EFFECT OF ZINC AND BORON ON THE GROWTH AND YIELD OF BRRI dhan29 IN RED-TERRACE SOIL

BY

S. M. ARIFUZZAMAN

Registration No. 07-02585

A Thesis

Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
IN
SOIL SCIENCE

SEMESTER: JULY-DECEMBER, 2008

Approved by:

Supervisor
(Prof. Dr. Alok Kumar Paul)
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

Co-Supervisor
(Prof. Dr. Syed Anwarul Haque)
Department of Soil Science
Bangladesh Agricultural University
Mymensingh-2202

Chairman
(A. T. M. Shamsuddoha)
Associate Professor
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

DEPARTMENT OF SOIL SCIENCE
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

*This is to certify that the thesis entitled "Effect Of Zinc And Boron On The Growth And Yield Of BRRI Dhan29 In Red-Terrace Soil" submitted to the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SOIL SCIENCE**, embodies the result of a piece of bona fide research work carried out by **S. M. Arifuzzaman**, Registration No. **07-02585** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: 31.12.2008
Place: Dhaka, Bangladesh

Professor Dr. Alok Kumar Paul
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

At every moment the author would like to express his profound gratefulness to the Almightily Allah, the merciful and the beneficent to all creations for blessing to present this thesis.

The author wishes to express his sincere gratitude and indebtedness to his honorable teacher and research Supervisor Professor Dr. Alok Kumar Paul, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, outstanding assistance, valuable advice and suggestions for the successful completion of the research work and preparation of this manuscript.

The author sincerely expresses his heartfelt gratitude and deepest sense to his Co-supervisor Professor Dr. Syed Anwarul Haq, Department of Soil Science, Bangladesh Agricultural University, Mymensingh for his kind co-operation and constructive suggestions in all phases of the research work.

The author whishes to pay his gratefulness to all the honorable teachers of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for their kind illuminating suggestions during the research work period. The author is proud to express his heartiest gratitude to his parents and elder brother for their sacrifice and rendered inspiration for his higher study.

The author thanks to his friend, Md. Khairul Alam, Scientific Officer, Soil Science Division, BARI, Gazipur for his cordial co-operation and inspiration during the research work. The author extends his cordial thanks to his all friends especially Rifat, Nazmul, Mony, Iqbal, Zahid, Samim, Jakir, Rubel Junior brother Sajib, Santo, Abu Syed, and well-wishers for their co-operation and sacrifice during the experiment period and preparing this manuscript.

Last, but not least, the heartfelt gratitude and indebtedness is expressed to the authors beloved Father-Md. Ashraf Ali, Mother-Mrs. Nadira Sultana, Brothers-Dr. Nahid, Rana, Munam, Rumman, Sakib, Hamim Sisters- Nigar, Jabin, Jubily, Sumaiya and all relatives for their affectionate feelings, helpful suggestions and encouragement during the study that enabled the author to reach up this higher level of education and proper completion of the research work.

The Author

EFFECT OF ZINC AND BORON ON THE GROWTH AND YIELD OF BRRI dhan29 IN RED-TERRACE SOIL

ABSTRACT

The field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka during the boro season from 1 November 2007 to 15 March 2008 to observe the performance of zinc and boron on the yield and yield contributing characters of BRRI dhan29. The experiment consists of three levels of zinc viz. 0, 2.5 and 5.0 kg ha^{-1} and three levels of boron viz. 0, 1 and 2 kg ha^{-1}. The experiment was laid out in factorial randomized complete block design with three replications. Application of Zn significantly influenced all the growth and yield contributing characters except plant height (cm), panicle length (cm) and sterile spikelets $panicle^{-1}$ whereas boron fertilization significantly influenced all parameters except plant height (cm), panicle length (cm) and 1000 grain weight. Five kg Zn ha^{-1} and two kg B ha^{-1} Zn_5 x B_2 influenced plant to produce the highest grain yield. The maximum yield 5.56 tha^{-1} was recorded for this combination effect. Integrated use of zinc and boron significantly influenced contents and uptake of zinc (Zn) and boron (B) in the grain and straw of BRRI dhan29. In all cases of contents and uptakes of Zn and B in both grain and straw as affected by Zn and B fertilizations, Zn_5B_2 performed the highest results.

CONTENTS

Contd.

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

Chapter 1

INTRODUCTION

Rice (*Oryza sativa*), the staple food crop in Bangladesh, covers about 77% of the total cropped area of 13.9 million hectares. Bangladesh ranks fourth in the world both in acreage and production of rice (FAO, 2000). But the average yield is quite lower (2.15 t ha^{-1}) compared to other leading rice growing countries such as China, Korea, Japan and USA producing 6.23, 6.59, 6.70 and 7.04 t ha^{-1}, respectively (FAO, 2000).

For our existence, priority should be given to attain self sufficiency in grain production. This can be done either by increasing the total area under rice crop cultivation or by increasing per hectare yield by using fertilizers as a means of supplementing the natural food supplies of the soil. But our cultivated land is limited and horizontal expansion of land area is not possible. Therefore, the only option left is to increase the per hectare yield of rice. It is now well agreed that depleted soil fertility is a major constraint for higher crop production in Bangladesh. Indeed, yield of several crops including rice is now stagnating and even declining (Bhuiyan, 1991).

Soil fertility depletion has been resulted from continuous exhaustion of fertility for centuries without sufficient return of essential plant nutrients to the soil in the form of fertilizer and lack of proper soil management practices. Due to the crop intensification and adoption of modern technology like use of high yielding varieties, chemical fertilizer, pesticides etc. the fertility status of the soil in respect of both macro and micronutrient elements have been depleted (Zaman, 1994) and their deficiencies are observed to be more prominent in rice crop.

Initially the farmers were not aware of fertilizer use for commercial production of crops as well as proper maintenance of soil fertility. Gradually they are being well acquainted with the need for fertilizer for crop nutrition. Farmers were using these elements through fertilizers as urea, triple superphosphate and muriate of potash. But recently advanced research have indicated the deficiency of nutrients like B and Zn for which gypsum and ZnO or $ZnSO_4$, respectively are recommended to use meet the deficiency of these elements. Zinc was recognized as an essential element for rice cultivation long ago. In Bangladesh, Zn deficiency has been reported in Gangetic alluvium soils, like the soils of Rajshahi, Faridpur, Pabna, Kustia, Jessore, Barisal, Khulna, North-west part of Dhaka district, i.e. Manikgonj and Dhamrai and in haor areas of Sylhet. The light sandy soils of northern part of Bangladesh are also reported to be Zn deficient (BRRI, 1980). Since rice is grown in wet land condition under diverse soil and climatic situation, it suffers from deficiency and toxicity of micronutrients like Zn.

The amount of nutrient taken up by a crop is closely related to the total amount of biomass it produces. In general the higher the crops yield the higher the nutrient removal by crop. A two fold yield increase will naturally remove two fold more nutrients from soil. As a consequence, the practice of intensive cropping system coupled with use of high yielding varieties are likely to favour the deterioration of soil health and emergence of new nutrient deficiency. Rice is the principal cereal crop in Bangladesh. The production of rice in this country has although increased to a considerable extent, its yield potential as viewed by Bhuiyan (1991), has leveled off. Depletion of soil fertility has been identified as a major constraint for higher rice yield. Before 1980's deficiency of NPK was a major problem but thereafter along with NPK, deficiency of S and Zn are frequently reported (Jahiruddin *et al*., 1981; Hoque, 1986; Islam *et al*., 1986) and more frequently B deficiency in wheat is reported in some soils (Jahiruddin *et al*.,1992; Jahiruddin, 1993). It is likely that B deficiency may also arise in rice. Zinc deficiency occurs only locally but may be widespread on the calcareous Ganges River Floodplain and sandy soils, peat soils, high pH saline soils and light textured Piedmont soils. Zinc deficiency in Bangladesh is acute and widespread in light textured and irrigated soils, where high yielding varieties are cultivated. Among the different problem soils identified in Bangladesh zinc deficient soil occupies 1.75 m ha^{-1}. Especially calcareous soils (pH >7.5) with moderate to high organic matter content (>1.5% organic C) are likely to be Zn-deficient due to high HCO_3^- in soil solution.

Boron is a micronutrient requiring for plant growth relatively to a smaller amount. The total B content of soils lies between 20 and 200 ppm with the available (hot water soluble) B fraction ranging from 0.4-0.5 (Gupta, 1979). Tourmaline containing 3-4% B is the major B bearing mineral. Boron occurs in soils mainly as undissociated H_3BO_3 and subject to soil pH changes this acid is not deprotonated (dissociated). This may be the main reason why B is leached so easily from soil. Plants absorb B principally in the form of H_3BO_3 and to a smaller extent as $B_4O_7^{2-}$, $H_2BO_3^-$, HBO_3^-, plant require B for a number of growth processes. such as new cell development, 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.

Thus an investigation was undertaken with an objective of examining the effects of zinc and boron on BRRI dhan29 in Red-Terrace Soils. Considering the above facts a field study was undertaken with the following objectives:

i. To determine the optimum growth and yield performance of BRRI dhan29 by the application of different dosages of zinc and boron

ii. To calculate the effect of zinc and boron on the growth and yield of BRRI dhan29 in Red Terrace soil

CHAPTER 2
REVIEW OF LITERATURE

Chapter 2

REVIEW OF LITERATURE

An attempt is made in this chapter to present a brief review of review of research works in relation to the effect of Zn and on rice. In the present review, attention has been paid to the recent works particularly after 1980. In the review, effects of these elements on yield components and nutrients composition on rice have 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.

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 1.1-1.2 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 positively 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 favourable 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. Treatments comprised a control; recommended fertilizer dose (RFD; 80 : 45 : 20 N : P_2O_5 : K_2O kg) with 20 × 10 cm spacing; RFD+15 kg with 20 × 10 cm spacing ; 15% RFD with 20 × 10 cm spacing; RFD with 15 × 15 cm spacing; local practice (60 : 40 : 0 N : 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 to RFD with optimum plant population (4.4 laks 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 number and 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 to 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 analyses were 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 in 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 25 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*,. (2001) reported that zinc is the most growth and yield limiting micronutrient in US rice production. They conducted two field Studies to evaluate several dry, granular and liquid Zn 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 times. Application of dry granular Zn sources performed the best when applied at either PPI or PRE.

Vasudeva and Ananthanarayana (2001) conducted a field experiment in India to investigate the effect of added zinc 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 tones) and fertilizers N, $P_2 0_5$, 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 $\mu g\ g^{-1}$). 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 to 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}). The 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) reported from 3 years field experiments 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-8141 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 + Mo 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 amylose 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. Jaya and BR11 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.,* (1997) 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 productively.

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 seed 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 7.2% and straw yield by 12.9% over sole N.

Kumar and Singh (1996) reported that dipping the seedlings in 2% ZnSO4 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 green-house 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

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, lignification, 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}, number of spikes $plant^{-1}$, 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 to 0.35 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 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 applications of Zn + B on yield of rainfed 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 rainfed conditions. The highest grain yield of 3.66 t ha^{-1} and straw yield of 4.81 t 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 BR11 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 NPKSZn 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

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 preparation of soil and plant samples and the methods for the chemical 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, Sher-e-Bangla Nagar, Dhaka. This soil belongs to the Modhupur tract (AEZ 28). The selected plot was medium high land and the soil series was Tejgaon series. The soil characteristics were silty loam in texture with pH value 5.8 and C:N ratio 8:1. The site of the experimental plot is in the 23°74' latitude and 90°35' longitude 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 during boro (November-March) season.

3.3 Plant materials

One modern rice variety BRRI dhan29 was tested. The life cycle of this variety ranges from 150-155 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 three levels each. The experimental treatments were as follows:

Factor-A: Zn (Zn_0, $Zn_{2.5}$ and $Zn_{5.0}$ kg ha^{-1})

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

Treatment combinations:

T_1 : $Zn_0 + B_0$

T_2 : $Zn_0 + B_1$

T_3 : $Zn_0 + B_2$

T_4 : $Zn_{2.5} + B_0$

T_5 : $Zn_{2.5} + B_1$

T_6 : $Zn_{2.5} + B_2$

T_7 : $Zn_5 + B_0$

T_8 : $Zn_5 + B_1$

T_9 : $Zn_5 + B_2$

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

Table 1. Nutrients, their sources and rates used for the experiment

Name of the fertilizer	Rate (kg ha^{-1})	Chemical formula
Nitrogen	220	$CO(NH_2)_2$
Triple super phosphate (TSP)	130	$Ca(H_2PO_4)_2$
Muriate of potash (MOP)	100	KCl
Borax	0, 1.0, 2.0	$Na_2B_4O_7$, $10H_2O$
Zinc oxide	0, 2.5, 5.0	ZnO

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 subplot. The size of the unit plot was 4.0 m × 2.5 m. Total plots in the experiment field were 27. There were 1 m drains between the blocks. The treatments were randomly distributed to each block.

