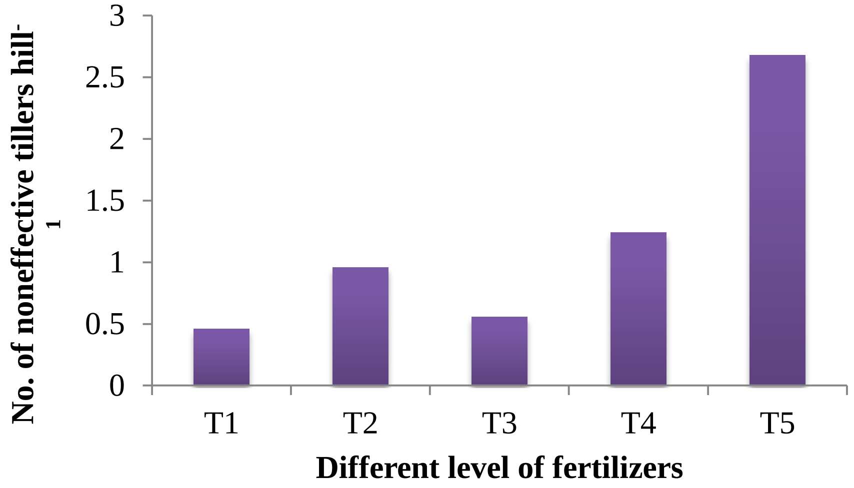


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 3. Effect of different level of fertilizers on the no. of effective tillers hill^{-1} of rice (LSD $_{(0.05)}$ = 1.93)

4.4 Effect of different level of fertilizers on no. of non-effective tillers hill^{-1}

Different level of fertilizers exerted significant variation on no. of non-effective tillers hill^{-1} of rice (Figure 4). Result of the experiment showed that the maximum no. of non-effective tillers hill^{-1} (2.68) was recorded from treatment T_5 followed by T_4 (1.24) where as the minimum no. of non-effective tillers hill^{-1} (0.46) was recorded from treatment T_1 which was statistically similar with T_3. The higher number of non-effective tillers hill^{-1} was might be due to lower supply of micro nutrients (Zn, B and Cu) because these nutrients help to boosting the effective tillers production of rice.



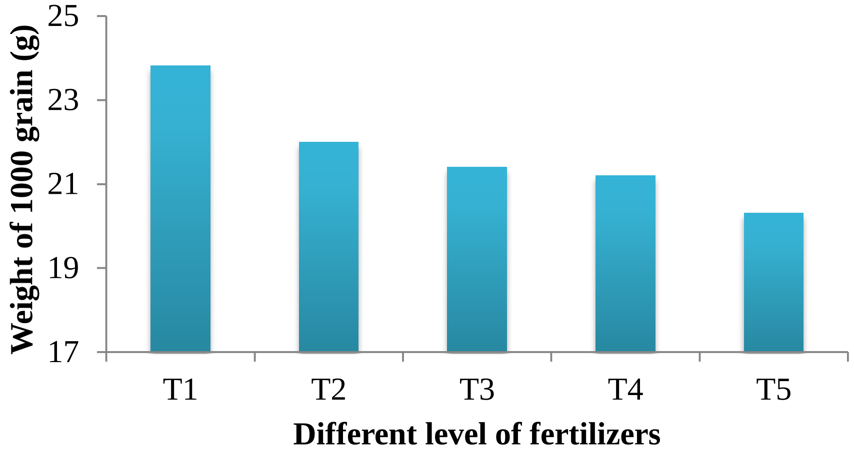
T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 4. Effect of different level of fertilizers on the no. of non effective tillers hill^{-1} of rice (LSD $_{(0.05)}$ = 0.14)

4.5 Effect of different level of fertilizers on weight of 1000 grain

Different level of fertilizers had significant variation on weight of 1000 grain of rice (Figure 5).The result of the experiment revealed that, the maximum weight of 1000 grain (23.82 g) was gained by T_1 which showed statistical similarity with T_2 and the minimum weight of 1000 grain (20.31 g) was gained by T_5 which showed statistical similarity with rest of the treatments except T_1. T_1gave

17.28 % more weight of 1000 grain over treatment T_5. The present findings are in agreement with Siddika *et al*. (2016) and Nawaz *et al.* (2004) who reported that 1000-grain weight of rice were significantly affected by Zn and Cu fertilization and 1000-grain weight was found maximum in the treatments where Zn and Cu were applied @ 10 kg ha^{-1}. 1000-grain weight was significantly increased (13.39 %) by zinc application over control (Mustafa *et al.*, 2011). These findings are in line with results of Naik and Das (2007) and Ghani *et al*. (1990) who reported that soil application of zinc increased 1000-grain weight of rice. Narimani *et al.* (2010) and El-Nahhal (2004) also found higher weight of 1000-kernel in durum wheat due to combined application of Zn and Cu. Saleem *et al.* (2011) found that, residual effect at 2 kg B ha^{-1} resulted in significantly higher 1000-grain weight than 1 kg B ha^{-1} and equal with 3 kg B ha^{-1} rate. 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 Ashraf *et al.* (2004). They concluded that 1000-grain weight of rice increased with the increasing level of residual B fertilizer. But our result was not in line with the result of Hossain *et al.* (1997) who reported that micronutrient deficiency might limit the grain yield of rice by reducing tillering and grain formation, but not affecting the 1000-grain weight rice.

