RESPONSE OF UREA SUPERGRANULE AND PRILLED UREA ON GROWTH AND YIELD OF BORO RICE

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A Thesis

Submitted to the Department of Soil Science,
Sher-e-Bangla Agricultural University, Dhaka-1207
In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
IN
SOIL SCIENCE
SEMESTER: JANUARY-JUNE' 2014

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CERTIFICATE

This is to certify that thesis entitled, **"RESPONSE OF UREA SUPERGRANULE AND PRILLED UREA ON GROWTH AND YIELD OF BORO RICE"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SOIL SCIENCE,** embodies the result of a piece of *bona fide* research work carried out by **MD. MAHMUDUL HASAN, Registration No. 07-02524** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

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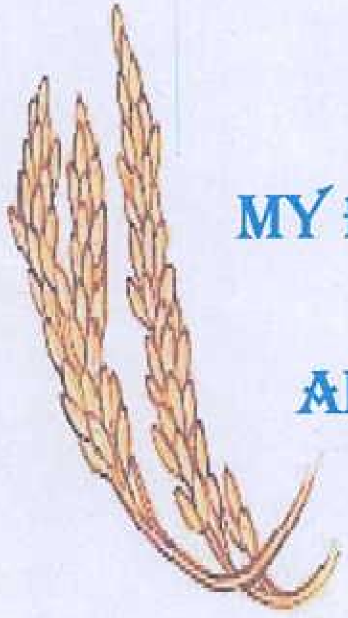

DEDICATED

TO

MY BELOVED PARENTS

AND

ALL THE FARMERS

ACKNOWLEDGEMENTS

All praises to the almighty **Allah** 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 heartiest respect, deep sense of gratitude and sincere, profound appreciation to his supervisor, **Mst. Afrose Jahan,** Professor, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for her sincere guidance, scholastic supervision, constrictive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis. Likewise grateful appreciation is conveyed to Co-supervisor, **Dr. Alok Kumar Paul**, Professor, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for his constant encouragement, cordial suggestions, constructive criticisms and valuable advice to conduct the research work as well as preparation of the thesis.

The author would like to express his deepest respect and boundless gratitude to all the respected teachers of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for their scholarly suggestions, constructive criticism, support, encouragement and sympathetic consideration during the course of studies and for providing unforgettable help at the time of preparing the thesis.

The author appreciates the assistance rendered by the stuffs of Soil Science Department and all labors and stuff of Sher-e-Bangla Agricultural University farm, for their valuable and sincere help in carrying out the research work.

The author wishes to extend his special thanks to Hasanuzzaman Hasan sir, Raihan Salamat Ullah, Amit Partha Mondal, Ezaz Shah, Shoaib Muktadir, Anarul Islam, Toufiqur Rashid, Hasan Shamim and all other friends and all well wishers for their help during experimentation, active encouragement and inspiration to complete this study.

Finally the author is very glad to express his gratefulness and deepest appreciation to his father Md. Abdul Wahab, mother Mst. Mahmuda Begum, brother Md. Moinul Hasan, sister Kbd. Wahida Jasmin and other relatives for their great sacrifices, endless prayers, blessings and support to reach him at this level of higher education.

The Author

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ABSTRACT

A research work was carried out at the Research Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from December 2012 to May 2013 in order to determine the suitable nitrogen source to observe the growth performance with a view to increasing the grain yield of boro rice. The experiment consisted of two factors. Factor A: Nitrogen Sources (5 levels); T_0: No nitrogen (control), T_1: Recommended dose of USG, T_2: 150 KgNha^{-1} as USG, T_3: Recommended dose of prilled urea and T_4: 150 KgNha^{-1} as prilled urea, and factor B: Variety (4 levels); V_1: BRRI dhan29, V_2: BRRI hybriddhan2, V_3: BRRI dhan58 and V_4: Heera 4. The experiment was set up following split-plot design with three replications. Experimental results showed that nitrogen sources had significant effect on plant height, tillers hill^{-1}, effective tillers hill^{-1}, non-effective tillers hill^{-1}, grains panicle^{-1}, unfilled grains panicle^{-1}, grain yield, straw yield, biological yield and harvest index. The application of T_2 treatment showed the highest grain yield (7.96 t ha^{-1}) and straw yield (9.50 t ha^{-1}) than any other sources of nitrogen treatments. All the studied characters except harvest index varied significantly due to varieties. BRRI dhan29 gave the higher grain yield (7.15 t ha^{-1}) than Heera 4 (6.83 t ha^{-1}), BRRI hybriddhan2 (6.75 t ha^{-1}) and BRRI dhan58 (6.50 t ha^{-1}) which is mainly attributable to the highest number of grains panicle^{-1} (102.71). The combination of the T_2 treatment and BRRI dhan29 had the higher performance in terms of producing the highest grain yield (8.46 t ha^{-1}) and straw yield (9.94 t ha^{-1}) among the interaction effects. The N, P and K uptake both in grain and straw of boro rice increased significantly due to application of nitrogen fertilizer. The highest total N, P and K uptake 145.29 kg ha^{-1}, 33.14 kg ha^{-1} and 17.24 kg ha^{-1}, respectively was observed in T_2 treatment. The mean apparent recovery of N by tested varieties was obtained (77.54%) with the application of T_2 treatment, but the nitrogen use efficiency was highest (33.20 kg grain kg^{-1} N applied) in T_1 treatment. Findings revealed that application of 150 KgNha^{-1} as USG showed the superiority over other sources of nitrogen to produce higher grain yield of boro rice. Interaction treatment of T_2V_1 i.e. application of 150 KgNha^{-1} as USG with BRRI dhan29 performed best and interaction of T_2 treatment with other tested varieties were also promising in producing higher yield.

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LIST OF ACRONYMS

AEZ = Agro- Ecological Zone
AIS = Agricultural Information System
BARC = Bangladesh Agricultural Research Council
BBS = Bangladesh Bureau of Statistics
BINA = Bangladesh Institute of Nuclear Agriculture
BRRI = Bangladesh Rice Research Institute
cm = Centimeter
cv. = Cultivar
CGR = Crop growth rate
CAR = Conventional application rate
DAT = Days after transplanting
^{0}C = Degree Centigrade
DF = Degree of freedom
DAP = Di-ammonium phosphate
DMA = Dry matter accumulation
DMRT = Duncan's Multiple Range Test
EC = Emulsifiable Concentrate
et al. = and others
etc. = Etcetera
FAO = Food and Agriculture Organization
FYM = Farmyard manure
g = Gram
GDP = Gross domestic product
HI = Harvest Index
HYV = High yielding variety
hr = hour
IRRI = International Rice Research Institute
Kg = Kilogram
LV = Local variety
LAI = Leaf area index
m = Meter
m^2 = Meter squares

MPCU = Mussorie phos-coated urea
MV = Modern variety
MoP = Muriate of potash
mm = Millimeter
viz. = Namely
N = Nitrogen
NFAA = Nitrogen fertilizer application amount
NS = Non significant
% = Percent
CV % = Percentage of Coefficient of Variance
P = Phosphorus
K = Potassium
ppm = Parts per million
PU = Prilled urea
SAU = Sher-e- Bangla Agricultural University
S = Sulphur
SRDI = Soil Resource and Development Institute
SCU = Sulphur coated urea
SHR = Super hybrid rice
t ha^{-1} = Tons per hectare
USG = Urea supergranules
UDP = Urea deep placement
Zn = Zinc
TSP = Triple super phosphate
TDM = Total dry matter
Kg ha^{-1} = Kilogram per hectare

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is a semi-aquatic grass belongs to the family Poaceae. It 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 (IRRI 2005). About 95% of the world rice is consumed in Asia (Rotshicld, 1996), grown in wide range of climatic zones, to nourish the mankind (Chaturvedi, 2005). The area and production of total rice in Bangladesh is about 11.52 million hectares and 33.89 million tons, respectively where boro covers the production of 18.76 million tons. In boro season local & HYV rice covers about 41.6 lac hectares area with production of 157.4 lac metric tons and hybrid rice covers about 6.4 lac hectares area with production of 30.2 lac metric tons, respectively (BBS, 2012). Rice is also the main food crop of Bangladesh and it covers about 80% of the total cropped area of the country (AIS, 2013). But the grain yield per hectare is still low compared to other major rice growing countries of the world. Rice provides nearly 48% of rural employment, about two-third of total calorie supply and about one-half of the total protein intakes of an average per person in the country. About 75% of the total cropped area and over 80% of the total irrigated area is covered by rice. Thus, rice plays a vital role in the livelihood of the people of Bangladesh. Total rice production in Bangladesh was about 10.97 million tons in the year 1971 when the country's population was only about 70.88 millions. At present the country is now producing about 34.45 million tons to feed her 156.6 million people (BBS, 2013). This indicates that the increase of rice production was much faster than the increase of population. This increased rice production has been possible largely due to the adoption of modern rice varieties on around 70.24% of the rice land which contributes to about 83.39% of the country's total rice production (BBS, 2012). However, there is no reason to be complacent. Population growth rate in Bangladesh is two million people per year and the population will reach 233.2 million by 2050, going by the current trend (BBS, 2012). Bangladesh will require more than 55.0 million tons of rice per year to feed its people by the year 2050. Bangladesh will require about 31.3 to 42.0 million tons of rice for the year 2030 (IFPRI, 2012). During this time total rice area will also shrink to 10.68 million hectares. Rice (clean) yield therefore, needs to be increased from the present average yield 4.34 t ha^{-1} (BRRI, 2011). Therefore, it is an urgent need of the time to increase rice production through increasing the yield.

Rice yield can be increased in many ways like developing new high yielding variety and by adopting proper management practices to the existing varieties to achieve their potential yield is important.

Proper fertilization is an important management practice which can increase the yield of rice. Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Youshida, 1981). Among the fertilizers nitrogenous fertilizer has immense effect on the yield of rice. Proper application of urea supergranule (USG) and prilled urea is an important step towards augmentation of rice yields. Nitrogen is the top most important nutrient and it is a key input for rice production in the rice growing countries as well in Bangladesh (Hasan *et al.*, 2002). Total N uptake by rice plant ha^{-1} varies among rice varieties. Nitrogen is required in adequate amount at early, at mid-tillering and panicle initiation stage for better grain development (Ahmed *et al.*, 2005).

The soil nitrogen content of the country is also very low due to warm climate accompanied by extensive cultivation practices with little addition of manures in the crop fields. As a result, most of the flooded rice fields experience a shortage of nitrogen, so the addition of costly nitrogen fertilizers should always be done to maintain its availability. The nitrogen efficiency especially of urea fertilizer is very low (30-35%) in rice cultivation (IFDC, 2007). BRRI (1990) reported that nitrogen has a positive influence on the production of effective tillers. However, heavy application of nitrogen does not always give higher yield. In spite of that, the farmers use urea fertilizer by broadcast method during cultivation and most of the applied fertilizers are lost through volatilization, denitrification, run-off and leaching. According to Craswell *et al.* (1980) broadcast application of urea on the surface soil causes losses up to 50% but point placement of USG in 10 cm depth results negligible loss. Prilled urea also plays a vital role in improving physical, chemical and biological properties of the soil and ultimately enhances crop production. Wani *et al.* (1999) revealed that 120 kg N ha^{-1} as USG was the best in producing the yield and yield attributes of rice. Iqbal (2011) found that during paddy growth, nitrogen losses from different nitrogen treatments varied 2.82-5.07%. Hence, this study was undertaken to evaluate the response of different varieties with prilled urea and USG for optimum yield of rice. So, the present experiment was taken with the following objectives:

i. To investigate the role of variety and urea fertilizer application method on growth and yield of boro rice,
ii. To verify the effect of USG on the growth and yield of boro rice and to compare the effectiveness of USG over prilled urea, and
iii. To find out the optimum doses of N fertilizers for optimum rice production.

Chapter 2

Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

High production of any crops depends on manipulation of basic ingredients of agriculture. Growth and yield of rice is greatly influenced by environmental factors like day length or photoperiod, temperature, humidity, variety and agronomic practices such as transplanting time, spacing and number of seedlings hill^{-1}, fertilization and irrigation. Among the factors variety and level of nitrogen fertilizer application are important especially for the production of boro rice.

Nitrogen is one of the macro-nutrients used in Bangladesh in the form of urea. There is different form of urea. USG is one of them which greatly influences crop yield. Prilled urea is another form of urea. Many experiments were conducted by national and international institutions. A number of studies were conducted in Bangladesh on different forms of urea as the source of nitrogen especially prilled urea dose and dose of USG also an important factor in research farms and farmers filed under different agro-ecological conditions. An attempt has been made in this chapter to review the literatures and research finding on the level of prilled urea and USG application as the source of nitrogen and varietal performance in boro rice production.

2.1 Effect of N-fertilizer

2.1.1 Plant height

Zohra (2012) conducted an experiment with 3 different T. *aman* varieties and highest plant height was recorded when 3 pellets of USG/4 adjacent hills were applied.

Razib (2010) observed the highest plant height (100.2 cm) of rice when 120 kg N ha^{-1} was applied.

Mizan (2010) reported that the highest plant height (98.32 cm) was obtained from 160 kg N ha^{-1} followed by 120 kg N ha^{-1}.

Ahammed (2008) observed that leaf area increased with increasing level of nitrogen application from 40 kg N ha^{-1} up to 120 kg N ha^{-1}.

Rahman (2007) found that effect of depth of placement of USG significantly influenced all growth characters and the yield attributes except plant height.

Salem (2006) reported that the nitrogen levels had a positive and significant effect on growth parameters of rice plants in boro season. Increasing nitrogen levels up to 70 kg ha^{-1} significantly increased leaf area index and plant height. The highest plant height at harvest was recorded about 92.81 cm when rice plants were fertilized with the highest nitrogen level of 70 kg ha^{-1}. On the contrary, the lowest value of the height was recorded about 80.21 cm when rice plants received no nitrogen fertilizer.

Meena *et al.* (2003) reported that between two levels of N 100 and 200 kg ha^{-1}, application of 200 kg ha^{-1} significantly increased the plant height (127.9 cm) of rice and total number of tillers hill^{-1} (16.3).

Ahmed *et al.* (2002) observed 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. Plants receiving no nitrogenous fertilizers were significantly shorter than other treatments. They also stated that nitrogen influences cell division and cell enlargement and ultimately increases plant height.

Alam (2002) found that plant height increased significantly with the increase of level of USG/4 hills. Rahman (2003) also observed that different level of USG did not affect the plant height.

Mishra *et al.* (2000) reported that the application of 76 kg N ha^{-1} USG at 14 DAT increased plant height, panicle length, N uptake and consequently the grain and straw yields of lowland rice.

Sahrawat *et al.* (1999) found that nitrogen level significantly influenced plant height of rice. Increasing levels of nitrogen increased the plant height significantly up to 120 kg N ha^{-1}.

Chowdhury *et al.* (1998) noted that the longest plant height of 112.1 cm was produced by nitrogen application at 100 kg ha^{-1} and was followed by 75 kg ha^{-1} due to the excellent vegetative growth of rice.

Thakur (1993) observed that the highest plant height of rice was obtained from 120 kg N ha^{-1} and the lowest one from the control.

Rekhi *et al.* (1989) conducted an experiment on a loamy sand soil with rice cv. PR 106 providing 0, 37.5, 75.0 or 112.5 kg N ha^{-1} as prilled urea (PU) or USG. PU was applied in three equal splits at transplanting, tillering, and panicle initiation and USG was placed 8-10 cm deep in alternate rows, equidistant from 4 hills. They found that PU produced the longest plant, higher number of panicles and higher amount of nitrogen uptake.

Singh and Singh (1986) reported that the plant height increased significantly with the increase in the levels of nitrogen from 27 to 87 kg N ha^{-1}. Deep placement of USG resulted in the highest plant height than pilled urea.

The varieties differing in plant type markedly differ in their response to added nitrogen levels (Evant *et al*, 1960; Tanaka *et al*, 1964). Nitrogen fertilization also influenced the plant height (Talukdar, 1973; Hoque *et al.*, 1977; BRRI, 1989).

2.1.2 Number of effective tillers hill^{-1}

Azam (2009) conducted an experiment with 3 varieties and observed, in general, the number of total tillers hill^{-1} was increased as the USG level increased but highest no. of total tillers hill^{-1} was produced when 55 kg N ha^{-1} applied as USG.

Hasan (2007) conducted an experiment during the *aman* season of 2006 and recorded the increased number of tillers hill^{-1} with increased nitrogen level as USG.

Singh and Shivay (2003) evaluated that the effective tillers hill^{-1} was significantly affected by the level of nitrogen and increasing levels of nitrogen significantly increased the number of effective tillers hill^{-1}.

Alam (2002) observed that total tillers hill^{-1} and effective tillers hill^{-1} increased significantly with the increase of level of USG, when USG was applied as one, two, three and four granules/4 hills during the boro season.

Krishnan and Nayak (2000) found that increasing levels of N application resulted in more secondary tillers which contributed little to grain resulting in low harvest index.

Ahsan (1996) stated that tillering is strongly correlated with nitrogen content of the plant. The incremental level of nitrogen increase the number of tiller hill^{-1}. Results showed that the highest number of tiller hill^{-1} (31) was obtained at 150 kg N ha^{-1} and declined with the lower level of nitrogen.

Kumar *et al* (1995) stated that an increase in N level from 80 to 120 kg N ha^{-1} significantly increased total tillers $hill^{-1}$.

Thakur (1991b) concluded that the yield attributes of rice like number of productive tillers m^{-2} and grain weight $panicle^{-1}$ increased with increasing levels of nitrogen.

Idris and Matin (1990) noticed that the maximum number of tillers $hill^{-1}$ was produced with 140 kg N ha^{-1} which was statistically similar to 60, 80, 100 and 120 kg N ha^{-1}. The minimum number of tillers $hill^{-1}$ was obtained from the control treatment (0 kg N ha^{-1}).

Mirzeo and Reddy (1989) worked with different modified urea materials and levels of N (30, 60 and 90 kg N ha^{-1}). They reported that root zone placement of USG produced the highest number of tillers at 30 or 60 days after transplanting.

Tillering of rice plant is strongly influenced by nitrogen supply (IRRI, 1968; BRRI, 1989) and adequate nitrogen is necessary during tillering stage to ensure sufficient number of panicle bearing tillers (Hall and Tacket, 1962)

Tanaka *et al.* (1964) reported that at a higher N level, rice plants have vigorous growth, high maximum tillers $plant^{-1}$ but lower percentage of effective tillers $hill^{-1}$.

2.1.3 Number of Grains $panicle^{-1}$

Zohra *et al.* (2012) observed that the number of grains $panicle^{-1}$ was varied significantly due to different level of USG.

Rajarathinam and Balasubramaniyan (1999) indicated that there was no appreciable change in grains $panicle^{-1}$ due to higher dose of N above 150 kg ha^{-1}. They also noticed an appreciable reduction in grains $panicle^{-1}$ at 250 kg N ha^{-1}.

Idris and Matin (1990) noted that the length of panicle of rice was highly related with the application of increased level of nitrogen. They also stated that panicle formation and elongation was directly related with the contribution of nitrogen.

Jee and Mahapatra (1989) observed that number of panicles m^{-2} were significantly higher with 90 kg N ha^{-1} as deep placed USG than split application of urea.

Singh and Kumar (1983) stated that grain yield increased consistently with increasing N application up to 87 kg ha^{-1} USG produced the higher grain yield of than ordinary urea applied in three equal split dressings and other N sources.

Lal *et al.* (1983) studied the effects of deep placement of USG or PU on yields of cv. Jaya and Govind revealed that with random transplanting, deep placement of USG increased yield of cv. Jaya and Govind by 0.4 and 1.1 t ha^{-1} respectively over yields with broadcast application of PU.

Yosida and Parao (1976) reported that in rice at higher nitrogen level the number of grain become decreased due to lodging.

2.1.4 Weight of 1000-grain (g)

Azam *et al.* (2009) conducted an experiment during the *aman* season with 3 different T. *aman* varieties by using both USG and prilled urea as a source of N. He observed that source and dose of nitrogen did not show significant effect on 1000-grain weight. The highest 1000-grain weight (24.70 g) was obtained with USG applied at 55 kg N ha^{-1} and lowest (24.09 g) 1000-grain weight was observed at 110 kg N ha^{-1} as PU.