3.6. Land preparation

Land preparation was started on 10 November 2007. The land was prepared by repeated ploughing and cross ploughing followed by laddering. After uniformly levelling 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 at 3 November, 2007 and covered with a thin layer of fine earth. Proper care of the seedlings was taken in the nursery.

3.8 Fertilizer application

All the fertilizers except N were added to the soil during final land preparation. Urea was applied in three equal splits. The first split was applied on 24 December, 2008, 15 days after tillering stage. The second split on 11 January, 2008, 32 days after transplanting and third split on 2 February, 2008, 52 days after transplanting. The fertilizers were mixed thoroughly with the soil by hand (Table 2).

3.9 Transplanting of seedling

Thirty two days old seedlings were uprooted carefully from the seedbed and transplanted in the experimental plots on 09 December 2007 following different spacing. 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 remove them three times from the field during the period of experiment. Weeding was done after 15, 32 and 52 days of transplanting (Table 2).

3.13. Disease and insect pest control

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

3.14 Harvesting and threshing

The crop was harvested plot wise at maturity from 5 March, 2008. 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 yields 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

Intercultural operations	Working date
First ploughing of the field	10 November, 2007
Second ploughing and laddering	20 November, 2007
Third ploughing and laddering	30 November, 2007
Final ploughing, plot preparation and application of fertilizers (TSP, MP, Gypsum, ZnO)	2 December, 2007
Intercultural operations	**Working date**
Transplanting of seedlings	9 December, 2007
First split application of urea and first weeding	24 December, 2007
Second split application of urea and second weeding	11 January, 2008
Third split application of urea and third weeding	2 February, 2008
Insecticides spraying – i. Basudin 10G (granular) ii. Sumithion 50EC	 10 January, 2008 19 January, 2008
Harvesting and threshing	5 March, 2008 to 9 March, 2008

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.

i. Plant height
ii. Number of tillers $hill^{-1}$
iii. Number of effective tillers $hill^{-1}$
iv. Number of non-effective tillers $hill^{-1}$
v. Panicle length (cm)
vi. Total spikelets $panicle^{-1}$
vii. Grains $panicle^{-1}$
viii. Sterile spikelets $panicle^{-1}$
ix. Weight of 1000-grain (g)
x. Grain yield (t ha^{-1})
xi. Straw yield (t ha^{-1})
xii. Biological yield (t ha^{-1})
xiii. Harvest index (%)

3.15.1 Data collection

Data on following parameters were collected in average form 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.

3.15.1.2 Total number of tillers $hill^{-1}$

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

3.15.1.3 Number of effective tillers hill^{-1}

The panicles that had at least one grain were considered as bearing tillers.

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

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

3.15.1.5 Panicle length

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

3.15.1.6 Total spikelets panicle^{-1}

Number of both filled and empty spikelets panicle^{-1} was counted.

3.15.1.7 Number of grains panicle^{-1}

Number of grains panicle^{-1} was counted.

3.15.1.8 Sterile spikelets panicle^{-1}

Sterile spikelets panicle^{-1} was counted.

3.15.1.9 Weight of 1000-grain

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

3.15.1.10 Grain and straw yields ha^{-1} (t ha^{-1})

After harvesting of the crop, grain yield of each unit plot was dried and weight. 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.

3.15.1.11. Biological yield (t ha^{-1})

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

3.15.1.12. Harvest index (%)

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

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

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 on 15 October 2007. The samples were air-dried, grounded and sieved through a 2 mm (10 meshes) sieve and preserved for analysis.

3.16.2 Plant sample

Plant samples were collected from every individual plot for laboratory analysis at maturity stage of the crop. Plants were collected from each plot by cutting above ground level. The plant samples were washed first with tap water and then with distilled water several times. The plant samples were dried in the electric oven at 70^0C for 48 hours. After that the samples were grounded in an electric grinding machine and stored for chemical analysis. The plant samples were collected by avoiding the border area of the plots.

3.17 Soil sample analysis

The initial and post harvest soil sample were analyzed for both physical and chemical properties. The properties studied included texture, pH, bulk density, particle density, organic matter, total N, available P, exchangeable K, available S 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 was 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

Soil organic carbon was determined by wet oxidation method.

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 were estimated by Micro-kjeldahl method where soils were digested with 30% H_2O_2 conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: 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 N H_2SO_4.

3.17.6 Available Phosphorous

Available phosphorous was extracted from the soil by shaking with 0.5 M $NaHCO_3$ 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 nm 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).

3.17.8 Available sulphur

Available sulphur was extracted from the soil with $Ca(H_2PO_4)_2.H_2O$. Sulphur in the extract was determined by the turbidimetric method using a Spectrophotometer (LKB Novaspec, 4049).

3.18 Chemical analysis of plant sample

3.18.1 Digestion of plant samples with nitric-perchloric acid mixture

An amount of 0.5g of sub-sample was taken into a dry clean 100 ml Kjeldahl flask, 10 ml of di-acid mixture (HNO_3, $HClO_4$ in the ratio of 2:1) was added and kept for few minutes. Then, the flask was heated at a temperature rising slowly to 200°C. Heating was instantly stopped as soon as the dense white fumes of $HClO_4$ occurred and after cooling, 6ml of 6N HCl were added to it. The content of the flask was boiled until they became clear and colorless. This digest was used for determining P, K, S and Zn.

3.18.2 Phosphorous

Phosphorous in the digest was determined by ascorbic acid blue color method with the help of a Spectrophotometer (LKB Novaspec, 4049).

3.18.3 Potassium

Potassium content in the digested plant sample was determined by flame photometer.

3.18.4 Sulphur

Sulphur content in the digest was determined by turbidimetric method using a Spectrophotometer (LKB Novaspec, 4049).

3.18.5 Nitrogen

Plant samples were digested with 30% H_2O_2, conc. H_2SO_4 and a catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Selenium powder in the ratio of 100: 10: 1, respectively) for the determination of total nitrogen by Micro-Kjeldahl method. 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 N H_2SO_4.

3.18.6 Zinc

Zinc content in the digested plant sample was determined by flame photometer.

3.18.7 Boron

Boron content in the digested plant sample was determined by flame photometer.

3.19 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

Chapter 4

RESULTS AND DISCUSSION

An investigation was carried out to find out the effect of different levels of zinc (Zn) and boron (B) on the performance of BRRI dhan29. The results have been presented and discussed in this chapter. The effects due to application of different levels of boron, namely 0, 1 and 2 kg/ha and different levels of zinc, namely 0, 2.5 and 5.0 kg ha^{-1} on the performance of BRRI dhan29 have been shown in tables 3-5 and figures: 1-9.

4.1 Plant height (cm)

4.1.1 Effect of zinc

The application of different levels of Zn had insignificant effect on plant height. The tallest plant (143 cm) was found due to application of 5.0 kg Zn ha^{-1} (Table 3). The shortest plants 136 cm were found in the treatment 0 kg Zn ha^{-1} but plant height increased gradually with the increase of rates of Zn. Ahmed *et al.* (1986) found that application Zn showed an increase in all the growth parameters of rice.

Table 3. Effect of zinc on yield and yield contributing characters of rice cv. BRRI dhan29

Parameter	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Total spikelets panicle^{-1} (no.)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Zn_0	136a	9.22c	6.24b	4.45a	23.6a	136a	123b	15.1a	25.7a	4.65b	6.15b	10.79b	43.01a
$Zn_{2.5}$	139a	10.36b	7.18ab	3.14b	24.2a	139a	124b	14.9a	24.8a	5.20a	6.50ab	11.66ab	44.62a
$Zn_{5.0}$	143a	12.40a	8.06a	1.94c	24.9a	143a	132a	14.0a	25.6a	5.32a	7.05a	11.52a	44.92a
Level of significance	NS	*	*	*	NS	*	*	NS	**	*	*	*	**
$S\bar{x}$	-	0.15	0.16	0.11	-	0.87	1.33	-	0.25	0.08	0.10	0.15	0.37
CV (%)	-	4.21	6.89	10.01	-	3.06	3.17	-	2.99	4.84	4.69	3.83	3.57

Figures in a column having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT at 5% level of probability.

* = Significant at 5% level of probability.

** = Significant at 1% level of probability.

NS = Not significant.

4.1.2 Effect of boron

Application of different levels of B had no significant effect on plant height. The tallest (143cm) and shortest (135cm) plants were obtained from the application of B at 2 kg ha^{-1} and 0 kg ha^{-1}, respectively (Table 4 and Fig. 1). Kendig *et al.* 2005. also reported the similar findings earlier.

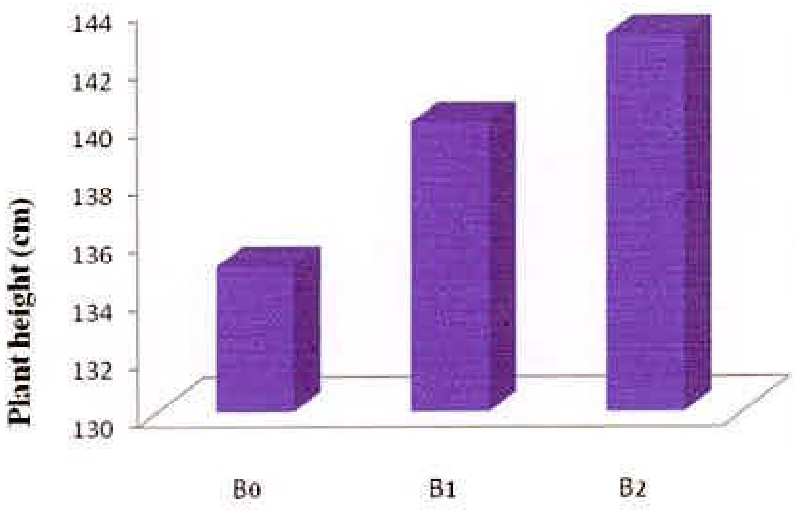

Fig. 1. Effect of boron levels on plant height of BRRI dhan 29

4.1. 3 Interaction effect of zinc and boron

Plant height did vary significantly due to interaction effect of zinc and boron fertilizer at any dates of sampling (Table 5). But, numerically the tallest plant height (152 cm) was obtained at the combination of Zn_5 x B_2 (5 kg Zn ha^{-1} × 2 kg B ha^{-1}). On the other hand, the shortest plant height (134 cm) was obtained at the treatment combination of Zn_0B_0 (0 kg Zn ha^{-1} × 0 kg B ha^{-1}).

4. 2 Total number of tillers $hill^{-1}$ (no.)

4.2.1 Effect of Zn

The effect of Zn on total number of tillers $hill^{-1}$ has showed significant variation. In this case, the highest total number of tillers $hill^{-1}$ (12.4) was found at the highest level of Zn application (5 kg Zn ha^{-1}) and the lowest total number of tillers $hill^{-1}$ (9.22) was found with no zinc application (Table 3 and Fig. 2). This finding coincided with that of Balakrishnan, K. and Natarajaramam, N. 1986.

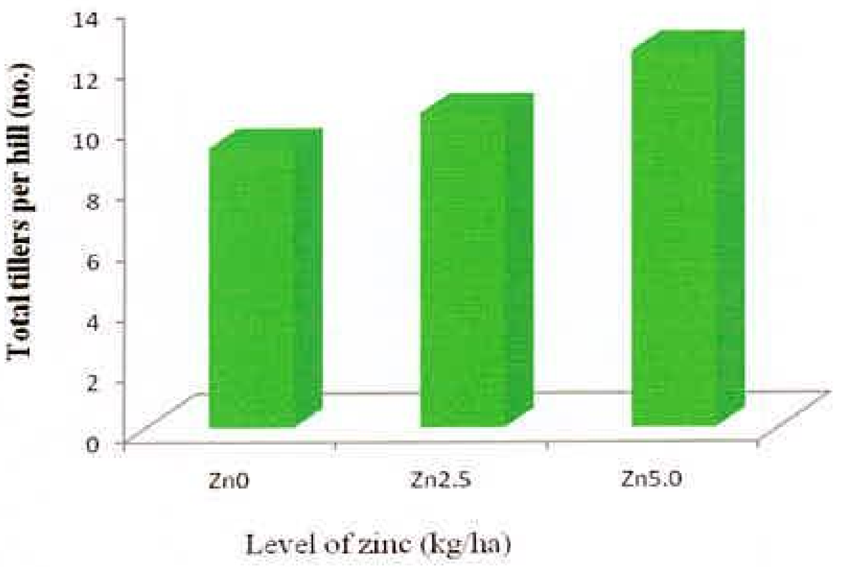

Fig. 2. Effect of zinc on total tillers per hill (no.)

