EFFECT OF NITROGEN SOURCES ON SPIKELET STERILITY AND YIELD OF BORO RICE

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December, 2013

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REGISTRATION NO. 07-02203

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

MASTER OF SCIENCE

IN

AGRONOMY

SEMESTER: JANUARY-JUNE, 2012

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CERTIFICATE

*This is to certify that the thesis entitled " **EFFECT OF NITROGEN SOURCES ON SPIKELET STERILITY 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 AGRONOMY,** embodies the result of a piece of bonafide research work carried out by **SHEIKH SALAMAT ULLAH, REGISTRATION NO. 07-02203,** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

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ACKNOWLEDGEMENTS

All praises are due to the almighty Allah for His gracious kindness and infinite mercy in all the endeavors of the author to let him successfully complete the research work and the thesis leading to Master of Science.

*The author would like to express his heartfelt gratitude and most sincere appreciations to his Supervisor **Dr. A.K.M. Ruhul Amin**, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his valuable guidance, advice, immense help, encouragement and support throughout the study. Likewise, grateful appreciation is conveyed to Co-supervisor **Dr. Tuhin Suvro Roy** Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for constant encouragement, cordial suggestions, constructive criticisms and valuable advice to complete the thesis.*

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

The author wishes to extend his special thanks to Hasanuzzaman Hasan sir, Mr. Anwar, Mr. Shamim, Mr. Badsha and Mr. Apu for their help during experimentation. Special thanks are due to all other friends for their support and encouragement.

The author is deeply indebted to his father and mother and other relatives for their moral support, encouragement and love with cordial understanding.

Finally, the author appreciates the assistance rendered by the staff members of the Department of Agronomy, Sher-e-Bangla Agricultural University Farm, Dhaka, who have helped him during the period of experimentation.

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ABSTRACT

A research work was carried out at the Agronomy Farm, Sher-e-Bangla Agricultural University, and Dhaka during the period from November 2012 to June 2013 in order to determine the suitable nitrogen source to observe the growth performance with a view to increasing the grain yield by reducing spikelet sterility in boro rice. The experiment comprised four sources of nitrogen viz. no nitrogen, BRRI recommended dose of prilled Urea, Govt. approved dose of mixed NPK and BARC recommended dose of urea super granule (USG), and four varieties viz. BRRI dhan29, BRRI dhan58, BADC SL8H and Heera. The experiment was set up in a split-plot design with three replications. Experimental results indicated 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}, spikelet sterility (%), grain yield, straw yield, biological yield and harvest index. The application of USG showed the highest grain yield (8.64 t ha^{-1}) and the lowest spikelet sterility (%) than any of nitrogen and other sources of nitrogen treatments. All the studied characters except harvest index varied significantly due to varieties. Among the varieties, BRRI dhan29 out yielded Heera, BADC SL8H and BRRI dhan58 by 0.85, 1.13 and 1.98 t ha^{-1}, respectively which is mainly attributable to the highest number of grains panicle^{-1} (98.57) and markedly lower level of spikelet sterility (11.13 %). The combination of the USG application and BRRI dhan29 had the higher performance in terms of producing the highest grain yield by significant reduction of spikelet sterility (%) among the interaction effects.

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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	=	Diammonium phosphate
DMA	=	Dry matter accumulation
DMRT	=	Duncan' 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	=	Murate 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 I

INTRODUCTION

Rice is a staple food for more than 3 billion people in the world (IRRI 2005), and it is grown in wide range of climatic zones to nourish the mankind. It is the staple food for more than two billion people in Asia and many millions on Africa and Latin America. About 95% of the world rice is consumed in Asia (Rotshicld, 1996). It is one of the most important cereal crops of the world, grown in wide range of climatic zones, to nourish the mankind (Chaturvedi, 2005). The area and the production of rice crop in Bangladesh are 11.35 million hectares and 31.98 million metric tons respectively (BBS, 2011).

