EFFECT OF ZINC AND BORON ON THE GROWTH AND YIELD OF T. AMAN RICE (BRRI dhan34)

Md. Riajul Islam

DEPARTMENT OF SOIL SCIENCE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

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BY

Md. Riajul Islam

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Approved by:

(Dr. Md. Asaduzzaman Khan**)**
Professor
Department of Soil Science
Sher-e-Bangla Agricultural University, Dhaka
Supervisor

(Dr. Alok Kumar Paul**)**
Professor
Department of Soil Science
Sher-e-Bangla Agricultural University, Dhaka
Co-Supervisor

(Mohammad Mosharraf Hossain**)**
Chairman
Examination Committee
Associate Professor
Department of Soil Science
Sher-e-Bangla Agricultural University, Dhaka-1207

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ABSTRACT

The experiment was carried out in a typical rice growing soil of Sher-e-Bangla Agricultural University, Dhaka, during the period from 24th July to 24th November 2014 to study the effect of zinc and boron on the growth and yield of T. Aman rice (BRRI dhan34). The experiment was laid out into Randomized Complete Block Design (RCBD) with three replications. Two factors were comprised with study viz. factor A: B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1} and B_2 = 4 kg B ha^{-1} and Factor B: Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1} and Zn_2 = 4 kg Zn ha^{-1}. Data were recorded on different growth, yield and yield contributing parameters. Most of the parameters showed significant difference among the treatment. Results indicated that the highest straw weight ha^{-1} (8.07 t) was recorded from B_1Zn_1; the number of total tiller hill^{-1} (19.81) and effective tiller hill^{-1} (14.53) were received from B_1Zn_0. Again, the highest panicle length (25.28 cm), filled grain panicle^{-1} (143.60), total grain panicle^{-1} (161.40), grain weight ha^{-1} (5.72 t ha^{-1}) and harvest index (45.77 %) were recorded from B_2Zn_2. The highest plant height (132.30 cm), non effective tiller hill^{-1} (5.55) and un-filled grain panicle^{-1} (56.52) were achieved from the treatment combination of B_1Zn_2, B_0Zn_2 and B_0Zn_0 respectively. The treatment combination B_2Zn_2 performed better for increasing the yield of T. Aman rice and improved the nutrient status of post harvest soil of AEZ 28.

LIST OF CONTENTS

LIST OF CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

%	=	Percent
^{0}C	=	Degree Centigrade
AEZ	=	Agro-ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
BRRI	=	Bangladesh Rice Research Institute
BCR	=	Benefit Cost Ratio
cm	=	Centimeter
DAS	=	Days after sowing
DAT	=	Days after sowing
et al.	=	and others *(at elli)*
FAO	=	Food and Agricultural Organization of the United Nations
g	=	gram (s)
Kg	=	Kilogram
Kg/ha	=	Kilogram/hectare
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
m	=	Meter
MoA	=	Ministry of Agriculture
MoP	=	Muriate of potash
p^{H}	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
t ha^{-1}	=	ton per hectare
TSP	=	Triple Superphosphate

CHAPTER I

INTRODUCTION

Rice is the main staple food of around half of the world's population. On a global basis, rice provides 12% and 15% per capita of dietary energy and protein, respectively (Maclean *et al.*, 2002). Rice contributes 91.12% of the total grain production and covers 68% of the total calorie intake of this country's people (MoA, 1996). Rice is grown in about 72.47% of the arable land of 10.12 million hectares. Out of total rice production in this country about 60% come from Aman and the rest 18% and 22% come from Aus and Boro crops, respectively (BBS, 1999). During the last two decades, Bangladesh agriculture has moved from a low crop intensity and low yielding state to one in which intense cropping and higher yields per unit area are being increasingly sought. Fertilizer is one of the most important measures for sustainable agricultural production. In modern fanning, fertilizer application is an essential component contributing about 50% of the world's production (Pradhan, 1992). Higher crop yields naturally have higher requirement of nutrients). Thus, use of balanced fertilizers along with management practices can play a key role in sustaining higher yield of crops under different cropping patterns and also can preserve soil health on a long term basis.

Among the micronutrient elements, the deficiency of Zn and B is reported in some soils and crops of Bangladesh (Jahiruddin *et al*., 1994, Islam *et al*., 1997). Jahiruddin and Islam (1999) tested 20 soil samples from Old Brahmaputra Floodplain (AEZ 9) and observed some 25% soils to be deficient with boron. Besides Zn and B, deficiencies of other micronutrients may also occur in this country due to high cropping intensity. Zinc and boron are important micro-nutrients both for the growth of plants and for human beings. Reports showed that 30% soil in the world exhibit Zinc deficiency to different extents

(Cakmak *et al*., 2009) and more than two billion people cannot be supplied with sufficient Zinc. Zinc is one of the most important micronutrients essential for plant growth especially for rice grown under submerged condition. Zinc is essential for several biochemical processes in the rice plant, such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation, and membrane integrity. Soil or foliar applications of Zn may also increase grain zinc concentration and thus contribute to grain nutrition. Soil application of Zn about 4 mg kg^{-1} and 6 kg ha^{-1} in pot culture and field study gave maximum yield in calcareous soil. In rice, soil zinc application has been reported to increase grain yield whereas foliar Zn application increased grain concentration of Zn. Zinc deficiency is a well-documented nutritional and health problem in human populations in most of Asian countries where rice is the dominating staple food crop. Zn fertilization reduces adverse impacts of a single-form zinc fertilizer on crude protein and starch accumulation in rice seeds, and strengthen rice against disease or adversity and thereby improve quality of irrigated rice and increase yield. Boron (B) is responsible for better pollination, seed setting and grain formation in different rice varieties, 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) observed that there was a substantial increase in grain yield of rice varieties due to reduced panicle sterility after B application. Maximum grain yield by soil 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 increased rice grain yield and number of grains per panicle (Lin and Zhu, 2000). Similarly, Rashid *et al*., 2006) reported enhanced paddy yield due to reduced panicle sterility by B application appreciably. 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). Boron nutrition is more important during the reproductive stage as compared to the vegetative stage of the crop in cereals (Rerkasem and Jamjod, 1997). From the above mentioned facts, this study was undertaken by the following objectives:

Objectives:

1. To study the effect of Zn and B on the growth and yield of BRRI dhan34
2. To observe the soil fertility and improvement due to use of Zn and B
3. To evaluate the effect of different levels Zn and B on the quality of rice grain in respect of Zn and B status.

CHPATER II

REVIEW OF LITERATURE

In this chapter to present a brief review of research works in relation to the effect of Zn and B on yield and growth of transplanted Aman rice and effects of these elements on yield components and nutrients composition on rice has been covered. However, the available literature, related to the topic has been presented below.

2.1 Effect of boron on growth and yield of rice

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).

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_3B0_3 and to a smaller extent as $B_40_7^{2-}$, H_2B0_3, $HB0_3^{2-}$. The major B bearing mineral is tourmaline containing 3-4% B. Boron mainly occurs in soil as undissociated H_3B0_3 and this might be the prime reason for which B is leached so easily from the soil.

Khan *et al*., (2007) conducted a field experiment during 2004-05 on wheat and rice to study the response of boron application in wheat-rice system. Two levels of boron viz., 1 and 2 kg ha^{-1} with control were studied with the basal dose of N, P_2O_5 and K_2O as 120-90-60 kg ha^{-1}. Wheat variety Naseer-2000 and rice variety IRRI-6, both were planted in RCB design with three replications in a permanent layout. 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. The direct application of 2 kg B ha^{-1} to each crop could be recommended for economical yield. Boron concentration in the leaves of wheat and rice was significantly affected by the application of boron that ranged from 10.37-14.91 and 3.52-5.81 mg kg^{-1}, respectively. Similarly the boron concentration in soil was also significantly affected by boron concentration in wheat and rice and ranged from 0.18-0.51 and 0.17-0.61 mg kg^{-1}, respectively. The highest concentration in leaf and soil in wheat was found from 2 kg ha^{-1}, while cumulative application of 2 kg ha^{-1} proved to be the highest in both the crops.

Dunn *et al*., (2005) found that soil sampling and testing for Boron is currently not a common practice for farmers producing rice (*Oryza sativa* L.) in the south-eastern 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.

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) conducted 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 the 1000-grain weight increased with B application.

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.

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.

Sheudzhen (1991) reported that application of 0.05, 0.10 or 0.5% B, Co, Mo, Zn, Mn increased the number of spikelets panicle^{-1}, decreased spikelet sterility, increased grain weight plant^{-1} and gave paddy yields of 7.77 - 8.09 t ha^{-1} compared with 7.55 + with NPK alone. They also reported that trace elements increased grain protein, N and P contents.

Islam (1992) carried out a long -term experiment of wheat-mungbean-T. Aman cropping pattern at Wheat Research Centre (WRC), Dinajpur (1988 -90). He found that Zn and B application had beneficial effect on that pattern. Residual effects of Zn, S and B showed pronounced effect in increasing the grain yield of rice.

Dutta *et al*., (1992) in a field trials in Assam (India) with paddy and wheat reported economic response to Zn applications in rice, wheat and mustard responded economically to B confirming Zn and B deficiency in the soil studied. The application of 25 kg ha^{-1} borax was recommended in deficient soils.

Mondal *et al*., (1992) conducted a missing element trial in Sonatala silt loam soil at BAU farm in T. man season of 1990 to investigate the nutrient treatment for BR11 rice. They observed significant response of the crop to boron.

Sur and Ali (1992) in alluvial soils of North Bengal and red lateritic soil of South Bengal (India) reported that B and Zn applications significantly increased yield of Kharif rice. Rates of 25 to 37.5 kg ha^{-1} $ZnSO_4$ and 10 to 15 kg ha^{-1} borax were recommended for economic returns.

Dutta *et al*., (1993) conducted field trials with rice in Assam. The crop gave economic responses to B applications. The application of 10 kg ha^{-1} borax was recommended in deficient soils.

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.

(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.

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

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

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

Hossain (1996) carried out an experiment on integrated nutrient management for BR11 rice at BAU Farm. Results showed that B concentration in grain and straw increased rice yield when boron was applied to soil.

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.

BRRI scientists (1998) conducted several experiments at Rangpur to study the effect of B and FYM on four HYV rice varieties. They found that application of FYM and B alone increased grain yield in all varieties except BRRI Dhan27 than when NPK was applied. A combination of FYM and B encouraged vegetative growth and thereby lowering the harvest index. Vegetative growth of BRRI Dhan27 was highly encouraged by FYM and B applied together. They suspected that BRRI Dhan27 might be less tolerant to B stress.

Mandal *et al.*, (1987) observed that under submerged conditions the yield components and grain yield of rice were increased with application of 16 kg B ha ^{1} along with NPK.

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.

Islam *et al.*, (1997) conducted a field experiment on a silt loam soil in Bangladesh to study the effect of S, Zn and B application on autumn rice. The autumn rice responded significantly to S, Zn and B. The highest grain yield was observed in S+Zn+B treatment with a record of 41.8% yield increase over control. On the other hand, the single application of S, B or Zn gave yield increase of 23.3%, 21.7% and 14.6% respectively.

BRRI scientist (1998) conducted several experiments at BRRI Farm, 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 of 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.

Mandal and Haider (2000) conducted a pot experiment, rice cv. BR 11 was given all combinations of 0. 4, 8 or 12 kg Zn and 0. 5. 10 or 20 kg S ha^{-1}. Addition of 8 kg Zn + 20 kg S ha gave the best performance in growth and yield of the crop.

Slaton *et al.,(*2001) reported that zinc is the most growth and yields limiting micronutrient in rice production, they conducted two field studies to evaluate several dry granular and liquid Zn sources applied at pre-plant incorporated (PPI) pre-emergence (PRIi) and pre-flood (PF) for rice yield in Arkansas. USA. Application of liquid chelated and inorganic Zn sources at rates from 1 to 2 lb Zn $acre^{-1}$ produce high yields across all applied at either PIM or PRI.

Channabasavanna and Biradar (2001) conducted an experiment with different levels of organic manures and zinc on the yield and yield attributes of transplanted summer rice. Results showed that application of organic manure and zinc increased panicles $hill^{-1}$ and seeds $panicle^{-1}$ of rice. The yield obtained with the application of 2 t ha^{-1} poultry manure along with 25 Kg $ZnSO_4$ ha^{-1}.

Ullah *et al.,* (2001) conducted a field experiment with different levels of zinc sulphate on the yield of rice cv. BRRI dhan11. Results showed soil application of zinc sulphate increased plant height, tiller number. 1000-grain weight, grain and straw yields and grain and straw zinc contents.

Verma *et al.,* (2001) carried out a field experiment at Chandra Shekar University of Agricultural and Technology, Kanpur. Uttar Pradesh. India where three levels of zinc sulphate (0, 20 and 40 kg ha^{-1}) were tested in paddy grown nursery. The results indicated that the use of $ZnSO_4$ did not have significant effect in grain yield and yield attributes in rice particularly grown after rice nursery in which nursery was fertilized al 25 Kg $ZnSO_4ha^{-1}$.

Singh *et al.,* (2002) performed a field experiment at the North Pastern I till University, Shillong, Meghalaya, India to elucidate the distribution adsorption and utilization of Zn in wetland soils, and its uptake by plant from nutrient solutions. It is concluded that the use of Zn fertilizers increased the yield of rice in wetland soils of Meghalaya.

Mythili *et al.*,(2003) conducted a field experiment to the zinc and sulfur deficient soil of India to study the effects of green manure (CM) and inorganic Zn and S fertilizer combinations on the field of a short duration rice cultivar (ADT 3b). NPK (100:50:50) and as $ZnSO_4$ (5 kg Zn ha^{-1}) and S as gypsum (50 kg S ha^{-1}) coupled with green manure (*Sesbania aculeata* at 10 t ha^{-1}) produced the highest grain (5627 kg ha^{-1}) and straw (5723 kg ha^{-1}) yields.

Singh and Singh (2004) observed that zinc sulfate was the superior source compared to others. Zinc application increased chlorophyll and increased the tissue concentration of Zn. Ca. Mg, K and P, whereas Na content decreased. Zinc modified the elemental composition of plant tissues favorably and thereby accelerated plant growth and yield.

Swarup and Yaduvanshi (2004) conducted experiments from 1994-2001 on wet season and winter season wheat cropping system at Llihaini Majra Experiment Farm, Kaithal. India. The N, P. K and Zn doses as per treatments (120 kg N, 26 kg P, 42 kg K and 3 kg Zn ha^{-1}) were applied as urea, single superphosphate, murate of potash and zinc sulphate, respectively. They found that zinc application improved the yield of rice.

Wang *el al.*, (2005) studied the effects of zinc on rice germination by soaking seeds of rice in zinc solution at levels of (0, 0.5, 3.0 and 5.0 mg litre^{-1}). When zinc concentration was (3.0 g/litre,) germination rate increased effectively, increasing by 38 9%. The growth of promule, particularly the radicle was promoted. Seed activity increased by 122.34%. In the early stage of germination, membrane penetration of seeds was improved, and superoxide dismulase (SOD) activity increased by 56.96%, and catalase (CAT) activity increased by 221.53%.