4.2.2 Effect of boron

The result revealed from the Table 2 that the application of different level of boron (B) had significant effect on total number of tillers $hill^{-1}$. The highest total number of tillers $hill^{-1}$ (11.23) was found when applied 2 kg B ha^{-1} and the lowest total number of tillers $hill^{-1}$ (9.93) was found when no B was applied (Table 4). Nayar *et al.* (1983) found that application B showed an increase in all the growth parameters of rice.

Table 4. Effect of boron on yield and yield contributing characters of rice cv. BRRI dhan29

Parameter	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Total spikelets panicle^{-1} (no.)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
B_0	135a	9.93b	6.98a	3.65a	24.1a	135a	121b	15.8a	25.1a	4.75b	6.35a	11.10b	42.80a
B_1	140a	10.82ab	7.13a	2.37ab	24.3a	140a	128ab	14.8a	25.8a	5.15ab	6.61a	11.87ab	43.95a
B_2	143a	11.23ab	7.36a	2.52a	24.5a	143a	131a	13.4a	25.2a	5.26a	6.75a	12.07a	43.80a
Level of significance	NS	*	*	*	NS	*	*	**	NS	*	*	*	NS
$S\bar{x}$	-	0.15	0.16	0.11	-	0.87	1.33	0.60	-	0.10	0.10	0.15	-
CV (%)	-	4.21	6.89	10.01	-	3.06	3.17	12.35	-	4.69	4.69	3.83	-

Figures in a column having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT at 5% level of probability.

* = Significant at 5% level of probability.

** = Significant at 1% level of probability.

NS = Not significant.

4.2.3 Interaction effect of zinc and boron

The interaction effect of Zn and B fertilizer on total number of tillers $hill^{-1}$ was insignificant (Table 5). The highest total tillers $hill^{-1}$ (12.98) was obtained at the treatment combination of Zn_5B_2 (5 kg Zn ha^{-1} × 2 kg B ha^{-1}). Similar result was obtained from Zn_5B_1 (5 kg Zn ha^{-1} × 1 kg B ha^{-1}). Whereas, the lowest total number of tillers $hill^{-1}$ (8.55) was obtained at the combination of Zn_0B_0 (0 kg Zn ha^{-1} 0 kg B ha^{-1}).

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

4.3.1 Effect of zinc

The effect of Zn on the number of effective tillers $hill^{-1}$ was significant (Table 3). Application of 5 kg Zn ha^{-1} produced the highest number of effective tillers $hill^{-1}$ (8.06) which was statistically similar to the amount of 2.56 kg Zn ha^{-1} (7.18). The lowest number of effective tillers $hill^{-1}$ (6.24) was found in the control treatment. The application of Zn increased the number of effective tillers $hill^{-1}$ and the performance of 5 kg Zn ha^{-1} was satisfactory in producing number of tillers $hill^{-1}$.

Khanda, C.M. and Dixit, L. 1996 reported the simliar results.

4.3.2 Effect of boron

Boron had significant effect on the number of effective tillers $hill^{-1}$ of BRRI dhan28. It was observed that all the treatments showed increasing trend on the number of effective tillers $hill^{-1}$ over control. The results showed that the highest effective tillers $hill^{-1}$ (7.36) was found when the dose of 2 kg B ha^{-1} was applied which was statistically different from other boron levels (Table 4). It might be due to more boron received by the plants which enhanced production of effective tillers $hill^{-1}$. On the other hand, the lowest number of effective tillers $hill^{-1}$ (6.98) was found in control treatment when no boron was used. Shorroeks, V.M. 1974 also reported the similar findings earlier.

4.3.3 Interaction effect of zinc and boron

Combination effect of Zn and B did not show significant on the number of effective tillers $hill^{-1}$. It was found that the combination of $Zn_{5.0}\times B_{2.0}$ (5 kg Zn ha^{-1} × 2 kg B ha^{-1}) produced the maximum number of effective tillers $hill^{-1}$ (8.38) and the minimum number of effective tillers $hill^{-1}$ (6.12) was produced by the combination of Zn_0B_0 (0 kg Zn ha^{-1} × 0 kg B ha^{-1}) (Table 5).

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

4.4.1 Effect of zinc

It was observed that the variation due to different levels of zinc was significant for non-effective tillers $hill^{-1}$ at 1% level of probability (Table 3). It was observed from the results that the control treatment (no zinc) produced the maximum number of non-effective tillers $hill^{-1}$(4.45). The minimum number of non-effective tillers $hill^{-1}$ (1.94) was obtained when 3.46 kg Zn ha^{-1} was used and the other treatments showed statistically similar results (Fig. 3).

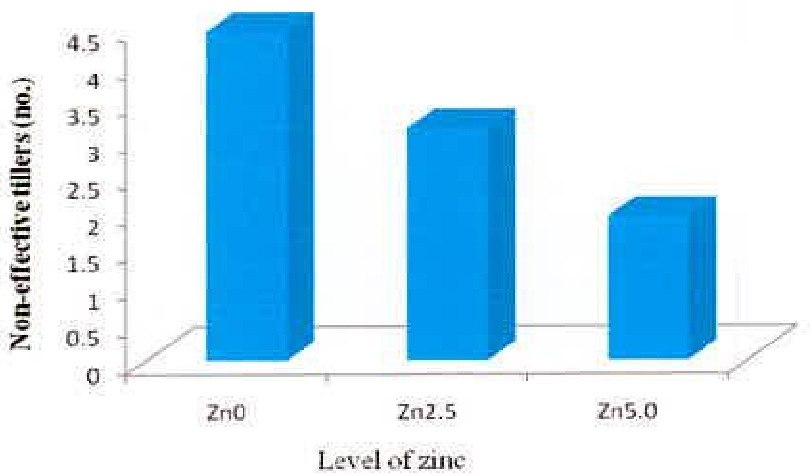

Fig. 3. Effect of zinc on non-effective tillers

4.4.2 Effect of boron

Boron had significant effect on the number of non-effective tillers $hill^{-1}$ of BRRI dhan29 at 1% level of probability (Table 4). From the experimental results, it was observed that control treatment (0 kg B ha^{-1}) produced the maximum number of non-effective tillers $hill^{-1}$ (3.65) differing significantly from the number of non-effective tillers $hill^{-1}$ in the dose of 1 and 2 kg B ha^{-1}. On the other hand, the minimum number of non-effective tillers $hill^{-1}$ (2.52) was obtained when 2 kg B ha^{-1} was applied (Table 4).

4.4.3 Interaction effect of zinc and boron

The variation due to application of different levels of Zn and B was insignificant for non-effective tillers $hill^{-1}$ (Table 5). Non-effective tillers $hill^{-1}$ ranged from 5.20 to 1.36 of which the maximum number of non-effective tillers $hill^{-1}$ (5.20) was produced by the combination of Zn_0B_0 (0 kg Zn ha^{-1} × 0 kg B ha^{-1}) and the minimum number of non-effective tillers $hill^{-1}$ (1.36) was produced by the combination of Zn_5B_2 (5 kg Zn ha^{-1} × 2 kg B ha^{-1}) (Table 5).

Table 5. Interaction effect of zinc and boron on yield and yield contributing characters of rice cv. BRRI dhan29

Interaction (B× Zn)	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Total spikelets panicle^{-1} (no.)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Zn_0 x B_0	134b	8.55e	6.12d	5.20a	23.4a	134b	121c	15.8a	25.7ab	4.25d	6.00d	10.25e	41.46b
Zn_0 x B_1	139ab	9.25de	6.23d	4.50ab	23.5a	139ab	124c	12.2ab	25.8ab	4.83c	6.19cd	11.02de	43.82ab
Zn_0 x B_2	136ab	9.86cd	6.36cd	3.66b	23.8a	136ab	125c	14.2ab	25.5ab	4.86c	6.25bcd	11.11cde	43.74ab
$Zn_{2.5}$ X B_0	136ab	10.00cd	6.96bcd	3.50bc	24.2a	136ab	119c	16.3a	24.1b	5.10abc	6.13cd	11.23cde	45.91a
$Zn_{2.5}$ x B_1	140ab	10.23bcd	7.22bcd	3.40bc	24.2a	140ab	126c	13.9ab	25.9a	5.15abc	6.63abc	11.65cd	44.20a
$Zn_{2.5}$ x B_2	141ab	10.85bc	7.35abc	2.53cd	24.3a	141ab	127bc	14.3ab	24.2b	5.36abc	6.75abc	12.11abc	44.26a
Zn_5 x B_0	136ab	11.25b	7.85ab	2.26de	24.6a	136ab	121c	15.2ab	25.3ab	4.91bc	6.91ab	11.82bcd	41.53b
Zn_5 x B_1	140ab	12.96a	7.95ab	2.20de	25.0a	140ab	135ab	12.2ab	25.4ab	5.46ab	7.00a	12.94a	43.82ab
Zn_5 x B_2	152a	12.98a	8.38a	1.36e	25.3a	152a	141a	11.5b	25.9a	5.56a	7.25a	12.81ab	43.40ab
Level of significance	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	**
S$\bar{x}$	-	-	-	-	-	-	1.33	-	-	-	-	-	0.37
CV (%)	-	-	-	-	-	-	3.17	-	-	-	-	-	3.57

Figures in a column having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT at 5% level of probability.

* = Significant at 5% level of probability.

** = Significant at 1% level of probability. NS = Not significant.

4.5 Panicle length (cm)

4.5.1 Effect of zinc

The length of panicle as affected by different levels of Zn had no significant effect (Table 3). But, numerically, the longest panicle (24.9 cm) was obtained when 5 kg Zn ha^{-1} was used and the shortest (23.6 cm) was found in control treatment (Table 3). The present study is in partial agreement with the result obtained by Balakrishnan and Natarajaratnam (1986) who reported that the highest panicle length was found by the application of 25 kg Zn ha^{-1} and the lowest length in control treatment.

4.5.2 Effect of boron

The panicle length of BRRI dhan28 responded insignificantly to different levels of boron (Table 4). The panicle length ranged from 24.5 cm to 24.1 cm. The results revealed that the longest panicle (24.5 cm) was produced by the application of 2 kg B ha^{-1}. The shortest panicle (24.1 cm) was obtained when no boron was used (Table 4).

4.5.3 Interaction effect of zinc and boron

Panicle length was insignificantly affected by the interaction between Zn and B application (Table 5). The longest panicle (25.3 cm) was produced by the treatment combination of Zn_5B_2 (5 kg Zn ha^{-1} × 2 kg B ha^{-1}) and the shortest (23.4 cm) was obtained when no Zn and B were used (Table 5).

4.6. Total spikelets panicle^{-1} (no.)

4.6.1 Effect of zinc

The results revealed from the Fig. 4, that the application of different levels of Zn had significant effect on total spikelets panicle^{-1}. The highest total spikelets panicle^{-1} (143) was found when 5 kg Zn ha^{-1} was applied and the lowest total spikelets panicle^{-1} (136) was found in the treatment of 0 kg Zn ha^{-1}.

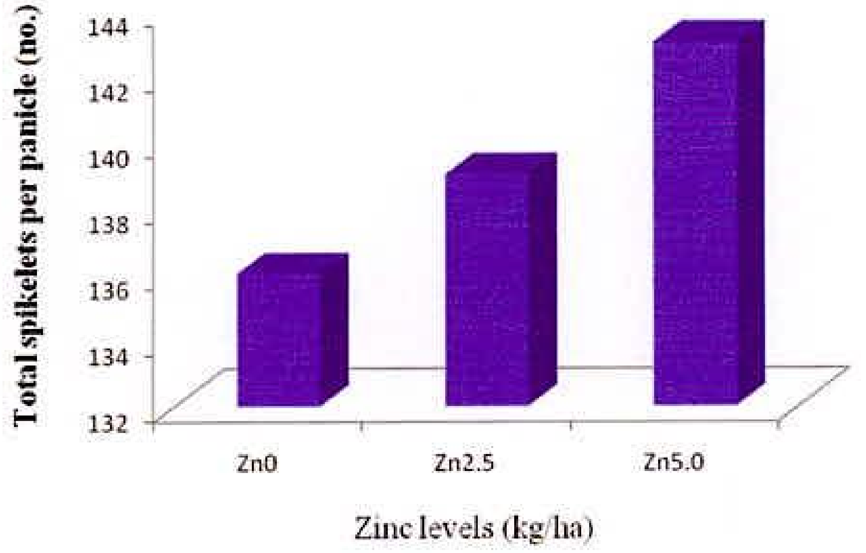

Fig. 4. Effect of zinc on the total spikelets per panicle (no.)