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 31.98 million tons to feed her 153 million people. 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. 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, if it follows by the current trend. 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 needs to be increased from the present 2.44 to 3.74 t ha^{-1} (BRKB, 2007). 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 agronomic management practices to the existing varieties to achieve their potential yield is important. So to develop the high yielding varieties, Japan initiated first breeding programme in 1981 (Wang, 2001). In 1989, IRRI started super rice breeding programme to give up to 30% more yield (1.3-1.5 t ha^{-1}) than the current modern high yielding plant types (IRRI. 1993) Generally the yield of hybrid rice varieties is 10%-15% more than the improved inbred varieties. It has great potentiality for food security of poor countries where arable land is scarce, population is expanding and labor is cheap. In our country, BRRI has started breeding programme for the development of super high yielding varieties with large panicles and high yield potentialities.

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. Nitrogen not only enhances the yield of rice but also reduces the spikelet sterility. 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 status 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. The use of USG and Mixed fertilizer has often been advocated to minimize nitrogen losses because organic manures act as a great source of plant nutrients, especially of N, P, K and S, and also prevents leaching loss of the nutrients. 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 urea super granule @ 120 kg N ha^{-1} 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%. Application of heavy nitrogen increases tillering and spikelet number per plant and this, in turn, reduces the number of engorged pollen grains per anther, leading into increased spikelet sterility (Gunawardena *et al.*, 2003). Hence, this study was undertaken to evaluate the response of different varieties with prilled urea, Mixed NPK and USG for obtaining optimum yield and to reduce spikelet sterility of rice. So, the present experiment was taken in Boro season with the following objectives:

i.) To assess the suitable nitrogen sources for optimum growth and yield by reducing spikelet sterility in boro rice,

ii.) To find out suitable variety with lower spikelet sterility and higher yield of boro season, and

iii.) To determine the interaction effect of nitrogen sources and variety on the spikelet sterility and yield of boro rice.

Chapter II

REVIEW OF LITERATURE

Higher yield of any crops depends on manipulation of variety, environment and agronomic practices (planting density, fertilizer, irrigation etc). Among the above factors variety and N-fertilization are more responsible for the growth and yield of rice. High yielding varieties (HYV) are generally more responsive to nitrogen application as they produce higher yield with increasing nitrogen levels up to a certain end. The available relevant reviews of the related works done in the recent past have been presented and discussed in this chapter.

2.1 Effect of Nitrogen

2.1.1. 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 92.81cm when rice plants were fertilized with the highest nitrogen level of 70 kg ha^{-1}. On the contrary, the lowest value of plant height was recorded to be 80.21 cm when rice plants received no nitrogen fertilizer.

Zohra (2012) conducted an experiment with 3 different T. *aman* varieties under variable rates of USG fertilizer and highest plant height was recorded when 3 pellets of USG were applied within four adjacent hills of rice.

Rahman (2006) found that effect of depth of placement of USG significantly influenced all growth characters and the yield attributes and yield except plant height.

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).

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.

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

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.

Mishra *et al*. (2000) carried out a field experiment in 1994-95 in Orisha, India and 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.

Ahmed *et al.* (2000) observed that among 5 levels, 80 kg N ha^{-1} gave the highest plant height (155.86cm) and the height decreased gradually with decreased levels of nitrogen fertilizer application. Plants receiving no nitrogenous fertilizers were significantly shorter than that of other treatments. They also stated that nitrogen influences cell division and cell enlargement and ultimately increases plant height.

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 (127.9cm) of rice and total number of tillers $hill^{-1}$ (16.3).

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 112.1cm 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.

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

Idris and Matin (1990) noticed that the maximum number of tiller 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 tiller tillers $hill^{-1}$ was obtained from the control treatment (0 kg ha^{-1}).

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

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}.

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 USG applied@55kg Nha^{-1}.

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)

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.

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.

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) 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.

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

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

2.1.3 Grains panicle^{-1} (no.)

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

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

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.

2.1.4 Spikelet sterility (%)

BRRI (1976) undertook an investigation to observe the sterility level of a rice variety Mala. They observed that the application of nitrogen at panicle initiation stage increased the spikelet number as well as yield with high sterility (%).

Gunawardena *et al* (2003) observed in a green house experiment that N increased tillering and spikelet number per plant of rice and this, in turn, reduced the number of engorged pollen grains per anther, leading into increased spikelet sterility under low temperature condition.

