INFLUENCE OF NITROGEN AND ZINC ON GROWTH, YIELD AND NUTRIENTS CONTENT OF BRRI dhan33

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A Thesis
Submitted to the Department of Agricultural Chemistry,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

IN

AGRICULTURAL CHEMISTRY

SEMESTER: JANUARY-JUNE, 2013

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CERTIFICATE

This is to certify that the thesis entitled, "**INFLUENCE OF NITROGEN AND ZINC ON GROWTH, YIELD AND NUTRIENTS CONTENT OF BRRI dhan33"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN AGRICULTURAL CHEMISTRY,** embodies the result of a piece of *bona fide* research work carried out by **MD. RAKIBUL HASAN,** Registration No. **05-01667** 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 duly been acknowledged.

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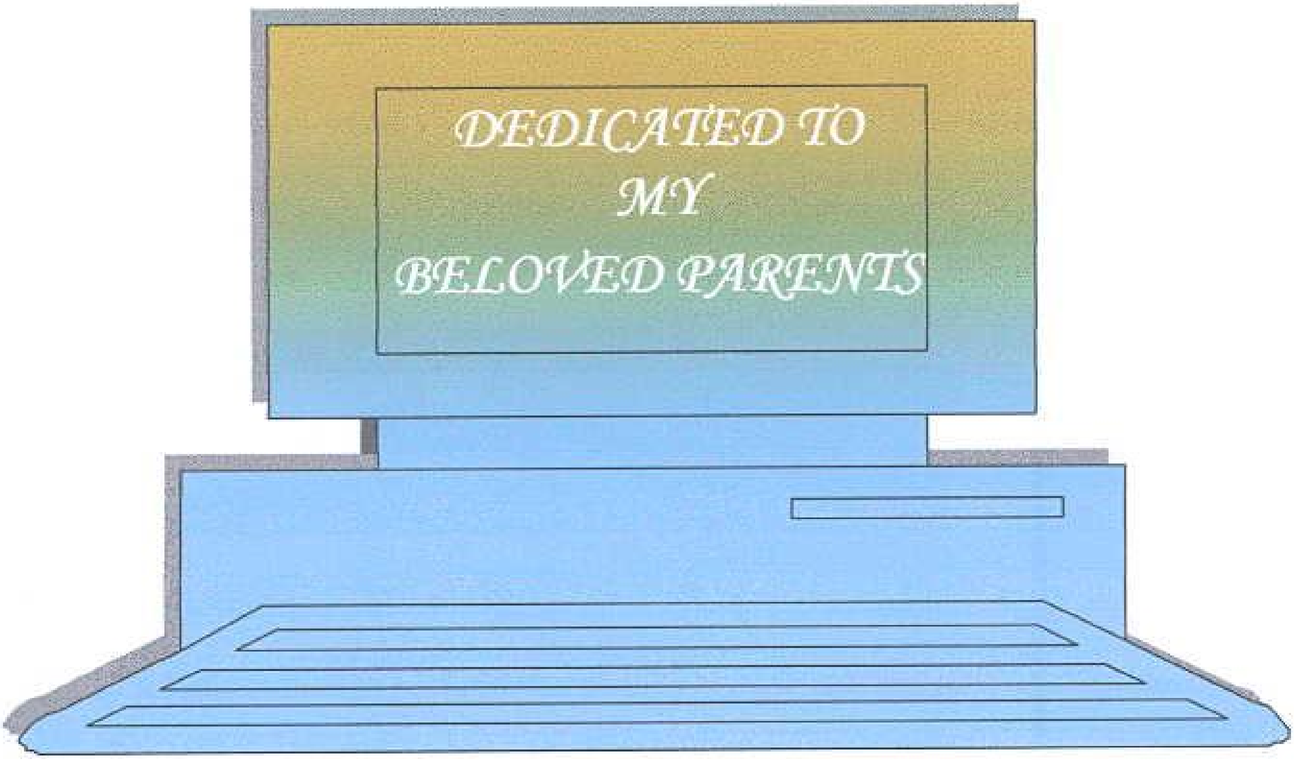
Place: Dhaka, Bangladesh


DEDICATED TO
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BELOVED PARENTS

ACKNOWLEDGEMENT

Alhamdulillah, all praises are due to the almighty Allah Rabbul Al-Amin for his gracious kindness and infinite mercy in all the endeavors the author to let him successfully complete the research work and the thesis leading to Master of Science.

The author would like to express his heartfelt gratitude and most sincere appreciations to his Supervisor Dr. Sheikh Shawkat Zamil, Assisstant Professor, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, for his valuable guidance, advice, immense help, encouragement and support throughout the study. Likewise grateful appreciation is conveyed to Co-supervisor Dr. Abdur Razzaque, Professor, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, for constant encouragement, cordial suggestions, constructive criticisms and valuable advice to complete the thesis.

The author would like to express his deepest respect and boundless gratitude to all the respected teachers of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study and research work.

The author wishes to extend his special thanks to Sheikh Mohammad Masum, Md. Shoaib Mahmud Shouvo for their help during experimentation. Special thanks to all other friends for their support and encouragement to complete this study.

The author is deeply indebted to his father and grateful to his respectful mother, sisters and other relative's for their moral support, encouragement and love with cordial understanding.

Finally the author appreciate the assistance rendered by the staffs of the Department of Agricultural Chemistry and Agricultural Chemistry Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka, who have helped him during the period of study.

The author

ABSTRACT

An experiment was conducted at the experimental field of the Department of Agronomy in Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during T. *aman* season in 2012. The study was to find out the effect of nitrogen (N) and zinc (Zn) application on growth, yield and nutrient content of BRRI dhan33. The experiment was laid out in a randomized complete block design with three replications. Five nitrogen levels viz. 0 (control), 75, 100, 125 and 150 kg N ha^{-1} were applied where urea was used as nitrogen source. On the other hand two levels of zinc i.e. 0 (control) and 2.5 kg ha^{-1} Zn were applied as $ZnSO_4.7H_2O$. From the result it was observed that all the growth and yield components significantly increased with nitrogen and zinc application. Effect of nitrogen levels showed a significant variation on plant height, total tiller production, panicle length, number of filled grain $panicle^{-1}$ and 1000 grain-weight. Among the different nitrogen levels the highest grain yield 5.07 t ha^{-1} was obtained from the application of 100 kg N ha^{-1}, On the other hand zinc application @ 2.5 kg ha^{-1} gave a significant variation regarding growth characteristics and yield contributing characteristics hence result higher yield (4.63 t ha^{-1}), was obtained. From the combined effect it was found that the highest grain yield (5.57 t ha^{-1}) was obtained from the combined application of 125 kg N ha^{-1} and 2.5 kg Zn ha^{-1}. Among different combinations, 125 kg N ha^{-1} along with 2.5 kg Zn ha^{-1} scored the highest nitrogen content (1.84%) in grain. A significant variation was observed on nitrogen and potassium content in straw due to the combined effect of nitrogen and zinc but there was no significant effect on phosphorus and sulphur content.

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LIST OF ACRONYMS

AEZ	=	Agro- Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
Ca	=	Calcium
cm	=	Centi-meter
cv.	=	Cultivar
DAT	=	Days after transplanting
^{0}C	=	Degree Centigrade
DF	=	Degrees of freedom
EC	=	Emulsifiable Concentrate
et al.	=	and others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram
HI	=	Harvest Index
HYV	=	High yielding variety
hr	=	hour
IRRI	=	International Rice Research Institute
Kg	=	Kilogram
Kg/ha	=	Kg per hectare
LV	=	Local variety
LYV	=	Low yielding varieties
LSD	=	Least significant difference
m	=	Meter
m2	=	meter squares
MPCU	=	Mussoriephos-coated urea
MV	=	Modern variety
mm	=	Millimeter
Mg	=	Magnesium
Mn	=	Manganese
viz.	=	Namely
N	=	Nitrogen
@	=	At the rate
ns	=	Non-significant
%	=	Percent

CV %	=	Percentage of Coefficient of Variance
P	=	Phosphorus
$ZnSO_4$	=	Zinc Sulphate
K	=	Potassium
ppm	=	Parts per million
PU	=	Prilled urea
RBD	=	Randomized Block Design
Zn	=	Zinc
USG	=	Urea super granules
UNDP	=	United Nations Development Program
$t\ ha^{-1}$	=	Tons per hectare
TSP	=	Triple Super Phosphate

Chapter 1
Introduction

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop of the world and the staple food of more than 3 billion people or more than half of the world's population. Rice is grown in more than a hundred countries with a total harvested area of nearly 160 million hectares, producing more than 700 million tons every year (IRRI, 2010). Rice is grown in Bangladesh under diverse ecosystem like irrigated, rainfed and deep water conditions in three distinct overlapping seasons namely *aus*, *aman* and *boro*. About 80 percent of cropped area of this country is used for rice cultivation (IRRI, 2006). The average yield of rice in Bangladesh is 3.64 t ha^{-1} (BRRI, 2011). The population of Bangladesh is still growing by two million every year and may increase by another 30 million over the next 20 years, Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. During this time total rice area will also shrink to 10.28 million hectares. Therefore, rice yield needs to be increased from the present 3.64 to 3.74 t ha^{-1} (BRRI, 2011).

