EFFECT OF MICRONUTRIENTS ON YIELD AND GROWTH OF T. AMAN

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DECEMBER, 2014

ACKNOWLEDGEMENTS

All praises are due to Almighty Allah, the Great, Gracious and Merciful, whose blessings enabled the author to complete this research work successfully. The author deems it a much privilege to express his enormous sense of gratitude to the almighty creator for his ever ending blessings for the successful completion of the research work.

The author feels proud to express his deep sense of gratitude, sincere appreciation and immense indebtedness to his supervisor ***Professor Dr. Alok Kumar Paul****, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for his continuous guidance, cooperation, constructive criticism and helpful suggestions, valuable opinion in carrying out the research work and preparation of this thesis, without his intense co-operation this work would not have been possible.*

The author feels proud to express his deepest respect, sincere appreciation and immense indebtedness to his co-supervisor ***Professor Mst. Afrose Jahan****, Department of Soil Science Sher-e-Bangla Agricultural University, Dhaka, for her scholastic and continuous guidance during the entire period of course and research work and preparation of this thesis.*

The author expresses his sincere respect to ***Associate Professor Dr. Mohammad Issak****, Chairman, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for valuable suggestions and cooperation during the study period. The author wants to remember the* ***Assistant Professor Syfullah Shahriar*** *for his speechless support and the author also expresses his heartfelt thanks to all the teachers of the Department of Soil Science, SAU, for their valuable teaching, suggestions and encouragement during the period of the study.*

The author wishes to pay his gratefulness to specially ***Rizwana Khondoker Aurin*** *for her great support. The author extended his wishes to TM Arifur Rahman Timun, Hasan Hafizur Rahman, Sadikur Rahman Bittu. Md. Ali Rubel,Md. Ashraful Islam Pulok and Khondoker Hadi Imam.*

The author sincerely thanks all the officials and laboratory staffs of the Department of Soil Science, Sher-e-Bangla Agricultural University.

The author expresses his sincere appreciation to his grandfather, father, mother, teachers, friends and farm laborers for their inspiration, help and encouragement throughout the study.

Dhaka, Bangladesh ***The Author***
December, 2014

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By

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ABSTRACT

The experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July 2013 to December 2013 to study the effect of micronutrients on yield and growth of T.Aman. BRRI dhan34 was used as the test crop in this experiment. The experiment consists of two factors i.e. Zinc fertilizer plus Boron fertilizer, with 3 replications and 12 treatment combinations as, T_1: Zn_0B_0 (0 kg Zn ha^{-1} x 0 kg B ha^{-1}), T_2: Zn_0B_1 (0 kg Zn ha^{-1} x 1 kg B ha^{-1}), T_3: Zn_0B_2 (0 kg Zn ha^{-1} x 2 kg B ha^{-1}), T_4: Zn_1B_0 (1 kg Zn ha^{-1} x 0 kg B ha^{-1}), T_5: Zn_1B_1 (1 kg Zn ha^{-1} x 1 kg B ha^{-1}), T_6: Zn_1B_2 (0 kg Zn ha^{-1} x 2 kg B ha^{-1}), T_7: Zn_2B_0 (2 kg Zn ha^{-1} x 0 kg B ha^{-1}), T_8: Zn_2B_1 (2 kg Zn ha^{-1} x 1 kg B ha^{-1}), T_9: Zn_2B_2 (2 kg Zn ha^{-1} x 2 kg B ha^{-1}), T_{10}: Zn_3B_0 (3 kg Zn ha^{-1} x 0 kg B ha^{-1}), T_{11}: Zn_3B_1 (3 kg Zn ha^{-1} x 1 kg B ha^{-1}), and T_{12}: Zn_3B_2 (3 kg Zn ha^{-1} x 2 kg B ha^{-1}). Combined application of zinc @ 2 kg and boron @ 2 kg ha^{-1} produced the highest grain yield 6.72 t ha^{-1}, the highest straw yield 8.17 t ha^{-1}, the highest plant height (151.30 cm), the maximum number of effective tillers $hill^{-1}$ (9.25), the longest panicle (26.27 cm), highest number of grains $panicle^{-1}$ (158.70). On the other hand in most of the cases, the lowest results were found in the control treatment. So it could be concluded that application of Zn and B at the rate of 2 kg ha^{-1} in addition to recommended doses of all other fertilizers may be applied for transplanted aman rice crops for better yield and growth.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

Bangladesh is an agro-based country. Rice is the principal food of this country. It occupies 77% of total cropped area. At present rice alone constitutes about 92% of the total food grains produced annually in the country. It provides 75% of the calories and 55% of the proteins in the average daily diet of the people. Rice is rich in carbohydrate. The protein content is about 8.5 percent. The thiamin and riboflavin contents are 0.27 and 0.12 micrograms, respectively (Bhuiyan *et al.*,2002). In Bangladesh, food security has been and will remain a major concern because food requirement is increasing at an alarming rate due to increasing population. Projected supply and demand balance showed that the country will require 34-35 million tons of food grain by the year 2020 while the supply would be 27-33 million tons (Shahabuddin *et al*., 1999). Rice yield, in general, is comparatively lower than that of other South East Asian countries because of poor fertilizer management. Micronutrients are as important as the primary and secondary nutrients in plant nutrition. However, the amounts of micronutrients required for optimum nutrition are much lower. Micronutrient deficiency is considered one of the major causes of declining the productivity trends in rice growing countries. The availability of micronutrients in soils depends on the solubility of micronutrients, the pH and redox potential of the soil solution and nature of binding sites on the organic and inorganic particle surfaces. Soil fertility is an important factor, which determines the growth of plants. Soil fertility is determined by the presence or absence of macro and micronutrients, which are required in minute quantities for plant growth. Micronutrients also enhance plant productivity; leaf area and grain yield as well as enhance the enzymatic system of plants.

Zinc plays an important role in different metabolic processes in plant. Zinc is classified as micronutrient but Zn deficiency is third most important nutritional factor after nitrogen and phosphorus limiting the growth of rice. Zinc deficiency occurs in soils of Gangetic alluvium. As long as 70 years ago, zinc was recognized as essential micronutrient (Sommer and Lipman, 1926). Since then, numerous studies have indicated that zinc deficiency is a serious nutritional problem for upland crops.

Boron as an important mineral nutrient stimulates a number of physiological processes in vascular plants. It is important for carbohydrate metabolism, translocation and development of cell wall and RNA metabolism (Herrera-Rodriguez *et al*. 2010 Siddiky *et al.* 2007; Marschner, 1995). Boron has been found to play a key role in pollen germination and pollen tube growth, stimulation of plasma membrane, anther development, floret fertility and seed development (Wang *et al*. 2003; Oosterhuis, 2001). Deficiency of B causes reduction in leaf photosynthetic rate, total dry matter production, plant height and number of reproductive structures during squaring and fruiting stage (Zhao and Oosterhuis, 2003). Boron fertilization increases 46.1% seed yield of rapeseed in light textured soils (Yang *et al*. 2009). Hussain ,(2006) reported significantly higher grain yield of rice with cumulative application as compared to direct and residual application of Zn and B in rice.

Keeping in view the important role of micronutrients in increasing crop grain yield, the present piece of research work was carried out -

•To evaluate , the individual effect of Zinc & Boron on the yield and growth of T.Aman rice.

•To evaluate the suitable dose of Zinc & Boron for better yield and growth of T.Aman rice.

•To investigate, the interaction effect of Zinc & Boron on T.Aman rice.

CHAPTER 2

Review of Literature

Rice has wide adaptability to different environmental conditions, as it is evident from its worldwide distribution. In Bangladesh, Transplanted aman rice grown in the area where the depth of water does not usually exceed 0.5m. Yield and growth of rice are determined by the morphological parameters such as plant height, number of effective tiller, number of spikelet per panicle, percentage filled grain and spikelet weight as well as by environmental factors. 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. With regards to nutrient use, their source rate and methods of application have been attended. This section is divided in to three subsections with regards to Zn and B. This subsection begins with a short description about occurrence, form and function of the nutrient elements. However, the available literature, related to the topic has been presented below.

2.1 Effect of Zinc on Rice

Chitdeshwari *et al.,* (2005) found that the indirect effect of water soluble + exchangeable and complexed Zn fractions through its association with occluded form was found to be positive and significant in rice yield.

Ghatak *et al*., (2005) showed that application of 30 kg $ZnSO_4$ ha^{-1} recorded the highest values of yield attributes of rice.

Rajput *et al.*, (2005) showed that the recommended rate of fertilizer along with 25 kg ha^{-1} of zinc sulphate gave the highest grain yield of rice 50.5 q ha^{-1}.

Singh *et al.*, (2005) suggested that magnesium can be beneficial, in addition to zinc, in alkali soil.

Slaton *et al*., (2005) found that Zn treatments included Zn solutions sprayed at 104-1.2 kg Zn ha^{-1} and dry granular Zn fertilizers broadcasted at 11.2 kg Zn ha^{-1}. Zn fertilizer source, averaged across application times, significantly affected grain yield at all sites, with Zn fertilizer application increasing yields by 12-180 g compared with untreated control in rice.

Das *et al.*, (2004) showed that the amount of Zn content in and uptake by grain (17.6 mg kg^{-1} and 85.6 g ha^{-1}) and straw (17.0 mg kg^{-1} and 123.4 g ha^{-1}) were increased significantly in the treatment F_3 where twice foliar application of Zn as Zn-EDTA at 0.058 g was made with the simultaneously highest increase in grain (4.9 t ha^{-1}) and straw (7.2 t ha^{-1}), respectively, compared to foliar applications of same levels of Zn as $ZnSO_4$ being 16.0 and 38.8 g increase in the yield of grain and straw, respectively, over that of the control, no application of Zn. The result also clearly indicated that the yield of both grain and straw due to foliar application of Zn either in the form of Zn-EDTA or $ZnSO_4$ were significantly correlated with the Zn uptake by grain and straw, being more significant with Zn-EDTA application. The grain yield VS. Zn content in grain showed a significant positive correlation, suggesting an important role of Zn towards contributing the yield of rice.

Jha *et al.*, (2004) found in calcareous soil, the recommended level of zinc as $ZnSO_4$ (5 kg ha^{-1}) for paddy was favorable for ARA of autochthonous cyanobacteria.

Bhat *et al*., (2002) carried out a field experiment to study the efficiency of various cultural management practices for improving the yield attributing characters and grain yield of rice. Treatment comprised a control; recommended fertilizer dose (RFD; 80:45:20:P_2O_5: K_2O kg) with 20 x 10 cm spacing; RFD+15 kg with 20x10cm spacing; 15% RFD with 15x15 cm spacing; local practice (60:40:P_2O_5:K_2O) with random spacing; and RFD with random spacing. The results of two years study revealed that application of 15 kg $ZnSO_4$ in addition with optimum plant population (4.4 lacs ha) proved significantly superior to the other treatment combinations. The yield advantage obtained by applying $ZnSO_4$ with RFD was 22.7% over RFD alone and 12% over RFD+10 t FYM ha Mean maximum panicle weight were also recorded with the application of $ZnSO_4$ + RFD which led to higher grain yield of the crop.

Lora *et al.*, (2002) conducted an experiment determine the effect of Zn application (at 0,8,16,24 and 32 kg ZnO ha^{-1}) on yield and quality of 3 rice cultivars. Observations were recorded for yield, tiller number per plant, plant height, number of grain per panicle, 1000-seed weight and milling quality. Foliar, soil and benefit: cost analysis was also performed. The best effect on yield was observed at 16 kg Zn/ha for R-1, Selecta and Tailandia I II. A significant effect on number of grain per panicle and seed weight was also observed.

Mythili *et al*., (2002) conducted a greenhouse experiment on two Zn deficient soils using rice as a test crop to study the effect of green manure on the relative efficiency of applied Zn. Radio-tracer viz., ^{65}Zn was tagged to two sources of Zn ($ZnSO_4$ and EDTA-Zn at kg

Zn ha^{-1}) to determine the contribution of fertilizer sources. Incorporation of *Sesbania aculeata* at 10 t ha^{-1} could contribute approximately 64, 4, 42, 0.6 and 11 kg of N, P, K, Zn and S ha^{-1}, respectively. The beneficial effect of integrated use of green manure (GM) with inorganic fertilizer nutrients particularly, $ZnSO_4$ in clay loam and EDTA-Zn in sandy loam soil was evident due to higher uptake and increased dry matter yield obtained at harvest. NPK+GM+$ZnSO_4$ + gypsum application recorded the highest grain, straw and root yields in both the soils.

Prasad *et al*., (2002) conducted a field experiment I Bihar, India for five years to study the optimal frequency of zinc fertilizer application on zinc deficient in the rice-wheat cropping system. The treatments were soil and foliar application of zinc sulphate at different doses. The results indicated that the pooled yield of rice was higher than that of wheat grain. The frequency of zinc application, based on 10 cropping systems, indicated that the use of 15 kg zinc sulphate ha^{-1} as soil application after a two-crop interval was found to be optimal. The rates of increase in yields of rice and wheat were 52.4 and 21.0 kg per kg of zinc sulphate, respectively and the percent increase in yield of rice was 46.6 and in wheat 38.1. The rice and wheat yields in the cropping system were significantly correlated with zinc removal.

