PERFORMANCE OF AMAN RICE AS INFLUENCED BY NITROGEN AND ZINC ON THE YIELD OF BRRI DHAN 39

By

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REGISTRATION NO. 26126/00426

A Thesis

Submitted to the Department of Soil Science
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE (M.S.)
IN
SOIL SCIENCE

SEMESTER: JULY-DECEMBER, 2007

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CERTIFICATE

This is to certify that the thesis entitled, " PERFORMANCE OF AMAN RICE AS INFLUENCED BY NITROGEN AND ZINC ON THE YIELD OF BRRI DHAN 39" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment 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 JHARNA RANI SARKER, Registration No. 26126/00426 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged by her.

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DEDICATED TO
MY
BELOVED PARENTS

ACKNOWLEDGEMENT

All praises to the almighty "God" who enable me to complete a piece of research work and prepare this thesis for the degree of Master of Science (M.S.) in Soil Science.

I would like to express my earnest gratitude, hearty respect, immense indebtedness, profound appreciation and deepest sense of respect to my research supervisor Professor Dr. Alok Kumar Paul, Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka for his scholastic guidance and immense help in preparing the thesis.

I would like to express my deepest sense of respect, gratitude and profound indebtedness to my reverend co-supervisor Professor Dr. Gopi Nath Chandra Sutradhar, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his constant guidance, cooperation, encouragement, constructive criticism and technical help during the course of research work and in preparing this thesis.

Further, I would like to express my sincere appreciation and indebtedness to my esteemed teacher Associate Professor A.T.M. Shamsuddoha, Chairman, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his valuable advice to conduct the research work.

I would like to express my sincere gratitude to my respectable teacher Professor Dr. Md. Nurul Islam, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his valuable advice and providing necessary facilities to conduct the research work.

I would also like to express my deepest respect and thanks to all my honourable teachers Associate Professor, Dr. Md. Asaduzzaman Khan, Mst. Afrose Jahan and Assistant Professor Md. Mosharraf Hossain and Lecturers Mohammad Issak, Md. Saiful Islam Bhuiyan and Saikat Chowdhury, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for their valuable teaching, direct and indirect advice, encouragement and cooperation during the whole study period.

I owe special gratitude and feel highly esteemed to place sincere thanks to the Dean Professor Dr. Md. Hazrat Ali for helping me in several ways.

I would like to express my gratitude and cordial thanks to the Co-Ordinator Professor Md. Shamsul Hoque for his direct and indirect advice during the whole study period.

I am grateful to the authority of Soil Resource Development Institute for allowing me to conduct my research work in Soil Science Laboratory.

I would also like to express my gratitude and cordial thanks to Ms Wadia Rahman, Chief Scientific Officer (CSO), Soil Resource Development Institute, Dhaka for her generous cooperation.

I expresses my unfathomable tributes, sincere gratitude and heartfelt indebtedness from my core of heart to my father Sunil Kumar Sarker, mother Kanak Prova Sarker, husband Shidhwaretho Sanker Paul, father-in-law, mother-in-law and my sisters whose blessing inspiration and moral support opened the gate and paved to way of higher study.

I feel much pleasure to convey the profound thanks to my friends, well wishers for their active encouragement and inspiration during my M.S. Course study.

Jharna Rani Sarker

Place: Dhaka, Bangladesh

Dated: 31, December, 2007

ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm during the period from July 2006 to October 2006 to find out the performance of Aman rice as influenced by nitrogen and zinc on the yield of BRRI Dhan 39 . There were 16 treatments combinations comprising of four levels of N (0, 50, 100 and 150 kg N ha^{-1}) and four levels of Zn (0, 5, 10 and 15 kg Zn ha^{-1}). The maximum plant height (112 cm), total number of tiller plant^{-1} (12.16), number of effective tiller plant^{-1} (11.79), panicle length plant^{-1} (23.80 cm), number of filled grain panicle^{-1} (88.46) and grain yield (4.91 t ha^{-1}) were recorded under the treatment of 100 kg N ha^{-1}. Straw yield increased significantly upto 150 kg N ha^{-1}, but the grain yield showed a significant negative effect at this rate of N application. Plant height, total tillers, effective tillers and panicle length increased significantly with increasing Zn application upto 5 kg Zn ha^{-1}, while the number of filled grain panicle^{-1}, grain yield and straw yield enhanced with increasing Zn doses upto 10 kg Zn ha^{-1}. However the application of 15 kg Zn ha^{-1} had a significant negative effect on grain yield but not on straw yield. The T_{11} (N_2Zn_2) treatment combination at the rate of 100 kg N ha^{-1} and 10 kg Zn ha^{-1} perform better than other treatments in the present trial considering rice yield and yield contributing parameters. The interaction effect of different doses of nitrogen and zinc showed statistically significant differences in consideration of total tiller, effective tiller, filled grain and grain yield of rice. From the viewpoint of grain yield and nutrient content of rice and the nutrient requirement of the crop, the N and Zn combination (N_2Zn_2) at the rate of 100 kg N ha^{-1} and 10 kg Zn ha^{-1} was considered to be the balanced combination of fertilizer for the maximum output through cultivation of rice in Deep Red Brown Terrace Soil.

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Chapter I

INTRODUCTION

Food is the prime fundamental demand for human beings in the world. Its demand will continue to increase in the days to come. More than two third of the world's population are presently living in the developing countries where agricultural production is not sufficient to meet the need of the country. Bangladesh is a densely populated agro-based country where rice (*Oryza sativa L.*) is the most extensively cultivated cereal crop. Bangladesh is the fourth largest rice growing country of the world. Rice is the staple food of Bangladesh. It has 8.65 million hectares of arable land of which 75% is devoted to rice cultivation (BBS, 2004). Rice based cropping system has been practiced in Bangladesh since the beginning of modern agricultural practices. The climate and soil of Bangladesh are favorable for year round rice cultivation.

Bangladesh, being an agro-based country, has been suffering from acute food shortage for a long time as a result of which she has to import million tons of food grain annually to feed her hungry millions. Side by side the population of this over-populated part of the world is increasing progressively at an alarming rate. The rate of increase in population being much greater than that of food production. Rice constitutes 95% of food grain production among the other food grain crops in Bangladesh.

In Bangladesh, there are three diverse growing seasons of rice namely aus, aman, and boro. Among these three seasons, transplanting aman rice covers the largest area. In Bangladesh, about two-third of the cultivated land area is occupied by rice (AIS, 2000). Increased rice production in this country is essential to meet the food demand of the teeming population. Unfortunately, the yield of rice is very low in Bangladesh (3.34t ha^{-1}) compared to Australia (9.65 t ha^{-1}), Korean Republic (6.59 t ha^{-1}), Japan (6.70 t ha^{-1}) and

Spain (6.59 t ha^{-1}) (FAO, 2002). Nutritional deficiency in soil is one of the major constraints which may lead to yield decrease by many folds.

During the last two decades, Bangladesh agriculture has moved from a low crop intensity and low yielding state to one in which intense cropping and higher yields per unit area are being increasingly sought. Higher crop yields naturally have higher demands of nutrients and more pressure on the soil for available forms of nutrients. As cropping intensity and yield levels go up, the uptake and removal of plant nutrients through harvested crop and other routes from the soil are likely to increase.

Nutrient stresses in Bangladesh soils are increasing day by day. One of the major reason is that nutrient removals far exceed nutrient additions in most situations, as a result nutrient balances in the soil are negative (Mian, 1990). Such a situation favours an increase in nutrient deficient areas, severity of the existing deficiencies and number of nutrients deficient at site.

Depletion of soil fertility has been identified as a major constraint for higher crop yield. Over the years, the Bangladesh Agriculture has experienced with an area of multiple nutrient deficiencies. Deficiencies of five nutrients such as N, P, K, S and Zn are now widespread (Islam *et al.*, 1990; Mondal *et al.*, 1992; Islam and Hossain, 1993; Islam *et al.*, 1996). In the past, only three primary nutrients viz. N, P and K along with one secondary nutrient S are commonly used by the farmers of Bangladesh. The importance of micronutrient nutrition of crops is almost ignored. They are however, essential plant nutrients and play a significant role in crop nutrition which finally leads to healthy growth and increased yield. Presently the need for micronutrient fertilization in soil is increasing, yet the proportion of different fertilizer used in the country is not quite balanced. Nitrogen alone constitutes about 80 percent of the total nutrients used in country which can not help to improve crop productivity unless other limiting nutrients are supplemented along with nitrogen (BARC, 1997).

Micronutrient deficiencies in general, are reported from different parts of the globe in world literature. Zinc deficiencies are widespread throughout the world, especially in the rice land of Asia and deficiencies occur in neutral and calcareous soils (Tisdale *et al.*, 1997). It was reported that about 2.0 million hectares of agricultural land are zinc deficient under different Agro Ecological Zones. Zinc is essential for numerous enzyme systems and is capable of forming many stable bonds with nitrogen and sulphur ligands.

Zinc plays an important role in many physiological functions in plants. It acts as the constituent of plant metabolic enzyme system as alcohol dehydrogenage, carbonic anhydrase and various peptidases. Zinc is involved in biosynthesis of tryptophene, a precursor of auxin which is essential for elongation. It also been found to be essential for normal chlorophyll formation in plants.

Among many factors, deficiency of nitrogen and zinc is now considered as one of the major reasons for low yield of rice in Bangladesh. The low level of organic matter is the main cause of poor physical properties and less available of other nutrients in Bangladesh soil. With the cultivation of HYV crops, intensive cropping and cultivation of cereals have depleted further the organic matter and hence nitrogen. Nitrogen is lost from soil through ammonia volatilization, denitrification, leaching, surface runoff and chemical fixation by microbes. The increased N-use efficiency can be achieved by split application of N during the period when rice crop is capable of absorbing and making maximum use of it for the production of grains.

In the recent years, efforts are being made to increase the per hectare yield of rice in Bangladesh by using nitrogenous fertilizers at proper dose in the cultivation of high yielding varieties. The use of balanced fertilizers in these HYV varieties is associated with some other factors, like plant protection, adequate irrigation, flood control facilities and other improved cultural operations. The application of proper doses of nitrogen in rice crop along with phosphorus, potassium, zinc and sulphur, increased the grain yield up to 5.7 ton ha^{-1} (BRRI, 1987). So, balanced N-application to the rice crop is a prerequisite condition for obtaining optimum potentiality of rice.

Zinc deficiency had been reported in many rice soils in Bangladesh (BRRI, 1980). Zinc deficiency occurs in Gangetic alluvium soils.

Zinc is classified as micronutrient but Zn deficiency is the third most important nutritional factor after nitrogen and phosphorus limiting the growth of wet land rice. A survey of Zn nutrition in rice in Bangladesh shows that soils with high pH and calcareous soils of North Western districts and also the soils which have been intensively cultivated with transplanted rice have Zn deficiency problem. Hence, there is an urgent need to maximize the rice production by applying different nutrients like N and Zn to our soils.

Depending on the existing soil, land type and varied cropping patterns it has been estimated that Bangladesh needs at least 4.0 million tons of fertilizers but currently applied about 2.25 million tons that is 56% of the total demand. This creates continuous stress on the soil of Bangladesh (FAO, 2004). If our farmers apply optimum doses of major nutrients with optimum doses of zinc in his land then he will get maximum yield from his field. Considering the above background, the experiment was conducted at Sher-e-Bangla Agricultural University farm under the agro-ecological zone of Madhupur Tract (AEZ-28) with the following objectives:

i. To find out the optimum dose of nitrogen for maximum yield of rice.

ii. To find out the optimum dose of Zn for maximum yield of rice.

iii. To find out the interaction effect of nitrogen and zinc on the yield of Aman rice BRRI Dhan 39.

iv. To find out the effect of nitrogen and Zinc on their content and uptake by BRRI Dhan 39 Aman rice.

Chapter II

REVIEW OF LITERATURE

A number of research works on rice and its response to different rates of nitrogen and zinc fertilizers have been carried out in Bangladesh and in different rice growing countries of the world. In this chapter an attempt has been made to review some of the available information related to the effect of different rates of nitrogen and zinc on the yield, yield contributing characters and chemical composition of rice plants.

2.1 Effect of nitrogen on rice yield

Nitrogen is a primary macronutrient occurring in soils both in organic and inorganic forms. There was no nitrogen bearing minerals. Plant absorb N mainly in the form of NH_4^+ and NO_3^-. It is an integral component of many essential plant compounds. Nitrogen can dramatically stimulates plant productivity, especially it encourages above ground vegetative growth of plants. A good supply of nitrogen also stimulates root growth and development, protein content of seed and foliage as well as the uptake of other nutrients. It is essential for carbohydrates use within the plants. It is a major part of all amino acids, enzymes, nucleic acids and chlorophyll.

It was found from a field experiment that 68, 101, or 135 kg N ha^{-1} increased significantly rice grain yield (Wells, 1980). Mishra and Singh (1980) conducted 2 years study and showed that the application of N at the rate of 75 and 25 kg ha^{-1} at transplanting and maximum tillering stage, respectively gave significantly the highest yield. It was observed that grain yield increased 3.80 to 4.92 t ha^{-1} by applying 80 kg N

ha^{-1} and 11.3 kg S ha^{-1}. Plant height, panicles $hill^{-1}$ and straw yield were also increased by nitrogen and sulphur fertilization (Haque and Khan, 1981).

Mahayan and Nager (1981) reported from a field experiment that paddy yields of rice increased significantly by increasing of nitrogen rate from 50-150 kg N ha^{-1}. It was cited from a field experiment that using 0, 30, 60, 90 or 120 kg N ha^{-1} in addition to 40 kg P_2O_5, 60 kg K_2O ha^{-1} at sowing time increased grain yield significantly with the increasing rate of nitrogen (Bacha and Lopes, 1982). Brandon *et al.* (1982) reported that paddy yields were increased significantly with the application of nitrogen at 60, 120 or 180 kg N ha^{-1}.

Nossai and Vargas (1982) observed that maximum yield of rice was produced with 200 kg N ha^{-1}. They also reported that number of tillers $hill^{-1}$ and panicle length was also increased linearly with increasing the rate of nitrogen. Kim *et al.* (1983) conducted a field trial on rice cultivar Kiyonishike with no N fertilizer or 84 kg N ha^{-1}. They showed that at most sampling date's plant height, stem number, leaf area, below ground dry weight and ear weight were higher compared to no N fertilizer.

It was found that significantly higher grain yield of rice with 120 kg N ha^{-1} than 40 kg N ha^{-1} (Subbiah, 1983). Thind *et al.* (1983) studied the influence of nitrogen application on grain yield of rice and observed that increasing rate of nitrogen application increased the yield significantly up to 180 kg N ha^{-1}. It was experimented that the effect of different levels of nitrogenous fertilizers reported the highest paddy yield with 120 kg N ha^{-1} in the kharif season (Ayyasamy and Venkatasamy, 1983). It was found that 50, 100 or 150 kg N

ha^{-1} and 3, 6 or 9 kg Zn ha^{-1} increased the number of total tiller $hill^{-1}$ significantly (Jahiruddin, 1983)

Awan *et al.* (1984) reported that application of nitrogen with different levels on rice increased plant height, panicle length, 1000-grain weight, grain and straw yield significantly. It was experimented on rice and reported that application of 50, 100 or 150 kg N ha^{-1} increased the grain yield significantly (Jakhro, 1984). Devi and Nair (1984)) reported that the area, total area of the 4 top leaves and number of spikelets in 4 drought resistant tall upland rice increased with increasing N up to 40 kg N ha^{-1}. An additive element trial with BR3 and BR4 rice was carried out at BAU farm and farmers' fields during 1980-82 by Eaqub and Mian (1984). Their experimental results showed that application of N alone significantly increased the grain yield. A significant effect of P was obtained in the aman season of 1981 at BAU farm and farmers' fields and in the boro season of 1982 at farmers' field. Application of K had no positive effect on rice.

Khole and Mitra (1985) reported from an experiment that higher level of nitrogen was effective for higher yield of rice significantly. Thangamuthu (1985) observed that with stubble incorporation, chemical N application could be reduced without yield loss. Forty five cm tall stubble with 50% of the normal N fertilizer yielded the highest among treatment and at per with the recommended application of 100-22-42 kg NPK ha^{-1}. Momuat *et al.* (1985) conducted a field experiment with nitrogen on rice and concluded that grain yield of two rice varieties increased significantly with 60 kg N ha^{-1} and 90 kg N ha^{-1}, respectively. Rajagopalan and Palensiamy (1985) studied the effect of various levels of nitrogen on rice and reported that 75 kg N ha^{-1} produced maximum grain yield of rice.

It was cited from a field experiment with different levels of nitrogen and found that application of 20, 40 and 60 kg N ha^{-1} increased grain yield significantly and the yield decreased with further increment in N rate (Ram *et al.*, 1985). Gupta (1986) reported that application of 50, 100 or 120 kg N ha^{-1} increased grain yield significantly compared to control. He reported that yield increased up to 80 kg N ha^{-1} and higher dose decreased it significantly. Joy *et al.* (1986) conducted an experiment with two doses of nitrogen (50 & 100 kg N ha^{-1}) and reported that 5.8 ton ha^{-1} grain yield by the application of 100 kg N ha^{-1}, was obtained.

Kumar (1986) studied the effect of different levels of nitrogen on transplanting Aman paddy and reported that paddy yield increased significantly with the N application. It was observed from a field experiment with different rates of nitrogen and found maximum grain yield with 60 kg N ha^{-1} (Lopes and Carmana, 1986). It was found that plant height, number of tillers $hill^{-1}$, paddy yield of rice is better under 120 kg N ha^{-1} (Reddy, 1986). Reddy *et al.* (1986) reported that application of 30, 60 and 90 kg N ha^{-1} to rice gave paddy yields of 2.89, 3.77 and 4.39 t ha^{-1}, respectively. Pattel *et al.* (1987) reported that application of 80, 100, 120 and 140 kg N ha^{-1} to rice cultivar IR-22 gave yield of 3.74, 4.23, 4.51 and 4.74 t ha^{-1}, respectively; 100 kg N was optimum economic rate. Nitrogen applied in a single dressing and 2-4 dressing gave similar yields.

It was found that application of 120 kg nitrogen increased yield of rice grain and 1000-grain weight significantly (Dalar and Dixit, 1987). It was experimented that yield of paddy increased by the application of nitrogen up to 100 kg N ha^{-1} and then decreased with the increasing rate of nitrogen (Maskina *et al.*, 1987). Subbiah *et al.* (1988) in an experiment with two rice cultivars IR50 and IR20 each grown in two seasons and found that increasing N rates increased grain yield from 3.71 to 4.69 t ha^{-1} in IR20 and from 4.14 to 6.58 t ha^{-1} in IR50 when both cultivars were grown in the kharif season. Milam *et al.* (1988) conducted a field experiment with two rice cv. Lemont and Newbonnet and found that grain yield for both cv. increased from 4155 kg ha^{-1} without N to 6364 kg ha^{-1} with 168 kg N ha^{-1}.

It was experimented at different stations that using 0, 40, 80 and 120 kg N ha^{-1} with BR-9, BR-11 and BR-16 tests varieties. Blanket doses of P, K and S at the rate of 25, 35 and 16 kg ha^{-1}. The varieties BR-9 and BR-16 produced the highest grain yield ranging from 5.5 to 6.0 t ha^{-1} (BRRI, 1988).

Dikshit and Paliwal (1989) reported that rice cv. cauveri was grown in a pot experiment with 0, 40, 80 and 120 ppm N as urea and 0, 20, 40, 60 ppm S as sodium sulphate. Rice grain yield, grain: husk ratio and grain N, S, sugar and starch contents increased with increasing levels of applied N and S. Grain K content was increased by N application but not by S. It was found from the field experiment on rice that using 0, 30, 60, 90 or 120 kg N ha^{-1} increased grain and straw yield significantly at 50 kg N ha^{-1} (Kehinde and Fagode, 1989). Hossain *et al.* (1989) carried out an experiment with rice cv. Basmati 370 on sandy clay loam soil with 0, 30, 60, 90, 120 and 150 kg N ha^{-1} and found grain yield of 3.9 t ha^{-1} due to application of 150 kg N ha^{-1}. Pandey *et al.* (1989) carried out a field trial with rice cv. Pat Dhan 4 and obtained mean grain yield of 6.6 and 7.2 t ha^{-1} by applying 120 or 180 kg N ha^{-1}.

Wells *et al.* (1990) in a field experiment found rice yield increasing from 3236 kg ha^{-1} without N to 7710 kg ha^{-1} with 202 kg N ha^{-1}. They also found that urea and ammonium nitrate solution gave yields of 6536 and 7221 kg ha^{-1} when broadcast and 5333 and 6293 kg ha^{-1} when added into the irrigation water at 126 and 202 kg N ha^{-1}, respectively. Islam *et al.* (1990) observed that the effect of nitrogen on the grain yield of rice was highly significant. There was an increasing trend in grain yield with an increase in levels of nitrogen up to 80 kg ha^{-1}. However, with further increase in nitrogen application there was some decrease in grain yield.