Cihatak *el al.*, (2005) conducted a Held experiment during kharif (rainy) season 2001 in West Bengal. India, to determine the effect of zinc fertilizer on transplanted rice cv. IR-36 grown on red and laterite soil. treatments comprised:

0, 10, 20. 30 and 40 kg $ZnSO_4$ ha^{-1}. Results revealed that zinc fertilizer application significantly increased the plant height, effective tillers, panicle length, grains per panicle, grain and straw yields, uptake of Zn, N and K by plant. Application of 30 kg $ZnSO_4$ ha^{-1} recorded the highest values of yield attributes, yield, up take of N and k by plant. Similarly, the net return was also maximum upon treatment with 30 kg $ZnSO_4$ $ha^{-1.}$

Khan *et al.*, (2005) performed a pot experiment to determine the response of rice cv. IRRI-6 . grown in different soil series, namely Nolak (silty clay). Zandani (silty clay loam), Saggu (clay), Tikken (loam clay), Ruslum (silly), Ramak (clay), Sodhra (loamy sand) and Shahdeia (silt loam), to different levels of Zn (0. 0.5. 1.0 and 1.5%). The increase of Zn level from 0.5 to 1.5% had a drastic effect on the Zn content in the soil and in rice.

Misra and Abidi (2006) conducted an experiment to evaluate the effect zinc sulphate (0, 10, 20, 30 and 40 kg ha^{-1}) on the grain yield and yield attributes (plant height and number of tillers per plant) of different hybrid rice cultivars, i.e. NDRH-2, Proagro-61, Proagro-6201, Proagro-6207 and Proagro-6444. The highest yield was recorded for Proagro-6444 treated with Zn at 30 kg ha^{-1}.

The study was conducted Boonchuay *et al*. (2012) applied 8 foliar Zn treatments of 0.5% zinc sulfate ($ZnSO_4 \cdot 7H_2O$) to the rice plant at different growth stages. Foliar Zn increased paddy Zn concentration only when applied after flowering, with larger increases when applications were repeated. The largest increases of up to ten-fold were in the husk, and smaller increases in brown rice Zn. In the first few days of germination, seedlings from seeds with 42 to 67 mg Zn kg^{-1} had longer roots and coleoptiles than those from seeds with 18 mg Zn kg^{-1}, but this effect disappeared later. The benefit of high seed Zn in seedling growth is also indicated by a positive correlation between Zn concentration in germinating seeds and the combined roots and shoot dry weight. Zinc in rice grains can be effectively raised by foliar Zn application after flowering, with a potential benefit of this to rice eaters indicated by up to 55% increases of brown rice Zn and agronomically in more rapid early growth and establishment.

An experiment was carried out by Ilma *et al*., (2012) at Sari, Mazandaran, Iran. This experiment was done as split plot in randomized complete blocks design based three replications. Zinc fertilizer application was chosen as main plots (0, 2 and 4 kg ha^{-1}) and genotypes as sub plots. The maximum panicle number per m^2 and harvest index were observed with 4 kg Zn ha^{-1} and the least of those was obtained in control treatment. The highest zinc content in grain, zinc uptake in grain and straw, and nitrogen uptake in grain were observed with 4 kg Zn ha^{-1}, as the most zinc content in straw, nitrogen, potassium, phosphorus and sulphur content in grain and straw, and nitrogen uptake in straw were observed highest with application of 4 and 2 kg Zn ha^{-1}.

Muthukumararaja and Sriramachandrasekhara (2012) reported that zinc deficiency in flooded soil is impediment to obtain higher rice yield. Zinc deficiency is corrected by application of suitable zinc fertilizer. The results revealed that rice responded significantly to graded dose of zinc. The highest grain (37.53 g pot^{-1}) and straw yield (48.54 g pot^{-1}) was noticed at 5 mg Zn kg^{-1}, which was about 100% and 86% greater than control (no zinc) respectively. The highest zinc concentration and uptake in grain and straw and DTPA-Zn at all stages was noticed at 7.5 mg Zn $kg^{-1.}$ The linear regression analysis showed grain zinc concentration and grain Zn uptake caused 89.64 and 89.01% variation in rice yield. Similarly, the linear regression analysis of DTPA-Zn caused 98.31, 96.34 and 93.12% variation in yield of rice at tillering, panicle initiation and harvesting stages, respectively. The agronomic, physiological and agro physiological apparent recovery and utilization efficiencies was highest at lower level of zinc application and decreased with Zn doses.

The study was conducted by Mustafa *et al*., (2011) at agronomic research area, University of Agriculture, Faisalabad, 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, $ZnSO_4$ 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. Maximum productive tillers per m^2 (249.80) were noted with basal application at the rate 25 kg ha^{-1} of ZnSO^4 (21% Zn) 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} of $ZnSO_4.7H_2O$) and minimum paddy yield (4.17 t ha^{-1}) was noted in Zn_7 (foliar application at 75 DAT @ 0.5% Zn solution).

Naik and Das (2007) reported that rice is mostly transplanted under puddled low land soil conditions in India, where zinc (Zn) deficiency is a common problem. The objective of this study was to find out the efficacy of split application of Zn on growth and yield of rice in an inceptisol. The split application of Zn as $ZnSO_4.7H_2O$ performed better than its single basal application, while the split application of Zn-EDTA did not show any significant difference on yield and yield components of rice over its single basal application. Zn-EDTA was found to be better for growth and yield of rice among the two sources of Zn. The soil application of Zn at 1.0 kg ha^{-1} as Zn-EDTA (T_7) recorded highest grain yield of 5.42 t ha^{-1}, filled grain percentage of 90.2%, 1000-grain weight of 25.41 g and number of panicles m-2 of 452. The Zn content of grain and straw were also found to be maximum in the treatment T_7 i.e. 38.19 and 18.27 mg Zn kg^{-1}, respectively. Linear regression studies indicated that grain yield of rice is significantly influenced by Zn content of grain, Zn content of straw and DTPA extractable Zn content of soil at the level of 95.96, 96.74 and 95.57%, respectively.

A pot experiment was conducted by Khan *et al*.,(2007) at Faculty of Agriculture Gomal University, Pakistan to evaluate the effect of different levels of zinc application on the yield and growth components of rice at eight different soil series. Zn as $ZnSO_4.7H_2O$ (21% Zn) was applied @ 0, 5, 10 and 15kg ha^{-1} along with the basal doses of 120 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1}. Thirty days old four seedlings of rice cv. IRRI-6 were grown. The increasing levels of Zn in these soil series significantly influenced yield and yield components of rice. Application of 10 kg Zn ha^{-1} appeared to be an optimum dose for rice crop in these soil series.

A study was carried out by Cheema *et al*.,(2006) to evaluate the effect of four zinc levels on the growth and yield of coarse rice cv. IR-6 at Faisalabad, Pakistan. Four zinc levels *viz*., 2.5, 5.0, 7.5 and 10 kg $ZnSO_4$ ha^{-1} increased yield and yield component as compared with control. Plant height, number of tillers $hill^{-1}$, panicle bearing tillers, number of primary and secondary spikelets, panicle size, 1000 grain weight, paddy and straw yield and harvest index showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}.

A field experiment was conducted by Ullah *et al*.,(2001) in Mymensingh, Bangladesh, to study the effect of zinc sulfate (0, 10, and 20 kg ha^{-1}) on rice cv. BR30. Zinc sulfate, along with 60 kg P_2O_5 and 40 kg K_2O ha^{-1}, was incorporated during land preparation. 80 kg N ha^{-1} was applied by 3 equal installments during land preparation, and at 25 and 60 days after transplanting. Plant height; tiller number; 1000-grain weight; grain and straw yields; and grain, straw, and soil Zn contents increased with zinc sulfate application. The tallest plants (75.667 cm) and the highest number of tillers (10.60 $hill^{-1}$), 1000-grain weight (28.700 g), and the concentration of Zn in straw (101.93 ppm) and grain (73.33 ppm) were obtained with 20 kg zinc sulfate ha^{-1}.

Binod *et al*., (1998) conducted an experiment on rice (cv. Sita) with soil application of 0, 12.5 and 25 kg $ZnSO_4$ ha^{-1}. After transplanting, plants were fertilized with soil amount of 0, 12.5 and 25 kg $ZnSO_4$ ha^{-1} and they obtained best results with application of 25 kg $ZnSO_4$ ha^{-1}.

Singh *et al*., (2012) at main campus of ICAR Research Complex of Eastern Region Patna with four levels of both nutrients i.e. sulphur and zinc. Based on three years of experimentation, results revealed that rice plant height is significantly influenced by sulphur and zinc. Tallest plant (101.7 cm) was recorded at maturity with application of 6 kg Zn ha

A field experiment was conducted by Dixit *et al*., (2012) to study the effect of sulphur and zinc on yield, quality and nutrient uptake by hybrid rice grown in sodic soil. They reported that increasing doses of sulphur and zinc significantly increased their uptake by hybrid rice crop. The interaction effect of sulphur and zinc was found non-significant and the highest grain and straw yields were recorded with application of 40 kg S and 10 kg Zn ha^{-1}.

The experiment was conducted by Tarafder *et al*., (2008) conducted an experiment with eight treatments for potato $S_{15}Zn_2$ (T_2, T_4 and T_8), S_8Zn_1 (T_5 and T_6) and S_0Zn_0 (T_1, T_3 and T_7), for boro rice $S_{20}Zn_4$ (T_3, T_5, T_6 and T_7) and S_0Zn_0 (T_1, T_3, T_4 and T_6). The experiment was laid out in a randomized complete block design with three replications. In Boro rice, growth and yield attributes, grain and straw yields responded significantly to S and Zn. The average grain yield varied from 3.51 to 5.27 t ha^{-1} over the treatments. In case of T. aman rice, the grain and straw yields responded significantly to S and Zn.

An experiment was conducted 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). There were seven treatments viz. S_0Zn_0, $S_{10}Zn_0$, $S_{20}Zn_0$, $S_0Zn_{1.5}$, S_0Zn_3, $S_{10}Zn_{1.5}$ and $S_{20}Zn_3$. The subscripts of S and Zn represent the dose in kg ha^{-1}. The highest grain (5.76 t ha^{-1}) and straw (7.32 t ha^{-1}) yields were recorded from $S_{20}Zn_3$ treatment (100% recommended dose). The

S_0Zn_0 (control) had the lowest grain yield with 4.35 t ha^{-1} as well as the lowest straw yield with 5.47 t ha^{-1}. The application of both S and Zn fertilizers significantly increased S and Zn contents as well as their uptake over control.

The effect of single and multiple applications of S and Zn in a continuous rice cropping system on loam soil were investigated by Hoque and Jahiruddin (1994) at Mymensingh, Bangladesh. The treatments were S alone, Zn alone and S + Zn, each added to the 1st crop, 1st and 2nd crops or all 3 crops. The rate of S was 20 kg ha^{-1} (gypsum form) and Zn was 10 kg ha^{-1} and reported that crop yields were increased by S but not by generally by Zn. From the above review of literature it is evident that sulphur and zinc and their combination have a significant influence on yield and yield components of rice. The literature suggests that optimum use of sulphur and zinc increases the grain yield of rice. Reduction in grain yield is mainly attributed by the reduced number of tiller hill-1, grains $panicle^{-1}$ and thousand grain weights due to restriction of development of these parameters for the effect of sulphur and zinc.

Jahiruddin *et al.,* (1981) reported that when Zn was applied to acid clay type soil of Bangladesh, a significant increase in the grain and straw yields of boro rice was obtained. It was also reported by Bhuiya *et al.* (1981) that the grain and straw yields of nee were increased with the application of 10kg $ZnSO_4$ ha^{-1}.

Sharma *et al.,* (1982) observed that the grain yield of rice was increased from 3.21 t ha^{-1} without Zn to 5.78 t ha ^{1} with Zn application.

Ahmed *et al.,* (1983) reported increase in all the growth parameters of rice after Zn application in the field. The maximum effect was noted with 10kg Zn ha $^{-1}$ for plant height and 20kg Zn ha ^{1} for number of tillers $hill^{1}$.

A field experiment was conducted by Singh *et al.,*(1983) on an alluvial calcareous sandy loam soil and observed that application of 5kg Zn ha^{-1} significantly increased the grain and straw yields of rice production. They also observed that application of 10kg Zn ha $^{-1}$ decreased the grain yield of rice.

Swamp (1983) stated that the grain and straw yields of rice were increased with application of Zn.

Babiker (1986) carried out an experiment with rice (cv. Giza 171 and Giza 180) treated with 9, 25, 50 or 75 kg $ZnSO_4$ ha $^{-1}$ in nursery and field. He observed that leaf area, heading date, plant height, tillering capacity, productive tillers, panicle length, number of filled and unfilled grains panicle^{-1}, 1000-grain weight, harvest index and grain : straw ratio were significantly affected by rice cultivars and $ZnSO_4$ rates. It was concluded that 50 kg $ZnSO_4$ ha^{-1}, especially for nursery grown rice, was the most effective and economic rate for improving grain yield and its components.

Nagarajam and Manickam (1986) conducted nee experiment on 4 soil types at 9 locations in Tamil Nadu and observed that the paddy yields were increased from 3.93 to 4.121 ha^{-1} by applying 25 kg $ZnSO_4$ ha^{-1}.

Balakrishnar and Natarajaratnam (1986) found that application of 25 kg $ZnSO_4$ ha^{-1} with NPK on rice increased the effective tillers hill^{-1}, panicle length, total grain and filled grains panicle^{-1}, 1000-grain weight and paddy yield. Grain and straw yields were 16.7% and 22.8% higher over control, respectively.

Singh *et al.*, (1987) reported that application of 15 kg $ZnSO_4$ ha^{-1} in 36 out of the 47 field trials increased rice yields by 5.2-31.7%, the average increase 11.2%

Salam and Subramonian (1988) observed that application of 5.7 kg Zn ha^{-1} increased the grain yield of rice but did not affect the straw yield Zinc application increased the uptake of Zn by plant.

Chibba *et al.*, (1989) conducted a field trial in Zn deficient soil in Indian Punjab with 0, 5 or 10 kg Zn ha^{-1} as $ZnSO_4$, and Zn frits on Joya rice and found that rice grain yield was significantly increased with Zn application irrespective of rates or sources. Among sources, the highest rice grain yield was produced by $ZnSO_4$ and Zn frits whereas ZnO was least effective.

Mostafa (1990) reported from Egypt that application of $ZnSO_4$ either to soil or foliar spray significantly increased the grain yield of rice.

Dixit and Khanda (1994) observed that application of $ZnSO_4$ increased the gram yield of rice. A pot experiment under flooded condition conducted by Sarkuran *et al.* (1999) also revealed that Zn application increased the grain yield of rice.