Nutrients imbalance in soils produces low fertilizer use efficiency, low yields and low farmer profit (Tiwari, 2002). It also results in further depletion of the most deficient nutrients in the soil. Once a nutrient is reached to its critical level, yields fall dramatically even when large amounts of other nutrients are applied (PPIC, 2000). Hence, the importance of balanced fertilization must be realized in increasing crop yields. Nevertheless, the present world requires modern varieties of rice for increasing rice production. Rice crop yields largely depend upon the soil conditions (it's native nutrient status) and also on the supply of available nutrients (chemical fertilizer) like Phosphorus (P), Sulphur (S), and Zinc (Zn). Most of the farmers of Bangladesh have a tendency to apply more amount of nitrogen to obtain higher yield. Our farmers mainly use urea as nitrogenous fertilizer which accounts for about 75% of the total fertilizer used in Bangladesh (Bhuiya, 1991). Most of the rice soils of Bangladesh are deficient in nitrogen and consequently the response of modern rice varieties to application has always been observed remarkable. Nitrogen use efficiency for rice crop largely ranges from 25% to 35% and seldom exceeds even up to 50% (Singh and Yadav, 1985). Along with other management practices for increasing the efficiency of applied nitrogen fertilizer, the selection of nitrogen efficient rice variety may be a good option. Therefore, to increase the efficiency of applied nitrogen fertilizer, the selection of nitrogen efficient advanced lines can be a good option to minimize losses of nitrogen as well as to develop high yielding nitrogen utilization efficient varieties. Nitrogen is the most important nutrient for growth and yield of rice and it is an influential factor in rice production and its immense role in increasing rice productivity is well documented. Recovery of applied nitrogen by rice plants under local conditions is below at present (Sirisena *et al.* 2001). Nitrogen is comparatively cheaper and its effects are quickly visible, therefore farmers give priority to nitrogen application, sometimes exceeding the requirement without considering the balanced nutrient management. Balanced fertilizer management practice increases the nitrogen use efficiency and therefore is important to achieve higher rice yield as well as to save foreign exchange by reducing the fertilizer wastage.

Zinc deficiency was recognized as a widespread and an important plant nutritional problem throughout the rice growing countries. It is also the major micronutrient deficiency problem in most of the soils of Bangladesh (Gupta and Patalia, 1993). Zinc has a crucial role to play in various aspects of plant physiology, including cell membrane integrity, gene expression, carbohydrates photosynthetic metabolisms, detoxification of reactive oxygen species, phytohormone activity and the proper functioning of a number of enzymes (Cakmak, 2000). Therefore, the lack of sufficient Zinc may cause severe yield reduction. It has been reported that the deficiency of Zinc is aggravated by excess Calcium (Ca), Magnesium (Mg), Copper (Cu), Iron (Fe), Manganese (Mn) and Phosphorus (P) and prolonged submergence would depress zinc availability and uptake. Zinc deficiency has also been observed with high bicarbonate content, Mg/Ca ratio>1 in soil, nitrogen rates and sources. Applied zinc to soil would recover deficiency problem in plants and improve the use efficiencies of other nutrients by rice plants, subsequently giving higher yields. Antagonistic and synergistic effects between applied nutrients have been observed in many crops, but the interaction effect between applied zinc and nitrogen on nitrogen use efficiency, growth and grain yield of rice grown in soils of Bangladesh has a little information or almost nil.

Therefore, the objectives of the present research work were:

1. To identify the effect of nitrogen and zinc on growth and yield of BRRI dhan33.
2. To find out the combined effect of nitrogen and zinc on nutrients content of straw and grain of BRRI dhan33.

Chapter 2
Review of literature

REVIEW OF LITERATURE

The continuous and imbalanced use of the chemical fertilizers under intensive cropping systems has been considered to be the main cause for declining crop yield and soil environmental degradation. All essential elements must be present in optimum amounts and in forms usable by plants. The nitrogen is a major component of proteins, hormones, chlorophyll, vitamins and enzymes, that is essential for rice. The rice plants require a large amount of nitrogen at the early and mid- tillering stage to maximize the number of panicles (Ditta, 1990). The recommended doses of other nutrients are also necessary for potential rice yield. Considering the above point, available literatures were reviewed under nitrogen and zinc application for rice.

2.1 Effect of nitrogen

Nitrogen absorbed by rice during the vegetative growth stages contributed in growth during reproduction and grain-filling through translocation nitrogen is very essential for the growth and development of crops. It enhances biomass and seed yield subject to the efficient water supply. Lack of N results stunted growth, pale yellow color, small grain size and poor vegetative as well as reproductive performance. Nitrogen is an essential component of amino acid and related protein of the plant structure. An increase in yield of cereals with increasing rate of nitrogen has been reported earlier (Khan *et al.*, 1994).

Awan *et al.* (2011) conducted an experiment to study the effect of different nitrogen levels (110, 133 and 156 kg N ha^{-1}) in combination with different row spacing (15 cm, 22.5 cm and 30 cm). They noted that maximum level of nitrogen (156 kg N ha^{-1}) produced maximum effective tillers irrespective of spacing.

BRRI (2008) conducted an experiment to study the comparative study of some promising lines with BRRI modern rice varieties to different nitrogen levels *viz.* 0, 30, 60, 90, 120 and 150 kg N ha^{-1}. It was reported that tiller production with nitrogen @ 120 kg ha^{-1} produced significantly higher tiller than those of lower nitrogen level.

Islam *et al.* (2008) conducted an experiment to study the effect of nitrogen and number of seedlings per hill on the yield and yield components of T. *aman* rice (BRRI dhan33). They noted that panicle length, number of grain $panicle^{-1}$ increased with the application rate of N up to 100 kg ha^{-1} and then declined.

Lin *et al.* (2008) conducted an experiment to find out the effect of plant density and nitrogen fertilizer rates (120, 150, 180 and 210156 kg N ha^{-1}) on grain yield and nitrogen uptake of hybrid rice. They observed that there was a better response to N fertilization, as increasing N application from 120 to 180 kg N ha^{-1} (by 50%) raised yield by 17%. Raising the application rate to 210 kg N ha^{-1} (by 75%) boosted yield by 24.1%.

Field experiments were conducted by Wan *et al.* (2007) in China to study the effects of different nitrogen fertilizer application regimes (basal and panicle applications) on the yield, quality and nitrogen use efficiency of super japonica hybrid rice cv. Changyou 1. They indicated that yield was significantly influenced by the different nitrogen fertilizer application regimes. The regime with the highest yield was at the basal to panicle application ratio of 58.34:41.66 and equal split panicle applications at the fourth and second leaf age from the top.

BRRI (2006) reported that the maximum tillers $hill^{-1}$ (10.2) was produced with 120 kg N ha^{-1} compared to 90 and 0 kg N ha^{-1} application, respectively.

Salem (2006) reported that the nitrogen levels had a positive and significant effect on growth parameters of rice plants. Increasing nitrogen levels up to 70 kg ha^{-1} significantly increased plant height. The highest plant height was recorded about 92.81 cm with 70 kg N ha^{-1}.

Ahmed *et al.* (2005) reported that among 5 levels, 80 kg N ha^{-1} gave the highest plant height (155.86 cm) and the height decreased gradually with decreased levels of nitrogen fertilizer application.

A study was conducted by Verma *et al.* (2004) in Madhya Pradesh, India to investigate the effect of planting date (20 July; and 5 and 20 August) and N rates (50, 100 and 150 kg ha^{-1}). They revealed that N at 100 and 150 kg ha^{-1} resulted in the highest yield.

Lang *et al.* (2003) found that the increase in nitrogen fertilizer application rate enhanced grains per panicle, effective panicles per plant, and total florets per plant.

Maitti *et al.* (2003) conducted an experiment to study the effects of nitrogen fertilizer rate (0, 120, and 140 kg ha^{-1}) on the performance of 1 cultivar (IET-4786) and 4 hybrid varieties (ProAgro 6Y213, ProAgro 6Y3024, ProAgro 6111N, and ProAgro 6201) of rice in Mohanpur, West Bengal, India. The nitrogen fertilizer was applied during transplanting (50%) and at the tillering and panicle initiation stages (50%). They reported that the application of 140 kg N ha^{-1} resulted in the highest increase in grain yield (by 76.2%), number of panicles (by 109.00%), number of filled grains per panicle (by 26.2%), and 1000-grain weight (5.80%) over the control, and the highest nitrogen (136.701 kg ha^{-1}), phosphorus (132.029 kg ha^{-1}), and potassium (135.167 kg ha^{-1}) uptake.

Meena *et al.* (2003) reported that application of 200 kg N ha^{-1} significantly increased the plant height (127.9 cm) of rice while they applied another dose, 100 kg N ha^{-1}.

Singh and Shivay (2003) found that increasing levels of nitrogen significantly increased the grain and straw yields.

Wang *et al.* (2002) reported that the tiller number increased with increasing nitrogen levels.

2.2 Effect of zinc on rice

Anil *et al.* (2012) reported that Rice is important crop of Indo Gangetic Plains of Bihar, productivity of system is stagnate and somewhere going down, to ascertain the role of sulphur and zinc an experiment was conducted at main campus of ICAR Research Complex of Eastern Region Patna with four levels of both nutrients i.e. sulphur and zinc, total 16 treatments were tested in Randomized Block Design. Both the nutrients were applied to rice and their direct and residual response was ascertained to rice and lentil in sequence. Based on three years of experimentation, results revealed that rice plant height is significantly affected by zinc. Tallest plant (101.7 cm) was recorded at maturity with application 5 kg Zn application. Maximum (281.2 kg ha^{-1}) nitrogen uptake was recorded with 5 kg zinc treatment.

Bandra and Silva (2001) reported that application of Zinc at the rate of 2.5 kg Zn ha^{-1} induced the nitrogen use efficiency from 15.6 to 19.4 kg grain yield per kilogram of applied nitrogen and nitrogen recovery from 31% to 41% by rice and augmented higher rice yield. A combination of 100 kg nitrogen and 2.5 kg zinc gave the same yield as that of 125 kg N ha^{-1} alone. The interaction between nitrogen and zinc on grain yield was synergistic.

Chapter 3

Materials and Methods

MATERIALS AND METHODS

Details of different materials used and methodologies followed in the experiment are presented in this chapter.

3.1 Description of the experimental site

3.2 Location

The field experiment was conducted at field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from August to November, 2012. The location of the experimental site has been shown in Appendix I.

3.3 Soil

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium high land with non-calcareous dark grey soil. The pH value of the soil was 5.6. The characteristics of the experimental soil have been shown in Appendix II.