Idris and Matin (1990) conducted a nitrogen trial in rice at Mymensingh, Bangladesh. Plant height was found to increase up to 12 kg N ha^{-1} compared to control and then it was found to decrease at 140 kg N ha^{-1}. The highest plant height was recorded from 80 kg N ha^{-1} and the lowest one from 0 ha^{-1}, which was statistically identical with 60, 80, 100 and 120 kg N ha^{-1}. They also found that straw increased from 0 to 120 kg N ha^{-1} and at 140 kg N ha^{-1}, straw yield decreased. The lowest straw yield was obtained at 120 kg N ha^{-1} and the lowest at the control.

A field experiment was conducted by Ameta and Singh (1990) at Udaipur, Rajstan. They observed that increasing fertilizer N application from 30 to 120 kg ha^{-1} increased rice grain yields linearly from 3.52 to 5.36 t ha^{-1}. It was observed that the yield attributes like panicle m^{-2} and panicle weight increased with increasing levels of N. Thakur (1991) cited that higher yield with higher level of N might be due to better N uptake. Ghosh *et al.* (1991) conducted a field experiment in a typical lowland situation in farmer's field. The results showed that the addition of N increased the number of ear-bearing tillers and number of grains panicle^{-1}. They also found that addition of N increased grain yield significantly.

Murty *et al.* (1992) conducted a field experiment with 6 varieties of rice as main plot treatments and 4 levels of N as subplot treatments. It was observed that the mean grain and straw yield was 3.4, 4.2, 5.1, 4.5 and 4.2, 4.8, 6.0, 6.4 t ha^{-1}, respectively, by applying 0, 40, 80 and 120 kg N ha^{-1} in the treatments. It was cited from a field trial that in the rainy seasons of 1982-86 at Parbhani, Maharashtra, rice was given 0-120 kg N ha^{-1} as urea or urea super granules. Grain yield increased with up to 120 kg urea and 100 kg urea super granules (Bhale and Salunke, 1993).

Raju and Reddy (1993) showed that nitrogen had a significant effect on yield and yield components of rice. Application of N at the rates of 80 and 120 kg ha^{-1} markedly improved the mean yield by 31.7 and 45.5%, respectively. Quayum and Prasad (1994) conducted field trials during kharif season involving 5 rates of N (0, 35.5, 75, 112.5 and 120 kg ha^{-1}) and six different source of nitrogen with rice cv. Sita, and found that application up to 112.5 kg N ha-1 increased grain (4.37 t ha^{-1}) and straw yield (5.49 t ha^{-1}). Mukherjee and Mandal (1995) conducted a field experiment in 1987-88 in West Bengal, rice cv. Ratna was given 100 kg N ha^{-1} as urea in 2-3 splits in 3 different ratios 90:10:0, 70:20:10 and 50:30:20 at transplanting, tiller initiation and panicle initiation, respectively. They found that grain yields were over 20% higher in the control plots.

Azad *et al.* (1995) observed that plant height and panicle length increased significantly with increase in the levels of nitrogen from 0 to 75 kg N ha^{-1}. It was reported that nitrogen application up to 120 kg ha^{-1} increased the grain yield of rice. The increase in yield with 40, 80 and 120 kg N ha^{-1} over the control was 24, 33 and 34%, respectively (Hossain *et al.*, 1995). Panda *et al.* (1996) observed that N fertilizers application significantly increase the grain yield of rice. Andrade and Amorim Neto (1996) observed that increasing level of applied N increased plant height, panicle m^{-2}, grain panicle^{-1} and grain yield, significantly. BINA (1996) started that the effect of different levels of nitrogen was significant only for number of tillers hill^{-1}, effective tillers hill^{-1}, straw yield and crop duration. The highest number of total and productive tillers hill^{-1} was obtained from the highest level (120 kg ha^{-1}) of N application.

Chander and Pandey (1996) cited that application of 120 kg N ha^{-1} resulted significant increase in grains panicle^{-1}, effective tillers m^{-2} and grain yield compared to 60 kg N ha^{-1}. Carreres *et al.* (1996) reported that grain yield increased with increasing amount of N fertilizer up to 70 kg N ha^{-1}. Nitrogen rates appeared to affect grain yield by causing variations in the number of panicle m^{-2}. It was reported from experiment that the increased levels of nitrogen significantly influenced the grain yields. The maximum grain and straw yield of 4.58 and 6.21 t ha^{-1} were obtained from 90 kg N ha^{-1}. The increase over 0, 30 and 60 kg N was 49.8, 20.7 and 3.7% for grain, and 56.1, 25.2 and 10.1% for straw, respectively (Khanda and Dixit, 1996). Navin *et al.* (1996) conducted a field trail in winter rice, showed that with an increased in the nitrogen level (from 0 to 120 kg N ha^{-1}), there was an increase in plant height, number of spikelets panicle^{-1}, 1000-grain weight and grain and straw yields.

Paraye *et al.* (1996) conducted a field trial at Waraseoni in the 1989-90 rainy seasons, yield of rice cv. R.269 was the highest (4.47 t ha^{-1}) when 100 kg N ha^{-1} was applied 30% basally, 40% at tillering and 30% at panicle initiation. Islam and Bhuiya (1997) studied the effect of nitrogen and phosphorus on the growth, yield and nutrient uptake of deep-water rice. They observed that nitrogen and phosphorus fertilizer significantly increased the number of fertile tiller m^{-2} and also that of grains panicle^{-1}, which in turn resulted in significant increase in grain yield. The application of 60 kg N ha^{-1} alone gave 22% yield benefit over control. Singh *et al.* (1998) studied the performance of three hybrids KHR 1, proAgro 103 and MGR 1 using Jaya and Rasi as standard checks at four levels of N (0, 60, 120 and 180 kg ha^{-1}). They observed that the varieties responded linearly to the applied N levels up to 120 kg ha^{-1}.

Rajarathinam and Balasubramaniam (1999a) observed that there was no appreciable change in the yield on the yield attributes due to application of higher dose of N above 150 kg ha^{-1}. It was reported from experiment that the higher grain yield of hybrid rice CoRH-2 was produced by the application of 200 kg N ha^{-1}. However, application of 250 kg N ha^{-1} reduced the grain yield significantly (Rajarathinam and Balasubramaniam, 1999b). Chopra and Chopra (2000) reported that application of N at the rate of 80 or 120 kg ha^{-1} improved the entire yield attributes compared with the control. Zhang *and Wang* (2002) experimented on the agronomic performance of a newly developed site specific nutrient management (SSNM) technique for nitrogen fertilizer application to directly sown early rice against farmers fertilizer practice (FFM) in Jinhua, Zhejiang, China. Results showed that SSNM increased rice yield significantly and improved N use efficiency substantially.

Duhan *et al.* (2002) reported that the rice yield and uptake of nutrient increased significantly with increasing N levels. Moreover, the application of nitrogen along with various green manuring (GM) showed additive effects on the yield and uptake of micronutrients. Under all GM treatments, the yield and uptake were always higher with 120 kg N ha^{-1} than with lower level of nitrogen. Amin *et al.* (2004) reported that increased plant density significantly increase number of panicles per square meter, sterility and straw yield while increased fertilizer dose of NPK increased plant height, sterility, normal kernels and 1000 grain weight.

2.2 Effect of zinc on rice yield:

Zinc is an essential micronutrient which is required by plant to a smaller amount. Total Zn contain in soil is 10-300 ppm. Zinc is absorbed by plants in the form of Zn^{2+}. The normal concentration of Zn in dry matter of plants ranged from 25 to 150 ppm. Sphaterite (ZnS), Smithosnite ($ZnCO_3$), Hemimorphite ($Zn_4(OH)_2.Si_2O_7$) and Franklinite (ZnO,Fe_2O_3) are the important Zn containing minerals. Deficiencies are usually associated with leaf concentrations of less than 20 ppm. Zinc deficiencies are wide spread throughout the world, especially in the wetland rice of Asia and deficiencies occurring neutral and calcareous soils (Tisdale *et al.*, 1997). Zinc is essential for numerous enzyme systems and is capable of forming stable bonds with nitrogen and sulfur legends. Zinc is involved in a diverse range of enzymatic activities. The important functional roles of Zn are (i) Auxin metabolism, (ii) Influence on the activities of dehydrogenase and carbonic anhydrous enzymes, (iii) Synthesis of cytochrome C and (iv) Stabilization of ribosomal fractions (Tisdale *et al.*, 1990).

It was found that zinc and sulphur application to nursery bed resulted significant increase in grain yield of rice (Mowardi *et al.*, 1980). Sedbery *et al.* (1980) showed that application of Zn chelate significantly increased Zn content in Saturn rice plant. Wells (1980) observed that Zn content in rice plants was the highest at early seedling stage, then decreased to maximum at vegetative lag growth stage and then gradually increased until just prior to heading. It was observed that the application of 10 kg $ZnSO_4$ ha^{-1} increased the yields of rice grain and straw from 0.89 to 2.04 and 1.44 to 3.04 t ha^{-1} respectively. They also found that the root dipping in 2% ZnO suspension before transplanting increased grain and yields to 1.94 and 2.74 t ha^{-1} respectively (Bhuiya *et al.*, 1981). Dubey *et al.* (1981) reported that the critical limit below which a response to applied Zn could be expected was 21 ppm Zn in the 3rd leaf of rice.

Jahiruddin *et al.* (1981) reported that a significant increase in grain and straw yields of Tepi boro was contained when Zn was applied to acid clay type soil of Bangladesh. It was observed that Zn application increased grain yield ranged from 21.8 to 247.1% and that in straw yield from 8.6 to 505.5%. They also found that the grain yield was positively correlated with plant zinc content. The critical Zn concentration for response to zinc fertilizer was 13.5 ppm in rice plant (Rathore *et al.*, 1982). Sharma *et al.* (1982) reported that the yield of rice increased from 3.21 tha^{-1} without Zn to 5.78 t/ha with Zn application. It was noted in the field experiment that Zn application showed an increase in all the growth parameters of rice. The effect was found to be minimum at 10 kg ha^{-1} for plant weight and at 20 kg Zn ha^{-1} for number of tillers $hill^{-1}$ (Ahmed *et al.*, 1983).

Sadhana and Takkar (1983) reported that Zn application increased 14% dry matter yield of rice over control. Sarker *et al.* (1983) reported that application of 5 kg Zn ha^{-1} significantly increased paddy yield over control however further increase in Zn rate was not effective. Singh *et al.* (1983) conducted a field experiment on an alluvial calcareous sandy loam soil where application of Zn up to 5 kg ha^{-1} significantly increased the grain and straw production while at 10 kg Zn ha^{-1} level the yield tended to decrease.

Singh (1985) conducted an experiment with 10 non-calcareous alluvial soils and found that Zn application significantly increased Zn concentration in various plant parts in all soils irrespective of the initial Zn status. Singh and Abrol (1985) showed the varieties Kaveri, Jaya and Ratna exhibited a reduced grain and straw yield from the increasing salt stress. When irrigated with water having the highest salinity level (12 mhos cms^{-1}) Kaveri and Ratna proved more susceptible to salt stress than Jaya. Zinc application increased the grain and straw yields in all the cultivars over no zinc treatment (control). Balakrishnan and Natarajaratnam (1986) reported that application of 25 kg $ZnSO_4$ ha^{-1} with NPK on rice increased the effective tillers $hill^{-1}$, panicle length, total grain and filled grains $panicle^{-1}$, 1000-grain weight and paddy yield. Grain and straw yields were 16.7% and 22.8% higher over control, respectively.

Nagarajan and Manickam (1986) reported that paddy yield of rice grown on 4 soil types at 9 locations in Tamil Nadu were increased from 3.93 to 4.12 t ha^{-1} by applying 25 kg $ZnSO_4$ ha^{-1}. Muniz *et al.* (1987) conducted field trails at 6 sites with rice (cv.IR-880, J-104 and caribe 1). They used 0, 5, 10, 15 or 20 kg Zn ha^{-1} as zinc sulphate at different types soils with up to 1.5 ppm Zn, the yield responded to application of 5 kg Zn ha^{-1}. Application of Zn generally increased the number of fertile stems m^{-2} but not 1000-grain weight. Baker *et al.* (1988) reported that the application of Zn in different levels 0, 1.5, 3.0 mg Zn kg^{-1} soil resulted in greater Zn uptake and greater dry matter yield. Machii *et al.* (1988) reported that application of 60 kg $ZnSO_4$ ha^{-1} applied to rice incrased the yield from 4.45 to 5.22 t ha^{-1}.

It was cited that application of 5.7 kg Zn ha^{-1} increased the grain yield but did not affect the straw yield. Zinc application increased the uptake of Zn by plant (Salam and

Subramanian, 1988). Varshney (1988) stared that application of 20 kg $ZnSO_4$ ha^{-1} increased paddy yields from 2.9 to 3.9 t ha^{-1} in 1977 and from 3.5 to 3.3 t ha^{-1} in 1978. Zinc application increased the number of tillers and panicles $hill^{-1}$, panicle length and 1000-grain weight. It was found from a field trial on a Zn deficient soil in Punjab, India that with Zn application 0, 5 or 10 kg $Znha^{-1}$ as $ZnSO_4$, ZnO and Zn-frits on Jaya rice increased grain yields significantly. Among the sources, $ZnSO_4$ and Zn-frits produced the highest rice grain yield; ZnO was least effective (Chhibba *et al.*, 1989). Choudhury and Hore (1989) showed that application of S and Zn increased both grain and straw yields of Pajam rice. The highest grain yield of 4.04 t ha^{-1} was obtained with 10 kg Zn along with 30 kg S ha^{-1}. Hossain *et al.* (1989) reported that the application of zinc in the form of $ZnSO_4$ ha^{-1} significantly increased grain and straw yields as well as different yield components except the number of tillers $hill^{-1}$.

Prasad *et al.* (1989) conducted a field experiment with a wheat-rice cropping sequence to evaluate the relative effectiveness of organic sources of Zn in a Zn deficient calcareous soil. Total Zn contents in biogas slurry, poultry manure, compost, sewage sludge and pressmud were 105, 106, 585 and 95 ppm, respectively. The relative contribution from organic source of Zn and $ZnSO_4$ as Zn in increasing yields and Zn uptake was in the order poultry manure>compost>pressmud>biogas>>slurry sewage>sludge>$ZnSO_4$. The Zn use efficiency (2.0-8.1%) of biogas slurry and these organic wastes were greater than that of $ZnSO_4$ application (0.32-1.5%). The residual effect of Zn application through these organic sources of Zn persisted even after the harvest of the 4th crop of wheat and rice. Biogas slurry and other organic wastes maintained higher levels of available Zn (1.75 ppm) in zinc deficient Calcareous soil than zinc sulphate (0.89 ppm).

Sahu *et al.* (1989) reported that the grain yield of rice significantly increased with Zn application either as seed soaking or root dip or foliar spray. Sarker *et al.* (1989) reported that the effects of Zn application 20 kg $ZnSO_4$ ha^{-1} to the soil during seed bed preparation or 3 foliar sprays of 0.5% $ZnSO_4$ + 0.25% lime at 10 days intervals after transplanting gave grain yields of 7.2-7.4 t ha^{-1} compared with 5.6 t ha^{-1} without Zn. Mostafa (1990) reported from Egypt that the application of $ZnSO_4$ either soil or foliar spray significantly increased the grain yield of rice.

Gupta and Potalia (1991) studied the effect of various concentration of Zn on grain and straw yields and found that Zn application increased grain and straw yields of rice. Shah and Dutta (1991) reported that application of Zn @ 10 kg Zn ha^{-1} was sufficient to correct Zn deficiency in rice although the highest grain yield was obtain with 4 kg Zn ha^{-1}. Zinc content of rice plants increased when Zn was applied the increase being most pronounced with 4 kg Zn ha^{-1}. Conversely, plant Zn contain decreased slightly when high doses of Zn were applied. Zinc and S uptake correlated positively and significantly with grain yield when it was applied with Zn.

Sachdev and Deb (1991) conducted a green house experiment on rice (cv. M101). They studied the effects of 0, 5, 10 or 15 ppm Zn as $ZnSO_4$ on Zn uptake and dry matter yield measured at 15, 30, 45 and 60 days after transplanting. It was observed that dry matter yield and Zn content and uptake increased with increase in Zn application. Zinc content of rice was significantly correlated with DTPA extractable soil Zn. Srivastav *et al.* (1992) reported that application of all Zn treatments ($ZnSO_4$, 20 kg ha^{-1} soil applied or 5 kg ha^{-1} as a foliar spray and chelated Zn at the rate of 1 kg ha^{-1} soil applied or 500 g ha^{-1} as foliar spray) increased rice yield and Zn uptake compared with control (no. Zn) plots. In both application methods, yield and Zn uptake were higher when chelated Zn applied; soil application of chelated Zn gave the highest yield of 6.9 t ha^{-1}. It was found from field trials in 5 districts of Uttar Pradesh (India) with rice, wheat and pearl millet (*Pennisetum glaucum*) that 25 kg ha^{-1} $ZnSO_4$ is the most economic recommended dose for the above crops (Prasad *et al.*, 1992). Shah (1993) conducted a field trial on course textured S and Zn deficient soil to study the interaction of S and Zn in relation to the nutrition and yield of rice. He found that S application at the rate of 50 kg ha^{-1} significantly increased grain yield over control, but Zn application had no effect on grain yield of rice. Zinc content in straw and Zn uptake at harvest decreased with increasing applied S levels but Zn level did not influence S content and uptake.

Prasad and Umar (1993) in a field trail on rice (cv. Sita, Pankaj and Jaishree) at Patna and Bihar with four Zn rates 0, 5, 10 and 20 kg $ZnSO_4$ ha^{-1}. They reported that grain and straw yields increased with increasing Zn rates. They also observed that grain yield did not differ significantly between cultivars, while straw yield was lowest in sita, Zn uptake increased with rate of applied Zn. It was observed from a field experiment that in flooded condition application of $ZnSO_4$ increased the grain yield of rice (Dixit and Khanda, 1994). Jahiruddin *et al.* (1994) conducted a field experiment on sonatala silt loam soil at BAU farm, Mymensingh in boro season of 1992. They found that grain yield was significantly improved after combined application of S, Zn and B which resulted in 28% yield increase over control. Zaman *et al.* (1994) in a field trail on Non-calcareous Dark Grey Floodplain soil and reported that application of Zn had a position effect on grain yield of rice.

Khanda and Dixit (1996) reported that application of Zn significantly increased the grain and straw yields over no 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. Arf *et al.* (1996) conducted a field trial with rice (cv. Rio Paranaiba) using 0, 5, 10 or 20 kg Zn ha^{-1} and 0, 0.5, 1.0 or 2.0 kg B ha^{-1}. They observed that seed yield was not affected by the treatments, but the yield of whole grains was highest with 10 kg Zn ha^{-1}. It was reported that dipping the seedling in 2% $ZnSO_4$ solution gave higher yield (5.15 t ha^{-1}) almost similar to the application of 25 kg $ZnSO_4$ as compared to control (Kumar and Singh, 1996).

Agarwal *et al.* (1997) conducted a field trail on rice-wheat cropping pattern at Kanpur (India) in 1990-93. They reported that mean yield of each crop and net returns were greatest when 25 kg $ZnSO_4$ ha^{-1} was applied to the crop. Chen *et al.* (1997) carried out a field experience in Rice Research Institute of Yunnan Agricultural University, Kunming, on soils 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 yield significantly, especially in Hexi 35 and Yungeng 34. Grain amylase content of milled rice was increased by Zn application. Sakal *et al.* (1997) reported that the continuous rice-wheat system with increasing NPK fertilizer applications is the cause of depleting the soil available micronutrients reserve, particularly available Zn, leading to decline in crop productivity. Channal and Kandaswamy (1997) conducted a field experiment with rice (cv. Co-43) at Trichi, Tamil Nadu that was supplied with 12.5 t ha^{-1} of dhaincha or composted coir pith, gypsum with or without 5 ton dhaincha or no amendments and 0-50 kg $ZnSO_4$ ha^{-1}. They found that cowpea (cv. C-152) was grown on the same plots after rice on residual fertility. The application of 37.5 kg $ZnSO_4$ and gypsum + dhancha produced the highest rice grain yield of 5.63 t ha^{-1}. Cowpea seed yield was highest rice grain of 5.63 t ha^{-1}. Cowpea seed yield was highest (0.44 t ha^{-1}) on plot receiving 50 kg $ZnSO_4$ and gypsum + dhaincha. Ingle *et al.* (1997) carried out a field trail at Sindewahi, Maharashtra, using rice cv. Sye-75 was given 0, 5, 10 or 15 kg Zn ha^{-1} as $ZnSO_4$ or ZnO. They observed that grain yield was increased with increasing Zn rates but was not affected by source of Zn.