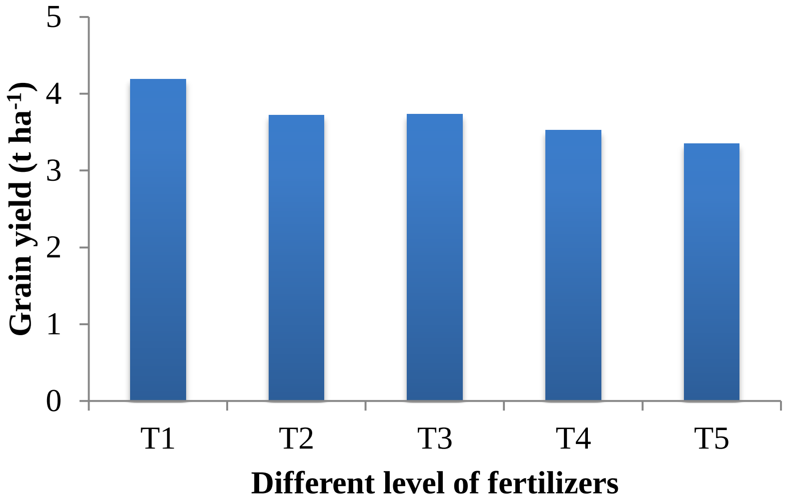


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 5. Effect of different level of fertilizers on the weight of 1000 grain of rice (LSD $_{(0.05)}$ = 1.95)

4.6 Effect of different level of fertilizers on grain yield

Significant variation was found on the grain yield of rice due to different levels of fertilizer application (Figure 6). The result of the experiment showed that, the highest grain yield (4.19 t ha^{-1}) was produced by T_1 treatment followed by T_3 (3.74 t ha^{-1}), T_2 (3.73 t ha^{-1}) and T_4 (3.53 t ha^{-1}) and the lowest grain yield (3.35 t ha^{-1}) was produced by T_5 treatment which was statistically similar with T_4. Treatment T_1 produced 25.08% more grain yield over T_5. The higher grain yield might be attributed to better performance of growth and yield parameters through adequate availability of micro nutrients especially Zn, B and Cu in soil, which in turn, favorably influenced physiological processes and build up of photosynthates stored into the sink (economical parts-grain) (Suresh and Salakinkop, 2016, Tabassum *et al.*, 2013, Babu *et al.*, 2007 and Sachdev *et al.*, 1988). Rahman *et al.* (2006) concluded that, there was increased grain yield of 16.5% upon application of 2.5 kg Zn ha^{-1}; while 15% upon application of 5.0 kg Zn ha^{-1} in rice. These findings are consistence with previous researches that indicated combination of zinc with other elements improved the photosynthetic attributes and had a positive effect on reproductive organs to produce more grain yield (Suresh and Salakinkop, 2016 and Zayed, 2011). Moreover, by supplying plants with micronutrients (Zn, B and Cu) through soil application, there was increased yield and quality as well as macronutrient use efficiency. Zn is essential for several enzymes that regulate metabolic activities in plants. They involve in auxin production, transformation of carbohydrate and regulation of sugar in plants. Similar findings were reported by a number of researchers Kulhare *et al.*(2016), Muthukumararaja and Sriramachandrasekharan (2012), Mustafa *et al.* (2011), Fageria *et al*. (2011), Rehman *et al*. (2008), Khan *et al*. (2007), Chaudhary *et al*. (2007) Jena *et al*. (2006), Mandal *et al*. (2000), Mandol and Halder (1998), Hoque and Jahiruddin (1994), Ahkter *et al.* (1994) and Gupta and Kala (1992) who reported Zn contribution gave significantly higher rice grain yield than control. Islam *et al.* (1997) observed that application of 5kg Zn ha^{-1} increased the grain yield of rice by 15%. Slaton *et al*. (2005b) observed 12 to 180%, while Fageria *et al*. (2011) reported 97% increase in rice yield due to zinc fertilization. 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, panicles, weight of spikelet and fully ripened spikelets improved. Dobermann and Fairhurst, 2000, reported that, B plays a key role in carbohydrate metabolism, sugar transport and pollen viability in rice. B has long been identified as one of the major constraints for grain crop production in the world. Moreover, B is also associated with male sterility and grain set failure in grain crops, particularly in wheat (Rerkasem and Jamjod, 2004 and Rerkasem *et al.*, 2004). Rerkasem and Jamjod (2004) also found that B deficiency impaired the function of anthers and resulted in severe reduction in yield. Again, Cheng and Rerkasem (1993) reported that, B deficiency depresses pollen germination and the fertilization process. These findings are consistent with those of Kumar *et al.* (2017), Rao *et al.,* (2013), Sharma *et al.*, (2013), Arif *et al.* (2012), Liew *et al.* (2012), Quddus *et al.* (2011), Saleem *et al.* (2011), Yang *et al.* (2009), Ehsan-Ul-Haq *et al*. (2009), Rashid *et al*. (2007). They reported that soil-applied B produced significantly higher yields over the control. Copper is needed in photosynthesis, respiration, carbohydrate metabolism and sugar transport in rice plant. It also plays a critical role in the formation of pollen and fertilization in rice (Dobermann and Fairhurst, 2000). Khush and Peng (1996) stated that translocation and accumulation of photosynthate (carbohydrate) produced in leaves and stems into the grains are prerequisites for higher grain filling rates. Gupta *et al.* (2008) reported that high N supply to high yielding crop may accentuate Cu deficiency due to the lower availability of Cu in plants of high N nutritional status. Dobermann and Fairhurst (2000) also reported that Cu affected pollen viability in rice plant. On the contrary, copper deficiency reduces seed production in wheat, and this is mainly due to male sterility rather than decrease in photosynthetic CO_2 fixation (Gupta *et al.*, 2008) and (Dobermann and Fairhurst, 2000). Similar findings were also reported by Siddika *et al*. (2016), Imtiaz *et al*. (2010), Nawaz *et al.* (2004) and Qadir *et al*. (1986).