3.4 Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October to March. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the Dhaka meteorology centre, Dhaka for the period of experimentation have been presented in Appendix III.

3.5 Plant materials and features

Rice cv. BRRI dhan33was used as plant materials for the present study. This variety is recommended for aman season. The features of the variety presented below:

3.6 Experimental details

3.6.1 Treatments

The experiment consisted of two factors as mentioned below:

Factor A: Nitrogenous fertilizer Level (N)

1) N_0 = 0 kg N ha^{-1}
2) N_1 = 75 kg N ha^{-1}
3) N_2 = 100 kg N ha^{-1}
4) N_3 = 125 kg N ha^{-1}
5) N_4 = 150 kg N ha^{-1}

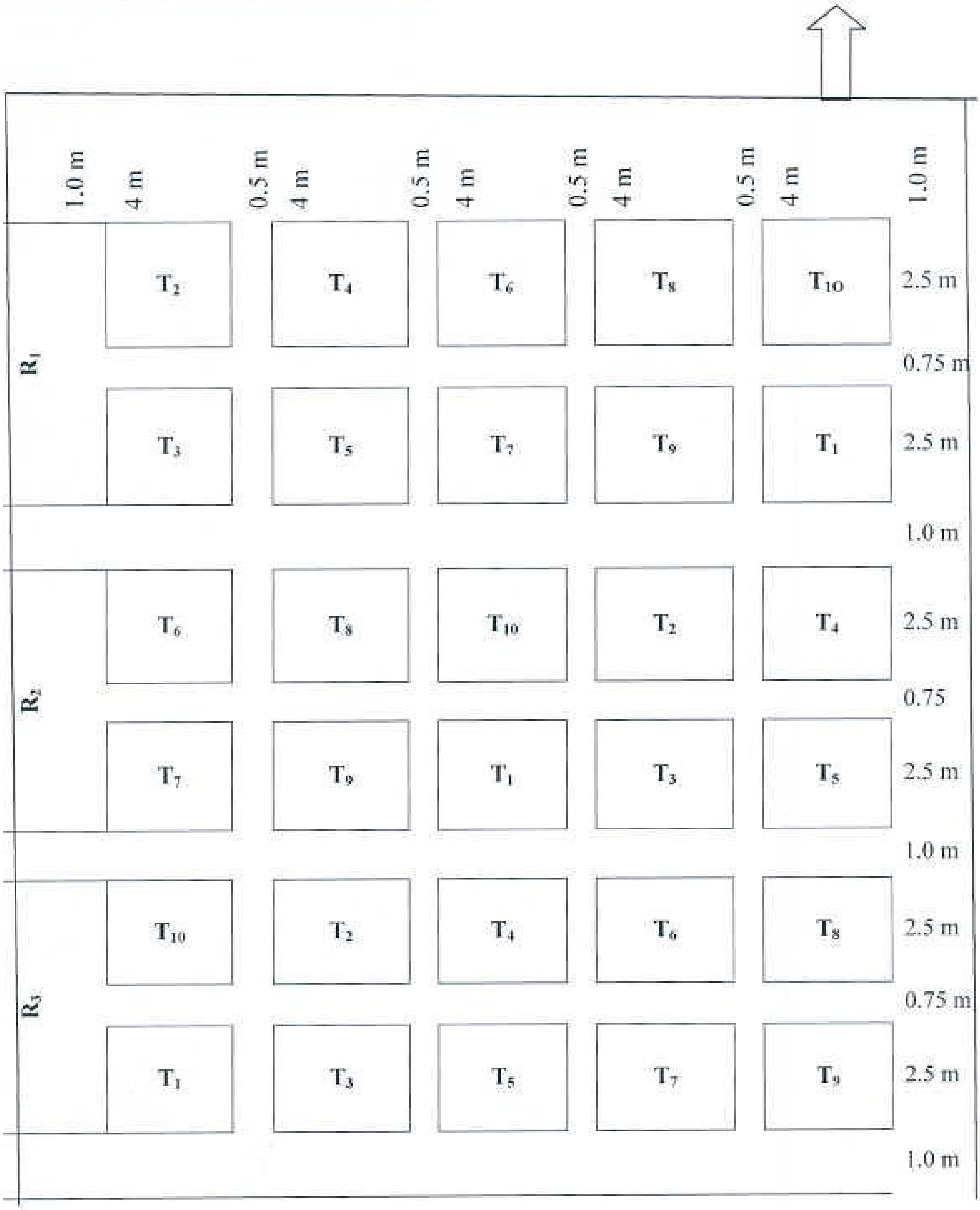
Factor B: Zinc fertilizer Level (Zn)

1) Zn_0 = 0 kg Zn ha^{-1} applied as $ZnSO_4$
2) Zn_1= 2.5 kg Zn ha^{-1} applied as $ZnSO_4$

3.6.2 Experimental design

The experiment was laid out in a Randomized Complete Block design with three replications. There were 10 treatment combinations. The total numbers of unit plots were 30. The size of unit plot was 3 m × 2.5 m (7.5 m^2). The distances between plot to plot and replication to replication were 1 m.

3.6.3 Layout of Experimental Field



Note: $T_1 = N_0Zn_0$, $T_2 = N_0Zn_1$, $T_3 = N_1Zn_0$, $T_4 = N_1Zn_1$, $T_5 = N_2Zn_0$, $T_6 = N_2Zn_1$, $T_7 = N_3Zn_0$ $T_8 = N_3Zn_1$, $T_9 = N_4Zn_0$ and $T_{10} = N_4Zn_1$

3.7 Growing of crops

3.7.1 Raising of seedlings

3.7.1.1 Seed collection

The seeds of the test crop i.e. BRRI dhan33 was collected from Bangladesh Rice Research Institute (BRRI), Joydevpur, Gazipur.

3.7.1.2 Seed sprouting

Healthy seeds were selected by specific gravity method and then immersed in water bucket for 24 hours and then it was kept tightly in gunny bags. The seeds started sprouting after 48 hours and were sown in nursery bed after 72 hours.

3.7.1.3 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on July 10, 2012 in order to transplant the seedlings in the main field.

3.7.2 Preparation of the main field

The selected plot for the experiment was opened in 25 July, 2012 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good puddle condition. Weeds and stubble were removed, and finally obtained a desirable puddled condition of soil for transplanting of seedlings.

3.7.3 Fertilizers and manure application

The fertilizers N, P, K, S and Zn in the form of urea, TSP, MoP, Gypsum and $ZnSO_4$, respectively were applied. The entire amount of TSP, MoP, Gypsum at rate of 100 kg ha^{-1}, 70 kg ha^{-1}, 60 kg ha^{-1} and 10 kg ha^{-1} respectively were applied during the final land preparation. Nitrogenous and zinc sulphate fertilizer was applied as per treatment arranged.

3.7.4 Uprooting seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on August 06, 2012 without causing much mechanical injury to the roots.

3.7.5 Transplanting of seedlings in the field

The twenty eight days old seedlings were transplanted in the main field on August 06, 2012 and the rice seedlings were transplanted in lines each having a line to line distance of 25 cm and plant to plant distance was 15 cm in the well prepared plot.

3.7.6 Cultural operations

The details of different cultural operations performed during the course of experimentation are given below:

3.7.6.1 Irrigation and drainage

The experimental plots required two irrigations during the crop growth season and sometimes drainages were done at the time of heavy rainfall.

3.7.6.2 Gap filling

Gap filling was done for all of the plots at 7-10 days after transplanting (DAT) by planting same aged seedlings.

3.7.6.3 Weeding

Weeding was done from each plot at 30 and 45 DAT. Hand weeding was done from each plot.

3.7.6.4 Plant protection

There were negligible infestations of insect-pests during the crop growth period. Yet to keep the crop growth in normal, Basudin was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 mL ha^{-1} were applied to control stem borer and rice bug.

3.8 Harvesting, threshing and cleaning

The maturity of crop was determined when 85% to 90% of the grains become golden yellow in color. The crop was harvested plot wise at maturity on 16 October, 2012 by cutting the whole plants at the ground level with sickle. The harvested crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in sun. Before harvesting, ten hills were selected randomly for each plot and cut at the ground level for collecting data on yield contributing characters and chemical analysis.

3.9. General observations

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants which were vigorous and luxuriant in the treatment plots than that of control plots.

3.9.1 Detecting the flowering stage (50%) and observation of heading

With experience, it was felt that identifying the flowering stage should need to follow regular field observations as flowering date (50%) were recorded after visual observations. Therefore, regular observations were made accordingly.

3.10 Data recording

The following data were collected during the study period:

3.10.1 Data on growth parameters

1. Plant height (cm) at 15 days interval
2. Number of tillers hill^{-1} at 15 days interval

3.10.2 Data on yield and yield contributing parameters

1. Number of effective tillers hill^{-1}
2. Length of panicle (cm)
3. Number of grains panicle^{-1}
4. Number of fertile spikelets (filled grains)panicle^{-1}
5. Weight of 1000 grain (g)
6. Grain yield (t ha^{-1})
7. Straw yield (t ha^{-1})
8. Biological yield (t ha^{-1})
9. Harvest index (%)
10. Initial soil analysis
11. Grain analysis for N and S content (%)
12. Straw analysis for N, P, K and S content (%)

3.10.3 Procedure of recording data

3.10.3.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 15, 30, 45, 60 DAT (days after transplanting) and at harvest. Data were recorded as the average of same 10 plants pre-selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

3.10.3.2 Number of tillers hill^{-1}

The number of tillers hill^{-1} was recorded at 15, 30, 45, 60 DAT and at harvest by counting total tillers as the average of same 5 hills selected at random from the inner rows of each plot.

3.10.3.3 Length of panicle

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

3.10.3.4 Number of grains panicle^{-1}

The total number of grains was collected randomly from selected 10 plants of panicle of a plot and then average number of grains panicle^{-1} was calculated.