Singh *et al*., (2002) conducted a field experiment at the North Eastern Hill 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 zinc fertilizers increased the yield of rice in wetland soils of Meghalaya. The results further indicate that only a fraction of total quality of applied Zn could be utilized by rice plants. The availability of residual Zn for the next crop was also very low.

Slaton *et al.,* (2002) reported that zinc is the most growth and yield omitting micronutrient in US rice production. They conducted two field Studies to evaluate several dry, granular and liquid AZn sources applied at pre-plant incorporated) PPI), pre-emergence (PRE) 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 acre^{-1} produced high yields across all application time. Application of dry granular Zn sources performed the best when applied at either PPI or PRE

Vasudeva and **Ananthanarayan**a (2001) conducted a field experiment in India to investigate the effect of added Zn based on zinc adsorption maxima on paddy rice yield and nutrient dynamics in acid soils (Ultic Paleustalf). The treatments comprised different levels (0,2.5,10,20 and 40 kg which correspond to 0, 0.22, 0.55, 1.10, 1.65 and 2.20% of zinc adsorption maxima) and sources of zinc (and ZnO) along with recommended dose of farmyard manure (5 tons) and fertilizers N, P_2O_5 and K_2O(75:75:90). Results showed that the paddy rice responded well with zinc application at 20 gm in acid soils which gave a maximum grain yield of 7002 kg. With regards of zinc source, the plants, which received as ZnO showed lower yield compared to zinc.

Verma *et al.*, (2001) carried out a field experiment at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India where three levels of zinc sulphate (0, 20, and 40 kg)were tested in paddy grown after paddy nursery. The results indicate that the use did not have significant effect in grain yield and yield attributes in rice particularly grown after rice nursery in which nursery was fertilized at 25 kg.

Herawati *et al.*, (2000) stated that zinc concentrations were the highest in rice grown in Histosols (27.4 µg g^{-1}). The amount of cadmium, copper and zinc in rice were not correlated with the content of these metals in soil, but the presence of these metals in soil was correlated with each other.

Tunga and **Nayak** (2000) carried out a field study in West Bengal in 1997 at wet season, 4 high yielding rice cultivars were given 5 fertilizers treatments, comprising 4 NPK rates plus the highest NPK rate with Zn. Grain yield raised from 3.99 t ha^{-1} in cv. MW 10 ton 5.48 in MPH 504. Yield was 2.63 t ha^{-1} without NPK and increased significantly up to 5.03 t with 90:45:45 kg NPK ha^{-1}.Higher NPK application and 30 kg $ZnSO_4$ ha^{-1} did not significantly affect the grain yield.

Usha *et al.*, (2000) conducted an experiment in Kerala, India in 1997 to study the effect of micronutrients on sustainable rice yields with application of Zn and Cu (5 and 10 kg ha^{-1}). Treatments did not significantly affect grain yield during the first and second cropping seasons of 1998 while it was significant in both seasons in 1999. The highest yield was obtained with 100% NPK and farm yard manure at 5 t ha^{-1} while $ZnSO_4$ and $CuSO_4$ was lower in all the cropping seasons.

Ahmed and **Hossain** (1999) conducted a field experiment of wheat mungbean-rice cropping sequence that application of Zn along with NPKS increased rice yield.

Li *et al.,* (1999) observed in hydroponic and field experiments that rice yield was significantly increase and rice quality was improved by zinc fertilizer application.

Sharma *et al*., (1999) conducted a field experiment in 1994/95 and 1995/96 at Hanumangarh, Rajasthan, India, rice cv. Java and PR 106 given 0, 12, 24, or 36 kg $ZnSO_4$ ha^{-1} at 30 or 45 days after transplanting. Yields increased with increasing rates of Zn application, with 36 kg Zn giving the highest yield followed by 2 sprayings.

Chitdeshwari and **Krishnasamy** (1998) studied the effect of different levels of zinc and zinc enriched organic manures on the availability of micronutrients under submergence in zinc deficient rice soils. The application of 2.5 mg Zn kg^{-1} enriched with farmyard manure + leaf manure increased the Zn status at all stages of crop growth.

Haloi (1998) studied the effect of foliar sprays of four growth promoters (Brassin [brassinolide], Prithvi, Falan and Zinc phenolic) on rice cv. IET 10016 and Ranjit and observed the Brassin and Prithvi accelerated vegetative growth, while Zinc phenolic and Falan promoted reproductive components of the crop. Falan significantly improved harvest index. Grain yield increases over controls varied from 19.0% to 40.2% depending on the dose of growth promoter.

Patra and **Poi** (1998) applied different forms of trace elements to rice cv IET5656 and IET-S141 in trace element deficient soil at Majdia, North Bengal, India. They reported that the best result (grain yield 2.39 t ha^{-1}) was obtained with foliar application of 500 g chelated Zn ha^{-1} followed by foliar application of Zn + B +M_0 mixture + organic manures (grain yield 2.36 t ha^{-1}).

Agarwal and **Suraj** (1997) conducted a field experiment at Kanpur in 1992-93 and 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 in Rice Research Institute of Yunnan Agricultural University, Kunming on soil low in zinc with rice cultivars Xunza 29, Hexi 35 and Yungeng 34 using 0 or 5 kg Zn ha^{-1}. They observed that application of Zn increased yields significantly especially in Hexi 35 and Yungeng 34. Grain amylase content of milled rice was increased by Zn application.

Ingle *et al.*, (1997) conducted a field trial at Sindewahi, Maharashtra, using rice cv. Sye-75 given 0, 5, 10 or 15 kg Zn ha^{-1} as $ZnSO_4$ or ZnO. They observed that grain yields was increased with increasing Zn rates but was not affected by sources of Zn.

Trivedi and **Verma** (1997) carried out field trials in the 1992 and 1993 seasons, rice cv. Java and BRII were given 0, 5, 11.2 or 16.8 kg Zn ha^{-1}. The experimental soil was low in DTPA extractable Zn (0.06 mg kg^{-1}) with pH of 7.9 crop yield and Zn uptake were increased by applied Zn, with quadratic relationships with application rate. Economic analysis indicated an optimum application rate of 11.9 kg Zn ha^{-1}.

Sakal *et al.,* (1996) reported that the continuous rice-wheat system with increasing NPK fertilizer applications is the cause of depleting soil available micronutrients reserve, particularly available Zn, leading to decline in crop productivity.

Arif *et al.,* (1996) conducted a field trial with rice (cv. Rio Paranaiba) using 0, 5, 10 or 29 kg Zn and 0, 0.5, 1.0 or 2.0 kg B. They observed that weed yield was not affected by the treatments, but the yields of whole grain were greatest with 10 kg Zn.

Devarajan and **Krishnasamy** (1996) conducted a pot experiment with rice cv. ADT-36 was given the NPK with 0, 1.25, 2, 5, 3.75 or 5.0 ppm Zn as or Zn enriched organic manure. They observed that grain yield was highest with FYM composted with 2.5 ppm Zn+ green manure.

Khanda and **Dixit** (1996) conducted a field experiment at Bhubaneshwar, Orissa during summer 1991 and 1992 with 2 sources of zinc ($ZnSO_4$ and Zn EDTA) and reported that application of Zn significantly increased the grain and straw yields over the plots without zinc application. They stated that the combined application of N and Zn increased the grain yield by 7.0% and straw yield by 12.9% over sole N.

Kumar and **Singh** (1996) reported that dipping the seedlings in 2% $ZnSO_4$ solution gave higher yield (5.15 t ha^{-1}) almost similar to the application of 25 kg $ZnSO_4$ compared to control.

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

Ugurluoglu and **Kacar** (1996) carried out a greenhouse experiment; rice was grown on soils from different rice growing areas of Turkey, and given 0, 2, 4 or 8 ppm Zn as ZnO,

$ZnSO_4$, H_2O or Zn-EDTA compared with the control. They found that the greatest increase in dry matter was obtained with ZnO on the corum soil.

2.2 Effect of Boron on Rice

Boron deficiency in crops is more widespread than the deficiency of any other micronutrient in the world. Adequate B nutrition is critical not only for high yields but also for high quality crops, Boron has many physiological functions in plants such as sugar transport, cell wall synthesis, reproduction, pollen tube growth, pollen germination, lignifications, carbohydrate metabolism, RNA metabolism, membrane integrity, ascorbate metabolism, respiration, indole acetic acid metabolism (IAA), phenol metabolism, and oxygen activation.

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 B 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 B produced significantly greater yields than rice with foliar-applied B and rice with no B applied. In 1999 and 2001, there was no significant difference between yields obtained with foliar or soil B applications.

Singh *et al*., (1990) conducted a field trials during the rainy seasons of 1987-88 at Barapani, Meghalaya to see the effects of three, six or nine kg Zn ha^{-1}, 1.5 kg B ha^{-1}or application of Zn+B on yield of rain fed of submerged rice (cv.Ngoba). Zinc and boron application increased rice yield compared with the untreated control. The increase in yield due to be application was 31% higher under submerged than rain fed conditions. The highest grain yield of 3.66 t ha^{-1} and straw yield of 4.81t ha^{-1} was obtained from application of B under submerged conditions.

Mondal *et al*., (1992) conducted missing element trials to investigate the nutrient requirements for BR-11 rice in Sonatala silt loam soils at Bangladesh Agricultural University farm in the T-aman season of 1990. They observed a significant response of the crop to N P K S Zn and B. Further they noted that unlike their elements, Cu and Mo did not have positive effects on rice yield.

CHAPTER 3
MATERIALS AND METHODS

This chapter presents a brief description about the work which is related to the experiment. It represents a brief description about the experimental site, soil, climate, crops, treatments, experimental design followed, land preparation, seedling transplanting, intercultural operations, harvesting, data recording, collection and statistical analysis.

3.1 Experimental Site and Season

The experiment was laid out in the Red-terrace soil of Sher-e-Bangla Agricultural University (SAU) farm, situated at Sher-e-Bangla Nagar, Dhaka. This soil belongs to the Modhupur tract (AEZ 28). The selected plot was medium high land and soil series was Tejgaon series. The soil characteristics were silt loam in texture with value pH 5.6. The site of the experimental plot is in the $23^{0}74^{'}$ latitude and 90^{0} 35’ longitudes with an elevation of 8.2 m above sea level.

3.2 Climate

The climate of the experimental area is characterized by sub-tropical accompanied by bright sunshine associated with moderately high temperature and sometimes heavy rainfall during Aman season (May-December). The weather conditions of crop growth period such as monthly mean rainfall (mm), mean temperature (^{o}C), sunshine hours and humidity (%) are presented in Appendices 3.

3.3 Plant Materials

One modern rice variety BRRI dhan 34 was tested as test crop. The life cycle of this variety ranges from 135 to 142 days. Seed of this variety was collected from Breeding Division of Bangladesh Rice Research Institute (BRRI).

3.4 Treatments

There were Zinc and Boron at four and three levels respectively. The experimental treatments were as follows:

Factor-A: Zn ($Zn_{0,}$ $Zn_{1,}$ Zn_2 and Zn_3 kg ha^{-1})

Factor-B: B ($B_{0,}$ B_1 and B_2 kg ha^{-1})

Treatment Combinations:

T_1	:	Zn_0B_0
T_2	:	Zn_0B_1
T_3	:	Zn_0 B_2
T_4	:	$Zn_{1.}B_0$
T_5	:	Zn_1B_1
T_6	:	Zn_1B_2
T_7	:	Zn_2B_0
T_8	:	Zn_2B_1
T_9	:	Zn_2B_2
T_{10}	:	Zn_3B_0
T_{11}	:	Zn_3B_1
T_{12}	:	Zn_3B_2