Khanda and Dixit (1996) observed that application of Zn increased the grain and straw yields significantly over no zinc application. They also stated that the combined application of N and Zn increased the grain yield by 7.2% and straw yield by 12.9% over sole N.

Singh *et al.*, (1996) observed that grain yield of rice was increased significantly with upto 100 kg N ha^{-1} alone or with Zn. Net returns were highest with applying 150 kg N + 25 kg Zn ha^{-1}.

Agarwal and Suraj (1997) found that mean yield of each crop (rice/wheat) and net returns were the greatest when each crop was given 25 kg $ZnSO_4$ ha^{-1}.

Chen *et al.*, (1997) carried out a field experiment at the Rice Research Institute of Yunnan Agricultural University, Kunming, on soils low in zinc with rice cultivates Xunza 29, Hexi 35 and Yungeng 34 using 0 or 5 kg Zn ha^{-1}. They observed that application of Zn increased yield significantly, especially in Hexi35 and Yungeng 34. Grain amylose content of milled rice was increased by Zn application

Channal and Kandaswamy (1997) conducted a field experiment with rice (cv. CO-43) at Trichi, Tamil Nadu that was supplied with 12.5 t ha^{-1} of dhaincha (*Sesbania* sp.) or composted coir pith, gypsum with or without 5 t dhaincha or no amendments and 0-50 kg $ZnSO_4$ ha^{-1}. They found that cowpea (cv. C-152) was grown on the same plots after residual fertility. The application of 37.5 kg $ZnSO_4$

and(gypsum + dhaincha) produced the highest rice grain yield of 5.63 t ha^{-1}. Cowpea seed yield was highest (0.44 t $ha^{-1'}$) on plot receiving 50 kg $ZnSO_4$ and (gypsum + dhaincha.)

Binod *et al.*, (1998) conducted an experiment on nee (cv. Sita) grown in the nursery was given soil application of 0, 12.5 or 25 kg $ZnSO_4$, was sprayed with 0.5% $ZnSO_4$ solution 3 weeks after sowing or seedling roots were dipped in 2% ZnO suspension. After transplanting, plants were given soil applications of 0, 12.5 or 25 kg $ZnSO_4$ ha^{-1}, or were sprayed with 0.5% $ZnSO_4$ solution 3 or 3+5 weeks after transplanting. They obtained best results with application of 25 kg $ZnSO_4$ to transplanted plants, spraying with 0.5% $ZnSO_4$ solution 3 weeks after transplanting or dipping seedling roots in 2% ZnO suspension. Zinc application in the nursery was effective in correcting Zn deficiency and improving yield even when zinc was not applied after transplanting.

Singh *et al.*, (1999) conducted a long term experiment under "International Network on Soil Fertility and Sustainable Rice Farming (INSURF)" at GB Pant University of Agriculture and soil application of 0, 12.5 or 25 kg $ZnSO_4$ ha^{-1}, was sprayed with 0.5% $ZnSO_4$ solution 3 weeks after sowing or seedling roots were dipped in 2% ZnO suspension. After transplanting, plants were given soil applications of 0, 12.5 or 25 kg $ZnSO_4$ ha^{-1}, or were sprayed with 0.5% $ZnSO_4$ solution 3 or 3+5 weeks after transplanting. They obtained best results with application of 25 kg $ZnSO_4$ to transplanted plants, spraying with 0.5% $ZnSO_4$ solution 3 weeks after transplanting or dipping seedling roots in 2% ZnO suspension. Zinc application in the nursery was effective in correcting Zn deficiency and improving yield even when zinc was not applied after transplanting.

CHAPTER III

Materials and Methods

3.1 Location of the experimental field

The experiment was carried out on the farm of Sher-e-Bangla Agricultural Univervisty, Dhaka. The location of the site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level.

3.2 Characteristics of the soil

The soil of the experimental field is silt loam in texture belonging to the ago-ecological zone of Madhapur Tract (AEZ-28). The soil belongs to “The Modhupur Tract”, AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details were presented in Appendix 1.

3.3 Climate

Subtropical in nature, characterized by three distinct seasons. The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al.*, 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix 2.

3.4 Plant material

BRRI dhan34 was used for the experiment as test crop.

3.5 Experimental design

The experimental was laid out in a Randomized Completely Block Design (RCBD) with three replications having 9 treatment combinations. There were 9 plots of size 2 m × 3 m in each of 3 replications. The treatments of the experiment were assigned at random into each replication. The layout of the experiment was shown in Fig.1.

3.6 Treatments

There were three level of Zn (0, 2, 4 kg/ha) and three levels of B (0, 2, 4 kg/ha) was considered for the treatment combinations as follows

Factor A: Three levels of Boron

B_0 = 0 kg B ha^{-1}

B_1 = 2 kg B ha^{-1}

B_2 = 4 kg B ha^{-1}

Factor B: Three levels of Zinc

Zn_0 = 0 kg Zn ha^{-1}

Zn_1 = 2 kg Zn ha^{-1}

Zn_2 = 4 kg Zn ha^{-1}

Treatment Combination of experiment

B_0Zn_0, B_0Zn_1, B_0Zn_2, B_1Zn_0, B_1Zn_1, B_1Zn_2, B_2Zn_0, B_2Zn_1, B_2Zn_2

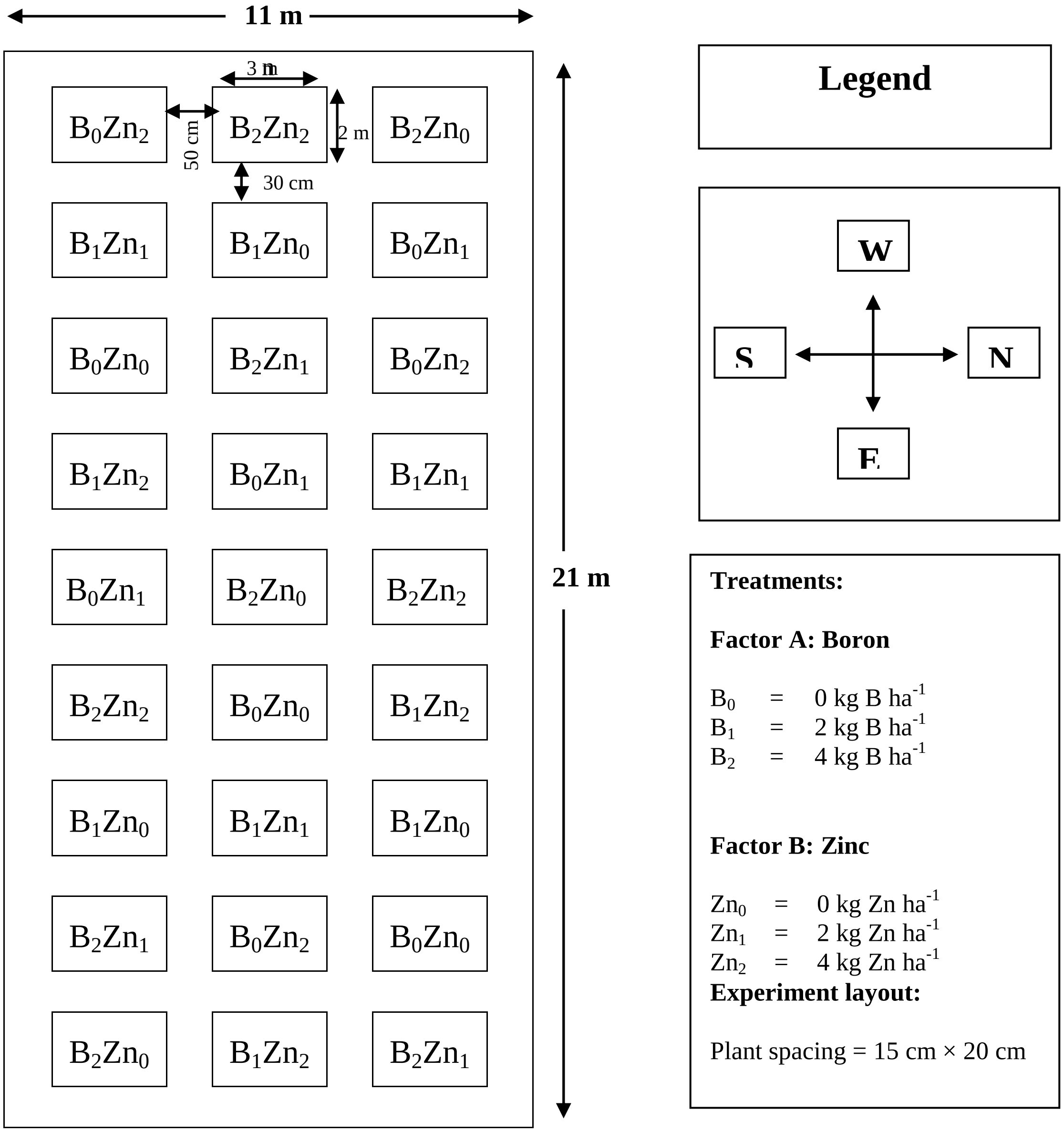

Fig. 1. Layout of experiment field

3.7 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.

3.8. 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 June, 2014 in order to transplant the seedlings in the main field.

3.9. Preparation of the main field

The plot selected for the experiment was opened in the first week of July 2014 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.

3.10 Fertilizers and manure application

The fertilizers N, P, K, S and B in the form of urea, TSP, MoP, Gypsum and borax, respectively were applied. The entire amount of TSP, MoP, Gypsum, Zinc sulphate and borax were applied during the final preparation of land. Urea was applied in three equal installments at post recovery, tillerings and before panicle initiation stage. The dose and method of application are shown in Table 1.

Table 1. Dose and method of application of fertilizers in rice field

Fertilizers	Dose (kg/ha)	Application (%)			
		Basal	1st installment	2nd installment	3rd installment
Urea	150	0	33.33	33.33	33.33
TSP	100	100	--	--	--
MoP	100	100	--	--	--
Gypsum	60	100	--	--	--
Borax	As per treatment	100	--	--	--
$ZnSO_4$	As per treatment	100	--	--	--

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 July 24, 2014 without causing much mechanical injury to the roots.

3.12 Transplanting of seedlings in the field

The seedlings were transplanted in the main field on 24 the July, 2014 with a spacing 15 cm from hill to hill and 20 cm from row to row.

3.13 Intercultural operations:

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

3.13.1 Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water upto 3 cm in the early stages to enhance tillering and 4-5cm in the later stage to discourage late tillering. The field was finally dried out at 15 days before harvesting.

3.13.2 Gap filling

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

3.13.3 Weeding

The crop was infested with some common weeds, which were controlled by uprooting and remove them three times from the field during the period of experiment. Weeding was done after 15, 32 and 52 days of transplanting.

3.13.4 Top dressing

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

3.14 Plant protection

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

3.15 Harvesting, threshing and cleaning

The rice plant was harvested depending upon the maturity of plant and harvesting was done manually from each plot. The BRRI dhan34 was harvested on 24 November 2014. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The straw was sun dried and the yields of grain and straw plot^{-1} were recorded and converted to t ha^{-1}.

3.16 Data recording

The following data were collected during the study period:

The data will be collected and recorded:

a) Plant height at harvest
b) Number of total tiller hill^{-1}
c) Number of effective tiller hill^{-1}
d) Number of non-effective tiller hill^{-1}
e) Panicle length (cm)
f) Number of filled grain per panicle
g) Number of un-filled grain pancle^{-1}
h) Total grain per panicle
i) 1000 –grain weight
j) Grain yield ha^{-1}
k) Straw yield ha^{-1}
l) Harvest index

3.16.1 Procedure of recording data

a) 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.

b) Number of total tillers hill^{-1}

Total tillers which had at least one leaf visible were counted. It includes both productive and unproductive tillers.

c) Number of effective tillers hill^{-1}

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

d) Number of non-effective tillers hill^{-1}

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

e) Panicle length

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

f) Number of filled grains panicle^{-1}

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

g) Number of unfilled grains panicle^{-1}

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

h) Total grains panicle^{-1}

The total number of grains was calculated by adding filled and unfilled grains and then average number of grains panicle^{-1} was recorded.

i) 1000 seed weight

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

j) Grain weight ha^{-1}

Grains obtained from each unit plot were sun-dried and weighed carefully. The central 3 lines from each plot were harvested, threshed, dried, weighed and finally converted to t ha^{-1} basis.

k) Straw weight ha^{-1}

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of central 3 lines were harvested, threshed, dried and weighed and finally converted to t ha^{-1} basis.

l) Harvest index

The harvest index was calculated with the following formula:

Harvest index = (Grain yield ×100) ÷ Biological yield

Biological yield = Grain yield + Biological yield

3.17 Collection of Samples

3.17.1 Soil Sample

The initial soil samples were collected randomly from different spots of the field selected for the experiment at 0-15 cm depth before the land preparation and mixed thoroughly to make a composite sample for analysis. Post harvest soil samples were collected from each plot at 0-15 cm depth in November 30, 2014.

The samples were air-dried, grounded and sieved through a 2 mm sieve and preserved for analysis.

3.18 Soil Sample Analysis

The postharvest soil samples were analyzed for both physical and chemical properties in the laboratory of Soil Resource Development Institute (SRDI), Farmgate, Dhaka.

The soil properties studied included pH, organic matter, total N, available P, exchangeable K and available Zn and available B. The soil was analyzed by the following standard methods:

3.18.1 Soil pH

Soil pH was determined by glass electrode pH meter in soil-water suspension having soil: water ratio of 1:2.5 as outlined by Jackson (1962).

3.18.2 Organic Matter

Organic carbon in soil sample was determined by wet oxidation method. The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage.

3.18.3 Total Nitrogen

Total nitrogen of soil samples was estimated by Micro-kjeldahl Method where soils were digested with 30% H_2O_2 concentrated H_2SO_4 and catalyst mixture (K_2SO_4: CuSO4, 5 H_2O: Selenium powder in the ratio of 100:10:1, respectively). Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01 NH_2SO_4.

3.18.4 Available Phosphorous

Available phosphorous was extracted from the soil by shaking with 0.5 M$NaCO_3$ solution of pH 8.5. The phosphorous in the extract was then determined by developing blue color using $SnCl_2$ reduction of phosphomolybdate complex. The absorbance of the molybdophosphate blue color was measured at 660 μm wave length by spectrophotometer and available P was calculated with the help of a standard curve.

3.18.5 Exchangeable Potassium

Exchangeable potassium in the soil sample was extracted with 1N ammonium acetate (NH_4OAc) and the potassium content was determined by flame photometer.

3.19 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means were estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSIONS

The results of the present study are presented in several terms. The experiment was conducted to study the effect of zinc and boron on the growth yield of T. Aman rice (BRRI dhan34) of different levels of zinc and boron on the performance of BRRI dhan34. The results are presented and discussed under the following parameters.