3.10.3.5 Weight of 1000 grains

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

3.10.3.6 Grain yield

Grains obtained from demarked area of each unit plot were sun-dried and weighed carefully and finally converted to t ha^{-1} basis. The central 3 m^2 from each plot were harvested, threshed, dried, and cleaned, weighed.

3.10.3.7 Straw yield

Straw obtained from each treatment were sun-dried and weighed carefully and finally converted to t ha^{-1} basis. The dry weight of straw of central 3 m^2 were harvested, threshed, dried and weighed

3.10.3.8 Biological yield

Grain yield and straw yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield.

3.10.3.9 Harvest index

Harvest index was calculated from the grain and straw yield of rice from each treatment and expressed in percentage.

$$\text{HI (\%)} = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.10.4 Chemical analysis of plant samples

3.10.4.1 Collection and preparation of plant samples

Straw samples were collected after threshing for N, P, K, and S analyses and grain samples were collected for N and S analyses. The plant samples were dried in an oven at 70 ^{0}C for 72 hours and then ground by a grinding machine (wiley- mill) to pass through a 20-mesh sieve. The samples were stored in plastic vial for analyses of N, P, K, and S according to Thomas *et al.* (1967). The grain and straw samples were analyzed for determination of N, P, K, and S concentrations. The methods were as follows:

3.10.4.2 Digestion of plant samples with sulphuric acid for N

For the determination of nitrogen an amount of 0.5 g oven dry, ground sample were taken in a macro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 mL conc. H_2SO_4 were added. The flasks were heated at 160^0 C and added 2 mL 30% H_2O_2 then heating was continued at 360^0 C until the digests become clear and colorless. After cooling, the content was taken into a 50 mL volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

3.10.4.3 Determination of nitrogen

The nitrogen content of the samples was determined by macro Kjeldhal method as described by Page *et al.*, (1982).

3.10.4.4 Digestion of plant samples with nitric-perchloric acid for P, K and S

A sub sample weighing 0.5 g was transferred into a dry, clean 100 mL digestion vessel. Ten ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^0C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. P, K, and S were determined from this digest by using different standard methods.

3.10.4.5 Determination of P, K, and S from plant samples

3.10.4.5.1 Phosphorus

Plant samples (straw) were digested by di-acid (Nitric acid and Perchloric acid) mixture and P content in the digest was measured by blue color development (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 5 ml for straw sample from 50 ml digest by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al.*, 1982).

3.10.4.5.2 Potassium

One milli-liter of digest sample for the straw was taken and diluted 20 ml volume to make desired concentration so that the flame photometer reading of samples were measured within the range of standard solutions. The concentrations were measured by using standard curves.

3.10.4.5.3Sulphur

Sulphur content was determined from the digest of the plant samples (grain and straw) with $CaCl_2$ (0.15%) solution as described by Page *et al.* 1982. The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

3.11 Statistical Analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques using MSTAT-C package and the mean values were separated using least significant differences (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

Chapter 4
Results and Discussion

RESULTS AND DISCUSSION

4.1 Plant height

4.1.1 Effect of nitrogen on plant height

Effect of nitrogen levels showed a significant variation on plant height at all growth stages except 15 DAT. (Figure 1 and Appendix IV). Regardless of treatment differences, plant height increased progressively up to 60 DAT maturity. At 15 DAT maximum plant height (48.58 cm) was observed with N_4 and minimum (39.11 cm) was obtained with control. At 30 DAT the tallest plant (71.46 cm) was found with N_4 which was followed by N_3, $N_2$and N_1 and the shortest (50.07 cm) plant with N_0. At 45 and 60 DAT the highest plant height 92.78 cm and 118.4 cm were obtained with N_4 and shortest 66.88 cm and 91.75 cm plant with N_0, respectively. The similar trend was obtained at harvesting where highest (136.9 cm) plant height with N_4 and shortest (106.2 cm) with N_0 which was in conformed with the results of Joseph *et al.* (1991).

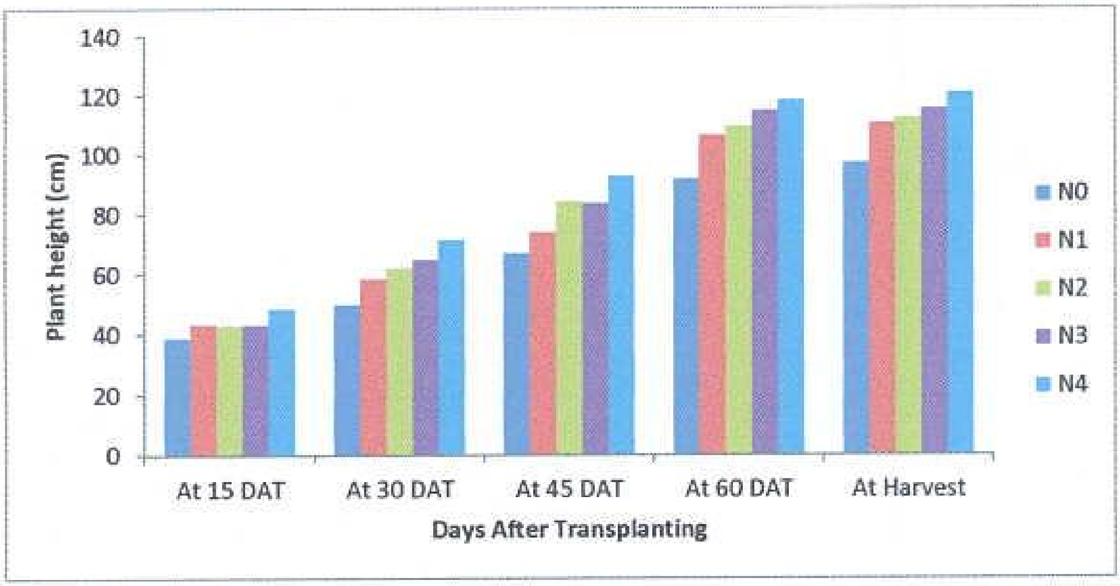


Figure.1. Effect of different levels of nitrogen on plant height of BRRI dhan33
Note: N_o = 0 kg N ha^{-1}, N_1 = 75 kg N ha^{-1}, N_2 = 100 kg N ha^{-1}, N_3 = 125 kg N ha^{-1}, N_4 = 150 kg N ha^{-1}

4.1.2 Effect of Zinc on plant height

Application of Zinc showed a significant variation in plant height for at growth stages except 15 DAT (Figure 2 and Appendix IV). All observing dates result showed that Zn_1 gave maximum plant height. At harvest the highest (130.27 cm) plant height was observed from Zn_1. Malik *et al.* (2011) found that application of Zinc had significant positive influence on growth of rice compared to control.

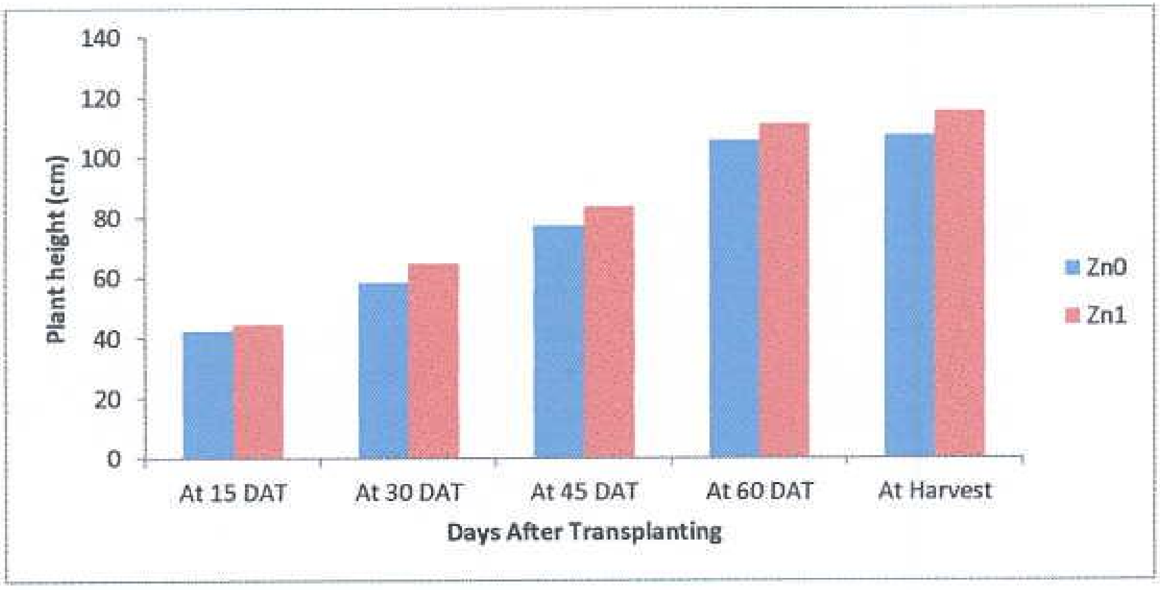


Figure 2.Effect of different levels of zinc on plant height of BRRI Dhan33

Note: Zn_0 = 0 kg Zn ha^{-1}, Zn_1= 2.5 kg Zn ha^{-1}

4.1.3 Combined effect of nitrogen and zinc

Combined effect of nitrogen and zinc on plant height showed a significant variation on plant height for all growth stages except 15 DAT (Table 1). Regardless of treatment differences, plant height increased progressively up to 60 DAT maturity. At 15 DAT, maximum plant height (48.62 cm) was observed with N_4Zn_1 and minimum (34.77 cm) was with N_0Zn_0. At 30 DAT, tallest plant (75.94 cm) was found with N_4Zn_1 and shortest (48.47 cm) plant with N_0Zn_0. At 45 DAT, the highest plant height (94.60 cm) was obtained with

45 DAT, the highest plant height (94.60 cm) was obtained with N_4Zn_0 and shortest (62.82 cm) plant with N_0Zn_0. At 60 DAT, highest plant height (122.3 cm) was obtained with $N_4Zn_1$and shortest plant (87.62 cm) with N_0Zn_0. The similar trend was also obtained at harvesting where highest (143.2 cm) plant height with N_4Zn_1 and shortest (101.1 cm) with N_0Zn_0.