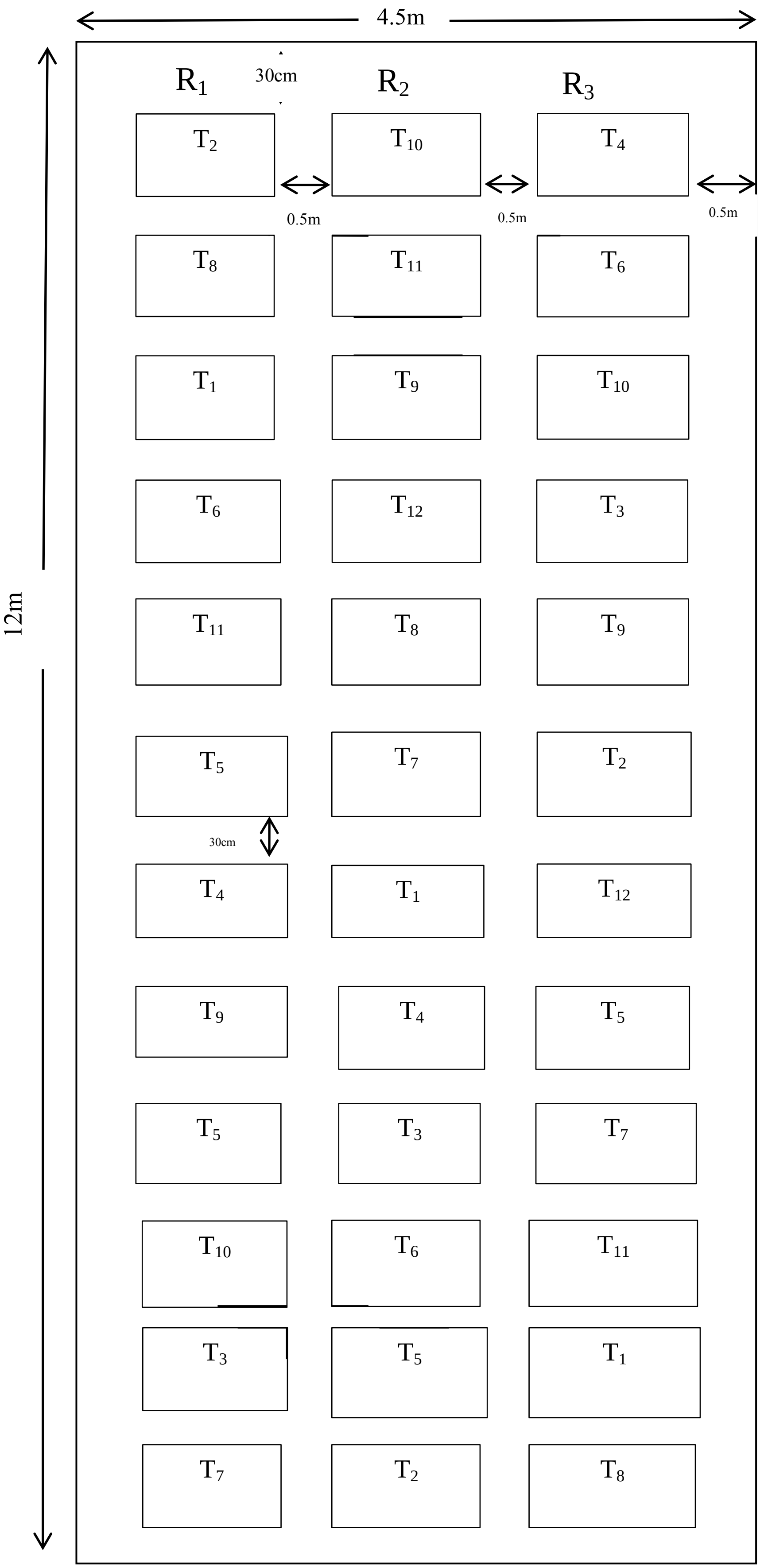
Every treatment received N, P and K as basal doses. The rates and sources of nutrients used in the study are given in Table-1:

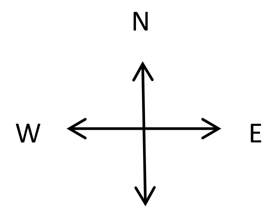
Table-1: Name of the Element, rate (kg ha^{-1}) and name of the fertilizers used for the experiment

Name of the Element	Rate (kg ha^{-1})	Name of the Fertilizer
N	120	Urea
P	20	Triple Super Phosphate(TSP)
K	60	Muriate of Potash(MoP)
Zn	0, 1.0, 2.0, 3.0	Gypsum
B	0, 1.0, 2.0	Boric acid

3.5 Experimental Design and Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications whereas nitrogen was in the main plot and spacing in sub-plot. The size of the unit plot was 3.0 m x 1.8 m. Total plots in the experiment field were 36. The treatments were randomly distributed to each block.





Plant to plant distance: (50cm) 0.5 m

Row to row distance: (50cm) 0.5 m

Distance between replications: (50 cm) 0.5m

Distance between treatments: (30cm) 0.3m

Length: 12m; Width: 4.5m

Total Area: 54 m^2

Factor-A: Zn (Zn_0, Zn_1, Zn_2 and Zn_3 kg ha^{-1})

Factor-B: B (B_0, B_1 and B_2 kg ha^{-1})

Replications:

R_1: Replicaiton 1

R_2: Replicaiton 2

R_3: Replicaiton 3

Treatment Combinations:

T_1	:	Zn_0B_0
T_2	:	Zn_0B_1
T_3	:	Zn_0 B_2
T_4	:	$Zn_{1.}B_0$
T_5	:	Zn_1B_1
T_6	:	Zn_1B_2
T_7	:	Zn_2B_0
T_8	:	Zn_2B_1
T_9	:	Zn_2B_2
T_{10}	:	Zn_3B_0
T_{11}	:	Zn_3B_1
T_{12}	:	Zn_3B_2

Figure 1: Layout of experimental plot

3.6 Land Preparation

Land preparation was completed on July 24, 2013. The land was prepared by repeated ploughing and cross ploughing followed by laddering. After uniformly leveling and puddling, the experimental plots were laid out as per treatments and design of the experiment.

3.7 Seedling Raising

A well puddled land was selected for seedling raising. The sprouted seeds were sown uniformly on July 4, 2013 and covered with a thin layer of fine earth. Proper care for the seedlings was taken in the nursery.

3.8 Fertilizer Application

All the fertilizers except Urea full were added to the soil during final land preparation. Urea was applied in three splits. The first split half of total amount of Urea was applied on July 24, 2013 with final land preparation. The second split on August 13, 2013, 18 days after transplanting and third split on August 25, 2013, 30 days after transplanting. The fertilizers were mixed thoroughly with the soil (Table 2).

3.9 Transplanting of seedling

Twenty two days old seedlings were uprooted carefully from the seedbed and transplanted in the experimental plots on July 26, 2013. Two to three seedlings were transplanted in each hill.

3.10 Intercultural Operations

Intercultural operations were done for ensuring and maintaining the normal growth of the crop. The detailed intercultural operations were recorded in the Table 2. The following intercultural operations were done as and when required.

3.11 Irrigation

After transplanting 5-6 cm water was maintained in each plot through irrigation during the growth period.

3.12 Weeding

The crop was infested with some common weeds, which were controlled by uprooting and removing them three times from the field during the period of experiment. Weeding was done after 18, 30, and 43 days of transplanting (Table 2).

3.13 Diseases and Insect Pest Control

There were some incidence in insects specially grasshopper, rice stem borer, rice ear cutting caterpillar, thrips and rice bugs which were controlled by spraying Sumithion 50 EC and topdressing of Basudin 10 G. Narrow brown spot of rice was controlled by spraying Tilt.

3.14 Harvesting and Threshing

The crop was harvested plot wise at maturity on December 02, 2013. The harvested crop of each plot was bundled separately and brought to the threshing floor. The harvested crops were threshed, cleaned and processed. Grain and straw yield were recorded plot wise and moisture of straw was calculated on oven dry basis. Grain and straw yields were converted into t ha^{-1}.

Table-2: Dates of different operations done during the field study

Operations	Working Dates
First ploughing of the field	July 05, 2013
Second ploughing of the field	July 15, 2013
Final ploughing of the field	July 24, 2013
Application of fertilizers (Urea-1st split, TSP, MP, Gypsun, Boric Acid)	July 24, 2013
Transplanting of seedlings	July 26, 2013
Intercultural Operations	**Working Dates**
Second split application of urea and First weeding	August 13, 2013
Third split application of urea and Second weeding	August 25, 2013
Third Weeding	September 07, 2013
Insecticides application	October 21, 2013 to November 05, 2013
Harvesting and threshing	December 2, 2013 to December 4, 2013

Figure 2: Before harvesting

3.15 Data Collection and Recording

Six hills were selected randomly from each unit plot prior to harvest for recording data on crop parameters and the yield of grain and straw were taken plot wise

The following parameters were recorded at harvest:

- Plant height (cm)
- No. of effective tiller/plant
- No. of non-effective tiller/plant
- Panicle length(cm)
- No. of grain / panicle
- Number of grains $panicle^{-1}$
- Weight of 1000 grains (g)
- Grain and straw yields ($t\ ha^{-1}$)
- Biological Yield ($t\ ha^{-1}$)
- Soil sample from each plot (post-harvest)

3.15.1 Data Collection

Data on following parameters were collected on average of considering five plants or panicles.

3.15.1.1 Plant Height

Plant height was measured from the base of the plant to the tip of the tallest panicle. The heights of five plants were measured with a meter scale and the mean height was expressed in cm.

3.15.1.2 Number of effective tillers hill^{-1}

The panicle that had at least one grain was considered as bearing tillers from preselected five plants. After that it was averaged and expressed as number of effective tillers hill^{-1}.

3.15.1.3 Number of non-effective tillers hill^{-1}

Number of non-effective tillers hill^{-1} was calculated as like number of effective tillers hill^{-1}.

3.15.1.4 Panicle Length

Panicle Length was measured from the basal node of rachis to the tip of the panicle.

3.15.1.5 Number of grains panicle^{-1}

Number of grains panicle^{-1} was counted obtained from preselected five plants. After that it was averaged and expressed as number of grain spike^{-1}

3.15.1.6 Weight of 1000 grains (g)

One thousand grain was counted from the seeds obtained from the samples plants and weighed by using an electric balance.

3.15.1.7 Grain and straw yields ha^{-1} ($t\ ha^{-1}$)

After harvesting of the crop, grain yield of each unit plot was dried and weighed. The result was expressed as kg ha^{-1} on 14% moisture basis. After harvesting of the crop, straw yields obtained from each unit plot were dried and weighed carefully. The results were expressed as kg ha^{-1} and expressed on oven dry basis.

3.15.1.8 Biological Yield ($t\ ha^{-1}$)

Biological yield was calculated from addition of grain yield and straw yield.

3.15.1.9 Harvest Index (%)

The harvest index (HI) was calculated by dividing the actual yield of seeds by the biological yield of the crop. It was expressed as percentage.

$$\text{Harvest Index} = \frac{\text{Seed Yield } (t\ ha^{-1})}{\text{Biological Yield } (t\ ha^{-1})} \times 100$$

3.16 Collection of Samples

3.16.1 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 December 6, 2013. The samples were air-dried, grounded and sieved through a 2 mm sieve and preserved for analysis.

3.17 Soil Sample Analysis

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

Table 3. Physical and chemical properties of the initial soil sample

Characteristics	Value
Particle size analysis	
% Sand	30
% Silt	40
% Clay	30
Textural class	Clay loam
Consistency	Granular and friable when dry
pH	5.6
Bulk Density (g/cc)	1.45
Particle Density (g/cc)	2.53
Organic carbon (%)	0.67
Organic matter (%)	1.15
Total N (%)	0.06
Available P (ppm)	20.0
Exchangeable K (meq/100g soil)	0.12

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

3.17.1 Particle Size Analysis

Particle size analysis of soil sample was done by hydrometer method. The textural class ascertained using USDA textural triangle.

3.17.2 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).

3.17.3 Organic Carbon

Organic carbon of the soil was determined by wet oxidation method described by Walkley and Black (1934). To obtain organic matter content, the amount of organic carbon was multiplied by the van Bemmelen factor of 1.73. The result was expressed on percentage.

3.17.4 Organic Matter

The Organic Matter content was determined by multiplying the percent organic carbon with Van Bemmelen factor 1.73.

3.17.5 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 ($K_2SO_{4:}$ $CuSO_{4,}$ 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.

3.17.6 Available Phosphorous

Available phosphorous was extracted from the soil by shaking with 0.5 $MNaCO_3$ 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 mm wave length by spectrophotometer and available P was calculated with the help of a standard curve.

3.17.7 Exchangeable Potassium

Exchangeable Potassium in the soil sample was extracted with 1N neutral ammonium acetate (NH_4OAc) and the potassium content was determined by flame photometer (Black. 1965).

3.18 Statistical Analysis

The data were analyzed statistically by F-test to examine whether treatment effects were significant (Gomez and Gomez, 1984). The mean comparisons for the treatments were evaluated by LSD test. The software package, MSTATC was followed for statistical analysis.

CHAPTER 4

RESULTS AND DISCUSSION

The results of the experiment conducted under field conditions are presented in several Tables and Figures. The experiment was conducted to study the effect 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 Effect of Zinc

4.1.1 Plant Height

The application of different level of Zn has a significant effect on plant height. Plant height increased gradually with the increase rates of Zn. The tallest plant (142.40 cm) was found due to application of 3 kg Zn ha^{-1} (Table 4). The shortest plant height (135.90 cm) was found in the treatment 0 kg Zn ha^{-1}. Ahmed *et al.* (1986) found that application of Zn increases all the growth parameters of rice significantly.