4.6.2 Effect of boron

Results showed that the total spikelets panicle^{-1} of BRRI dhan29 was influenced significantly by the different levels of boron (Fig. 5). The total spikelets panicle^{-1} was the highest (143) when the highest dose of boron (2 kg B ha^{-1}) was used which was statistically different from other boron levels. The lowest total spikelets panicle^{-1} (135) was found when no boron was used (Table 4).

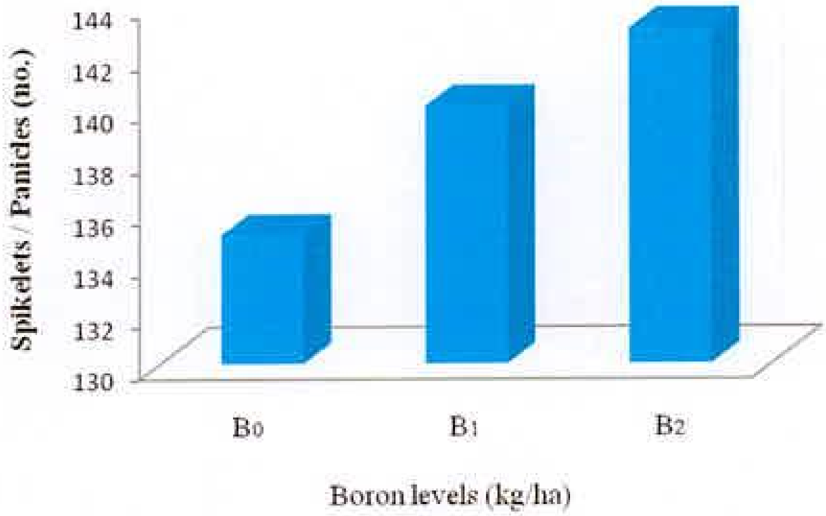

Fig. 5. Effect of boron levelson the total spikelets/panicle

4.6.3 Interaction effect of boron and zinc

Total spikelets panicle^{-1} was insignificantly affected by the interaction between Zn and B application (Table 5). The highest total spikelets panicle^{-1} (152) was found in the treatment combination of Zn_5B_2 (5 kg Zn ha^{-1} × 2 kg B ha^{-1}). The lowest total spikelets panicle^{-1} (134) was found in the treatment combination of Zn_0B_0 (0 kg Zn ha^{-1} × 0 kg B ha^{-1}) (Table 5)

4.7. Grains panicle^{-1}

4.7.1 Effect of zinc

The variation of the number of grains panicle^{-1} due to Zn application at different levels was significant at 1% level of probability (Table 3). The results indicate that the highest number of grains panicle^{-1} (132) was obtained when 5 kg Zn ha^{-1} was applied and the lowest (123) was found in the control treatment.

4.7.2 Effect of boron

The results revealed that the number of grains panicle^{-1} was highly significant due to the application of B at different levels (Table 4). It was observed that the number of grains panicle^{-1} varied 131 to 120 among which the highest number of grains panicle^{-1} (131) was obtained when 2 kg B ha^{-1} was applied and the lowest was obtained with no application of boron (Fig. 6).

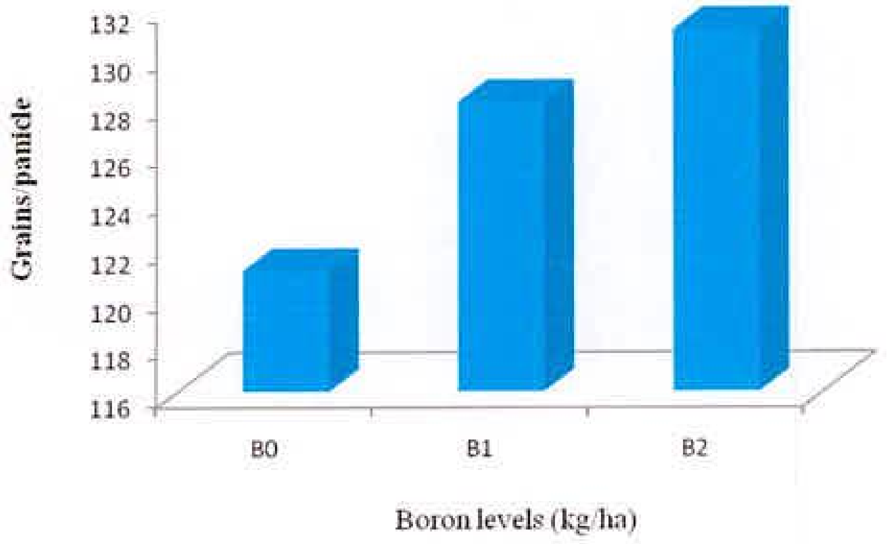

Fig. 6. Effect of boron levels on grains/panicle of BRRI dhan29

4.7.3 Interaction effect of zinc and boron

The combined application of Zn and boron at different levels had a significant effect on the total grains panicle^{-1} (Fig. 8). The results revealed that the number of grains panicle^{-1} varied from 141 to 122 due to the effect of zinc and boron application. The highest number of grains panicle^{-1} was obtained by the treatment combination of Zn_5B_2 (5 kg Zn ha^{-1} × 2 kg B ha^{-1}). On the other hand, the lowest number of grains panicle^{-1} was found in the control treatment where Zn and B were not used (Table 5)

4.8 Sterile spikelets panicle^{-1}

4.8.1 Effect of zinc

A significant variation was found in the number of sterile spikelets panicle^{-1} of BRRI dhan29 due to the application of Zn at different levels (Table 3). The highest number of sterile spikelets panicle^{-1} (15.1) was obtained in the treatment Zn_0 and the lowest (14.0) was obtained from the treatment Zn_5 (5 kg Zn ha^{-1}).

4.8.2 Effect of boron

The variation in the number of sterile spikelets panicle^{-1} due to B application was significant at 1% level of probability. Number of sterile spikelets panicle^{-1} as affected by boron application has been presented in Fig. 7. The results indicate that the number of sterile spikelets panicle^{-1} varied from 15.8 to 13.4 due to the effect of boron application. The highest number of sterile spikelets panicle^{-1} was produced by the control treatment. The lowest number of sterile spikelets panicle^{-1} was found in the treatment B_2 where 2 kg B ha^{-1} was applied.

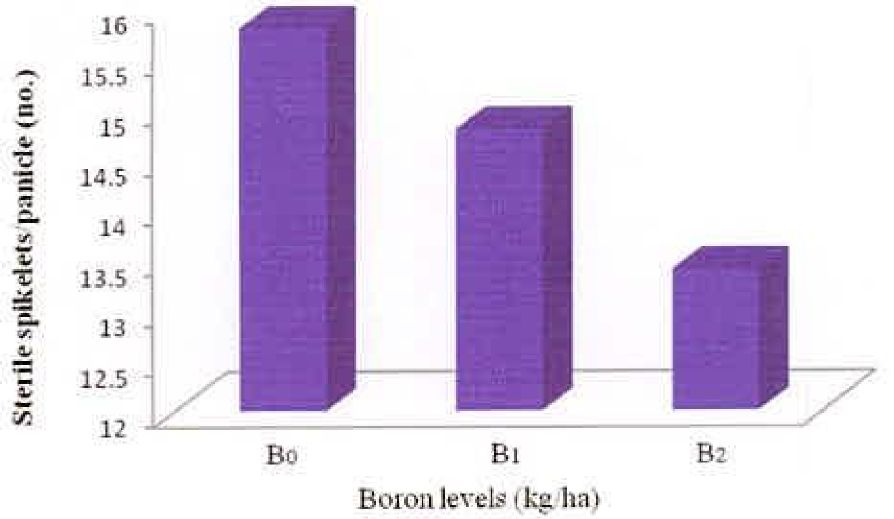

Fig. 7. Effect of boron levels on sterile spikelets/panicle of BRRI dhan29

4.8.3 Interaction effect of zinc and boron

The combination of zinc and boron application at different levels had no significant effect on sterile spikelets panicle^{-1}. The highest number of sterile spikelets panicle^{-1} (16.4) was produced by the interaction of $Zn_{2.5}B_0$ treatment. On the contrary, the lowest number of sterile spikelets panicle^{-1} (11.5) was produced by the treatment combination of Zn_5B_2 (5 kg Zn ha^{-1} × 2 kg B ha^{-1}) where the maximum doses were applied (Table 5).

4.9 1000-grain weight (g)

4.9.1 Effect of zinc

The application of different levels of Zn significantly influenced the 1000-grain weight of BRRI dhan29. The highest 1000-grain weight (25.6 g) was recorded in the treatment of Zn_5 (5 kg Zn ha^{-1}). On the other hand, the lowest 1000-grain weight (24.7 g) was found in the treatment of Zn_0 (0 kg Zn ha^{-1}) (Table 3).

Balakrishnan and Natarajaratnam (1986) also reported that the application of zinc increased the 1000-grain weight of rice.

4.9.2 Effect of Boron

The application of different levels of B was not significantly influenced the 1000-grain weight of BRRI dhan29 (Table 4). It was revealed that 1000-grain weight varied from 25.1 to 25.2 g due to effect of different levels of B application. The highest 1000-grain weight was found when 2 kg B ha^{-1} was applied. The lowest 1000-grain weight was found in the treatment of B_0 (51 kg B ha^{-1}). Islam (1978) reported that B application increased 1000-grain weight of rice.

4.9.3 Interaction effect of boron and zinc

The interaction effect of Zn and B application had no significant effect on 1000-grain weight of BRRI dhan29 (Table 5). The results indicate that 1000-grain weight varied from 26.0 to 25.8 g (Table 5). The highest 1000-grain weight was produced when the highest level of B and Zn were applied. On the contrary, the lowest 1000-grain weight was produced by the interaction of the treatment of $Zn_{2.5} \times B_0$ (2.5 kg Zn ha^{-1} × 0 kg B ha^{-1}).

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

4.10.1 Effect of zinc

The application of different levels of Zn significantly influenced the grain yield of BRRI dhan29 (Fig. 8). It appeared that the grain yield of rice varied from 5.32 to 4.65 t ha^{-1}. Maximum grain yield was recorded in the treatment of Zn_5 (5 kg Zn ha^{-1}). Minimum grain yield was recorded in the control treatment. The increase in grain yield due to the application of Zn was reported by many investigators (Das *et al*., 1993; and Sharma *et al*., 1999).

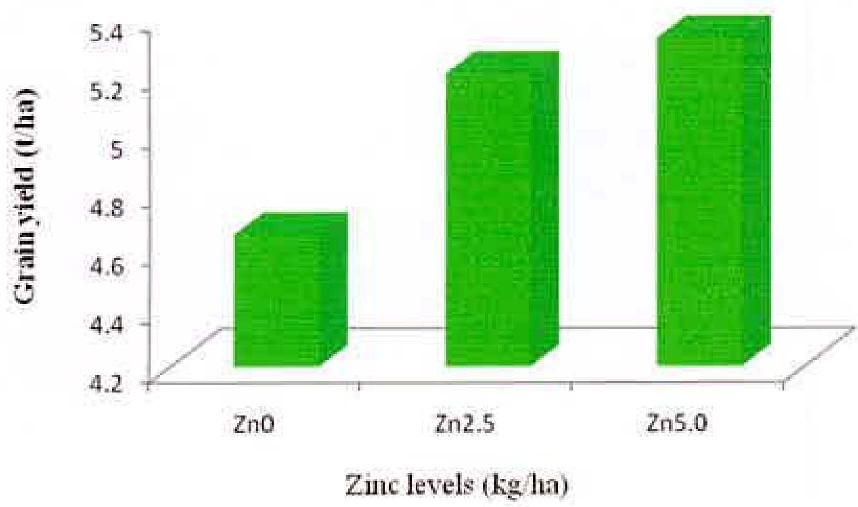

Fig. 8. Effect of zinc level on the grain yield of BRRI dhan29

4.10.2 Effect of boron

Grain yield is the ultimate object of rice cultivation. The yield of rice is mainly dependent on the number of effective tillers hill^{-1}, number of grains panicle^{-1}, weight of individual grains or 1000-grain weight. Analysis of variance showed that boron had a significant effect on grain yield (Table 4). From the results, it was observed that grain yield ranged from 5.26 to 4.75 t ha^{-1} due to the application of different levels of boron. The highest grain yield was produced by the application of 2 kg S ha^{-1}. The lowest grain yield was recorded when no boron was applied (Fig 9). Rodrigues *et al.* also similar result earlier.