4.1 Plant height

4.1.1 Effect of boron

Application of boron significantly influenced the plant height of Aman rice (Fig. 2 and Appendix 3). The findings showed that the longest plant (124.40 cm) was found in B_1 (2 kg ha^{-1}) followed by B_0 (0 kg ha^{-1}) where the shortest plant height (122.70 cm) was recorded from B_2 (4 kg ha^{-1}). Khan *et al.*, (2007) found similar result in case of plant height. They observed that plant height was significantly influenced by B application with the range from 3.51 to 6.11 t ha^{-1}.

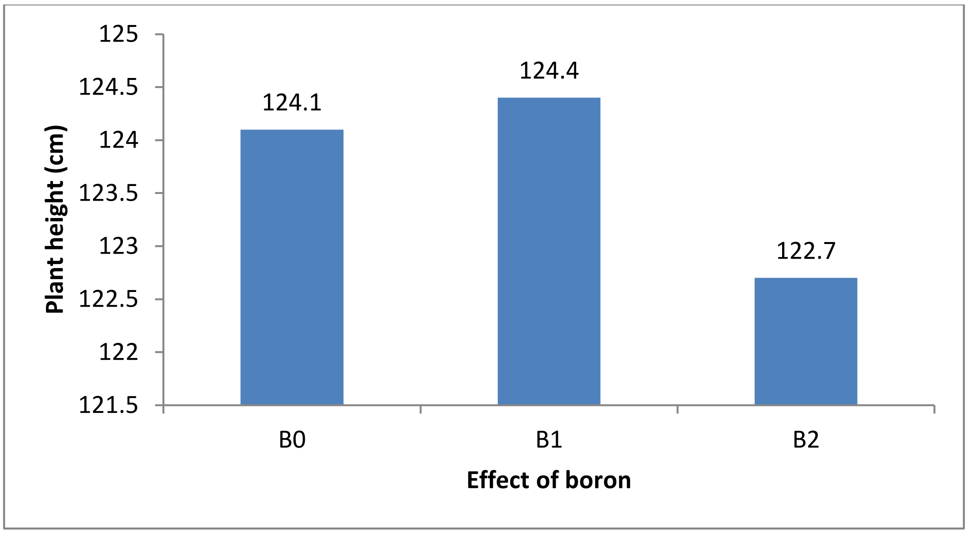

Fig. 2. Effect of B on plant height of BRRI dhan34.(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

4.1.2 Effect of zinc

The experimental findings showed that the plant height of Aman rice varied significantly due to the application of different level of Zinc (Fig. 3 and Appendix 3). Result showed that the longest plant (126.10 cm) was recorded under Zn_2 (4 kg ha^{-1}) followed by Zn_0 (Control) while the shortest plant (120.00 cm) was achieved from Zn_1 (2 kg ha^{-1}). The results obtained from the present study was conformity with the findings of Ullah *el al.*, (2001). They found that soil application of zinc sulphate increased plant height. Cheema *et al.*, (2006) also reported that plant height showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}. Similar results also found by Dixit *et al.*, (2012) and Mustafa *et al.* ,(2011).

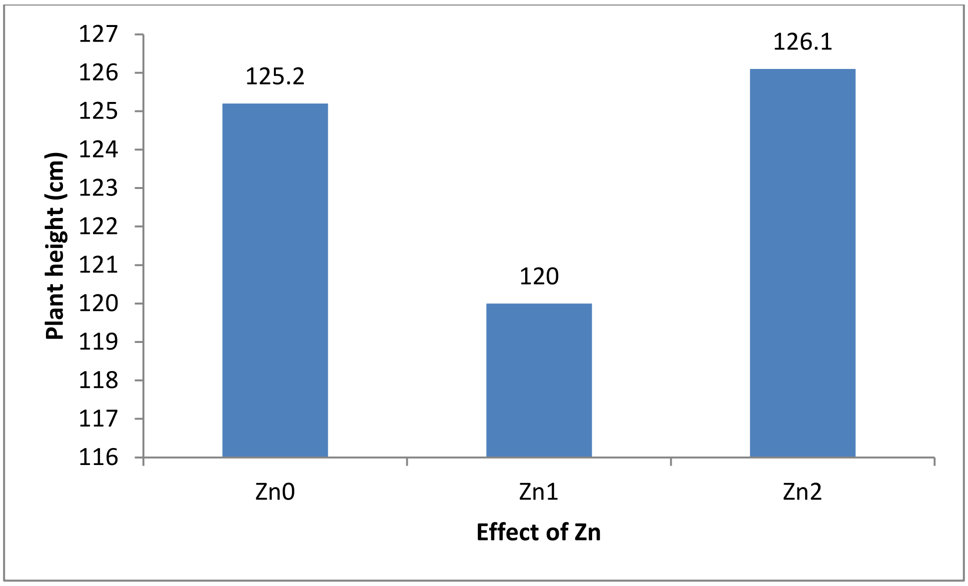

Fig. 3. Effect of Zn on plant height of BRRI dhan34.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})

4.1. 3 Combined effects zinc and boron

Significant variation was found with the combined effect boron and zinc for plant height of Aman rice (Table 2 and Appendix 3). Result revealed the longest plant (132.30 cm) was recorded from B_1Zn_2 followed by B_2Zn_2 where the shortest plant (117.80 cm) was achieved by B_0Zn_1 followed by B_1Zn_1 and B_2Zn_0.

4.2 Number of total tiller hill^{-1}

4.2.1. Effect of boron

Application of boron significantly influenced the number of total tiller hill^{-1} of Aman rice (Fig 4 and Appendix 3). The findings showed that the highest number of total tiller hill^{-1} (18.26) was found in B_1 (2 kg ha^{-1}) followed by B_0 (Control) where the lowest number of total tiller hill^{-1} (15.52) was recorded from B_2 (4 kg ha^{-1})

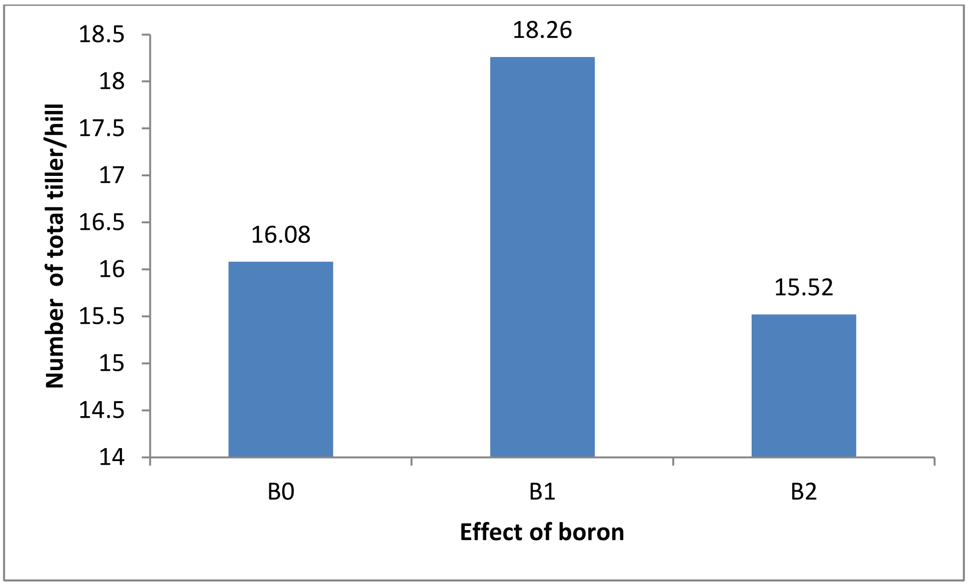

Fig. 4. Effect of B on number of total tiller hill^{-1} of BRRI dhan34.

(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

4.2.2 Effect of zinc

Number of total tiller hill^{-1} was influenced significantly by application of zinc (Fig 5 and Appendix 3). Result showed that the highest number of total tiller hill^{-1} (17.21) was recorded under Zn_0 (Control) followed Zn_1 (2 kg ha^{-1}) which was statistically identical with Zn_2 (4 kg ha^{-1}) while the lowest number of total tiller hill^{-1} (15.54) was achieved from Zn_1 (2 kg ha^{-1}). Similar results was also observed by Ullah *el al.* (2001). They found that soil application of zinc sulphate increased tiller number. Cheema *et al.*, (2006) also reported that number of tillers hill^{-1} showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}.

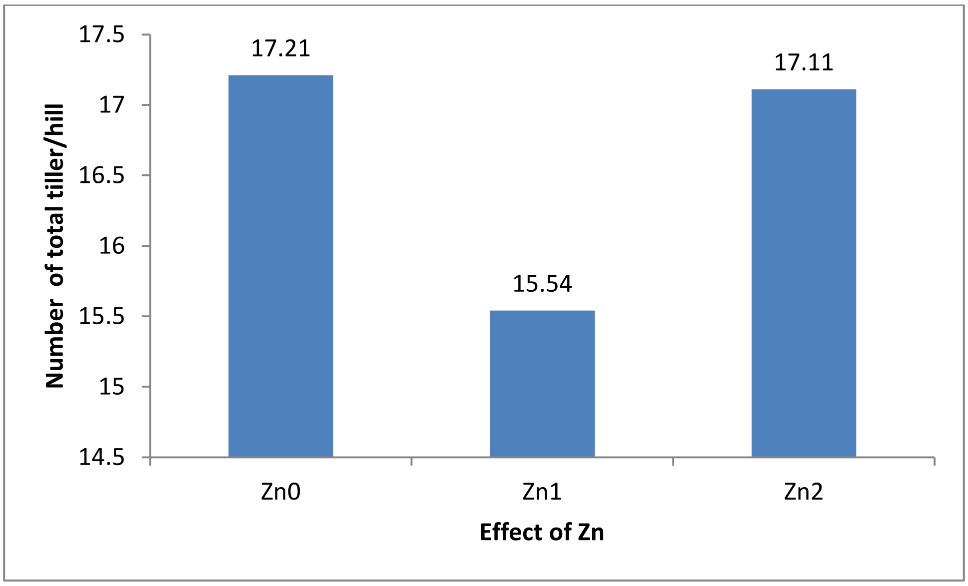

Fig. 5. Effect of Zn on number of total tiller hill^{-1} of BRRI dhan34.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})

4.2. 3 Combined effect zinc and boron

Combined effect of zinc and boron influenced significantly the number of total tiller hill^{-1} of the test crop (fig 6 and Appendix 3). Result revealed that the highest number of total tiller hill^{-1} (19.81) was recorded from B_1Zn_0 which was statistically same with B_0Zn_2 and followed by B_1Zn_1 where the lowest number of total tiller hill^{-1} (13.52) was achieved with B_2Zn_1 followed by B_0Zn_1 and B_2Zn_0.

4.3 Number of effective tiller hill^{-1}

4.3.1 Effect of boron

Application of boron influenced significantly in terms of effective tiller hill^{-1} of T.Aman rice (Fig 6 and Appendix 3). The findings showed that the highest number of effective tiller hill^{-1} (12.97) was found in B_1 (2 kg ha^{-1}) followed by B_0 (Control) where the lowest number of effective tiller hill^{-1} (10.76) was recorded from B_2 (4 kg ha^{-1}).

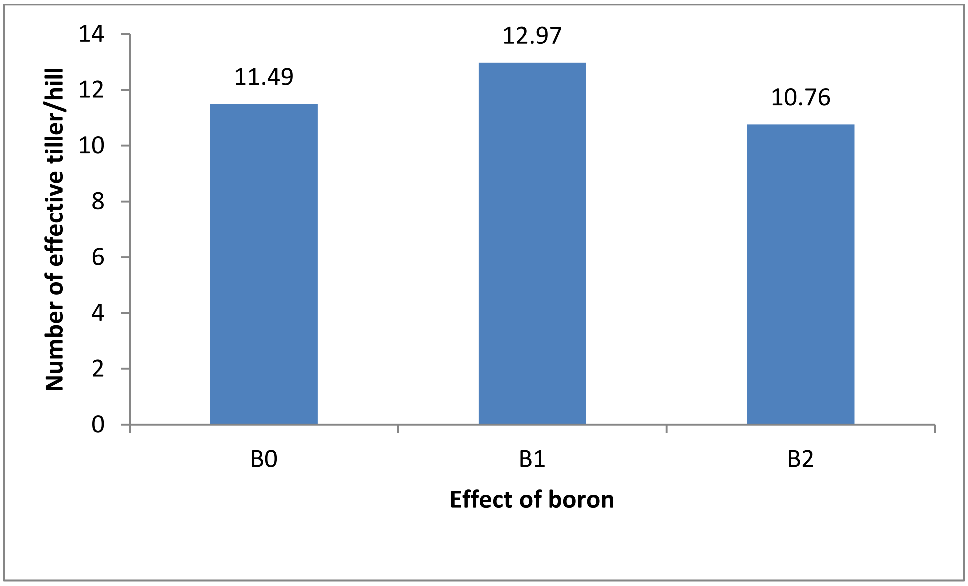

Fig. 6. Effect of B on number of effective tiller hill^{-1} of BRRI dhan34.

(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

4.3.2 Effect of zinc

There was a significant variation for number of effective tiller hill^{-1} by application of different level of zinc of T.Aman rice (Fig 7 and Appendix 3). Result showed that the highest number of effective tiller hill^{-1} (11.72) was recorded from Zn_0 (Control) which was statistically same with Zn_2 (4 kg ha^{-1}) while the lowest number of effective tiller hill^{-1} (10.97) was achieved from Zn_1 (2 kg ha^{-1}). Similar results was observed by Ullah *el al.*, (2001), Cheema *et al.*, (2006) and Babiker (1986) observed that productive tillers were significantly affected by rice cultivars and $ZnS0_4$ rates. 50 kg $ZnS0_4$ ha^{-1}, especially for nursery grown rice, was the most effective and economic rate for improving grain yield and its components.

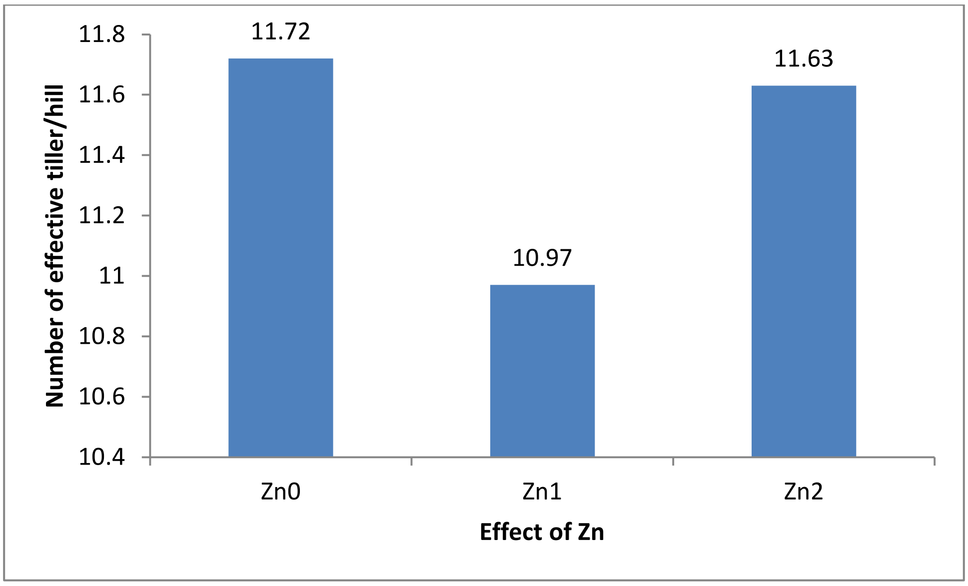

Fig. 7. Effect of Zn on number of effective tiller hill^{-1} of BRRI dhan34.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})

4.3.3 Combined effect zinc and boron

Combined effect of boron and zinc influenced significantly the number of effective tiller hill^{-1} (Table 2 and Appendix 3). Result revealed that the highest number of effective tiller hill^{-1} (14.53) was recorded from B_1Zn_0 which was followed by B_1Zn_0, B_1Zn_1 and B_0Zn_2 where the lowest number of effective tiller hill^{-1} (8.99) was achieved by B_0Zn_1 followed by B_2Zn_1 and B_2Zn_0.