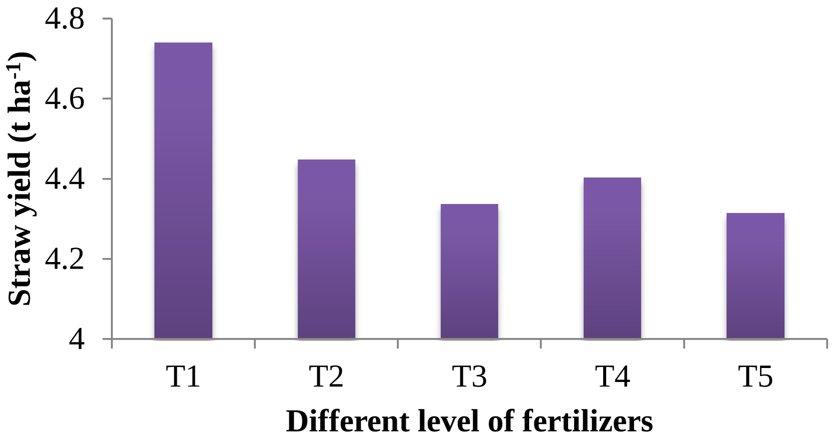


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 6. Effect of different level of fertilizers on the grain yield of rice (LSD $_{(0.05)}$ = 0.34)

4.7 Effect of different level of fertilizers on straw yield

Straw yield of rice significantly differed due to application of different levels of fertilizer (Figure 7). Result showed that, the highest straw yield (4.74 t ha^{-1}) was produced by T_1 treatment which was statistically similar with treatment T_2 on the other hand the lowest straw yield (4.31 t ha^{-1}) was produced by T_5 treatment which was statistically similar with rest of the treatments except T_1. This result was in coincide with the results of Islam *et al.* (1997) who reported that, there was a significant increase in the straw yield of BR11 rice due to application Zn. Saleem et al. (2011) reported that, the highest straw yield was recorded at 3 kg B ha^{-1} over control. This result was in agreement with the findings of Rashid *et al.* (2007). Paddy 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).

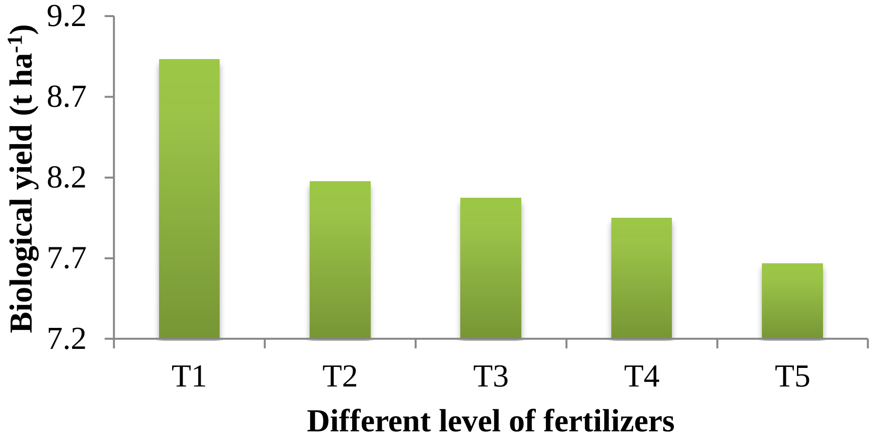


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 7. Effect of different level of fertilizers on the straw yield of rice (LSD $_{(0.05)}$ = 0.30)