Table 1: Combined effect of nitrogen and zinc on plant height (cm) of BRRI dhan33

Treatment		At 15 DAT	At 30 DAT	At 45 DAT	At 60 DAT	At Harvest
Combined effect of Nitrogen and Zinc						
Zn_0	N_0	34.77 a	48.47 e	62.82 d	85.62 h	86.1 e
	N_1	43.10 a	55.03 cde	65.72 d	103.7 f	106.0 d
	N_2	38.99 a	58.96 bcd	83.64 ab	108.2 e	113.7 c
	N_3	47.00 a	61.95 bc	82.12 bc	113.3 bcd	115.0 bc
	N_4	48.54 a	66.98 b	90.95 ab	114.5 bc	115.7 bc
Zn_1	N_0	43.45 a	51.67 de	70.93 cd	95.88 g	96.3 d
	N_1	43.79 a	61.79 bc	82.40 abc	109.5 de	110.3 c
	N_2	47.10 a	65.45 b	84.60 ab	110.8 cde	121.2 b
	N_3	39.54 a	67.94 ab	84.83 ab	116.2 b	120.3 b
	N_4	48.62 a	75.94 a	94.60 a	122.3 a	128.2 a
Level of significance		NS	**	*	*	**
CV%		18.23	7.57	7.62	2.26	2.68

* 5% level of Significance** 1% level of significance

Note: N_0= 0 kg N/ha, N_1= 75 kg N/ha, N_2= 100 kg N/ha, N_3= 125 kg N/ha, N_4= 150 kg N/ha Zn_0 = 0 kg Zn/ha, Zn_1= 2.5 kg Zn/ha.

4.2 Total tillers

4.2.1 Effect of nitrogen

Regardless of treatment differences, no. of total tillers increased progressively up to 60 DAT (Figure 3 and Appendix V). Treatment N_4 scored maximum no. of total tillers (8.67, 13.83, 17.00 and 21.67) at 15, 30, 45 and 60 DAT respectively and minimum (3.67, 5.33, 8.67 and 11.67) was obtained with found that tiller number increased with increasing nitrogen and 120 and 160 kg N ha^{-1} produced statistically similar tiller $hill^{-1}$. On the other hand Peng *et al.* (1996) reported that nitrogen supply controlled the tiller production of rice plant unless other factors such as spacing or light became limiting.

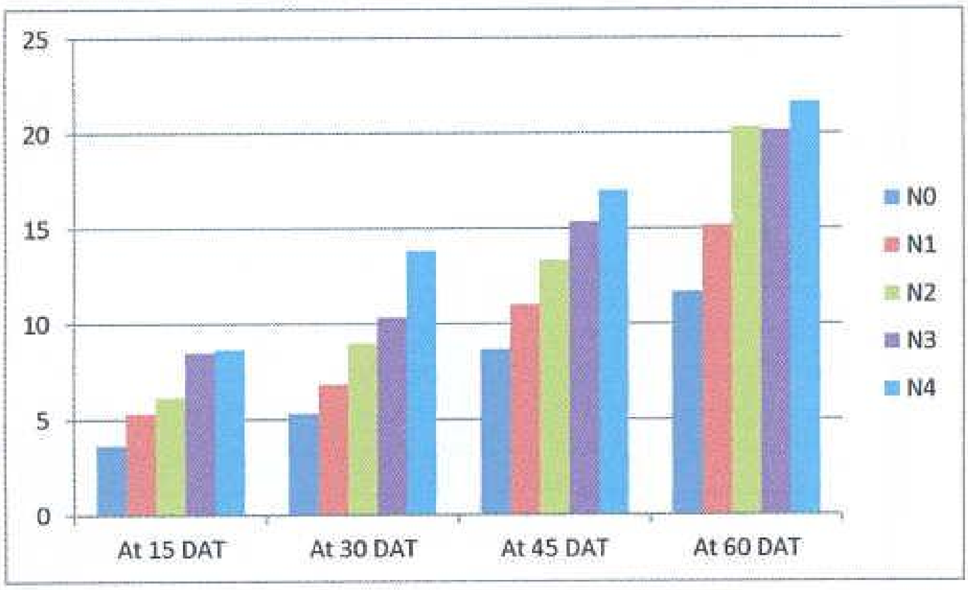


Figure. 3. Effect of different levels of nitrogen on number of total tiller per hill of BRRI dhan33

Note: N_0 = 0 kg N ha^{-1}, N_1 = 75 kg N ha^{-1}, N_2 = 100 kg N ha^{-1}, N_3 = 125 kg N ha^{-1}, N_4 = 150 kg N ha^{-1}

4.2.2 Effect of Zinc

Effect of Zinc levels showed a significant variation on total no. of tillers for all growth stages up to 60 DAT (Figure 4 and Appendix V). Results of all observing date showed that Zn_1 gave highest no. of total tillers (7.27, 10.07, 14.27 and 19.60) at 15, 30, 45 and 65 DAT respectively. Malik *et al.* (2011) found that application of Zinc had significant positive influence on tiller production of rice compared to control.

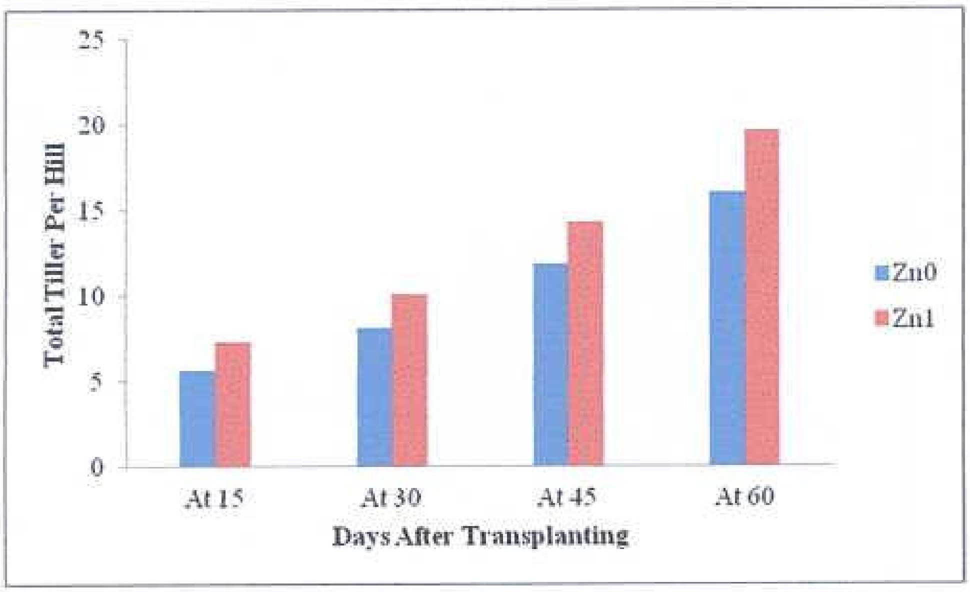


Figure. 4. Effect of different levels of Zinc on number of total tiller per hill of BRRI dhan33

Note: Zn_0 = 0 kg Zn ha^{-1}, Zn_1= 2.5 kg Zn ha^{-1}

4.2.3 Combined effect of nitrogen and zinc on total tillers number

Combined effect of nitrogen and zinc on total number of tillers showed a significant variation for all growth stages up to 60 DAT (Table 2). At 15 DAT maximum number of tiller (10.00) was observed with N_4Zn_1which was statistically similar with N_3Zn_1 (9.33) and minimum (3.00) was obtained with N_0Zn_0 which is statistically similar with N_oZn_1 (4.33). At 30 DAT, the highest number of tillers (16.33) was found with N_4Zn_1 and the lowest (5.00) plant with N_0Zn_0which is statistically at par with N_0Zn_1 (5.67). At 45 DAT, the highest number of tiller (19.33) was obtained with N_4Zn_1 and the shortest (7.67) with N_0Zn_0which was statistically similar with N_0Zn_1, N_1Zn_0 and N_1Zn_1. At 60 DAT, the highest number of tillers (25.33) was obtained with $N_4Zn_1$and lowest (10.00) with N_0Zn_0.

Table 2: Combined effect of nitrogen and zinc on number of total tiller of BRRI dhan33

Treatment		At 15 DAT	At 30 DAT	At 45 DAT	At 60 DAT
Combined effect of nitrogen and zinc					
Zn_0	N_0	3.00 g	5.00 h	7.67 f	10.00 g
	N_1	5.00 f	7.00 efg	11.00 def	15.00 ef
	N_2	5.33 ef	8.33 def	12.33 cde	19.33 cd
	N_3	7.67 bc	8.67 de	13.67 bcd	17.67 de
	N_4	7.33 cd	11.33 bc	14.67 bc	18.00 de
Zn_1	N_0	4.33 fg	5.67 gh	9.67 ef	13.33 f
	N_1	5.67 def	6.67 fgh	11.00 def	15.33 ef
	N_2	7.00 cde	9.67 cd	14.33 bcd	21.33 bc
	N_3	9.33 ab	12.00 b	17.00 ab	22.67 ab
	N_4	10.00 a	16.33 a	19.33 a	25.33 a
Level of significance		**	**	*	**
CV%		14.40	10.66	13.40	9.57

* 5% level of Significance** 1% level of significance

Note: N_0 = 0 kg N ha^{-1}, N_1 = 75 kg N ha^{-1}, N_2 = 100 kg N ha^{-1} N_3 = 125 kg N ha^{-1}, N_4 = 150 kg N ha^{-1} Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2.5 kg Zn ha^{-1}

4.3 Effective tiller hill^{-1}

4.3.1 Effect of nitrogen

The number of effective tillers hill^{-1} varied significantly due to various nitrogen levels (Table 3). Treatment N_4 scored the highest number of effective tillers hill^{-1} (12.33) which was statistically similar with N_2 and N_3 and the lowest (7.50) was observed in treatment N_0 Similar trends were also reported by Islam *et al.* (2008).