Chopra and Chopra (2004) showed that N had significant effects on yield attributes such as plant height, panicle $plant^{-1}$ and 1000-grain weight. Cumulative effect of yield attributing and nutrient characters resulted in significant increase in seed yield at 120 kg N ha^{-1} over 60 kg N ha^{-1} and the control.

A field experiment was conducted by Maiti *et al.* (2003) during the boro season with the nitrogen fertilizer applied during transplanting, at the tillering and panicle initiation stages. They found increased number of higher number of panicles, number of filled grains $panicle^{-1}$, 1000-grain weight and grain yield.

Chopra and Sinha (2003) conducted an experiment with the treatments comprised of 4 N levels (0, 60, 120 and 180 kg N ha^{-1}) and results showed that N had significant effects on yield attributes such as plant height, panicles $plant^{-1}$ and 1000-seed weight. Cumulative effects of yield attributing characters resulted in significant increase and seed yield at 120 kg N ha^{-1} over 60 kg N ha^{-1}.

Alam (2002) observed that 1000-grain weight was not influenced by level of USG.

Garcia and Azevedo (2000) conducted an experiment with 5 doses of nitrogen fertilizer (0, 50, 100, 150 and 200 kg N ha^{-1}) and concluded that weight of 1000-grains increased with increase in nitrogen fertilizer up to 150 kg N ha^{-1}.

Naseem *et al.* (1995) recorded lower 1000-grain weight in the control treatment than in the plots received fertilizer nitrogen.

Ali *et al.* (1993) showed that weight of 1000 grains was higher when 100 kg nitrogen ha^{-1} was applied in three equal splits at basal 30 days and 60 days after transplanting.

Rahman *et al.* (1985) noted that there was a little relationship between nitrogen and weight of 1000 grains of rice.

Tanaka *et al.* (1964) noted that increasing rate of N decreased 1000-grain weight in the traditional varieties of rice.

2.1.5 Grain and straw yield (t ha^{-1})

Zohra *et al.* (2012) conducted an experiment with different level of USG on 3 different varieties of T. *aman* rice. Among the 6 doses of USG, highest grain yield was produced when the crop was fertilized with 2 pellet of USG/4 hills and lowest grain yield was recorded in the control treatment.

Das (2011) found the highest grain yield (4.28 t ha^{-1}) of rice using the 240 kg prilled urea ha^{-1} and the lowest grain yield (3.06 t ha^{-1}) using the no nitrogen application in a field trial with prilled urea.

Islam *et al.* (2011) carried out an experiment on the effectiveness of NPK briquette on rice in tidal flooded soil condition. They found that NPK briquettes, USG and prilled urea (PU) produced statistically similar grain yield but gave significantly higher grain yield than N control.

Azam (2009) conducted a field experiment during *aman* season involving 5 rates of N (0, two as prilled urea and two as USG) found that, highest straw yield (6.11 t ha^{-1}) was produced by 110 kg N ha^{-1} as USG.

Singh and Gangwer (2009) claimed each incremental dose of nitrogen gave significantly higher straw yield.

In a field experiment on agronomy field laboratory, BAU, Hussain (2008), evaluated that maximum utilization of N was possible due to proper application of N as USG placement or crop N demand. If the doses of N are higher or lower than demand, it will be overdose or deficiency of N and then yield will be reduced.

Hasan (2007) found the effect of level of USG significantly influences all the yield attributes except 1000 grain weight. In his experiment, the highest grain and straw yields were found (5.20 and 7.45 t ha^{-1}, respectively) from the level of USG @ 3 pellets/4 hill or 90 kg N ha^{-1} as USG.

Xie *et al.* (2007) in his experiment found that the level of nitrogen application depends on the variety for obtaining the highest grain yield.

Dwivedi *et al.* (2006) conducted a field experiments to evaluate the effects of nitrogen levels on growth and yield of hybrid rice. They found 184.07 kg N ha^{-1} was the optimum rate for highest yield.

Rahman (2005) determined the nitrogen level and found that the grain yield of rice was increased with increasing nitrogen levels and the highest yield (4.19 t ha^{-1}) was attained with 150 kg N ha^{-1} while further increase in nitrogen level decreased the grain yield. It was estimated that the grain yield with 150 kg N ha^{-1} was 35.8, 18.9, 5.0 and 6.0% higher than those obtained with 0, 50, 100 and 200 kg N ha^{-1}, respectively.

Mashkar and Thorat (2005) conducted a field experiment during the 1994 kharif season in Konkan, Maharashtra, India, to study the effects of different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}) on the N, P and K uptake and grain yield of scented rice cultivars (Pula Basmati 1, Kasturi, Indrayani and Sugandha). The different levels of N had significant effect in augmenting the uptake of N, P and K nutrients and grains as well as straw yield of rice. Application of 120 kg N ha^{-1} recorded significantly higher N, P and K uptake in rice compared to the rest of the N levels. Every increment of 40 kg N ha^{-1} from 0 to 120 kg N ha^{-1} increased the total N uptake by 49.55, 34.30 and 27.17% total P uptake by 40.33, 27.06 and 20.32% and total K uptake by 32.43, 20.70 and 17.25%, respectively.

Salam *et al.* (2004) conducted an experiment to determine the level of nitrogen (0, 40, 80 and 120 kg N ha^{-1}) and the highest grain yield was recorded from the application of 80 kg N ha^{-1}.

Miah *et al.* (2004) carried out an experiment with transplanted rice cv. BINA dhan 4. They found that the values of the parameters measured were higher with application of USG compared to application of urea.

Elbadry *et al.* (2004) in pot and lysimeter experiment showed that the increasing level of N had statistically significant difference on growth parameters and yield attributes like dry weight, number of productive tillers, grain and straw yields of rice .

Rahman (2003) found that two USG per 4 hills produced the higher grain and straw yields (5.22 and 6.09 t ha^{-1}, respectively).

Dongarwar *et al.* (2003) conducted a field experiment in Shandara, Maharashtra, India to investigate the response of the rice (KJTRH-1), Jaya and Sawarna to 4 fertilizer rates i.e.75, 100, 125 and 150 kg N ha^{-1}. There was a significant increase in grain yield with successive increase in fertilizer rate. The highest grain yield (53.05 q ha^{-1}) was obtained with 150 kg N ha^{-1} and KJSTRH-1 produced a significant higher yield than Jaya (39.64 q ha^{-1}) and Sawarna (46.06 q ha^{-1}).

Singh and Kumar (2003) conducted a field experiment and recorded the application of slow release fertilizers (USG), biogas slurry and blue green algae + prilled urea (PU) significantly increased grain and straw yield, nitrogen uptake, nitrogen use efficiency, and nitrogen recovery in rice. The highest grain yield, nitrogen recovery was recorded with the application of USG.

Ahmed *et al.* (2002) revealed that USG was more efficient than PU at all levels of nitrogen in producing all yield components and in turn, grain and straw yields. Placement of 160 kg N ha^{-1} as USG produced the highest grain yield (4.32 t ha^{-1}) which was statistically identical to that obtained from 120 kg N ha^{-1} as USG and significantly superior to that obtained from any other level and source of nitrogen.

Nayak and Panda (2002) carried out a field experiment on transformation of applied urea and its efficient utilization in rainfed lowland rice (*Oryza sativa* L.) and observed that management practices on grain and straw yields was good. The treatments included surface broadcasting of prilled urea (PU) with partial or thorough incorporation at sowing, basal banding of PU in solid, solution or suspension form with or without SSP and MoP, deep placement of USG or urea mudlumps (UML) with or without SSP or MoP in submerged soil and surface broadcasting of PU onto submerged land at tillering state.

Wopereis *et al.* (2002) stated that rice yields increased significantly as a result of N application on two N dressing (applied at the onset of tillering and at panicle initiation) with a total of approximately 120 kg N ha^{-1} in farmer's fields.

Sarkar *et al.* (2001) reported that application of nitrogen increased straw yield significantly up to 120 kg N ha^{-1}.

Nitrogen fertilizer was applied to the rice crop at the of 0, 96 and 144 kg N ha^{-1} in urea form and the main results indicated that increasing nitrogen levels up to 144 kg ha^{-1} significantly increased straw yield (Ebaid and Ghanem, 2000).

Pandey and Tiwari (1996) evaluated the rate of 87 kg N ha^{-1} as a basal application of USG and to dressing as PU and observed that grain yield and N use efficiency were the highest with N applied as a basal application of USG.

Surendra *et al.* (1995) applied N @ 0, 40, 80, 120 kg ha^{-1} from USG and urea dicyandiamide @ 80 kg N ha^{-1}. They observed that USG and urea dicyandiamide produced significantly more panicle $hill^{-1}$, grains $panicle^{-1}$, panicle weight and grain yield than PU @ 80 kg N ha^{-1}.

Quayum and Prasad (1994) conducted field trial during *Kharif* season involving 5 rates of N (0, 35.5, 75, 112.5 and 120 kg N ha^{-1}) as USG with rice cv. Sita found that application up to 112.5 kg N ha^{-1} increased grain (4.37 t ha^{-1}) and straw yields (5.49 t ha^{-1}). It is concluded that the slow release of fertilizers were effective for rainfed lowland rice.

Singh *et al.* (1993) pointed out that application of 30 or 60 kg N ha^{-1} as PU or USG gave the highest grain yield and N uptake increased with the rate of N application and was highest with deep placed USG.

Zaman *et al.* (1993) found that USG consistently produced significantly higher grain yield than PU.

Bhale and Salunke (1993) conducted a field trial to study the response of upland irrigated rice to nitrogen applied through urea and USG. They found that grain yield increased with up to 120 kg N ha^{-1} as urea and 100 kg N ha^{-1} as USG.

Kamal *et al.* (1991) used different forms of urea and level of nitrogen @ 29, 58, 87 kg N ha^{-1} in rice. They reported that total tiller varied significantly due to forms in 1985, but during 1986 there was no significant variation. PU was significantly inferior to the other forms. The highest number of tillers was produced in treatment where USG were applied. 1000-grain weight was not significantly influenced by the forms of urea. Among the three doses of nitrogen, total tiller was the highest when 87 kg N ha^{-1} was applied. Productive tillers also followed a similar trend.

Rama *et al.* (1989) carried out an experiment with different modified urea materials @ 27, 54, 87 kg N ha^{-1}. They observed that spikelets panicle^{-1}, % sterility and 1000-grain weight did not differ significantly due to different modified urea materials viz., prilled urea, sulphur coated urea, urea super granules.

Das (1989) reported that the dry matter yield, concentration of NH_4^+-N content in soil, N uptake and grain and straw yields of rice were higher with application of USG than PU.

Mohanty *et al.* (1989) observed that placement of USG in rice gave significantly higher grain and straw yields of 36% and 39% in dry and 17% and 18% in wet season, respectively than split application of PU.

Dalai and Dixit, (1987) reported that nitrogen had marked effect both on yield and yield attributes of rice. They observed that grain and straw yields increased significantly at each successive level of N due to increase in the number of panicles , length of panicle, spikelet panicle^{-1} and weight of 1000-grain.

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

Gaudin (2012) carried out an experiment on the kinetics of ammonia disappearance from deep-placed urea supergranules (USG) in transplanted rice: the effects of deep placement USG application and PU fertilizer. He found that ammonia disappearance from the placement site is faster for the second application, and it appears that the rice roots took up ammonia at a higher concentration: 20 mM for the second application versus 10 mM for the first application.

Iqbal (2011) carried out an experiment on determination of the effects of five fertilizer application rates on vertical leaching from 30 cm and 60 cm soil layers and) found that during paddy growth, nitrogen losses from different nitrogen treatments varied 2.82-5.07% application of the urea compared to USG.

Mishra *et al.* (1999) reported that apparent N recovery in rice also increased from 21% for PU to 40% for USG. Here Rice showed a greater response to N upon USG placement than split application of PU.

2.1.7 Harvest index (%)

Sarker *et al.* (2001) obtained the nitrogen response of a Japonica and an Indica rice variety with different nitrogen levels viz. 0, 40, 80 and 120 kg N ha^{-1}. They observed that application of nitrogen increased grain and straw yields significantly but harvest index was not increased significantly.

Dwivedi (1997) noticed that application of nitrogen significantly increased the growth yield and yield components grain yield, straw yield as well as harvest index with 60 kg N ha^{-1}.

2.2. Effect of variety

Variety has profound effect on different plant characters. The genetic make-up of a variety and environment mainly influence the varietal performance of a crop. Response of rice to nitrogenous fertilizer is largely influenced by variety (BRRI, 1988); soil fertility (BRRI, 1989); environmental factors and management practices. Grain yield increase generally with nitrogen, addition up to a certain level. Research findings indicated the positive response of rice to nitrogen fertilization (Islam, 1961, IRRI, 1964; Pandey and Sinha, 1971; BRRI, 1980).

2.2.1 Effect on crop characters

Hasan (2007) has found that plant height, effective tillers hill^{-1}, grains panicle^{-1} differed significantly among the varieties. Islam (1995) found that among the four modern rice varieties (viz., BR10, BR11, BR22 and BR23), the highest and the lowest number of non-bearing tillers hill^{-1} were produced by cultivar BR11 and BR10, respectively.

Bisne *et al.* (2006) conducted an experiment with eight promising varieties using four CMS lines of rice and showed that plant height differed significantly among the varieties and Pusa Basmati gave the highest plant height in each line.

Rahman (2006) found that number of effective and non-effective tillers hill^{-1}, and grain failed to show any significant difference in BRRI dhan28 and BRRI dhan29 varieties of rice.

BRRI (2006) evaluated yield performance of three high yielding varieties namely BRRI dhan30, BRRI dhan3l, BRRI dhan32 in *aman* season and revealed that effective tillers hill^{-1} of the above mentioned varieties were 7, 8 and 8, respectively.

Myung (2005) worked with four different panicle types of rice varieties and observed that the primary rachis branches (PRBs) panicle^{-1} and grains were more on Sindongjinbyeo and Iksan467 varieties, but secondary rachis branches (SRBs) were fewer than in Dongjin and Saegyehwa varieties.

Rahman (2003) found that plant height, effective tillers hill^{-1}, panicle length and grains panicle^{-1} differed significantly between the varieties. Swant *et al.* (1986) conducted an experiment with the new rice cv. R-73-1-1, R-711 and the traditional cv. Ratna and reported that the traditional cv. Ratna was the shortest among the varieties.

Bokyeong *et al.* (2003) reported that applied with same nitrogen dose Sindongjinbyeo and Dosan467 of rice varieties gave high primary rachis branches than Sindongjinbyeo and Dongjin varieties.

Khisha (2002) observed that the plant height was significantly influenced by variety. He found the highest plant height (129.94 cm) in BINA dhan5, which was significantly higher than those of Sonar Bangla 1 and BRRI dhan29.

Hasan *et al.* (2002) observed that BRRI dhan34 produced the highest number of grains panicle^{-1} and Alok 6201 produced the lowest number of grains panicle^{-1} and highest number of sterile spikelets panicle^{-1}.

Niu *et al.* (2001) conducted an experiment with three rice varieties viz. Hong 12A/Tianjin1244, Hong21A/Tianjin1244 and Hong264/Tianjin1244. Results revealed that grains panicle^{-1} was 186.2, 139.2 and 205.7, respectively.

Nuruzzaman *et al.* (2000) observed that tiller number varied widely among the varieties and the number of tillers plant^{-1} at the maximum tillering stage ranged between 14.3 and 39.5 in 1995 and 12.2 and 34.6 in 1996. Among all the varieties, IR36 followed by Suweon 258 produced the highest tiller number and Dawn produced the lowest value.

Bhowmick and Nayak (2000) worked with two hybrids (CNHR2 and CNHR3) and two high yielding rice varieties (IR36 and IR64) and found that CNHR2 produced more number of productive tillers and filled grains panicle^{-1} than any other variety, whereas IR36 gave the highest 1000-grain weight, number of panicles m^{-2} and filled grains panicles^{-1} of any two varieties.

BRRI (1998) revealed that 1000-grain weight was 24, 22, 25, 20, 23, 18 and 17 g in Kuichabinni, Leda binni, Chandanbinni, Dudhmethi, Marakabinni and Nizershail and one high yielding variety BR25, respectively. The average plant height of BRRI dhan30, BR22, BR-23 and IRATOM-24 were 120 cm, 125 cm, and 80 cm, respectively (BRRI, 1995),

BINA (1998) conducted a field trial during the boro season of 1997-98. It was found that the hybrid rice Alok 6201 gave higher number of tillers hill^{-1} and effective tillers hill^{-1} than the modern variety IRATOM 24. Mia (1993) reported that plant height different significantly among BR3, BR11, BR22, Nizersail, Pajarn and Badshbhog varieties in *aman* season.

BRRI (1995) found out the performance of BR14, Pajam, BR5 and Tulshimala. Tulshimala produced the highest and BR14 produced the lowest number of spikelets. They observed that the finer the grain size, the higher was the number of spikelets.

BINA (1993) conducted an experiment with four varieties/advance lines (IRATOM24, BR14, BINA13 and BINA19) and reported significant variation in plant height, number of non-bearing tillers hill^{-1}, panicle length and unfilled spikelets panicle^{-1}. They also noted that grain yield did not differ significantly among the varieties.

Chowdhury *et al.* (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. number of productive tillers hill^{-1}, length of panicle, 1000-grain weight, grain yield and straw yield. On the other hand, the cultivar Pajam produced significantly taller plant, higher number of total spikelets panicle^{-1}, grains panicle^{-1}, unfilled spikelets panicle^{-1}.

Hossain and Alam (1991) reported that the growth characters like plant height, total tillers hill^{-1} and the number of grains panicle^{-1} differed significantly among BR3, BR11, BR14 and Pajam varieties of rice in boro season.

Idris and Matin (1990) conducted an experiment with six varieties and observed that panicle length differed among varieties and it was greater in IR 20 than in indigenous and high yielding varieties.

BRRI (1989) concluded that plant height differed among the varieties. Plant height, total tillers hill^{-1} and the number of spikelets panicle^{-1} differed significantly among BR3, BR11, BR14, Pajam and Jagali varieties in boro season.

Shamsuddin *et al.* (1988) conducted an experiment with nine varieties of rice and showed that plant height differed significantly among the varieties.

Sawant *et al.* (1986) conducted an experiment with the new rice cv. R-73-1-1, R-R-711 and the traditional cv. Ratna and reported that the lowest plant height was found in traditional cv. Ratna rice variety.

2.2.2 Effect on grain and straw yield

Hossain (2007) conducted an experiment during the *aman* season of 2006 with five varieties of transplant *aman* rice (viz., BRRI dhan30, BRRI dhan32, BRRI dhan34, BRRI dhan39, and Nizershail). The varieties showed significant variation on all the yield contributing characters and yield except panicle length.

Xie *et al.* (2007) found that Shanyou63 variety gave the higher yield (12 t ha^{-1}) compared to Xieyou46 variety (10 t ha^{-1}).

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattan, CR 666-16 and Mukti, and observed that Mukti (5268 kg ha^{-1}) out yielded the other genotypes and recorded the maximum number of filled grams and had lower spikelet sterility (25.85%) compared to the others.

Sumit *et al.* (2004) worked with newly released four commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar Dhan 1) and two high yielding cultivars (HYV) as controls (Pant Dhan 4 and Pant Dhan 12) and reported that KHR 2 gave the best yield (7.01 t ha^{-1}) among them.

Kabir *et al.* (2004) studied with rice cv. Begenbitchi, Chinigura-1 and Kalijira and reported that Chinigura produced the highest 1000 grain weight.

Hossain *et al.* (2003) conducted experiment with rice cv. Sonar Bangla1, BRRI dhan39 and Nizershail and reported that the highest grain yield was obtained from Sonar Bangla 1 followed by BRRI dhan39 and Nizershail.

Hasan *et al.* (2002) worked with two hybrids (Sonar Bangla 1and Alok 6201) and one inbred (BRRI dhan34) rice varieties. They found that grain and straw yields were highest (4.87 t ha^{-1} and 7.72 t ha^{-1}, respectively) in BRRI dhan34 compared to Sonar Bangla 1 and Alok 6201 (4.28 t ha^{-1} and 3.86 t ha^{-1}, respectively).