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

4.4.1. Effect of boron

Significant variation was found by application of boron in terms of number of non-effective tiller hill^{-1} for T. Aman rice (Fig 8 and Appendix 3). The findings showed that the highest number of non-effective tiller hill^{-1} (4.65) was found in B_0 (Control) followed by B_1 (2 kg ha^{-1}) where the lowest non effective tiller hill^{-1} (3.99) was recorded from B_2 (4 kg ha^{-1}).

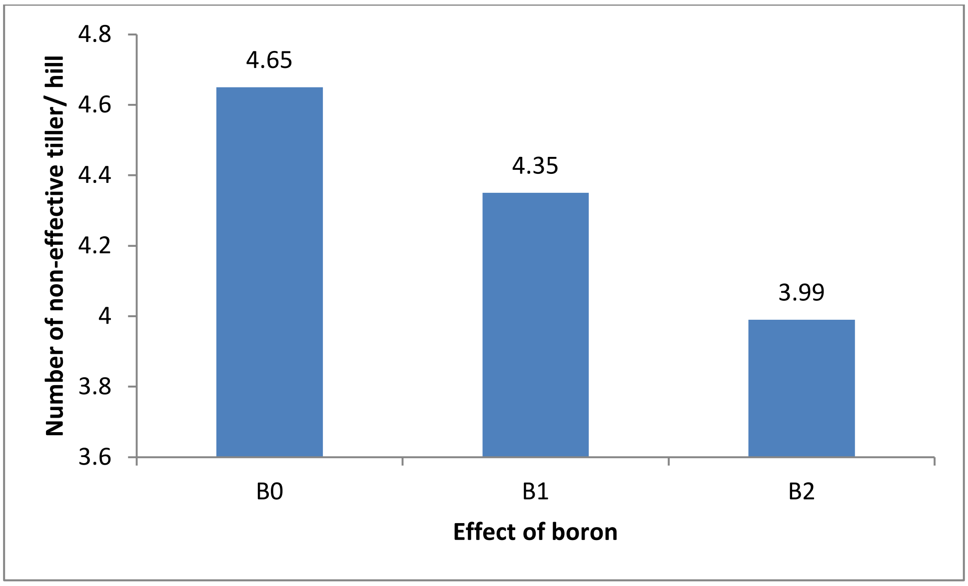

Fig. 8. Effect of B on number of non-effective tiller hill^{-1} of BRRI dhan34**.**

(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

4.4.2 Effect of zinc

Application of zinc influenced significantly the number of non-effective tiller hill^{-1} of T.Aman rice (Fig 9 and Appendix 3). Result showed that the highest number of non-effective tiller hill^{-1} (4.92) was recorded under Zn_2 (4 kg ha^{-1}) which was statistically similar with Zn_0 (Control) while the lowest non effective tiller hill^{-1} (3.91) was achieved from Zn_1 (2 kg ha^{-1}). Similar results was also observed by Babiker (1986).

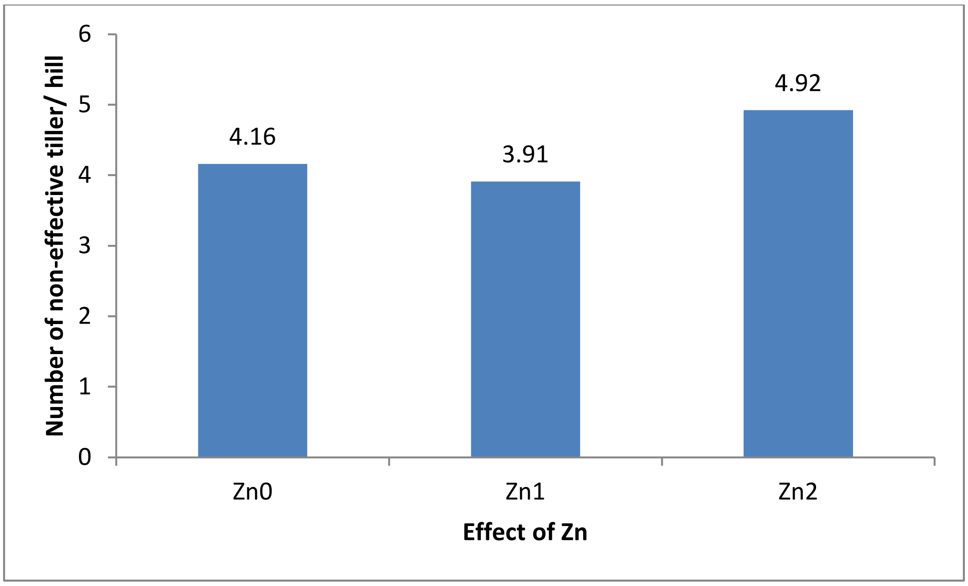

Fig. 9. Effect of Zn on number of non-effective tiller hill^{-1} of BRRI dhan34.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})

4.4.3 Combined effect boron and zinc

Boron and zinc influenced in significantly the non-effective tiller hill^{-1} of BRRI dhan34 under the present study (Table 2 and Appendix 3). Result revealed that the highest number of non-effective tiller hill^{-1} (5.55) was recorded from B_0Zn_2 followed by B_0Zn_0, B_1Zn_2 and B_2Zn_2 where the lowest number of non-effective tiller hill^{-1} (3.65) was obtained from B_2Zn_1which was statistically identical with B_0Zn_1 and B_2Zn_0 followed by B_1Zn_0 and B_1Zn_1.

4.5 Panicle length (cm)

4.5.1 Effect of boron

Significant variation was observed by the application of different boron levels in terms of panicle length (cm) of Aman rice (Fig 10 and Appendix 3). The findings showed that the longest panicle (24.28 cm) was found in B_2 (4 kg ha^{-1}) followed by B_1 (2 kg ha^{-1}) where the shortest panicle (23.38 cm) was recorded from B_0 (Control). Khan *et al.*, (2007) found spike length was significantly different from control for the same treatment of B application.

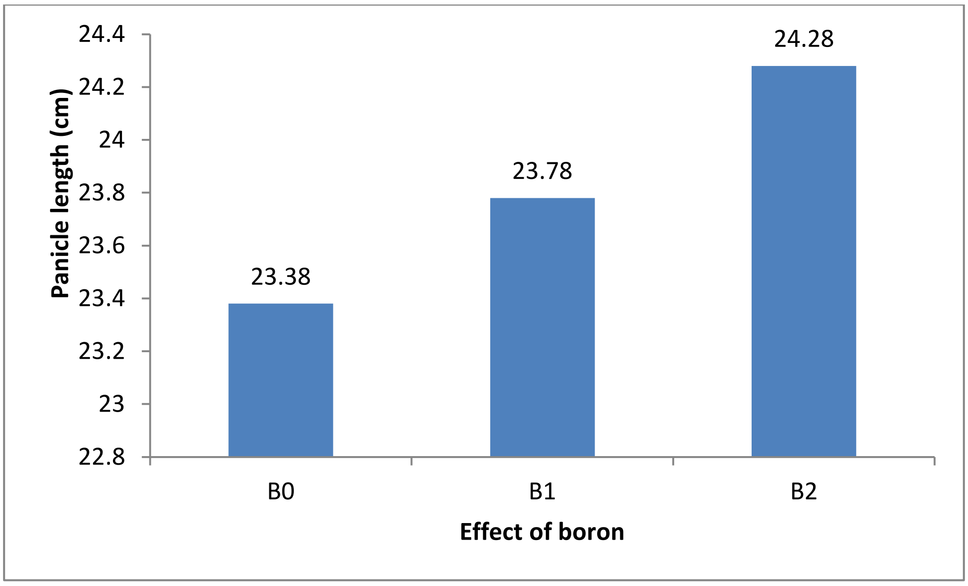

Fig. 10. Effect of B on panicle length of BRRI dhan34.

(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

4.5.2 Effect of zinc

The experimental findings showed that application of zinc significantly influenced the panicle length of T. Aman rice (Fig 11 and Appendix 3). Result showed that the highest panicle length (24.10 cm) was recorded under Zn_1 (2 kg ha^{-1}) followed by Zn_2 (4 kg ha^{-1}) while the lowest panicle length (22.38) was achieved from Zn_0 (Control). The result obtained from the present study was similar with Babiker (1986). He observed that panicle length was significantly affected by rice cultivars and $ZnSO_4$ rates.

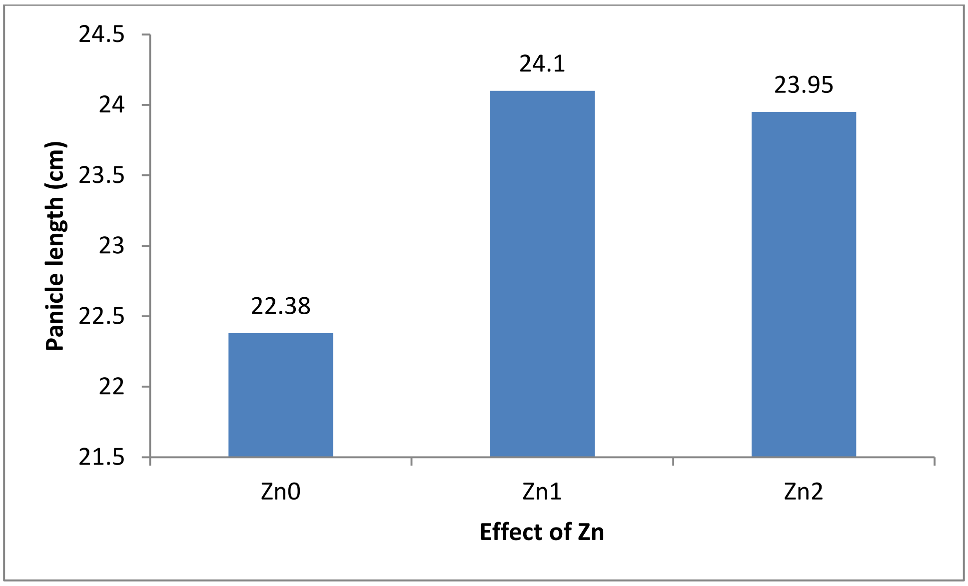

Fig. 11. Effect of Zn on panicle length of BRRI dhan34.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})

4.5. 3 Combined effect zinc and boron

Combined effect of boron and zinc influenced panicle length of T. Aman rice significantly (Table 2 and Appendix 3). The highest panicle length (25.28 cm) was recorded from B_2Zn_2 followed B_2Zn_1 where the shortest panicle length (22.60 cm) was achieved by B_0Zn_2 which was statistically similar with B_1Zn_0 and B_2Zn_0.

Table 2. Effect of Zn and B on growth and yield contributing parameters of BRRI dhan34

Treatment	Plant height (cm)	Number of total tiller $hill^{-1}$	Number of effective tiller $hill^{-1}$	Number of non-effective tiller $hill^{-1}$	Panicle length (cm)
B_0Zn_0	127.30 c	17.29 c	10.77 f	4.66 b	24.07 bc
B_0Zn_1	117.00 i	14.78 f	8.99 h	3.75 c	23.46 cd
B_0Zn_2	123.10 e	19.44 a	12.00 c	5.55 a	22.60 e
B_1Zn_0	125.40 d	19.81 a	14.53 a	4.18 bc	23.00 de
B_1Zn_1	120.60 g	18.33 b	13.05 b	4.33 bc	24.35 b
B_1Zn_2	132.30 a	17.33 c	11.33 e	4.54 b	23.97 bc
B_2Zn_0	117.80 h	15.24 e	9.867 g	3.67 c	23.06 de
B_2Zn_1	122.30 f	13.52 g	10.87 f	3.65 c	24.49 b
B_2Zn_2	128.00 b	16.55 d	11.55 d	4.66 b	25.28 a
$LSD_{0.05}$	1.324	0.1920	0.1920	0.6748	0.6095
CV (%)	6.44	8.57	9.75	7.89	11.24

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability and numeric data represents the mean value of 3 replications.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})
(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

4.6 Number of filled grain panicle^{-1}

4.6.1 Effect of boron

Application of boron significantly influenced the filled grain panicle^{-1} of T. Aman rice (Fig 12 and Appendix 4).The findings showed that the highest filled grain panicle^{-1} (118.90) was found in B_2 (4 kg ha^{-1}) followed by B_1 (2 kg ha^{-1}) where the lowest filled grain panicle^{-1} (84.31) was recorded from B_0 (Control).

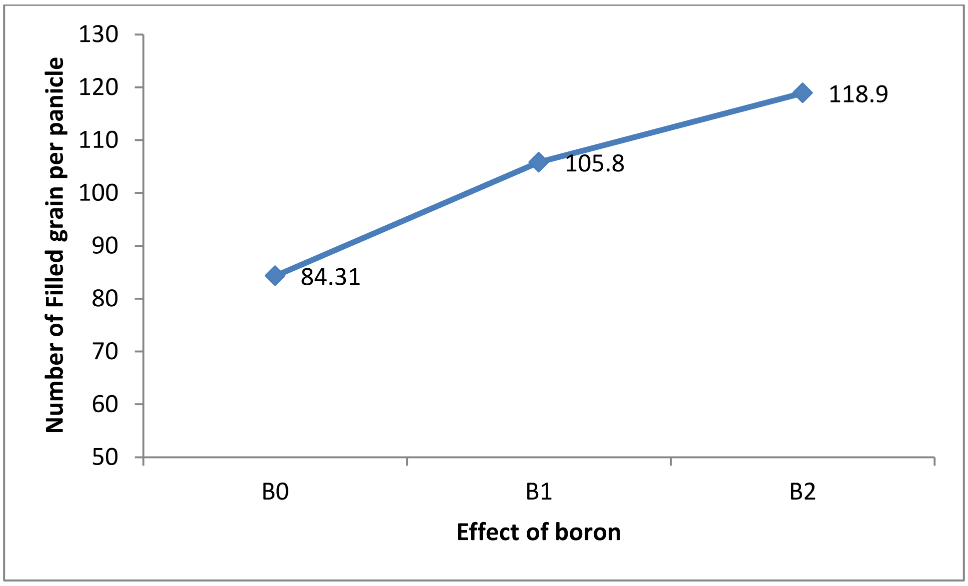

Fig. 12. Effect of B on number of filled grain panicle^{-1} of BRRI dhan34.