Table 4. Effect of zinc on plant height, number of effective tillers $hill^{-1}$ and number of non-effective tillers $hill^{-1}$characteristics of BRRI dhan34

Treatments	Plant height (cm)	Number of effective tillers $hill^{-1}$	Number of non-effective tillers $hill^{-1}$
Zn_0	135.90 c	6.17 d	4.27 a
Zn_1	138.60 b	7.11 b	3.47 c
Zn_2	142.20 a	8.35 a	2.99 d
Zn_3	142.40 a	6.57 c	3.93 b
$LSD_{(0.05)}$	1.71	0.23	0.20
CV (%)	5.73	4.93	3.21

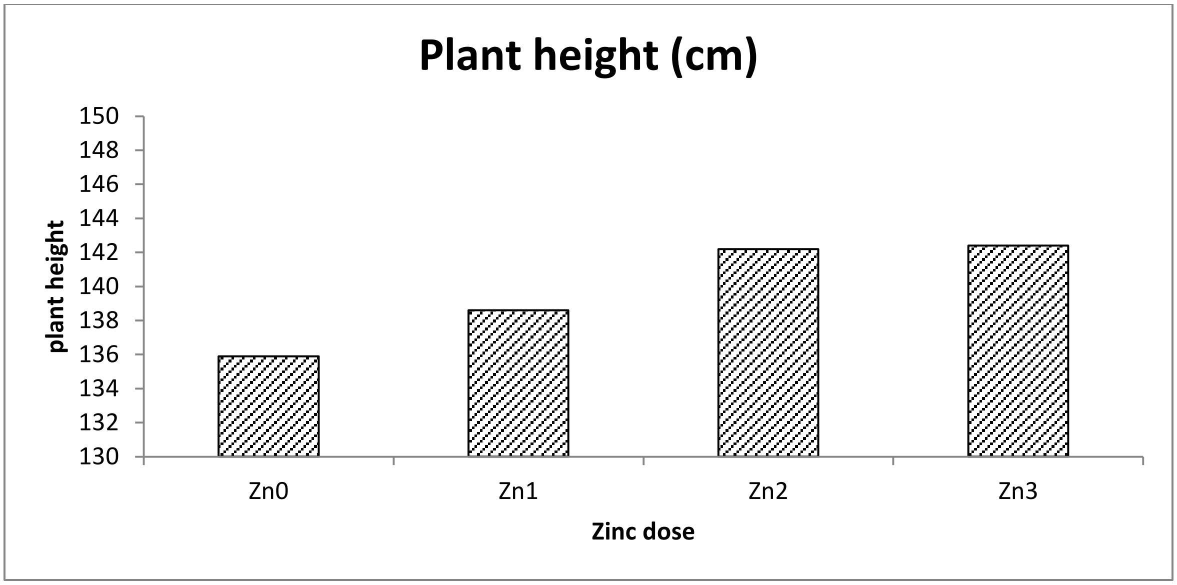


Figure 3: Effect of Zinc on plant height of BRRI dhan34

4.1.2 Number of effective tillers hill^{-1}

There was a significant effect of the treatments on number of effective tiller per hill (Table 4). Application of 2 kg Zn ha^{-1} produced the highest number of effective hill^{-1} (8.35). The lowest number of effective tillers hill^{-1} (6.17) was found in the Zn_0 treatment (Figure 4).

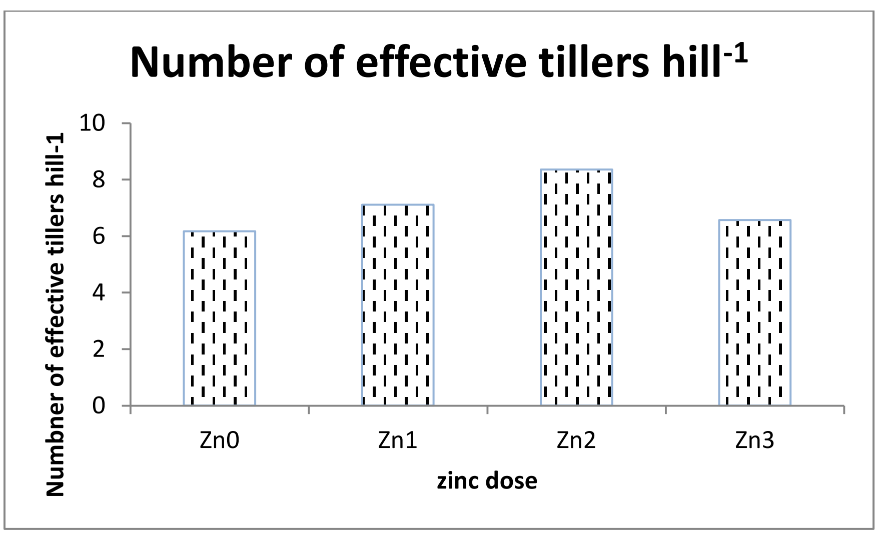


Figure 4: Effect of Zinc on Number of effective tillers hill^{-1}

4.1.3 Number of non-effective tillers $hill^{-1}$

It was observed that the variation due to different levels of Zinc was significant for non-effective tillers $hill^{-1}$ (Table 4). The highest number of non-effective tiller per hill (4.27) was found in Zn_0 treatment and lowest number of non-effective tiller per hill (2.99) was found in Zn_2 treatment (Figure 5).

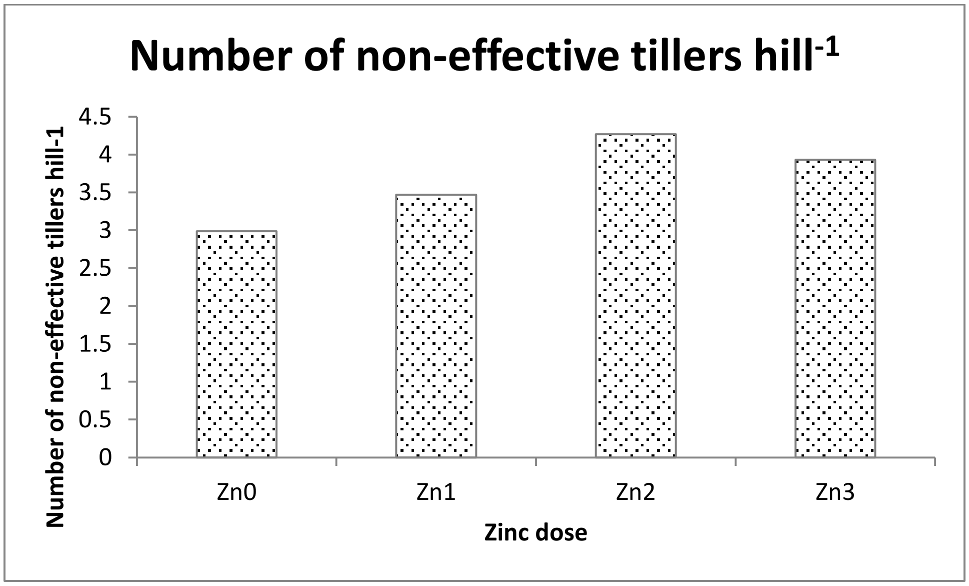


Figure 5: Effect of Zinc on Number of non-effective tillers $hill^{-1}$

4.1.4 Panicle length (cm)

The length of panicle was significantly affected by different levels of Zn (Table 5). The longest panicle (25.62 cm) was obtained from Zn_2 receiving 2 kg Zn ha^{-1} and the shortest (23.21 cm) was found in control treatment (Figure 6).

Table 5. Effect of zinc on Panicle length (cm), number of grains panicle^{-1} and 1000 grain weight (gm) of BRRI dhan 34

Treatments	Panicle length (cm)	Number of grains panicle^{-1}	1000 grain weight (gm)
Zn_0	23.21 c	123.80 c	30.09 d
Zn_1	24.60 b	126.60 c	32.38 b
Zn_2	25.62 a	148.60 a	33.80 a
Zn_3	24.42 b	142.90 b	31.29 c
$LSD_{(0.05)}$	0.37	3.04	0.37
CV (%)	4.89	7.33	4.70

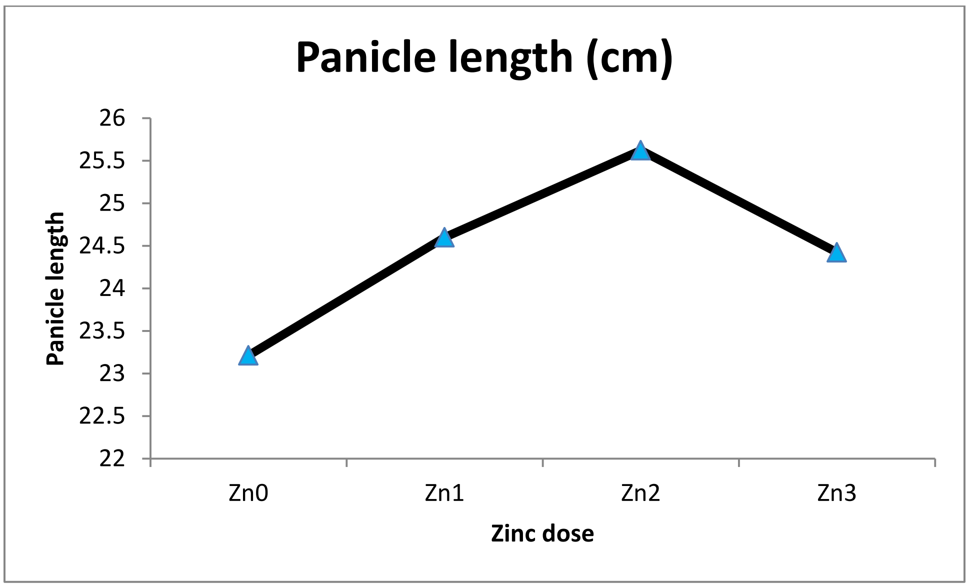


Figure 6: Effect of Zinc on Panicle length (cm)

4.1.5 Number of Grains Panicle^{-1}

Application of different levels of Zinc has a significant effect on the number of grains per panicle (Table 5). The results indicate that the highest number of grains panicle^{-1} (148.60) was obtained when 2kg Zn ha^{-1} was applied and the lowest (123.80) was found in Zn_0 treatment (control).

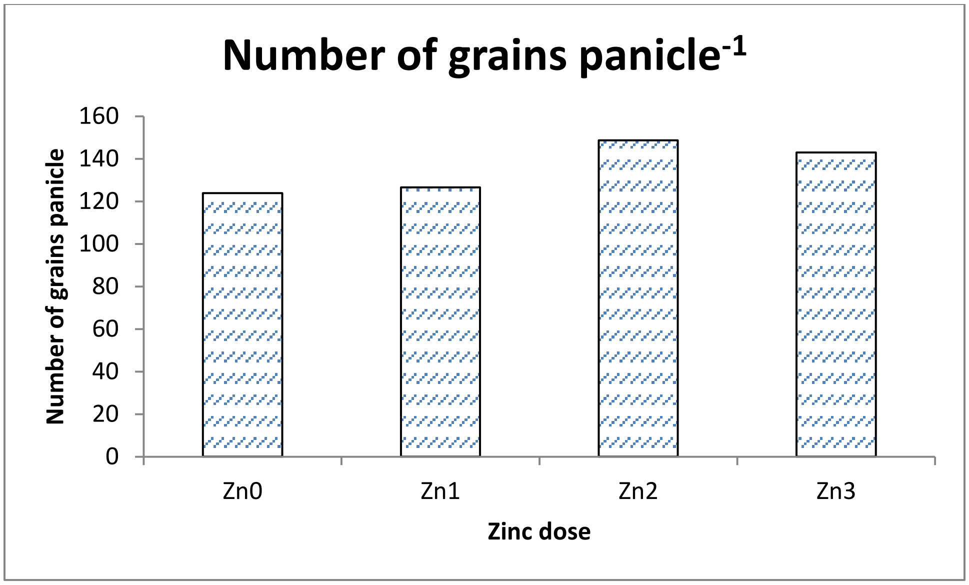


Figure 7: Effect of Zinc on Grain Panicle^{-1}

4.1.6 1000 grain weight (gm)

The application of different level of Zn has a significant influence on 1000 grain weight of BRRI dhan34 (Table 5). The highest 1000 grain weight (33.80 gm) was recorded in Zn_2 treatment receiving 2 kg Zn ha^{-1}. On the other hand, the lowest 1000 grain weight (30.09 gm) was found in Zn_0 treatment (figure 8).

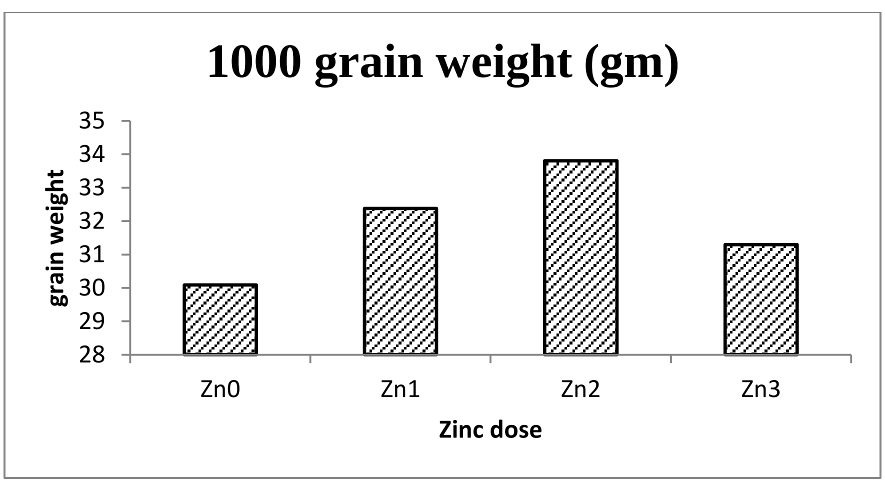


Figure 8: Effect of Zinc on 1000-grain weight (gm)

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

Grain yield of BRRI dhan34 was significantly influenced by the application of different levels of Zn (Table 6) Grain yield of rice varied from 4.99 to 6.38 t ha^{-1}. Maximum grain yield was found in Zn_2 treatment that receiving 2 kg Zn per ha and lowest grain yield was observed in Zn_0 treatment that receiving no Zn fertilizer (control).