4.3.2 Effect of zinc

The number of effective tillers hill^{-1} varied significantly due to application of Zinc (Table 3). Treatment Zn_1 scored the highest no. of effective tillers hill^{-1} (11.60) and the lowest (10.33) was observed in treatment Zn_0.

4.3.3 Combined effect of nitrogen and zinc

Combined effect of nitrogen and zinc showed a significant variation on no. of effective tillers hill^{-1}. Highest effective tiller hill^{-1} (13.00) was observed from N_2Zn_1 which was statistically at par with N_1Zn_1, N_2Zn_0, N_4Zn_1, N_3Zn_1, N_4Zn_0 and N_3Zn_0. The lowest value (6.67) was observed from N_0Zn_0. This may be due to the application of Zinc that increased nitrogen use efficiency that ultimately resulted highest effective tillers hill^{-1}. Similar findings were reported by Islam *et al.* (2008) and Abdul and Balasubramanian (1988).

4.4 Panicle length

4.4.1 Effect of nitrogen

Panicle length varied significantly due to various nitrogen levels (Table 3). Treatment N_4 scored the longest panicle (25.87 cm) which was statistically at par with N_3 and lowest (20.30 cm) was observed in treatment N_0. Similar results were also reported by Islam *et al.* (2008).

4.4.2 Effect of zinc

There was no significant variation observed on panicle length due to various zinc levels (Table 3). Numerically highest value was recorded from treatment Zn_1 (24.61 cm) and lowest (23.62 cm) was observed in treatment Zn_0.Sarwar*et al.* (2011) also observed the low size of panicle length in without zinc application.

4.4.3 Combined effect of nitrogen and zinc

Combination effect of nitrogen and zinc showed a significant variation on panicle length. N_3Zn_1 scored the longest panicle (26.30 cm) which was statistically similar with N_2Zn_1, N_4Zn_0 and N_4Zn_1 and the lowest value (20.27 cm) was observed in N_0Zn_0which was statistically at par with N_0Zn_1. Similar results were reported by Bandara and Silva (2001) who showed that panicle length of rice was affected by zinc application at various levels of nitrogen.

4.5 Filled grain panicle^{-1}

4.5.1 Effect of nitrogen

Number of filled grain panicle^{-1} varied significantly due to various nitrogen levels (Table 3). Treatment N_4 scored the highest number of filled grain panicle^{-1} (90.67) which was statistically at par with N_3, N_2 and N_1. The lowest no. of filled grain panicle^{-1} (66.83) was observed in treatment N_0.

4.5.2 Effect of zinc

No. of filled grain panicle^{-1} varied significantly due to various zinc levels (Table 3). Treatment Zn_1 scored the highest number of filled grain panicle^{-1} (89.67) and lowest (79.87) was observed in treatment Zn_0.

4.5.3 Combined effect of nitrogen and zinc

Combined effect of nitrogen and zinc showed a significant variation on filled grain panicle^{-1}. N_3Zn_1 scored the highest no. of filled grain panicle^{-1} (96.67) which was statistically similar with N_1Zn_0, N_1Zn_1, N_2Zn_0, N_2Zn_1, N_3Zn_0, N_4Zn_0 and N_4Zn_1. The lowest number of filled grain panicle^{-1} (58.67) was observed in N_0Zn_0 which was statistically at par with N_0Zn_1. This may be due to the sufficient supply of Zinc to the plants that was beneficial for grain filling. Similar observations were made by Bala and Natarajatnam (1986).

Table 3: Effect of nitrogen and zinc on yield and yield contributing characters of BRRI dhan33

Treatment		Effective tiller $hill^{-1}$	Panicle length (cm)	Filled grain $panicle^{-1}$	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw Yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Effect of nitrogen									
N_0		7.50 c	20.30 c	66.83 b	23.61 c	3.08 c	4.13 c	7.22 d	42.64 ab
N_1		10.50 b	24.28 b	86.00 a	24.66bc	3.95 b	5.18 b	9.13 c	43.03 ab
N_2		12.17 a	24.62 b	90.50 a	25.43ab	5.07 a	6.17 a	11.23 a	45.04 a
N_3		12.33 a	25.52 a	89.83 a	26.41 a	4.90 a	6.40 a	11.30 a	43.07 ab
N_4		12.33 a	25.87 a	90.67 a	24.37bc	4.10 b	6.38 a	10.48 b	39.14 b
Level of significance		**	**	*	*	**	*	**	*
Effect of zinc									
Zn_0		10.33 b	23.62 a	79.87 b	24.59 a	3.81 b	5.57 a	9.39 b	40.61 a
Zn_1		11.60 a	24.61 a	89.67 a	25.20 a	4.63 a	5.73 a	10.36 a	44.56 a
Level of siginificance		*	**	*	*	**	NS	**	*
Combined effect of nitrogen and zinc									
Zn_0	N_0	6.67 d	20.27 d	58.67 c	22.81 c	2.83 e	4.10 b	6.93 e	40.85 ab
	N_1	10.00 bc	23.60 c	79.33 ab	24.30bc	3.40 de	4.77 b	8.17 d	41.49 ab
	N_2	11.33 ab	23.53 c	86.00 ab	26.19ab	4.67abc	6.17 a	10.83 bc	43.07 ab
	N_3	11.67 ab	24.73bc	83.00 ab	25.60ab	4.23 cd	6.43 a	10.67 bc	39.54 ab
	N_4	12.00 ab	26.00ab	92.33 ab	24.09bc	3.93 cd	6.40 a	10.33 c	38.10 b
Zn_1	N_0	8.33 cd	20.33 d	75.00 bc	24.41bc	3.33 de	4.17 b	7.50 de	44.43 ab
	N_1	11.00 ab	24.97 b	92.67 ab	25.03a-c	4.50 bc	5.60 a	10.10 c	44.56 ab
	N_2	13.00 a	25.70ab	95.00 ab	24.68bc	5.47 ab	6.17 a	11.63 ab	47.02 a
	N_3	13.00 a	26.30 a	96.67 a	27.21 a	5.57 a	6.37 a	11.93 a	46.60 a
	N_4	12.67 a	25.73ab	89.00 ab	24.66bc	4.27 cd	6.37 a	10.63 bc	40.18 ab
Level of significance		*	*	*	*	**	*	**	*
CV%		10.92	2.72	12.06	4.77	12.64	7.88	5.56	9.06

* 5% level of Significance** 1% level of significance

Note: N_0 = 0 kg N ha^{-1}, N_1 = 75 kg N ha^{-1}, N_2 = 100 kg N ha^{-1}, N_3 = 125 kg N ha^{-1}, N_4 = 150 kg N ha^{-1} Zn_0 = 0 kg Zn ha^{-1}, Zn_1= 2.5 kg Zn ha^{-1}

4.6 1000-grain weight

4.6.1 Effect of nitrogen

1000-grain weight varied significantly due to various nitrogen levels (Table 3). Treatment N_3 scored the highest 1000-grain weight (26.41 g) which was statistically at par with N_2 (25.43 g). The lowest 1000-grain weight (23.61 g) was observed in treatment N_0 which was statistically at par with N_1 (24.66 g).

4.6.2 Effect of zinc

There was no significant variation observed on 1000-grain weight due to various zinc levels (Table 3). Numerically highest value was recorded from treatment Zn_1 (25.20 g) and lowest (24.59 g) was observed in treatment Zn_0. Similar results were reported by Avsar *et al.* (2001) who stated that zinc application was not effective on 1000 grain weight.

4.6.3 Combined effect of nitrogen and zinc

Combined effect of nitrogen and zinc showed a significant variation on 1000-grain weight. N_3Zn_1 scored the highest 1000-grain weight (27.21 g) which was statistically similar with N_1Zn_1, N_2Zn_0 and N_3Zn_0. The lowest 1000-grain weight (22.81 g) was observed in N_0Zn_0 which was statistically at par with N_0Zn_1, N_1Zn_0, N_1Zn_1, N_2Zn_1 and N_4Zn_0.

4.7 Grain yield

4.7.1 Effect of nitrogen

Grain yield varied significantly due to application of various levels of nitrogen (Table 3). Treatment N_2 scored the highest grain yield (5.07 t ha^{-1}) which was statistically at par with N_3 (4.90 t ha^{-1}). The lowest grain yield (3.08 t ha^{-1}) was observed from treatment N_0. This may be due to the highest effective tillers hill^{-1}, more filled grains panicle^{-1} and highest number of grains panicle^{-1} which was supported by Abdul and Balasubramanian (1988), Biswapati *et al.* (2000), Obrador *et al.* (2003), and Islam *et al.* (2008).

4.7.2 Effect of zinc

Grain yield varied significantly due to application of various levels zinc (Table 3). Treatment Zn_1 scored the highest grain yield (4.63 t ha^{-1}) and lowest (3.81 t ha^{-1}) was observed in treatment Zn_0.Yadi *et al.* (2012) also found similar results stated that the superiority of zinc application for grain yield may be due to the improvement of soil properties to support the roots of treated plants.

4.7.3 Combined effect of nitrogen and zinc

Combined effect of nitrogen and zinc showed a significant variation on grain yield. N_3Zn_1 scored the highest grain yield (5.57 t ha^{-1}) which was statistically similar with N_2Zn_0 and N_2Zn_1. The lowest grain yield (2.83 t ha^{-1}) was observed in N_0Zn_0 which was statistically at par with N_0Zn_1 and N_1Zn_0. This may be due to the application of zinc that increased nitrogen use efficiency which ultimately resulted highest grain yield. Similar findings were reported by Abdul and Balasubramanian (1988).