Khisha (2002) stated that grain yield was significantly influenced by cultivar. The highest grain yield was obtained in Sonar Bangla 1 which was statistically identical with BINA dhan6 (5.51 t ha^{-1}) and BRRI dhan29 (5.26 t ha^{-1}). The author also observed that 1000-grain weight was significantly influenced by cultivar. He found the highest 1000-grain weight (26.26 g) in Sonar Bangla 1, followed in order by BINA dhan6 (25.07 g) and BRRI dhan29 (19.33 g).

BINA (2001) evaluated the performance of BINA dhan6, a boro rice variety as compared to other locally grown rice varieties (BRRI dhan29, Tepi boro and Lakhai). Among the varieties, BINA dhan6 performed the best of all and resulted the highest yield (8.9 t ha^{-1}) while the country wise popular variety BRRI dhan29 yielded 7.4 t ha^{-1}. The cvs. Tepi boro produced the least yield (4.23t ha^{-1}) and Lakhai also gave lower grain yield (4.23 t ha^{-1}) though they possessed the much higher straw yield than the MVs.

Ahmed *et al.* (2000) conducted an experiment with hybrid rice 6201 and BRRI dhan32 during the *Kharif* season of 1998 at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. They found that BRRI dhan32 produced higher grain yield (3.85 t ha^{-1}) than that of hybrid rice 6201 (3.25 t ha^{-1}).

Patel (2000) reported the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36. The mean yield increased with Kranti over IR36 was 7.1% and 10.0% for grain and straw respectively.

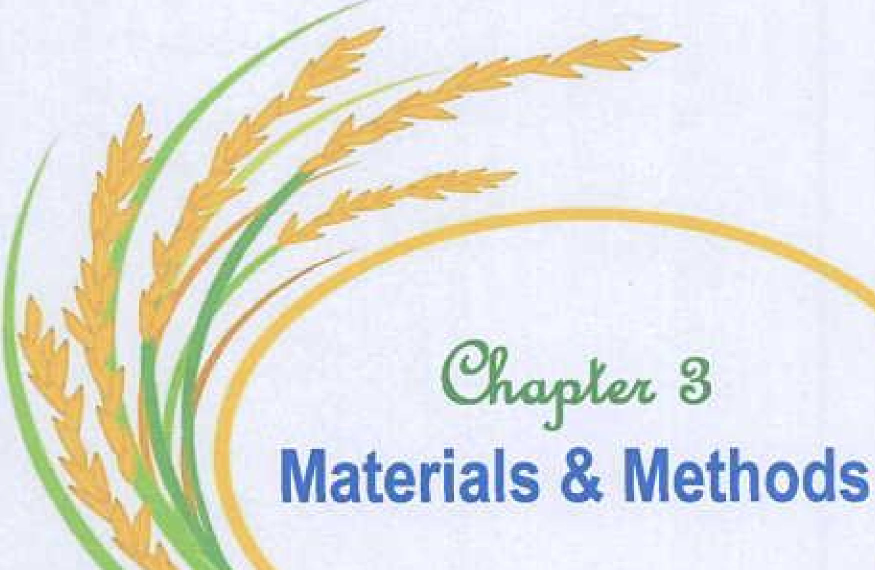
Srivastva and Tripathi (1998) observed that increase in grain yield in local check in comparison to hybrid might be attributed to the increased effective tillers m^{-2}, fertile grains $panicle^{-1}$, panicle weight and 1000-grain weight. Thirteen rice hybrids were evaluated at three locations of BADC farm during the boro season of 1995- 96. Two hybrids out yielded the check variety of same duration by more than 1 t ha^{-1} (Julfiquar *et al.,* 1998).

BRRI (1997) reported that the weight of 1000-grain of Halio, Tilockachari, Nizershail and Latishail was 26.5 g, 27.7 g, 25.2 g and 25.0 g, respectively. BRRI (1995) carried out an experiment to find out varietal performances of BR4,BR10, BR11, BR23 and BR25 including two local checks Rajasail Challish and Nizersail. The results indicated that BR4, BR10, BR11, Challish and Nizersail produced yields of 4.38, 3.12, 3.12, 3.12 and 2.70 t ha^{-1}, respectively.

BRRI (1995) conducted an experiment with rice cv. BR10, BR22, BR23 and Rajasail at three locations in the *aman* season. It was found that BR23 gave the highest yield (5.71 t ha^{-1}) which was similar to BR22 (5.02 t ha^{-1}) and the check Rajasail yielded the lowest (3.63 t ha^{-1})

Chowdhury *et al.* (1993) observed that the cultivar BR23 showed superior performance over cultivar Pajam in respect of number of productive tillers $hill^{-1}$, length of panicle, 1000-gram weight, grain and straw yields but cultivar Pajam produced significantly taller plants, more number of total spikelet $panicle^{-1}$, grain $panicle^{-1}$ and sterile spikelet $panicle^{-1}$. They also observed that the finer the grain size the higher the number of spikelet

Ali and Murship (1993) conducted a final trial with three rice cutlivars (BR23, BR11 and Kumragoir). They stated that local Kumragoir statistically out yielded than the modern cultivars BR23 and BR11.



Chapter 3

Materials & Methods

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with a brief description on experimental period, experimental site, climate, soil, and land preparation, layout of the experimental design, intercultural operations, data recording and their analyses. Details of materials and methods used in this experiment are given below:

3.1 Experimental period

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the Boro season of December 2012 to May 2013.

3.2 Description of the experimental site:

3.2.1 Geographical location

The experimental site is geographically situated at 23°77□ N latitude and 90°33□ E longitude at an altitude of 8.6 meter above sea level. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28 (Anon., 1988). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix I.

3.2.2 Climate

The experimental site under the sub-tropical climate that is characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during Rabi season (October-March). The weather data during the study period at the experimental site are shown in Appendix II.

3.2.3 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4-5.6. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from the experimental field. The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

3.3 Experimental details

3.3.1 Treatments

Two factors of treatments included in the experiment were as follows:

Factor A: Nitrogen Sources

- T_0: No nitrogen (Control)
- T_1: Recommended dose of USG
- T_2: 150 Kg N ha^{-1} as USG
- T_3: Recommended dose of Prilled urea
- T_4: 150 Kg N ha^{-1} as Prilled urea

Here, BARC recommended dose of USG is 75 Kg N ha^{-1} and BRRI recommended dose of prilled urea is 120 Kg N ha^{-1}.

The description of the source of nitrogen treatments is given below:

- **No nitrogen (Control):**

  No nitrogen fertilizer was applied. All other fertilizers were applied as per Bangladesh Rice Research Institute (BRRI) recommended dose (Adhunik Dhaner Chas, 2011).

- **Recommended dose of USG:**

  Urea supergranules (weight 2.7 g per granule) were applied for every four hills at 10 DAT. USG were placed 10 cm below surface using urea supergranule placement stick. The rate of nitrogen supplied is 75 kg N ha^{-1} as per Bangladesh Agricultural Research Council (BARC) recommended dose of USG.

- **150 Kg N ha^{-1} as USG:**

  Urea supergranules (weight 2.7 g per granule) were applied two times for every four hills. First dose of USG were applied at 10 DAT and second dose were applied at tillering stage. Urea supergranules were placed 10 cm below surface using urea supergranule placement stick. The rate of nitrogen supplied is 150 kg N ha^{-1}.

- **Recommended dose of Prilled urea:**
  Prilled urea was applied as 260 kg ha^{-1} in three equal splits considering the life cycle of the varieties. The rate of nitrogen supplied is 120 kg N ha^{-1} as per Bangladesh Rice Research Institute (BRRI) recommended dose.

- **150 Kg N ha^{-1} as Prilled urea:**
  Prilled urea was applied as 325 kg ha^{-1} in three equal splits considering the life cycle of the varieties. The rate of nitrogen supplied is 150 kg N ha^{-1}.

Factor B: Variety - 4

- V_1: BRRI dhan29
- V_2: BRRI hybriddhan2
- V_3: BRRI dhan58
- V_4: Heera 4

There were on the whole 20 (5×4) treatments combination as T_0V_1, T_0V_2, T_0V_3, T_0V_4, T_1V_1, T_1V_2, T_1V_3, T_1V_4, T_2V_1, T_2V_2, T_2V_3, T_2V_4, T_3V_1, T_3V_2, T_3V_3, T_3V_4, T_4V_1, T_4V_2, T_4V_3, T_4V_4.

3.3.2 Experimental design

The experiment was laid out following split plot design with three replications where main plot was for variety (Factor B) and subplot was for treatment (Factor A). There were 20 treatment combinations. The total numbers of unit plots were 60. The size of unit plot was 7 m^2 (3.5 m × 2 m). Layout of the experiment was done on December 15, 2012 with the distances between plot to plot and replication to replication were 0.5 m and 1.0 m, respectively. For better understanding the layout of the experiment has been presented in Appendix IV.

3.4 Crop/planting material

High yielding variety BRRI dhan29 and BRRI dhan58; hybrid variety BRRI hybriddhan2 and Heera 4 of boro season were used as test crop.

The description of the variety is given below:

- **BRRI dhan29:**

  BRRI dhan 29, a high yielding variety of boro season was developed by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, Bangladesh. It takes about 155 to 160 days to mature. It attains at a plant height of 95-100 cm. The grains are medium slender with light golden husks and kernels are white in color. The cultivar gives an average grain yield of 7.5 t ha^{-1}.

- **BRRI hybriddhan2:**

  Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur released BRRI hybrid dhan2 for boro season in the year of 2008. This variety gives a very high yield of 8.0 t ha^{-1} in 145 days of growth duration and the plant height reaches almost 105 cm. The grains of BRRI hybriddhan2 are medium, thick with light golden husks.

- **BRRI dhan58:**

  BRRI dhan 58, a high yielding variety of boro season was developed by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, Bangladesh. It takes about 150 to 155 days to mature. It attains at a plant height of 100-105 cm. The grains are medium slender with light golden husks and kernels are white in color. The cultivar gives an average grain yield of 7.0-7.5 t ha^{-1}.

- **Heera 4:**

  Heera 4 was introduced by Supreme Seed Company Ltd. from China. The grains of Heera 4 are medium, thick with light golden husks. It takes about 150 days to mature. The cultivar gives an average grain yield of 7.5-8.0 t ha^{-1}.

3.5 Crop Management

3.5.1. Seed Collection

Healthy seeds of BRRI dhan29, BRRI dhan58 and BRRI hybriddhan2 were collected from the Breeding Division, BRRI, Joydebpur, Gazipur. Heera 4 was collected from Supreme Seed Company Ltd., Dhaka.

3.5.1.2 Sprouting of seed

The seeds were soaked in water in bucket for 24 hours. Then seeds were taken out of water and kept thickly in gunny bags. The seeds started sprouting after 48 hours and became suitable for sowing after 72 hours.

3.5.1.2 Raising of seedlings

Seedlings were raised on a high land in the south-east side of the Research farm of SAU. Seeds were sown in the seedbed on December 07, 2012 for raising seedlings. Each variety of seed was sown in separate beds. The nursery beds were prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed as and when needed. Proper care was taken to raise seedlings in the nursery bed. The beds were kept weed free throughout the period of seedling raised.

3.5.2 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 collected 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 sample was air-dried and sieved through a sieve and stored in a clean plastic container for physical and chemical analysis.

3.5.3 Preparation of experimental land

The experimental field was first ploughed on December 10, 2012 with the help of a tractor drawn rotary plough, later on December 12, 2012 the land was irrigated and prepared by three successive ploughing and cross ploughing with a tractor drawn plough and subsequently leveled by laddering. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on December 15, 2012 according to experimental specification.

3.5.4 Fertilizer application

Triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate was applied at the rate of 148-178-100-15 kg ha^{-1} (Adhunik Dhaner Chas, 2011). Full dose of TSP, MoP, gypsum and zinc sulphate were applied as basal dose at final land preparation of individual plots. Prilled urea was applied to T_3 and T_4 treatment plot in three equal splits at 15, 30 and 55 days after transplanting (DAT) for BRRI dhan29 and BRRI dhan58 and in case of BRRI hybriddhan2 and Heera 4, the splits were 10, 21 and 42 DAT, respectively. USG was applied at 10 DAT for treatment T_1; treatment T_2 was applied at 10 DAT and at tillering stage.

3.5.5 The uprooting of seedlings

For nursery seedlings 35 days old seedlings were uprooted carefully on January 11, 2013 and were kept in soft mud in shade. The seedbeds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots.

3.5.6 Transplanting of seedlings

Seedlings were transplanted on January 11, 2013 in the well-puddled experimental plots. Spacings were given 25 cm × 15 cm for all the varieties. Soil of the plots was kept moist without allowing standing water at the time of transplanting. Two seedlings for BRRI dhan29 and BRRI dhan58 and one seedling for BRRI hybriddhan2 and Heera 4 were transplanted hill^{-1}.

3.5.7 Inter-cultural operations

3.5.7.1 Gap filling

After one week of transplanting gap filling were done to maintain the constant population number. After transplanting the nursery seedlings gap filling was done whenever it was necessary using the seedling from the previous source.

3.5.7.2 Weeding

Weed infestation was a severe problem during the early stage of crop establishment. The experimental plots were infested with some common weeds. To minimize weed infestation, manual weeding through hand pulling was done three times during entire growing season.

3.5.7.3 Irrigation and drainage

Irrigation was done by alternate wetting and drying from transplanting to maximum tillering stage. From panicle initiation (PI) to hard dough stage, a thin layer of water (2-3 cm) was kept on the plots. Water was removed from the plots during ripening stage.

3.5.7.4 Plant protection measures

Plants were infested with rice stem borer (*Scirphophaga incertolus*) and leaf hopper (*Nephotettix nigropictus*) to some extent which were successfully controlled by applying Diazinon @ 10 ml/10 liter of water for 5 decimal lands on February 13 and by Furadan 5G @ 10 kg/ha on March 14, 2013. Crop was protected from birds during the grain filling period. For controlling the birds watching was done properly, especially during morning and afternoon. No remarkable disease infestation was noticed in the field. So no control measure was needed against diseases.

3.5.8 Harvesting and post harvest processing

Maturity of crop was determined when 90% of the grains become golden yellow in color. The harvesting of BRRI dhan58, BRRI hybriddhan2 and Heera 4 was done on May 07, 2013. The harvesting of BRRI dhan29 was done on May 18, 2013. Hills from the central $2m^2$ area of each plot were harvested for collecting data on crop yield. The harvested crop of each plot was bundled separately, tagged properly and brought to the clean threshing floor. The crops were threshed by pedal thresher and then grains were cleaned. The grain and straw weights for each plot were recorded after proper sun drying and then converted into ton hectare^{-1}. The grain yield was adjusted at 14% moisture level.

3.6 Collection of Plant Samples

Five hills were randomly selected from each plot at maturity to record the yield contributing characters. Grain and straw samples were kept for chemical analyses.

3.7 Recording of data

Data were collected on the following parameters-

3.7.1 Growth parameter

1. Plant height (cm) at 20 days interval starting from 25 DAT
2. Tillers hill^{-1} (no.) with 20 days interval starting from 25 DAT

3.7.2 Plant and yield components

1. Plant height at harvest (cm)
2. Tillers hill^{-1} (no.) at harvest
3. Effective tillers hill^{-1} (no.)
4. Non-effective tillers hill^{-1} (no.)
5. Panicle length (cm)
6. Filled grains panicle^{-1} (no.)
7. Unfilled grains panicle^{-1} (no.)
8. Weight of 1000-grains (g)
9. Grain yield (t ha^{-1})
10. Straw yield (t ha^{-1})
11. Biological yield (t ha^{-1})
12. Harvest index (%)

3.8 Procedure of recording data

A brief outline on data recording procedure followed during the study is given below:

3.8.1 Growth characters

3.8.1.1 Plant height (cm)

The first plant height was measured at 25 DAT and continued up to harvest with 20 days interval. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading and to the tip of the flag leaf after heading. From each plot, plants of 5 hills were measured and averaged.

3.8.1.2. Tiller hill^{-1} (no.)

Number of tillers hill^{-1} was counted at 20 days interval starting from 25 DAT. Only those tillers having three or more leaves were used for counting.

3.8.2 Yield and yield components

The sample plants of 5 hills were harvested randomly from each plot and tagged them separately. Data on yield components were collected from the sample plants of each plot.

3.8.2.1 Total tillers hill^{-1} (no.)

Tillers with at least one visible leaf were counted. It included both effective and non-effective tillers.

3.8.2.2 Number of effective tillers hill^{-1}

Tillers having panicles which had at least one grain were considered as effective tillers.

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

The panicle which had no grain was recorded as non-effective tillers.

3.8.2.4 Panicle length (cm)

The measurement of panicle length was taken from basal node of the rachis to apex of each panicle and expressed in centimeter (cm). Each observation was an average of 5 hills.

3.8.2.5 Filled Grains panicle^{-1} (no.)

Presence of any kernel in the spikelet was considered as grain and total number of filled grain on each panicle was counted.

3.8.2.6 Unfilled grains panicle^{-1} (no.)

Spikelet having no food material inside was considered as unfilled spikelet i.e. sterile spikelet and the number of such spikelet present in each panicle was recorded.

3.8.2.7 Weight of 1000-grain (g)

One thousand clean dried grains from the seed stock of each plot were counted separately and weighed by using a digital electric balance at the stage the grain retained 14% moisture and the mean weight were expressed in gram.

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

Grains obtained from the central 2m^2 areas of each plot were sun dried, cleaned, weighed carefully and adjusted at 14% moisture level. Dry weight of grams of each plot was converted into t ha^{-1}.

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

Straw obtained from the central 2m^2 area of each plot were sun dried, cleaned, weighed separately and finally converted into t ha^{-1}.

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

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

Biological yield (t ha^{-1}) = Grain yield (t ha^{-1}) + Straw yield (t ha^{-1})

3.8.2.11 Harvest index (%)

It is the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.9 Analyses of Soil Samples

Soil samples were analyzed for both physical and chemical properties such as texture, pH, organic carbon, total nitrogen, available P and exchangeable K. These results have been presented in Appendix III.

The soil samples were analyzed following standard methods as follows:

3.9.1 Textural class

Particle size analysis of soil was done by hydrometer method and the textural class was determined by plotting of values for %sand, %silt and %clay to the Marshall's Triangular Coordinate following the USDA system.

3.9.2 Soil pH

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

3.9.3 Organic matter content

Organic carbon was determined by wet oxidation method as outlined by Black (1965). The oxidization of organic C was done with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and the excess $K_2Cr_2O_7$ solution was titrated with 1N $FeSO_4$. To obtain the organic matter content, the value of organic carbon was multiplied by Van Bammelen factor of 1.73 and the results were expressed in percentage.

3.9.4 Total nitrogen

One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se=100: 10: 1), 2 mL 30% H_2O_2 and 5 mL H_2SO_4 were added. The flasks were swirled and allowed to stand for about 10 minutes. Then heating was continued until the digest was clear and colorless. After cooling, the content was taken into 100 mL volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digest was used for nitrogen determination. After completion of digestion, 40% NaOH was added with the digest for distillation. The evolved ammonia was trapped into 4% H_3BO_3 solution and 5 drops of mixed indicator of bromocressol green ($C_{21}H_{14}O_5Br_4S$) and methyl red ($C_{10}H_{10}N_3O_3$) solution. Finally the distillate was titrated with standard 0.01 NH_2SO_4 until the color changed from green to pink (Bremner and Mulvaney, 1982). The amount of N was calculated using the following formula.

$$\% \mathrm{N} = \frac{(\mathrm{T}-\mathrm{B}) \times \mathrm{N} \times 0.014 \times 100}{\mathrm{S}}$$

Where, T= Sample titration value (mL) of standard H_2SO_4

B= Blank titration value (mL) of standard H_2SO_4

N = Strength of H_2SO_4

S= Sample weight in gram

3.9.5 Available phosphorus

Available phosphorus was extracted from the soil samples by shaking with 0.5 M $NaHCO_3$ solution at pH 8.5 following Olsen method (Olsen *et al.*, 1954). The extracted phosphorus was determined by developing blue color by $SnCl_2$ reduction of phosphomolybdate complex and measuring the intensity of color colorimetrically at 660 nm wavelength and the readings were calibrated to the standard P curve.