Table 6. Effect of zinc on grain yield (t ha^{-1})**, straw yield** (t ha^{-1})**, biological yield ((**t ha^{-1}) **and harvest index (%) of BRRI dhan 34**

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Zn_0	4.99 d	7.15 b	12.14 d	41.08 d
Zn_1	6.18 b	7.34 b	13.51 c	45.72 a
Zn_2	6.38 a	8.00 a	14.38 a	44.36 b
Zn_3	5.88 c	7.85 a	13.73 b	42.66 c
$LSD_{(0.05)}$	0.09	0.23	2.21	1.07
CV (%)	4.94	4.80	4.91	4.15

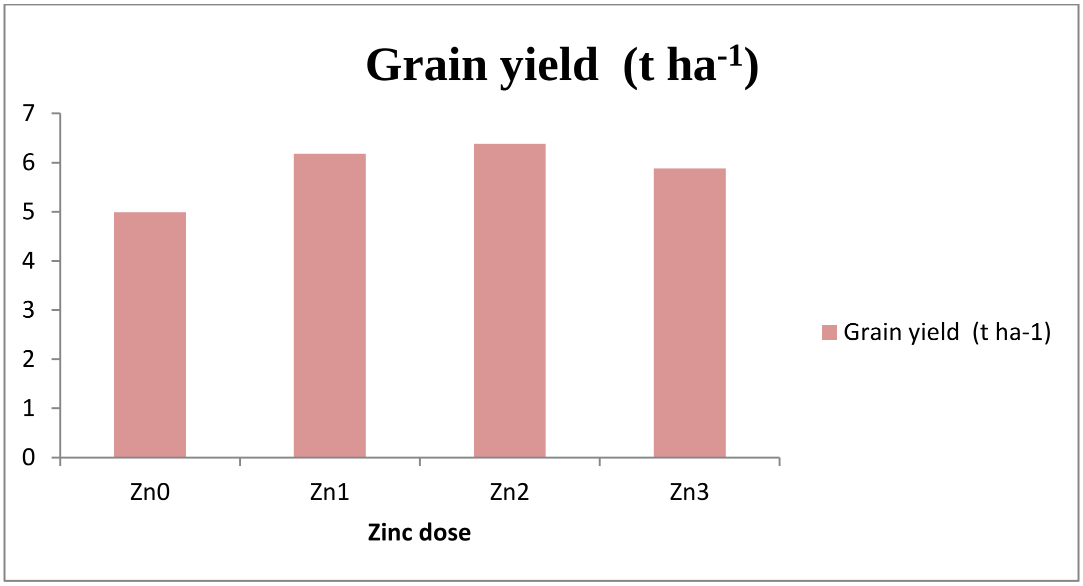


Figure 9: Effect of Zinc on Grain yield (t ha^{-1})

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

Application of different levels of Zn has significant effect on straw yield of BRRI dhan34 (Table 6). The straw yield ranged from 7.15 to 8.00 t ha^{-1}.The highest straw yield was recorded in the treatment of Zn_2 and the lowest straw yield was found in Zn_0 treatment receiving no Zn fertilizer.

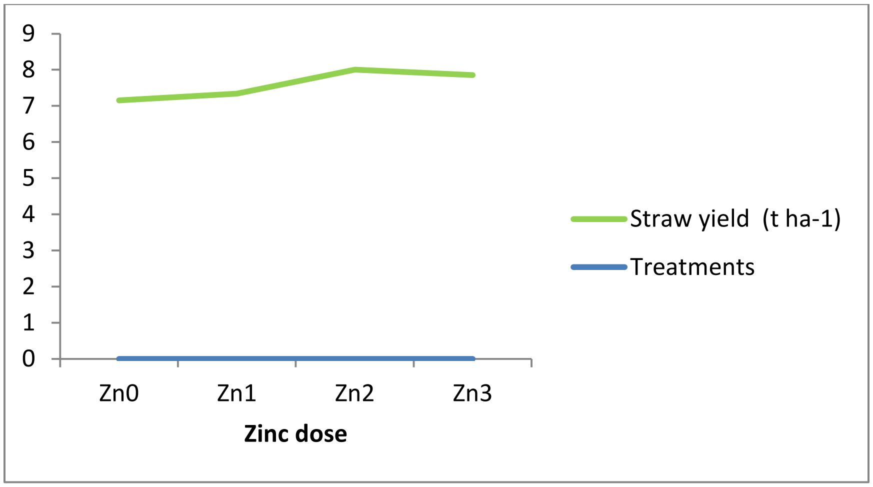


Figure 10: Effect of Zinc on Straw yield (t ha^{-1})

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

Application of Zn showed the significant variation on biological yield of BRRI dhan 34 (Table 6). The highest biological yield (14.38 t ha^{-1}) was recorded from Zn_2 treatment (2 kg Zn ha^{-1}). On the other hand, the lowest biological yield (12.14 t ha^{-1}) was found in Zn_0 treatment.

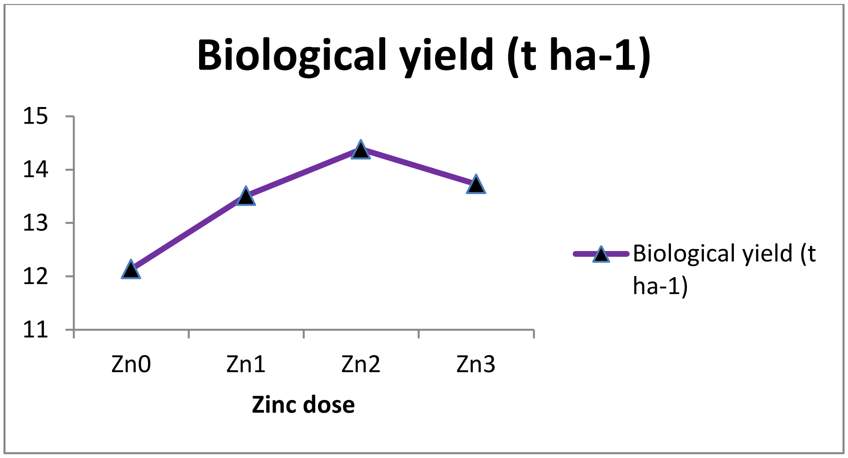


Figure 11: Effect of Zinc on Biological yield (t ha^{-1})

4.1.10 Harvest index (%)

Harvest index was significantly influenced by the application of Zn at different levels (Table 6). It was observed that, the highest harvest index (45.72 %) was recorded in Zn_1 treatment and the lowest harvest index (41.08 %) was found in Zn_0 the treatment (control).

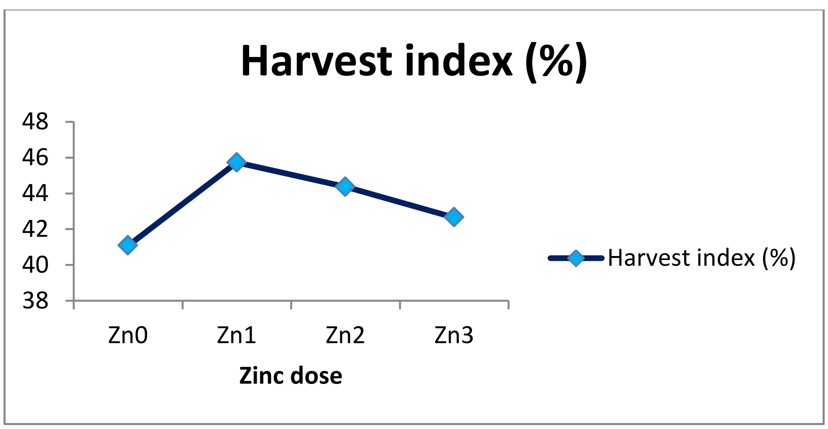


Figure 12: Effect of Zinc on Harvest index (%)

4.2 Effect of Boron

4.2.1 Plant height

The application of different levels of Boron has a significant effect on plant height. Plant height increased gradually with the increased rates of B. The tallest plant (142.60 cm) was found due to application of 2 kg B ha^{-1} (Table 7). The shortest plant height (135.70 cm) was found in the treatment 0 kg B ha^{-1}. Dunn *et al. (*2005).also reported the similar findings earlier.

Table 7. Effect of boron on plant height, number of effective tillers $hill^{-1}$ and number of non-effective tillers $hill^{-1}$ of BRRI dhan34

Treatments	Plant height (cm)	Number of effective tillers $hill^{-1}$	Number of non-effective tillers $hill^{-1}$
B_0	135.70 c	6.80 b	3.78 a
B_1	141.10 b	7.14 a	3.50 b
B_2	142.60 a	7.27 a	3.06 c
$LSD_{(0.05)}$	1.49	0.20	0.18
CV (%)	5.73	4.93	3.21

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

Boron has a significant effect on the number of effective tillers $hill^{-1}$ of BRRI dhan 34. The results showed that the highest effective tillers $hill^{-1}$ (7.27) was found in B_2 treatment receiving 2 kg B ha^{-1}, which was statistically similar with B_1 treatment.(Table 6). The lowest number of effective tiller $hill^{-1}$ (6.80) was found inB_0 treatment. Shorroeks(1974) also reported the similar findings earlier.

4.2.3Number of non-effective tillers $hill^{-1}$

Number of non-effective tiller was significantly influence by different levels of Boron (Table 7).The highest non effective tiller $hill^{-1}$ found in B_0 treatment that receiving no B fertilizer. On the other hand, the lowest number of non-effective tillers $hill^{-1}$ (3.06) was observed in B_2 treatment that receiving 2 kg B ha^{-1} (Figure 13)

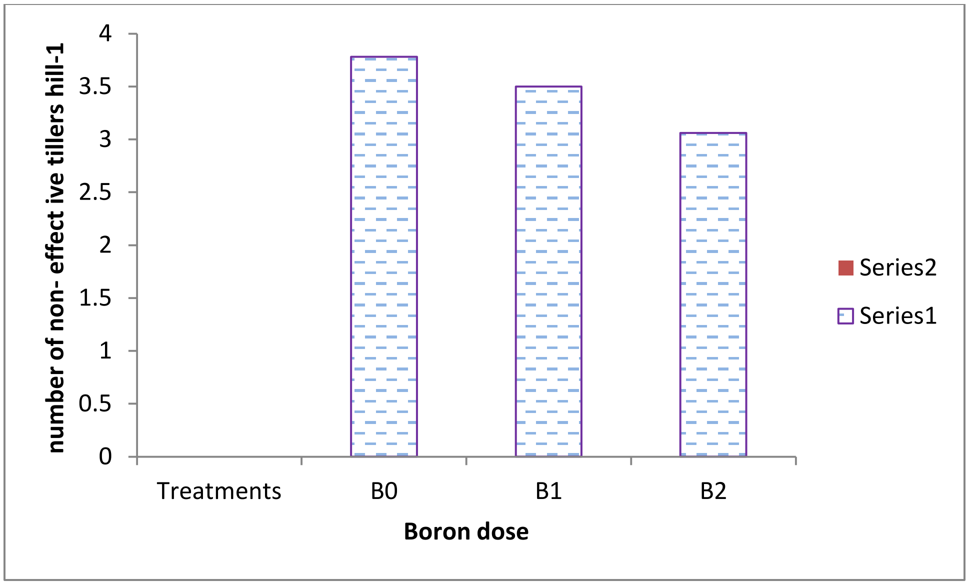


Figure 13: Effect of Boron on non-effective tillers hill^{-1}

4.2.4 Panicle length (cm)

The panicle length of BRRI dhan34 responded insignificantly to different levels of Boron (Table 8). The panicle length ranged from 24.77 cm to 24.15 cm. The results revealed that the longest panicle (24.77 cm) was produced by the application of 2 kg B ha^{-1}. The shortest panicle (24.15 cm) was obtained when no Boron was used (Figure 14).