Pandey and Khan, (1969) observed that the number of unfilled spikelets and sound grains per plant of rice increased with higher levels of nitrogen fertilization. The cultivar IRB produced more unfilled spikelets than Kalimpong but at the same time it produced higher number of sound grains. A positive correlation was observed between the number of spikelet sterility and the number of fertile tillers (0.84), number of sound grains (0.97), grain weight per plant (0.98) and dry matter per plant (0.68).

Ota and Yamada (1965) conducted an experiment using two varieties of rice M-4 and Murungkayan-302 with different application of nitrogen at different stages of growth. They showed that without nitrogen fertilization at growth period and application of nitrogen at reproductive stage caused serious sterility.

2.1.5 Weight of 1000-grain (g)

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.

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 (24.70g) was obtained with USG applied at 55kg N ha^{-1} and lowest (24.09g) 1000- grain weight was observed at 110 kg N as PU.

2.1.6 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.

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.

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

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 .

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}.

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.

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-gram.

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.

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.

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.

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.

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 (6.11t ha^{-1}) was produced by 110kgN ha^{-1}as USG.

Quayum and Prasad (1994) conducted field trial during *Kharif* season involving 5 rates of N (0, 35.5, 75, 112.5 and 120 kg 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 rain fed lowland rice.

Das (1989) reported that the dry matter yield, concentration of $NH4^+$ 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.

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).

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

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.

2.2. 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

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.

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.

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.

Myung (2005) worked with four different panicle types of nee 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 Dong]ml 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 Dcsan467 of rice varieties gave high primary rachis branches than Sindongjinbyeo and DongjinNo.l 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. Result 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.

BRRl (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.

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.

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 (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.

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.

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, BRII, BR 14 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 (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),

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}.

Shamsuddin *et al.* (1988) conducted an experiment with nine varieties of nee 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 *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 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).

Kamal *et al.* (1988) conducted a field trial with three rice cv. BR3, IR20 and Pajam2 and observed that BR3 gave the highest yield and Pajam 2 gave the lowest yield.

Hossain (2007) conducted an experiment during the *aman* season of 2006 with five varieties of transplant *aman* rice (viz., BRRI dhan3O, BRRI dhan32, BRRI dhan34, BRRI dhan39, and Nizershail). The varieties showed significant variation on all the yield contributing characters and yield except-panicle length.

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

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 dhan.29 (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 dhan.29, Tepiboro 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 1t 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, 27.7g, 25.2g and 25.0g, 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, BR1O, BR11, Challish and Nizersail produced yields of 4.38, 3.12, 3.12, 3.12 and 2.70 t ha^{-1} respectively.

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

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 nee 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 nee 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 ha^{-1}) among them

Munoz *et al.* (1986) noted that IR8025A hybrid rice cultivar produced an average yield of 7.11 ha^{-1} which was 16% higher than the commercial variety Oryzica Yacu-9.

BRRI (1995) conducted an experiment with nee cv. BR10, BR22, BR23 and Rajasail (de) 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

BINA (1992) reported in a field experiment that under transplanting conditions the grain yield of BINA13 and B1NA19 were 5.39 and 5.57 t ha^{-1}, respectively and maturity of the above strains were 160 and 166 days, respectively.

2.2.3 Spikelet Sterility (%)

BRRI (1994) also reported that among the four varieties of rice viz. BR14, Pajam, BR5 and Tulsimala, BR14 produced the highest tillers hill^{-1} and the lowest number of spikelet panicle^{-1} respectively They also observed that the finer the grain size, the higher was the number of spikelet panicle^{-1}.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental period

The experiment was conducted at the Agronomy Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the Boro season of December 2012 to May 2013. Details of materials and methods used in this experiment are given below:

3.2 Description of the Experimental Site:

3.2.1 Geographical location

The experimental site is geographically situated at 23°41N latitude and 90°22$^{/}$E longitude at an altitude of 8.6 meter above sea level. 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 III.

3.2.3 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series (AEZ 28). The land was located 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 the Soil Resource and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix IV.