4.8 Straw yield

4.8.1 Effect of nitrogen

Straw yield varied significantly due to application of various levels of nitrogen (Table 3). Treatment N_3 scored the highest straw yield (6.40 t ha^{-1}) which was statistically similar with N_2 and N_4. The lowest straw yield (4.13 t ha^{-1}) was observed from treatment N_0. Awan *et al.* (2011) observed that increased level of nitrogen application gave highest straw yield.

4.8.2 Effect of zinc

There was no significant variation observed on straw yield due to various zinc levels (Table 3). Numerically highest value was recorded from treatment Zn_1 (5.73 t ha^{-1}) and lowest (5.57 t ha^{-1}) was observed in treatment Zn_0. With the application of Zn, similar results were reported by Ditta (1990) who showed that straw yield increased due to application of various levels of Zinc.

4.8.3 Combined effect of nitrogen and zinc

Combined effect of nitrogen and zinc showed a significant variation on straw yield. N_3Zn_0 scored the highest straw yield (6.43 t ha^{-1}) which was statistically similar with N_1Zn_1, N_2Zn_0, N_2Zn_1, N_3Zn_1, N_4Zn_0 and N_4Zn_1. The lowest straw yield (4.10 t ha^{-1}) was observed in N_0Zn_0 which was statistically at par with N_0Zn_1 and N_1Zn_0. This may be due to the higher availability of nitrogen to the plants that offer vigorous growth and higher tillers increasing straw yield. Yadi *et al.* (2012) also supported this result.

4.9 Biological yield

4.9.1 Effect of nitrogen

Application of various levels of nitrogen significantly varied biological yield (Table 3). Treatment N_3 scored the highest biological yield (11.30 t ha^{-1}) which was statistically at par with N_2. The lowest biological yield (7.22t ha^{-1}) was observed from treatment N_0.

4.9.2 Effect of zinc

Biological yield varied significantly due to application of zinc (Table 3). Treatment Zn_1 scored the highest biological yield (10.36 t ha^{-1}) and lowest (9.39 t ha^{-1}) was observed in treatment Zn_0. The result agreed with the findings of Ahmed *et al.* (2005) who observed the effect of Nitrogen dose on biological yield (t ha^{-1}) of rice.

4.9.3 Combined effect of nitrogen and zinc

Combination effect of nitrogen and zinc on showed a significant variation on biological yield. N_3Zn_1 scored the highest biological yield (11.93 t ha^{-1}) which was statistically at par with N_2Zn_1. The lowest biological yield (6.93 t ha^{-1}) was observed in N_0Zn_0 which was statistically at par with N_0Zn_1.

4.10 Harvest index

4.10.1 Effect of nitrogen

Harvest index varied significantly due to application of various levels of nitrogen (Table 3). Treatment N_2 scored the highest harvest index (45.04%) which was statistically at par with N_0, N_1 and N_3. The lowest harvest index (39.14%) was observed from treatment N_4.

4.10.2 Effect of zinc

There was no significant variation observed on harvest index due to various zinc levels (Table 3). Numerically highest value was recorded from treatment Zn_1 (44.56%) and lowest (40.61%) was observed in treatment Zn_0. Similar findings were made by Cheema *et al.* (2006) who showed that harvest index was affected by zinc application.

4.10.3 Combined effect of nitrogen and zinc

A significant variation was observed on harvest index due to the combined effect of nitrogen and zinc (Table 3). Among different combinations, N_2Zn_1 scored the highest harvest index (47.02%) which was statistically similar with N_0Zn_0, N_0Zn_1, N_1Zn_0, N_1Zn_1, N_2Zn_0, N_3Zn_0, N_3Zn_1 and N_4Zn_1. The lowest harvest index (38.10%) was observed in N_4Zn_0.

4.11. Nitrogen and sulphur content in grain

4.11.1 Effect of nitrogen

nitrogen and sulphur content in grain varied significantly due to application of various levels of nitrogen (Table 4). Treatment N_3 scored the highest nitrogen content (1.60%) and the lowest (1.25%) was observed from treatment N_0. On the other hand the highest sulphur content (0.51%) was found from N_1 and the lowest (0.45%) was observed from N_4.

4.11.2 Effect of zinc

There was significant variation observed on nitrogen content and sulphur content due to various zinc levels (Table 4). The highest value of nitrogen content was recorded from treatment Zn_1 (1.52%) and lowest (1.34%) was observed in treatment Zn_0. On the other hand the highest sulphur content (0.50%) of grain was found from Zn_1.

4.11.3Combined effect of nitrogen and zinc

A significant variation was observed on nitrogen and sulphur content due to the combined effect of nitrogen and zinc (Table 4). Among different combinations, N_3Zn_1 scored the highest nitrogen content (1.84%) in grain which was statistically similar with N_4Zn_1 (1.60%). The lowest nitrogen content (1.19%)

in grain was observed in N_0Zn_0. On the other hand the highest sulphur content (0.54%) in grain was found from N_1Zn_1 and the lowest (0.43%) was observed from the combination of N_4Zn_0.

4.12 Nutrient content in straw

4.12.1 Effect of nitrogen

There was a significant variation on nitrogen content due to various levels of nitrogen fertilizer but there was no significant variation on sulphur, phosphorus and potassium content of straw (Table 4). The highest nitrogen content (0.70%) in straw was found from N_3 which was statistically similar with N_4 (0.63%) and the lowest nitrogen content in straw was observed from N_0.

4.12.2 Effect of zinc

There was a significant variation on nitrogen and potassium content due to various levels of zinc but there was no significant variation on sulphur and phosphorus content of straw (Table 4). The highest nitrogen content (0.62%) in straw was found from Zn_1. The highest potassium content (0.26 %) was also found from zinc applied plot.

4.12.3Combined effect of nitrogen and zinc

A significant variation was observed on nitrogen, and potassium content in straw due to the combined effect of nitrogen and zinc but there was no significant effect on sulphur and phosphorus content (Table 4). Among different combinations, N_3Zn_1 scored the highest nitrogen content (0.94%) in straw and the lowest nitrogen content (0.29%) in straw was observed in N_0Zn_0. However, potassium content in straw was the highest (0.32%) in N_0Z_1 and the lowest (0.14%) was observed from N_4Zn_0.

Table 4.Effect of nitrogen and zinc on nutrient content (%) of grain and straw of BRRI dhan33

Treatment		Nitrogen content in grain (%)	Sulphur content in grain (%)	Nitrogen content in straw (%)	Phosphorus content in straw (%)	Potassium content in straw (%)	Sulphur content in straw (%)
Effect of Nitrogen							
N_0		1.25 c	0.48 ab	0.35 c	0.15	1.31	0.23
N_1		1.23 bc	0.52 a	0.39 bc	0.15	1.32	0.23
N_2		1.49 ab	0.49 ab	0.59 ab	0.19	1.25	0.27
N_3		1.60 a	0.49 ab	0.70 a	0.22	1.29	0.30
N_4		1.53 a	0.45 b	0.63 a	0.22	1.23	0.30
Level of significance		**	**	*	NS	NS	NS
Effect of zinc							
Zn_0		1.34 b	0.47	0.43 b	0.19	1.24	0.27
Zn_1		1.52 a	0.50	0.62 a	0.18	1.26	0.26
Level of significance		**	**	*	NS	*	NS
Combined effect of nitrogen and zinc							
Zn_0	N_0	1.19 c	0.48 ab	0.30 c	0.15	1.31 ab	0.23
	N_1	1.20 c	0.49 ab	0.29 c	0.15	1.25 a-c	0.23
	N_2	1.48 bc	0.46 ab	0.58 bc	0.17	1.23 a-c	0.25
	N_3	1.35 bc	0.49 ab	0.45 bc	0.26	1.23 a-c	0.34
	N_4	1.46 bc	0.43 b	0.56 bc	0.22	1.14 c	0.30
Zn_1	N_0	1.29 bc	0.49 ab	0.34 bc	0.15	1.33 a	0.23
	N_1	1.38 bc	0.54 a	0.48 bc	0.15	1.29 a-c	0.23
	N_2	1.50 bc	0.51 ab	0.60 bc	0.21	1.25 a-c	0.29
	N_3	1.84 a	0.49 ab	0.94 a	0.18	1.25 a-c	0.26
	N_4	1.60 ab	0.47 ab	0.70 ab	0.21	1.17 bc	0.29
Level of significance		*	*	*	NS	*	NS
CV%		12.41	10.06	5.03	6.20	3.46	2.22

* 5% level of Significance** 1% level of significance

Note: N_0= 0 kg N ha^{-1}, N_1 = 75 kg N ha^{-1}, N_2= 100 kg N ha^{-1}, N_3= 125 kg N ha^{-1}, N_4= 150 kg N ha^{-1} Zn_0= 0 kg Zn ha^{-1}, Zn_1= 2.5 kg Zn ha^{-1}

Chapter 5

Summary and conclusion

SUMMARY AND CONCLUSION

The field experiment was conducted at field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from August to November, 2012. The experimental treatments included five Nitrogen level viz. 0 kg N ha^{-1}, 75 kg N ha^{-1}, 100 kg N ha^{-1}, 125 kg N ha^{-1}, and 150 kg Nha^{-1}; and two levels of Zinc i.e., 0 kg/ha^{-1} and 2.5 kg/ha^{-1}. The experiment was laid out in a Randomized Complete Block design with three replications. There were 10 treatments combinations. The total numbers of unit plots were 30. The size of unit plot was 3 m x 2.5 m = 7.5 m^2.

. The grains were cleaned and sun dried to moisture content of 12 %. Straw was also sun dried properly.