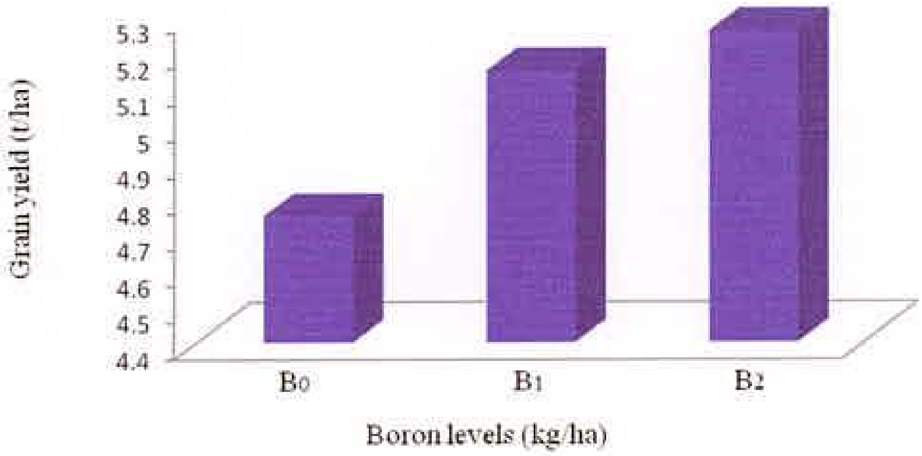

Fig. 9. Effect of boron levels on the grain yield of BRRI dhan29

4.10.3 Interaction effect of zinc and boron

The interaction effect of zinc and boron application had no significant effect on grain yield (Table 5). But numerically, the highest grain yield (5.56 t ha^{-1}) was obtained from the treatment combination of Zn_5B_2 (5 kg Zn ha^{-1} × 2 kg B ha^{-1}) and the lowest grain yield (4.25 t ha^{-1}) was obtained from the control treatment (0 kg Zn ha^{-1} × 0 kg B ha^{-1}).

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

4.11.1 Effect of zinc

Straw yield of BRRI dhan29 was significant due to application of different levels of Zn (Table 1). From the result it was observed that the straw yield range from 7.053 to 6.147 t ha^{-1}. The highest straw yield was recorded in the treatment of Zn_5. The lowest straw yield was found in the control treatment. Similar results were also reported by Singh *et al* (1991) and Jahiruddin *et al* (1983).

4.11.2 Effect of boron

The effect of different levels of B on straw yield was highly significant (Table 4). It was observed that the highest straw yield (6.75 t ha^{-1}) was obtained with the application of the highest dose of boron (B_2). The lowest straw yield (6.35 t ha^{-1}) was found in the control treatment. Rodrigues *et al.* and Shorroeks, V.M. 1974 also reported the similar findings earlier.

4.11.3 Interaction effect of boron and zinc

The analysis of variance shows that the interaction effect of B and Zn at the different levels was not significant on the straw yield (Table 5). From the result, it was observed that the highest straw yield (7.25 t ha^{-1}) was produced by the treatment combination of Zn_5B_2 (5 kg Zn ha^{-1} × 2 kg B ha^{-1}). The lowest straw yield (6.00 t ha^{-1}) was recorded in the control combination.

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

4.12.1 Effect of zinc

Biological yield of BRRI dhan29 responded significantly due to application of different levels of Zn (Table 3). The highest biological yield (11.52 t ha^{-1}) was recorded from the treatment of Zn_5 (5 kg Zn ha^{-1}) which was statistically identical with the treatments of $Zn_{2.5}$. On the other hand, the lowest biological yield (10.79 t ha^{-1}) was found in the control treatment (Table 3).

4.12.2 Effect of boron

Significant response was observed in biological yield due to application of different levels of B on BRRI dhan29 (Table 4). The biological yield of BRRI dhan29 varied from 12.07 to 11.10 t ha^{-1}. The highest biological yield was obtained from the treatment of B_2 (2 kg B ha^{-1}) and the lowest obtained in the control treatment (Table 4).

4.12.3 Interaction effect of boron and zinc

The analysis of variance shows no significant effect of interaction of Zn and B at the different levels. From the result, it was observed that the highest biological yield (12.94 t ha^{-1}) was produced by the treatment combination of Zn_5B_1 (5 kg Zn ha^{-1} × 1 kg B ha^{-1}). The lowest biological yield (10.25 t ha^{-1}) was produced by the treatment combination of Zn_0B_0 (0 kg Zn ha^{-1} × 0 kg B ha^{-1}) (Table 5).

4.13 Harvest index (%)

4.13.1 Effect of zinc

Harvest index was not significantly influences by the application of Zn at different levels. It was observed that numerically, the highest harvest index (44.92%) was recorded in the treatment of Zn_5. On the contrary, the lowest harvest index (43.01%) was found in the treatment of Zn_0 (Table 3).

4.13.2 Effect of boron

Application of different levels of B had insignificant effect on harvest index (Table 4). From the results, it was evident that the treatment of B_1 (1 kg B ha^{-1}) produced the highest harvest index (43.95%). The lowest harvest index (42.80%) was obtained in the treatment of B_0.

4.13.3 Interaction effect of boron and zinc

The interaction effect of Zn and B at different levels showed significant effect on harvest index (Table 5). It reveals that the highest harvest index (45.91%) was produced by the interaction of $Zn_{2.5}$ X B_0 and the lowest harvest index (41.46%) was found in the treatment of Zn_0 x B_0.

4.14 Contents and uptake of zinc (Zn) and boron (B) in the grain and straw of BRRI dhan29 as affected by integrated use of zinc and boron

4.14.1 Effect of zinc on zinc and boron concentrations in grain and straw of BRRI dhan29

4.14.1.1 Effect of zinc on zinc concentrations in grain and straw of BRRI dhan29

Zinc concentration of grain and straw was significantly influenced by the application levels of zinc (Table 6). The highest zinc concentration in both grain (26.50 %) and straw (26.73 %) of BRRI dhan29 was recorded in $Zn_{5.0}$ (5 kg/ha), which showed statistically different result with $Zn_{2.5}$ and Zn_0 treatments. On the other hand, the lowest zinc concentration in BRRI dhan29 grain (16.28 %) and straw (20.87 %) was recorded in Zn_0 treatment where no zinc was applied.

Table 6. Effect of zinc fertilizer on the zinc concentrations in grain and straw of BRRI dhan29

Zinc fertilizers (kg/ha)	Zinc concentration (ppm)	
	Grain	Straw
Z_0	16.28 c	20.87 c
$Z_{2.5}$	20.46 b	22.26 b
$Z_{5.0}$	26.50 a	26.73 a
$LSD_{0.05}$	**0.80**	**0.04**

4.14.1.2 Effect of zinc on boron concentrations in grain and straw of BRRI dhan29

Boron concentration of grain and straw was significantly influenced by the application levels of zinc (Table 7). The highest boron concentration in both grain (22.86%) and straw (25.32%) of BRRI dhan29 was recorded in $Zn_{5.0}$ (5 kg/ha), which showed statistically different result with $Zn_{2.5}$ and Zn_0 treatments. On the other hand, the lowest zinc concentration in BRRI dhan29 grain (19.48 %) and straw (21.20 %) was recorded in Zn_0 treatment where no zinc was applied.

Table 7. Effect of zinc fertilizer on the boron concentrations in grain and straw of BRRI dhan29

Zinc fertilizers (kg/ha)	Boron concentration (ppm)	
	Grain	Straw
Z_0	19.48 c	21.20 c
$Z_{2.5}$	20.88 b	23.33 b
$Z_{5.0}$	22.86 a	25.32 a
$LSD_{0.05}$	**0.80**	**0.04**

4.14.1.3 Combined effect of zinc and boron on zinc concentrations in grain and straw of BRRI dhan29

Significant effect of combined application of different doses of zinc and boron fertilizer on the zinc concentration was observed in grain and straw of BRRI dhan29 (Table 8). The highest concentration of zinc in the grain (29.29 %) and straw (29.65 %) was recorded in the treatment combination of Zn_5B_1. On the other hand, the lowest zinc concentration in grain (15.49 %) and straw (18.11 %) was found in Zn_0B_0.

Table 8. Combined effect of zinc and boron on zinc concentrations in grain and straw of BRRI dhan29

Zn × B Fertilizer (kg/ha)	Zn concentration (ppm)	
	Grain	Straw
Zn_0 x B_0	15.49 g	18.11 g
Zn_0 x B_1	16.39 fg	21.32 f
Zn_0 x B_2	16.95 f	23.19 d
$Zn_{2.5}$ X B_0	18.91 e	21.36 f
$Zn_{2.5}$ x B_1	20.11 e	22.29 e
$Zn_{2.5}$ x B_2	22.35 d	23.13 d
Zn_5 x B_0	24.0c5	24.14 c
Zn_5 x B_1	26.15 b	26.39 b
Zn_5 x B_2	29.29 a	29.65 a
$LSD_{0.05}$	**1.38**	**0. 07**

4.14.2.1 Effect of boron on zinc concentrations in grain and straw of BRRI dhan29

Zinc concentration both grain and straw was not significantly influenced by application levels of boron (Table 9). The highest zinc concentration in BRRI dhan29 both grain (20.22 %) and straw (16.71 %) was recorded in B_2 (1 kg/ha), which showed statistically similar result with other treatments. On the other hand, the lowest zinc concentration in BRRI dhan29 both grain (18.12 %) and straw (12.91 %) was recorded in B_0 treatment where no boron was applied.

Table 9. Effect of boron fertilizer on the zinc concentrations in grain and straw of BRRI dhan29

B fertilizers (kg/ha)	Zn concentration (ppm)	
	Grain	Straw
B_0	18.12 c	12.91 c
B_1	19.02 b	14.22 b
B_2	20.22 a	16.71 a
$LSD_{0.05}$	**0.75**	**1.01**

4.14.2.2 Effect of boron on boron concentrations in grain and straw of BRRI dhan29

Boron concentration of grain and straw was significantly influenced by the application levels of boron (Table 10). The highest boron concentration in both grain (21.52%) and straw (18.33%) of BRRI dhan29 was recorded in B_2 (2 kg ha^{-1}), which showed statistically different result with B_1 and B_0 treatments. On the other hand, the lowest zinc concentration in BRRI dhan29 grain (16.95 %) and straw (9.00 %) was recorded in B_0 treatment where no boron was applied.

Table 10. Effect of boron on boron concentrations in grain and straw of BRRI dhan29

B fertilizers (kg/ha)	B concentration (ppm)	
	Grain	Straw
B_0	16.95 c	9.00 c
B_1	18.88 b	16.02 b
B_2	21.52 a	18.83 a
$LSD_{0.05}$	**0.75**	**1.01**

4.14.2.3 Combined effect of zinc and boron fertilizers on the boron concentrations in grain and straw of BRRI dhan29

Significant effect of combined application of different doses of zinc and boron fertilizer on the boron concentration was observed in both grain and straw of BRRI dhan29 (Table 11). The highest concentration of boron in the both grain (23.50 %) and straw (12.91 %) was recorded in the treatment combination of Zn_5B_2. On the other hand, the lowest boron concentration in both grains (16.05 %) and straw (7.95 %) was found in Zn_0B_0.

Table 11. Combined effects of zinc and boron fertilizers on the boron concentrations in grain and straw of BRRI dhan29

Zn × B Fertilizer (kg/ha)	B concentration (ppm)	
	Grain	Straw
Zn_0 x B_0	16.05 f	7.95 f
Zn_0 x B_1	18.10 d	14.16 d
Zn_0 x B_2	20.22 bc	16.63 bc
$Zn_{2.5}$ X B_0	17.15 ef	8.92 ef
$Zn_{2.5}$ x B_1	19.05 cd	15.79 cd
$Zn_{2.5}$ x B_2	20.85 b	17.95 b
Zn_5 x B_0	17.65 e	10.12 e
Zn_5 x B_1	19.50 c	18.10 b
Zn_5 x B_2	23.50 a	21.91 a
$LSD_{0.05}$	**1.31**	**1.75**

4.15.1 Effect of zinc and boron on zinc and boron uptake in grain and straw of BRRI dhan29

4.15.1.1 Effect of zinc on zinc uptake in grain and straw of BRRI dhan29

Zinc uptake of grain and straw was significantly influenced by application levels of zinc (Table 12). The highest zinc uptake in BRRI dhan29 grain (0.160 kg ha^{-1}) and straw (0.210 kg ha^{-1}) was recorded in Zn_2 (5 kg ha^{-1}) treatment. On the other hand, the lowest Zn uptake in BRRI dhan29 grain (0.082 kg ha^{-1}) and straw (0.116 kg ha^{-1}) was recorded in Zn_0 treatment where no zinc was applied.