3.3 Experimental details

3.3.1 Treatments

Two sets of treatments included in the experiment are as follows:

Factor A: Nitrogen Source - 4

i) No nitrogen (T_o)
ii) BRRI recommended dose of prilled urea (T_1)
iii) Recommended dose of mixed NPK (T_2)
iv) BARC recommended dose of urea super granule(USG) (T_3)

The BRRI recommended dose of urea in Madhupur tract (AEZ 28) for hybrid and inbred varieties are 150 and 120 kg ha^{-1} respectively. BARC recommended dose of urea super granule (USG) is 66 kg ha^{-1}. Mixed NPK dose was 30-35 kg ha^{-1}.

Factor B: Variety - 4

i) Heera

ii) BADC SL8H

iii) BRRI dhan58

iv) BRRI dhan29

3.3.2 Experimental design

The experiment was laid out following split plot design with three replications where main plot was for Treatment (Factor A) and subplot was for variety (Factor B). The size of the unit plot was 4 m x 2.5 m. The spaces between replications and unit plots were 1.0m and 0.50m, respectively. For better understanding the layout of the experiment has been presented in Appendix II.

3.4 Crop / Planting Material

High yielding variety BRR1 dhan29 and BRRI dhan58 and hybrid variety BADC SL 8H and Heera of boro season were used as test crop. BRRI dhan29 and BRRI dhan58 were developed by Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The grains of BRRI dhan29 and BRRI dhan58 are medium-slender with light-golden husks. BADC SL8H was introduced in Bangladesh Agricultural Development Corporation (BADC) and Heera was introduced by Supreme Seed Company Ltd. from China. The grains of BADC SL 8H are golden, slightly slender and comparatively larger in size. The grains of Heera are medium, thick with light golden husks.

3.5 Crop Management

3.5.1. Seed Collection

Healthy seeds of BRRI dhan29 and BRRI dhan58 were collected from the Breeding Division, BRRI, Joydebpur, Gazipur. BADC SL8H and Heera were collected from Bangladesh Agricultural Development Corporation (BADC) and Supreme Seed Company Ltd. respectively.

3.5.1.2 Sprouting of seed

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 Agronomy farm of SAU. Each variety of seed was sown in separate beds. The nursery beds were prepared by puddling with repeated ploughing followed by laddering. Having 40 and 30 days old seedlings of BRRI dhan29 and hybrid varieties, respectively the sprouted seeds of BRRI dhan29 were sown 10 days earlier than the hybrid varieties. 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 opened with a tractor drawn disc plough 15 days before transplanting. The land was puddled thoroughly by repeated ploughing and cross ploughing with a power tiller subsequently leveled by laddering. The field layout was made on December 24, 2012 according to experimental specification immediately after final land preparation Weeds and stubble were cleared off from individual plots and finally plots were leveled properly by wooden plank so that no water pocket could remain in the puddled field.

3.5.4 Fertilizer application

Triple superphosphate, muriate of potash, gypsum and zinc sulphate were applied at the rate of 148-178-100-15 kg ha^{-1}, respectively except in the T_2 treatment plot (Adhunik Dhaner Chas ,2013). There were two rates for T_1 treatment plot of urea 260 and 325 kg ha^{-1} for inbred and hybrid rice, respectively. Full dose of triple super phosphate, muriate of potash, gypsum, zinc sulphate and cow dung (10 t ha^{-1}) were applied as basal dose at final land preparation of individual plots. Urea was applied to T_1 treatment plot in three equal splits on 15, 30 and 55 days after transplanting (DAT) for BRRI dhan29 and BRRI dhan58 and in case of hybrid varieties, the splits were 0, 21 and 42 DAT, respectively.

3.5.5 The uprooting of seedlings

Seedlings of 40 for BRRI dhan29 and BRRI dhan58 and 30 days old hybrid varieties, respectively were uprooted from the nursery beds carefully.

3.5.6 Transplanting

Seedlings were transplanted on December 25, 2012 in the well-puddled experimental plots. Spacings were given 25cm $\times$ 15cm for BRRI dhan29 and BRRI dhan58 and 20cm $\times$ 15cm for hybrid 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 hybrid varieties were transplanted $hill^{-1}$.