4.8 Effect of different level of fertilizers on biological yield

Biological yield of rice significantly varied due to application of different levels of fertilizer (Figure 8). Result revealed that, the highest biological yield (8.93 t ha^{-1}) was distinctly produced by T_1 treatment where as the lowest biological yield (7.67 t ha^{-1}) was produced by T_5 treatment which was statistically at par with rest of the treatments except T_1. This result was in line with the findings of Mustafa *et al*. (2011) and Gupta and Kala (1992) who reported that the supplemental application of Zn enhanced the biological yield of rice.

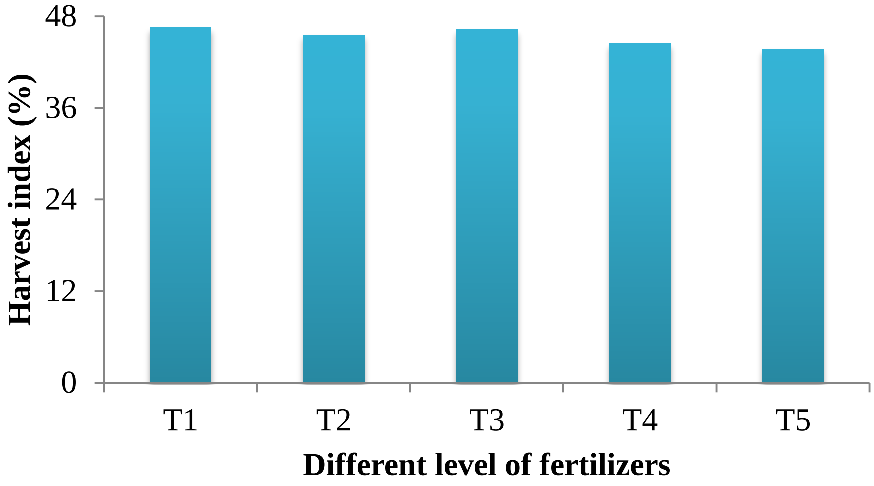


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 8. Effect of different level of fertilizers on the Biological Yield of rice (LSD $_{(0.05)}$ = 0.73)

4.9 Effect of different level of fertilizers on harvest index

Different levels of fertilizer had no significant effect on harvest index of rice (Figure 9). Numerically the maximum harvest index (46.52%) was recorded from treatment T_1 and the minimum one (43.72%) was recorded from T_5.

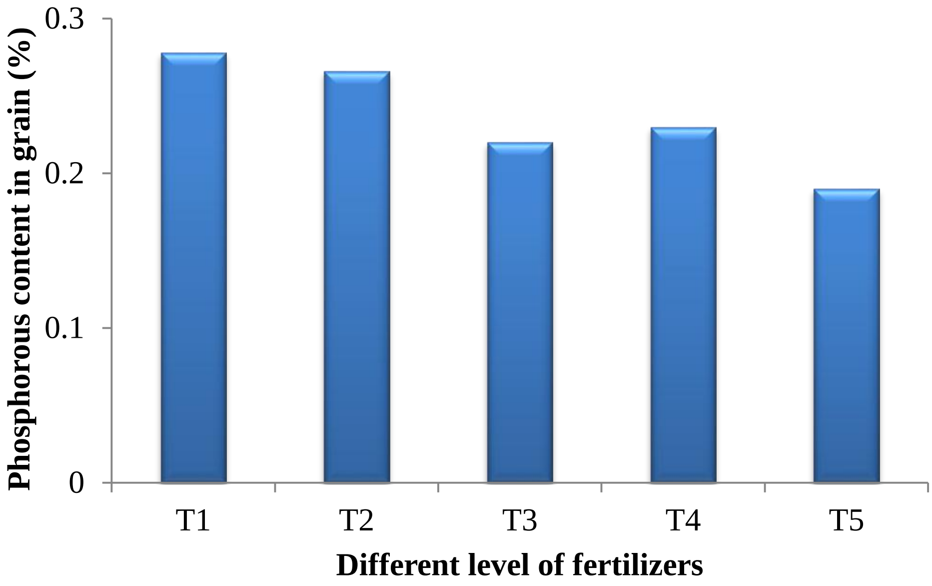


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 9. Effect of different level of fertilizers on the harvest index of rice (LSD $_{(0.05)}$ = NS)

4.10 Effect of different level of fertilizers on phosphorous content in grain

The phosphorous content in grain of rice was significantly varied by different levels of fertilizer (Figure 10). The maximum phosphorous content in grain of rice (0.28 %) was recorded from treatment T_1 which was statistically similar with treatment T_2 and the minimum phosphorous content in grain of rice (0.19 %) was recorded from treatment T_5. The available P content was higher in rice grain because micronutrients might be helpful for P availability to the rice plant which might be attributed higher P accumulation in rice grain. This observation was in conformity with the findings of Kumar *et al.* (2017) and Singh *et al.* (1976).