Table 12. Effect of zinc on the zinc uptake in the grain and straw

Zn –fertilizers (kg/ha)	Zn uptake (kg ha^{-1})	
	Grain	**Straw**
Zn_0	0.082 c	0.116 c
Zn_1	0.123 b	0.171 b
Zn_2	0.160 a	0.210 a
$LSD_{0.05}$	**0.001**	**0.001**

4.15.1.2 Effect of zinc on boron uptake in grain and straw of BRRI dhan29

Boron uptake of grain and straw was significantly influenced by application levels of zinc (Table 13). The highest B uptake of BRRI dhan29 in both grain (0.1343 kg ha^{-1}) and straw (0.1820 kg ha^{-1}) was recorded in Zn_2 (5 kg ha^{-1}) treatment. On the other hand, the lowest B uptake in BRRI dhan29 both grain (0.1063 kg ha^{-1}) and straw (0.1477 kg ha^{-1}) was recorded in Zn_0 treatment where no zinc was applied.

Table 13. Effect of zinc on boron uptake in grain and straw of BRRI dhan29

Zn- Fertilizer (kg/ha)	B uptake (kg ha^{-1})	
	Grain	**Straw**
Zn_0	0.1063 c	0.1477 c
$Zn_{2.5}$	0.1243 b	0.1678 b
$Zn_{5.0}$	0.1343 a	0.1820 a
$LSD_{0.05}$	**0.001**	**0.001**

4.15.1.3 Combined effect of zinc and boron fertilizers on zinc uptake in grain and straw of BRRI dhan29

Significant effect of combined application of different doses of zinc and boron fertilizer on the Zn uptake was observed in BRRI dhan29 (Table 14). The highest uptake of Zn in both the grain (0.175 kg ha^{-1}) and straw (0.230 kg ha^{-1}) was recorded in the treatment combination of Zn_5B_2. On the other hand, the lowest Zn uptake in both grain (0.072 kg ha^{-1}) and straw (0.098 kg ha^{-1}) was found in Zn_0B_0.

Table 14. Combined effect of zinc and boron fertilizers on zinc uptake in grain and straw of BRRI dhan29

Zn× B Fertilizer	Zn uptake (kg ha^{-1})	
	Grain	Straw
Zn_0 x B_0	0.072 i	0.098 i
Zn_0 x B_1	0.085 h	0.119 h
Zn_0 x B_2	0.089 g	0.131 g
$Zn_{2.5}$ X B_0	0.101 f	0.156 f
$Zn_{2.5}$ x B_1	0.129 e	0.169 e
$Zn_{2.5}$ x B_2	0.139 d	0.185 d
Zn_5 x B_0	0.146 c	0.189 c
Zn_5 x B_1	0.159 b	0.212 b
Zn_5 x B_2	0.175 a	0.230 a
$LSD_{0.05}$	**0.002**	**0.002**

4.15.2.1 Effect of boron on zinc uptake in grain and straw of BRRI dhan29

Zinc uptake of grain and straw was significantly influenced by application levels of boron (Table 15). The highest Zn uptake of BRRI dhan29 in both grain (0.0887 kg ha^{-1}) and straw (0.077 kg ha^{-1}) was recorded in B_2 (2 kg ha^{-1}) treatment. On the other hand, the lowest Zn uptake in BRRI dhan29 both grain (0.0677 kg ha^{-1}) and straw (0. 054 kg ha^{-1}) was recorded in B_0 treatment where no boron was applied.

Table15. Effect of boron on zinc uptake in grain and straw of BRRI dhan29

B fertilizers (kg/ha)	Zn uptake (kg ha^{-1})	
	Grain	Straw
B_0	0.0677 c	0.054 c
B_1	0.0740 b	0.058 b
B_2	0.0887 a	0.077 a
$LSD_{0.05}$	**0.001**	**0.001**

4.15.2.3 Effect of boron on boron uptake in grain and straw of BRRIdhan29

Boron uptake of grain and straw was significantly influenced by application levels of boron (Table 16). The highest B uptake of BRRIdhan29 in both grain (0.089kg ha^{-1}) and straw (0.083 kg ha^{-1}) was recorded in B_2 (2 kg ha^{-1}) treatment. On the other hand, the lowest B uptake in BRRIdhan29 both grain (0.060 kg ha^{-1}) and straw (0. 440 kg ha^{-1}) was recorded in B_0 treatment where no boron was applied.

Table 16. Effect of boron on boron uptake in grain and straw of BRRI dhan29

B fertilizers (kg/ha)	B uptake (kg ha^{-1})	
	Grain	Straw
B_0	0.060 c	0.440 c
B_1	0.080 b	0.062 b
B_2	0.089 a	0.083 a
$LSD_{0.05}$	**0.001**	**0.001**

4.15.2.3 Combined effect of zinc and boron fertilizers on B uptake in grain and straw of BRRI dhan29

Significant effect of combined application of different doses of zinc and boron fertilizer on the B uptake was observed in BRRI dhan29 (Table 17). The highest uptake of B in both the grain (0.109 kg ha^{-1}) and straw (0.113 kg ha^{-1}) was recorded in the treatment combination of Zn_5B_2. On the other hand, the lowest B uptake in both grain (0.053 kg ha^{-1}) and straw (0.037 kg ha^{-1}) was found in Zn_0B_0.

Table 17. Combined effect of zinc and boron fertilizers on B uptake (kg ha^{-1}) in the grain and straw

Zn× B Fertilizer (kg/ha)	B uptake (kg ha^{-1})	
	Grain	Straw
Zn_0 x B_0	0.053 h	0.037 g
Zn_0 x B_1	0.073 e	0.058 d
Zn_0 x B_2	0.077 d	0.067 c
$Zn_{2.5}$ X B_0	0.061 g	0.045 f
$Zn_{2.5}$ x B_1	0.078 d	0.059 d
$Zn_{2.5}$ x B_2	0.083 c	0.071 b
Zn_5 x B_0	0.066 f	0.049 e
Zn_5 x B_1	0.091 b	0.068 c
Zn_5 x B_2	0.109 a	0.113 a
$LSD_{0.05}$	**0.002**	**0.002**

4.16 Nutrient status of soil after harvest of BRRI dhan29 as affected by zinc and boron

4.16.1 Soil pH

Integrated application of zinc and boron showed insignificant effect respecting soil pH after harvest of BRRIdhan29 is presented in Table 18. Soil pH was varied significantly at 5.50 to 5.95. The highest pH of the soil (5.95) was recorded in treatment Zn_5B_0 and the lowest pH value (5.50) was observed in control treatment (Zn_0B_0).

4.16.2 Organic matter content of soil (%)

A significant variation was observed in organic matter content in soil after harvest of BRRI dhan29. Among the different treatments the highest organic matter content (1.38%) was obtained where 5.0 kg Zn and 2 kg B were applied which was followed by the treatment of Zn_5B_1 (1.28% OM). On the other hand, the lowest OM content (0.97%) was observed in the control (Zn_0B_0) treatment (Table 18).

4.6.3 Total nitrogen content of soil (%)

Total nitrogen content of soil after harvest of BRRI dhan29 was influenced by different doses of zinc and boron showed a statistically significant variation (Table 18). The highest N content (0.16%) of soil was observed in case of treatment Zn_5B_2 (5 kg Zn & 2 kg B) and it was followed by the treatment Zn_5B_1, Zn_0B_1 and $Zn_{2.5}B_1$ with the value of 1.14% in both the cases. In contrast, the lowest N content (0.11%) was obtained in the Zn_5B_0 treatment where no fertilizer was applied.

4.16.4 Phosphorous content of soil (ppm)

Different combinations of zinc and boron on the available phosphorous content of soil after harvest of BRRI dhan29 showed significant variation is presented in Table 18. It was revealed from the study that the performances of the most of the treatment differ significantly from each other. Among the different treatments, Zn_5B_2 treatment showed the highest P content (23.13 ppm) in soil after the harvest of BRRI dhan29. On the other hand, the lowest P content (15.15 ppm) was observed in the treatment Zn_0B_0 receiving no fertilizer.

4.16.5 Potassium content of soil (meq 100 g soil^{-1})

The combine effect of zinc and boron showed significant differences in respect of K content of soil after harvest of BRRI dhan29 (Table 18). However, the lowest K content of crop-harvested soil (0.11 meq 100 g soil^{-1}) was recorded in the treatment Zn_0B_0 (control) and the highest K content (0.22 meq 100 g soil^{-1}) was recorded with Zn_5B_2 followed by 0.19 meq 100 g soil^{-1} in treatment Zn_5B_1.

4.16.6 Sulphur content of soil (ppm)

Statistically significant difference was obtained in the sulphur content of soil after harvest of BRRI dhan29. Application of 5 kg Zn and 2 kg B showed the highest S content (22.23 ppm) in soil. The next highest S content (21.44 ppm) was found in treatment (Zn_0B0_2). On the contrary, the lowest S content (15.50 ppm) was observed in the Zn_0B_0 treatment where no fertilizer was applied (Table 18).

4.16.7 Zinc content of soil (ppm)

Significant variation was observed in the combine effect of zinc and boron in respect of zinc content of soil. Among the 12 treatments Zn_5B_2 shows the highest

Zn content (3.48 ppm) in the soil after harvest of BRR dhan29 when the lowest Zn content (1.00 ppm) was observed in control treatment (Table 18).

4.16.8 Boron content of soil (ppm)

Significant variation was observed in the combine effect of zinc and boron in respect of boron content of soil. Among the 12 treatments Zn_5B_2 shows the highest Zn content (0.19 ppm) in the soil after harvest of BRRI dhan29 when the lowest Zn content (0.09 ppm) was observed in control treatment (Table 18)

Table 18. Combined effect of zinc and boron on the pH, OM, total N, available P, K, S and Zn in the soil after harvest of BRRI dhan29

Treatment combination (Zn×B)	pH	OM	Total N	Available P	Available K	Available S	Available Zn	Available B
$Zn_0 \times B_0$	5.50	0.97	0.13	15.15	0.11	15.50	1.00	0.09
$Zn_0 \times B_1$	5.52	0.99	0.14	16.00	0.12	16.12	1.28	0.15
$Zn_0 \times B_2$	5.60	0.98	0.12	16.15	0.15	21.44	1.22	0.17
$Zn_{2.5} \times B_0$	5.80	1.10	0.13	15.21	0.14	17.01	1.18	0.10
$Zn_{2.5} \times B_1$	5.89	1.27	0.14	16.41	0.17	20.47	2.05	0.12
$Zn_{2.5} \times B_2$	5.87	1.18	0.15	17.79	0.19	21.46	2.85	0.18
$Zn_5 \times B_0$	5.95	1.18	0.11	16.32	0.15	18.54	2.94	0.10
$Zn_5 \times B_1$	5.80	1.28	0.14	21.01	0.19	18.12	3.00	0.13
$Zn_5 \times B_2$	5.64	1.38	0.16	23.13	0.22	22.23	3.48	0.19
Level of significance	NS	**	**	**	**	*	*	**
CV(%)	3.09	2.77	2.19	3.44	3.45	3.21	3.55	2.39

* = Significant at 5% level, ** = Significant at 1% level

NS = Not significant, CV= Co-efficient of variation

In this study it was observed that treatment Zn_3B_2 (5 kg Zn and 2 kg B) always produce better performance over the growth parameters and yield. So this treatment combination of zinc and boron may be helpful for BRRI dhan29 cultivation.

CHAPTER 5
SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

An experiment was conducted at the Soil Science Field of Sher-e-Bangla Agricultural University Farm, Dhaka during the boro season from November 1 to March 15, 2008, to study the effect of zinc and boron levels on growth and yield contributing characters of BRRI dhan29 in red-terrace soils. The soil of the experimental filed belongs to Madhupur tract representing Tejgaon series. The experiment was laid out in a Randimized Complete Block Design with three replications. The experiment consists of three levels of zinc viz. 0, 2.5 and 5.0 kg ha^{-1} and three levels of boron viz. 0, 1 and 2 kg ha^{-1}. The tested rice variety was BRRI dhan29. There were 27 plots (3 × 3), each plot measuring 4m×2.5m. All nutrients except N were added to soil at a time during final land preparation. Nitrogen was applied in three equal splits, the first application was made 15 days after transplanting (DAT), the second application was made 32 days after transplanting (DAT) and the third application was made 52 days after transplanting (DAT).

All management practices and intercultural operations such as weeding, irrigation and pest management were done as and when necessary. Five hills from each plot were selected randomly at harvest and tagged for taking data of plant height, total number of tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, panicle length, number of grains $panicle^{-1}$, number of sterile spikelets $panicle^{-1}$, 1000 grain yield (t ha^{-1}), grain yield (t ha^{-1}), straw yield, biological yield (t ha^{-1}) and harvest index (HI%)

Grain yield t ha^{-1} and straw yield t ha^{-1} were recorded from 25 hills ($1m^2$) and grain moisture was recorded and grain yield was expressed at 14% moisture. Straw yield was expressed on oven dry basis. The data recorded on plant parameters and statistically analyzed and the mean differences were adjudged by LSD test.