3.5.7 Inter-cultural operations

3.5.7.1 Gap filling

Seedlings of some hills died off and these were replaced by gap filling after one week of transplanting with seedlings from the same source.

3.5.7.2 Weeding

To minimize weed infestation, manual weeding through hand pulling was done three times during entire growing season. The first weeding was done at 16 DAT followed by first top dressing of urea. The second and third weeding were done at 31 DAT and 56 DAT followed by second and third top dressing of urea.

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 and leaf hopper to some extent which was successfully controlled by applying three times of Diazinon on 14 and 25 March, 2013 and one times of Ripcord on 02 April 2013. Crop was protected from birds during the grain filling period.

3.5.8 Harvesting and processing

The crop of each plot was harvested separately on different dates at full maturity when 80% of the grains become golden yellow in color. Hills from the central 4 m^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 Recording Data

Data were collected on the following parameters-

3.6.1 Growth parameter

1. Plant height at 20 days interval starting from 30 DAT
2. Tillers $hill^{-1}$ (no.) with 20 days interval starting from 30 DAT

3.6.2 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. Spikelet sterility (%)
   i. Sterility at the top portion of panicle (%)
   ii. Sterility at the middle portion of panicle (%)
   iii. Sterility at the bottom portion of panicle (%)
9. Weight of 1000-grains (g)
10. Grain yield (t ha-^{1})
11. Straw yield (t ha-^{1})
12. Biological yield (t ha-^{1})
13. Harvest Index (t ha-^{1})

3.7 **Data Recording Procedure**

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

3.7.1 Growth characters

3.7.1.1 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.

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

Number of tillers hill^{-1} was counted at 20 days interval starting from 25 DAT

3.7.2 Yield and yield components

The sample plants of 10 hills were harvested randomly from each plot and tagged them separately. Data on yield components were collected from the sample plants of each plot.

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

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

3.7.2.2 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.

3.7.2.3 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

3.7.2.4 Sterility (%)

Using the following formula, the percentage of sterility was calculated.

$$\text{Sterility (\%)} = \frac{\text{Number of sterile spikelet of the panicle}}{\text{Number of total spikelet of the panicle}} \times 100$$

3.7.2.5 Sterility at the top, middle and bottom portion of panicle (%)

From the sample hills, each panicle was divided into three equal parts by eye estimation. The apical, middle and lower parts were termed as top, middle and bottom portion of panicle, respectively. Number of sterile spikelets was counted from all the portions separately and then percentage of sterility (at the three portions) was calculated using the following formulae:

$$\text{Sterility (\%) at top portion} = \frac{\text{Sterile spikelets in the top portion of panicle}}{\text{Total number of spikelets in the whole panicle}} \times 100$$

$$\text{Sterility (\%) at mid portion} = \frac{\text{Sterile spikelets in the middle portion of panicle}}{\text{Total number of spikelets in the whole panicle}} \times 100$$

$$\text{Sterility (\%) at bottom portion} = \frac{\text{Sterile spikelets in the bottom portion of panicle}}{\text{Total number of spikelets in the whole panicle}} \times 100$$

3.7.2.6 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.

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

Grains obtained from the central $4m^2$ areas of each plot were sun dried, cleaned, weighed carefully and adjusted at 14% moisture level. Dry weights of grains of each plot were converted into t ha^{-1}.

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

Straw obtained from the central $4m^2$ area of each plot were sun dried, cleaned, weighed separately and finally converted into t ha^{-1}.

3.7.2.9 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})

3.7.2.10 Harvest index (%)

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

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

3.8 Statistical Analysis of the Data

All the collected data were analyzed following the analysis of variance (ANOVA) technique and the mean differences were adjudged at 5% level of probability using DMRT with a computer operated program named MSTAT-C.

Chapter IV

RESULT AND DISCUSSION

Data obtained from the study of nitrogen sources on spikelet sterility and yield of boro rice have been presented and discussed in this chapter. Treatment effects of nitrogen and variety on all the studied parameters have been presented in Table 1 to Table 14 and Figure 1 to Figure 9. Summary of analysis of variance (mean squares) for yield contributing characters and yield performance of boro rice as influenced by nitrogen sources and variety have been presented in Appendices.