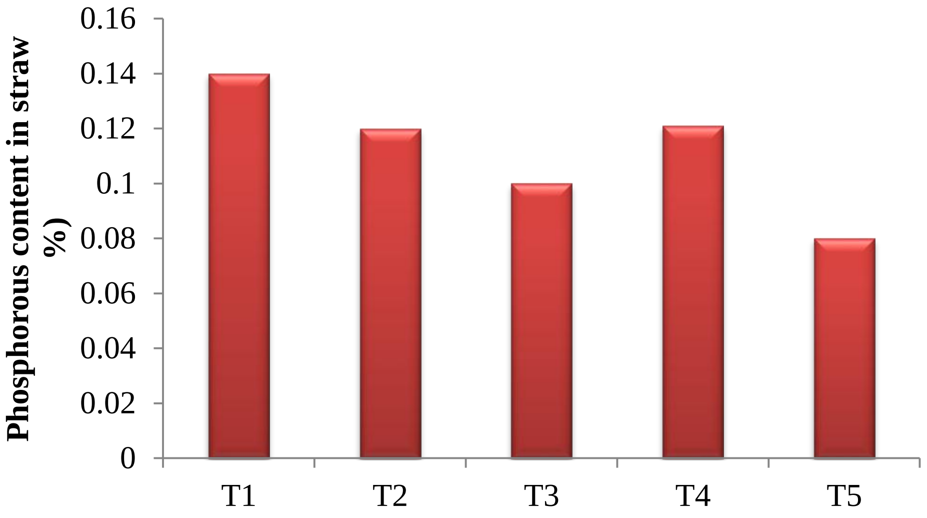


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 10. Effect of different level of fertilizers on the phosphorous content in grain of rice (LSD $_{(0.05)}$ = 0.01)

4.11 Effect of different level of fertilizers on phosphorous content in straw

The phosphorous content in straw of rice was significantly influenced by different levels of fertilizer (Figure 11). The maximum phosphorous content in straw of rice (0.14%) was recorded from treatment T_1 and the minimum phosphorous content in straw of rice (0.08%) was recorded from treatment T_5. The rest of the treatments contained intermediate amount of phosphorous in straw of rice.The available P content was higher in rice straw because micronutrients may be helpful for P availability to the rice plant which might be attributed higher P accumulation in rice straw. This observation was in conformity with the findings of Kumar *et al.* (2017) and Singh *et al.* (1976).

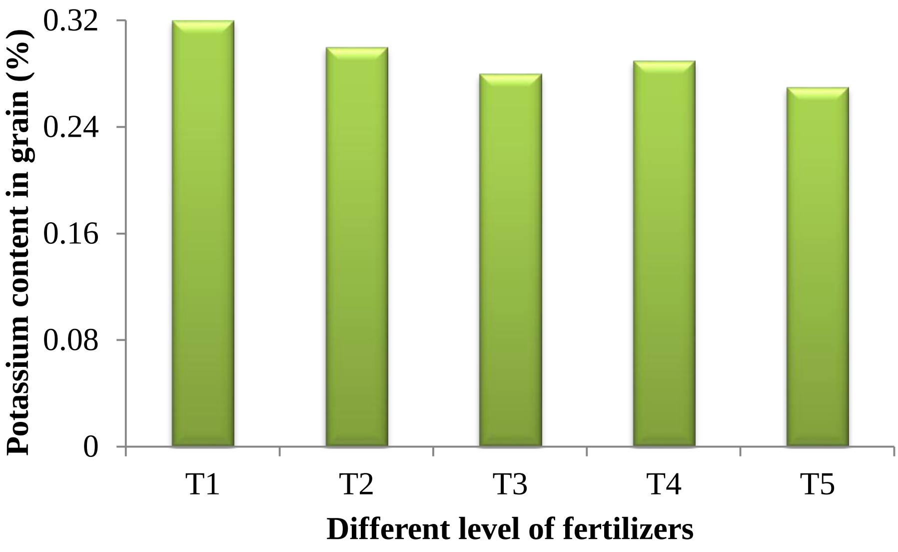


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 11. Effect of different level of fertilizers on the phosphorous content in straw of rice (LSD $_{(0.05)}$ = 0.01)