Effect of nitrogen levels showed a significant variation on plant height. The highest plant height (118.4 cm) was obtained from the plot applied 150 kg N ha^{-1} added plot and the shortest plant (91.75 cm) with control treatment. Regardless of treatment differences, no. of total tillers increased progressively up to 60 DAT due to supply of nitrogen. Maximum (21.67) number of total tillers per hill obtained from 150 kg N ha^{-1} whereas minimum (11.67) from control treatment. Maximum (12.33) effective tillers per hill, longest (25.87 cm) panicle length, highest (90.67) no. of filled grain $panicle^{-1}$ also obtained from treatment 150 kg N ha^{-1}(Table 3). On the other hand the highest 1000-grain weight was obtained from 125 kg N ha^{-1}. However, the highest (5.07 t ha^{-1}) grain yield was observed from 100 kg N ha^{-1}added plot which was also statistically similar with 125 kg N ha^{-1}added plot. Straw yield and Biological yield also maximum from 125 kg N ha^{-1}but highest harvest index obtained from 100 kg N ha^{-1}.

Application of zinc showed a significant variation on plant height for all growth characters and yield contributing characters. From the experiment it was observed that adding zinc increase all growth and yield contributing characters (Figure. 2). The maximum grain yield (4.63 t ha^{-1}) was obtained from 2.5 kg Zn ha^{-1} supplied plot.

Combined effect of nitrogen and zinc on plant height and tiller production showed a significant variation for all growth stages. Highest effective tiller $hill^{-1}$ (13.00) was observed from the combination of 100 kg N ha^{-1} with 2.5 kg Zn ha^{-1} while the longest (26.30 cm) panicle length, the highest no. of filled grain $panicle^{-1}$ (96.67) and the highest 1000-grain weight (27.21 g) from the combination 125 kg Zn ha^{-1} and 2.5 kg Zn ha^{-1} therefore, the highest grain yield (5.57 t ha^{-1}) and the highest biological yield (11.93 t ha^{-1}) also obtained from the same combination. Whereas the highest straw yield (6.43 t ha^{-1}) was obtained from the combination 100 kg N ha^{-1} and 0 kg Zn ha^{-1} is the highest (47.02%) harvest index

In higher levels of nitrogen the significant difference of nitrogen uptake due to application of zinc was observed. Nitrogen and sulphur content in grain varied significantly due to application of various levels of nitrogen. On the other hand there was significant variation also observed on nitrogen and sulphur content in grain due to zinc application. Among different combinations, 125 kg N ha^{-1} with 2.5 kg Zn ha^{-1} scored the highest nitrogen content (1.84%) in grain. A significant variation was observed on nitrogen and potassium content in straw due to the combined effect of nitrogen and zinc but there was no significant effect on phosphorus and sulphur content.

In conclusion it could be suggested that application of 125 kg N ha^{-1} coupled with 2.5 kg Zn ha^{-1} for modern variety like transplant *aman* cv. BRRI Dhan33 was found to be a promising practice for better nutrient management and good yield. Significant difference of nitrogen uptake due to application of zinc was observed. But suitable levels of Zinc are considerable. However, to reach a specific conclusion and recommendation, more research work like this should be done at different Agro-ecological zones.

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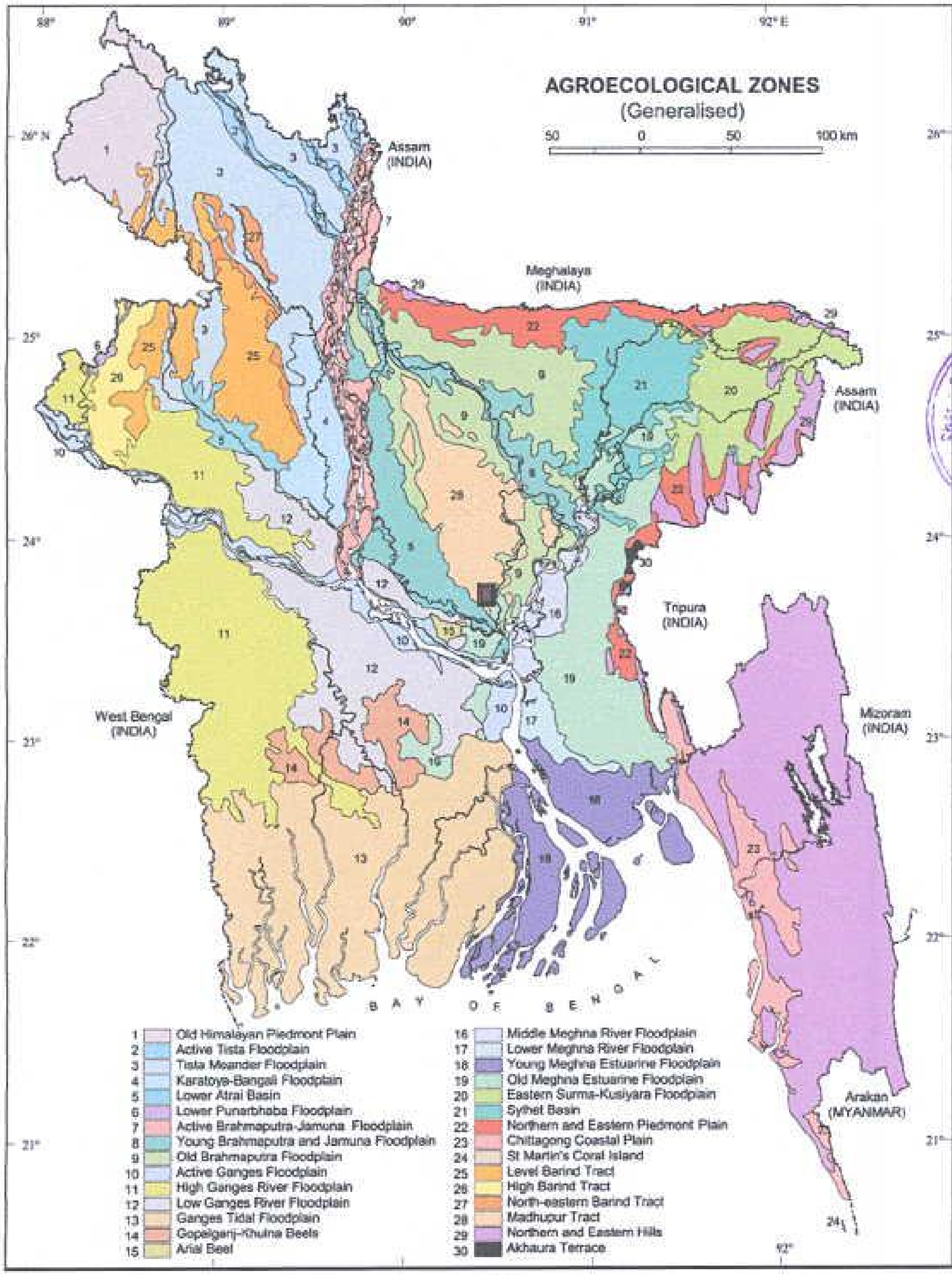
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Physiochemical properties of the initial soil

Characteristics	Value
Partical size analysis.	
% Sand	26
% Silt	45
% Clay	29
Textural class	silty-clay
. pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available Zn (ppm)	5

Appendix III. Weather data, 2012, Dhaka

Month	Average RH (%)	Average Temperature (°C)		Total Rainfall (mm)	Average Sunshine hours
		Min.	Max.		
June	81	25.5	32.4	628	4.7
July	84	25.7	31.4	753	3.3
August	80	26.4	32.5	505	4.9
September	80	26.4	32.0	179	3.0
October	78	23.8	31.4	320	5.2
November	77	19.9	29.0	111	5.7
December	69	15.0	25.8	0	5.5

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

Appendix IV. Effect of nitrogen and zinc on plant height (cm) of BRRI dhan33

Treatment	At 15 DAT	At 30 DAT	At 45 DAT	At 60 DAT	At Harvest
Effect of nitrogen					
N_0	39.11 a	50.07 d	66.88 c	91.75 d	97.2 c
N_1	43.44 a	58.41 c	74.06 c	106.6 c	110.7 b
N_2	43.05 a	62.20 bc	84.12 b	109.5 c	112.4 a
N_3	43.27 a	64.94 b	83.48 b	114.8 b	115.7 a
N_4	48.58 a	71.46 a	92.78 a	118.4 a	120.9 a
Level of significance	NS	**	**	*	**
Effect of zinc					
Zn_0	42.48 a	58.28 b	77.05b	105.46 b	107.29 b
Zn_1	44.50 a	64.56 a	83.47a	110.95 a	115.27 a
Level of significance	NS	**	*	*	**
CV%	18.23	7.57	7.62	2.26	2.68

* 5% level of Significance** 1% level of significance

Note: N_0 = 0 kg Nha^{-1}, N_1 = 75 kg Nha^{-1}, N_2 = 100 kg Nha^{-1}, N_3 = 125 kg Nha^{-1}, N_4 = 150 kg Nha^{-1} Zn_0 = 0 kg Znha^{-1}, Zn_1 = 2.5 kg Znha^{-1}

Appendix V. Effect of nitrogen and zinc on number of total tiller of BRRI dhan33

Treatment	At 15 DAT	At 30 DAT	At 45 DAT	At 60 DAT
Effect of nitrogen				
N_0	3.67 c	5.33 e	8.67 d	11.67 c
N_1	5.33 b	6.83 d	11.00 c	15.17 b
N_2	6.17 b	9.00 c	13.33 b	20.33 a
N_3	8.50 b	10.33 b	15.33 ab	20.17 a
N_4	8.67 a	13.83 a	17.00 a	21.67 a
Level of significance	*	**	**	**
Effect of zinc				
Zn_0	5.67 b	8.07 b	11.87 b	16.00 b
Zn_1	7.27 a	10.07 a	14.27 a	19.60 a
Level of significance	**	**	**	**
CV%	14.40	10.66	13.40	9.57

* 5% level of Significance** 1% level of significance

Note: N_0 = 0 kg Nha^{-1}, N_1 = 75 kg Nha^{-1}, N_2 = 100 kg Nha^{-1}, N_3 = 125 kg Nha^{-1}, N_4 = 150 kg Nha^{-1} Zn_0 = 0 kg Znha^{-1}, Zn_1 = 2.5 kg Zn ha^{-1}

Plate 1. Field view of experimental plot