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

Bansal *et al.* (1998) reported that high levels of Zn in soil decreased the absorption and translocation of Mn, Cu and Fe implants. The decrease in plant Mn concentration resulted in the appearance of Mn deficiency symptoms in rice despite its adequate level in soil. Islam and Haque (1998) reported from two different sites on rice based cropping pattern that the uptake of NPKS decreased very much when low rate N and no S and Zn were added to Palima, Tangail site. At Palashbari, Gaibandha site, the uptake of NPK also markedly decreased when no zinc was added to the system. Patra and Poi (1998) applied different forms of trace elements to rice cv. IET-5656 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 obtain 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}). Ahmed and Hossain (1999) reported from 3 years field experiment of wheat' mungbean-rice cropping sequence that application of Zn along with NPKS increased rice yield.

Alam *et al.* (2000) reported that grain yield of rice was 3.61 t ha^{-1} without Zn and N application and increased to 4.2 t ha^{-1} with 50 kg Zn ha^{-1} and 150 kg N ha^{-1} on a soil deficient in Zn. Xiaopeng *et al.* (2005) found that application of 20 kg $ZnSO_4$ ha^{-1} in Zn deficient soil increased different growth characters and grain yield of rice. Increasing the dose of $ZnSO_4$ beyond 20 kg ha^{-1} did not lead to further significantly increase in any of the growth characters and grain yield of rice. Jiang *et al.* (2007) observed that uptake and distribution of zinc (Zn) either applied to the roots or to the leaves in rice during grain development stage increase 33% filled grain and thus increase the yield of rice.

Chapter III

MATERIALS AND METHODS

The experiment was conducted in the Sher-e-Bangla Agricultural University Farm, Dhaka, under the Agro Ecological Zone of Madhupur Tract, AEZ-28 during the T. *aman* season of 2006. For better understanding the site, it is shown in the Map of AEZ of Bangladesh (Fig. 1).

This chapter presents a brief description of the soil, crop, experimental design, treatments, cultural operations, collection of soil and plant samples and analytic methods followed in the experiment. This chapter has been divided into a number of sub-heads describe as below:

3.1 Experimental details of the site

3.1.1 Soil

The experiment was carried out in a typical rice growing soil of the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka, during T. *aman* season of 2006. The farm belongs to the General soil type, Deep Red Brown Terrace Soil under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. The morphological, physical and chemical characteristics of initial soil are presented in Tables 1 and 2.

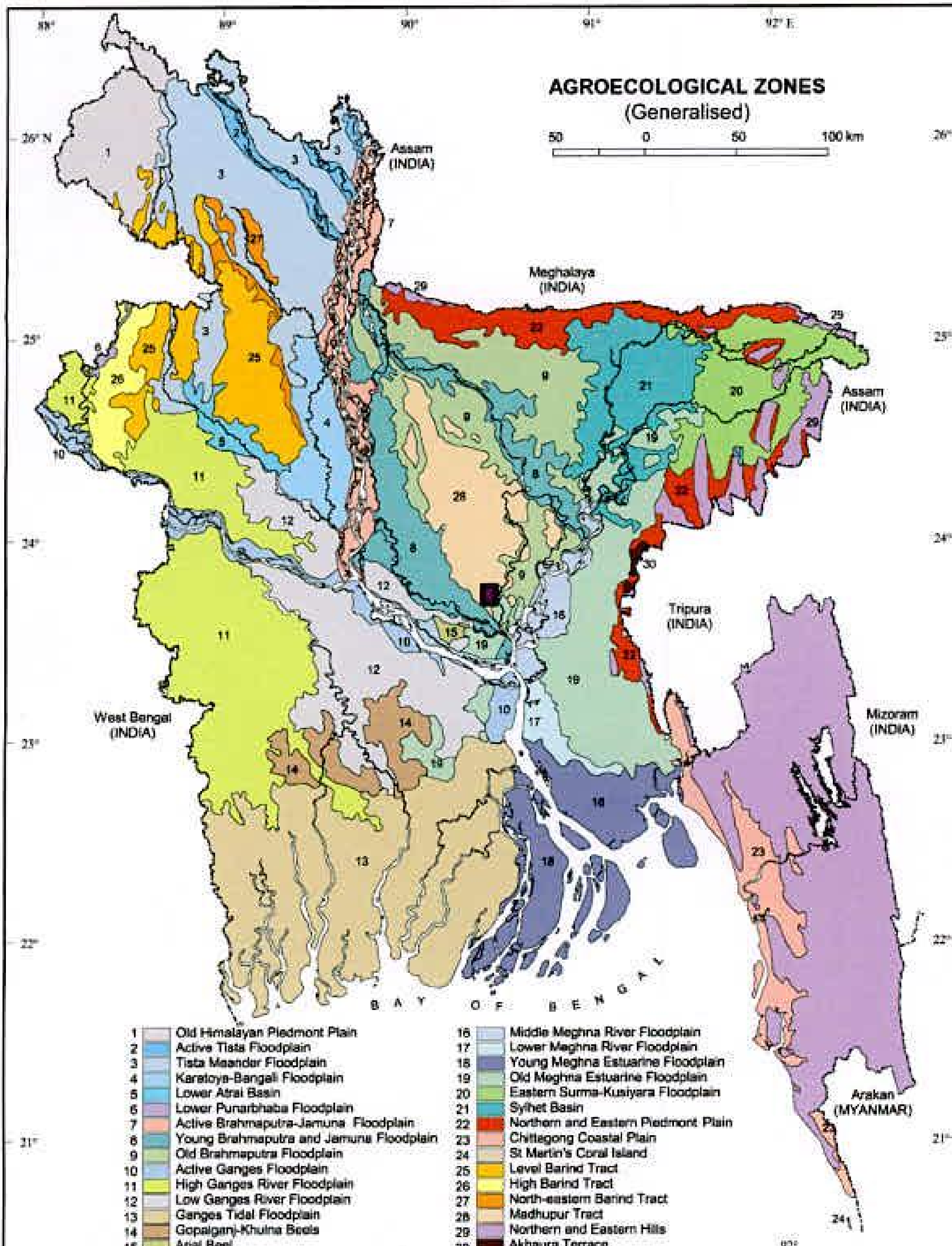


Figure 1. Map showing the experimental site under study

Table 1. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, Dhaka.
AEZ	Madhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

Table 2. Physical and chemical properties of the initial soil sample

Characteristics	Value
Particle size analysis	
% Sand	28.2
% Silt	41.2
% Clay	30.6
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.47
Organic matter (%)	0.81
Total N (%)	0.05
Available P (ppm)	18.1
Exchangeable K (meq/100g soil)	0.10
Available S (ppm)	40
Available Zn (ppm)	3.10

3.1.2 Climate

The climate of the experimental area is characterized by sub tropical accompanied by moderate high rainfall associated with relatively high temperature during T. *aman* season. The average temperature and rainfall data during the cropping period are shown in Appendix 1.

3.1.3 Crop

BRRI Dhan 39, a high yielding variety of rice, was used as a test crop. The variety was developed by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, as a short duration T. *aman* rice.

3.1.4 Land preparation

The experimental field was first opened on 5 July 2006 with the help of a power tiller, later the land was saturated with irrigation water and puddled by three successive ploughing and cross-ploughing. Each ploughing was followed by laddering to have a good puddled field. All kinds of weeds and residues of previous crop were removed from the field. The experimental plots were laid out as per treatment and design.

3.1.5 Experimental design

Design: Randomized Complete Block (RCB).

Treatment: 16

Replication: 3

Total number of plots: 48

Plot size: 4m × 3m

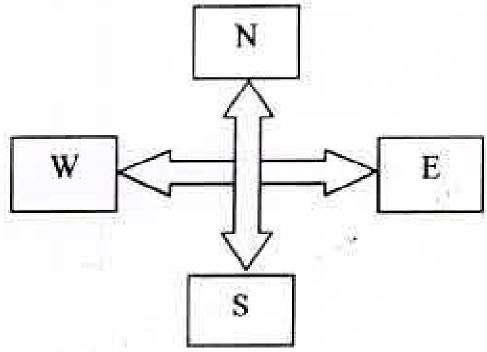
Block to block distance: 2m

Plot to plot distance: 1m

3.1.6 Layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each block was sub-divided into sixteen unit plots. The treatments were randomly distributed to the unit plots in each block. The total number of plots was 48 (16×3). The unit plot size was 4 m × 3 m. The spacing between blocks was 2 m and between plots 1m. The layout of the experiment has been shown in Fig. 2.

Plot size: 4 m x 3 m
Plot to plot distance: 1m
Block to block distance: 2 m



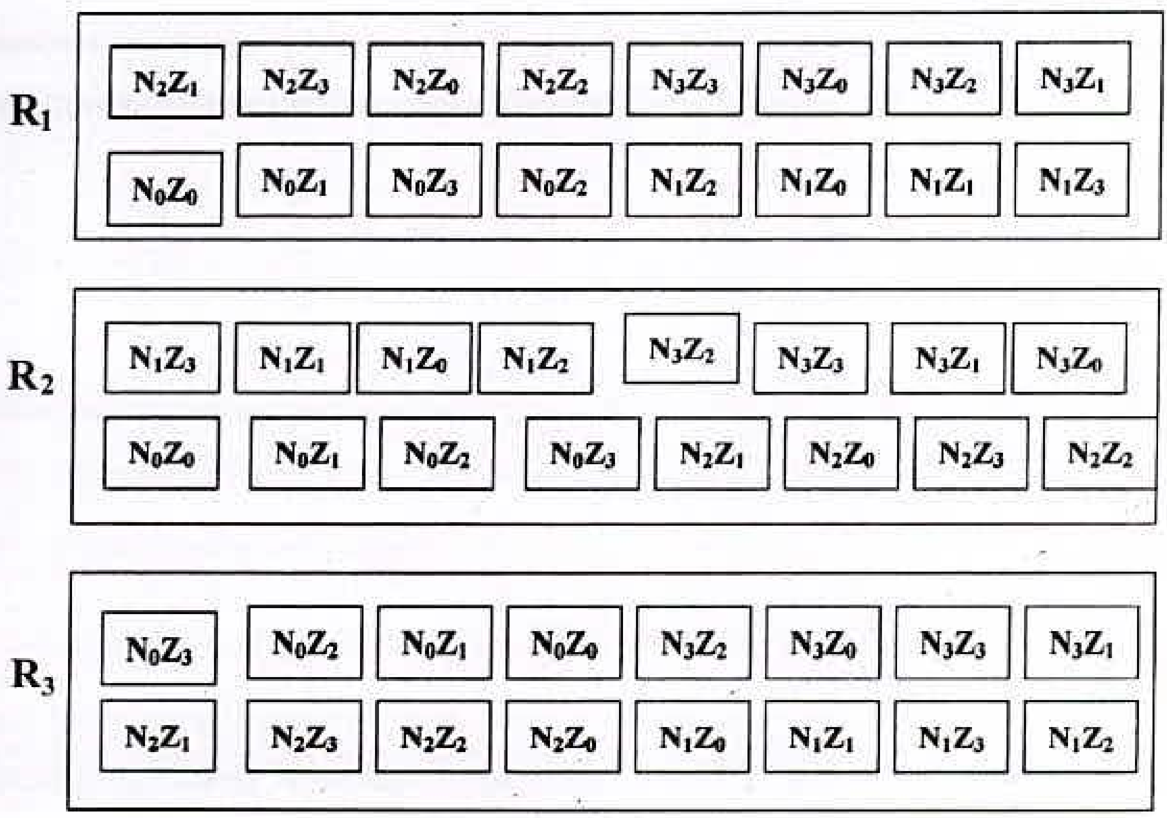


Figure 2: Layout of the experimental field

3.1.7 Raising of seedlings

A standard procedure was followed to raise seedlings in the seedbed. For this purpose, a previously prepared land was selected. The nursery bed was prepared by puddling the wetland with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed.

3.1.8 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were drawn by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.1.9 Treatments

There were sixteen treatments consisting of four level of nitrogen (0, 50, 100, 150 kg N ha^{-1}) and four level of zinc (0, 5, 10, 15 kg Zn ha^{-1}). There were 16 treatment combinations. The treatment combinations were as follows:

T_1 (N_0Zn_0): Control (0 kg N ha^{-1} + 0 kg Zn ha^{-1})

T_2 (N_1Zn_0): 50 kg N ha^{-1} + 0 kg Zn ha^{-1}

T_3 (N_2Zn_0): 100 kg N ha^{-1} + 0 kg Zn ha^{-1}

T_4 (N_3Zn_0): 150 kg N ha^{-1} + 0 kg Zn ha^{-1}

T_5 (N_0Zn_1): 0 kg N ha^{-1} + 5 kg Zn ha^{-1}

T_6 (N_1Zn_1): 50 kg N ha^{-1} + 5 kg Zn ha^{-1}

T_7 (N_2Zn_1): 100 kg N ha^{-1} + 5 kg Zn ha^{-1}

T_8 (N_3Zn_1): 150 kg N ha^{-1} + 5 kg Zn ha^{-1}

T_9 (N_0Zn_2): 0 kg N ha^{-1} + 10 kg Zn ha^{-1}

T_{10} (N_1Zn_2): 50 kg N ha^{-1} + 10 kg Zn ha^{-1}

T_{11} (N_2Zn_2): 100 kg N ha^{-1} + 10 kg Zn ha^{-1}

T_{12} (N_3Zn_2): 150 kg N ha^{-1} + 10 kg Zn ha^{-1}

T_{13} (N_0Zn_3): 0 kg N ha^{-1} + 15 kg Zn ha^{-1}

T_{14} (N_1Zn_3): 50 kg N ha^{-1} + 15 kg Zn ha^{-1}

T_{15} (N_2Zn_3): 100 kg N ha^{-1} + 15 kg Zn ha^{-1}

T_{16} (N_3Zn_3): 150 kg N ha^{-1} + 15 kg Zn ha^{-1}

Table 3. Sources and rates of different elements in the experiment

Source	**Rate ha^{-1}**	**Time of application**
TSP	80 kg	Final land preparation
MP	120 kg	Final land preparation
Gypsum	55 kg	Final land preparation

3.1.10 Application of fertilizers

The amounts of nitrogen, phosphorus, potassium, sulphur and zinc fertilizers required per plot were calculated from fertilizers rate per hectare. A blanket dose of 16 kg P, 60 kg K, and 10 kg S hectare^{-1} was applied to all plots in the forms of triple super phosphate (TSP), muriate of potash (MOP) and gypsum, respectively during final land preparation. Zinc was applied as per treatment in the form of $ZnSO_4$ on the day of transplanting. Nitrogen was also applied as per treatment in the form of urea in three equal splits. The first split was applied after 7 days of transplanting, the second split was applied after 30 days of transplanting i.e. at active vegetative stage and the third split was applied after 60 days of transplanting i.e. at panicle initiation stage.

3.1.11 Transplanting of seedlings

The seedlings of 30 days old were transplanted in the experimental plots on 21 July 2006. Plant spacing was 25 cm × 15 cm. The number of rows were 17 and number of hills were 20 in all plots. The seedlings were carefully uprooted from the seedbed before transplanting. Three seedlings were used per hill.

3.1.12 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop. Top dressing of urea was done as per schedule and the normal cultural practices including weeding and insecticides spray were done as and when necessary. There were some incidence of insect attack specially rice hispa, rice stem borer, rice bug, which were controlled by spraying Diazinon pillersuphan, Darsban, and Malathion. Irrigations were also done uniformly to the plots and maintained on water level of 5 to 4 cm throughout the growing period of the crop.

3.1.13 Plant sampling at harvest

Plants from $1m^2$ were randomly selected from each plot to record the yield contributing characters like plant height (cm), number of tillers $hill^{-1}$, panicle length (cm), number of grains $panicle^{-1}$, and 1000-grain weight (g). The selected hills were collected before harvesting. Grain and straw yields were recorded plot-wise and expressed at ton ha^{-1} on sun dry basis.

3.1.14 Harvesting

The crop was harvested at maturity on 29 October 2006. The harvested crop was threshed plot-wise. Grain and straw yields were recorded separately plot-wise and moisture percentage was calculated after sun drying. Dry weight for both grain and straw were also recorded.

3.1.15 Data collection

The data on the following yield contributing characters of the crop were recorded:

i) Plant height (cm)

ii) Number of effective and ineffective tillers $hill^{-1}$

iii) Panicle length (cm)

iv) Number of unfilled and filled grains $panicle^{-1}$

v) 1000-grain weight (g)

vi) Grain and straw yields (kg $plot^{-1}$)

3.1.15.1 Plant height (cm)

The plant height was measured from the ground level to the top of the panicle. Plants of 10 hills (1 m^2) were measured and average for each plot.

3.1.15.2 Number of tillers $hill^{-1}$

Ten hills were taken at random from each plot and the number of tillers $hill^{-1}$ were counted. The numbers of effective and uneffective tillers $hill^{-1}$ were also determined.

3.1.15.3 Panicle length

Measurement was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 10 hills.

3.1.15.4 Unfilled and filled grains panicle^{-1}

Ten panicles were taken at random to count unfilled and filled grains panicle^{-1} and averaged.

3.1.15.5 1000-grain weight

The weight of 1000-grains from each plot was taken after sun drying by an electric balance.

3.1.15.6 Grain and straw yields

Grain and straw yields were recorded separately plot-wise and expressed as t ha^{-1} on 14% moisture basis.

3.1.16 Chemical analysis of soil samples

Soil samples were analyzed for both physical and chemical properties in the laboratory of Soil Resource Development Institute (SRDI), Farmgate, Dhaka. The properties studied included soil texture, pH, organic matter, total N, available P, exchangeable K and available S and Zn. The physical and chemical properties of the initial soil have been presented in Table 2. The soil was analyzed by standard methods:

3.1.16.1 Particle size analysis

Particle size analysis of soil was done by Hydrometer Method (Bouyoucos, 1926) and the textural class was determined by plotting the values for % sand, % silt and % clay to the "Marshall's Textural Triangular Coordinate" according to the USDA system.

3.1.16.2 Soil pH

Soil pH was measured with the help of a Glass electrode pH meter using soil and water at the ratio of 1:2.5 as described by Jackson (1962).

3.1.16.3 Organic carbon

Organic carbon in soil was determined by Walkley and Black's (1934) Wet Oxidation Method. The underlying principle is to oxidize the organic carbon with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 1N $FeSO_4$ solution. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed in percentage.

3.1.16.4 Total nitrogen

Total nitrogen of soil was determined by Micro Kjeldahl method where soil was digested with 30% H_2O_2, conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se powder in the ratio of 100:10:1). Nitrogen in the digest was estimated by distillation with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.01N H_2SO_4 (Bremner and Mulvaney, 1982).

3.1.16.5 Protein

Protein content of grain and straw sample were estimated by multiplying percentage of total nitrogen with 6.25.

3.1.16.6 Available phosphorus

Available phosphorus was extracted from soil by shaking with 0.5 M $NaHCO_3$ solution of pH 8.5 (Olsen *et al.*, 1954). The phosphorus in the extract was then determined by developing blue colour using $SnCl_2$ reduction of phosphomolybdate complex. The absorbance of the molybdophosphate blue color was measured at 660 *n*m wave length by Spectrophotometer and available P was calculated with the help of standard curve.

3.1.16.7 Exchangeable potassium

Exchangeable potassium was determined by 1N NH_4OAC (pH 7.0) extract of the soil by using Flame photometer (Black, 1965).

3.1.16.8 Available zinc

Available zinc contents in soil were determined by 0.2% DTPA extracting method as described by Hunter (1984). The extractable Zn was measured by Atomic absorption spectrophotometer.

3.1.16.9 Available sulphur

Available sulphur in soil was determined by extracting the soil samples with 0.15% $CaCl_2$ solution (Page *et al.*, 1982) The S content in the extract was determined turbidimetrically and the intensity of turbid was measured by Spectrophotometer at 420 *n*m wave length.

3.1.17 Chemical analysis of plant samples

3.1.17.1 Preparation of plant samples

Ten selected hills plot^{-1} were collected immediately after harvest of the crop. The selected hills were threshed. Both grain and straw were cleaned and dried in an oven at 65^0 C for 48 hours. The dried samples were put into small paper bags and kept into a desiccator till being used.

3.1.17.2 Digestion of plant samples with sulphuric acid

For N determination, an amount of 0.1 g plant sample (grain/straw) was taken into a 100 ml Kjeldahl flask. An amount of 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se = 100:10:1), 2 ml 30% H_2O_2 and 3 ml conc. H_2SO_4 were added into the flask. The flask was swirled and allowed to stand for about 10 minutes, followed by heating at 200^0C. Heating was continued until the digest was clear, and colorless. After cooling, the contents were taken into a 100 ml volumetric flask and the volume was made with distilled water. A blank digestion was prepared in a similar way except plant sample. This digest was used for determining the nitrogen contents on plant samples.