The Zn fertilizer treatments differed significantly on total number of tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, panicle length, total spikelets $panicle^{-1}$, number of grains $panicle^{-1}$, number of sterile spikelets $panicle^{-1}$, 1000-grain yield (t ha^{-1}), grain yield (t ha^{-1}), straw yield, biological yield (t ha^{-1}) and harvest index (HI%) except plant height (cm), panicle length (cm) and sterile spikelets $panicle^{-1}$.

The highest number of total number of tillers $hill^{-1}$(12.4), number of effective tillers $hill^{-1}$(8.06), panicle length (24.9 cm), number of grains $panicle^{-1}$ (132), 1000-grain yield (26.0g), grain yield (5.32 t ha^{-1}), straw yield (7.05 t ha^{-1}), biological yield (11.52 t ha^{-1}) and harvest index (44.92 %) were found in $Z_{5.0}$ level except number of non-effective tillers $hill^{-1}$(4.45), number of sterile spikelets $panicle^{-1}$ (15.1) which were found in Zn_0 level.

Boron fertilization significantly influenced total number of tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, number of sterile spikelets $panicle^{-1}$, grain yield (t ha^{-1}), straw yield, biological yield (t ha^{-1}) and harvest index (HI%) except plant height (cm), panicle length (cm) and 1000-grain weight. The highest number of total number of tillers $hill^{-1}$(11.23), number of effective tillers $hill^{-1}$ (7.36), number of grains $panicle^{-1}$ (131), 1000-grain yield (25.2g), grain yield (5.26 t ha^{-1}), straw yield (6.75 t ha^{-1}), biological yield (12.07 t ha^{-1}) and harvest index (44.92 %) were found in B_2 level except number of non-effective tillers $hill^{-1}$ (3.65), number of sterile spikelets $panicle^{-1}$ (15.81) which were found in B_0 level and harvest index (43.95%) in B_1 level.

The interaction between zinc and boron had significant effect on grains $panicle^{-1}$ and harvest index but such interaction had no significant effect on plant height, total number of tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, panicle length, number of grains $panicle^{-1}$, number of sterile spikelets $panicle^{-1}$, 1000-grain yield (t ha^{-1}), grain yield (t ha^{-1}), straw yield and biological yield (t ha^{-1}). The highest number of grains $panicle^{-1}$ (141) and grain yield was found in Zn_5B_2 plots and the lowest was found in Zn_0B_0 (5.56 t ha^{-1}).

Considering all these factors studied it can be concluded that BRRI dhan29 could cultivated with zinc @ 5 kg ha^{-1} along boron 2 kg ha^{-1} for maximum yield in present situation in Bangladesh. However, before recommendation of the above findings to the farmers' level trial should be given in different locations of Bangladesh.

REFERENCES

REFERENCES

Agarwal, H.P. and Gupta, M.L. 1994. Effect of copper and zinc nutrient to rice. Ann. Agric. Res. 15(2): 162-166.

Agarwal, S. K. and Suraj, B. 1997. Effects of levels of zinc sulphate on the yield and net return in rice-wheat cropping sequence. Indian J. Agric. Res. 31(3): 174-178.

Ahmed, I.U.; Rahman, S.; Hossain, A.K.M.A. and Bhuiyan, N.I. 1986. Growth and Yield of rice (BR4 and BR3) as affected by nitrogen and sulphur fertilization. In: Proc. S ulphur in Agricultural Soils; S. Portch and S.G. Hussain eds., BARC, Dhaka.

Ahmed, S. and Hossain, M.B. 1999. Micronutrient status of long-term field experiment sunder wheat-mungbean-rice cropping sequence. Paper presented in the International meeting on "Long-term Experiment (LTE) on soil Fertility in Rice based cropping system" held at BRRI, Gazipur, Bangladesh, March 8-11, 1999.

Akhter, S.; Ali, M.I.; Jahiruddin, M.; Ahmed, S and Rahman, L. 1990. A study of Phosphorus and Zinc interaction in rice. Bangladesh J. Crop Sci. 1(2):99-109.

Anonymous. 1996. Annual International Review for 1995, Bangladesh Rice Research Institute, Joydedpur, Gazipur. pp. 10-11.

Arif, O.; Sa, Me, de.; Buzetti, S.; Rodrigues, R.; Stradioto, M.; de, F. and Lima, Fs, de. 1996. Response of upland rice given supplementary sprinkler irrigation to application of boron and zinc. J. Cientifica Jaboticabal. 24(1): 135-148.

Babiker, F.S.H. 1986. The effect of zinc sulphate levels on rice. Alexanderia J. Agric. Res. 31(2):480.

Baghdady, N.H.; Solaiman, M.F. and Farah, M.A. 1989. Effect of P fertilization on the response of wheat plant to zinc application. Cited from Soils and Fert. 52(8):1175.

Baker, M.N.; Ibrahim, A.E.M.; Abdel-Latif, E.A. and El-Ezz, N.A. 1988. Zinc Availability in the permanent field experiment at Bawim, Arab Republic of Egypt. Cited from Soils and Fert. 51(8):1582.

Balakrishnan, K. and Natarajaramam, N. 1986. Effect of zinc supplements on yield and yield components in certain rice varieties. Madras Agric. J. 73(10): 598-600.

Banasal, K.N. and Patel, K.C. 1986. Effect of Sources and levels of Zinc on the yield and composition of rice on alfisol under field condition. J.Agron. Crop Sci. 157(1):24-30.

BBS. 2004. Statistical Yearbook of Bangladesh. Bangladesh Bur. Statistics, Stat. Div. Minis. Planning, Govt. People's Repub. Bangladesh, Dhaka, pp 136-140.

Bhat, M.A.; Salroo, M.Y.; Mushki, G.M. and Shiekh, F.A. 2002. Yield enhancement of rice (*Oryza sativa* L.) under irrigated transplanted conditions of Kashmir Valley. Plant Archives. 2(1): 115-117.

Bhogal, N.S.; Gangwar, M.S.; Rathore, V.S. 1984. Effects of zinc phosphorus interaction on growth, zinc concentration and ribulose 1, 5-diphosphate carboxyls activity in two differentially susceptible rice varieties grown in mollisols. J. Nucl. Agric. Biol. 13(2) :48-52.

Bhuiya, Z. H.; Idris, M. and Jahiruddin, M. 1981. Response of IR8 to zinc fertilizer. Int. Rice Res. Newsl. 6(6): 11.

Bhuiyan, N.I. 1991. Issues concerning declining/stagnating productivity in Bangladesh agriculture. A paper presented at the National Workshop on Risk Management in Bangladesh Agriculture, held at BARC, Dhaka on August 24-27, 1991.

Bhuiyan, N.I. and Islam, M.S. 1986. Sulphur deficiency problems of wetland rice soils in Bangladesh agriculture. In Proc: sulphur in Agricultural Soils, S. Portch and C.G. Hussain ed., BARC, Dhaka.

Bhuiyan, N.I., Paul, D.N.R. and Jabber, M.A. 2002. Feeding the extra millions by 2025: Challenges for rice research and extension in Bangladesh. Proc. Workshop on Modern Rice Cultivation in Bangladesh, BRRI, Joydebpur, Gazipur, January 29-31, 2002.

Black, C.A. 1965 Methods of Soil Analysis, Part 2, Amer, Soc. Agron. Inc. Madison, Wisconsin, USA.

Brar, M.S. and Sekhon, G.S. 1980. Effects of applied Zn and Fe on the growth of rice. Riso. 28(2):125-131.

BRRI. 1980. Zinc deficiency in rice and its remedy. Bangladesh Rice Res. Inst., Joydebpur, Booklet No. 44 (2^{nd} ed.). pp. 1-2.

Chapman, A.L. 1980. Effect of sulphur, sulphuric acid and gypsum on the yield of rice on the cunnura soils of the old irrigations area in western Australia. Aust. J. Expt. Agric. And Ann. Husb. 20(107): 724-730.

Chapman, H.D. and Pratt, P.F. 1961. Methods of Analysis for Soils, Plants and Water, uni. Of Calif. Div. of agric. Sciences, Berkely, Calif.

Chen, L.; Fan, X.M.; Chen, L.J. and Fan, X.M. 1997. Grain quality response to phosphorus and zinc fertilizer in rice genotype. Chinese Rice Res. News. 5(3): 9-10.

Chitdeshwari, T. and Krishnasamy, R. 1998. Effect of zinc and zinc enriched orgnaic manures on the available micronutrient status in rice soils. Advances in Plant Sciences. Dept. of Soil Sci. and Agril. Chemistry. Agril. Research Station, Kovilpatti, India. 11(2): 211-219.

Chitdeshwari, T. and Krishnasamy, R. 2005. Path analysis of soil zinc fractions and rice yield as influenced by zinc enriched organic manures. Tamil Nadu Agril. University, India. 18(1): 235-237.

Das, D.K.; Karak, T. and Maiti, D. 2004. Effect of foliar application of different sources on Zn on the changes in Zn content, uptake and yield of rice. Bidhan Chandra Krishi Viswavidayalaya, West Bengal, India. 25(2): 253-256.

Dey, S.C. 1980. Effect of foliar application of some chemicals on growth and yield of rice C.V. Mashuri Journal-of-Research, Assam Agricultural University. 1:2, 206-208.

Dhillon, K.S. and Dhillon, S.K. 1986. Effect of different complexing agents on adsorption and translocation of ^{65}Zn in rice seedlings. J. Nucl. Agric. Biol. 15(1):23-28.

Dixit, U.C. and Patro, N. 1994. Effect of levels of N, P, K, Zn and plant density on nutritional uptake by summer rice. Orissa J. Agric. Res., 7(Supple): 102-104.

Dunn, D., Stevens, G. and Kendig, A. 2005. Boron fertilization of rice with soil and foliar applications. Online. Crop Management :10.1094/CM-2005-0210-01-RS.

Dutta, R.K., Lahiri, B.P. and Mia. M.A.D. 1998. Characterization of some aromatic fine rice cultivars in relation to their physico-chemical quality of grains. Indian Plant Physiol. 3(1): 6-64.

FAO (Food and Agriculture Organization). 2000. Production Year Book. Food and Agriculture Organization of the United Nations, Rome: 76-77.

Ghatak, R.; Jana, P.K.; Sounda, G.; Ghosh, R.K. and Bandyopadhyay, P. 2005. Response of transplanted rice to zinc fertilization at farmers field on red and laterite soils of West Bengal. Bidhan Chandra Krishi Viswavidayalaya, West Bengal, India. 9(2): 231-234.

Gomez, K.A. and Gomez, K.A. 1984. Statistical Procedures for Agricultural Research. 2nd Edn. John Wiley and Sons. pp. 207-215.

Gupta, U.C. 1979. Boron nutrition on crops. Adv. Agron. 31: 273-307.

Haloi, B. 1998. Performance of growth promoters on rice crop efficiency and yielding components. J. Agric. Sci. Soc. North-East. India. 11(2): 226-229.

Herawati, N.; Suzuki, S.; Hayashi, K.; Rival, I.F. and Koyama, H. 2000. Cadmium, copper, and zinc level in rice and soil of Japan, Indonesia and China by soil type. Bull. Env. Contamination and Toxicology. 64(1): 33-39.

Hoque, M.S. 1986. Sulphur status in some Bangladesh soils and response of rice to sulphur aoolications. In: Proc. sulphur in Agricultural Soils, S. Portch and S.G. Hussain eds., BARC, Dhaka.

Hoque, M.S. and Eaqub, M. 1984 Study on zinc and sulphur dfeiciency in Bangladesh Soils, Annual report . FAO Project (1983-84).

Hoque, M.S. and Jahiruddin, M. 1993. Effect of single and multiple applications of sulphur and zinc in a continuous rice cropping pattern. Indian J. Agric. Res., in press.

Hossain, S.M.A.; Sattar, M.; Ahmed, J.U. and Islam, M.S. 1987. Response of rice to sulphur and zinc fertilization. Indian J. Agric. Sci. 57(5): 343-346.

Hossain, T., Jilani, G. and Gaffer, A. 1989. Influence of rate and time of N application on growth and yield of rice in Pakistan. Intl. Rice Res. Newsl. 14(6):18.

Hunter, A.H. 1984. Soil Fertility Analytical services in Bangladesh. Consultancy report. BARC, Dhaka.

Ingle, S.N.; Borkar, D.K.; Chaphale. S.D. and Thakre, S.K. 1997. Effect of sources and levels of zinc on yield and nutrient uptake by rice. J. Soils Crops. 7(2): 157-159.