3.9.6 Exchangeable potassium

Exchangeable potassium was extracted from the soil samples with 1.0 N NH_4OAc (pH 7) and K was determined from the extract by flame photometer and calibrated with a standard curve (Black, 1965).

3.10 Chemical Analyses of Plant Samples

3.10.1 Preparation of plant samples

The representative grain and straw samples were dried in an oven at 65°C for about 24 hours before they were ground by a grinding machine. Then the ground samples were passed through a 10-mesh sieve and stored in paper bags and finally they were kept in desiccators. The grain and straw samples were analyzed for determination of N, P and K.

3.10.2 Digestion of plant samples for total nitrogen determination

For the determination of nitrogen 0.1 g of oven dry ground plant sample (both grain and straw separately) was taken in a micro-kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se = 100: 10: 1), 2 mL 30% H_2O_2 and 5 mL H_2SO_4 were added into the flask. The flask was swirled and allowed to stand for about 10 minutes. Then heating was continued until the digest was clear and colorless. After cooling, the content was taken in to a 100mL volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner (Bremner and Mulvaney, 1982).

3.11 Determination of N, P and K from Plant Samples

3.11.1 Nitrogen content (%)

The N concentration was determined by Semi–micro Kjeldahl method as described in section 3.9.4.

3.11.2 Phosphorus content (%)

Phosphorus concentration is digested grain and straw were determined from the extract by adding ammonium molybdate and $SnCl_2$ solution and measuring the colour with the help of spectrophotometer at 660 nm wavelength (Olsen *et al.* 1954).

3.11.3 Potassium content (%)

Potassium concentration in digested grain and straw were determined directly with the help of flame photometer (Black, 1965).

3.12 Nutrient Uptake

The uptake of N, P and K were calculated by multiplying the concentration of the nutrient in the grain and straw samples with the corresponding yields of grain and straw of crop. To calculate nutrient uptake by grain and straw the following equation was used:

Nutrient uptake (kg ha^{-1}) = $(Gy \times N_{Gr})/ 100 + (Sy \times N_{st})/100$

Where, Gy = Grain yield (kg ha^{-1})

Sy = Straw yield (kg ha^{-1})

N_{Gr} = Nutrient content in grain (%)

N_{st} = Nutrient content in straw (%)

3.13 Recovery Efficiency (Apparent Recovery) of Applied N Fertilizer (ANR)

Apparent Nitrogen Recovery (ANR) is defined as kg of N taken up per kg of fertilizer applied.

ANR (kg ha^{-1}) = (UN_{+N} - UN_{0N})/FN

Where, UN_{+N} is total N uptake (kg ha^{-1}) with grain and straw

UN_{0N} is total N uptake (kg ha^{-1}) in control

FN is amount of fertilizer N applied (kg ha^{-1})

3.14 Nitrogen Use Efficiency (NUE) in the Applied N Fertilizer

Nitrogen Use Efficiency (NUE) is defined as kg grain yield increase kg^{-1} N applied.

NUE = (Gy_{+N} – Gy_{0N})/ FN

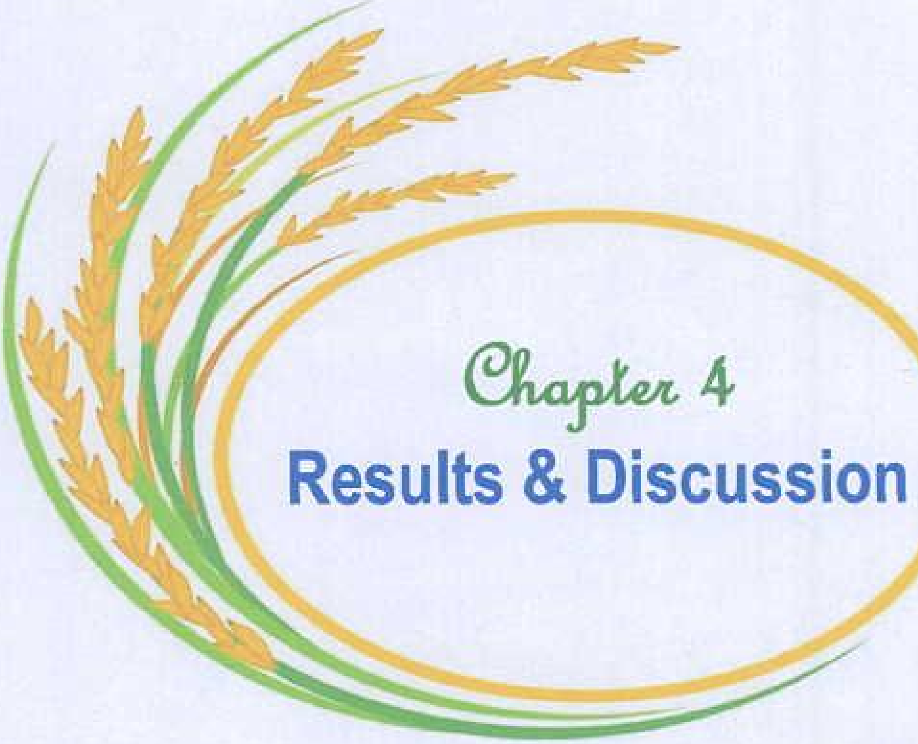
Where, Gy_{+N} = grain yield in treatment with N application

Gy_{0N} = grain yield in treatment without N application

FN = amount of fertilizer N applied (kg ha^{-1})

3.15 Statistical analysis of the data

The analysis of variance for different crop characters as well as for different nutrient concentrations of the treatments were made and the mean differences were judged at 5% level of probability by using Duncan's Multiple Range Test (DMRT) with a computer operated program named MSTAT-C.



Chapter 4

Results & Discussion

CHAPTER 4

RESULT AND DISCUSSION

Result obtained from the study of nitrogen sources on growth and yield of boro rice have been presented and discussed in this chapter. Treatments effect of nitrogen and variety on all the studied parameters have been presented in various tables and figures and discussed below under the following sub-headings.

4.1. Growth Performance

4.1.1 Plant height (cm)

4.1.1.1 Effect of nitrogen source

Effect of nitrogen source showed a significant variation on plant height for all growth stages except 45 DAT (Table 1). At harvest, the tallest plant (99.77 cm) was recorded from T_2 treatment (150 Kg N ha^{-1} as USG) and the shortest plant (87.04 cm) was recorded from the control condition (T_0) at 25 DAT, 45 DAT, 65 DAT and at harvest, the trend of plant height was similar as observed in 105 DAT. The results were similar with the findings of Meena *et al.* (2003), Sahrawat *et al.* (1999) and Thakur (1993) who observed higher plant height with the higher doses of nitrogen.

4.1.1.2 Effect of variety

Boro rice variety exhibited significant difference on plant height at different growth stages except 45 DAT (Table 2). Among the varieties, BRRI dhan29 showed significantly the tallest plant followed by BRRI dhan58 at all the growth stages (25, 45, 65, 85 and 105 DAT) and at harvest. Significantly the shortest plant was found in Heera 4 variety for all the growth stages. The results consistent with the findings of Bisne *et al.* (2006) who observed plant height differed significantly among the varieties.

Table 1. Effect of nitrogen sources on plant height (cm) at different days after transplantation of boro rice

Sources of Nitrogen	Days after transplanting (DAT)					
	25	45	65	85	105	At Harvest
T_0	14.83 c	44.83	65.07 c	78.01 b	85.24 b	87.04 b
T_1	17.85 a	50.31	69.85 ab	86.23 a	94.79 a	96.77 a
T_2	18.85 a	52.56	72.85 a	89.23 a	97.81 a	99.77 a
T_3	16.06 b	47.61	67.35 b	81.61 b	89.95 ab	91.66 ab
T_4	17.09 ab	48.47	68.48 ab	81.96 b	90.48 ab	92.07 ab
Sx□ Value	**0.58**	**NS**	**2.18**	**1.4**	**1.51**	**1.57**
CV (%)	**11.7**	**11.78**	**9.99**	**14.74**	**9.68**	**8.16**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

Here, T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

Table 2. Effect of variety on plant height (cm) at different days after transplantation of boro rice

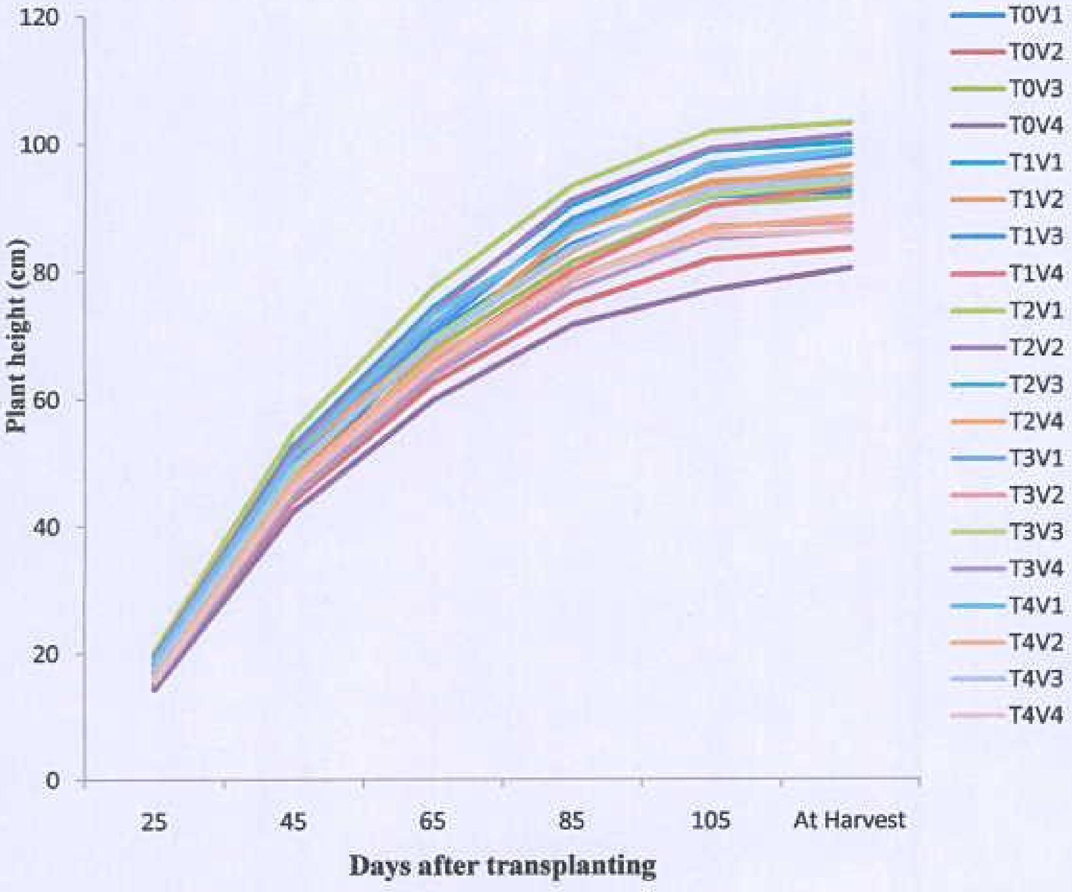
Varieties	Days after transplanting (DAT)					
	25	45	65	85	105	At Harvest
V_1	18.06 a	51.38	73.42 a	88.28 a	97.02 a	98.79 a
V_2	16.66 b	47.77	66.55 b	81.53 b	89.30 ab	90.55 ab
V_3	17.34 ab	49.32	70.08 ab	85.61 ab	94.06 a	95.91 a
V_4	15.68 b	46.56	64.83 b	78.21 b	86.23 b	88.59 b
Sx□ Value	**0.51**	**NS**	**1.71**	**1.34**	**1.21**	**1.32**
CV (%)	**11.67**	**11.77**	**9.98**	**14.72**	**9.67**	**8.15**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

Here, V_1: BRRI dhan29
V_2: BRRI hybriddhan2
V_3: BRRI dhan58
V_4: Heera 4

4.1.1.3 Interaction effect of nitrogen sources and variety

Interaction of nitrogen sources and variety showed an increasing trend with advances of growth period in respect of plant height (Fig.1). The rate of increase was much higher in the early stages of growth 25 DAT to 85 DAT. After that the increasing rate was much slower up to 105 DAT. However, the tallest plant (103.2 cm) was found in the $T_2 \times V_1$ interaction followed by $T_2 \times V_3$ interaction (101.32 cm), $T_1 \times V_1$ interaction (100.2 cm) and $T_4 \times V_1$ interaction (99.07 cm) at harvest. The shortest plant (80.50 cm) was found in $T_0 \times V_4$ interaction at harvest.



Here,

V_1: BRRI dhan29
V_2: BRRI hybriddhan2
V_3: BRRI dhan58
V_4: Heera 4

T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

Figure 1. Interaction effect of nitrogen sources and variety on plant height (cm) of boro rice at different days after transplantation. (Sx□=1.14, 2.15, 2.17, 2.79, 3.01 and 3.12 for 25, 45, 65, 85, 105 and At Harvest, respectively)

4.1.2 Tillers hill^{-1} (no.)

4.1.2.1 Effect of nitrogen source

Number of total tillers hill^{-1} varied significantly due to different nitrogen sources at 5 % level of significance (Table 3). At 25 days, the highest number of tillers hill^{-1} was (1.82) obtained with the application of treatment T_4 which was statistically similar with the application of treatment T_2 and T_1. The lowest number of tillers (1.39) hill^{-1} was obtained due to control treatment of no nitrogen. BRRI (2006), Ahsan (1996), Kumar *et al.* (1995) and Idris and Matin (1990) reported similar result that supports the present findings.

At 45 days, the highest number of tillers hill^{-1} was (8.61) obtained with the application of treatment T_2 which is 15.4 % higher than the lowest number of tillers (7.28) hill^{-1} obtained due to control treatment of no nitrogen.

At 65 days, the number of tillers hill^{-1} varied significantly due to nitrogen sources. The highest number of tillers hill^{-1} was (15.90) obtained with the application of treatment T_2 which is statistically dissimilar with the application of treatment T_4 and T_3. The lowest number of tillers (11.81) hill^{-1} obtained due to control treatment of no nitrogen.

At 85 days, the number of tillers hill^{-1} is ranged from 19.03 to 12.22. The highest number of tillers hill^{-1} was (19.03) obtained with the application of treatment T_2 which is 35.7 % higher than the lowest number of tillers (12.22) hill^{-1} obtained due to control treatment of no nitrogen. Application of treatment T_3 (16.07) and T_4 (16.33) is statistically similar.

At 105 days, the number of tillers hill^{-1} is ranged from 17.46 to 11.54. The highest number of tillers hill^{-1} was (17.46) obtained with the application of treatment T_2 which is 33.9 % higher than the lowest number of tillers (11.54) hill^{-1} obtained due to control treatment of no nitrogen. Application of treatment T_3 (15.51) and T_4 (15.85) is statistically similar.

At harvest, the number of tillers hill^{-1} was counted by adding both effective tiller hill^{-1} and non-effective tiller hill$^{-1.}$ The highest number of tillers hill^{-1} was (16.65) obtained with the application of treatment T_2 which is 42.5% higher than the lowest number of tillers (10.79) hill^{-1} obtained due to control treatment of no nitrogen. Application of treatment T_3 (15.29) and T_4 (15.51) is statistically similar.

The progressive improvement in the formation of tillers with USG levels might be due to steady and increased the availability of nitrogen which enhanced tillering. The results are in the full compliance with those of Kamal *et al.* (1991) and Pandey (1996) who recorded increased number of tillers hill^{-1} with increased nitrogen level of 150 Kg N ha^{-1} as USG placement at 10 DAT and tillering stage of rice.

Table 3. Effect of nitrogen sources on tiller number hill^{-1} at different days after transplantation of boro rice

Sources of Nitrogen	Days after transplanting (DAT)					
	25	45	65	85	105	At Harvest
T_0	1.39 b	7.28 c	11.81 d	12.22 d	11.54 d	10.79 d
T_1	1.79 a	8.24 a	14.90 a	17.60 b	16.88 b	16.32 b
T_2	1.80 a	8.61 a	15.90 a	19.03 a	17.46 a	16.65 a
T_3	1.73 a	7.71 bc	12.51 c	16.07 c	15.51 c	15.29 c
T_4	1.82 a	7.98 ab	14.07 b	16.33 c	15.85 c	15.51 c
Sx□ Value	**0.08**	**0.17**	**0.22**	**0.30**	**0.26**	**0.23**
CV (%)	**15.45**	**7.71**	**9.22**	**11.13**	**9.09**	**9.83**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

Here, T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

4.1.2.2 Effect of variety

Variety exerted significant effect on the number of tillers hill^{-1} at 5% level of probability after 65 DAT (Table 4). There is a non-significant effect found among varieties at 25 DAT, 45 DAT and 65 DAT.

At 85 DAT, the number of tillers hill^{-1} is ranged from 17.25 to 15.40. The highest number of tillers hill^{-1} (17.25) was produced by BRRI dhan29 which is 10.7 % higher than Heera 4 (15.40) hill^{-1}. Among the varieties, BRRI dhan29 and BRRI dhan58 produced statistically similar number of tillers hill^{-1} where as BRRI dhan58 (16.41) and BRRI hybriddhan2 (15.95) are statistically similar.

At 105 DAT, variety exerted significant effect on producing the number of tillers hill^{-1}. The highest number of tillers hill^{-1} was produced by BRRI dhan29 (16.50) whereas the lowest number of tillers hill^{-1} was produced by Heera 4 (14.25).

At harvest, the number of tillers hill^{-1} was counted by adding both effective tiller hill^{-1} and non-effective tiller hill^{-1}. The highest number of tillers hill^{-1} (15.92) was produced by BRRI dhan29 which is 14.07 % higher than the lowest one Heera 4 (13.68) hill^{-1}. BRRI dhan58 (15.13) and BRRI hybriddhan2 (14.93) were produced statistically similar number of tillers hill^{-1}. Variable effect of variety on number of total tillers hill^{-1} was also reported by BINA (1998), Nuruzzaman *et al.* (2000) and Jaiswal (2001) who noticed that number of total tillers hill^{-1} differed among the varieties. The variation in number of total tillers hill^{-1} as assessed might be due to varietal character.

Table 4. Effect of variety on tiller number hill^{-1} of rice at different days after transplantation of boro rice

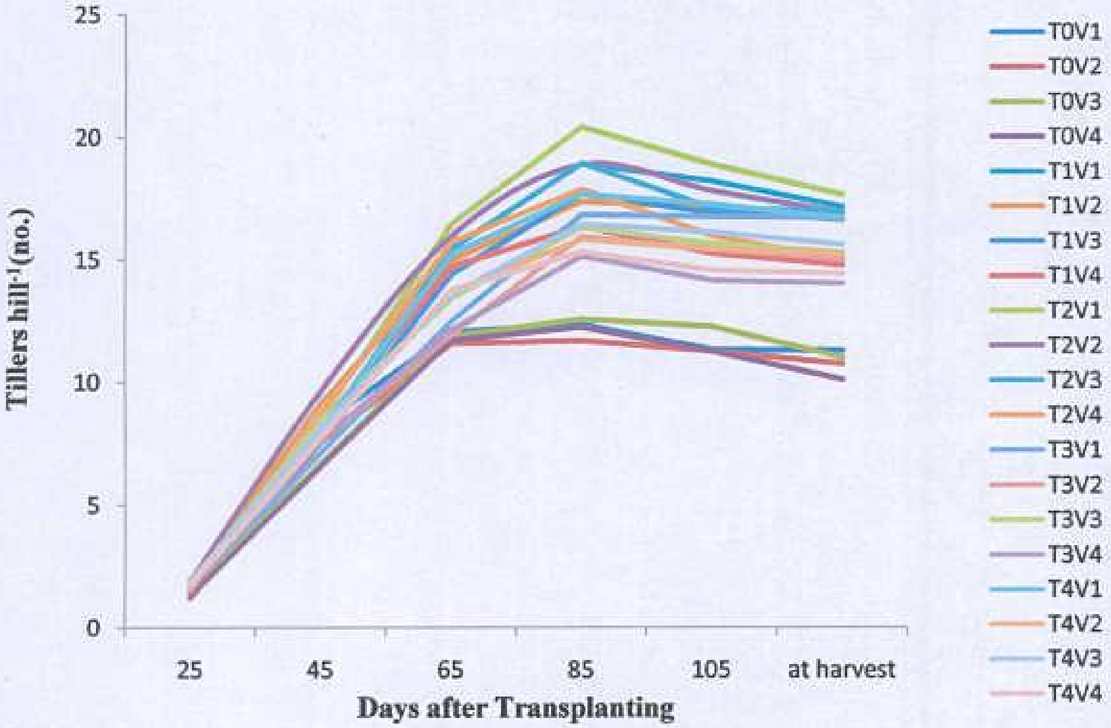
Variety	**Days after transplanting (DAT)**					
	25	**45**	**65**	**85**	**105**	**At Harvest**
V_1	1.72	7.99	14.34	17.25 a	16.50 a	15.92 a
V_2	1.71	8.39	13.63	15.95 b	15.42 b	14.93 b
V_3	1.83	7.69	13.75	16.41 b	15.62 b	15.13 b
V_4	1.56	7.78	13.62	15.40 c	14.25 c	13.68 c
Sx□ Value	**NS**	**NS**	**NS**	**0.31**	**0.09**	**0.3**
CV (%)	**15.43**	**7.71**	**9.21**	**11.12**	**9.09**	**9.82**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

Here, V_1: BRRI dhan29
V_2: BRRI hybriddhan2
V_3: BRRI dhan58
V_4: Heera 4

4.1.2.3 Interaction effect of nitrogen sources and variety

Tillers number hill^{-1} was significantly influenced by the interaction of nitrogen sources and variety at all sampling days (Fig. 2). For all interactions, the number of tillers increased from 25 DAT to 85 DAT and after that the tillers hill^{-1} reduced slightly. At harvest the highest number of tillers hill^{-1} (17.68) was found in the interaction of the $T_2 \times V_1$ treatment followed by $T_1 \times V_1$ (17.18) interaction treatment and $T_2 \times V_3$ (16.99) interaction treatment. The lowest number (10.12) of tillers hill^{-1} was found in the interaction of $T_0 \times V_4$.