3.1.17.3 Digestion of plant samples with nitric-perchloric acid mixture

An amount of 0.5 g of plant 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 raising slowly to 200^0C. Heating was instantly stopped as soon as the dense white fumes of $HClO_4$ occurred and after cooling, 6 ml of 6N HCl were added to it. The content of the flask was boiled until they become clear and colourless. This digest was used for determining P, K, S and Zn.

3.1.17.4 Determination of element in the digest

Nitrogen, phosphorus, potassium, sulphur and zinc content in the digest were determined by similar method as described in soil analysis.

3.1.18 Statistical Analysis

The statistical analysis for different character including the nutrient content and uptake were done following the ANOVA technique and the mean results in case of significant F-values were adjusted by the Duncan's Multiple Range Test (DMRT).

Chapter IV

RESULTS AND DISCUSSION

This chapter presents the experimental results along with their possible interpretation and discussion in relation to determine the effect of different levels of nitrogen and zinc on the yield and yield contributing characters of BRRI Dhan 39 as well as nitrogen and zinc content and their uptake by rice plants. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Yield and yield contributing character of rice

Yield contributing characters such as plant height (cm), number of total and effective tiller, panicle length (cm), number of filled and unfilled grain, 1000-seed weight (g), grain yield and straw yield (t ha^{-1}) were recorded in every plot of the trial.

4.1.1 Plant height

4.1.1.1 Effect of nitrogen on plant height

The effect of nitrogen showed a statistically significant variation in terms of plant height of BRRI Dhan 39 under the present trial (Appendix II). The maximum plant height (112 cm) was recorded in N_2 treatment comprising of 100 kg N ha^{-1} which was statistically similar (110 cm and 110 cm) with the treatment N_3 and N_1 comprising of 150 kg N ha^{-1} and 50 kg N ha^{-1}, respectively (Table 4 and Figure 3). The minimum plant height (105 cm) was recorded from the N_0 treatment i.e. control condition. Probably 100 kg N ha^{-1} ensured the favorable condition for growth and development of rice plant and the ultimate results is the tallest plant. The findings obtained in the present experiment are similar with some other researchers, Awan *et al.* (1984) and Haque and Khan (1981). Reddy *et al.* (1986) found significant increase in plant height of BR11 rice due to application of 120 kg N ha^{-1} over control treatment. Andrade and Amorim Neto (1996) observed that increasing level of applied N increased plant height of rice significantly. Navin *et al.* (1996) found that with an increase in the nitrogen level (from 0 to 120 kg N ha^{-1}), there was an increase in plant height of rice plant.

Table 4. Effect of different levels of nitrogen on yield and yield contributing characters of BRRI Dhan 39

Treatment	Plant height (cm)	Total tiller (No.)	Effective tiller (No.)	Panicle length (cm)	Filled grain (No.)	Unfilled grain (No.)	1000-seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
N_0	105 b	10.10 c	9.10 c	21.01 c	79.83 c	26.72 a	23.10	2.66 c	6.66 d
N_1	110 a	11.29b	10.77 b	22.29b	85.05b	24.02 b	24.05	3.47 b	7.02 c
N_2	112 a	12.16 a	11.79 a	23.80 a	88.15 a	23.63 b	24.17	4.91 a	7.72 b
N_3	110 a	11.2 b	10.95 b	23.67 a	88.46 a	24.52 b	23.98	3.47 b	8.08 a
$LSD_{(0.05)}$	3.7	0.41	0.41	0.63	3.00	2.14	--	0.19	0.16
Significance level	**	**	**	**	**	*	NS	**	**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

**: Significant at 1% level of probability; *: Significant at 5% level of probability; NS: Not significant

N_0 : 0 kg N ha^{-1}
N_1 : 50 kg N ha^{-1}
N_2 : 100 kg N ha^{-1}
N_3 : 150 kg N ha^{-1}

Zn_0 : 0 kg Zn ha^{-1}
Zn_1 : 5 kg Zn ha^{-1}
Zn_2 : 10 kg Zn ha^{-1}
Zn_3 : 15 kg Zn ha^{-1}

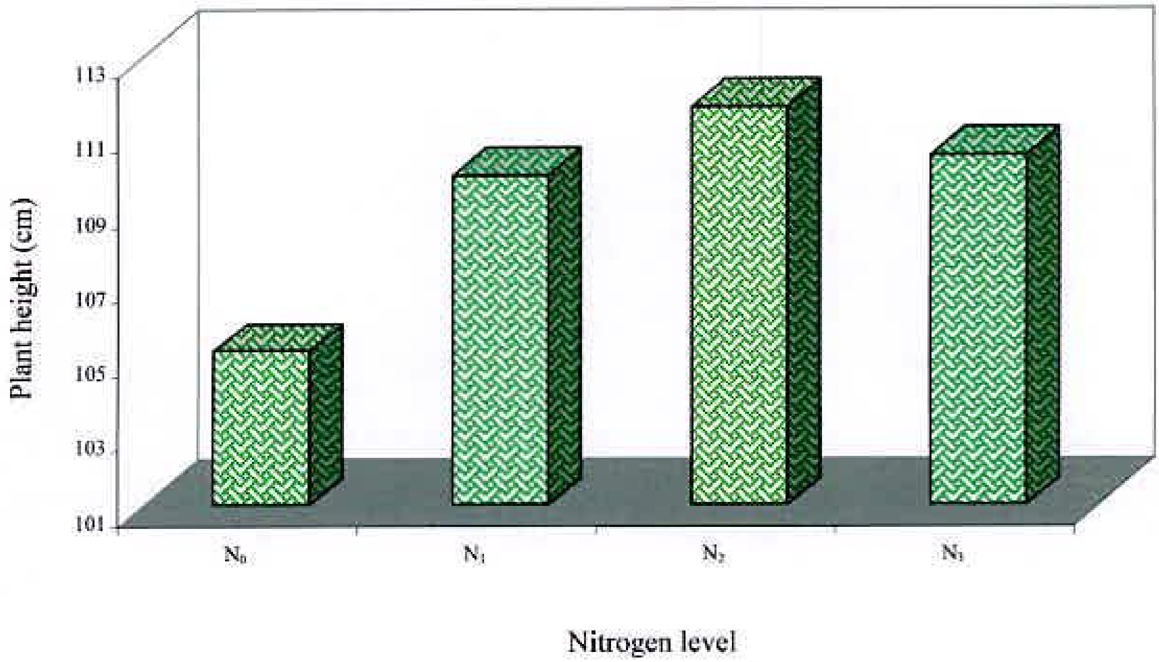


Figure 3. Effect of nitrogen on plant height of BRRI Dhan 39

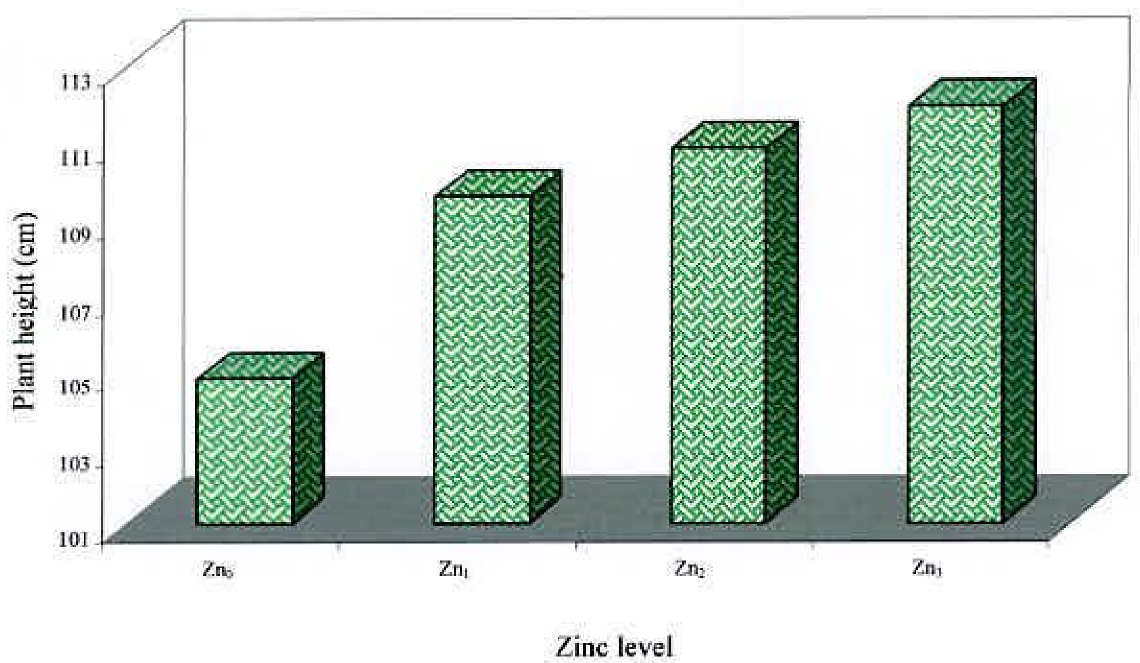


Figure 4. Effect of zinc on plant height of BRRI Dhan 39

4.1.1.2 Effect of zinc on plant height

Different level of zinc exhibited statistically significant differences for plant height (Appendix II). The maximum plant height (112 cm) was recorded in Zn_3 treatment comprising of 15 kg Zn ha^{-1} which was statistically identical (111 cm and 110 cm) with the treatments Zn_2 and Zn_1 comprising of 10 kg Zn ha^{-1} and 5 kg Zn ha^{-1}, respectively (Table 5 and Figure 4). On the other hand the minimum plant height (105 cm) was recorded from the Zn_0 treatment i.e. control condition.

Table 5. Effect of different levels of zinc on yield and yield contributing characters of BRRI Dhan 39

Treatment	Plant height (cm)	Total tiller (No.)	Effective tiller (No.)	Panicle length (cm)	Filled grain (No.)	Unfilled grain (No.)	1000 seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Zn_0	104.79 b	10.88 c	10.22 b	22.05 b	79.35 d	27.70 a	23.23	3.39 c	7.16 c
Zn_1	109.56 a	11.31 ab	10.81 a	22.64 ab	86.82 b	25.13 b	23.63	3.69 b	7.34 b
Zn_2	110.79 a	11.53 a	10.97 a	23.10 a	92.52 a	23.88 bc	24.25	3.91 a	7.52 a
Zn_3	111.90 a	11.03 bc	10.62 ab	22.99 a	82.80 c	22.17 c	24.19	3.51 bc	7.47 ab
$LSD_{(0.05)}$	3.707	.408	0.406	0.633	3.002	2.143	--	0.194	0.158
Significance level	**	*	**	**	**	*	NS	**	**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

** : Significant at 1% level of probability; * : Significant at 5% level of probability; NS : Not significant

N_0: 0 kg N ha^{-1}	Zn_0: 0 kg Zn ha^{-1}
N_1: 50 kg N ha^{-1}	Zn_1: 5 kg Zn ha^{-1}
N_2: 100 kg N ha^{-1}	Zn_2: 10 kg Zn ha^{-1}
N_3: 150 kg N ha^{-1}	Zn_3: 15 kg Zn ha^{-1}

4.1.1.3 Interaction effect of nitrogen and zinc on plant height

No significant interaction effect was recorded between nitrogen and zinc in consideration of plant height under the present experiment (Appendix II). But the maximum plant height (114 cm) was recorded from the treatment combination N_3Zn_1 comprising of 150 kg N ha^{-1} + 5 kg Zn ha^{-1} while the minimum plant height (102 cm) was recorded from N_0Zn_0 i.e. without nitrogen and zinc (Table 6).

4.1.2 Number of total tillers $hill^{-1}$

4.1.2.1 Effect of nitrogen on number of total tillers $hill^{-1}$

A statistically significant variation was recorded for the effect of nitrogen in terms of number of total tillers (Appendix II). The maximum number of total tiller (12.16) was recorded in N_2 treatment comprising of 100 kg N ha^{-1} which was followed by the treatment N_1 and N_3 comprising of 50 kg N ha^{-1} and 150 kg N ha^{-1}, respectively (Table 4) and the minimum number of total tiller (10.10) was recorded from the N_0 treatment i.e. control condition. Probably 100 kg N ha^{-1} ensured the favorable condition for growth and development of rice and the ultimate results is the maximum number of total tiller. Reddy *et al.* (1986) reported that maximum number of tillers of rice was obtained when 120 kg N ha^{-1} was applied in 3 equal splits than 2 equals at transplanting and tillering or single dressing at transplanting stage.

Table 6. Interaction effect of different levels of nitrogen and zinc on yield and yield contributing characters of BRRI Dhan 39

Treatment	Plant height (cm)	Total tiller (No.)	Effective tiller (No.)	Panicle length (cm)	Filled grain (No.)	Unfilled grain (No.)	1000-seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
N_0Zn_0	102	9.23 g	8.13 h	20.82	71.90 g	34.83 a	22.17	2.20 j	6.40
N_0Zn_1	103	10.20 f	9.00 g	20.99	80.77 def	28.13 bcd	22.67	2.73 hi	6.69
N_0Zn_2	106	10.50 ef	9.60 fg	21.11	86.63bcd	23.63d-g	23.50	3.07 gh	6.75
N_0Zn_3	109	10.47 ef	9.67 fg	21.12	80.03 df	20.27 gh	24.07	2.63 i	6.79
N_1Zn_0	106	10.93 c-f	10.17 ef	21.05	76.93 fg	23.50 d-g	23.57	3.07 gh	6.91
N_1Zn_1	110	11.50 bcd	11.10 bcd	22.23	83.73 cde	21.83 fgh	23.67	3.37 fg	6.99
N_1Zn_2	112	11.53 bcd	10.87 cde	23.06	95.63 a	33.17 a	24.80	4.00 d	7.07
N_1Zn_3	111	11.20 b-e	10.93 cde	22.82	83.90 cde	17.60 h	24.17	3.43 efg	7.11
N_2Zn_0	109	11.77 bc	11.13 bcd	23.14	84.57 cde	31.73 ab	23.60	4.47 c	7.42
N_2Zn_1	111	12.10 b	11.90 ab	23.72	84.47 cde	27.27 b-e	24.17	5.00 ab	7.62
N_2Zn_2	113	13.00 a	12.60 a	24.28	95.40 a	13.10 i	24.50	5.30 a	8.04
N_2Zn_3	114	11.77 bc	11.53 bc	24.07	88.17 bc	22.43 fg	24.40	4.87 b	7.82
N_3Zn_0	101	11.57 bcd	11.43 bc	23.19	84.00 de	20.73 gh	23.57	3.83 de	7.91
N_3Zn_1	114	11.43 bcd	11.23 bcd	23.62	98.33 a	23.30 efg	24.00	3.67 def	8.04
N_3Zn_2	112	11.10 c-f	10.80 cde	23.93	92.40 ab	25.63 cdef	24.20	3.27 fg	8.23
N_3Zn_3	114	10.70 def	10.33 def	23.93	79.10 ef	28.40 bc	24.13	3.10 gh	8.15
$LSD_{(0.05)}$	--	0.82	0.81	--	6.00	4.29	--	0.39	--
Significance level	NS	**	**	NS	**	**	NS	**	NS

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
** : Significant at 1% level of probability; NS : Not significant

N_0: 0 kg N ha^{-1} — Zn_0: 0 kg Zn ha^{-1}
N_1: 50 kg N ha^{-1} — Zn_1: 5 kg Zn ha^{-1}
N_2: 100 kg N ha^{-1} — Zn_2: 10 kg Zn ha^{-1}
N_3: 150 kg N ha^{-1} — Zn_3: 15 kg Zn ha^{-1}

4.1.2.2 Effect of zinc on total tillers hill^{-1}

In case of different levels of zinc, statistically significant variation was found for the number of total tiller (Appendix II). The maximum number of total tiller (11.53) was recorded in Zn_2 treatment comprising of 10 kg Zn ha^{-1} which was statistically identical (11.31) with the treatment Zn_1 (Table 5). On the other hand, the minimum number of total tiller (10.88) was recorded from the Zn_0 treatment i.e. without any addition of zinc. With increasing level of zinc, number of total tiller also increases but 10 kg Zn ha^{-1}

ensures the maximum total tiller. Varshney (1988) found that application of 20 kg $ZnSO_4$ ha^{-1} increased the number of tillers $hill^{-1}$ of rice.

4.1.2.3 Interaction effect of nitrogen and zinc on total tillers $hill^{-1}$

The interaction effect between nitrogen and zinc for the number of total tiller under the present trial showed statistically significant differences (Appendix II). The maximum number of tiller (13.00) was recorded from the treatment combination N_2Zn_2 comprising of 100 kg N ha^{-1} + 10 kg Zn ha^{-1} while the minimum number of tiller (9.23) was recorded from N_0Zn_0 i.e. without any nitrogen and zinc (Table 6). Some researchers found the similar results in their experiments. Jahiruddin (1983) reported that the numbers of total tillers $hill^{-1}$ were increased with the application of urea and $ZnSO_4$. Similar results were also observed by Haque and Khan (1981).

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

4.1.3.1 Effect of nitrogen on number of effective tillers $hill^{-1}$

In terms of number of effective tillers a statistically significant variation was recorded for the effect of nitrogen under the present trial (Appendix II). The maximum number of effective tiller (11.79) was recorded in N_2 treatment which was closely followed by the N_3 and N_1 treatment, respectively (Table 4) and the minimum number of effective tiller (9.10) was recorded from the N_0 treatment i.e. control condition. Generally 100 kg N ha^{-1} ensured the favourable condition for growth and development of rice and the ultimate results is the maximum number of effective tiller $hill^{-1}$. Hossain *et al.* (1989) found significant increase in number of effective tillers of BR11 rice due to application of 100 kg N ha^{-1} over control treatment. Ghosh *et al.* (1991) observed that the addition of N increased the number of ear-bearing tellers. Chander and Pandey (1996) cited that application of 120 kg N ha^{-1} resulted significant increase in effective tillers m^{-2} compared to 60 kg N ha^{-1}.

4.1.3.2 Effect of zinc on number of effective tillers $hill^{-1}$

Statistically significant differences were recorded for different levels of zinc in terms of number of effective tillers (Appendix II). The maximum number of effective tiller (10.97) was recorded in Zn_2 treatment which was statistically identical (10.81) with the treatment Zn_1 (Table 5). On the other hand, the minimum number of effective tiller (10.22) was recorded from the Zn_0 treatment i.e. without any zinc which was closely followed (10.62) by Zn_3 treatment under the present trial. Hossain *et al.* (1989) reported that the application of zinc in the form of $ZnSO_4$ ha^{-1} significantly increased grain and straw yields as well as different yield components of rice. Bhuiya and Eaqub (1988) found that 10 kg Zn ha^{-1} significantly increased the number of effective tillers $hill^{-1}$.

4.1.3.3 Interaction effect of nitrogen and zinc on number of effective tillers $hill^{-1}$

The interaction effect between nitrogen and zinc showed significant variation in terms of number of effective tiller (Appendix II). The maximum number of effective tiller (12.60) was recorded from the treatment combination N_2Zn_2 comprising of 100 kg N ha^{-1} + 10 kg Zn ha^{-1} while the minimum number of tiller (8.13) was recorded from N_0Zn_0 i.e. without any nitrogen and zinc (Table 6).

4.1.4 Panicle length

4.1.4.1 Effect of nitrogen on panicle length

In terms of panicle length statistically significant variations were recorded for the effect of different levels of nitrogen under the present trial (Appendix II). The longest panicle length (23.80 cm) was recorded in N_2 treatment which was statistically similar by the N_3 treatment (Table 4) and the shortest panicle length (21.01 cm) was recorded from the N_0 treatment i.e. control condition followed by N_1 treatment. Generally 100 kg N ha^{-1} ensure the optimum vegetative growth as well as longest panicle length. Rajagopalan and Palensiamy (1985) reported that application of 75 kg N ha^{-1} increase panicle length. Andrade and Amorim Neto (1996) observed that increasing level of applied N increased panicle m^{-2} significantly.

4.1.4.2. Effect of zinc on panicle length

Statistically significant variation was recorded for different level of zinc in terms of panicle length under the trial (Appendix II). The maximum panicle length (23.10 cm) was recorded in Zn_2 treatment comprising of 10 kg Zn ha^{-1} which was statistically identical (22.99) with the treatment Zn_3 and Zn_1, respectively (Table 5). On the other hand, the minimum panicle length (22.05 cm) was recorded from the Zn_0 treatment i.e. controls which was closely followed (22.64 cm) by Zn_1 treatment. With increasing of level zinc, panicle length also increases but 100 kg Zn ha^{-1} ensures the maximum panicle length.

4.1.4.3 Interaction effect of nitrogen and zinc on panicle length

Interaction effect between nitrogen and zinc exhibited no significant variation in terms of panicle length (Appendix II). The maximum panicle length (24.28 cm) was recorded from the treatment combination N_2Zn_2 comprising of 100 kg N ha-1 + 10 kg Zn ha-1 while the minimum panicle length (20.82 cm) was recorded from N_0Zn_0 i.e. without any nitrogen and zinc (Table 6). Similar results were observed by Haque and Khan (1981).