4.12 Effect of different level of fertilizers on potassium content in grain

The potassium content in grain of rice was significantly influenced by different levels of fertilizer (Figure 12). The potassium content in rice grain ranged from 0.32% to 0.27% was found during the study. The maximum potassium content in grain of rice (0.32 %) was recorded from treatment T_1 and the minimum potassium content in grain of rice (0.27 %) was recorded from treatment T_5 which was statistically similar with T_3. The rest of the treatments contained intermediate amount of potassium in rice grain. By supplying plants with micronutrients (Zn, B and Cu) through soil application, there was increased of macronutrient use efficiency which might be increased the available K for rice and finally higher accumulation in rice grain (Rahman *et al.*,2006).

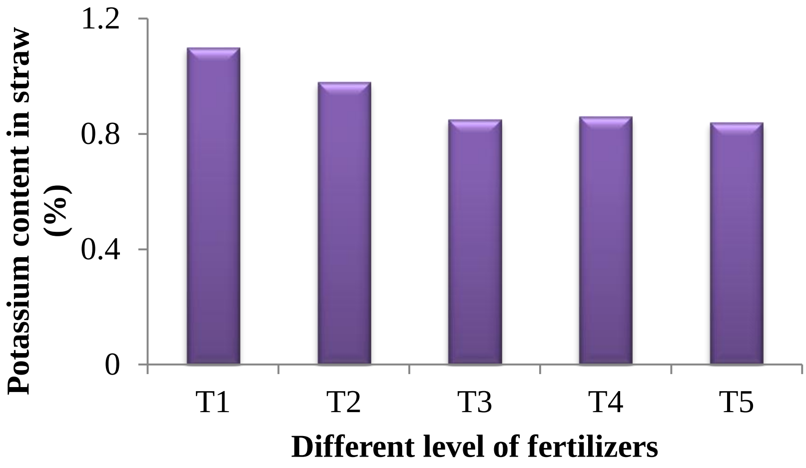


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 12. Effect of different level of fertilizers on the potassium content in grain of rice (LSD $_{(0.05)}$ = 0.01)

4.13 Effect of different level of fertilizers on potassium content in straw

The potassium content in rice straw was significantly influenced by different levels of fertilizer (Figure 13). The potassium content in rice grain ranged from 1.10% to 0.84% was found during the study. The maximum potassium content in straw of rice (1.10 %) was recorded from treatment T_1 and the minimum potassium content in grain of rice (0.84 %) was recorded from treatment T_5 which was statistically similar with T_3. By supplying plants with micronutrients (Zn, B and Cu) through soil application, there was increased of macronutrient use efficiency which might be increased the available K for rice plant consequently higher accumulation of K occurred in rice grain (Rahman *et al.*, 2006).

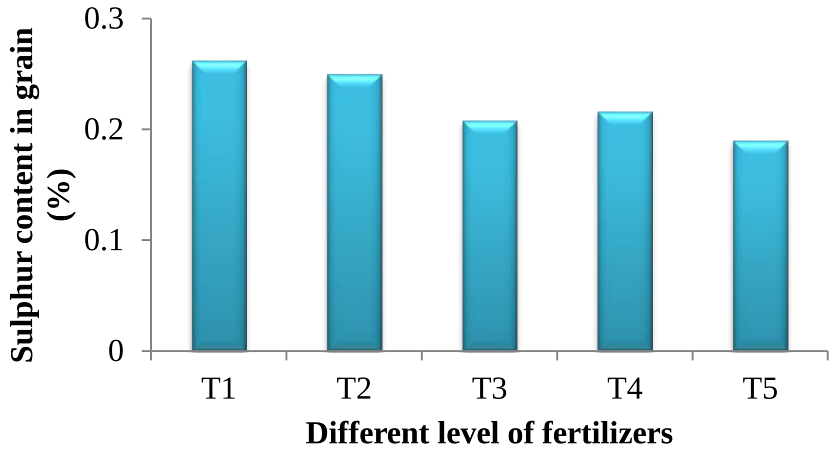


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 13. Effect of different level of fertilizers on the potassium content in stem of rice (LSD $_{(0.05)}$ = 0.01)

4.14 Effect of different level of fertilizers on sulphur content in grain

The sulphur content in grain of rice was significantly differed by different levels of fertilizer (Figure 14). The sulphur content in rice grain ranged from 0.26 % to 0.19 % was found during the study. The maximum sulphur content in grain of rice (0.26 %) was recorded from treatment T_1 followed by T_2 (0.25 ppm) and the minimum sulphur content in grain of rice (0.19 %) was recorded from treatment T_5. The rest of the treatments contained intermediate amount of sulphur in rice grain. The available S was influenced significantly by micronutrient application. The plots treated with $ZnSO_4$ had significantly higher content of available S than those which were not treated with $ZnSO_4$. The finding was in conformity with the results reported by Rahman *et al.* (2008), Poongothai *et al.* (1999), Islam *et al.* (1997), Mandata *et al.* (1994) and Khan *et al.* (1992) who noted that concentration of S in rice plant increased with increase rate of $ZnSO_4$ application. Though the level of applied B was slightly low, but the B had significant effect on available sulphur in plant sample **(**Kumar *et al*., 2017).