4.1. Growth Performance

4.1.1 Plant height (cm)

4.1.1.1 Effect of nitrogen source

Effect of nitrogen dose showed a significant variation on plant height for all growth stages except 45 DAT (Table 1). At harvest, the tallest plant (97.68 cm) was recorded from USG treatment and the shortest plant (86.61cm) was recorded from the control condition 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

Variety exhibited significant difference on plant height at different growth stages after 65 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 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 at different days after transplantation of boro rice

Sources of Nitrogen	**Days after transplanting (DAT)**					
	25	**45**	**65**	**85**	**105**	**At Harvest**
No Nitrogen	15.33 b	45.4	63.75 b	76.96 b	84.50 b	86.61 b
Prilled Urea	16.17 ab	46.74	65.38 b	79.61 b	87.35 b	88.67 b
Mixed NPK	16.79 ab	48.56	69.19 ab	84.22 a	92.79 a	94.56 a
USG	17.53 a	50.51	72.44 a	87.01 a	95.81 a	97.68 a
$S_{\bar{x}}$ Value	**0.57**	**NS**	**2.17**	**1.39**	**1.5**	**1.56**
CV (%)	**11.68**	**11.76**	**9.97**	**14.72**	**9.66**	**8.14**

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

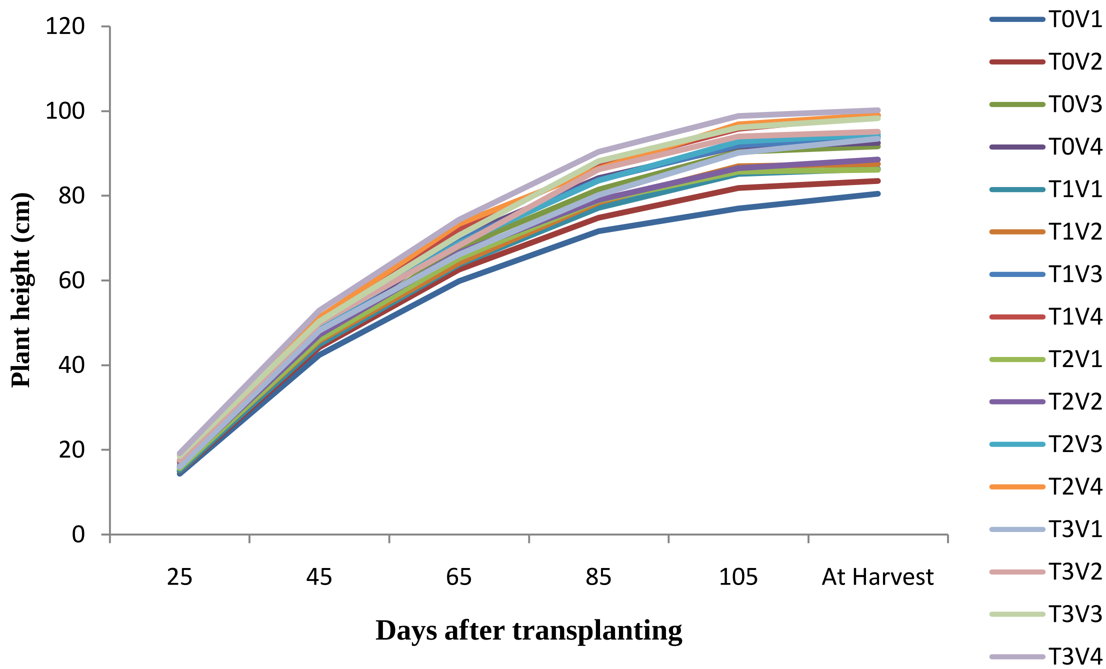
Table 2. Effect of variety on plant height at different days after transplantation of boro rice

Variety	**Days after transplanting (DAT)**					
	25	**45**	**65**	**85**	**105**	**At Harvest**
Heera	14.84	44.84	65.08	78.01 b	85.25 c	87.04 c
SL 8H	16.07	47.62	67.36	81.61 b	89.96 b	91.66 b
BRRI dhan58	17.08	48.45	68.47	81.94 b	90.47 b	92.05 b
BRRI dhan29	17.85	50.31	69.85	86.23 a	94.79 a	96.77 a
$S_{\bar{x}}$ Value	NS	NS	NS	1.34	1.21	1.32
CV (%)	9.94	12.46	11.28	9.32	12.26	11.74