4.1.5 Number of filled grains panicle^{-1}

4.1.5.1 Effect of nitrogen on filled grains panicle^{-1}

In terms of filled grain a statistically significant variation was recorded for the effect of nitrogen under the trial (Appendix II). The maximum number of filled grain (88.46) was recorded in N_3 treatment which was statistically similar (88.15) with the treatment N_2 (Table 4) and the minimum number of filled grain (79.83) was recorded from the N_0 treatment i.e. control. Panda and Leewrik (1972) reported that 0, 50, 100 or 150 kg N ha-1 increased the filled grains panicle^{-1}. Ghosh *et al.* (1991) found that the addition of N increased the number of grains panicle^{-1}. Chander and Pandey (1996) cited that application of 120 kg N ha^{-1} resulted significant increase in grains panicle^{-1} compared to 60 kg N ha^{-1}. Navin *et al.* (1996) found that with an increased in the nitrogen level (from 0 to 120 kg N ha^{-1}), there was an increase in number of spikelets panicle^{-1}.

4.1.5.2 Effect of zinc on filled grains panicle^{-1}

Statistically significant differences were recorded for different levels of zinc in terms of filled grain under the trail (Appendix II). The highest number of filled grain (92.52) was recorded in Zn_2 treatment which was closely followed (86.82) with the treatment Zn_1 (Table 5). On the other hand the lowest number of filled grain (79.35) was recorded from the Zn_0 treatment.

4.1.5.3 Interaction effect of nitrogen and zinc on filled grains panicle^{-1}

The interaction effect between nitrogen and zinc showed significant variation in terms of number of filled grain (Appendix II). The highest number of filled grain (98.33) was recorded from the treatment combination N_3Zn_1 which was statistically identical with the treatments N_2Zn_2, N_1Zn_2 and N_3Zn_2. The lowest number of filled grain (71.90) was recorded from N_0Zn_0 i.e. without any nitrogen and zinc (Table 6). Bhuiya and Eaqub (1988) conducted an experiment and found that 80 kg N with 10 kg $ZnSO_4$ ha^{-1} increased the number of filled grains panicle^{-1} significantly. Balakrishnan and Natarajaratnam (1986) reported that application of 25 kg $ZnSO_4$ ha^{-1} with NPK on rice increased the filled grains panicle^{-1}.

4.1.6 Number of unfilled grains panicle^{-1}

4.1.6.1 Effect of nitrogen on unfilled grains panicle^{-1}

A statistically significant variation was found among different doses of nitrogen in considering the number of unfilled grain panicle^{-1} under the present piece of experiment (Appendix II). The lowest number of unfilled grains (23.63) was recorded in N_2 treatment which was statistically similar with the N_1 and N_3 treatment, respectively (Table 4) and the highest number of unfilled grain (26.72) was recorded from the N_0 treatment i.e.

control condition. Generally 100 kg N ha^{-1} ensure the favorable condition for growth and development of rice and the ultimate results is the minimum number of unfilled grain. Amin *et al.* (2004) reported that increased fertilizer dose of NPK increase sterility of rice grain.

4.1.6.2 Effect of zinc on unfilled grains $panicle^{-1}$

Statically significant differences were recorded for different levels of zinc in terms of unfilled grain (Appendix II). The highest number of unfilled grains (27.70) was recorded in Zn_0 treatment i.e. in control under the present trial and the lowest number of unfilled grains (22.17) was obtained in Zn_3 treatment comprising of 15 kg Zn ha-1 which was statistically identical (23.88) with Zn_2 treatment (Table 5).

4.1.6.3 Interaction effect of nitrogen and zinc on filled grains $panicle^{-1}$

The interaction effect between nitrogen and zinc showed significant difference in consideration of number of unfilled grains $panicle^{-1}$ (Appendix II). The highest number of unfilled grains $panicle^{-1}$ was found in N_0Zn_0 treatment i.e. without any nitrogen and zinc (Table 6). On the other hand, the lowest (13.10) number of unfilled grains $panicle^{-1}$ was recorded in N_2Zn_2 treatment comprising of 100 kg N ha^{-1} + 10 kg Zn ha-1 (Table 6).

4.1.7 1000-grain weight

4.1.7.1 Effect of nitrogen on 1000-grain weight

In case of weight of 1000 seeds,no significant differences were found for the effect of nitrogen under the present trial (Appendix II). The highest 1000-grain weight of 24.17 was found in N_2 treatment and the lowest 23.10 in control treatment which was closely followed (23.98 g) by the N_3 treatment (Table 4). Navin *et al* (1996) found that with an increased in the nitrogen level (from 0 to 120 kg N ha^{-1}), there was an increase in 1000-grain weight of rice. Amin *et al.* (2004) reported that increased fertilizer dose of NPK increase 1000 grain weight.

4.1.7.2 Effect of zinc on 1000- grain weight

No significant differences were recorded for different levels of zinc in terms of weight of 1000 seeds under the present trail (Appendix II). The highest weight of 1000 seeds (24.25 g) were found in Zn_2 treatment and the lowest weight of 1000 seeds (23.23g) were observed in Zn_0 treatment which was closely followed by (23.63 g) with the treatment Zn_1 (Table 5). Varshney (1988) stared that application of 20 kg $ZnSO_4$ ha^{-1} increased 1000-grain weight of rice.

4.1.7.3 Interaction effect of nitrogen and zinc on 1000-grain weight

Interaction effect between nitrogen and zinc having no significant differences in consideration of weight of 1000 seeds (Appendix II). The highest 1000-grain weight (24.80) was recorded in N_1Zn_2 treatment and the lowest 1000-grain weight (22.17) was recorded in control condition. Balakrishnan and Natarajaratnam (1986) reported that application of 25 kg $ZnSO_4$ ha^{-1} with NPK on rice increased 1000-grain weight of paddy. Bhuiya and Eaqub (1988) reported that using 80 kg N with 10 kg Zn ha^{-1} produced the significant increase of 1000-grain weight.

4.1.8. Grain yield

4.1.8.1 Effect of nitrogen on grain yield

Grain yield of rice increased with increasing N levels upto 100 kg N ha^{-1} (N_2) (Table 4 and Figure 5). However, further increase in N level upto 150 kg N ha^{-1} decreased rice yield significantly. The possible reason may be over growth of rice plant due to excessive nitrogen application. Navin *et al.* (1996) reported that with an increased in the nitrogen level (from 0 to 120 kg N ha^{-1}), there was an increase in grain yields.

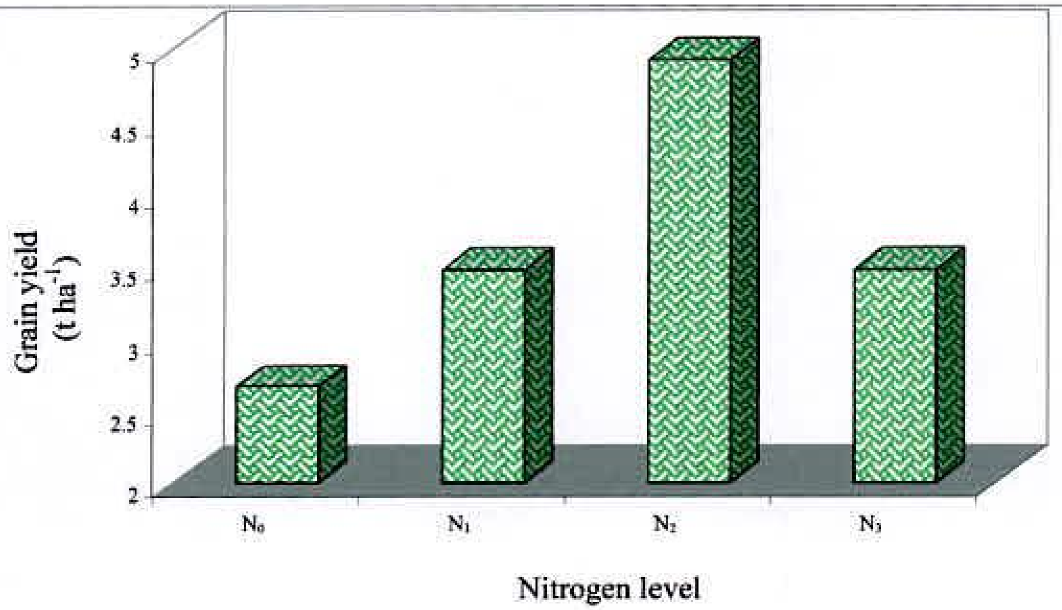


Figure 5. Effect of nitrogen on grain yield of BRRI Dhan 39

4.1.8.2 Effect of zinc on grain yield

A statistically significant difference was recorded for different level of zinc in terms of grain yield hectare^{-1} (Appendix II). The highest grain yield (3.91 t ha^{-1}) was recorded in Zn_3 treatment which was closely followed by (3.69 t ha^{-1}) with the treatment Zn_1 (Table 5 and Figure 6). On the other hand, the lowest grain yield (3.39 t ha^{-1}) was recorded from the Zn_0 treatment i.e. without zinc which was closely followed (3.51 t ha^{-1}) by Zn_3 treatment (Figure 4). Choudhury and Hore (1989) showed that the highest grain yield of 4.04 t ha^{-1} was obtained with 10 kg Zn along with 30 kg S ha^{-1}. Hossain *et al.* (1989) reported that the application of zinc in the form of $ZnSO_4$ ha^{-1} significantly increased grain yields.

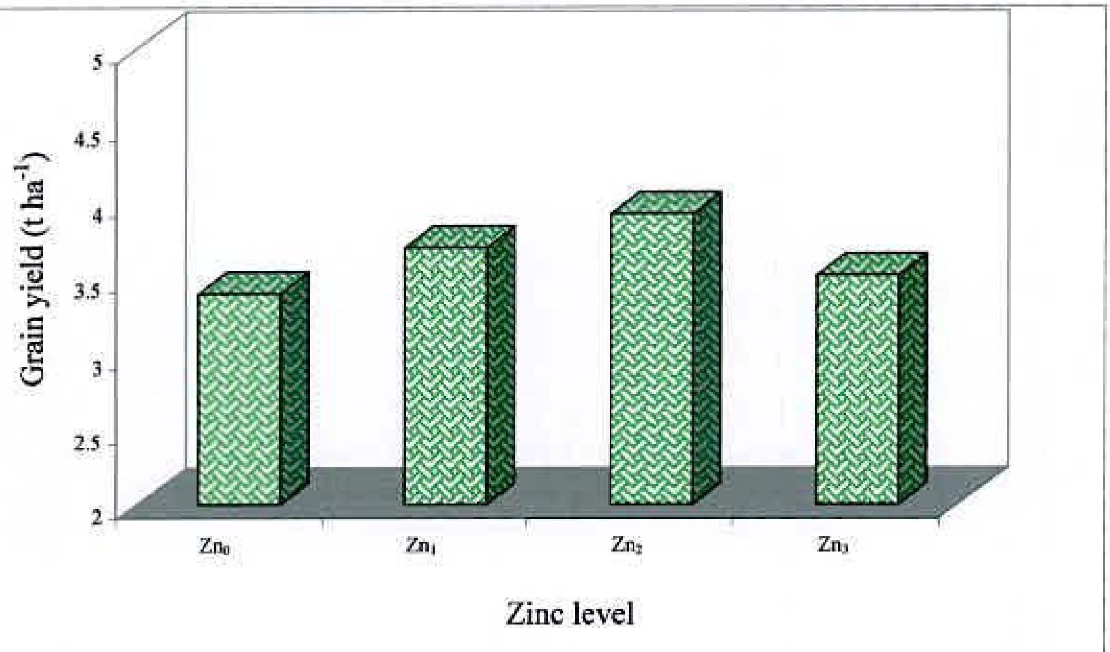


Figure 6. Effect of zinc on grain yield of BRRI Dhan 39

4.1.8.3 Interaction effect of nitrogen and zinc on grain yield

The interaction effect between nitrogen and zinc showed significant differences in terms of grain yield per hectare (Appendix II). The highest grain yield (5.30 t ha^{-1}) was recorded from the treatment combination N_2Zn_2 on the other hand the lowest (2.20 t ha^{-1}) was recorded from control condition (Table 6 and Figure 7). Bhuiya and Eaqub (1988) found that 80 kg N and 10 kg Zn ha^{-1} produced maximum yield of grain of rice. Hossain *et al.* (1989) reported that Zn application with NPK fertilizers produced maximum grain yield of rice but was not statistically significant. Eaqub and Mian (1984) observed that the application of 6 kg Zn with NPK fertilizers produced the highest grain yield of rice. Singh and Yadav (1990) reported that grain yield of rice increased with increasing NPK rate and with increasing pyrites rate at the high and medium NPK application rates.

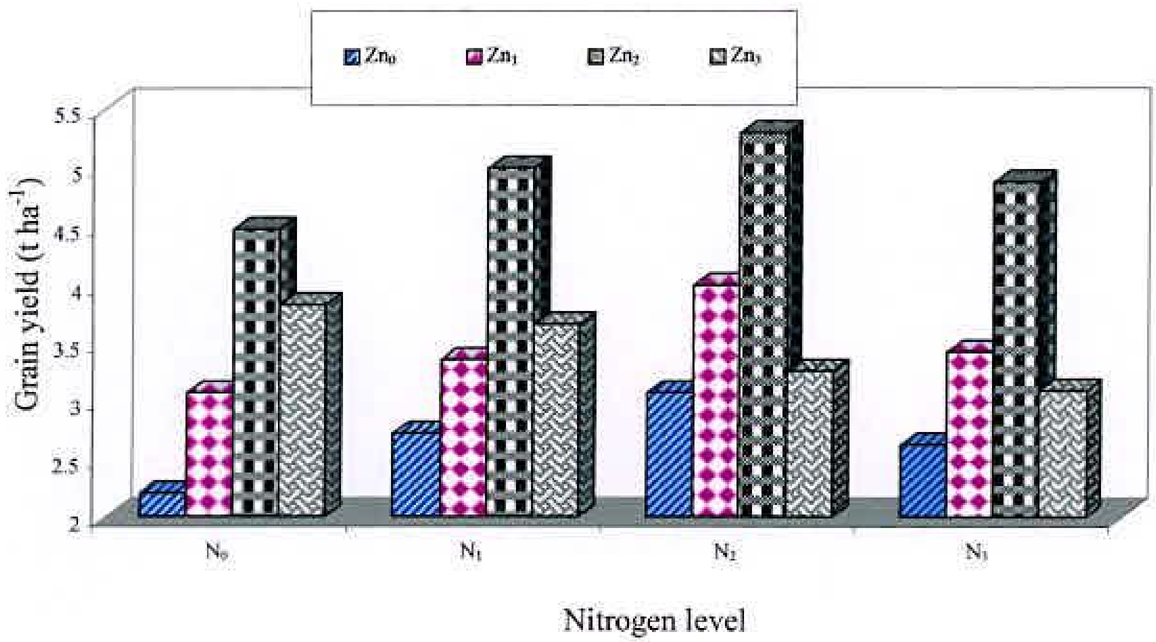


Figure 7. Effect of nitrogen and zinc on grain yield of BRRI Dhan 39

4.1.9 Straw yield

4.1.9.1 Effect of nitrogen on straw yield

The effect of nitrogen on straw yield under the field condition showed a statistically significant difference (Appendix II). The highest significant straw yield (8.08 t ha^{-1}) was recorded in N_3 treatment (Table 4 and Figure 8) and the lowest straw yield (6.66 t ha^{-1}) was recorded from the N_0 treatment i.e. control condition. Idris and Matin (1990) found that straw increased from 0 to 120 kg N ha^{-1} and at 140 kg N ha^{-1}, straw yield decreased. The highest straw yield was obtained at 120 kg N ha^{-1} and the lowest at the control. Navin *et al.* (1996) showed that with an increased in the nitrogen level (from 0 to 120 kg N ha^{-1}), there was an increase in straw yield of rice. Khanda and Dixit (1996) stated that the combined application of N and Zn increased the grain yield by 7.2%.

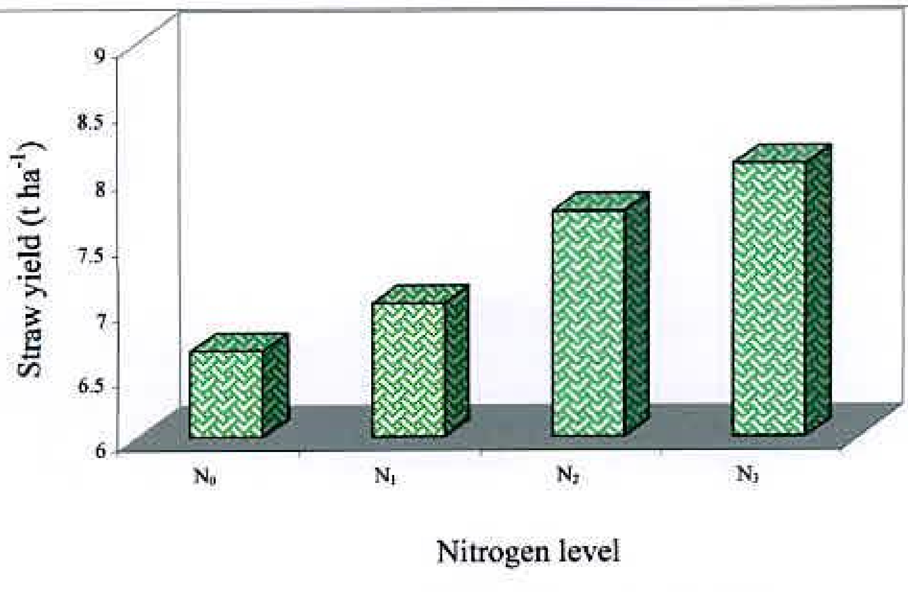


Figure 8. Effect of nitrogen on straw yield of BRRI Dhan 39

4.1.9.2 Effect of zinc on straw yield

Statistically significant variation was recorded for different level of zinc in terms of straw yield per hectare (Appendix II). The highest straw yield (7.52 t ha^{-1}) was recorded in Zn_2 treatment which was statistically similar with the treatment Zn_3 (Table 5 and Figure 9). Again the lowest straw yield (7.16 t ha^{-1}) was recorded from the Zn_0 treatment i.e. without zinc which was closely followed (7.34 t ha^{-1}) by Zn_1 treatment. Jahiruddin *et al.* (1981) reported that a significant increase in straw yields of Tepi boro was contained when Zn was applied to acid clay type soil of Bangladesh. Hossain *et al* (1989) reported that the application of zinc in the form of $ZnSO_4$ ha^{-1} significantly increased straw yields.

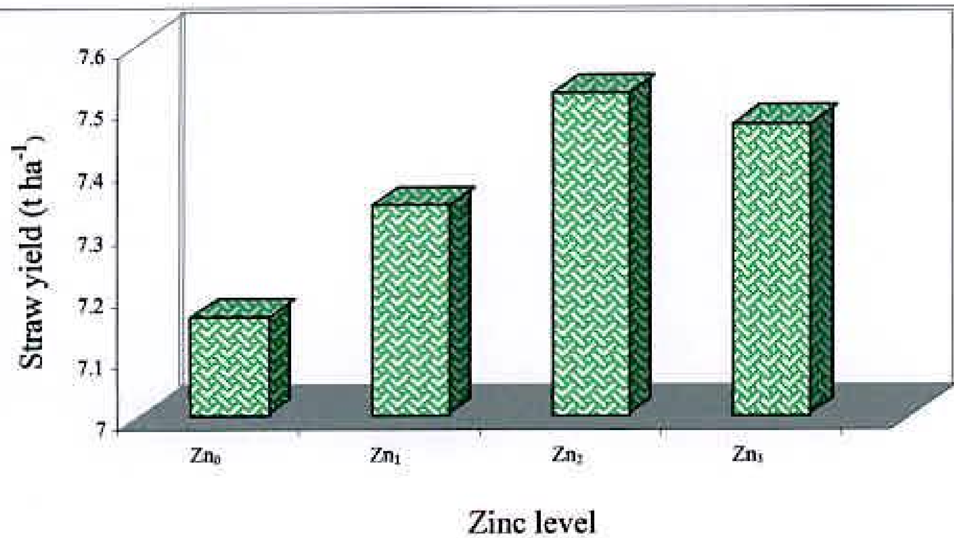


Figure 9. Effect of zinc on straw yield of BRRI Dhan 39

4.1.9.3 Interaction effect of nitrogen and zinc on straw yield

The interaction effect between nitrogen and zinc had no significant differences in terms of straw yield per hectare (Appendix II). The highest straw yield (8.23 t ha^{-1}) was recorded from the treatment combination N_3Zn_2. On the other hand, the lowest (6.40 t ha^{-1}) was recorded from control condition (Table 6) (Figure 10). Bhuiya and Eaqub (1988) also reported higher straw yield by 10 kg Zn and 82 kg N ha^{-1}.