Here,

V_1: BRRI dhan29
V_2: BRRI hybriddhan2
V_3: BRRI dhan58
V_4: Heera 4

T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

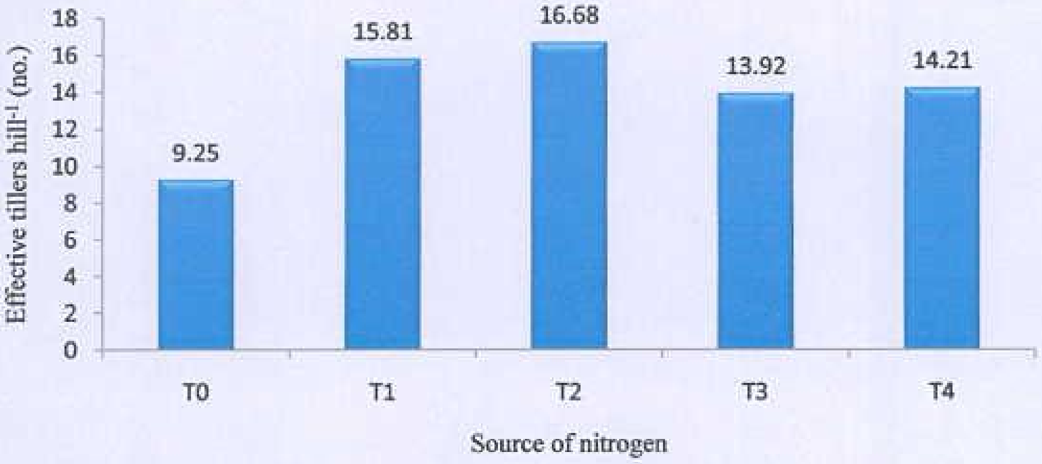
Figure 2. Interaction effect of nitrogen sources and variety on tiller number hill^{-1} of boro rice at different days after transplantation. (Sx□=0.15, 0.35, 0.45, 0.57, 0.53 and 0.46 for 25, 45, 65, 85, 105 and At Harvest, respectively)

4.2 Yield components of boro rice

4.2.1 Effective tillers hill^{-1} (no.)

4.2.1.1 Effect of nitrogen source

Number of effective tillers hill^{-1} was significantly affected due to different nitrogen sources at 5 % level of probability (Fig. 3.). The trend of effective tillers hill^{-1} was that it was lowest with no nitrogen, 120 kg N ha^{-1} as prilled urea and 150 kg N ha^{-1} as prilled urea showed intermediate and similar level of effective tillering and its peak with USG. The highest number of effective tillers (16.68) hill^{-1} was obtained due to application of treatment T_2 and the lowest number of effective tillers (9.25) hill^{-1} was obtained due to no nitrogen i.e. control condition. Hari *et al.* (2000), Thakur (1991a) and Tanaka *et al.* (1964) also found similar result that increasing levels of nitrogen increased the number of effective tillers.



Here, T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

Figure 3. Effect of nitrogen sources on effective tiller number $hill^{-1}$ of boro rice. (Sx□=0.16)

4.2.1.2 Effect of variety

The pattern of effective tillers $hill^{-1}$ among the varieties has been presented in (Fig. 4). The figure showed that the highest number of effective tillers $hill^{-1}$ (14.96) was found in BRRI dhan29 followed by BRRI dhan58 (14.20) and BRRI hybriddhan2 (13.98). The lowest number of effective tillers $hill^{-1}$ was obtained in Heera 4 (12.76). The result indicated that BRRI dhan29 produced 5.08%, 6.55% and 14.70% higher effective tillers $hill^{-1}$ than BRRI dhan58, BRRI hybriddhan2 and Heera 4, respectively. The probable reason of the differences in producing effective tillers $hill^{-1}$ may be the genetic make-up of the variety which is primarily influenced by heredity. These findings collaborate with those reported by BINA (1998), Om *et al.* (1998) and Bhowmick and Nayak (2000) who stated that effective tillers $hill^{-1}$ was varied with variety.

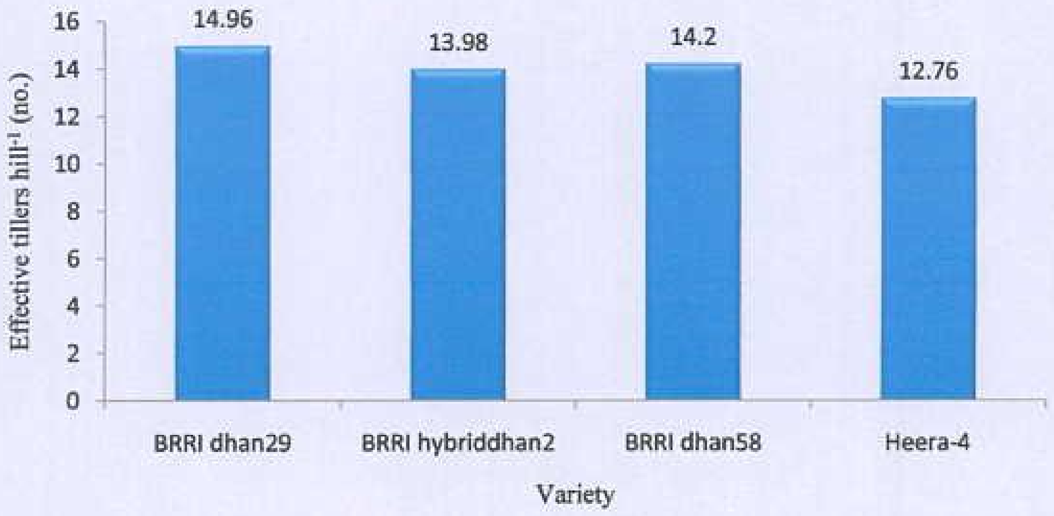


Figure 4. Effect of variety on effective tiller number hill^{-1} of boro rice. (Sx□=0.24)

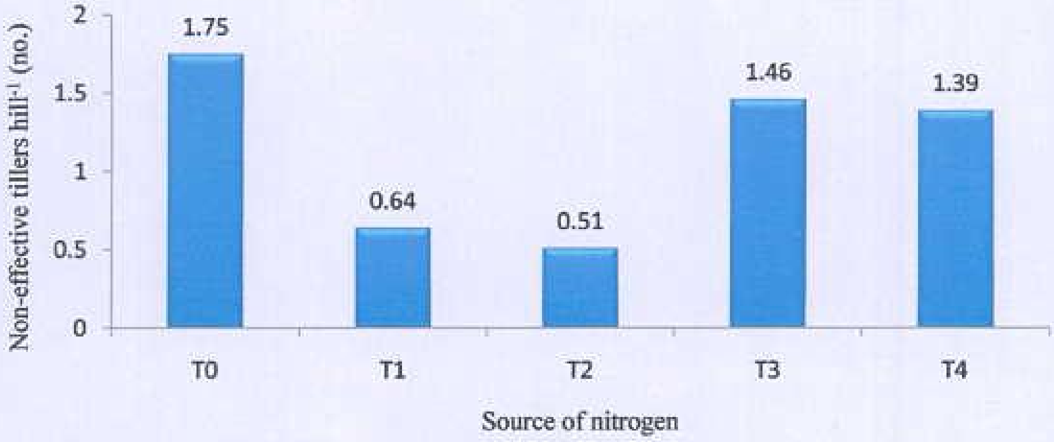
4.2.1.3 Interaction effect of nitrogen sources and variety

Significant interaction between nitrogen sources and variety was found in producing effective tillers hill^{-1} (Table 8). Irrespective of varieties, USG source of nitrogen showed increased number of effective tillers hill^{-1} ranged (15.17-17.81) than no nitrogen ranged (8.56 -9.87). The highest number of effective tillers hill^{-1} (17.81) was counted in the interaction of $T_2 \times V_1$ treatment which was statistically similar with $T_2 \times V_2$ treatment and $T_2 \times V_3$ treatment. The lowest number of effective tillers hill^{-1} (8.56) was counted in $T_0 \times V_4$ interaction treatment.

4.2.2 Non-effective tiller hill^{-1} (no.)

4.2.2.1 Effect of nitrogen source

Non-effective tillers hill^{-1} due to nitrogen sources has been shown in Fig 5. The highest number of non-effective tillers hill^{-1} (1.75) was found at no nitrogen i.e. control condition and the lowest number of non-effective tillers hill^{-1} (0.51) was found due to the application of T_2 treatment. Application of T_3 treatment (1.46) and T_4 treatment (1.39) produced the statistically similar non-effective tillers hill^{-1}.



Here, T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

Figure 5. Effect of nitrogen sources on non-effective tiller number hill^{-1} of boro rice. (Sx□=0.03)

4.2.2.2 Effect of variety

Non-effective tillers hill^{-1} exerted significant difference among the varieties (Fig. 6). The highest number of non- effective tillers hill^{-1} (1.53) was obtained in BRRI dhan29 followed by Heera 4 (1.05) and BRRI hybriddhan2 (1.02). The lowest number of non-effective tillers hill^{-1} was produced by BRRI dhan 58 (1.00) which is statistically similar with Heera 4 and BRRI hybriddhan2.

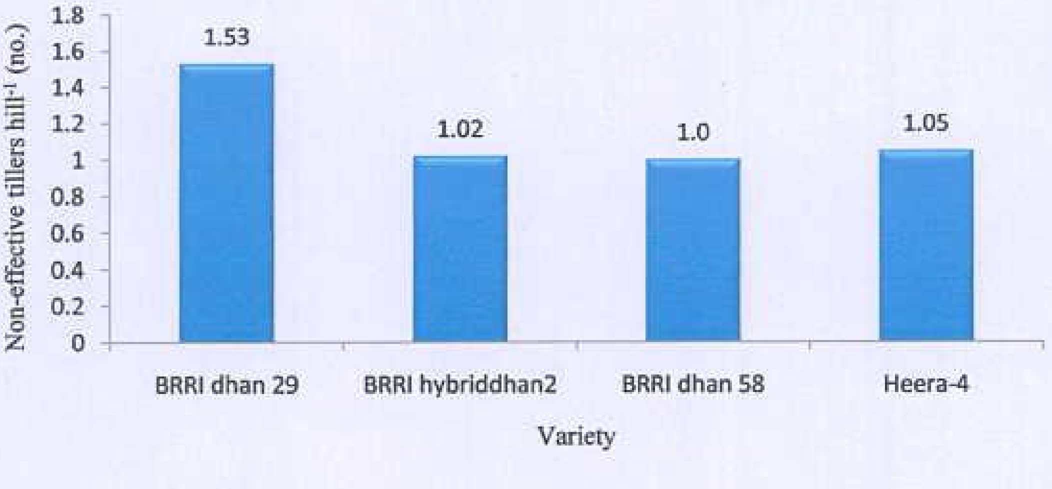


Figure 6. Effect of variety on non-effective tiller number hill^{-1} of boro rice. (Sx□=0.03)

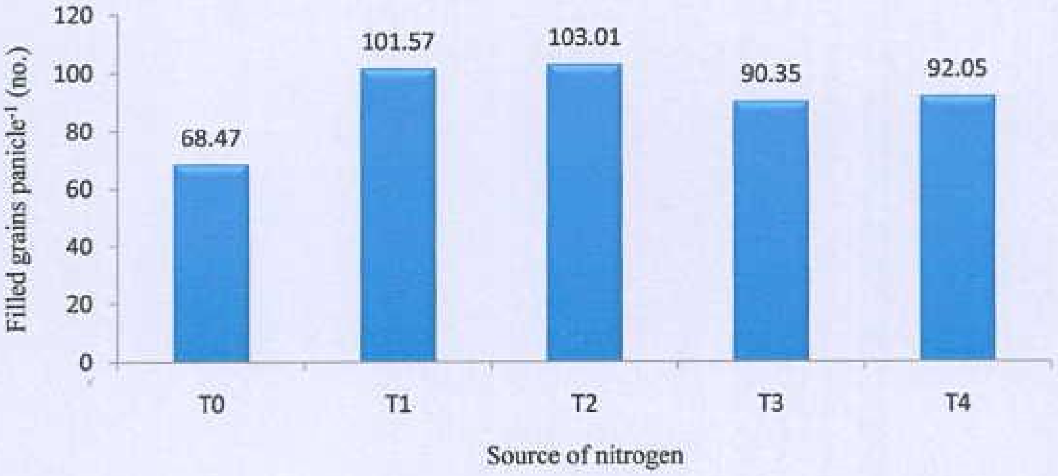
4.2.2.3 Interaction effect of nitrogen sources and variety

Significant interaction between nitrogen source and variety was found on non-effective tillers hill^{-1} (Table 8). The highest number of non-effective tillers hill^{-1} (2.28) was recorded from the interaction of $T_0 \times V_1$ and the lowest number of non-effective tillers hill^{-1} (0.42) was recorded from the interaction of $T_2 \times V_2$.

4.2.3 Filled grain panicle^{-1} (no.)

4.2.3.1 Effect of nitrogen source

Nitrogen sources showed significant variation on production of filled grains panicle^{-1} (Fig.7). The figure showed that the lowest number of grains panicle^{-1} (68.47) was obtained from the no nitrogen i.e. control condition whereas the highest number of grains panicle^{-1} was obtained by the application of treatment T_2 (103.01). T_2 treatment produced 33.58%, 1.39%, 12.29% and 10.63% higher number of grains panicle^{-1} number of grains panicle^{-1} than treatment T_0 (68.47), T_1 (101.57), T_3 (90.35) and T_4 (92.05), respectively. The result agreed with the findings of Kumar *et al.* (1986) and Thakur *et al.* (1995) in that increasing level of nitrogen significantly increased the number of filled grains panicle^{-1}.



Here, T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

Figure 7. Effect of nitrogen sources on filled grain panicle^{-1} of boro rice. (Sx□=2.1)

4.2.3.2 Effect of variety

Variety differed significantly in production of number of grains panicle^{-1} (Table 5). The highest number of grains panicle^{-1} (102.71) was observed in BRRI dhan29 followed by BRRI dhan58 (89.64) and Heera 4 (86.73). The lowest number of grains panicle^{-1} (85.26) was obtained in BRRI hybriddhan2. The result showed that BRRI dhan29 produced 12.72 %, 15.55 % and 16.98 % higher grains panicle^{-1} than BRRI dhan58, Heera 4 and BRRI hybriddhan2, respectively.

Table 5. Effect of variety on filled grain number panicle^{-1} of boro rice

Variety	Filled Grain panicle^{-1}
BRRI dhan29	102.71 a
BRRI hybriddhan2	85.26 b
BRRI dhan58	89.64 b
Heera 4	86.73 b
Sx□ Value	**2.08**
CV (%)	**9.95**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

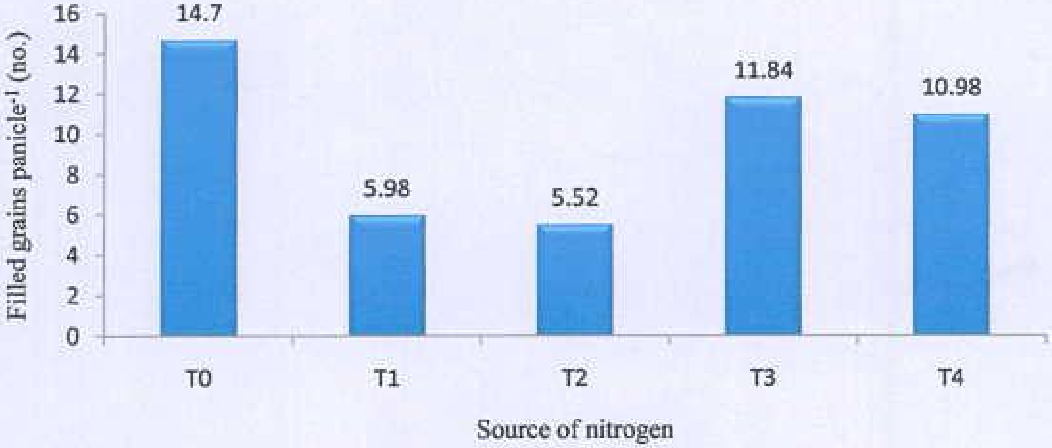
4.2.3.3 Interaction effect of nitrogen source and variety

Significant interaction between nitrogen and variety was observed on filled grains panicle^{-1} (Table 8). Interaction comprised with treatment T_2 with all the varieties showed higher number of grains panicle^{-1} than the interactions comprised with T_0 treatment with all the varieties (Table 8). The highest number of filled grains panicle^{-1} (116.32) was noted in the interaction of $T_2 \times V_1$ treatment followed by $T_1 \times V_1$ (115.12) interaction treatment, $T_4 \times V_1$ (106.16) interaction treatment, $T_3 \times V_1$ (105.12) interaction treatment and $T_2 \times V_3$ (102.93) treatment. The lowest number of grains panicle^{-1} (63.2) was obtained in the interaction treatment of $T_0 \times V_2$.

4.2.4 Unfilled grain panicle^{-1} (no.)

4.2.4.1 Effect of nitrogen source

Nitrogen had significant influence on the unfilled grains panicle^{-1} (Fig. 8). The figure showed that lowest (5.52) number of unfilled grain was obtained due to the application of treatment T_2 followed by treatment T_4 (10.98), T_3 (11.84) and T_1 (5.98). The highest (14.70) number of unfilled grain panicle^{-1} was obtained due to T_0 treatment i.e. controlled condition. The result was supported by BRRI (2006) that without nitrogen application increased the maximum number of unfilled grains panicle^{-1} in boro rice.



Here, T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

Figure 8. Effect of nitrogen sources on unfilled grain number panicle^{-1} of boro rice. (Sx□=0.50)

4.2.4.2 Effect of variety

A significant variation was observed among the varieties on the number of unfilled grains panicle^{-1} (Table 6). The highest number of unfilled grains panicle^{-1} (11.87) was obtained in BRRI dhan29 followed by BRRI dhan58 (11.71) and BRRI hybriddhan2 (8.60). The lowest number of unfilled grains panicle^{-1} (7.03) was obtained in Heera 4. BINA (1993) observed the similar result that the production of unfilled grains panicle differed with variety to variety.