(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

4.6.2 Effect of zinc

Application of zinc influenced significantly the filled grain panicle^{-1} of T. Aman rice (Fig 13 and Appendix 4). Result showed that the highest filled grain panicle^{-1} (125.40) was recorded under Zn_2 (4 kg Zn ha^{-1}) followed by Zn_1 (2 kg Zn ha^{-1}) while the lowest filled grain panicle^{-1} (78.46) was achieved from Zn_0 (Control). Similar results was found by Babiker (1986). He observed that number of filled grain panicle^{-1} was significantly affected by $ZnS0_4$ rates.

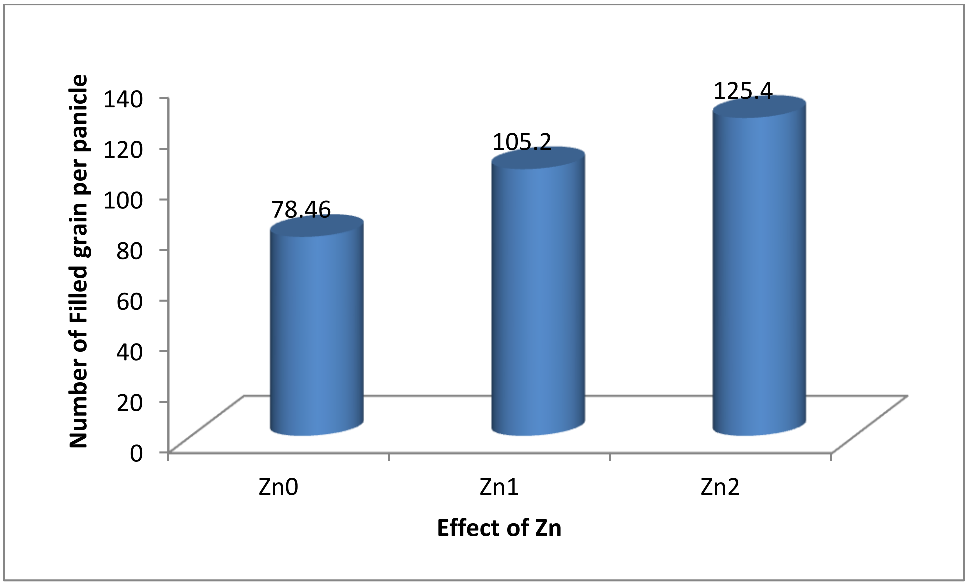

Fig. 13. Effect of Zn on number of filled grain panicle^{-1} of BRRI dhan34.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})

4.6.3 Combined effect boron and zinc

Significant variation was found by combined effect boron and zinc in case of filled grain panicle^{-1} of T. Aman rice (Table 3 and Appendix 4). Result revealed the highest filled grain panicle^{-1} (143.60) was recorded from B_2Zn_2 followed B_2Zn_1 and where the lowest filed grain panicle^{-1} (67.46) were achieved by B_0Zn_0 followed by B_0 Zn_1 and B_1Zn_0 and B_2Zn_0.

4.7 Number of un-filled grain panicle^{-1}

4.7.1 Effect of boron

There was significant variation by application of boron in terms of un-filled grain number panicle^{-1} for T. Aman rice (Fig 14 and Appendix 4). The findings showed that the highest number of un-filled grain panicle^{-1} (46.55) was found in B_0 (Control) followed by B_1 (2 kg B ha^{-1}) where the lowest number of un-filled grain panicle^{-1} (29.47) was recorded from B_2 (4 kg B ha^{-1}).

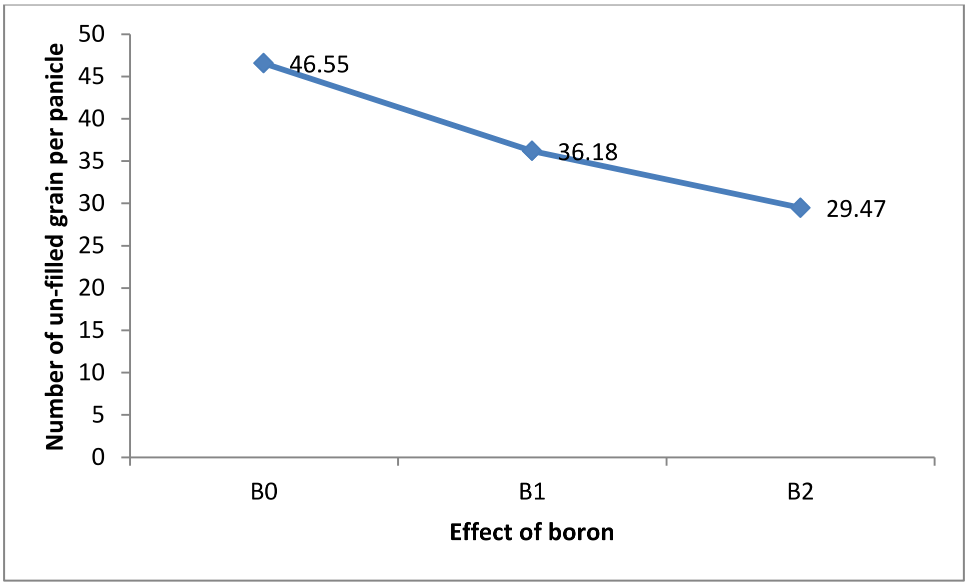

Fig. 14. Effect of B on number of un-filled grain panicle^{-1} of BRRI dhan34.

(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

4.7.2 Effect of zinc

The experimental findings showed significant variation in terms of un-filled grain number panicle^{-1} by application of different zinc levels (Fig 15 and Appendix 4). Result showed that the highest number of un-filled grain panicle^{-1} (50.23) was recorded from Zn_0 (Control) followed by Zn_1 (2 kg Zn ha^{-1}) while the lowest number of un-filled grain panicle^{-1} (26.30) was achieved from Zn_2 (4 kg Zn ha^{-1}). Similar results was found by Babiker (1986). He observed that number of un-filled grain panicle^{-1} was significantly affected by $ZnS0_4$ rates.

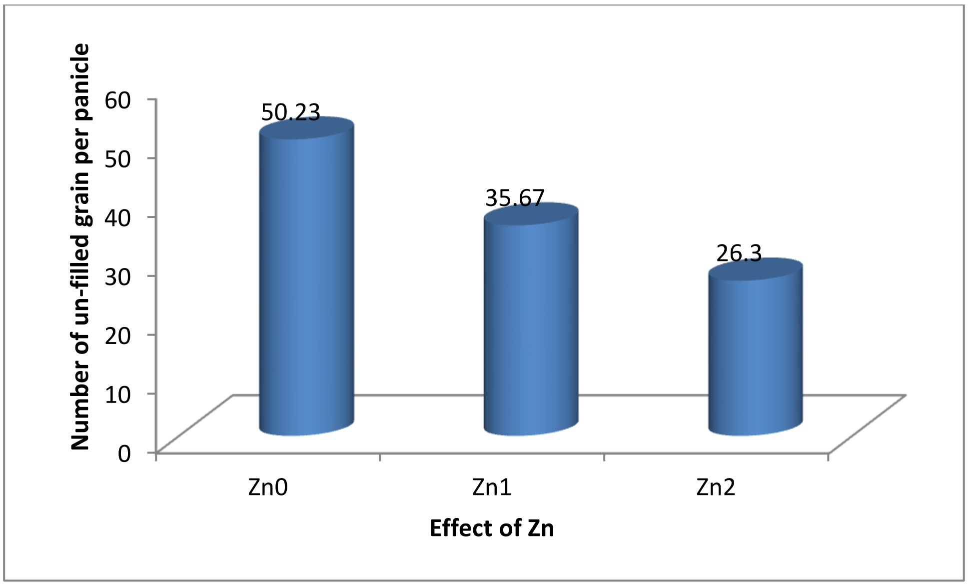

Fig. 15. Effect of Zn on number of un-filled grain panicle^{-1} of BRRI dhan34.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})

4.7.3 Combined effect zinc and boron

Combined effect of boron and zinc had significant influenced on number of un-filled grain panicle^{-1} of T. Aman rice (Table 3 and Appendix 4). Result revealed the highest number of un-filled grain panicle^{-1} (56.52) was recorded from B_0Zn_0 followed B_1Zn_0 where the lowest number of un-filled grain panicle^{-1} (18.82) was achieved by B_2Zn_2 followed by B_1Zn_2, B_2Zn_1 and B_2Zn_1.

4.8 Number of total grain panicle^{-1}

4.8.1 Effect of boron

Significant variation was found by the application of boron in terms of number of total grain panicle^{-1} of T. Aman rice (Fig 16 and Appendix 4). The findings showed that the highest number of total grain panicle^{-1} (148.10) was found in B_2 (4 kg ha^{-1}) followed by B_1 (2 kg ha^{-1}) where the lowest number of total grain panicle^{-1} (130.90) was recorded from B_0 (Control).

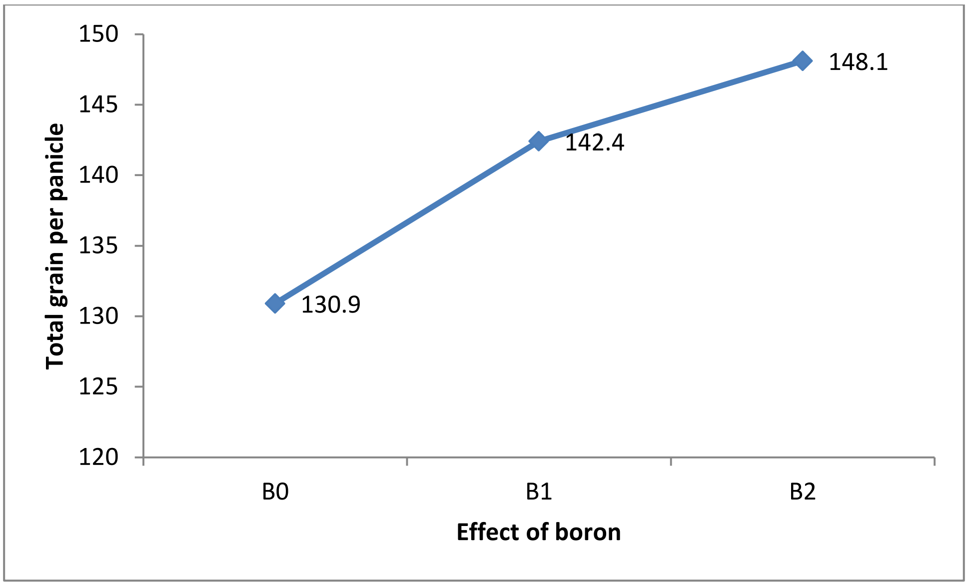

Fig. 16. Effect of B on number of total grain panicle^{-1} of BRRI dhan34.

(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

4.8.2 Effect of zinc

Application of zinc influenced significantly the number of total grain panicle^{-1} of T. Aman rice (Fig 17 and Appendix 4). Result showed that the highest number of total grain panicle^{-1} (151.40) was recorded from Zn_2 (4 kg ha^{-1}) followed by Zn_1 (2 kg ha^{-1}) while the lowest total grain panicle^{-1} (128.80) was achieved from Zn_0 (Control). Similar results was found by Babiker (1986).

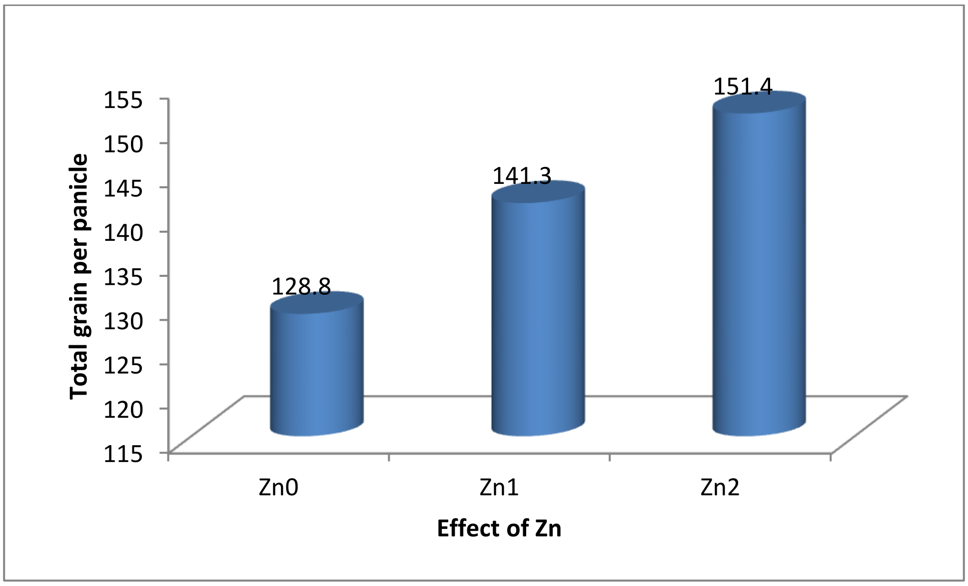

Fig. 17. Effect of Zn on number of total grain panicle^{-1} of BRRI dhan34.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})

4.8.3 Combined effect zinc and boron

Boron and zinc combination effect influenced significantly the number of total grain $panicle^{-1}$ of T. Aman rice (Table 3 and Appendix 4). Result revealed that the highest number of total grain $panicle^{-1}$ (161.40) was recorded from B_2Zn_2 followed by B_1Zn_2 where the lowest number of total grain $panicle^{-1}$ (124.00) was recorded from B_0Zn_0 followed by B_1Zn_0 and B_0Zn_1.

Table 3. Effect of Zn and B on yield contributing parameters of BRRI dhan34

Treatment	Number of Filled grain panicle^{-1}	Number of un-filled grain panicle^{-1}	Total grain panicle^{-1}
B_0Zn_0	67.46 i	56.52 a	124.00 i
B_0Zn_1	82.39 g	48.50 c	130.90 g
B_0Zn_2	103.10 e	34.63 e	137.70 e
B_1Zn_0	75.37 h	52.44 b	127.80 h
B_1Zn_1	112.50 d	30.64 f	144.40 d
B_1Zn_2	129.50 b	25.45 h	155.00 b
B_2Zn_0	92.55 f	41.72 d	134.40 f
B_2Zn_1	120.70 c	27.86 g	148.50 c
B_2Zn_2	143.60 a	18.82 i	161.40 a
$LSD_{0.05}$	0.05996	0.1920	0.5474
CV (%)	8.54	6.39	7.26

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability and numeric data represents the mean value of 3 replications.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})
(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

4.9 1000 - seed weight

4.9.1. Effect of boron

Non-significant variation was observed by the application of boron in terms of 1000 seed weight of T. Aman rice (Table 4 and Appendix 5). But the findings showed that the highest 1000 seed weight (14.65 g) was found in B_2 (4 kg B ha^{-1}) where the lowest 1000 seed weight (14.09 g) was recorded from B_0 (Control). Xiong (1987) found that the application of 0.8 - 1.2 ppm B resulted in 1-5 days earlier heading and the 1000-grain weight increased with B application. Khan *et al.*, (2007) also found 1000-grain weight was also significantly different with B treatments.