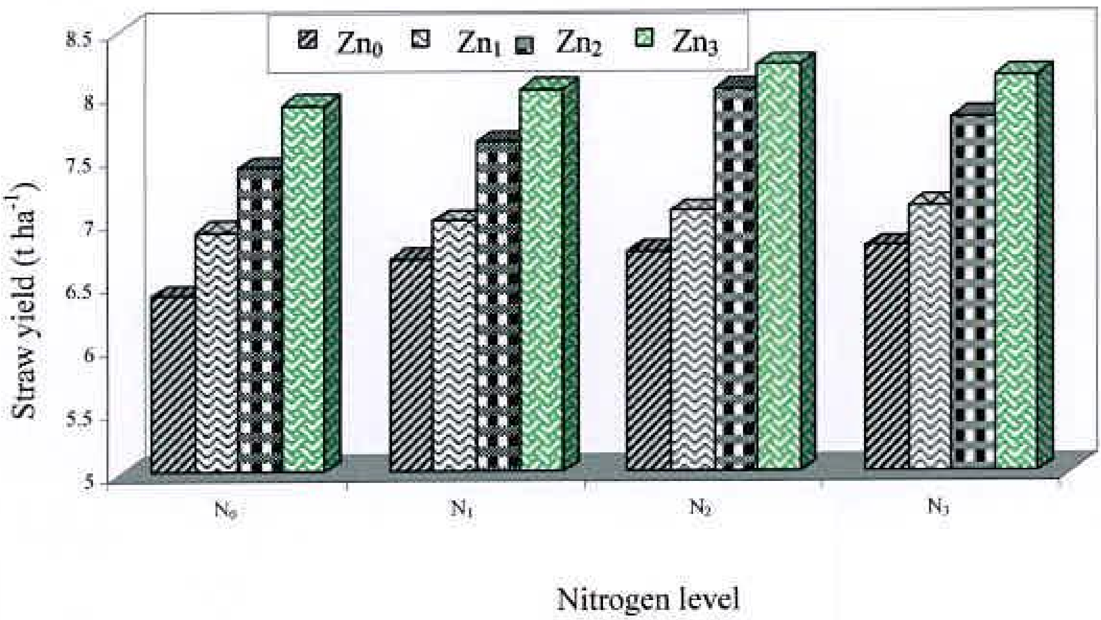


Figure 10. Effect of nitrogen and zinc on straw yield of BRRI Dhan 39

4.2 Nutrient content by grain and straw

Rice grain and straw were collected and then analysis was done to see the nutrient content in rice grain and straw due to the application of nitrogen and zinc.

4.2.1 Effect of nitrogen and zinc on the total N content of grain and straw

Total nitrogen in grain showed statistically significant variations for the effect of nitrogen under the present trial (Appendix III). The highest total nitrogen (1.40%) was recorded in N_3 treatment comprising of 150 kg N ha-1 which was statistically identical (1.38%) by the N_3 and N_1 treatment comprising of 150 and 50 kg N ha-1, respectively (Table 7 and Figure 11) and the lowest total nitrogen (1.30%) in grain from the N_0 treatment i.e. control condition.

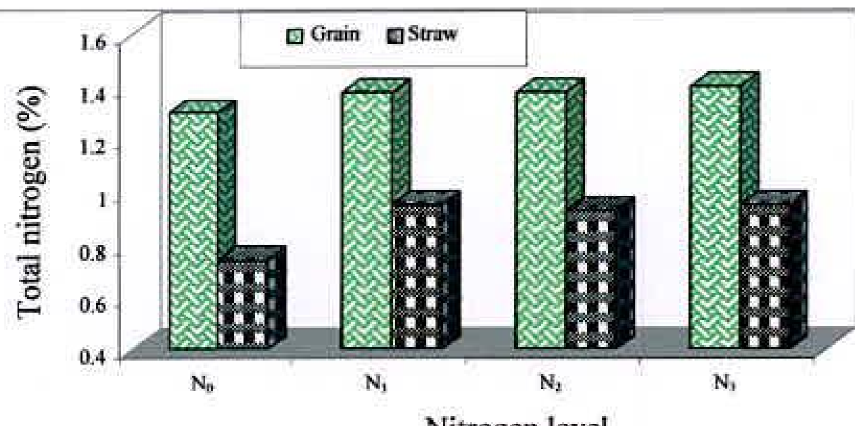


Figure 11. Effect of nitrogen on total nitrogen on grain and straw of BRRI Dhan 39

A statistically significant difference was recorded for different level of zinc in terms of total nitrogen in grain (Appendix III). The highest (1.41%) total nitrogen in grain was recorded in Zn_3 treatment which was statistically identical (1.39%) with the treatment Zn_2 (Table 8 and Figure 12). On the other hand the lowest (1.32%) total nitrogen in grain was recorded from the Zn_0 treatment i.e. 0 kg Zn ha^{-1} which was closely followed (1.34%) by Zn_1 treatment (Table 8).

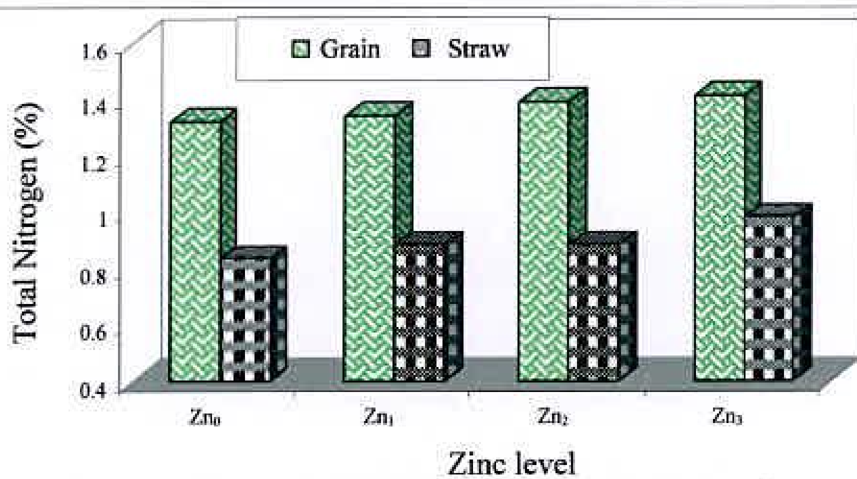


Figure 12. Effect of zinc on total nitrogen on grain and straw of BRRI Dhan 39

The interaction effect between nitrogen and zinc showed significant differences in terms of total nitrogen in grain (Appendix III). The highest (1.51%) total nitrogen in grain recorded from the treatment combination of N_3Zn_2 comprising of 150 kg N ha-1 + 10 kg Zn ha-1. On the other hand, the lowest (1.30%) % total N was recorded from control condition (Table 9).

The effect of different levels of nitrogen on % total nitrogen in straw having statistically significant differences under the present trial (Appendix III). Total nitrogen (0.95%) in straw was recorded in N_1 and N_3 treatment comprising of 50 and 150 kg N ha^{-1} which was statistically identical (0.93%) by the N_2 treatment comprising of 100 kg N ha-1 (Table 7 and Figure 11) and the lowest total nitrogen (0.74%) in straw from the N_0 treatment i.e. under control condition.

Statistically significant difference was recorded for different level of zinc in terms of total nitrogen in straw (Appendix III). The highest (0.98%) total nitrogen in straw was recorded in Zn_3 treatment which was statistically identical (0.88%) with the treatment Zn_2 and Zn_1, respectively (Table 8 and Figure 12). On the other hand, the lowest (1.32%) total nitrogen in straw was recorded under the Zn_0 treatment i.e. without zinc treatment (Table 8).

The interaction effect between nitrogen and zinc showed significant differences in terms of total nitrogen in grain (Appendix III). The highest (1.23%) total nitrogen in straw was recorded from the treatment combination N_1Zn_3 comprising of 50 kg N ha^{-1} + 15 kg Zn ha^{-1} and the lowest % total N (0.74%) was recorded from control condition (Table 9). Panda and Tilak (1970) observed the similar result.

Table 7. Effect of different levels of nitrogen on N, Protein and Zn content of BRRI Dhan 39

Treatment	Total N (%)		Protein (%)		Zn (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
N_0	1.30 b	0.74 b	8.12 b	4.61 c	0.0022 b	0.0025b
N_1	1.38 a	0.95 a	8.59 a	5.96 a	0.0023 ab	0.0025b
N_2	1.38 a	0.93 a	8.65 a	5.79 b	0.0024 a	0.0029a
N_3	1.40 a	0.95 a	8.76 a	5.97 a	0.0023 ab	0.0026b
$LSD_{(0.05)}$	0.046	0.037	0.242	0.124	0.00012	0.00018
Significance level	**	**	**	**	*	**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

** : Significant at 1% level of probability; * : Significant at 5% level of probability;

N_0: 0 kg N ha^{-1}
N_1: 50 kg N ha^{-1}
N_2: 100 kg N ha^{-1}
N_3: 150 kg N ha^{-1}

Zn_0: 0 kg Zn ha^{-1}
Zn_1: 5 kg Zn ha^{-1}
Zn_2: 10 kg Zn ha^{-1}
Zn_3: 15 kg Zn ha^{-1}

4.2.2 Effect of nitrogen and zinc on the protein content of grain and straw

Protein in grain showed statistically significant variations for the effect of different levels of nitrogen under the present trial (Appendix III). Maximum protein content (8.76%) was recorded in N_3 treatment comprising of 150 kg N ha^{-1} which was statistically identical to N_2 and N_1 treatment comprising of 100 and 50 kg N ha^{-1}, respectively (Table 7) and the lowest protein content (8.12%) in grain was recorded from the N_0 treatment.

A statistically significant difference was recorded for different level of zinc in terms of protein in grain (Appendix III). The highest (8.84%) protein content in grain was recorded in Zn_3 treatment which was statistically identical (8.70%) with the treatment Zn_2 (Table 8). On the other hand, the lowest (8.23%) protein content in grain was recorded from the Zn_0 treatment which was statistically similar (8.36%) to Zn_1 treatment (Table 8).

The interaction effect between nitrogen and zinc showed significant differences in protein content of grain (Appendix III). The highest (9.43%) protein content in grain was recorded from the treatment combination N_3Zn_2 comprising of 150 kg N ha^{-1} + 10 kg Zn ha^{-1}, on the other hand, the lowest (8.12%) was recorded under control condition (Table 9).

Protein content in straw showed statistically significant differences for the effect of nitrogen under the present trial (Appendix III). The highest protein content (5.97%) in straw was recorded in N_3 treatment which was statistically identical (5.96%) to N_1 treatment (Table 7) and the lowest protein content (4.61%) in straw from the N_0 treatment.

Statistically significant difference was recorded for different level of zinc in terms of protein in straw (Appendix III). The highest (6.09%) protein content in straw was recorded in Zn_3 treatment which was statistically different from other treatments Zn_1, Zn_2 and Zn_0 (Table 8). The lowest (5.22%) protein content in straw was recorded from the Zn_0 treatment.

The interaction effect between nitrogen and zinc showed significant differences in terms of protein in grain (Appendix III). The highest (7.68%) protein content in straw was recorded from the treatment combination N_1Zn_3 comprising of 50 kg N ha^{-1} + 15 kg Zn ha^{-1} and the lowest (0.4.62%) was recorded under control condition (Table 9).

Table 8. Effect of different levels of zinc on N, Protein and Zn content of BRRI Dhan 39

Treatment	Total N (%)		Protein (%)		Zn (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
Zn_0	1.32 b	0.83 c	8.23 b	5.22 c	0.0021b	0.0023b
Zn_1	1.34 b	0.88 b	8.36 b	5.51 b	0.0023a	0.0026a
Zn_2	1.39 a	0.88 b	8.70 a	5.51 b	0.0024 a	0.0028a
Zn_3	1.41 a	0.98 a	8.84 a	6.09 a	0.00.24a	0.0027a
$LSD_{(0.05)}$	0.046	0.037	0.242	0.124	0.00012	0.00018
Significance level	**	**	**	**	**	**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

** : Significant at 1% level of probability;

N_0 : 0 kg N ha^{-1}
N_1 : 50 kg N ha^{-1}
N_2 : 100 kg N ha^{-1}
N_3 : 150 kg N ha^{-1}

Zn_0 : 0 kg Zn ha^{-1}
Zn_1 : 5 kg Zn ha^{-1}
Zn_2 : 10 kg Zn ha^{-1}
Zn_3 : 15 kg Zn ha^{-1}

Table 9. Interaction effect of different levels of nitrogen and zinc on N, Protein and Zn content of BRRI Dhan 39

Treatment	Total N (%)		Protein (%)		Zn (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
N_0Zn_0	1.30 d	0.74 ef	8.12 c	4.62 f	0.0020	0.0021
N_0Zn_1	1.30 d	0.77 e	8.12 c	4.81 f	0.0022	0.0025
N_0Zn_2	1.32 d	0.77 e	8.25 c	4.81 f	0.0022	0.0026
N_0Zn_3	1.28 d	0.67 f	8.00 c	4.18 g	0.0024	0.0027
N_1Zn_0	1.33 d	0.77 e	8.31 c	4.81 f	0.0021	0.0023
N_1Zn_1	1.36 cd	0.91 cd	8.50 bc	5.68 de	0.0022	0.0024
N_1Zn_2	1.37 bcd	0.91 cd	8.56 bc	5.68 de	0.0024	0.0026
N_1Zn_3	1.44 abc	1.23 a	9.00 ab	7.68 a	0.0023	0.0027
N_2Zn_0	1.34 cd	0.88 d	8.37 c	5.50 e	0.0023	0.0027
N_2Zn_1	1.36 cd	0.91 cd	8.50 bc	5.68 de	0.0024	0.0030
N_2Zn_2	1.37 bcd	0.87 d	8.56 bc	5.43 e	0.0023	0.0029
N_2Zn_3	1.47 a	1.05 b	9.18 a	6.56 b	0.0024	0.0028
N_3Zn_0	1.30 d	0.95 cd	8.12 c	5.93 cd	0.0020	0.0022
N_3Zn_1	1.33 d	0.94 cd	8.31 c	5.87 cd	0.0025	0.0026
N_3Zn_2	1.51 a	0.98 bc	9.43 a	6.12 c	0.0025	0.0029
N_3Zn_3	1.46 ab	0.95 cd	9.18 a	5.93 cd	0.0023	0.0027
$LSD_{(0.05)}$	0.091	0.075	0.483	0.247	--	--
Significance level	**	**	**	**	NS	NS

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
**: Significant at 1% level of probability; NS: Not significant

N_0: 0 kg N ha^{-1}
N_1: 50 kg N ha^{-1}
N_2: 100 kg N ha^{-1}
N_3: 150 kg N ha^{-1}

Zn_0: 0 kg Zn ha^{-1}
Zn_1: 5 kg Zn ha^{-1}
Zn_2: 10 kg Zn ha^{-1}
Zn_3: 15 kg Zn ha^{-1}

4.2.3 Effect of nitrogen and zinc on zinc content of grain and straw

The effect of different levels of N on zinc content in grain having significant variation (Appendix III). Maximum Zn content in grain (0.0024%) was recorded in N_2 treatment comprising of 100 kg N ha^{-1} which was statistically identical (0.0023%) by the N_1 and N_3

treatment comprising of 50 and 100 kg N ha^{-1}, respectively (Table 7 and Figure 13) and the lowest Zn content (0.0022%) in grain from the N_0 treatment.

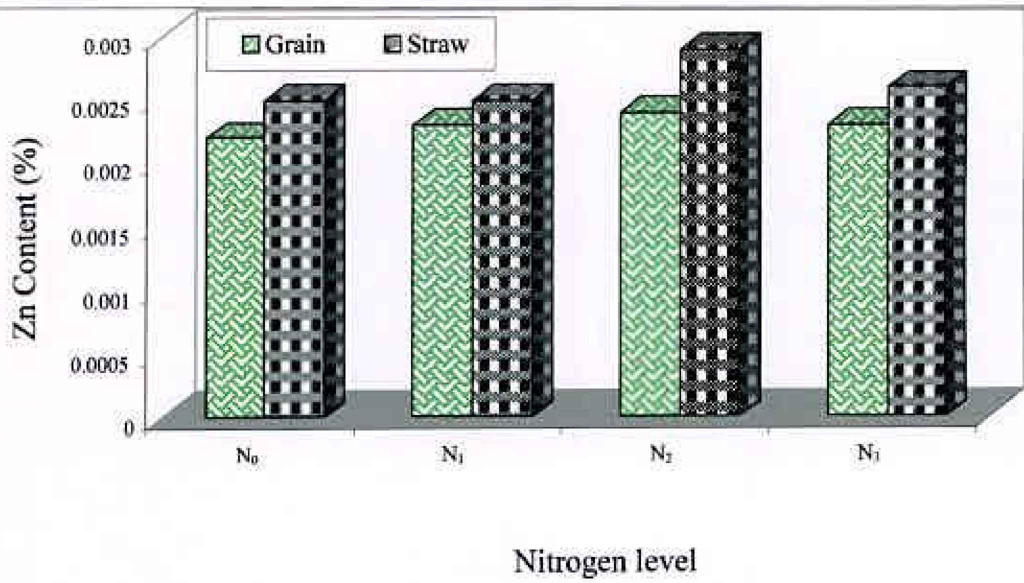


Figure 13. Effect of nitrogen on Zn content on grain and straw of BRRI Dhan 39

A statistically significant difference was recorded for different level of zinc in terms of Zn content in grain (Appendix III). The highest (0.0024%) Zn content in grain was recorded under Zn_3 and Zn_2 treatment, respectively which was statistically identical (0.0023%) with the treatment Zn_1 (Table 8 and Figure 14). The lowest (0.0021%) Zn in grain was recorded from the Zn_0.

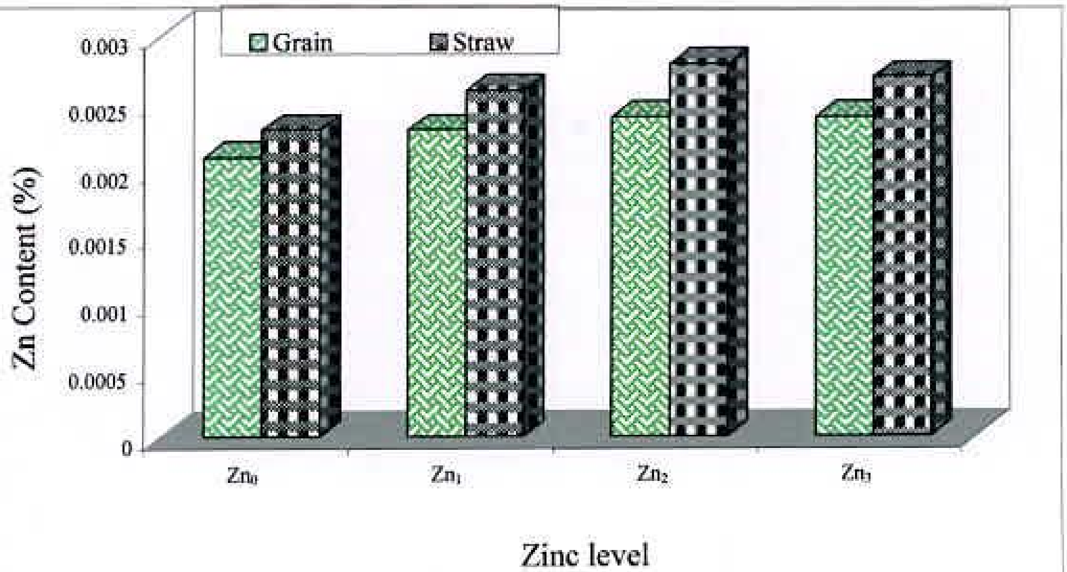


Figure 14. Effect of zinc on Zn content on grain and straw of BRRI Dhan 39

The interaction effect between nitrogen and zinc showed no significant differences in terms of Zn content in grain (Appendix III). The highest (0.0025%) Zn content in grain was recorded from the treatment combination of N_3Zn_2 and N_3Zn_1 and the lowest (0.0020%) was recorded from control condition (Table 9).

Zinc in straw showed statistically significant differences for the effect of nitrogen under the present trial (Appendix III). Zinc content (0.0029%) in straw was recorded in N_2 treatment comprising of 100 kg N ha^{-1} (Table 7 and Figure 13) and the lowest Zn content (0.0025%) in straw from the N_0 treatment.

Statistically significant difference was recorded for different levels of zinc in terms of Zn content in straw (Appendix III). The highest (0.0028%) Zn content in straw was recorded in Zn_2 treatment which was statistically similar (0.0027% and 0.0026%) with the treatment Zn_3 and Zn_1, respectively (Table 8 and Figure 14). On the other hand, the lowest (0.0023%) Zn content in straw was recorded from the Zn_0 treatment.

The interaction effect between nitrogen and zinc showed significant differences in terms of Zn in grain (Appendix III). The highest (0.0030%) Zn content in straw was recorded from the treatment combination N_2Zn_1 and the lowest (0.0021%) was recorded from control condition (Table 9).