Table 8 . Effect of boron on panicle length (cm), number of grains panicle^{-1} and 1000 grain weight (gm) of BRRI dhan 34

Treatments	Panicle length (cm)	Number of grains panicle^{-1}	1000 grain weight (g)
B_0	24.15 b	130.20 b	31.37 c
B_1	24.47 ab	136.90 a	31.78 b
B_2	24.77 a	139.30 a	32.52 a
$LSD_{(0.05)}$	0.32	2.63	0.32
CV (%)	4.89	7.33	4.70

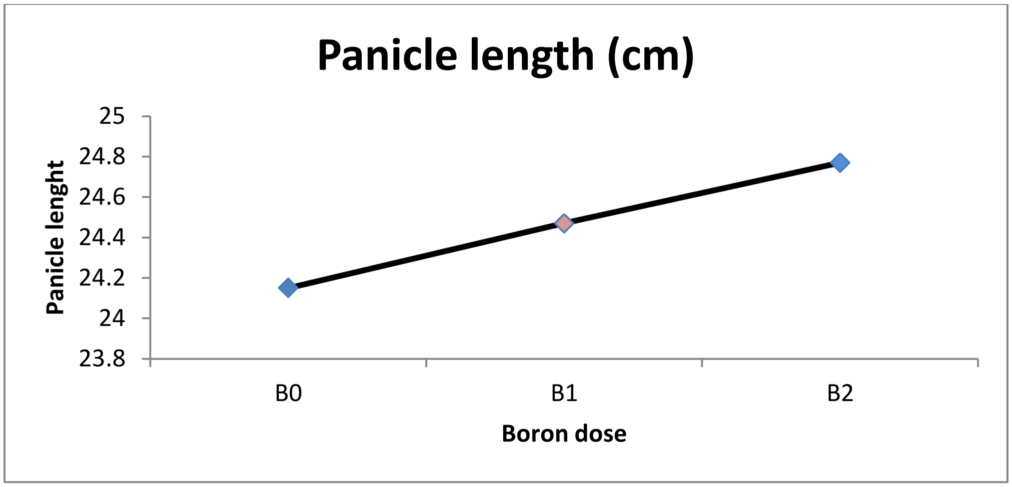


Figure 14: Effect of Boron on Panicle length (cm)

4.2.5 Number of Grain Panicle^{-1}

Application of Boron has significant effect on number of grain panicle $^{-1}$ of BRRI dhan 34 (Table 8). The number of grain panicle^{-1} was varied from 130.20 to 139.30. The highest number of grain panicle^{-1} (139.30) was obtained from B_2 treatment receiving 2 kg B ha-1 and the lowest number of grain panicle^{-1} (130.20) was observed in B_0 treatment with no boron fertilization (figure 15).

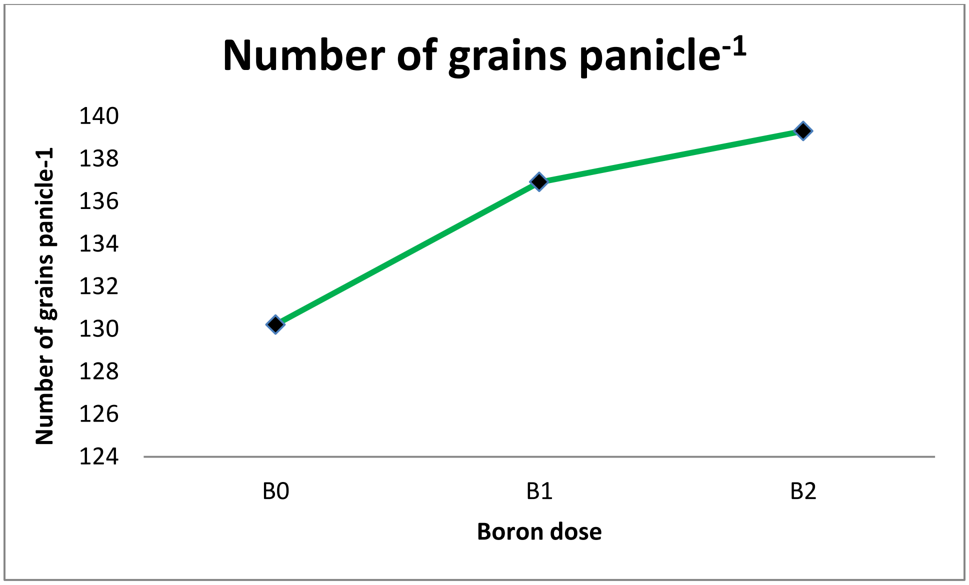


Figure 15: Effect of Boron on number of grain panicle^{-1}

4.2.6 1000-grain weight (g)

1000 grain weight of BRRI dhan34 was significantly influenced by the application of different levels of Boron (Table 8). 1000 grain weight of BRRI dhan 34 was varied from 31.37 to 32.52 gm. The highest 1000 grain weight (32.52 gm) was found in B_2 treatment (2 kg B ha^{-1}) and the lowest1000 grain weight (31.37 gm) was found in B_0 treatment. Islam (1978) reported that B application increased 1000 grain weight of rice significantly.

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

Grain yield of BRRI dhan 34 was significantly influence by the different levels of Boron application (Table 9). Grain yield of BRRI dhan 34 was ranged from 5.52 to 6.16 t ha^{-1}. The highest grain yield (6.16 t ha^{-1}) was observed in B_2 treatment that receiving 2 kg B ha^{-1}. The lowest grain yield (5.52 t ha^{-1}) was observed in B_0 treatment with no B fertilization. (Figure 16)

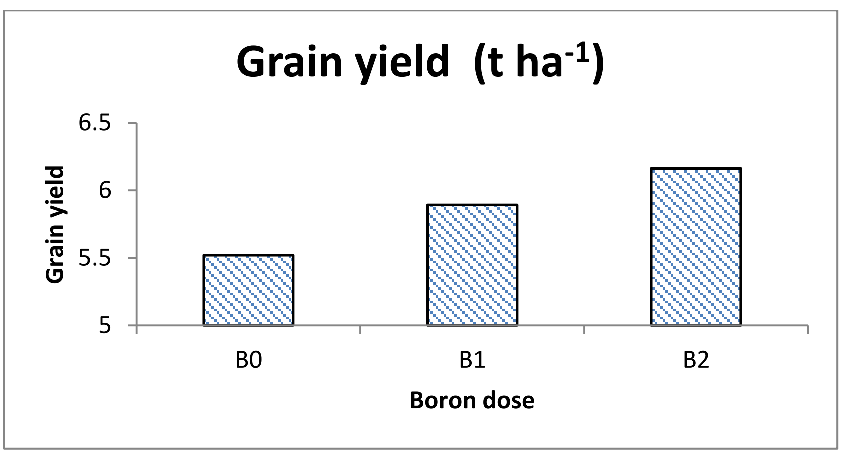


Figure 16: Effect of Boron on grain yield (t ha^{-1})

Table 9. Effect of boron on grain yield (t ha^{-1})**, straw yield** (t ha^{-1})**, biological yield** (t ha^{-1}) **and harvest index (%) of BRRI dhan 34**

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
B_0	5.52 c	7.50 c	13.05 c	42.27 b
B_1	5.89 b	7.53 b	13.39 b	43.91 a
B_2	6.16 a	7.73 a	13.89 a	44.18 a
$LSD_{(0.05)}$	0.08	0.20	0.18	0.93
CV (%)	4.94	4.80	4.91	4.15

4.2.8 Straw yield (t ha-1)

The effect of different levels of B on straw yield was highly significant. It was observed that the highest straw yield (7.73 t ha^{-1}) was obtained with the application of 2 kg B ha^{-1} (B_2). The lowest straw yield (7.50 t ha^{-1}) was found in B_0 treatment with no fertilizer. Rodrigues *et al* and Shorrocks (1974) also reported the similar findings earlier.

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

Significant response was observed in biological yield due to application of different levels of B on BRRI dhan 34 (Table 9). The biological yield of BRRI dhan34 varied from 13.05 to 13.89 t ha^{-1}. The highest biological yield (13.89 t ha^{-1}) was obtained from B_2 treatment with 2 kg B ha^{-1} and lowest biological yield (13.05 t ha^{-1}) was obtained in the B_0 treatment (Figure 17).

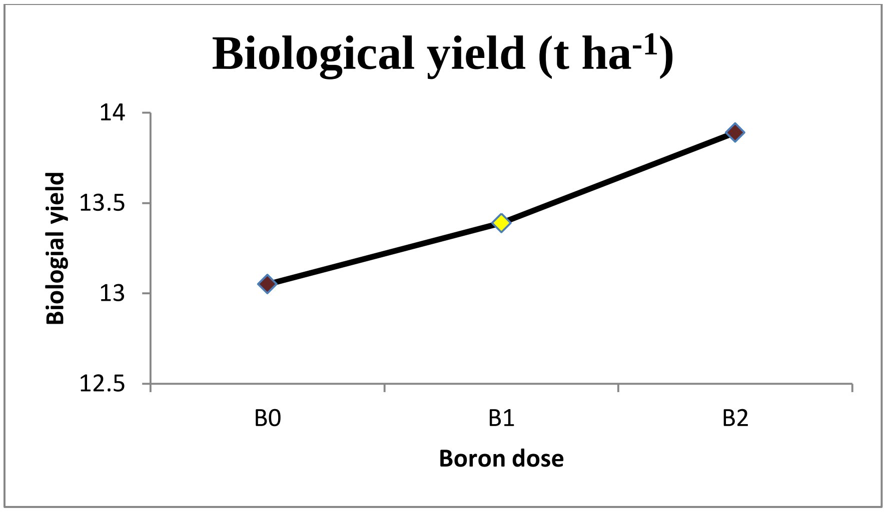


Figure 17: Effect of Boron on Biological yield (t ha^{-1})

4.2.10 Harvest index (%)

Application of different levels of B has a significant effect on harvest index. From the result, it was evident that the highest index (44.18%) was found in B_2 treatment with the application of 2 kg B ha^{-1} and the lowest harvest index (42.27 %) was obtained in B_0.treatment (Figure 18)

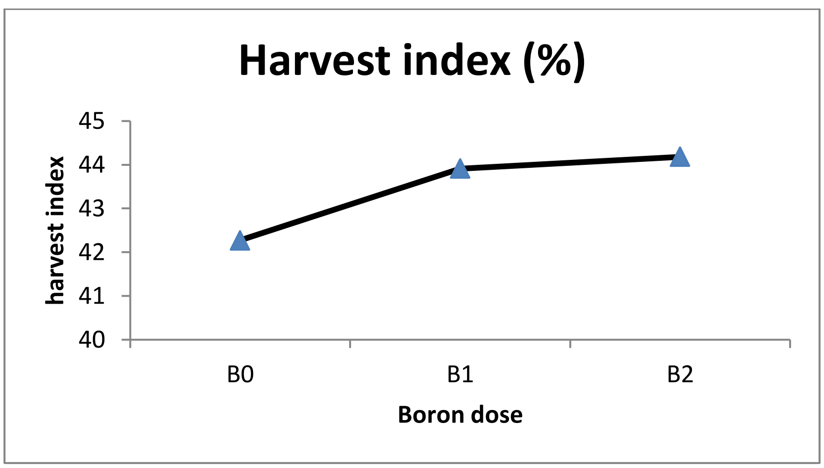


Figure 18: Effect of Boron on Harvest index (%)

4.3 Interaction effect of Zinc and Boron

4.3.1 Plant height

Interaction effect of Zn and B has a significant effect on plant height of BRRI dhan34. (Table 10) The tallest plant height (151.30 cm) was obtained from Zn_2B_2 treatment that receiving 2kg Zn ha^{-1} and 2kg B ha^{-1}. On the other hand, the shortest plant height (132.70 cm) was found in Zn_0B_0 treatment with no Zn and B fertilization.

Table 10. Interaction effect of zinc and boron on plant height, Number of effective tillers $hill^{-1}$ and Number of non-effective tillers $hill^{-1}$ characteristics of BRRI dhan34

Treatments	Plant height (cm)	Number of effective tillers $hill^{-1}$	Number of non-effective tillers $hill^{-1}$
Zn_0B_0	132.70 f	2.93 f	5.14 a
Zn_0B_1	139.00 d	6.23 e	4.83 b
Zn_0B_2	136.00 e	6.36 e	3.33 e
Zn_1B_0	135.00 e	6.96 d	3.18 ef
Zn_1B_1	140.00 d	7.17 cd	3.15 ef
Zn_1B_2	140.70 cd	7.23 c	4.09 c
Zn_2B_0	136.00 e	7.85 b	4.08 c
Zn_2B_1	139.30 d	7.95 b	3.01 f
Zn_2B_2	151.30 a	9.25 a	3.90 c
Zn_3B_0	139.00 d	6.24 e	2.62 g
Zn_3B_1	146.00 b	7.23 c	3.02 f
Zn_3B_2	142.30 c	6.24 e	3.64 d
$LSD_{(0.05)}$	1.71	0.23	0.20
CV (%)	5.73	4.93	3.21

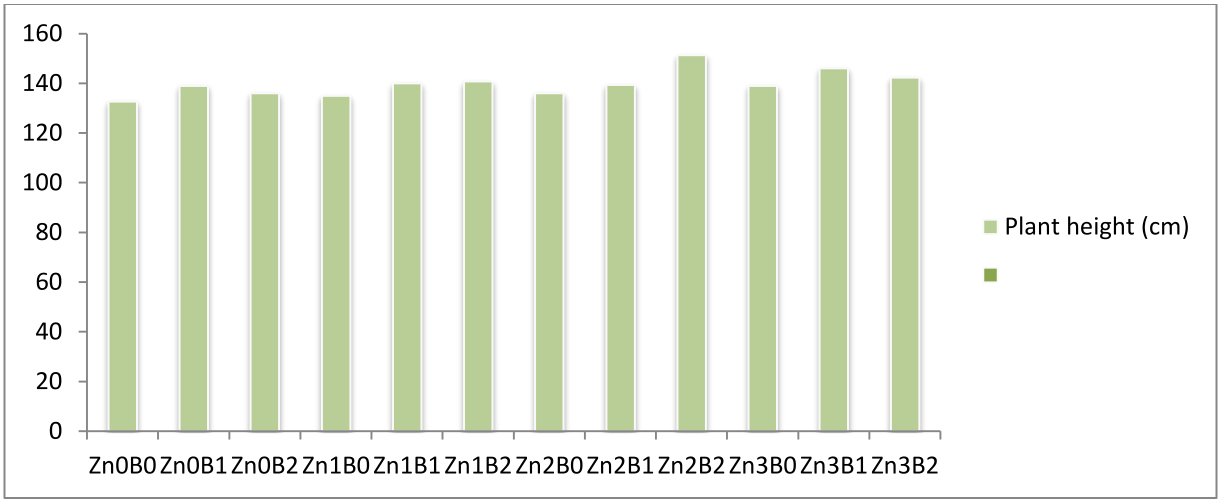


Figure 19: Combined effect of Zinc and Boron on plant height

4.3.2 Number of effective tillers hill^{-1}

Combined effect of Zn and B has a significant on the number of effective tillers hill^{-1} of BRRI dhan34 (Table 10). It was found that the maximum number of effective tillers hill^{-1} (9.25) was influenced by Zn_2B_2 treatment which receiving 2 kg Zn and 2 kg B per ha. On the other hand the minimum number of effective tillers hill^{-1} (2.93) was obtained from Zn_0B_0 treatment (figure 20).