Table 6. Effect of variety on producing unfilled grain panicle^{-1} of boro rice

Variety	Un-filled Grain panicle^{-1}
BRRI dhan29	11.87 a
BRRI hybriddhan2	8.60 c
BRRI dhan58	11.71 b
Heera 4	7.03 d
Sx□ Value	**0.47**
CV (%)	**12.59**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

4.2.4.3 Interaction effect of nitrogen sources and variety

A significant interaction between nitrogen dose and variety was observed on unfilled grains panicle (Table 8). The interaction result showed that interaction of BRRI dhan29 with all the nitrogen doses produced higher number of unfilled grains panicle^{-1} (ranged 4.47-19.69) followed by BRRI dhan58 (16.88) irrespective of all nitrogen sources. However, the highest number of unfilled grains panicle^{-1} (19.69) was found in $T_0 \times V_1$ interaction and the lowest number of unfilled grains panicle^{-1} (4.47) was counted in the interaction of $T_2 \times V_1$.

4.2.5 Weight of 1000–grains (g)

4.2.5.1 Effect of nitrogen source

The weight of 1000 grains was significantly influenced by the different levels of nitrogen (Table 7). The highest weight (23.72 g) of 1000-grains was recorded due to application of treatment T_2 followed by treatment T_1 (22.67 g) and T_4 (22.28). The lowest weight (21.50 g) of 1000-grain was recorded from the T_0 treatment i.e. no nitrogen treatment. The result fairly agreed with the findings of Mohaddesi *et al.* (2011) that 1000 grain weight had significant effect with increasing nitrogen levels but Rahman (2003) and Azad *et al.* (1995) found that the level of nitrogen didn't influence the weight of 1000-grain weight significantly which is dissimilar with this findings.

Table 7. Effect of nitrogen sources on weight of 1000 –grains of boro rice

Sources of nitrogen	Weight of 1000 grains (g)
T_0	21.50 c
T_1	22.67 a
T_2	23.72 a
T_3	21.95 bc
T_4	22.28 ab
Sx□ Value	**0.16**
CV(%)	**8.51**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

Here, T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

4.2.5.2 Effect of Variety

Variety had significant effect on the weight of 1000-grains. The highest weight (23.34 g) was observed in BRRI hybriddhan2 followed by Heera 4 (22.98 g) and BRRI dhan58 (22.36 g) and the lowest weight (21.00 g) was observed in BRRI dhan29 (Fig. 9). The result showed that BRRI hybriddhan2 produced 10.02%, 4.20% and 1.54% heavier seed than BRRI dhan29, BRRI dhan58 and Heera 4, respectively.

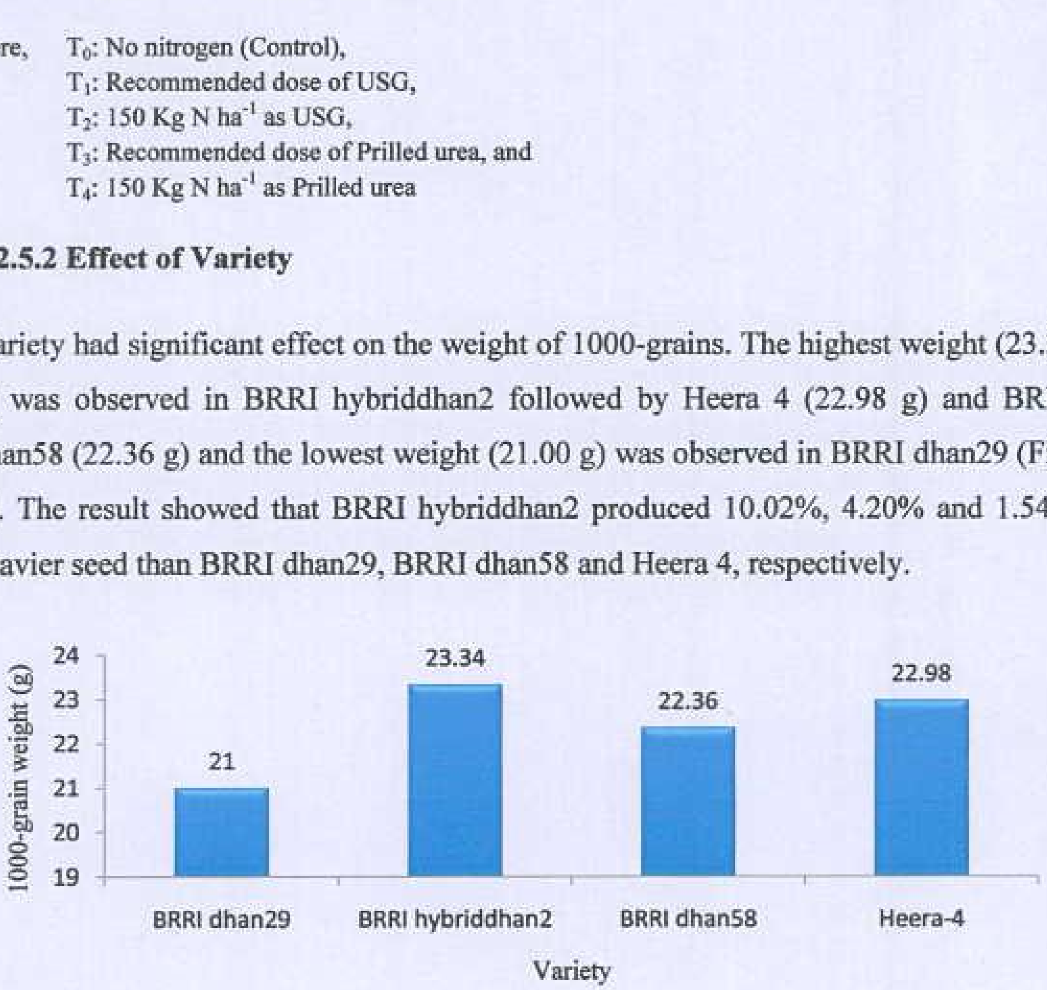


Figure 9. Effect of variety on weight of 1000 grains of boro rice. (Sx□=0.18)

4.2.5.3 Interaction effect of nitrogen sources and variety

A significant interaction between nitrogen sources and variety was found on the weight of 1000-grains (Table 8). The maximum weight of 1000-grains (24.86 g) was obtained in the interaction of $T_2 \times V_4$ treatment that was statistically similar with the interaction of $T_2 \times V_2$ (24.53 g) treatment, $T_1 \times V_4$ (23.80 g) treatment and $T_2 \times V_3$ (23.52 g) treatment. The minimum weight of 1000-grains (20.40 g) was obtained in the interaction of $T_0 \times V_1$ treatment. The result also showed that BRRI hybriddhan2 produced higher level of 1000-grains weight than other interactions irrespective of nitrogen levels.

Table 8. Interaction effects of nitrogen sources and variety on yield components of boro rice

Interaction (Nitrogen sources × Variety)	Effective tillers^{-1} (no.)	Non-Effective tillers^{-1} (no.)	1000 Seed wt. (g)	Filled Grain Panicle^{-1}	Un-filled Grain Panicle^{-1}
$T_0 \times V_1$	9.87 i	2.28 a	20.40 h	70.87 i	19.69 a
$T_0 \times V_2$	9.02 ij	1.73 c	22.53 b-e	63.2 i	12.98 cd
$T_0 \times V_3$	9.55 ij	1.46 de	21.42 f-h	66.68 i	16.88 b
$T_0 \times V_4$	8.56 j	1.56 cd	21.66 e-g	73.13 h	9.26 e
$T_1 \times V_1$	16.93 a	0.77 g	20.93 gh	115.12 a	4.97 hi
$T_1 \times V_2$	16.13 ab	0.52 h	23.49 ab	96.54 d	5.38 h
$T_1 \times V_3$	16.03 a-c	0.66 gh	22.48 b-e	101.53 c	7.93 g
$T_1 \times V_4$	14.17 d-g	0.62 gh	23.80 a	93.12 c-e	5.63 h
$T_2 \times V_1$	17.81 a	0.57 h	21.97 d-g	116.32 a	4.47 hi
$T_2 \times V_2$	16.93 a	0.42 hi	24.53 a	97.84 d	5.08 h
$T_2 \times V_3$	16.83 a	0.54 h	23.52 ab	102.93 bc	7.43 g
$T_2 \times V_4$	15.17 b-d	0.53 h	24.86 a	94.92 c-e	5.13 h
$T_3 \times V_1$	15.03 c-e	2.09 b	20.82 gh	105.12 b	15.75 b
$T_3 \times V_2$	13.78 fg	1.28 ef	23.03 a-c	83.12 fg	9.96 e
$T_3 \times V_3$	14.13 d-g	1.18 f	22.18 c-f	87.78 ef	13.67 c
$T_3 \times V_4$	12.76 h	1.29 ef	21.77 d-g	85.39 f	8 f
$T_4 \times V_1$	15.17 b-d	1.98 b	20.92 gh	106.16 b	14.48 bc
$T_4 \times V_2$	14.07 e-g	1.16 f	23.15 a-c	85.63 f	9.64 e
$T_4 \times V_3$	14.47 d-f	1.16 f	22.24 c-f	89.31e	12.64 d
$T_4 \times V_4$	13.15 gh	1.27 ef	22.81 a-d	87.12 ef	7.16 g
Sx□ Value	**0.33**	**0.06**	**0.33**	**4.21**	**1.03**
CV (%)	**7.31**	**9.99**	**8.51**	**9.94**	**12.59**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

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

4.2.6.1 Effect of nitrogen sources

Grain yield was significantly influenced by different sources of nitrogen (Table 9). The maximum grain yield (7.96 t ha^{-1}) was obtained due to application of treatment T_2 followed by treatment T_4 (7.34 t ha^{-1}). Numerical value indicated that treatment T_2 out yielded by 3.29, 1.06, 0.80 and 0.62 t ha^{-1} over T_0, T_3, T_1 and T_4 treatment, respectively. Improvement of yield component such as number of effective tillers $hill^{-1}$ and number of grains $panicle^{-1}$ in these treatments ultimately resulted in high yield of grains. Idris and Matin (1990) reported that application of nitrogen increased the yield of rice which supports the results.

4.2.6.2 Effect of variety

Varieties differed significantly in producing grain yield (Table 10). Among the four varieties BRRI dhan29 showed its superiority in producing highest grain yield which was 9.09%, 5.59% and 4.47% higher than BRRI dhan58, BRRI hybriddhan2 and Heera 4, respectively. However, BRRI dhan29 produced the highest grain yield (7.15 t ha^{-1}). Heera 4 produced the second highest grain yield (6.83 t ha^{-1}) which was statistically similar with BRRI hybriddhan2 (6.75 t ha^{-1}). The lowest grain yield (6.50 t ha^{-1}) was found in BRRI dhan58. The results relate with the findings of Xie *et al.* (2007), Sumit *et al.* (2004) and Meena *et al.* (2003) who observed yield variations among hybrid and high yielding varieties.

4.2.6.3 Interaction effect of nitrogen dose and variety

Grain yield influenced significantly by the interaction of nitrogen sources and variety (Table 11). Among the interaction treatments, the highest grain yield (8.46 t ha^{-1}) was recorded in the interaction of $T_2 \times V_1$ followed by $T_2 \times V_4$ (8.03 t ha^{-1}), $T_1 \times V_1$ (7.41 t ha^{-1}) and $T_2 \times V_2$ (7.89 t ha^{-1}) interaction treatments. The lowest grain yield (4.35 t ha^{-1}) was observed in $T_0 \times V_3$.

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

4.2.7.1 Effect of nitrogen source

Straw yield varied significantly with the different sources of nitrogen (Table 9). Straw yield was significantly highest (9.50 t ha^{-1}) at treatment T_2 that followed by treatment T_1 (9.20 t ha^{-1}). The lowest straw yield (6.49 t ha^{-1}) was found in T_0 treatment. Elbadry *et al.* (2004), Meena *et al.* (2003) and El-Rewainy (2002) observed similar view on straw yield due to nitrogen application.

4.2.7.2 Effect of variety

Straw yield differed significantly due to varietals differences (Table 10) BRRI dhan29 gave the highest straw yield (9.04 t ha^{-1}) followed by Heera 4 (8.51 t ha^{-1}) which was statistically similar with BRRI hybriddhan2 (8.32 t ha^{-1}). The lowest straw yield was found in BRRI dhan58 (8.21 t ha^{-1}). The differences in straw yield among the varieties might be attributed to the genetic makeup of the varieties. Chowdhury *et al.* (1993), Kumar *et al.* (1996) and Patel (2000) reported variable straw yield among the varieties.

4.2.7.3 Interaction effect of nitrogen sources and variety

There observed a significant difference among the interactions of nitrogen sources and varieties in respect of straw yield (Table 11). The maximum straw yield (9.94 t ha^{-1}) was found from the interaction of $T_2 \times V_1$ followed by $T_1 \times V_1$ (9.81 t ha^{-1}) and $T_2 \times V_4$ (9.42 t ha^{-1}) which are statistically similar with each other. The minimum straw yield (5.98 t ha^{-1}) was found from the interaction of $T_0 \times V_3$.

4.2.8 Biological Yield (t ha^{-1})

4.2.8.1 Effect of Nitrogen sources

Biological yield differed significantly due to the different sources of nitrogen treatments (Table 9). Application of treatment T_2 produced the highest biological yield (17.47 t ha^{-1}) than treatment T_1 (16.36 t ha^{-1}) and T_4 (16.26 t ha^{-1}) of nitrogen sources. The lowest biological yield (11.16 t ha^{-1}) was recorded at no nitrogen i.e. control condition treatment. The result agreed with the findings of Ahmed *et al.* (2005) who observed the significant effect of nitrogen on biological yield (t ha^{-1}) of rice.

4.2.8.2 Effect of variety

Significant variation in biological yield was observed due to varietals difference and it ranges from 14.71-16.19 t ha^{-1} (Table 10). The highest and lowest biological yield was obtained from BRRI dhan29 and BRRI dhan58, respectively. Heera 4 (15.34 t ha^{-1}) and BRRI hybriddhan2 (15.07 t ha^{-1}) are statistically similar in case of biological yield.

4.2.8.3 Interaction effect of nitrogen source and variety

Significant variation in biological yield (t ha^{-1}) was observed in the interaction effect of nitrogen source and variety (Table 11). The results showed that the interaction between $T_2 \times V_1$ gave the highest biological yield (18.40 t ha^{-1}) that similar with $T_2 \times V_4$ (17.45 t ha^{-1}) and $T_1 \times V_1$ (17.22 t ha^{-1}) interactions. The lowest biological yield (10.33 t ha^{-1}) was found in $T_0 \times V_3$ interaction treatment.

4.2.9 Harvest Index

4.2.9.1 Effect of nitrogen source

Effect of nitrogen sources exerted significant variation on harvest index (Table 9). Harvest index was highest at T_2 treatment (45.63%) and the lowest harvest index (41.88%) was obtained from no nitrogen treatment. Statistically similar harvest index was found from the application of treatment T_4 (45.14%) and T_3 (45.06%).

4.2.9.2 Effect of variety

No significant difference was observed for harvest index (%) due to varietal differences (Table 10). However, BRRI hybriddhan2 showed the maximum numerical harvest index (44.79%) followed by Heera 4 (44.52%) and BRRI dhan29 (44.19%). The lowest harvest index was found in BRRI dhan58 (44.17%). Alam *et al.* (2009) also found the similar findings.

4.2.9.3 Interaction effect of nitrogen sources and variety

Harvest index was significantly influenced by the interaction effect of nitrogen source and variety (Table 11). The maximum harvest index (46.07%) was observed in $T_2 \times V_2$ interaction that followed by $T_2 \times V_2$ interaction (46.01%), $T_4 \times V_2$ interaction

(45.96%) and $T_2 \times V_1$ (45.96%). The minimum harvest index (41.44%) was found in the interaction treatment effect of $T_0 \times V_1$.

Table 9. Effect of nitrogen source on yield and harvest index of boro rice

Sources of Nitrogen	**Grain Yield (t ha^{-1})**	**Straw Yield (t ha^{-1})**	**Biological Yield (t ha^{-1})**	**Harvest Index (%)**
T_0	4.67 e	6.49 e	11.16 e	41.88 d
T_1	7.16 b	9.20 b	16.36 b	43.84 c
T_2	7.96 a	9.50 a	17.47 a	45.63 a
T_3	6.90 d	8.40 d	15.31 d	45.06 b
T_4	7.34 c	8.92 c	16.26 c	45.14 b
Sx□ Value	**0.12**	**0.12**	**0.21**	**0.56**
CV(%)	**9.11**	**11.41**	**9.59**	**11.33**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

Here, T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

Table 10. Effect of variety on yield and harvest index of boro rice

Variety	**Grain Yield (t ha^{-1})**	**Straw Yield (t ha^{-1})**	**Biological Yield (t ha^{-1})**	**Harvest Index (%)**
BRRI dhan 29	7.15 a	9.04 a	16.19 a	44.19
BRRI hybriddhan2	6.75 b	8.32 b	15.07 b	44.79
BRRI dhan 58	6.50 c	8.21 c	14.71 c	44.17
Heera 4	6.83 b	8.51 b	15.34 b	44.52
Sx□ Value	**0.09**	**0.11**	**0.21**	**NS**
CV (%)	**9.13**	**11.43**	**9.59**	**11.33**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

Table 11. Interaction effects of nitrogen sources and variety on yield and harvest index of boro rice

Interaction Nitrogen Sources × Variety	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest Index (%)
$T_0 \times V_1$	4.94 fg	6.98 fg	11.92 fg	41.44 c
$T_0 \times V_2$	4.66 g	6.47 h	11.13 h	41.86 bc
$T_0 \times V_3$	4.35 g	5.98 h	10.33 h	42.11 bc
$T_0 \times V_4$	4.75 g	6.53 gh	11.28 gh	42.10 bc
$T_1 \times V_1$	7.41 ab	9.81 a	17.22 ab	43.03 b
$T_1 \times V_2$	7.14 ab	9.39 ab	16.53 a-c	43.19 b
$T_1 \times V_3$	6.95 c-e	9.18 bc	16.13 cd	43.08 b
$T_1 \times V_4$	7.16 ab	9.47 ab	16.63 ab	43.05 b
$T_2 \times V_1$	8.46 a	9.94 a	18.40 a	45.96 a
$T_2 \times V_2$	7.89 ab	9.23 ab	17.12 ab	46.07 a
$T_2 \times V_3$	7.49 ab	9.01 bc	16.50 cd	45.37 ab
$T_2 \times V_4$	8.03 a	9.42 ab	17.45 ab	46.01 a
$T_3 \times V_1$	7.23 bc	9.28 ab	16.51 b-d	43.79 b
$T_3 \times V_2$	6.85 ef	8.74 ef	15.59 ef	43.93 b
$T_3 \times V_3$	6.57 fg	8.71 ef	15.28 ef	42.99 bc
$T_3 \times V_4$	6.98 ef	9.23 ef	16.22 ef	43.01 b
$T_4 \times V_1$	7.72 ab	9.08 ab	16.80 a-c	45.93 a
$T_4 \times V_2$	7.24 bc	8.51 bc	15.75 d	45.96 a
$T_4 \times V_3$	7.15 bc	8.73 de	15.88 e	45.01 ab
$T_4 \times V_4$	7.27 bc	8.69 bc	15.96 d	45.55 ab
Sx□ Value	**0.27**	**0.26**	**0.41**	**1.11**
CV (%)	**9.13**	**11.43**	**9.57**	**11.33**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

Here,

V_1: BRRI dhan29	T_0: No nitrogen (Control),
V_2: BRRI hybriddhan2	T_1: Recommended dose of USG,
V_3: BRRI dhan58	T_2: 150 Kg N ha^{-1} as USG,
V_4: Heera 4	T_3: Recommended dose of Prilled urea, and
	T_4: 150 Kg N ha^{-1} as Prilled urea

4.3 Effect of nitrogen sources on N, P and K uptake by boro rice

4.3.1 Nitrogen Uptake

The N uptake both in grain and straw of boro rice increased significantly due to application of USG and Prilled urea (Table 12). The N uptake by grain ranged from 17.31 kg ha^{-1} to 86.16 kg ha^{-1} and that by straw from 11.67 kg ha^{-1} to 59.13 kg ha^{-1}. The highest N uptake by grain (86.16 kg ha^{-1}) and straw (59.13 kg ha^{-1}) was obtained in treatment T_2 (150 Kg N ha^{-1} as USG) and the lowest N uptake by grain (17.31 kg ha^{-1}) and straw (11.67 kg ha^{-1}) was found in T_0 (Control) i.e. no nitrogen treatment. The total N uptake by rice was also influenced significantly by different treatments. The highest total N uptake (145.29 kg ha^{-1}) was observed in treatment T_2 (150 Kg N ha^{-1} as USG) and the lowest value (28.98 kg ha^{-1}) was found in treatment T_0 (control).