4.3 Nutrient uptake by grain and straw

Nutrient uptake by grain and straw were calculated for nitrogen and zinc

4.3.1 Nitrogen uptake

4.3.1.1 Nitrogen uptake by grain

Statistically significant variations in nitrogen uptake by grain were found due to the application of different levels of nitrogen (Appendix IV). The highest significant nitrogen uptake (50.99 kg ha^{-1}) by grain was recorded in N_2 treatment comprising of 100 kg N ha^{-1} which was statistically different from all other N levels (Table 10). The lowest nitrogen uptake (34.63 kg ha^{-1}) by grain from the N_0 treatment i.e. under control condition.

A statistically significant difference was recorded for different level of zinc in terms of nitrogen uptake by grain (Appendix IV). The highest (54.30 kg ha^{-1}) nitrogen uptake by grain was recorded in Zn_2 treatment which was statistically higher from other Zn levels (Table 11). The lowest (44.77 kg ha^{-1}) nitrogen uptake by grain was recorded from the Zn_0 treatment.

The interaction effect between nitrogen and zinc showed significant differences in terms of nitrogen uptake by grain (Appendix IV). The highest (72.58 kg/ha) nitrogen uptake by grain was recorded from the treatment combination N_2Zn_2 comprising of 100 kg N ha^{-1} + 10 kg Zn ha^{-1} and the lowest (28.61 kg/ha) was recorded from control condition (Table 12).

4.3.1.2 Nitrogen uptake by straw

The effect of different levels of nitrogen on nitrogen uptake by straw showed statistically significant differences under the present trial (Appendix IV). Maximum nitrogen uptake (77.20 kg ha^{-1}) by straw was recorded in N_2 treatment comprising of 100 kg N ha^{-1} which was closely followed by (71.66 kg ha^{-1}) by the N_2 treatment comprising of 100 kg N ha^{-1} (Table 10) and the lowest nitrogen uptake (49.04 kg ha^{-1}) by straw from the N_0 treatment i.e. control condition.

Statistically significant difference was recorded for different level of zinc in terms of nitrogen uptake by straw (Appendix IV). The highest (73.12 kg ha^{-1}) nitrogen uptake by straw was recorded in Zn_3 treatment which was superior to all other Zn level. The lowest (60.23 kg ha^{-1}) nitrogen uptake by straw was recorded from the Zn_0 treatment (Table 11).

Significant differences were found by the interaction effect between nitrogen and zinc in terms of nitrogen uptake by grain (Appendix IV). The highest (87.41 kg ha^{-1}) nitrogen uptake by straw was recorded from the treatment combination N_1Zn_3 comprising of 50 kg N ha^{-1} + 15 kg Zn ha^{-1}. On the other hand the lowest (47.34 kg ha^{-1}) was recorded from control condition (Table 12). Panda and Das (1970) showed that Zn application increased N uptake by rice grain and straw.

Table 10. Effect of different levels of nitrogen on N and Zn uptake by plant of BRRI Dhan 39

Treatment	N uptake (kg ha^{-1})		Zn uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw
N_0	34.63 c	49.04 d	0.059 c	0.165 b
N_1	47.72 b	67.15 c	0.079 b	0.176 b
N_2	50.99 a	71.66 b	0.012 a	0.220 a
N_3	48.31 b	77.20 a	0.080 b	0.210 a
$LSD_{(0.05)}$	2.842	2.815	0.0058	0.0137
Significance level	**	**	**	**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

**: Significant at 1% level of probability; *: Significant at 5% level of probability;

N_0 : 0 kg N ha^{-1} — Zn_0 : 0 kg Zn ha^{-1}
N_1 : 50 kg N ha^{-1} — Zn_1 : 5 kg Zn ha^{-1}
N_2 : 100 kg N ha^{-1} — Zn_2 : 10 kg Zn ha^{-1}
N_3 : 150 kg N ha^{-1} — Zn_3 : 15 kg Zn ha^{-1}

Table 11. Effect of different levels of zinc on N and Zn uptake by plant of BRRI Dhan 39

Treatment	N uptake (kg ha^{-1})		Zn uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw
Zn_0	44.77 c	60.23 c	0.072 c	0.167 c
Zn_1	49.55 b	65.00 b	0.087 ab	0.193 b
Zn_2	54.30 a	66.70 b	0.092 a	0.208 a
Zn_3	50.02 b	73.12 a	0.083 b	0.203 ab
$LSD_{(0.05)}$	2.842	2.815	0.0058	0.0137
Significance level	**	**	**	**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

**: Significant at 1% level of probability

N_0 : 0 kg N ha^{-1} — Zn_0 : 0 kg Zn ha^{-1}
N_1 : 50 kg N ha^{-1} — Zn_1 : 5 kg Zn ha^{-1}
N_2 : 100 kg N ha^{-1} — Zn_2 : 10 kg Zn ha^{-1}
N_3 : 150 kg N ha^{-1} — Zn_3 : 15 kg Zn ha^{-1}

4.3.2 Zinc uptake

4.3.2.1 Zinc uptake by grain

Zinc uptake by grain showed statistically significant variations for the effect of different levels of nitrogen under the present trial (Appendix IV). The highest Zn uptake (0.092 kg ha^{-1}) by grain was recorded in N_2 treatment comprising of 100 kg N ha^{-1} which was statistically different from N_3, N_1 and N_0 treatment (Table 10) and the lowest Zn uptake (0.059 kg ha^{-1}) by grain from the N_0 treatment i.e. control condition.

A statistically significant difference was recorded for different level of zinc in terms of Zn uptake by grain (Appendix IV). The highest (0.092 kg ha^{-1}) Zn uptake by grain was recorded in Zn_2 treatment which was closely followed by (0.087 kg ha^{-1}) with the treatment Zn_1 (Table 11). The lowest (0.072 kg ha^{-1}) Zn uptake by grain was recorded from the Zn_0 treatment.

The interaction effect between nitrogen and zinc showed significant differences in terms of Zn uptake by grain (Appendix IV). The highest (0.012 kg ha^{-1}) Zn uptake by grain was recorded from the treatment combination N_2Zn_1 and N_2Zn_3 comprising of 100 kg N ha^{-1} + 5 kg Zn ha^{-1} and 100kg N ha^{-1} +15 kg Zn ha^{-1} respectively. The lowest (0.044 kg ha^{-1}) was recorded from control condition (Table 12).

4.3.2.2 Zinc uptake by straw

Zinc uptake by straw showed statistically significant differences for the effect of nitrogen under the present trial (Appendix IV). The highest Zn uptake (0.220 kg ha^{-1}) by straw was recorded in N_2 treatment comprising of 100 kg N ha^{-1} which was statistically similar by (0.210 kg ha^{-1}) by the N_3 treatment comprising of 150 kg N ha^{-1} (Table 10) and the lowest Zn uptake (0.165 kg ha^{-1}) by straw from the N_0 treatment i.e. under control condition.

Statistically significant difference was recorded for different level of zinc in terms of Zn uptake by straw (Appendix IV). The highest (0.208 kg ha^{-1}) Zn uptake by straw was recorded in Zn_2 treatment which was statistically similar (0.203 kg ha^{-1}) with the treatment Zn_3 (Table 11). The lowest (0.167 kg ha^{-1}) Zn uptake by straw was recorded from the Zn_0 treatment.

The interaction effect between nitrogen and zinc showed no significant differences in terms of Zn uptake by straw (Appendix IV). The highest (0.233 kg ha^{-1}) Zn uptake by straw was recorded from the treatment combination N_2Zn_2 comprising of 100 kg N ha^{-1} + 10 kg Zn ha^{-1} and the lowest (0.134 kg ha^{-1}) was recorded from control condition (Table 12). Baker *et al.* (1988) reported that the application of Zn in different levels 0, 1.5, 3.0 mg Zn kg^{-1} soil resulted in greater Zn uptake and greater dry matter yield. Salam and Subamanian (1988) reported that zinc application increased the uptake of Zn by plant. Sachdev and Deb (1991) observed that dry matter yield and Zn content and uptake increased with increase in Zn application.

Table 12. Interaction effect of different levels of nitrogen and zinc on N and Zn uptake by plant of BRRI Dhan 39

Treatment	N uptake (kg ha^{-1})		Zn uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw
N_0Zn_0	28.61 h	47.34 hi	0.044 i	0.134
N_0Zn_1	35.69 fg	51.47 h	0.060 h	0.168
N_0Zn_2	40.49 ef	51.85 h	0.067 e-h	0.175
N_0Zn_3	33.72 gh	45.50 i	0.063 gh	0.183
N_1Zn_0	40.82 ef	53.18 h	0.065 fgh	0.159
N_1Zn_1	45.79 de	63.64 g	0.074 d-g	0.168
N_1Zn_2	54.79 bc	64.38 fg	0.096 b	0.184
N_1Zn_3	49.46 cd	87.41 a	0.079 de	0.192
N_2Zn_0	59.87 b	65.28 fg	0.010 b	0.200
N_2Zn_1	67.99 a	69.32 efg	0.012 a	0.229
N_2Zn_2	72.58 a	69.92 def	0.010 b	0.233
N_2Zn_3	71.52 a	82.12 ab	0.012 a	0.219
N_3Zn_0	49.79 cd	75.13 cde	0.076 def	0.174
N_3Zn_1	48.75 cd	75.58 cd	0.092 bc	0.209
N_3Zn_2	49.32 cd	80.65 bc	0.082 cd	0.239
N_3Zn_3	45.38 de	77.43 bc	0.071 d-h	0.220
$LSD_{(0.05)}$	5.68	5.63	0.0012	--
Significance level	**	**	**	NS

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
**: Significant at 1% level of probability; NS: Not significant

N_0: 0 kg N ha^{-1}
N_1: 50 kg N ha^{-1}
N_2: 100 kg N ha^{-1}
N_3: 150 kg N ha^{-1}

Zn_0: 0 kg Zn ha^{-1}
Zn_1: 5 kg Zn ha^{-1}
Zn_2: 10 kg Zn ha^{-1}
Zn_3: 15 kg Zn ha^{-1}

4.4 Nutrient content of post harvest soil

Nutrient content on post harvest soil were tested after harvest the crop and the status of total nitrogen, available Zn, available P, available S, exchangeable K value were measured.

4.4.1 Total N

Statistically significant variation is total nitrogen content of post harvested soil were found due to the application of different levels of N (Appendix V). Maximum total nitrogen (0.08%) in post harvested soil under N_1 and N_3 treatment comprising of 50 and 150 kg N ha^{-1} (Table 13) were recorded and the lowest total nitrogen (0.07%) was recorded in post harvest soil under the N_0 and N_2 treatment i.e. control condition and also 100 kg N ha^{-1}.

A statistically significant difference was recorded for different level of zinc in terms of total nitrogen in post harvest soil (Appendix V). The highest (0.08%) total nitrogen in post harvest soil was recorded in Zn_1 and Zn_3 treatment, respectively (Table 14). The lowest (0.07%) total nitrogen in post harvest soil was recorded from the Zn_0 and Zn_2 treatment.

The interaction effect between nitrogen and zinc showed no significant variations in terms of total nitrogen in post harvest soil (Appendix V). The highest (0.08%) total nitrogen in post harvested soil was recorded from the treatment combination N_0Zn_3, N_1Zn_1, N_0Zn_3, N_1Zn_3, N_2Zn_0, N_2Zn_3, N_3Zn_0, N_3Zn_1, N_3Zn_3, and the lowest (0.06%) was recorded from control condition (Table 15). BRRI (1980) reported similar results from their experiment earlier.

Table 13. Effect of different levels of nitrogen on nutrient content on post harvest of soil

Treatment	% of Total N	Available Zn (ppm)	Available P (ppm)	Available S (ppm)	Exchangeable K (meq/100 g soil
N_0	0.07 b	3.26 ab	17.56 b	20.30 d	0.122 c
N_1	0.08 a	3.53 a	17.77 b	23.48 c	0.142 b
N_2	0.07 b	3.55 a	17.91 ab	28.86 b	0.151 a
N_3	0.08 a	3.16 b	18.42 a	30.08 a	0.145 ab
$LSD_{(0.05)}$	0.0026	0.328	0.529	0.851	0.008
Significance level	*	*	*	**	**

In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability
**: Significant at 1% level of probability; * : Significant at 5% level of probability;

N_0: 0 kg N ha^{-1}
N_1: 50 kg N ha^{-1}
N_2: 100 kg N ha^{-1}
N_3: 150 kg N ha^{-1}

Zn_0: 0 kg Zn ha^{-1}
Zn_1: 5 kg Zn ha^{-1}
Zn_2: 10 kg Zn ha^{-1}
Zn_3: 15 kg Zn ha^{-1}

Table 14. Effect of different levels of zinc on nutrient content on post harvest of soil

Treatment	% of Total N	Available Zn (ppm)	Available P (ppm)	Available S (ppm)	Exchangeable K (meq/100 g soil
Zn_0	0.07 b	3.00 b	17.81 bc	24.37 c	0.135 b
Zn_1	0.08 a	3.53 a	18.02 ab	25.44 b	0.138 ab
Zn_2	0.07 b	3.33 ab	17.46 c	26.41 a	0.141 ab
Zn_3	0.08 a	3.63 a	18.37 a	26.50 a	0.145 a
$LSD_{(0.05)}$	0.0026	0.328	0.529	0.851	0.008
Significance level	*	**	*	**	**

In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

**: Significant at 1% level of probability; *: Significant at 5% level of probability

N_0: 0 kg N ha^{-1} | Zn_0: 0 kg Zn ha^{-1}
N_1: 50 kg N ha^{-1} | Zn_1: 5 kg Zn ha^{-1}
N_2: 100 kg N ha^{-1} | Zn_2: 10 kg Zn ha^{-1}
N_3: 150 kg N ha^{-1} | Zn_3: 15 kg Zn ha^{-1}

4.4.2 Available Zn

Available Zn (ppm) in post harvested soil showed statistically significant variations for the effect of nitrogen under the present trial (Appendix V). The highest available Zn (3.55 ppm) in post harvested soil was recorded in N_2 treatment comprising of 100 kg N ha^{-1} (Table 13) which was statistically similar (3.53 ppm) with N_1 treatment comprising of 50 kg N ha^{-1} and the lowest available Zn (3.26 ppm) in post harvest soil was recorded from the N_0 treatment i.e. control condition which was closely followed by N_3 treatment consisting of 150 kg N ha^{-1}.

A statistically significant difference was recorded for different level of zinc in terms of available Zn in post harvest soil (Appendix V). The highest (3.63 ppm) available Zn in post harvest soil was recorded in Zn_3 treatment (Table 14) which was statistically identical with the treatment Zn_1 and Zn_2 respectively. The lowest (3.00 ppm) available Zn in post harvest soil was recorded under the control treatment.

The interaction effect between nitrogen and zinc showed no significant variations in terms of available Zn in post harvest soil (Appendix V). The highest (3.89 ppm) available Zn in post harvested soil was recorded from the treatment combination N_2Zn_3 treatment and the lowest (2.83 ppm) was recorded from control condition (Table 15).

4.4.3 Available P

The effect of nitrogen in terms of available P (ppm) in post harvested soil was statistically significant under the present trial (Appendix V). The highest available P (18.42 ppm) in post harvested soil was recorded in N_3 treatment (Table 13) which was statistically identical (17.91 ppm) with N_2 treatment and the lowest available P (17.56 ppm) in post harvest soil from the N_0 treatment.

Significant variation was recorded for different level of zinc in terms of available P in post harvest soil (Appendix V). The highest (18.37 ppm) available P in post harvest soil was recorded in Zn_3 treatment (Table 14). Te lowest (17.81 ppm) available P in post harvest soil was recorded from the Zn_0 treatment.

The interaction effect between nitrogen and zinc showed significant variations in terms of available P in post harvest soil (Appendix V). The highest (19.91 ppm) available P in post harvested soil was recorded from the treatment combination N_2Zn_0 treatment and the lowest (15.41 ppm) was recorded from control condition (Table 15).

4.4.4 Available S

There were statistically significant differences for the effect of nitrogen in terms of available S (ppm) in post harvested soil under the present trial (Appendix V). Highest available S (30.08 ppm) in post harvested soil was recorded in N_3 treatment (Table 13) which was closely followed by (28.86 ppm) N_2 treatment and the lowest available S (17.56 ppm) in post harvest soil from the N_0 treatment i.e. control condition.

Significant variation was recorded for different level of zinc in terms of available S in post harvest soil (Appendix V). The highest (26.50 ppm) available S in post harvest soil was recorded in Zn_3 treatment (Table 14). On the other hand the lowest (24.37 ppm) available S in post harvest soil was recorded from the Zn_0 treatment.

The interaction effect between nitrogen and zinc showed significant variations in terms of available S in post harvest soil (Appendix V). The highest (30.86 ppm) available S in post harvested soil was recorded from the treatment combination N_2Zn_2 treatment and the lowest (19.00 ppm) was recorded from control condition (Table 15).

4.4.5 Exchangeable K

Statistically significant differences were found for the effect of nitrogen in terms of exchangeable K (meq/100 g soil) in post harvested soil under the present trial (Appendix V). The highest exchangeable K (0.151 meq/100 g soil) in post harvested soil was recorded in N_2 treatment (Table 13) which was closely followed by (0.145 meq/100 g soil) with N_3 treatment and the lowest exchangeable K (0.122 meq/100 g soil) in post harvest soil from the N_0 treatment.

Significant variation was recorded for different level of zinc in terms of exchangeable K in post harvest soil (Appendix V). The highest (0.145 meq/100 g soil) exchangeable K in post harvest soil was recorded in Zn_3 treatment (Table 14). The lowest (0.135 meq/100 g soil) exchangeable K in post harvest soil was recorded from the Zn_0 treatment.

The interaction effect between nitrogen and zinc showed significant variations in terms of exchangeable K in post harvest soil (Appendix V). The highest (0.157 meq/100 g soil) exchangeable K in post harvested soil was recorded from the treatment combination N_2Zn_3 treatment and the lowest (0.112 meq/100 g soil) was recorded from N_0Zn_1 treatment combination (Table 15).

Table 15. Interaction effect of different levels of nitrogen and zinc on nutrient content on post harvest of soil

Treatment	% of Total N	Available Zn (ppm)	Available P (ppm)	Available S (ppm)	Exchangeable K (meq/100 g soil)
N_0Zn_0	0.06	2.83	15.41 h	19.00 g	0.124 cde
N_0Zn_1	0.07	3.54	17.20 efg	20.09 fg	0.112 e
N_0Zn_2	0.07	3.08	18.11 c-f	20.52 efg	0.119 de
N_0Zn_3	0.08	3.57	19.53 ab	21.60 def	0.131 bcd
N_1Zn_0	0.07	3.09	18.62 bc	22.09 de	0.134 bcd
N_1Zn_1	0.08	3.42	18.97 abc	22.57 d	0.142 abc
N_1Zn_2	0.07	3.49	16.46 gh	24.31 c	0.144 ab
N_1Zn_3	0.08	4.12	17.03 fg	24.96 bc	0.147 ab
N_2Zn_0	0.08	3.19	17.29 d-g	26.12 b	0.141 ab
N_2Zn_1	0.07	3.51	18.79 abc	28.97 a	0.149 ab
N_2Zn_2	0.07	3.61	17.03 fg	30.86 a	0.157 a
N_2Zn_3	0.08	3.89	18.51 bc	29.49 a	0.157 a
N_3Zn_0	0.08	2.90	19.91 a	30.27 a	0.142 abc
N_3Zn_1	0.08	3.67	17.14 efg	30.12 a	0.148 ab
N_3Zn_2	0.07	3.13	18.23 cde	29.94 a	0.144 ab
N_3Zn_3	0.08	2.96	18.42 bcd	29.97 a	0.144 ab
$LSD_{(0.05)}$	--	--	1.060	1.702	0.017
Significance level	NS	NS	**	*	**

In a column,means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

**: Significant at 1% level of probability; *: Significant at 5% level of probability; NS: Not significant

N_0: 0 kg N ha^{-1}
N_1: 50 kg N ha^{-1}
N_2: 100 kg N ha^{-1}
N_3: 150 kg N ha^{-1}

Zn_0: 0 kg Zn ha^{-1}
Zn_1: 5 kg Zn ha^{-1}
Zn_2: 10 kg Zn ha^{-1}
Zn_3: 15 kg Zn ha^{-1}

Chapter V

SUMMARY AND CONCLUSION

The field experiment was conducted at the Sher-e-Bangla Agricultural University (SAU) farm, Dhaka, during the period from 5 July 2006 to 29 October, 2006 to study the performance of aman rice as influenced by nitrogen and zinc on the yield of BRRI Dhan 39 under Modhupur Tract (AEZ 28).

There were 16 treatments combinations comprising of four level of N (0, 50, 100 and 150 kg N ha^{-1}) and four level of Zn (0, 5, 10 and 15 kg Zn ha-1). A common dose of P (16 kg ha^{-1}), K (60 kg ha^{-1}) and S (10 kg ha^{-1}) were applied. The trial was laid out in Randomized Complete Block Design (RCBD) with three replications.