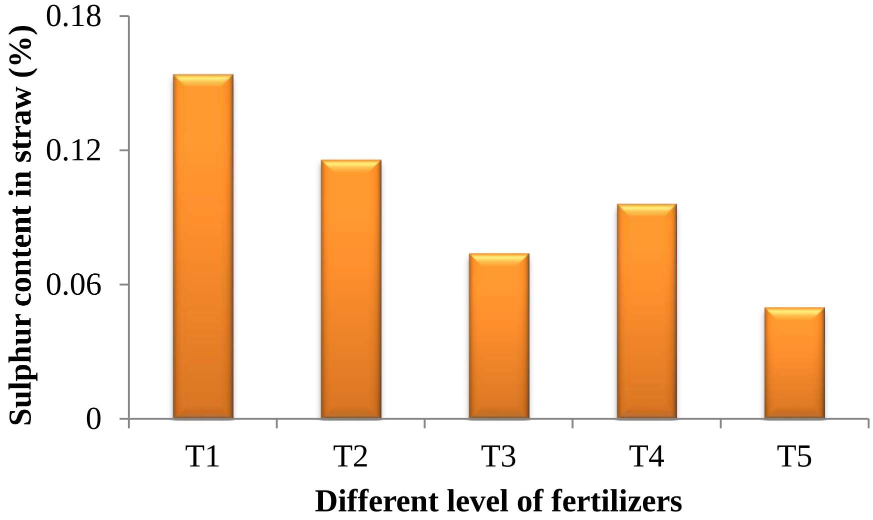


T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 14. Effect of different level of fertilizers on the sulphur content in grain of rice (LSD $_{(0.05)}$ = 0.01)

4.15 Effect of different level of fertilizers on sulphur content in straw

The sulphur content in straw of rice was significantly differed by different levels of fertilizer (Figure 15). The sulphur content in rice straw ranged from 0.15 % to 0.05 % was found during the study. The maximum sulphur content in straw of rice (0.15 %) was recorded from treatment T_1 followed by T_2 (0.12 %) and the minimum sulphur content in straw of rice (0.05 %) was recorded from treatment T_5. The rest of the treatments contained intermediate amount of sulpher in rice straw. The plots treated with $ZnSO_4$ had significantly higher content of available S than those which were not treated with $ZnSO_4$. The reason for this could be attributed to the release of S from $ZnSO_4$ to the soil consequently increased the S content in rice straw **(**Kumar *et al.*, 2017).



T_1=N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4, T_2= N_{55} +P_{35} +K_{65} +S_{18} +B_4 +Cu_4, T_3= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +Cu_4, T_4= N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 and T_5= N_{55} +P_{35} +K_{65} +S_{18} (control)

Figure 15. Effect of different level of fertilizers on the sulphur content in straw of rice (LSD $_{(0.05)}$ = 0.01)

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at the research field, Sher-e-Bangla Agricultural University, Dhaka during the period from January to May, 2016 to effect of Zn, B and Cu on the yield and quality of boro rice. The experimental field belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28. The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of single 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 experiment was laid out following Randomized Complete Block Design (RCBD) with four replications. There were 5 treatments. The total numbers of unit plots were 20. The size of unit plot was 13 m^2 (5.00 m × 2.60 m). The field was fertilized with nitrogen, phosphate, potash, sulpher, zinc, boron and copper at the rate of 120, 100, 70, 60, 10, 25, 10 kg ha^{-1}, respectively in the form of guti urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate, boric acid and copper sulphate.