4.9.2 Effect of zinc

Application of zinc was not influenced significantly the weight of 1000 seed of T. Aman rice (Table 4 and Appendix 5). But result showed that the highest 1000 seed weight (15.74 g) was recorded from Zn_2 (4 kg Zn ha^{-1}) followed by Zn_1 (2 kg Zn ha^{-1}) while the lowest 1000 seed weight (12.67 g) was achieved from Zn_0 (Control). Ullah *el al.,* (2001) found that soil application of zinc sulphate increased 1000-grain weight. Cheema *et al*., (2006) reported that 1000 grain weight showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}. Babiker (1986) observed that 1000-grain weight was significantly affected by rice cultivars and $ZnS0_4$ rates.

4.9.3 Combined effect zinc and boron

Combined effect of boron and zinc had non-significant effect on 1000 seeds weight of T. Aman rice (Table 4 and Appendix 5). But result revealed that the highest 1000 seed weight (16.00 g) was recorded from B_2Zn_2 where the lowest 1000 seed weight (11.94 g) was achieved by B_0Zn_0.

4.10 Grain yield ha^{-1}

4.10.1. Effect of boron

Application of boron influenced significantly in terms of grain weight ha^{-1} of T. Aman rice (Table 4 and Appendix 5). The findings showed that the highest grain weight (5 t ha^{-1}) was found in B_2 (4 kg B ha^{-1}) followed by B_1 (2 kg B ha^{-1}) while the lowest grain weight (4.39 t ha^{-1}) was recorded from B_0 (Control). Mandal *et al.,* (1987) observed that an application of 16 kg borax ha^{-1} along with NPK increased the yield components and gave higher paddy yields. Singh et al., (1990) showed that 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 was obtained from the application of B under submerged condition.

4.10.2 Effect of zinc

The experimental results showed significant variation by application of different zinc levels in case of grain weight ha^{-1} of T. Aman rice (Table 4 and Appendix 5). Results exposed that the highest grain weight (5.61 t ha^{-1}) was recorded from Zn_2 (4 kg Zn ha^{-1}) followed by Zn_1 (2 kg Zn ha^{-1}) where the lowest grain weight (4.56 t ha^{-1}) was achieved from Zn_0 (Control). Ullah *el al.,* (2001) found that soil application of zinc sulphate increased grain yields. Cheema *et al*., (2006) reported that paddy yield showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}. Cihatak *el al.,* (2005) found that that Zinc fertilizer application significantly increased grain yields, uptake of Zn by plant. Babiker (1986) observed that 50 kg $ZnS0_4$ ha^{-1}, especially for nursery grown rice, was the most effective and economic rate for improving grain yield and its components. Jahiruddin *et al.,* (1981) reported that when Zn was applied to acid clay type soil of Bangladesh, a significant increase in the grain and straw yields of boro rice was obtained. Sharma *et al.,* (1982) observed that the grain yield of rice was increased from 3.21 t ha^{-1} without Zn to 5.78 t ha^{-1} with Zn application. Ahmed *et al.,* (1983) reported increase in all the growth parameters of rice after Zn application in the field.

Swamp (1983) stated that the grain yields of rice were increased with application of Zn.

4.10.3 Combined effect zinc and boron

Combined effect of boron and zinc influenced significantly the grain weight ha^{-1} of T. Aman rice (Table 4 and Appendix 5). Result revealed that the highest grain weight (5.72 t ha^{-1}) was recorded from B_2Zn_2 followed B_1Zn_2 and B_2Zn_1while the lowest grain weight (3.98 t ha^{-1}) was achieved by B_0Zn_0 followed by B_1Zn_0 and B_0Zn_1.

4.11 Straw weight ha^{-1}

4.11.1. Effect of boron

Straw weight ha^{-1} of T.Aman rice was influenced significantly by application of boron (Table 4 and Appendix 5). The findings showed that the highest straw weight (7.16 t ha^{-1}) was found in B_2 (4 kg B ha^{-1}) followed by B_1 (2 kg B ha^{-1}) where the lowest straw weight (6.45 t ha^{-1}) was recorded from B_0 (Control). Singh *et al.,* (1990) found the highest straw yield of 4.81 t ha^{-1} were obtained from the application of B under submerged condition.

4.11.2 Effect of zinc

Application of zinc influenced significantly the straw weight ha^{-1} of T. Aman rice (Table 4 and Appendix 5). Result showed that the highest straw weight (7.78 t ha^{-1}) was recorded under Zn_1 (2 kg Zn ha^{-1}) followed by Zn_2 (4 kg Zn ha^{-1}) while the lowest straw weight (6.67 t ha^{-1}) was achieved from Zn_0 (Control). Cheema *et al*., (2006) reported that straw yield showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}. Cihatak *el al.,* (2005) found that that Zinc fertilizer application significantly increased the straw yields, uptake of Zn by plant. Ullah *el al.,* (2001) found that soil application of zinc sulphate increased straw yields.

4.11.3 Combined effect boron and zinc

Boron and zinc influenced significantly the straw weight ha^{-1} T. Aman rice (Table 4 and Appendix 5). Result revealed the highest straw weight (8.07 t ha^{-1}) was recorded from B_1Zn_1 followed B_2Zn_0 and B_2Zn_1 where the shortest straw weight (5.39 t ha^{-1}) was achieved by B_0Zn_0 followed by B_0Zn_2.

4.12 Harvest index

4.12.1. Effect of boron

Significant variation by application of boron was found in terms of harvest index of T. Aman rice (Table 4 and Appendix 5). The findings showed that the highest harvest index (41.22%) was found in B_2 (4 kg B ha^{-1}) followed by B_1 (2 kg B ha^{-1}) where the lowest harvest index (39.64%) was recorded from B_0 (Control).

4.12.2 Effect of zinc

Application of zinc influenced significantly the harvest index of T. Aman rice (Table 4 and Appendix 5). Result showed that the highest harvest index (44.49%) was recorded from Zn_2 (4 kg Zn ha^{-1}) followed by Zn_0 (Control) where the lowest harvest index (39.10%) was achieved from Zn_1 (2 kg Zn ha^{-1}). Cheema *et al*., (2006) reported that harvest index showed positive correlation with the increase in $ZnSO_4$ levels from 2.5 to 10 kg ha^{-1}. Babiker (1986) observed that harvest index was significantly affected by rice cultivars and $ZnS0_4$ rates.

4.12.3 Combined effect boron and zinc

Interaction effect of boron and zinc influenced significantly the harvest index of T. Aman rice (Table 4 and Appendix 5). Result revealed the highest harvest index (45.77%) was recorded from B_2Zn_2 followed B_0Zn_2 and B_2Zn_1 while the lowest harvest index (35.42%) was achieved by B_0Zn_1 followed by B_1Zn_0.

Table 4. Effect of Zn and B on yield and yield parameters of BRRI dhan34

Treatment	1000 seed weight (g)	Grain weight (t ha^{-1})	Straw weight (t ha^{-1})	Harvest index (%)
Effect of boron				
B_0	14.09	4.39 c	6.45 c	40.66 b
B_1	14.46	4.59 b	6.99 b	39.64 c
B_2	14.65	5.00 a	7.16 a	41.22 a
LSD $_{0.05}$	NS	0.426	0.273	0.624
Effect of zinc				
Zn_0	12.67	4.56 c	6.67 c	40.74 c
Zn_1	14.90	5.03 b	7.78 a	39.10 b
Zn_2	15.74	5.61 a	6.99 b	44.49 a
LSD $_{0.05}$	NS	0.421	0.476	1.034
Combined effect of zinc and boron				
B_0Zn_0	11.94	3.98 i	5.39 h	42.48 d
B_0Zn_1	12.11	4.16 h	7.58 c	35.42 h
B_0Zn_2	13.22	5.03 f	6.38 g	44.08 b
B_1Zn_0	13.02	4.57 g	7.02 f	39.43 g
B_1Zn_1	14.68	5.41 d	8.07 a	40.14 f
B_1Zn_2	15.56	5.68 b	7.34 d	43.62 c
B_2Zn_0	13.82	5.14 e	7.61 c	40.32 f
B_2Zn_1	15.50	5.52 c	7.70 b	41.75 e
B_2Zn_2	16.00	5.72 a	7.25 e	45.77 a
LSD $_{0.05}$	NS	0.108	0.116	0.187
CV (%)	8.623	7.321	11.567	9.137

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability and numeric data represents the mean value of 3 replications.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})
(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

4.13 Nutrient status of post-harvest soil of BRRI dhan34 as affected by zinc and boron

4.13.1 Soil pH

4.13.1.1 Effect of boron

Non-significant variation was observed by the application of boron in terms of pH in soil after harvest of T. Aman rice (Table 5 and Appendix 6). But the findings showed that the highest pH in postharvest soil (5.44) was found in B_1 (2 kg B ha^{-1}) where the lowest pH in postharvest soil (5.42) was recorded from B_0 (Control).

4.13.1.2 Effect of zinc

Application of zinc did not influence significantly the pH in postharvest soil of T. Aman rice (Table 5 and Appendix 6). But result showed that the highest pH in postharvest soil (5.44) was recorded from Zn_0 (Control) followed by Zn_1 (2 kg Zn ha^{-1}) while the lowest pH in postharvest soil (5.42) was achieved from Zn_2 (4 kg Zn ha^{-1}).

4.13.1.3 Combined effect boron and zinc

Combined application of zinc and boron had no significant effect on pH of post-harvest soil (Table 5 and Appendix 6). The highest pH (5.47) was recorded in the treatment combination of B_1Zn_0 and the lowest pH value (5.41) was in B_2Zn_1.

4.13.2 Organic matter content of soil (%)

4.13.2.1 Effect of boron

Significant variation was observed by the application of boron in terms of organic matter content in soil after harvest of T. Aman rice (Table 5 and Appendix 6). Findings showed that the highest organic matter content in soil after harvest (0.56%) was found in B_2 (4 kg ha^{-1}) which was statistically identical with B_1 (2 kg ha^{-1}) where the lowest organic matter content in soil after harvest (0.36%) was recorded from B_0 (Control).

4.13.2.2 Effect of zinc

Application of zinc influenced significantly the organic matter content in postharvest soil of T. Aman rice (Table 5 and Appendix 6). Result showed that the highest organic matter content in soil after harvest (0.54%) was recorded from Zn_2 (4 kg Zn ha^{-1}) while the lowest organic matter content in soil after harvest (0.44%) was achieved from Zn_0 (control) which was statistically identical with Zn_1 (2 kg Zn ha^{-1})

4.13.2.3 Combined effect zinc and boron

Combined application of boron and zinc had significant effect on organic matter content of post-harvest soil (Table 4 and Appendix 6). The highest organic matter content of post-harvest soil (0.65%) was recorded in treatment combination of B_2Zn_2 which was closely followed by B_1Zn_1, B_1Zn_2 and B_2Zn_0 where the lowest organic matter content of post-harvest soil (0.32%) was in B_0Zn_0 which was also significantly similar with the treatment combination of B_0Zn_1, B_0Zn_2 and B_2Zn_0.

4.13.3 Total nitrogen of soil (%)

4.13.3.1 Effect of boron

Non-significant variation was observed by the application of boron in terms of total nitrogen in soil after harvest of T. Aman rice (Table 5 and Appendix 6). Findings showed that the highest total nitrogen in postharvest soil (0.06%) was found in B_2 (4 kg B ha^{-1}) where the lowest total nitrogen in soil after harvest (0.04%) was recorded from B_0 (Control).

4.13.3.2 Effect of zinc

Application of zinc showed non-significant effect in terms of total nitrogen in postharvest soil of T. Aman rice (Table 5 and Appendix 6). Result showed that the highest total nitrogen t in soil after harvest (0.07%) was recorded from Zn_2 (4 kg ha^{-1}) while the lowest total nitrogen in soil after harvest (0.04%) was achieved from Zn_0 (control).

4.13.3.3 Combined effect boron and zinc

Total nitrogen of post-harvest soil was not significantly influenced by combined application of boron and zinc (Table 4 and Appendix 6). The highest N content (0.08%) was observed in B_2Zn_2. In contrast to the lowest N content (0.04%) was obtained in B_0Zn_1 and B_1Zn_0 treatment.

4.13.4 Available phosphorus

4.13.4.1 Effect of boron

Significant variation was observed by the application of boron in terms of available phosphorus in soil after harvest of T. Aman rice (Table 5 and Appendix 6). Findings showed that the highest available phosphorus in postharvest soil (20.20 ppm) was found in B_2 (4 kg B ha^{-1}) where the lowest total nitrogen in soil after harvest (16.13 ppm) was recorded from B_0 (Control).

4.13.4.2 Effect of zinc

Application of zinc influenced significantly the available phosphorus in postharvest soil of T. Aman rice (Table 5 and Appendix 6). Result showed that the highest available phosphorus after harvest (21.24 ppm) was recorded from Zn_2 (4 kg Z ha^{-1}) which was statistically similar with Zn_1 (2 kg Zn ha^{-1}) while the lowest available phosphorus in soil after harvest (15.67 ppm) was achieved from Zn_0 (control).

4.13.4.3 Combined effect zinc and boron

Phosphorus content of post-harvest soil was significantly influenced by combined application of zinc and boron (Table 5 and Appendix 6). Among the different treatments, B_2Zn_2 treatment showed the highest P content (24.18 ppm) in post-harvest soil. On the other hand, the lowest P content (14.13 ppm) was observed in B_0Zn_0 treatment with no Zn and B fertilization phosphorus content of soil (ppm).

4.13.5 Potassium content of soil

4.13.5.1 Effect of boron

Application of boron had no significant influence on potassium content of postharvest soil (meq/100 gm soil) (Table 5 and Appendix 6). But result showed that the highest potassium content in soil (meq/100 gm soil) after harvest (0.17) was recorded from B_2 (4 kg B ha^{-1}) where the lowest potassium content of soil (meq/100 gm soil) after harvest (0.13) was achieved from B_0 (control).

4.13.5.2 Effect of zinc

Application of zinc had no significant influence on potassium content of soil (meq 100 gm soil) in postharvest soil of T. Aman rice (Table 5 and Appendix 6). But results showed that the highest potassium content of soil (meq/100 gm soil) after harvest (0.18) was recorded from Zn_2 (4 kg Zn ha^{-1}) where the lowest potassium content of soil (meq/100 gm soil) after harvest (0.12) was achieved from Zn_0 (control).