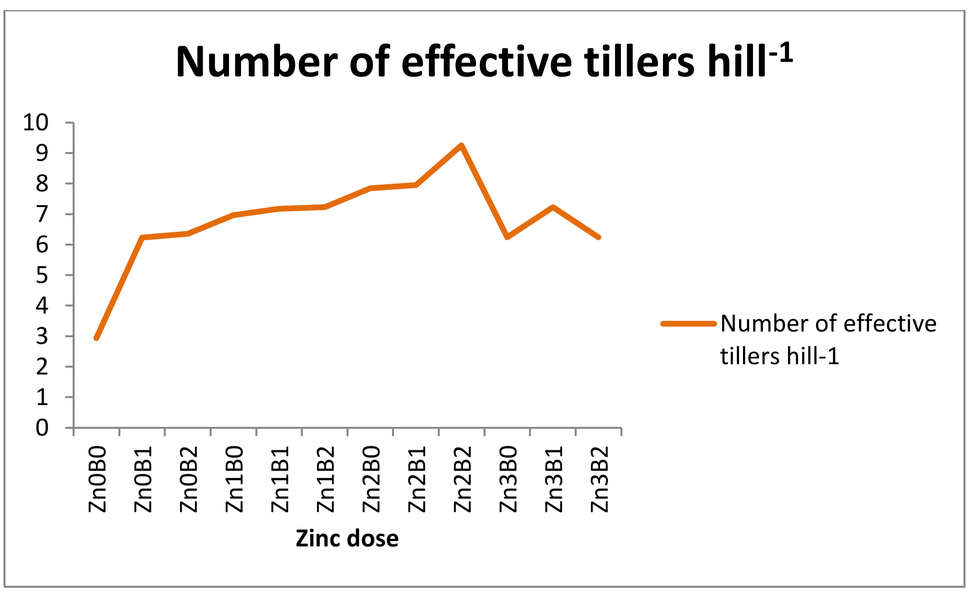


Figure 20: Combined effect of Zinc and Boron on number of effective tillers hill^{-1}

4.3.3 Number of non-effective tillers hill^{-1}

Interaction effect of Zn and B has a significant effect on non-effective tillers hill^{-1} of BRRI dhan34 (Table 10). Non-effective tillers hill^{-1} ranged from 2.62 to 5.14 of which the highest number of non-effective tillers hill^{-1} (5.20) was obtained from Zn_0B_0 with no Zn and B fertilization and the lowest number of non-tiller hill^{-1} (2.62) was found in Zn_3B_0 treatment which receiving 3 kg Zn and 0 kg B per ha.

4.3.4 Panicle length (cm)

The panicle length of BRRI dhan 34 significantly influenced by the interaction of Zn and B application (Table 11). The longest panicle (26.27 cm) was obtained from Zn_2B_2 treatment with 2 kg Zn and 2 kg B per ha and the shortest panicle (22.27 cm) was found in Zn_0B_0 (control).

Table 11. Interaction effect of zinc and boron on panicle length (cm), number of grains panicle^{-1} and 1000 grain weight (gm) of BRRI dhan 34

Treatments	Panicle length (cm)	Number of grains panicle^{-1}	1000 grain weight (gm)
Zn_0B_0	22.27 i	118.70 h	28.80 h
Zn_0B_1	23.47 h	122.70 g	30.80 f
Zn_0B_2	23.90 g	130.00 f	30.67 fg
Zn_1B_0	24.27 e-g	119.00 h	34.07 b
Zn_1B_1	24.60 de	127.30 f	30.93 f
Zn_1B_2	24.93 cd	133.30 e	32.13 d
Zn_2B_0	25.13 bc	141.00 d	32.27 d
Zn_2B_1	25.47 b	146.00 c	33.20 c
Zn_2B_2	26.27 a	158.70 a	35.93 a
Zn_3B_0	24.93 cd	142.00 d	30.33 g
Zn_3B_1	24.33 ef	151.70 b	32.20 d
Zn_3B_2	24.00 fg	135.00 e	31.33 e
$LSD_{(0.05)}$	0.37	3.04	0.37
CV (%)	4.89	7.33	4.70

4.3.5 Grains Panicle^{-1}

The combined application of Zn and B has a significant effect on the total grains panicle^{-1} (Table 11). The total number of grains panicle^{-1} of BRRI dhan 34 varied from 118.70 to 158.70. The highest number of grains panicle^{-1} (158.70) was obtained from the Zn_2B_2 treatment that receiving 2 kg Zn and 2 kg B ha^{-1}. On the other hand, the lowest number of grains panicle^{-1} (118.70) was found in Zn_0B_0 treatment where no Zn and B fertilization. (Figure 21)

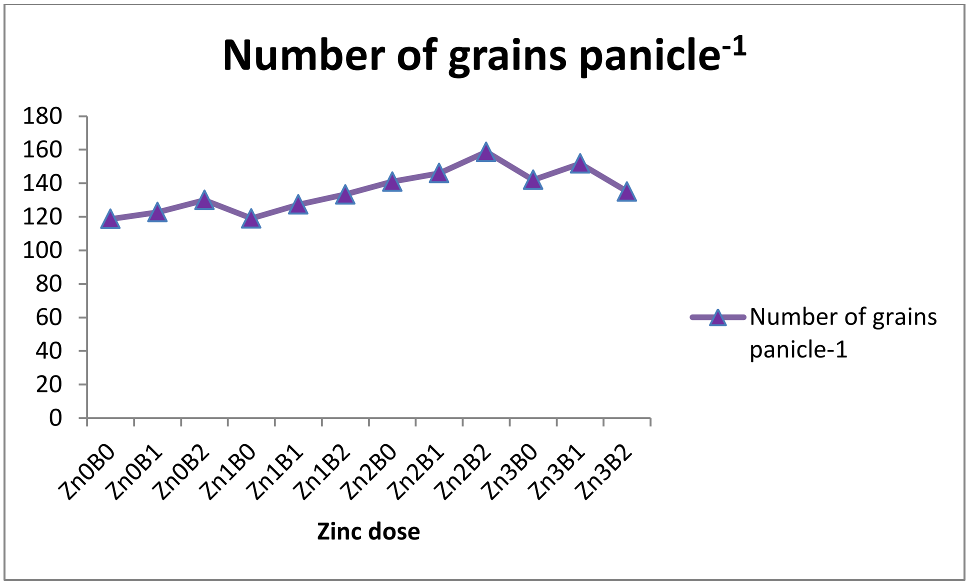


Figure 21: Combined effect of Zinc and Boron on Grain Panicle^{-1}

4.3.6 1000-grain weight (gm)

Combined effect of Zn and B has a significant on 1000 grain weight of BRRI dhan 34 (Table 11). The result indicates that 1000 grain weight varied from 28.80 to 35.93 gm (Table 11). The highest 1000-grain weight (35.93 gm) was found in Zn_2B_2 treatment that receiving 2 kg Zn and 2 kg B ha^{-1} and the lowest 1000-grain weight (28.80 gm) was found in Zn_0B_0 treatment combination where no Zn and B fertilization.

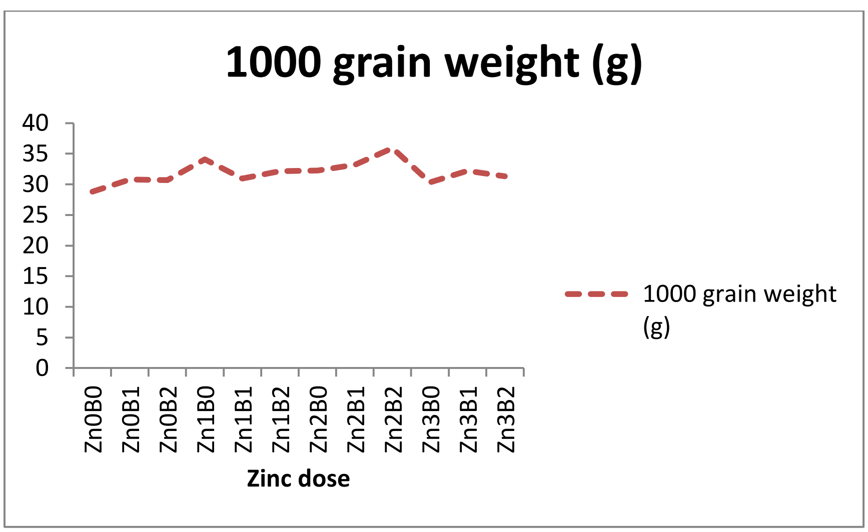


Figure 22: Combined effect of Zinc and Boron on 1000-grain weight (gm)

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

Grain yield of BRRI dhan34 was significantly influenced by the combined application of zinc and boron (Table 12). The highest grain yield (6.72 t ha^{-1}) was obtained from Zn_2B_2 treatment which receiving 2 kg Zn and 2 kg B ha^{-1}. On other side, the lowest grain yield (4.89 t ha^{-1}) was obtained from the Zn_0B_2 treatment.

Table 12. Interaction effect of zinc and boron on grain yield (t ha^{-1})**, straw yield** (t ha^{-1})**, biological yield** (t ha^{-1}) **and harvest index (%) of BRRI dhan 34**

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Zn_0B_0	5.17 f	7.13d	12.33 g	41.91 f
Zn_0B_1	4.91 g	7.17 d	12.03 h	40.78 g
Zn_0B_2	4.89 g	7.17 d	12.05 h	40.54 g
Zn_1B_0	6.07 d	7.17 d	13.23 e	45.84 a-c
Zn_1B_1	6.10 d	7.09 d	13.19 e	46.26 a
Zn_1B_2	6.36 c	7.75 c	14.11 c	45.07 bc
Zn_2B_0	5.94 e	7.83 bc	13.77 d	43.13 e
Zn_2B_1	6.49 b	8.00 ab	14.49 b	44.79 cd
Zn_2B_2	6.72 a	8.17 a	14.89 a	45.14 bc
Zn_3B_0	4.91 g	7.94 a-c	12.85 f	38.19 h
Zn_3B_1	6.07 d	7.78 bc	13.85 d	43.82 de
Zn_3B_2	6.55 b	7.83 bc	14.49 b	45.96 ab
$LSD_{(0.05)}$	0.09	0.23	2.21	1.07
CV (%)	4.94	4.80	4.91	4.15

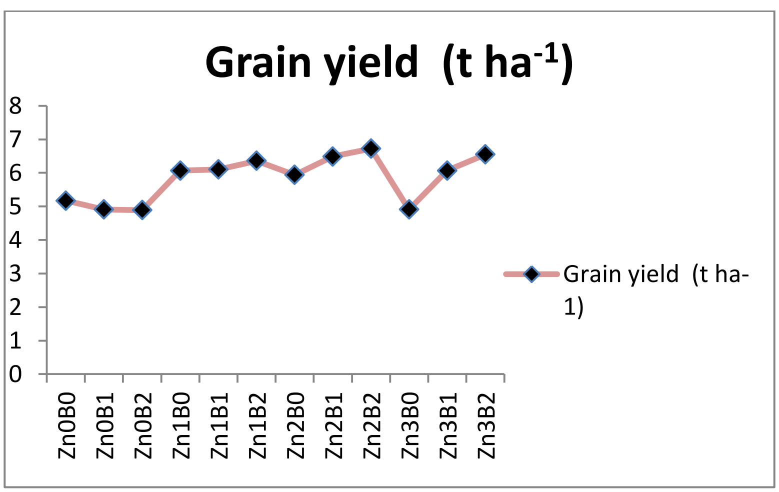


Figure 23: Combined effect of Zinc and Boron on grain yield (t ha^{-1})

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

The interaction effect of Zn and B was showed significant effect on the straw yield of BRRI dhan34 (Table 12). From the result, it was observed that the highest straw yield (8.17 t ha^{-1}) was found in Zn_2B_2 treatment which receiving 2 kg Zn and 2 kg B ha^{-1}. The lowest straw yield (7.13 t ha^{-1}) was obtained from Zn_0B_0 (control).