Islam, A.; Ahmed, F. and Ahmed, Z. 1986. Sulphur status of some soils of Bangladesh and effect of applied sulphur on the growth and yield of rice. In: Proc. Sulphur in Agriculture Soils, S, Portch and S.G. Hussain eds. BRAC, Dhaka.

Jackson, M.L. 1962. Soil Chemical Analysis. Prentice Hall. Inc. Englewood diffs. N.Y.

Jahiruddin, M. 1993. Combating floret sterility of wheat through boron supplement. BAU Res. Prog. 7: 36-44.

Jahiruddin, M.; Bhuiya, Z.H.; Hoque, M.S. and Rahman, L. 1981. Effects of rates and methods of zinc application on rice. Madras Agric. J. 68(4): 211-216.

Jahiruddin, M.; Hoque, M.S.; Haque, A.K.M.M. and Roy, P.K. 1992. Influence of boron, copper and molybdenum on grain formation of wheat. Crop Res. 5(1): 35-42.

Jha, M.N.; Prasad, A.N. and Misra, S.K. 2004. Effect of micronutrients on diazotrophic cyanobacteria and yield of paddy. Rajendra Agril. University, Bihar, India. 44(3): 171-174.

Kang, Y.L. 1988. Effects of organic matter and its anaerobic decomposition products on the growth and zinc uptake by rice. Dissertation-Abstracts-International, B-sciences and Engineering. 49:4, 953 B.

Khan, R., Akber Hussain Gurmani, H., Gurmani, A.R. and Zia, M.S. 2007. Effect of boron application on rice yield under wheat rice system International Journal of Agriculture & Biology 1560–8530/2006/08–6–805–808 http://www.fspublishers.org

Khanda, C. and Dixit, L. 1995. Effect of zinc and nitrogen fertilization on summer rice(Oryza sativa). Indian J. of Agronomy. Dept. of Agronomy. College of

Agriculture, Orissa Univ. of Agriculture and Technology, Bhubaneshwar, India. 40(4): 695-697.

Khanda, C.M. and Dixit, L. 1996. Effect on zinc and nitrogen fertilization on yield and nutrient uptake of summer rice (*Oryza sativa*). Indian J. Agron. 41(3): 368-372.

Kuldeep Singh. 1985. determination of critical limit of zinc in rice soils in India for predicting response of rice to zinc application. Cited from Soils and Fert. 48(2):190.

Li, Yan.; Qin, S.; Li, Y. and Qin, S.C. 1999. Effect of rice metabolism and the diagnosis of hidden zinc deficiency in rice. J. Fujian Agric. Univ. 28(1): 66-67.

Lora, R.; Cabezas, M.; Ramirez, C.J. and Olivar, H.A. 2002. Response of three varieties of rice to zinc applications in Villanueva (Casanare, Colombia). Suelos Ecauatoriales. 32: 14-22.

Misra, A.K.; Nayar, P.K. Patnaik, S. 1989. Effect of flooding on extractable Zn, Cu, B and Mo in soils and their relation with yield and uptake of these nutrients by rice. Indian J. Agric. Sci. 59(7):415-421.

Mondal, M.H.R.; Jahiruddin, M.; Rahman, M.M. and Hashem, M.A. 1992. An investigation on nutrient requirements for BR-11 rice in Old Brahmaputra Floodplain Soil. Bangladesh J. Crop Sci. 2(2): 22-31.

Mowardi, A.S.; Ghaly, M. and Hamduda, M.H.M. 1980. Effect of zinc on the yield of rice. Agric. Res. Rev. 58(5): 73-177.

Muniz, O.; Beltram, R.; Sanzo, R. ; Gonzalez, A; Guerra, A.; Hung, S.; Irigoyen, H. and Avila, U. 1987. The response of rice to the application of different rates of zinc sulphate on rice soils of cuba. Ciencia-Y-Technia-en-la-Agricultura, - Suelos-Y-Agroquimica. 10:1, 17-32.

Mythili, S.; Chitdeshwari, T. and Jayanthi, C. 2002. Radio-tracer study on zinc use efficiency by rice. J. Ecotoxicol. Environ. Monitoring. 12(4): 271-276.

Nag, P.; Nag, P.; Paul, A.K. and Mukharji, S. 1984. toxic action of zinc on growth and enzyme activities of rice seedlings. Environmental pollution, A. 36:1 45-59.

Nagarajan, R. and Manickam. T.S. 1986. Optimizing zinc application in rice soils of Tamil Nadu. Madras Agric. J. 73(1): 1-6.

Patra, B. and Poi, S.C. 1998. Effect of different micronutrient compounds on the growth and yield of paddy in North Bengal Soils. Environ. Ecol. 16(2): 438-440.

Polisetty, R.; Chandra, R.; Reddy, K.J.; Sirohi, G.S. 1987 effect of foliar application of zinc and manganese at various levels of nitrogen on grain yield of rice. Mysore J. Agric. Sci. 21(2):161-163.

Prasad, B.; Kumar, M. and Prasad, J. 1989. Direct effect of organic waster and zinc sulphate on zinc availability under cropping sequence of wheat and rice. Indian J. Agric. Sci. 59(5): 300-305.

Prasad, B.; Sharma, M.M. and Sinha, S.K. 2002. Evaluating zinc fertilizer requirement on Typic Haplaquent in the rice-wheat cropping system. J. Sustainable Agric. 19(3): 39-49.

Rajput, R.L.; Sharma, P. and Tomar, R.A.S. 2005. Effect of different level of fertilizer and varieties on grain yield of paddy. Krishi Vigyan Kendra, Agric. College, Gwalior, India. 20(1): 61-64.

Raju, R.K. 2000. Saru O Sughandhi Chal Desher Khanddho Mitate Balista Vumika Rakhbe. The Daily Inqilab, 1 April, p. 9.

Ramadass, R.; Krishnasamy, T. and Dhakshinamorthy, M. 1995. Response of paddy cultivars to zinc application. Madras Agric. J. 32(2): 142-143.

Rathore, G.S.; Dubey, S.B.; Khamparia, R.S.; Sharma, B.L. and Sinha, S.B. 1982. Response of paddy as influenced by zinc application and available zinc status od soils. Cited from Field Crop Abstr. 36(8): 656.

Sagwal, O.P.; Vijay, K. and Kumar, V. 1994. Effect of balanced use of fertilizers on productivity and profitability of Basmati rice. J. Haryana Agric. Univ., India. 39: 10-57.

Sakal, R.; Nayyar, V.K.; Sicgh, M.V.; Biswas, T.D. and Narayanasmy, G. 1997. Micronutrients status under rice-wheat cropping systems for sustainable soil productivity. Indian Soc. Soil. Sci. Bull. 18: 39-47.

Salam, A.M. and Subramanian, S. 1988. Influence of nitrogen, zinc and their interaction on the yield and nutrient uptake of IR20 rice (*Oryza sativa*) in different season. Indian J. Agril. Sci. 58(3): 190-193.

Sanchez, L.F. 1983. Correlation of zinc deficiency in irrigated rice cultivated on an Entisol of the Eastern Plains. Arroz. 32:17-24.

Sarker, A.K.; Leelabhai, K.S.; Mohon, G.V.M.; Subbiah, V.V.; Rao, I.V.S.; Deb, D.L. 1983. Zinc fertilization of flooded rice in vertisol of Hyderabad. Nuclear Agric. Biol. 12(4):96-99. Cited from Field Crop Abstr. 1984. 37(7):571.

Seethambaram, Y. ; Das, V.S.R.1985. Effect of zinc deficiency on kinetics of ribulose-1.5-biophosphate carboxylase of *Oryza sativa* L. and pennisetum americium (L) Leeke. Photosynthetica 19(1):72-79.

Seethambaram, Y.; Das V.S.R.1985. Effect od zinc deficiency on enzyme activities of nitrate reduction and ammonia assimilation of *Oryza sativa* L. and *Pennisetum americanum* L. Proc. Indian National Sci. Acad. B:Biol. Sci.52(4):491-494.

Shamsuddin, A. M., Islam, M. A. and Hossain, A. 1988. Comparative study on the yield and agronomic characters of nine cultivars of rice. Bangladesh J. Agril. Sci. 15(1): 121-124.

Sharma, A.K.; Renu-Singh; Singh, U.S. and Singh, R. 1988. Effect of vesicular-arvascular mycorriza on uptake of phosphorous and zinc in rice. Current Sci. 57: 901-902.

Sharma, P.N.; Sharma, C.P.; Agarwala, S.C. 1981 Boron deficiency effects in rice grown in sand culture. Cited from Soils and Fert. 48(8):990.

Sharma, S.K.; Bhunia, S.R. and Pattern, A.R.K. 1999. Effect of zinc fertilization on transplanted rice in Ghaggar flood plains of North-West Rajasthan. Annals Agril. Res. 20(2): 245-247.

Shorroeks, V.M. 1974. Boron-deficiency. Its prevention and came Borax consolidated Ltd. London, p.56.

Silva, A.R.DA. and Andrate, J.M.DE. 1983. Effect of trace elements on male sterility of upland wheat and soybean and rice yield in a red-yellow idtosol pesq. Agropec. Brassiliera. 18(3): 593-601. Cited from Soils and Fert. 1984. 47(8):990.

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

Singh, A.K.; Singh, N.P. and Nongkynrih, P. 2002. Response of rice to Zn in the soils of Meghalaya. Fertilizer News. 47(8): 53-54.

Singh, A.K.; Thakur, S.K. and Singh, S.S. 1996. Effect of N with and without FYM and Zn on yield, uptake and economics of rice. J. Res. Birsa Agril. Univ. 8(2): 175-176.

Singh, B.; Chipa, B.R. and Lai, P. 1992. A study on sodicity of water and zinc interaction in relation to soil properties, growth and yield of wheat grown on loamy sand soil. 36(1-2): 1-9.

Singh, B.P.; Singh, A. and Singh, B.N. 1990. Response of rice to zinc and boron application in acid Alfisols under-mid-altitude conditions of Meghalaya. Indian J. Agric. Sci. 60(1): 70-71.

Singh, H.P. and Singh, T.N. 2005. Enhancement in zinc response of rice by magnesium in alkali soil. University of Agril. and Tech., Faizabad, India. 10(2): 158-161.

Slaton, N.A.; Norman, R.J. and Wilson, C.E.Jr. 2005. Effect of zinc source and application time on zinc uptake and yield of flood irrigation rice. Univ. of Arkansas, USA. 97(1): 272-278.

Slaton, N.A.; Wilson, C.E. Jr.; Ntamatungiro, S.; Boothe, D.L.; Clark, S.D. and Norman, R.J. 2001. Effect of zinc fertilizer application time on rice yield. Research Series, Ankansas Agricultural Experiment Station, No. 485: 405-411.

Stefanski, K.S. 1985. The effects of various zinc compounds on plant growth. Cited from Soils and Fert. 48(4):427.

Tisdale, S.L.; Nelson, W.L. and Beaton, J.D. 1985. Soil Fertility and Fertilizers. 4th Ed. Mcmillan Pub. Comp., New York.

Tomar, P.S.; Upadhyay, A. and Sharma, J.K. 1994. Effect of Zn on yield and nutritional quality of grain and straw of rice cultivars. Annals Plant Physiol. 8(1): 66-68.

Trivedi, J.R. and Verma, M.M. 1997. Quality of rice as affected by potassium sources with molybedenum. Bangladesh J. Agric. Sci. 50(1): 38-42.

Tunga, A.K. and Nayak, R.L. 2000. Effect of nitrogen phosphorus. potassium and zinc on different high yield rice and hybrid rice varieties during wet season. J. Interacademicia. 4(4): 502-523.

Ugurluoglu, H. and Kacar, B. 1996. Effect of different zinc sources on the growth on rice (*Oryza sativa* L.) plants. Turkish J. Agriculture and Forestry. Ankara University. Ziraat, Fokultesi, Topark, Bolumu, Ankara, Turkey. 20(6): 473-478.

Usha, M.; Beena, C.; Balachandran, P.V. and Mathew, U. 2000. Effect of application of zinc and copper on the yield of rice. J. Trop. Agric. 38(1-2): 100-101.

Vasudeva and Ananthanarayana, R. 2001. Response of paddy to different levels of zinc application based on absorption maxima in acid soils of Karnataka. Madras Agric. J. 88(7-9): 498-500.

Verma, C.P.; Tripathi, H.N. and Prasad, K. 2001. Effect of FYM and zinc sulphate on yield and yield attributes of rice grown after paddy nursery. Crop Res. 21(3): 382-383.

Zaman, M.W.; Rahman, S.H.; Morzia, B. and Ahmed, S. 1994. Phosphorus and zinc interaction in rice grain. Progress. Agric. 5(2): 273-278.