4.13.5.3 Combined effect zinc and boron

The combined effect of zinc and boron had no significant effect on potassium content of post-harvest soil (Table 5 and Appendix 6). However the highest K content (0.21 meq/100 gm soil) was recorded in B_2Zn_2 and the lowest potassium content of post harvested soil (0.10 meq/100 gm soil) was recorded in B_0Zn_0 treatment.

4.13.6 Available B content of soil (meq/100 gm soil)

4.13.6.1 Effect of boron

Application of boron influenced significantly the boron content in postharvest soil of T. Aman rice (Table 5 and Appendix 6). Result showed that the highest boron content in soil after harvest (0.80 meq /100 gm soil) was recorded from B_2(4 kg ha^{-1}) where the lowest boron content in soil after harvest (0.35 meq/100 gm soil) was achieved from B_0 (control).

4.13.6.2 Effect of zinc

Application of zinc had no significant effect on boron content of postharvest soil (Table 5 and Appendix 6). But result showed that the highest zinc content in soil after harvest (0.64 meq/100 gm soil) was recorded from Zn_2 (4 kg Zn ha^{-1}) where the lowest zinc content in soil after harvest (0.60 meq/100 gm soil) was achieved from Zn_0 (control).

4.13.6.3 Combined effect zinc and boron

The combined effect of zinc and boron had significant effect on boron content of post-harvest soil (Table 5 and Appendix 6). The highest B content (0.82 meq/100 gm soil) was recorded in B_2Zn_2 treatment which was statistically identical with B_2Zn_1 and the lowest zinc content of post harvested soil (0.32 meq/100 gm soil) was recorded in B_0Zn_0.

4.13.7 Available Zn content of soil

4.13.7.1 Effect of boron

Application of boron influenced significantly the zinc content of postharvest soil of T. Aman rice (Table 5 and Appendix 6). Result showed that the highest zinc content in soil after harvest (3.32 meq/100 gm soil) was recorded from B_2(4 kg B ha^{-1}) where the lowest boron content in soil after harvest (3.11 meq/100 gm soil) was achieved from Zn_0 (control).

4.13.7.2 Effect of zinc

Application of zinc influenced significantly the zinc content of postharvest soil (Table 5 and Appendix 6). Result showed that the highest zinc content in soil after harvest (3.35 meq/100 gm soil) was recorded from Zn_2 (4 kg Zn ha^{-1}) where the lowest zinc content in soil after harvest (3.09 meq/100 gm soil) was achieved from Zn_0 (control).

4.13.7.3 Combined effect zinc and boron

The combined effect of zinc and boron had significant effect on zinc content of post-harvest soil (Table 5and Appendix 6). The highest Zn content (3.48 meq/100 gm soil) was recorded in B_2Zn_2 treatment where the lowest zinc content of post harvested soil (3.03 meq/100 gm soil) was recorded in B_0Zn_0.

Table 5. Effect of Zn and B and their interaction on the pH, organic matter, total N, available P, exchangeable K, available B and available Zn in the soil after harvest of BRRI dhan34

Treatment	p^H	Organic matter (%)	Total N_2 (%)	Available P (ppm)	Exchangeable K (meq/100 gm soil)	Available B (meq/100 gm soil)	Available Zn (meq/ 100 gm soil)
Effect of boron							
B_0	5.42	0.36 b	0.04	16.13 c	0.13	0.35 c	3.11 c
B_1	5.44	0.52 a	0.05	18.87 b	0.15	0.71 b	3.23 b
B_2	5.43	0.56 a	0.06	20.20 a	0.17	0.80 a	3.32 a
$LSD_{0.05}$	NS	0.063	NS	2.134	NS	0.052	0.016
Effect of zinc							
Zn_0	5.44	0.44 b	0.04	15.67 c	0.12	0.60	3.09 c
Zn_1	5.42	0.46 b	0.05	18.29 b	0.15	0.62	3.22 b
Zn_2	5.43	0.54 a	0.07	21.24 a	0.18	0.64	3.35 a
$LSD_{0.05}$	NS	0.062	NS	1.031	NS	NS	0.036
Combined effect of boron and zinc							
B_0Zn_0	5.43	0.32 c	0.06	14.13 i	0.10	0.32 e	3.03 g
B_0Zn_1	5.40	0.38 bc	0.04	16.05 g	0.13	0.36 d	3.10 ef
B_0Zn_2	5.43	0.39 bc	0.05	18.21 e	0.15	0.38 d	3.19 cd
B_1Zn_0	5.47	0.42 bc	0.04	15.83 h	0.12	0.70 c	3.08 fg
B_1Zn_1	5.44	0.56 ab	0.06	19.46 c	0.16	0.70 c	3.25 c
B_1Zn_2	5.42	0.59 ab	0.07	21.33 b	0.18	0.72 c	3.37 b
B_2Zn_0	5.42	0.58 ab	0.05	17.07 f	0.13	0.77 b	3.15 de
B_2Zn_1	5.41	0.44 bc	0.06	19.36 d	0.17	0.80 a	3.32 b
B_2Zn_2	5.45	0.65 a	0.08	24.18 a	0.21	0.82 a	3.48 a
$LSD_{0.05}$	NS	0.064	NS	0.062	NS	0.033	0.051
CV (%)	4.362	6.349	3.689	5.359	4.264	6.827	5.763

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability and numeric data represents the mean value of 3 replications.

(Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1})
(B_0 = 0 kg B ha^{-1}, B_1 = 2 kg B ha^{-1}, B_2 = 4 kg B ha^{-1})

CHAPTER V

SUMMERY, CONCLUSION AND RECOMMENDATIONS

The experiment was conducted in a typical rice growing soil on south west corner of main farm of Sher-e-Bangla Agricultural Univervisty, Dhaka, during the period from 24th July to 24th November 2014. The experiment was laid out into Randomized Complete Block Design (RCBD) with three replication. Two factors were comprised with study viz. factor A: B_0 = 0 kg ha^{-1}, B_1 = 2 kg B ha^{-1} and B_2 = 4 kg B ha^{-1} and Factor B: Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1} and Zn_2 = 4 kg Zn ha^{-1}. Data were recorded on different growth, and yield contributing parameters. Most of the parameters showed significant difference among the treatment.

In terms of boron application at different levels, significant variation was found for the most of the parameters. Results indicated that the highest plant height (124.40 cm), number of total tiller hill^{-1} (18.26 cm), effective tiller hill^{-1} (12.97), non effective tiller hill^{-1} (12.97) and highest total grain panicle^{-1}(148.10) was found in B_1 (2 kg B ha^{-1}). Again, the longest panicle (24.28 cm), highest filled grain panicle^{-1} (118.90), 1000 seed weigh (14.65 g), grain weight (5 t ha^{-1}), straw weight (7.16 t ha^{-1}), harvest index (41.22%) was found in B_2 (4 kg B ha^{-1}) and the highest un-filled grain panicle^{-1} (46.55) was found in B_0 (Control). On the other hand, the lowest plant height (122.70 cm), number of total tiller hill^{-1} (15.52 cm), effective tiller hill^{-1} (10.76) and the lowest non effective tiller hill^{-1} (10.76) was recorded from B_2 (4 kg ha^{-1}). Again, the lowest panicle length (23.38 cm), filled grain panicle^{-1} (84.31), un-filled grain panicle^{-1} (29.47), total grain panicle^{-1} (130.90), 1000 seed weight (14.09 g), grain weight (4.39 t ha^{-1}) the lowest straw weight (6.45 t ha^{-1}) was recorded from B_0 (Control).

In case of Zn application at different levels to rice variety BRRI dhan34, significant influence was observed. Results showed that the longest plant (126.10 cm), highest number of total tiller hill^{-1} (17.21 cm), number of effective tiller hill^{-1} (11.63), number of non-effective tiller hill^{-1} (11.63), number of filled grain panicle^{-1} (125.40), number of total grain panicle^{-1} (151.40), 1000 seed weight (15.74 g), grain weight (5.61 t ha^{-1}) and harvest index (44.49 %) was recorded from Zn_2 (4 kg Zn ha^{-1}) and the highest panicle length (24.10 cm), straw weight (7.78 t ha^{-1}) and the highest un-filled grain panicle^{-1} (50.23) was recorded from Zn_0 (Control). On the contrary, the shortest plant (120.00 cm), lowest number of effective tiller hill^{-1} (10.97), harvest index (39.10%) and the lowest number of non-effective tiller hill^{-1} (10.97) was recorded from Zn_1 (2 kg Zn ha^{-1}). Again, the lowest number of un-filled grain panicle^{-1} (26.30) and number of total tiller hill^{-1} (17.11) was achieved from Zn_2 (4 kg Zn ha^{-1}) and the lowest number of non-effective tiller hill^{-1} (10.97), panicle length (22.10 cm), number of filled grain panicle^{-1} (22.10), number of total grains panicle^{-1} (128.80), 1000 seed weight (13.87 g), grain weight ha^{-1} (4.5 t ha^{-1}) and the lowest straw weight ha^{-1} (6.67 t ha^{-1}) was achieved from Zn_0 (Control).

In case of combined effect of boron and Zinc, the longest plant (132.30 cm) and straw weight ha^{-1} (8.07 t ha^{-1}) was recorded from B_1Zn_2. Again, the number of total tiller hill^{-1} (19.11) and number of effective tiller hill^{-1} (14.53) were received from B_1Zn_0. But the highest panicle length (25.28 cm), number of filled grain panicle^{-1} (143.60), number of total grain panicle^{-1} (161.40), grain weight ha^{-1} (5.72 t ha^{-1}), harvest index (45.77 %) was recorded from B_2Zn_2. Where the highest number of non-effective tiller hill^{-1} (5.55) was from B_0Zn_2 and the highest number of un-filed grain panicle^{-1} (56.52) was from B_0Zn_0. In another consideration, the shortest plant (117.00 cm), the lowest number of total tiller hill^{-1} (13.52), number of effective tiller hill^{-1} (8.99), number of non-effective tiller hill^{-1} (8.99) and the lowest harvest index (35.42%) was achieved from B_0Zn_1. The lowest number of filled grain panicle^{-1} (67.46), number of total grain panicle^{-1} (124.00), 1000 seed weight (11.94 g), grain weight ha^{-1} (3.98 t ha^{-1}) and the lowest straw weight ha^{-1} (5.39 t ha^{-1}) was achieved by B_0Zn_0 and number of un-filled grain panicle^{-1} (25.45) and the shortest panicle (22.60 cm) was achieved from B_0Zn_2.

In terms of nutrient status in soil, boron had significant effect on organic matter available P, available B and available Zn but pH, total N and exchangeable K was not significantly influenced by boron. Again, zinc had significant effect on organic matter, available P and available Zn but pH, total N, exchangeable K and available B was not significantly influenced by zinc. For further observation, considering combined effect of boron and zinc, there were no significant effect on p^{H}, total N and exchangeable K. Organic matter, available P, available B and available Zn were significantly influenced by combined effect of boron and zinc. Results indicated that the highest organic matter (0.65%), available P content (24.18 ppm), available B content (0.82 meq/100 gm soil) and available Zn content (3.48 meq/100 gm soil) was recorded in B_2Zn_2.

From the above findings, it can be concluded that the highest performance regarding yield and yield contributing parameters the effect of B_2Zn_2 (B_2 = 4 kg B ha^{-1} and Zn_2 = 4 kg Zn ha^{-1}) gave the highest grain yield. So, this treatment combination can be treated as the best compared to others.

Recommendations:

Further study can be established to justify the present findings. Such study is needed in different Agro-Ecological Zones (AEZ) of Bangladesh for regional adaptability and other performance. Some other combinations of boron and zinc with different management practices may be included for further study.

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APPENDICES

Appendix 1. Monthly records of temperature, rainfall, and relative humidity of the experiment site during the period from July 2014 to October 2014

Year	Month	Air Temperature (^{0}c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2014	July	35.80	29.60	32.70	75.70	2.70	230.50
2014	August	36.30	30.50	33.40	74.60	3.00	227.80
2014	September	33.50	28.70	31.10	72.40	1.50	225.50
2014	October	32.60	27.80	30.20	68.50	Terace	222.40

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207

Appendix 2. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

Constituents	:	0-15 cm depth
P^H	:	5.45-5.61
Total N (%)	:	0.07
Available P (µ gm/gm)	:	18.49
Exchangeable K (meq)	:	0.07
Available S (µ gm/gm)	:	20.82
Available Fe (µ gm/gm)	:	229
Available Zn (µ gm/gm)	:	4.48
Available Mg (µ gm/gm)	:	0.825
Available Na (µ gm/gm)	:	0.32
Available B (µ gm/gm)	:	0.94
Organic matter (%)	:	0.83

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Appendix 3. Effect of Zn and B on growth and yield contributing parameters of BRRI dhan34

Source of variation	Degrees of freedom	Plant height (cm)	Number of total tiller hill^{-1}	Effective tiller hill^{-1}	Number of effective tiller hill^{-1}	Panicle length (cm)
Replication	2	0.461	0.3263	0.56	0.168	0.442
Factor A	2	3.821*	6.557*	5.941*	4.379*	4.893*
Factor B	2	5.261*	8.23*	10.628*	9.186*	11.173**
AB	4	2.191*	4.189*	3.634**	6.397**	3.194*
Error	16	1.854	1.478	1.457	3.091	3.806

Appendix 4. Effect of Zn and B on yield contributing parameters of BRRI dhan34

Source of variation	Degrees of freedom	Mean square		
		Filed grain per panicle	Un-filed grain per panicle	Total grain panicle^{-1}
Replication	2	0.166	0.352	0.340
Factor A	2	4.20*	2.938*	3.70*
Factor B	2	10.17*	6.179*	9.672**
AB	4	3.48**	4.384**	4.316*
Error	16	1.002	1.074	2.287

Appendix 5 Effect of Zn and B on growth and yield contributing parameters of BRRI dhan34

Source of variation	Degrees of freedom	Mean square of			
		1000 seed weight	grain weight/plot	straw weight/plot	Harvest index
Replication	2	0.212	0.323	0.393	0.134
Factor A	2	0.730^{NS}	5.124*	4.285*	1.174*
Factor B	2	6.62**	8.086*	8.792*	2.366**
AB	4	1.321*	3.634*	2.245*	0.651*
Error	16	1.110	1.166	1.238	0.341

Appendix 6. Nutrient status in soil regarding Zn and B use for the cultivation of BRRI dhan 34.

Source of variation	Degrees of freedom	p^H	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (meq/100 gm soil)	Available B (meq/100 gm soil)	Available Zn (meq/100 gm soil)
Replication	2	0.164	0.052	2.361	0.245	0.071	0.009	0.012
Factor A	2	NS	0.123	NS	2.375*	NS	0.00*	1.034*
Factor B	2	NS	0.360	NS	5.239*	NS	NS	2.739*
AB	4	NS	0.090	NS	1.413*	NS	0.213*	0.621*
Error	16	0.006	0.023	2.341	0.375	0.003	0.238	0.172