Results of the study revealed that different levels of fertilizers had significant effect on plant growth yield and yield contributing characters of rice except harvest index. The tallest plant height (102.90 cm) was recorded from T_1 (N_{55} +P_{35} +K_{65} +S_{18} +Zn_5 +B_4 +Cu_4) treatment, on the other hand the shortest plant height (89.40 cm) was recorded from T_5 [N_{55} +P_{35} +K_{65} +S_{18} (control)]. The maximum panicle length (24.74 cm) was recorded from T_1 treatment the minimum one (20.30cm) was recorded from T_5 treatment. The maximum no. of effective tillers $hill^{-1}$ (14.46) was given by treatment T_1 while the minimum no. of effective tillers $hill^{-1}$ (11.82) was given by treatment T_5. The maximum no. of non-effective tillers $hill^{-1}$ (2.68) was recorded from treatment T_5 where as the minimum no. of non-effective tillers $hill^{-1}$ (0.46) was recorded from treatment T_1. The maximum weight of 1000 grain (23.82 g) was gained by T_1 and the minimum weight of 1000 grain (20.31 g) was gained by T_5. T_1 gave 17.28 % more weight of 1000 grain over treatment T_5. The highest grain yield (4.19 t ha^{1}) was produced by T_1 treatment followed by T_3 (3.74 t ha^{-1}), T_2 (3.73 t ha^{-1}) and T_4 (3.53 t ha^{-1}) and the lowest grain yield (3.35 t ha^{-1}) was produced by T_5 treatment. Treatment T_1 produced 25.08% more grain yield over T_5. The highest straw yield (4.74 t ha^{-1}) was produced by T_1 treatment on the other the lowest straw yield (4.31 t ha^{-1}) was produced by T_5 treatment. The highest biological yield (8.93 t ha^{-1}) was distinctly produced by T_1 treatment where as the lowest biological yield (7.67 t ha^{-1}) was produced by T_5 treatment. Numerically the maximum harvest index (46.52%) was recorded from treatment T_1 and the minimum one (43.72%) was recorded from T_5.

The nutrient content on rice grain and straw was also significantly influenced by different levels of fertilizers. The result evident that, the maximum phosphorous content in grain of rice (0.28 %) was recorded from treatment T_1 and the minimum phosphorous content in grain of rice (0.19 %) was recorded from treatment T_5. The maximum phosphorous content in straw of rice (0.14%) was recorded from treatment T_1 and the minimum phosphorous content in straw of rice (0.08%) was recorded from treatment T_5. The maximum potassium content of rice grain (0.32%) was recorded from treatment T_1 and the minimum potassium content of rice grain (0.27%) was recorded from treatment T_5. The maximum potassium content in straw of rice (1.10%) was recorded from treatment T_1 and the minimum potassium content in grain of rice (0.84 %) was recorded from treatment T_5. The maximum sulpher content in grain of rice (0.26 %) was recorded from treatment T_1 followed by T_2 (0.25 %) and the minimum sulpher content in grain of rice (0.19 %) was recorded from treatment T_5. The maximum sulpher content in straw of rice (0.15 %) was recorded from treatment T_1 followed by T_2 (0.12 %) and the minimum sulpher content in straw of rice (0.05 %) was recorded from treatment T_5.

Reviewing above the results of the present piece of work, it might be concluded that, the micro nutrients had great response on the yield of boro rice. The treatment T_1 (N_{55}+P_{35}+K_{65}+S_{18}+Zn_5+B_4+Cu_4) produced maximum grain yield (4.19 t ha^{-1}) which could be a better production package for different rice grower in Bangladesh.

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APPENDICES

Appendix I. Monthly average temperature, relative humidity, total rainfall and sunshine of the experimental site during the period of January, 2016 to June, 2016

Month	Air temperature (ºC)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (h)
	Maximum	Minimum			
January, 2016	29.0	13.0	62	0	3.9
February, 2016	28.1	11.1	65	1	5.7
March, 2016	33.9	12.2	55	1	8.7
April, 2016	34.6	16.5	67	45	7.3
May, 2016	34.8	21.1	79	227	8.7
June, 2016	35.3	22.3	81	230	8.9

Appendix II. Analysis of variance of the data on growth parameters and yield of boro rice as affected by different levels of fertilizers

Source of variation	df	Mean square of value of			
		Plant height	Panicle length	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}
Replication	3	91.51	6.44	2.51	0.02
Fertilizers	4	137.95*	14.55*	6.11*	4.01*
Error	12	46.2	4.31	2.08	0.01

*Significant at 5% level of significance

^{NS} Non significant

Appendix III.Analysis of variance of the data on yield and yield contributing characters of boro rice as affected by different levels of fertilizers

Source of variation	df	Mean square of value of				
		1000 grain weight	Grain yield	Straw yield	Biological yield	Harvest index
Replication		1.50	0.05	0.01	0.05	5.65
Fertilizers		8.55*	0.49*	0.15*	1.11*	7.15^{NS}
Error		2.11	0.07	0.05	0.29	7.95

*Significant at 5% level of significance

^{NS} Non significant

Appendix IV.Analysis of variance of the data on chemical content in grain and straw of boro rice as affected by different levels of fertilizers

Source of variation	df	Mean square of value of					
		P in grain	P in straw	K in grain	K in straw	S in grain	S in straw
Replication		0.00	0.00	0.00	0.00	0.00	0.00
Fertilizers		0.006*	0.003*	0.002*	0.003*	0.004*	0.008*
Error		0.00	0.00	0.00	0.00	0.00	0.00

*Significant at 5% level of significance

^{NS} Non significant