4.3.2 Phosphorus uptake

The P uptake both in grain and straw of boro rice increased significantly due to application of USG and Prilled urea (Table 12). The P uptake by grain ranged from 5.72 kg ha^{-1} to 20.73 kg ha^{-1} and that by straw from 2.82 kg ha^{-1} to 12.41 kg ha^{-1}. The highest P uptake by grain (20.73 kg ha^{-1}) and straw (12.41 kg ha^{-1}) was obtained in treatment T_2 (150 Kg N ha^{-1} as USG) and the lowest P uptake by grain (5.72 kg ha^{-1}) and straw (2.82 kg ha^{-1}) was found in T_0 (Control) i.e. no nitrogen treatment. The total P uptake by rice was also influenced significantly by different treatments. The highest total P uptake (33.14 kg ha^{-1}) was observed in treatment T_2 (150 Kg N ha^{-1} as USG) and the lowest value (8.54 kg ha^{-1}) was found in treatment T_0 (control).

4.3.3 Potassium uptake

The K uptake both in grain and straw of boro rice increased significantly due to application of USG and Prilled urea (Table 12). The K uptake by grain ranged from 2.30 kg ha^{-1} to 9.71 kg ha^{-1} and that by straw from 1.41 kg ha^{-1} to 7.53 kg ha^{-1}. The highest K uptake by grain (9.71 kg ha^{-1}) and straw (7.53 kg ha^{-1}) was obtained in treatment T_2 (150 Kg N ha^{-1} as USG) and the lowest K uptake by grain (2.30 kg ha^{-1}) and straw (1.41 kg ha^{-1}) was found in T_0 (Control) i.e. no nitrogen treatment. The total K uptake by rice was also influenced significantly by different treatments. The highest total K uptake (17.24 kg ha^{-1}) was observed in treatment T_2 (150 Kg N ha^{-1} as USG) and the lowest value (3.71 kg ha^{-1}) was found in treatment T_0 (control).

Table 12. Effect of nitrogen supplied from USG and Prilled urea on N, P and K uptake by boro rice

Source of nitrogen	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_0	17.31 d	11.67 d	28.98 d	5.72 d	2.82 d	8.54 d	2.30 d	1.41 d	3.71 d
T_1	51.27 b	30.20 b	81.47 b	17.19 b	9.79 b	26.98 b	8.18 a	6.30 a	14.48 a
T_2	86.16 a	59.13 a	145.29 a	20.73 a	12.41 a	33.14 a	9.71 a	7.53 a	17.24 a
T_3	44.34 c	26.70 c	71.04 c	12.15 c	7.73 c	19.88 c	3.92 bc	3.13 bc	7.05 bc
T_4	60.39 b	41.04 b	101.43 b	14.96 bc	9.01 b	23.97 bc	4.91 b	3.91 b	8.82 b
Sx□ Value	**1.35**	**1.03**	**1.72**	**0.27**	**0.32**	**0.46**	**0.27**	**0.22**	**0.30**
CV (%)	**5.20**	**6.18**	**4.31**	**4.96**	**11.30**	**5.61**	**8.96**	**9.35**	**5.52**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

Here, T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

4.4 Nutrient (N, P and K) content in postharvest soil

N, P and K content in postharvest soil showed significant variation due to the effect of nitrogen fertilizers where N content varied from 0.048 to 0.093 %, P content varied from 0.019 to 0.033 % and K content varied from 0.028 to 0.046 % (Table 13). From the Table 15, it was also found that the highest value of the N, P and K content in postharvest soil were obtained from those soils which was treated by 150 Kg N ha^{-1} as USG placement at 10 DAT and tillering stage. Similarly, without nitrogen fertilizer treated soil showed the lowest N, P and K content.

Table 13. Effect of nitrogen sources on nutrient content (N, P and K) in postharvest soil of the experimental field

Source of nitrogen	N, P and K content in postharvest soil		
	N (%)	P (%)	K (%)
T_0	0.048 d	0.019 c	0.028 c
T_1	0.087 ab	0.031 ab	0.043 ab
T_2	0.093 a	0.033 a	0.046 a
T_3	0.079 b	0.028 b	0.039 ab
T_4	0.083 ab	0.030 ab	0.042 ab
Sx□ Value	**1.18**	**0.77**	**1.01**
CV (%)	**5.43**	**6.38**	**4.51**

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

Here, T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea

4.5 Apparent N Recovery (ANR)

The apparent N recovery by boro rice has been presented in Table 14. Mean apparent recovery of N by boro rice ranged from 35.05% to 77.54%. The data clearly indicate that the maximum values of grain and straw yield, total N uptake and apparent N recovery were obtained with the application of T_2 treatment. The reasons for high recovery of applied N could be the deep placement of 150 Kg N ha^{-1} as USG placement at 10 DAT and tillering stage in rice field that resulted in continuous supply of available nitrogen throughout the growth period of rice plant, which ultimately gave maximum N uptake.

4.6 Nitrogen Use Efficiency (NUE)

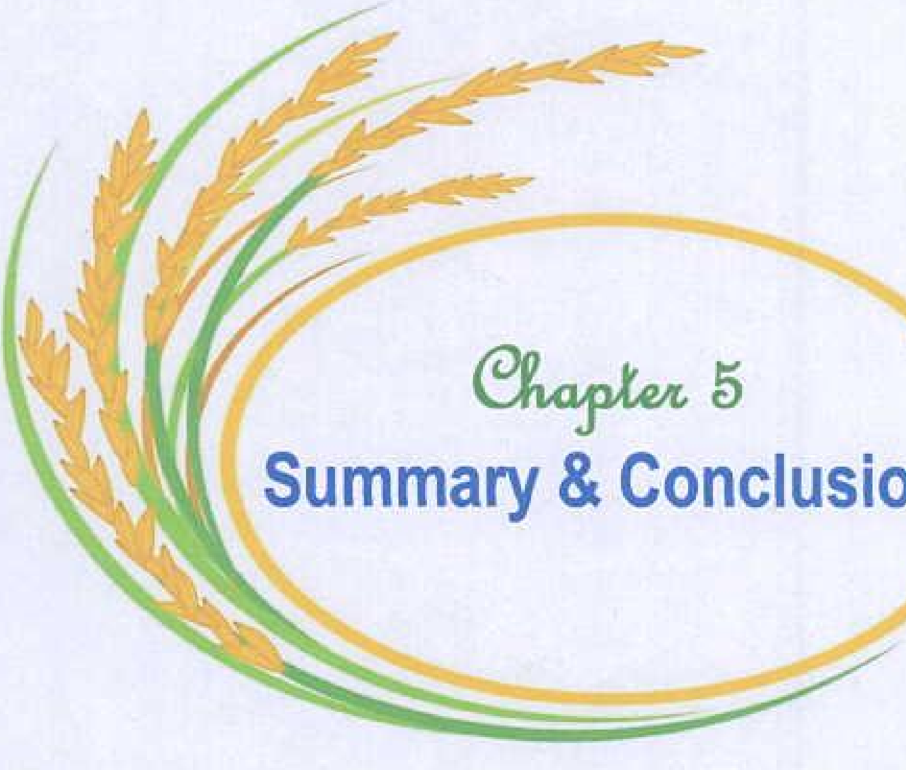
Nitrogen use efficiency (NUE) is a term used to indicate the relative balance between the amount of fertilizer N taken up and used by the crop versus the amount of fertilizer N lost. Nitrogen use efficiency represents the response of rice plant in terms of grain yield to N fertilizer. The highest value of NUE was obtained in T_1 treatment and the lowest value was found in T_3 treatment. The range of NUE varied from 17.80 to 33.20 (Table 14). This result indicates that recommended dose of USG in rice field decreases the losses of N or the rate of N, leading to efficient uptake and utilization of applied N.

Table 14. Effect of nitrogen supplied form Urea supergranule and Prilled urea on apparent N recovery (%) and nitrogen use efficiency (NUE) of boro rice

Treatments	N applied (kg ha^{-1})	Grain yield (kg ha^{-1})	Total N uptake (kg ha^{-1})	ANR (%)	NUE (kg grain kg^{-1} N applied)
T_0	-	4670 e	28.98 d	-	-
T_1	75	7160 b	81.47 b	69.98	33.20
T_2	150	7960 a	145.29 a	77.54	21.93
T_3	120	6900 d	71.04 c	35.05	18.58
T_4	150	7340 c	101.43 b	48.30	17.80

Values in column having different letter are significantly different and same letter are not significantly different at 0.05 level of probability by DMRT.

Here, T_0: No nitrogen (Control),
T_1: Recommended dose of USG,
T_2: 150 Kg N ha^{-1} as USG,
T_3: Recommended dose of Prilled urea, and
T_4: 150 Kg N ha^{-1} as Prilled urea
ANR = Apparent nitrogen recovery, and NUE = Nitrogen use efficiency



Chapter 5

Summary & Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was carried out at the Research Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from December 2012 to May 2013 to determine the suitable nitrogen sources to growth performance and to increase the yield of boro rice. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors. Factor A: Nitrogen Sources (5 levels); T_0: No nitrogen (control), T_1: Recommended dose of USG, T_2: 150 KgNha^{-1} as USG, T_3: Recommended dose of prilled urea and T_4: 150 KgNha^{-1} as prilled urea, and factor B: Variety (4 levels); V_1: BRRI dhan29, V_2: BRRI hybriddhan2, V_3: BRRI dhan58 and V_4: Heera 4. The experiment was laid out following split plot design with three replications where main plot was for variety (Factor B) and subplot was for treatment (Factor A). There were 20 treatment combinations. The total numbers of unit plots were 60. The size of unit plot was 7 m^2 (3.5 m × 2 m). Triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate was applied at the rate of 148-178-100-15 kg ha^{-1} as basal dose at final land preparation of individual plots.

Results revealed that nitrogen sources, variety and their interactions had significant effect on plant height at different days after transplanting. The tallest (99.77 cm) plant was recorded from T_2 treatment compared to the lower levels of nitrogen at harvest. At harvest, the tallest plant (98.79 cm) was observed in BRRI dhan29 and the shortest plant (88.59 cm) was observed in Heera. The tallest plant (103.2 cm) was found in the $T_2 \times V_1$ interaction treatment and the shortest plant (80.50 cm) was found in $T_0 \times V_4$ interaction at harvest.

The highest number of tillers hill^{-1} (19.03) was found in T_2 treatment at 85 DAT. The highest and lowest number of tillers hill^{-1} (17.25) and (15.40) were recorded from BRRI dhan29 and Heera 4, respectively. The interaction of $T_2 \times V_1$ was found promising in producing tillers hill^{-1}.

The highest number of effective tiller hill^{-1} (16.68) was counted T_2 treatment. BRRI dhan29 showed the highest number of effective tiller hill^{-1} (14.96) followed by BRRI dhan58 (14.20) and lowest number of effective tiller hill^{-1} (12.76) was recorded from Heera 4. The interaction of $T_2 \times V_1$ was found best in producing effective tiller hill^{-1}.

Significant difference was observed in producing non-effective tillers hill^{-1} due to nitrogen, variety and their interactions. The highest number of non-effective tillers hill^{-1} (1.75) was counted from no nitrogen treatment. The highest number of non-effective tillers hill^{-1} (1.53) was recorded in BRRI dhan29 whereas BRRI dhan58 produced the lowest number of non-effective tillers hill^{-1} (1.00). The highest number of non-effective tiller hill^{-1} (2.28) was found in the interaction of $T_0 \times V_1$ treatment and the lowest (0.42) was obtained from $T_2 \times V_2$ interaction treatment.

Nitrogen, variety and their interactions exhibited significant differences variation in producing filled grains panicle^{-1}. The highest number of filled grains panicle^{-1} (103.01) was counted at T_2 treatment whereas no nitrogen produces the lowest number of filled grains panicle^{-1} (68.47). The highest number of filled grains panicle^{-1} (102.71) was observed in BRRI dhan29 and the lowest number of filled grains panicle^{-1} (85.26) was observed in BRRI hybriddhan2. The interaction of $T_2 \times V_1$ showed the highest number of filled grains panicle^{-1} (116.32) and the lowest number of filled grains panicle^{-1} (63.2) was observed in $T_0 \times V_2$ interaction.

Without nitrogen produced the higher number of unfilled grains panicle^{-1} (14.70) compared to other nitrogen sources. BRRI dhan29 produced the highest number of unfilled grains panicle^{-1} (11.87) and the lowest number of unfilled grains panicle^{-1} was observed in Heera 4. The highest number (19.69) and the lowest number (4.47) of unfilled grains panicle^{-1} were observed $T_0 \times V_1$ and $T_2 \times V_1$ interaction.

Nitrogen, variety and their interaction was observed significant in case of weight of 1000 grain. The highest weight of 1000 seed weight (23.72) was found in T_2 treatment however the hybrid variety BRRI hybriddhan2 and the inbred variety BRRI dhan29 showed significantly the highest (23.34 g) and the lowest (21.00 g) weight of 1000-gram, respectively. The interaction of $T_2 \times V_4$ treatment produced the maximum weight of 1000-grain (24.86 g) whereas, $T_0 \times V_1$ interaction treatment produced the minimum weight of 1000 grains (20.40 g).

Grain yield varied significantly due to nitrogen sources, variety and their interaction. The highest grain yield (7.96 t ha^{-1}) was obtained T_2 treatment and the lowest grain yield (4.67 t ha^{-1}) was obtained no nitrogen. The maximum grain yield (7.15 t ha^{-1}) was found in BRRI dhan29 and the lowest grain yield (6.50 t ha^{-1}) was found in BRRI dhan58. The interaction of $T_2 \times V_1$ treatment produced the highest (8.46 t ha^{-1}) grain yield and the interaction of $T_0 \times V_3$ treatment produced the lowest grain yield (4.35 t ha^{-1})

The highest straw yield (9.50 t ha^{-1}) and biological yield (17.47 t ha^{-1}) was obtained at T_2 treatment whereas the lowest straw yield (6.49 t ha^{-1}) and biological yield (11.16 t ha^{-1}) was obtained at no nitrogen. Both the highest straw yield (9.04 t ha^{-1}) and the biological yield (16.19 t ha^{-1}) were found in BRRI dhan29 whereas BRRI dhan58 showed the lowest straw yield (8.21 t ha^{-1}) and biological yield (14.71 t ha^{-1}). Both the highest straw (9.94 t ha^{-1}) and biological (18.40 t ha^{-1}) yield were obtained in the interactions of $T_2 \times V_1$ treatment and the lowest both straw yield (5.98 t ha^{-1}) and biological (10.33 t ha^{-1}) yield were obtained in the interactions of $T_0 \times V_3$ treatment.

Nitrogen and the interaction of nitrogen source and variety showed significant variation on harvest index but variety found insignificant variation. The maximum harvest index (45.63%) was obtained at T_2 treatment and the minimum (41.88%) was obtained at no nitrogen treatment. The significantly highest harvest index (46.07%) was found in the interaction of $T_2 \times V_2$ treatment and the lowest harvest index (41.44%) was found in the interaction of $T_0 \times V_1$ treatment.

The N uptake both in grain and straw of boro rice increased significantly due to application of nitrogen fertilizer. The highest N uptake by grain (86.16 kg ha^{-1}) and straw (59.13 kg ha^{-1}) was found in T_2 treatment and the lowest N uptake by grain (17.31 kg ha^{-1}) and straw (11.67 kg ha^{-1}) was found in T_0 treatment. The highest total N uptake (145.29 kg ha^{-1}) was observed in T_2 (150 Kg N ha^{-1} as USG) and the lowest value (28.98 kg ha^{-1}) was found in T_0 (control) treatment.

The P uptake both in grain and straw of boro rice increased significantly due to application of nitrogen fertilizer. The highest P uptake by grain (20.73 kg ha^{-1}) and straw (12.41 kg ha^{-1}) was found in treatment T_2 and the lowest P uptake by grain (5.72 kg ha^{-1}) and straw (2.82 kg ha^{-1}) was found in T_0 treatment. The highest total P uptake

(33.14 kg ha^{-1}) was observed in treatment T_2 (150 Kg N ha^{-1} as USG) and the lowest value (8.54 kg ha^{-1}) was found in T_0 (control).

The K uptake both in grain and straw of boro rice increased significantly due to application of nitrogen fertilizer. The highest K uptake by grain (9.71 kg ha^{-1}) and straw (7.53 kg ha^{-1}) was found in treatment T_2 and the lowest S uptake by grain (2.30 kg ha^{-1}) and straw (1.41 kg ha^{-1}) was found in T_0 treatment. The highest total S uptake (17.24 kg ha^{-1}) was observed in treatment T_2 (150 Kg N ha^{-1} as USG) and the lowest value (3.71 kg ha^{-1}) was found in T_0 (control).

Mean apparent recovery of N by boro rice ranged from 35.05% to 77.54%. The maximum values of grain and straw yield, total N uptake and apparent N recovery were obtained with the application of T_2 treatment (150 Kg N ha^{-1} as USG).

Nitrogen use efficiency represents the response of rice plant in terms of grain yield to N fertilizer. The range of NUE varied from 17.8 to 33.20 kg grain kg^{-1} N applied. The highest value of NUE was obtained in T_1 treatment (Recommended dose of USG) and the lowest value was found in T_3 treatment (Recommended dose of Prilled urea).

Reviewing above the results of the present study, it might be concluded that

- ✓ 150 Kg N ha^{-1} as USG showed the superiority over other sources and application methods of nitrogen to produce higher grain yield of rice.
- ✓ Sources and application methods of nitrogen as USG showed the superiority over prilled urea.
- ✓ BRRI dhan29 showed the higher production than other tested varieties of boro rice.
- ✓ Interaction treatment of T_2 (150 Kg N ha^{-1} as USG) and V_1 (BRRI dhan29) performed best; interaction of T_2 treatment with other tested varieties were also promising in producing higher yield.
- ✓ The maximum values of apparent recovery of N by tested varieties were obtained with the application of T_2 treatment (150 Kg N ha^{-1} as USG). But the nitrogen use efficiency was maximum in T_1 treatment i.e. Recommended dose of USG.

This is a single year and single location trial so more research is needed in different agro–ecological zones (AEZ) of Bangladesh for regional adaptability and other performances.