The plant characters were recorded on each plot after final harvest. The data included were plant height, total tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, panicle length, unfilled and filled grains $panicle^{-1}$, 1000-grain weight and grain and straw yields. Chemical analysis of grain and straw and soil samples was also done. The collected data were analyzed statistically following Duncan's Multiple Range Test (DMRT).

The maximum plant height (112 cm) was recorded in N_2 treatment comprising of 100 kg N ha^{-1} which was statistically similar (110 cm and 110 cm) with the treatment N_3 and N_1 treatment comprising of 150 kg N ha^{-1} and 50 kg N ha^{-1}, respectively and the minimum plant height (105 cm) was recorded in control condition. The maximum (12.16) number of total tiller was recorded in N_2 treatment which was closely followed (11.29 and 11.20, respectively) by the treatment N_1 and N_3, respectively and the minimum (10.10) number of total tiller was recorded from the N_0 treatment i.e. control condition. The highest (11.79) number of effective tiller was recorded in N_2 treatment which was closely followed (10.95 and 10.77, respectively) by the N_3 and N_1 treatment, respectively and the lowest (9.10) number of effective tiller was recorded from the N_0 treatment. The longest (23.80 cm) panicle length was recorded in N_2 treatment which was statistically similar (23.67 cm) by the N_3 treatment and the shortest (21.01 cm) panicle length was recorded from the N_0 treatment. The maximum (88.46) number of filled grain was recorded in N_3 treatment which was statistically similar (88.15) with the treatment N_2 and the minimum (79.83) number of filled grain was recorded in control condition where no fertilizer was applied. The highest number of unfilled grains (26.72) obtained in N_0 (control) treatment. On the other hand, the lowest number of unfilled grains (23.63) was obtained in N_2 treatment which was statistically identical to N_1 and N_3 treatments respectively. The highest 1000-grain weight of 24.17g was found in N_2 treatment and the lowest 23.10g in control treatment which was closely followed (23.98 g) by the N_3 treatment. The highest (4.91 t ha^{-1}) grain yield was recorded in N_2 treatment which was statistically identical (3.47 t ha^{-1}) by the N_3 and N_1 treatment and the lowest (2.66 t ha^{-1}) grain yield was recorded from the N_0 treatment i.e. control condition. The highest (8.08 t ha^{-1}) straw yield was recorded in N_3 treatment which was closely followed by (7.22 t ha^{-1}) by the N_2 treatment and the lowest (6.66 t ha^{-1}) straw yield was recorded in control condition where no fertilizer was applied.

The highest total nitrogen (1.40%) was recorded in N_3 treatment and the lowest total nitrogen (1.30%) in grain from the N_0 treatment. The highest total nitrogen (0.95%) in straw was recorded in N_1 and N_3 treatment and the lowest total nitrogen (0.74%) in straw from the N_0 treatment i.e. control condition. The highest protein content (8.76%) in grain was recorded in N_3 treatment and the lowest protein content (8.12%) in grain from the N_0

treatment. The highest protein content (5.97%) in straw was recorded in N_3 treatment and the lowest protein content (4.61%) in straw from the N_0 treatment. The highest Zn content in grain (0.0024%) was recorded in N_2 treatment and the lowest Zn content (0.0022%) in grain from the N_0 treatment. The highest Zn (0.0059%) content in straw was recorded in N_2 treatment and the lowest Zn content (0.0025%) in straw from the N_0 treatment. The highest nitrogen uptake by grain (67.99 kg ha^{-1}) was recorded in N_2 treatment and the lowest nitrogen uptake (34.63 kg ha^{-1}) by grain from the N_0 treatment. The highest nitrogen uptake (77.20 kg ha^{-1}) by straw was recorded in N_3 treatment and the lowest nitrogen uptake (49.04 kg ha^{-1}) by straw from the N_0 treatment.

The highest total nitrogen (0.08%) in post harvested soil was recorded in N_1 and N_3 treatment and the lowest total nitrogen (0.07%) in post harvest soil was recorded from the N_0 and N_2 treatment. The highest available Zn (3.55 ppm) in post harvested soil was recorded in N_2 treatment and the lowest available Zn (3.26 ppm) in post harvest soil from the N_0 treatment. The highest available P (18.42 ppm) in post harvested soil was recorded in N_3 treatment and the lowest available P (17.56 ppm) in post harvest soil from the N_0 treatment. The highest available S (30.08 ppm) in post harvested soil was recorded in N_3 treatment (Table 13) and the lowest available S (17.56 ppm) in post harvest soil from the N_0 treatment. The highest exchangeable K (0.151 meq/100 g soil) in post harvested soil was recorded in N_2 treatment (Table 13) which was closely followed by (0.145 meq/100 g soil) with N_3 treatment and the lowest exchangeable K (0.122 meq/100 g soil) in post harvest soil from the N_0 treatment which was followed by (0.142 meq/100 g soil) with the N_1 treatment.

The tallest (112 cm) plant height was recorded in Zn_3 treatment which was statistically identical (111 cm and 110 cm) with the treatment Zn_2 and Zn_1 comprising of 10 kg Zn ha^{-1} and 5 kg Zn ha^{-1}, respectively. On the other hand, the shortest (105 cm) plant height was recorded from the Zn_0 treatment under the present trial. The maximum (11.53) number of total tiller was recorded in Zn_2 treatment which was statistically identical (11.31) with the treatment Zn_1. On the other hand, the minimum (10.88) number of total tiller was recorded from the Zn_0 treatment i.e. controls. The maximum (10.97) number of effective tiller was recorded in Zn_2 treatment which was statistically identical (10.81) with the treatment Zn_1. The minimum (10.22) number of effective tiller was recorded from the Zn_0 treatment. The longest (23.10 cm) panicle length was recorded in Zn_2 treatment which was statistically identical (22.99) with the treatment Zn_3. The shortest (22.05 cm) panicle length was recorded from the Zn_0 treatment. The maximum (92.52) number of filled grain was recorded in Zn_2 treatment which was closely followed (86.82) with the treatment Zn_1. The minimum (79.35) number of filled grain was recorded from the Zn_0 treatment. The highest number of unfilled grains (27.70) was recorded in Zn_0 treatment which was closely followed (25.13) by Zn_1 treatment and the lowest number of unfilled grains (22.17) was obtained in Zn_3 treatment which was closely related with Zn_2 treatment. The highest 1000-grain weight (24.25) was found in Zn_2 treatment and the lowest (23.23) was observed in Zn_0 treatment. The highest (3.91 t ha^{-1}) grain yield was recorded in Zn_3 treatment which was closely followed by (3.69 t ha^{-1}) with the treatment Zn_1. The lowest (3.39 t ha^{-1}) grain yield was recorded from the Zn_0 treatment. The highest (7.52 t ha^{-1}) straw yield was recorded in Zn_2 treatment and the lowest (7.16 t ha^{-1}) straw yield was recorded from the Zn_0 treatment.

The highest (1.41%) total nitrogen in grain was recorded in Zn_3 treatment. On the other hand, the lowest (1.32%) total nitrogen in grain was recorded from the Zn_0 treatment. The highest (0.98%) total nitrogen in straw was recorded in Zn_3 treatment and the lowest (1.32%) total nitrogen in straw was recorded from the Zn_0 treatment. The highest protein content in grain (8.84%) and straw (6.09%) was recorded in Zn_3 treatment and the lowest protein content in grain (8.23%) and straw (5.22%) was recorded from the Zn_0 treatment. The highest (0.0024%) Zn content in grain was recorded in Zn_3 and Zn_2 treatment. And the lowest (0.0021%) Zn content in grain was recorded from the Zn_0 treatment. The highest (0.0028%) Zn content in straw was recorded in Zn_2 treatment. On the other hand, the lowest (0.0023%) Zn content in straw was recorded from the Zn_0 treatment. The highest (54.30 kg ha^{-1}) nitrogen uptake by grain was recorded in Zn_2 treatment. And the lowest (44.77 kg ha^{-1}) nitrogen uptake by grain was recorded from the Zn_0 treatment. The highest (73.12 kg ha^{-1}) nitrogen uptake by straw was recorded in Zn_3 treatment. The lowest (60.23 kg ha^{-1}) nitrogen uptake by straw was recorded from the Zn_0 treatment. The highest (0.092 kg ha^{-1}) Zn uptake by grain was recorded in Zn_2 treatment and the lowest (0.072 kg ha^{-1}) Zn uptake by grain was recorded from the Zn_0 treatment. The highest (0.208 kg ha^{-1}) Zn uptake by straw was recorded in Zn_2 treatment and the lowest (0.167 kg ha^{-1}) Zn uptake by straw was recorded from the Zn_0 treatment.

The highest (0.08%) total nitrogen in post harvest soil was recorded in Zn_1 and Zn_3 treatment. On the other hand, the lowest (0.07%) total nitrogen in post harvest soil was recorded from the Zn_0 and Zn_2 treatment. The highest available Zn (3.63 ppm), available P (18.37 ppm), available S (26.50 ppm) and exchangeable K (0.145 meq/100 g soil) in post harvest soil was recorded in Zn_3 treatment and the lowest available Zn (3.00 ppm), available P (17.81 ppm), available S (24.37 ppm) and exchangeable K (0.135 meq/100 g soil) in post harvest soil was recorded from the Zn_0 treatment.

The tallest (114cm) plant height was recorded from the treatment combination N_1Zn_1 while the shortest (102 cm) plant height was recorded from N_0Zn_0. The maximum (13.00) number of tiller was recorded from the treatment combination N_2Zn_2 while the minimum (9.23) number of tiller was recorded from N_0Zn_0. The maximum (12.60) number of effective tiller was recorded from the treatment combination N_2Zn_2 while the minimum (8.13) number of tiller was recorded from N_0Zn_0 i.e. no nitrogen no zinc. The longest (24.28 cm) panicle length was recorded from the treatment combination N_2Zn_2 while the shortest (20.82 cm) panicle length was recorded from N_0Zn_0. The maximum (98.33) number of filled grain was recorded from the treatment combination N_3Zn_1 which was statistically similar (95.63, 95.40) with the treatment combination N_1Zn_2 and N_2Zn_2 respectively while the minimum (71.90) number of filled grain was recorded from N_0Zn_0. The highest number of unfilled grains panicle^{-1} was found in N_0Zn_0 treatment i.e. in control condition which was closely related with N_1Zn_2 treatment and the lowest number of unfilled grains panicle^{-1} was recorded in N_2Zn_2 treatment. The highest 1000-grain weight (24.80g) was recorded in N_1Zn_2 treatment and the lowest 1000-grain weight (22.17g) was recorded in control condition. The highest (5.30 t ha^{-1}) grain yield was recorded from the treatment combination N_2Zn_2 and the lowest (2.20 t ha^{-1}) was recorded from control condition. The highest (8.23 t ha^{-1}) straw yield was recorded from the treatment combination N_3Zn_2. On the other hand, the lowest (6.40 t ha^{-1}) was recorded from control condition.

The highest (1.51%) total nitrogen in grain recorded from the treatment combination N_3Zn_2 and the lowest (1.30%) was recorded from control condition. The highest (1.23%)

total nitrogen in straw was recorded from the treatment combination N_1Zn_3. And the lowest (0.74%) was recorded from control condition. The highest (9.43%) protein content in grain was recorded from the treatment combination N_3Zn_2 and the lowest (8.12%) was recorded from control condition. The highest (7.68%) protein content in straw was recorded from the treatment combination N_1Zn_3 on the other hand, the lowest (0.4.62%) was recorded from control condition. The highest (0.0025%) Zn content in grain was recorded from the treatment combination N_3Zn_2. On the other hand the lowest (0.0020%) was recorded from control condition. The highest (0.0030%) Zn content in straw was recorded from the treatment combination N_2Zn_1. The lowest (0.0021%) was recorded from control condition. The highest (72.58 kg ha^{-1}) nitrogen uptake by grain was recorded from the treatment combination N_2Zn_2 on the other hand, the lowest (28.61 kg ha^{-1}) was recorded from control condition. The highest (87.41 kg ha^{-1}) nitrogen uptake by straw was recorded from the treatment and the lowest (47.34 kg ha^{-1}) was recorded from control condition. The highest (0.012 kg ha^{-1}) Zn uptake by grain was recorded from the treatment combination N_2Zn_1 and the lowest (0.044 kg ha^{-1}) was recorded from control condition. The highest (0.233 kg ha^{-1}) Zn uptake by straw was recorded from the treatment combination N_2Zn_2. On the other hand the lowest (0.134 kg ha^{-1}) was recorded from control condition.

The highest (0.08%) total nitrogen in post harvested soil was recorded from the treatment combination N_0Zn_3, N_1Zn_1, N_0Zn_3, N_1Zn_3, N_2Zn_0, N_2Zn_3, N_3Zn_0, N_3Zn_1, N_3Zn_3, and the lowest (0.06%) was recorded from control condition. The highest (3.89 ppm) available Zn in post harvested soil was recorded from the treatment combination N_2Zn_3 treatment and the lowest (0.2.83 ppm) was recorded from control condition. The highest (19.91 ppm) available P in post harvested soil was recorded from the treatment combination

N_2Zn_0 treatment and the lowest (15.41 ppm) was recorded from control condition. The highest (30.86 ppm) available S in post harvested soil was recorded from the treatment combination N_2Zn_2 treatment and the lowest (19.00 ppm) was recorded from control condition. The highest (0.157 meq/100 g soil) exchangeable K in post harvested soil was recorded from the treatment combination N_2Zn_3 treatment and the lowest (0.112 meq/100 g soil) was recorded from N_0Zn_1 treatment.

The overall result shows that T_{11} treatment combination i.e. 100 kg N ha^{-1} and 10 kg Zn ha^{-1} perform better considering yield contributing characters such as total number of tiller $plant^{-1}$, number of effective tiller $plant^{-1}$, panicle length and grain yield of rice. For the confirmation of the present findings further research works should conduct at different regions of the country at farmers' level.

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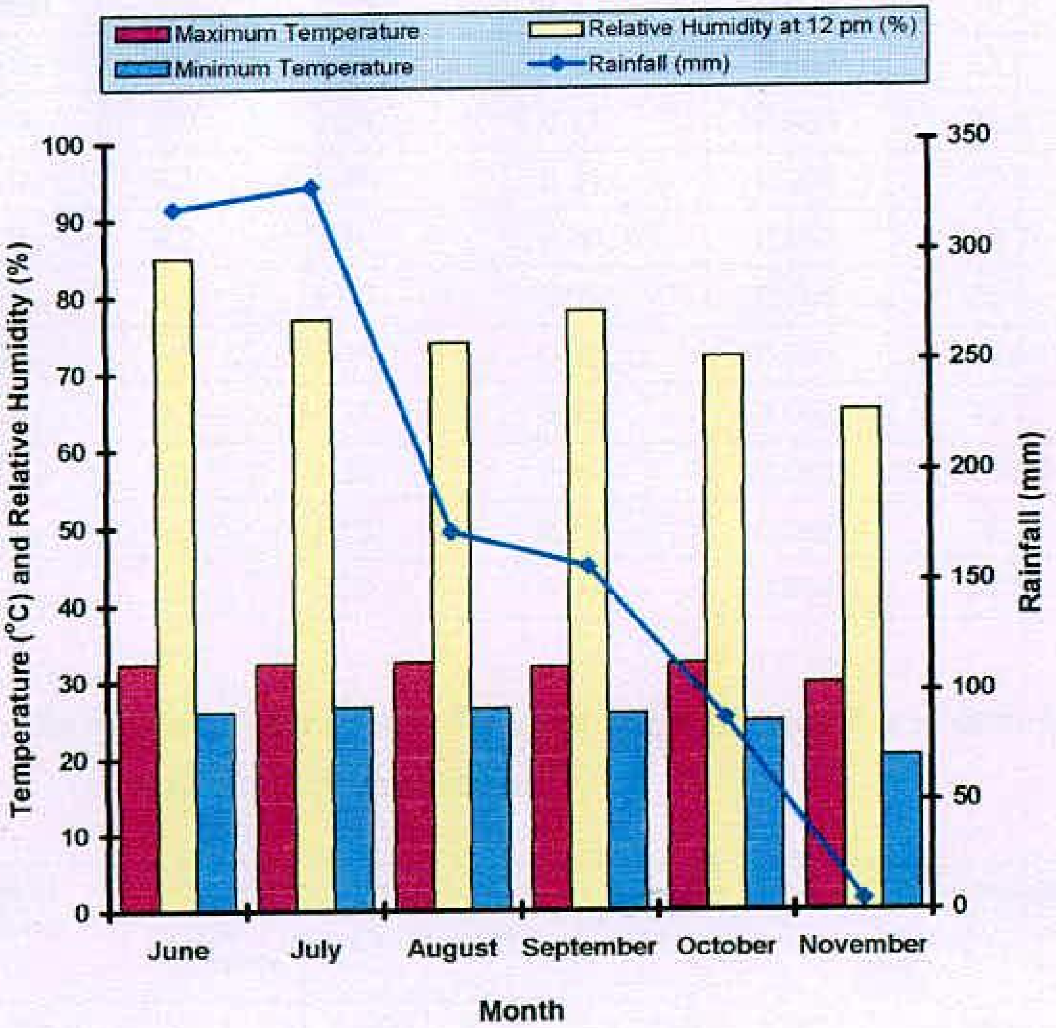
Appendix I. Monthly record of average air temperature, relative humidity and total rainfall of the experimental site during the period from June 2006 to November 2006



Source: Bangladesh Meteorological Department, Dhaka-1212

Appendix II. Analysis of variance of the data on yield and yield contributing characters of BRRI Dhan 39 at harvest as influenced by different levels of nitrogen and zinc fertilizer

Source of variation	Degrees of freedom	Mean square								
		Plant height (cm)	Total tiller (No.)	Effective tiller (No.)	Panicle length (cm)	Filled grain (No.)	Unfilled grain (No.)	1000 seed weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Replication	2	6.581	0.542	0.044	0.543	3.741	4.589	0.100	0.052	0.025
Factor A (N)	3	97.224**	8.545**	15.238**	20.668**	192.093**	22.767*	2.862	10.526**	5.058**
Factor B (Zn)	3	117.482*	1.023**	1.257**	2.666**	384.149**	64.913**	2.860	0.611**	0.318**
Interaction (A×B)	9	15.503	0.580*	0.883**	0.310	68.787**	135.779**	0.327	0.312**	0.024
Error	30	19.763	0.239	0.237	0.576	12.962	6.609	3.395	0.054	0.036

** : Significant at 1% level of probability; * : Significant at 5% level of probability;

Appendix III. Analysis of variance of the data on N, Protein and Zn content by plant of BRRI Dhan 39 as influenced by different levels of nitrogen and zinc

Source of variation	Degrees of freedom	Mean square					
		Total N (%)		Protein (%)		Zn (%)	
		Grain	Straw	Grain	Straw	Grain	Straw
Replication	2	0.004	0.004	0.116	0.031	0.00033	0.00058
Factor A (N)	3	0.024**	0.132**	0.953**	5.169**	0.0006*	0.0035**
Factor B (Zn)	3	0.024**	0.041**	0.975**	1.607**	0.0018**	0.0046**
Interaction (A×B)	9	0.008**	0.034**	0.316**	1.318**	0.00044	0.000535
Error	30	0.003	0.002	0.084	0.022	0.00022	0.00049

** : Significant at 1% level of probability;

Appendix IV. Analysis of variance of the data on N and Zn uptake by plant of BRRI Dhan 39 as influenced by different levels of nitrogen and zinc

Source of variation	Degrees of freedom	Mean square			
		N uptake (kg/ha)		Zn uptake (kg/ha)	
		Grain	Straw	Grain	Straw
Replication	2	24.01	16.521	1.334	4.698
Factor A (N)	3	2270.3**	1784.6**	68.369**	84.762**
Factor B (Zn)	3	182.11**	340.4**	8.8318**	40.515**
Interaction (A×B)	9	35.422	163.9**	1.5509**	2.913
Error	30	11.615	11.403	0.4911	2.711

** : Significant at 1% level of probability;

Appendix V. Analysis of variance of the data on nutrient content on post harvest of soil as influenced by different levels of nitrogen and zinc

Source of variation	Degrees of freedom	Mean square				
		% of Total N	Available Zn (ppm)	Available P (ppm)	Available S (ppm)	Exchangeable K (meq./100 g soil
Replication	2	0.0001	0.642	0.710	1.205	0.0001
Factor A (N)	3	0.00002*	0.453*	1.622*	252.700**	0.002**
Factor B (Zn)	3	0.00003*	0.938**	1.769*	11.939**	0.0001**
Interaction (A×B)	9	0.00002*	0.211	5.927**	3.053*	0.0001*
Error	30	0.00001	0.155	0.404	1.042	0.00001*

** : Significant at 1% level of probability; * : Significant at 5% level of probability