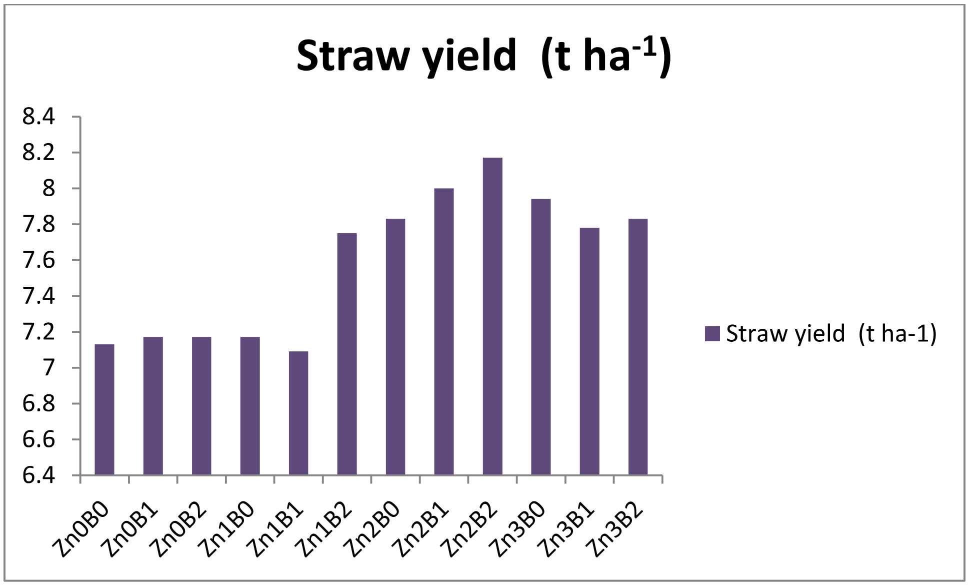


Figure 24: Combined effect of Zinc and Boron on Straw yield (t ha^{-1})

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

Combined effect of Zn and B has a significant on Biological yield of BRRI dhan34 (Table 12). From the result, it was observed that the highest biological yield (14.89 t ha^{-1}) was found in of Zn_2B_2 treatment that receiving 2 kg Zn and 2 kg B ha^{-1}. The lowest biological yield (12.03 t ha^{-1}) was obtained from Zn_0B_1 treatment.

4.3.10 Harvest index (%)

The interaction effect of Boron and Zinc at different levels was showed significant effect on harvest index of BRRI dhan34 (Table 12). The highest harvest index (46.26 %) was found in Zn_1B_1 treatment which receiving 1 kg Zn and 1 kg B ha^{-1} and the lowest harvest index (38.19 %) was obtained from Zn_3 B_0 treatment, that receiving 3kg Zn ha-1 and no B fertilization.

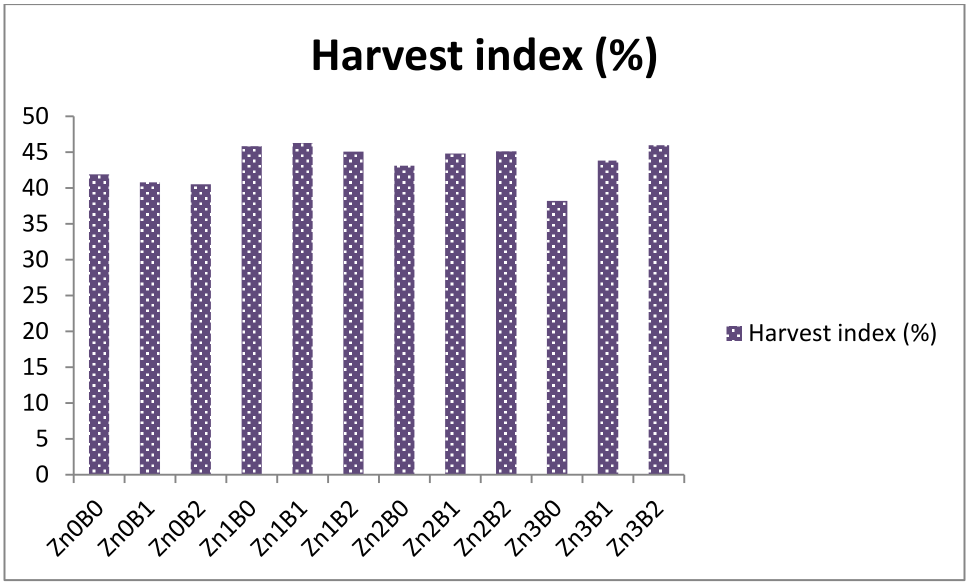


Figure 25: Combined effect of Zinc and Boron on Harvest index (%)

4.4 Nutrient Status of post-harvest soil of BRRI dhan34 as affected by Zinc and Boron

4.4.1 Soil pH

Combined application of zinc and boron has no significant effect on pH of post-harvest soil(Table 13). The highest pH (5.47) was recorded in treatment Zn_2B_2 receiving 2 kg Zn and 2 kg B per ha and the lowest pH value (5.40) in Zn_0B_0 treatment.

4.4.2 Organic Matter Content of Soil (%)

Combined application of zinc and boron has no significant effect on organic matter of post-harvest soil (Table 13). The highest OM (1.18%) was recorded in treatment Zn_2B_2 where 2.0 kg Zn and 2.0 kg B per ha were applied and the lowest OM value (1.03 %) in Zn_0B_0 treatment

4.4.3 Total Nitrogen Content of Soil (%)

Total nitrogen content of post-harvest soil was significantly influenced by combined application of zinc and boron (Table 13). The highest N content (0.09 %) of soil was observed in case of Zn_2B_2 treatment with 2 kg Zn and 2 kg B per ha. In contrast, the lowest N content (0.04%) was obtained in the Zn_0B_0 treatment where no Zn and B fertilizer were applied.

4.4.4 Phosphorus Content of Soil (ppm)

Phosphorus content of post-harvest soil was significantly influenced by combined application of zinc and boron (Table 13). Among the different treatments, Zn_2B_2 treatment showed the highest P content (24.13 ppm) in post-harvest soil. On the other hand, the lowest P content (14.15 ppm) was observed in Zn_0B_0 treatment with no Zn and B fertilization.

4.4.5 Potassium Content of Soil (meq 100 gm soil^{-1})

The combined effect of zinc and boron has significant effect on potassium content of post-harvest soil (Table 13). However the highest K content (0.19 meq 100 gm soil^{-1}) was recorded in Zn_2B_2 treatment that receiving 2 kg Zn and 2 kg B per ha and the lowest potassium content of post harvested soil (0.11 meq 100 gm soil^{-1}) was recorded in Zn_0B_0 treatment (control).

Table 13 . Interaction effect of zinc and boron on the pH, organic matter, total N, available P and exchangeable K in the soil after harvest of BRRI dhan 34

Treatments	pH	Organic matter (%)	Total N (ppm)	Available P (ppm)	Exchangeable K (meq 100 gm soil-1)
Zn_0B_0	5.40	1.03	0.04 f	14.15 g	0.11 f
Zn_0B_1	5.42	1.08	0.05 ef	16.00 f	0.13 ef
Zn_0B_2	5.40	1.14	0.07 c	18.15 d	0.16 c
Zn_1B_0	5.45	1.09	0.06 cd	17.21 e	0.15 cd
Zn_1B_1	5.45	1.10	0.05 de	19.41 c	0.14 de
Zn_1B_2	5.42	1.14	0.05 de	17.79 e	0.14 de
Zn_2B_0	5.42	1.16	0.07 c	19.32 c	0.16 c
Zn_2B_1	5.43	1.17	0.08 b	21.01 b	0.17 b
Zn_2B_2	5.47	1.18	0.09 a	24.13 a	0.19 a
Zn_3B_0	5.41	1.10	0.06 cd	17.00 e	0.15 cd
Zn_3B_1	5.43	1.13	0.06 cd	21.23 b	0.15 cd
Zn_3B_2	5.44	1.12	0.07 c	18.47	0.16 c
$LSD_{(0.05)}$	NS	NS	0.01	1.00	0.01
CV (%)	3.26	4.37	4.36	5.29	2.57

In this study it was found that Zn_2B_2 always gave better result over yield and growth parameter of BRRI dhan34. So this combination of micronutrianents (Zinc & Boron) is suggested for better result on T. Aman (BRRI dhan34) cultivation.

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July 2013 to December 2013 to study the effect of micronutrients on the yield and growth of T. Aman. BRRI dhan34 was used as the test crop in this experiment. The soil of the experimental field belongs to Madhupur tract representing Tejgaon series. The experiment was laid out in a Randomized Complete Block Design with three replications. The experiment consists of three replications. The experiment consists of four level of Zinc viz, 0, 1, 2 and 3 kg ha^{-1} and three level of Boron viz, 0, 1 and 2 kg ha^{-1}. There was 36 plots, each plot measuring 3m x 1.8 m. All nutrients and half of N were added to soil at a time during final land preparation. Rest of N applied in equal doses by top dressing, first dose of rest N applied 21 days after transplanting and 33 days after transplanting.

Necessary practice related this experiment, e.g. Weeding, irrigation and pest managements were done. Five hills from each plot were selected randomly at tagged for taking data of plant height, Total number of tillers $hill^{-1}$, effective and non-effective tillers $hill^{-1}$, 1000 grain yield and one $meter^2$ was cut from each plot for taking data of grain yield, straw yield, biological yield and harvest index.

Zn and Boron fertilizers as micronutrients were key fertilizer of this experiment. Where Zn fertilizer treatment show significant effect on plant height, total number of tillers $hill^{-1}$, effective and non-effective tillers $hill^{-1}$, 1000 grain weight etc.

Another pole stand B showed almost same case that it had influenced , total number of tillers hill-1, effective and non-effective tillers hill-1, 1000 grain, biological yield and harvest index.

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From the above discussion it can be concluded that Zinc and Boron had significant effect on plant height, panicle length, number of effective tillers hill^{-1}, number of non-effective tillers hill^{-1} ,1000-grain yield (t ha^{-1}), grains panicle^{-1} , biological yield (t ha^{-1}) and harvest index. In this experiment the highest yield was found in Zn_2B_2 plots and the lowest was found in Zn_0B_0. The application of inorganic fertilizer plus manure performed better compared to inorganic fertilizer. The application of Zn_2B_2 (2 kg Zn ha^{-1} x 2 kg B ha^{-1}) Recommended dose of Fertilizer was most favorable for improving yield and growth of T. Aman (BRRI dhan34) rice.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh

Appendix II. Morphological Characteristics of Sher-e-Bangla Agricultural University Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Fallow- T. Aman

Appendix III. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from July 2014 to December 2014

Month	Average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total Sunshine per day (hrs)
	Maximum	Minimum	Mean			
July, 2014	36.0	24.6	30.3	83	563	3.1
August, 2014	36.0	23.6	29.8	81	319	4.0
September,2014	34.8	24.4	29.6	81	279	4.4
October, 2014	34.8	18.0	26.4	77	227	5.8
November, 2014	29.7	20.1	24.9	65	5	6.4
December, 2014	26.9	15.8	21.35	68	0	7.0

Source: Bangladesh Meteorological Department (Climate & weather division), Agargoan. Dhaka – 1212

Appendix IV: Error mean square values for plant height and tiller characteristics of BRRI dhan 34

Source of variation	Degrees of freedom	Plant height	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}
Replication	2	4.000	0.096	0.001	0.186
Zine (A)	3	31.750*	43.002**	95.807**	132.281**
Boron (B)	2	107.889*	10.131**	24.101*	82.548*
A × B	6	7.306**	0.024*	0.697**	3.323*
Error	22	1.364	0.059	0.001	3.000

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix V: Error mean square values for panicle characteristics and 1000 grain weight of BRRI dhan 34

Source of variation	Degrees of freedom	Panicle length	Number of total spikelets panicle^{-1}	Number of grains panicle^{-1}	1000 grain weight
Replication	2	0.512	6.929	6.929	70.355
Zine (A)	3	61.214*	258.021*	258.021*	262.010*
Boron (B)	2	5.027*	121.587*	55.037**	79.470*
A × B	6	0.716**	6.669**	6.669*	3.795*
Error	22	1.949	15.077	15.077	36.725

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix VI: Error mean square values for yield contributing characters of BRRI dhan 34

Source of variation	Degrees of freedom	Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	0.009	0.068	0.058	29.538
Zine (A)	3	0.833*	1.577**	0.147*	1242.871*
Boron (B)	2	0.494**	1.040*	0.134*	723.641*
A × B	6	0.017*	0.018*	0.017*	18.225**
Error	22	0.004	0.024	0.017	11.292

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix VII: Error mean square values for zinc and boron concentrations of BRRI dhan 34

Source of variation	Degrees of freedom	Zinc concentration	Boron concentration
Replication	2	0.034	0.090
Zine (A)	3	1.827*	1.956**
Boron (B)	2	1.485**	1.037*
A × B	6	0.283*	0.495*
Error	22	0.102	0.2.34

*Significant at 5% level of probability

** Significant at 1% level of probability