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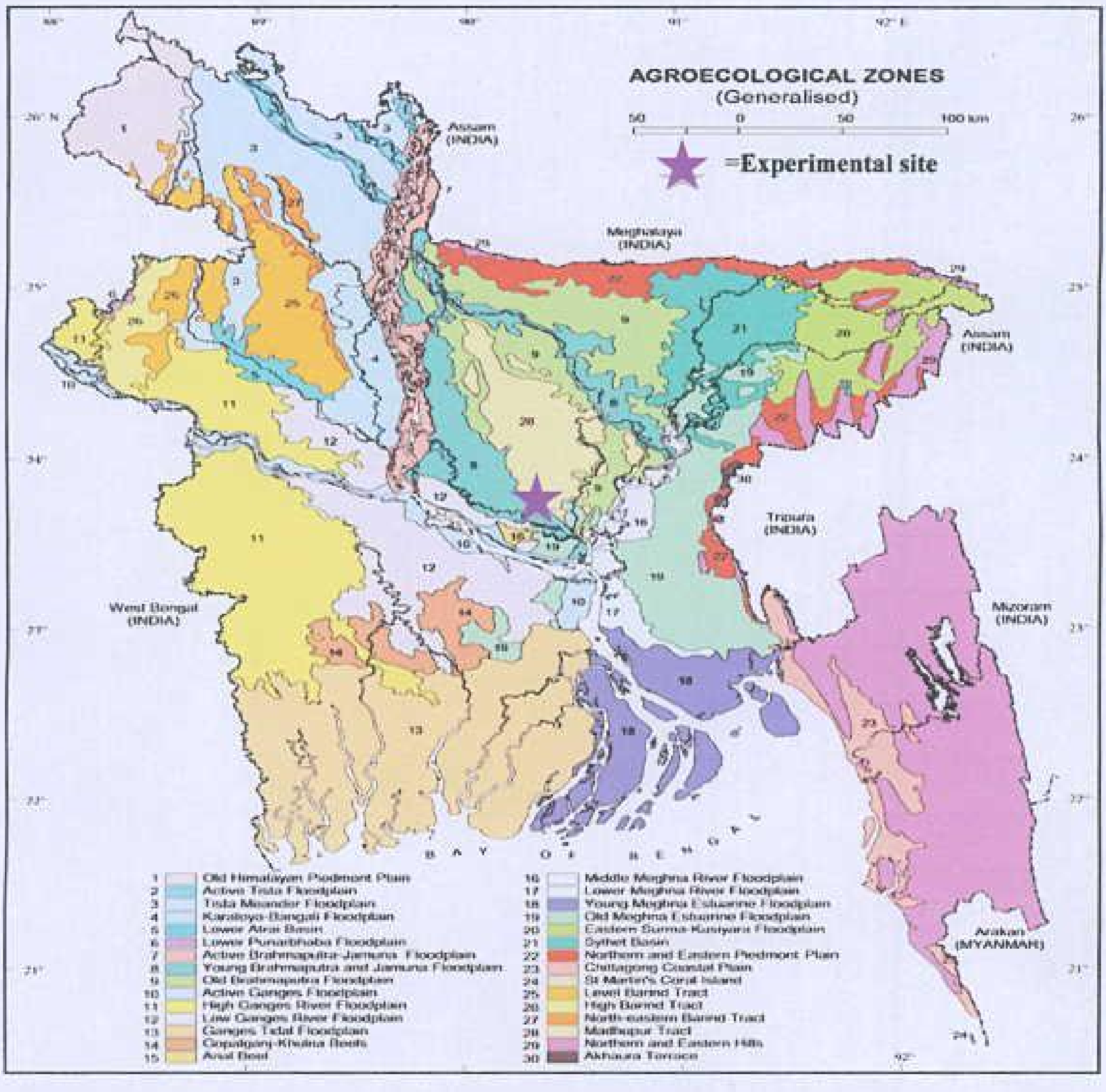
Appendices

APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Monthly average temperature and total rainfall of the experimental site during the period from December 2012 to May 2013

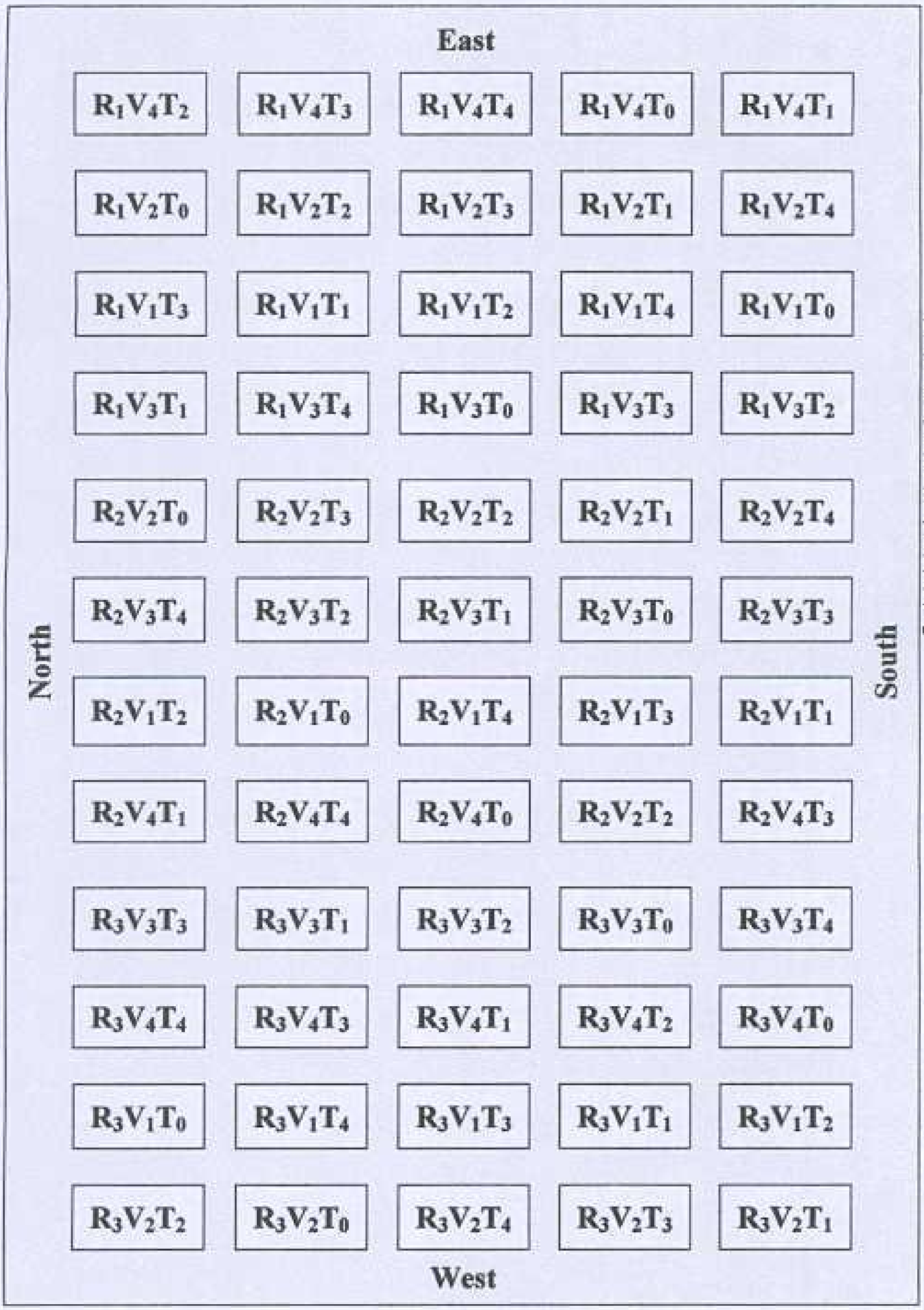
Year	Month	Air temperature (^0C)		Total rainfall (mm)
		Maximum	Minimum	
2012	December	25.87	15.1	35
2013	January	24.57	14.53	65
	February	26.67	15.1	155
	March	31.15	21.45	184
	April	34.35	24.5	281
	May	33.53	22.57	269

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

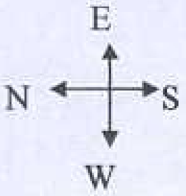
Appendix III. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth).

Physical characteristics		Chemical characteristics	
Constituents	Percent	Soil characters	Value
Sand	26	Organic carbon (%)	0.45
Silt	45	Organic matter (%)	0.78
Clay	29	Total nitrogen (%)	0.027
Textural class	Silty clay	Phosphorus	6.3 µg/g soil
		Potassium	0.10 µg/g soil

Appendix IV. Layout for experimental field.



$R_1V_4T_2$	$R_1V_4T_3$	$R_1V_4T_4$	$R_1V_4T_0$	$R_1V_4T_1$
$R_1V_2T_0$	$R_1V_2T_2$	$R_1V_2T_3$	$R_1V_2T_1$	$R_1V_2T_4$
$R_1V_1T_3$	$R_1V_1T_1$	$R_1V_1T_2$	$R_1V_1T_4$	$R_1V_1T_0$
$R_1V_3T_1$	$R_1V_3T_4$	$R_1V_3T_0$	$R_1V_3T_3$	$R_1V_3T_2$
$R_2V_2T_0$	$R_2V_2T_3$	$R_2V_2T_2$	$R_2V_2T_1$	$R_2V_2T_4$
$R_2V_3T_4$	$R_2V_3T_2$	$R_2V_3T_1$	$R_2V_3T_0$	$R_2V_3T_3$
$R_2V_1T_2$	$R_2V_1T_0$	$R_2V_1T_4$	$R_2V_1T_3$	$R_2V_1T_1$
$R_2V_4T_1$	$R_2V_4T_4$	$R_2V_4T_0$	$R_2V_2T_2$	$R_2V_4T_3$
$R_3V_3T_3$	$R_3V_3T_1$	$R_3V_3T_2$	$R_3V_3T_0$	$R_3V_3T_4$
$R_3V_4T_4$	$R_3V_4T_3$	$R_3V_4T_1$	$R_3V_4T_2$	$R_3V_4T_0$
$R_3V_1T_0$	$R_3V_1T_4$	$R_3V_1T_3$	$R_3V_1T_1$	$R_3V_1T_2$
$R_3V_2T_2$	$R_3V_2T_0$	$R_3V_2T_4$	$R_3V_2T_3$	$R_3V_2T_1$



Here,
Treatment combinations: 20
Replication: 3
Total no. of unit plots: 60
Unit plot size: 7 m^2
Unit plot length: 3.5 m
Unit plot width: 2 m
Plot to plot distance: 0.5 m
Replication to replication distance: 1 m

LIST OF PLATES

Plate no. 1. Seedbed preparation

Plate no. 2. Initial soil sample collection from the experimental plot

Plate no. 3. Seedling transplanting into main field

Plate no. 4. Field view of experimental field after seedling establishment

Plate no. 5. Irrigation and management practices

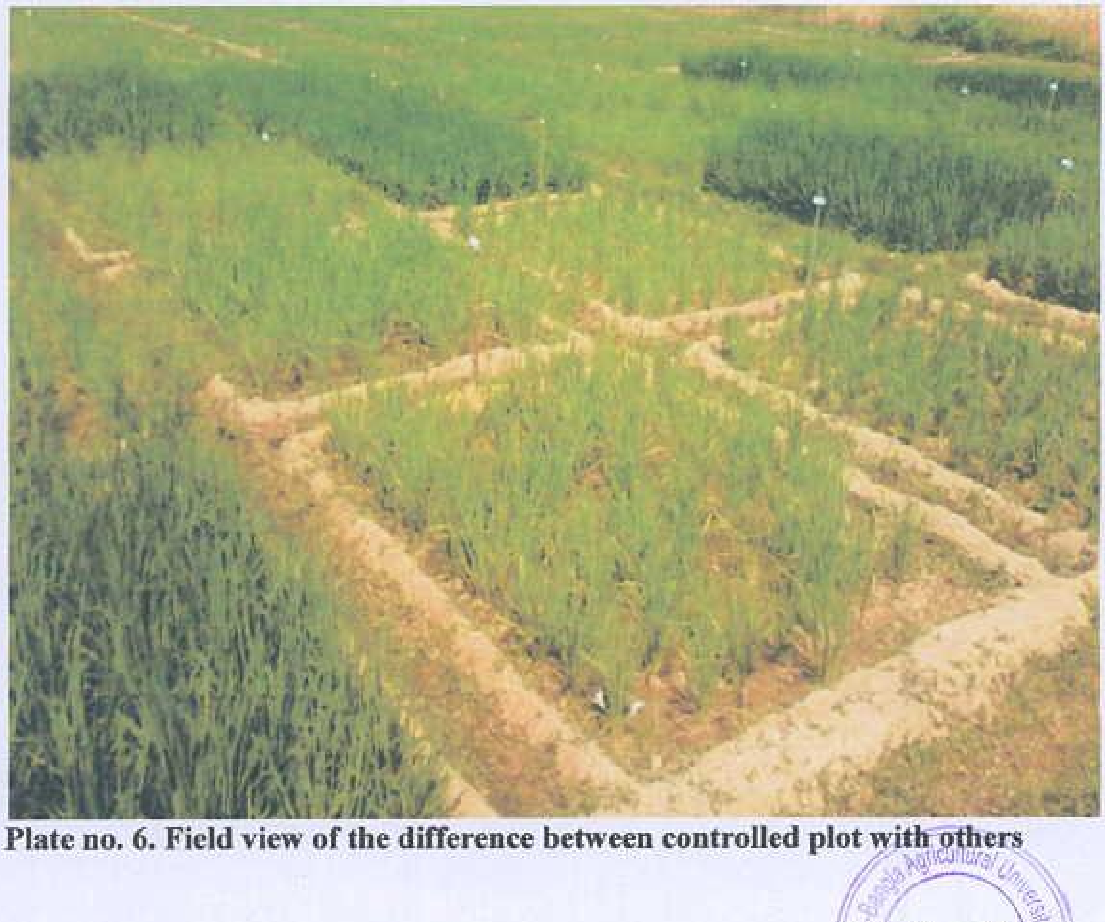


Plate no. 6. Field view of the difference between controlled plot with others

Plate no. 7. Field view of best variety at vegetative stage (BRRI Dhan29)

Plate no. 8. Field view at reproductive stage

Plate no. 9. Field view at ripening stage

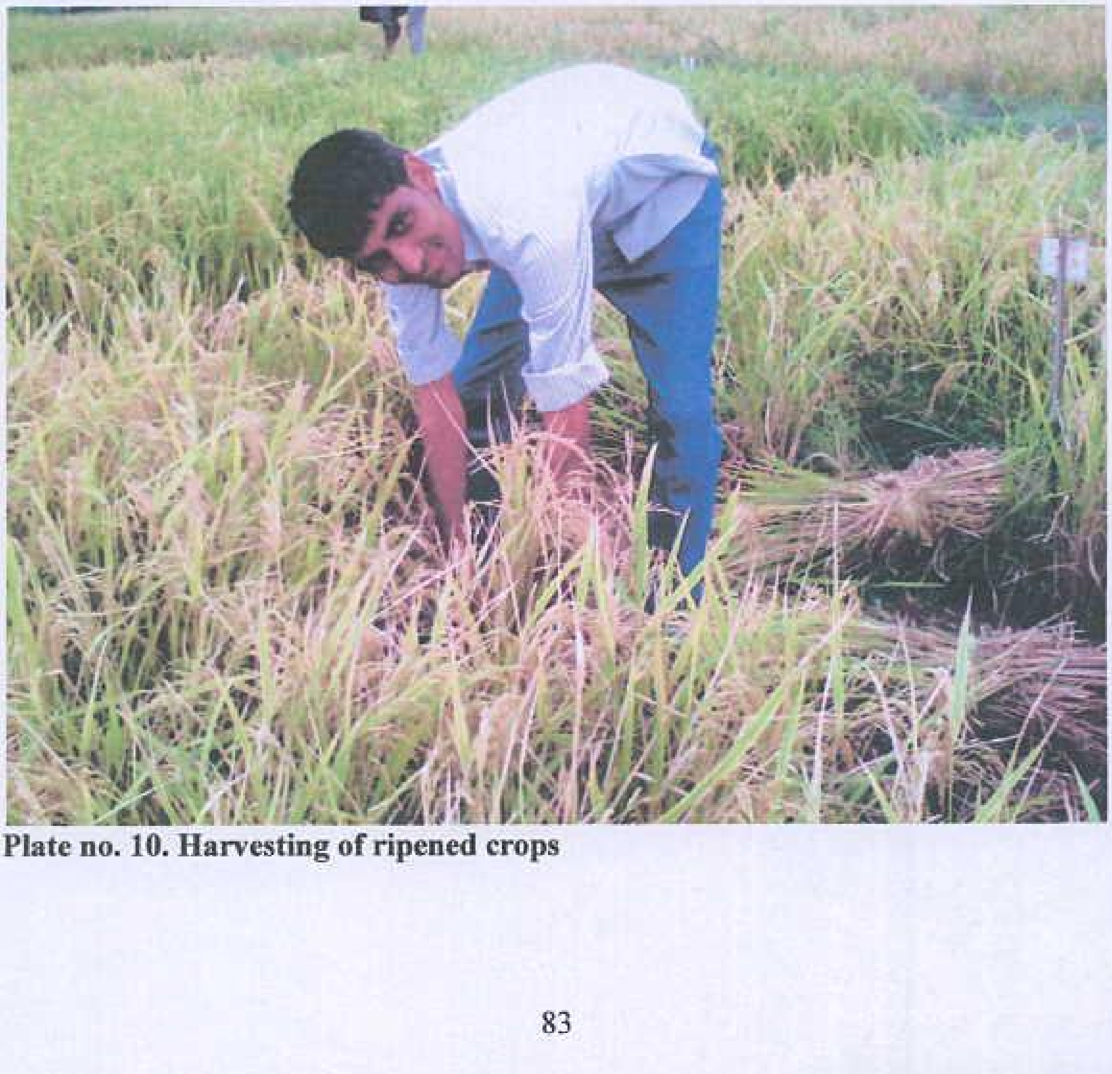
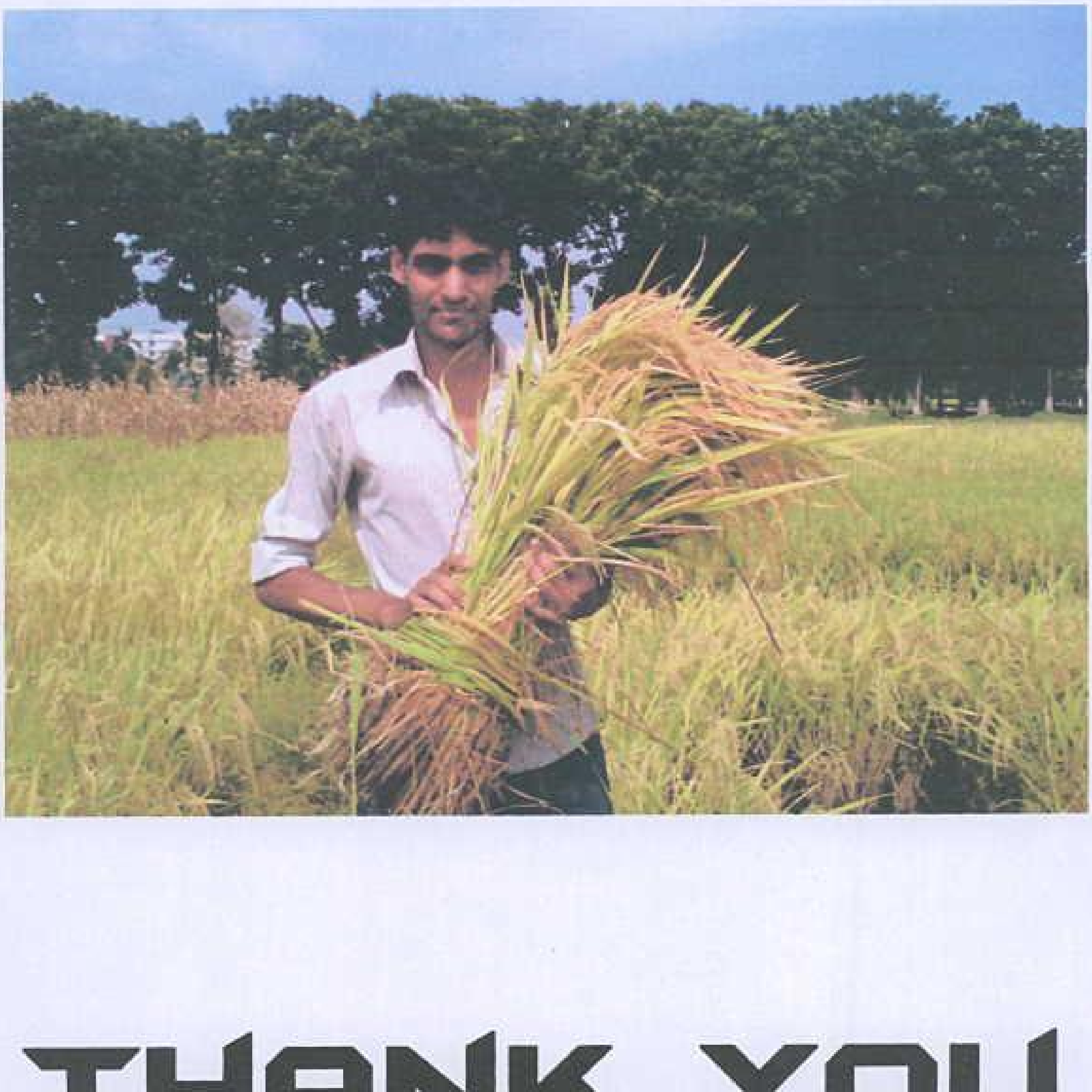


Plate no. 10. Harvesting of ripened crops



THANK YOU