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

4.1.1.3 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 increasing rate was much slower up to 105 DAT. However, the tallest plant (100.2 cm) was found in the USG × BRRI dhan29 interaction followed by Mixed NPK × BRRI dhan29 (99.04 cm) interaction, USG × BRRI dhan29 (98.97 cm) interaction and USG × BRRI dhan58 (98.32 cm) interaction at harvest. The shortest plant (80.50 cm) was found in no nitrogen × Heera interaction at harvest.



Here,

V_1=Heera	V_2=SL8H	V_3=BRRI dhan58	V_4=BRRI dhan29
T_0=Control	T_1=Prilled Urea	T_2=Mixed Urea	T_3=USG

Fig. 1. Interaction Effect of nitrogen sources and variety on plant height of boro rice at different days after transplantation of boro rice. ($S\bar{x}$= 1.14,2.15,2.17, 2.79, 3.01 and 3.12 for 25,45, 65, 85,105 and At Harvest.)

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 mixed NPK which was statistically similar with the application of USG and Prilled urea. The lowest number of tillers (1.36) hill^{-1} was obtained due to control treatment of no nitrogen.

BRRI (2006), Ahsan (1996), Kumar *et al* (1995) and ldris and Matin (1990) reported similar result that supports the present findings.

At 45 days, the highest number of tillers hill^{-1} was (8.25) obtained with the application of USG which is 12% 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 (14.90) obtained with the application of USG which is statistically dissimilar with the application of mixed NPK and prilled urea. 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 17.60 to 12.23. The highest number of tillers hill^{-1} was (17.60) obtained with the application of USG which is 31% higher than the lowest number of tillers (12.23) hill^{-1} obtained due to control treatment of no nitrogen. Other two sources mixed NPK (16.32) and prilled urea (16.07) are statistically similar.

At 105 days, the number of tillers hill^{-1} is ranged from 17.14 to 11.54. The highest number of tillers hill^{-1} was (17.14) obtained with the application of USG which is 33% higher than the lowest number of tillers (11.54) hill^{-1} obtained due to control treatment of no nitrogen. Other two sources mixed NPK (15.84) and prilled urea (15.51) 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 (16.83) obtained with the application of USG which is 33% higher than the lowest number of tillers (1.79) hill^{-1} obtained due to control treatment of no nitrogen. Other two sources mixed NPK (15.55) and prilled urea (15.29) 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 as USG.

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

Source of Nitrogen	Days after transplanting (DAT)					
	25	45	65	85	105	At Harvest
No Nitrogen	1.39 b	7.28 c	11.81 d	12.23 c	11.54 c	10.79 c
Prilled Urea	1.73 a	7.71 bc	12.51 c	16.07 b	15.51 b	15.29 b
Mixed NPK	1.82 a	7.97 ab	14.06 b	16.32 b	15.84 b	15.55 b
USG	1.79 a	8.25 a	14.90 a	17.60 a	17.14 a	16.83 a
S$\bar{x}$ Value	**0.08**	**0.17**	**0.22**	**0.29**	**0.26**	**0.23**
CV (%)	**15.44**	**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.

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 16.45 to 14.78. The highest number of tillers hill^{-1} (16.45) was produced by BRRI dhan29 which is 11% higher than Heera (14.78) hill^{-1}. Among the varieties, BRRI dhan29 and BRRI dhan58 produced statistically similar number of tillers hill^{-1} whereas BRRI dhan58 (15.77), Heera (14.78) and SL 8H (15.22) 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 (16.15) whereas the lowest number of tillers $hill^{-1}$ was produced by Heera (13.83).

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 $hill^{-1}$(16.03) was produced by BRRI dhan29 which is 17% higher than the lowest one Heera (13.35) $hill^{-1}$. BRRI dhan58 (14.66) and SL 8H (14.42) 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.

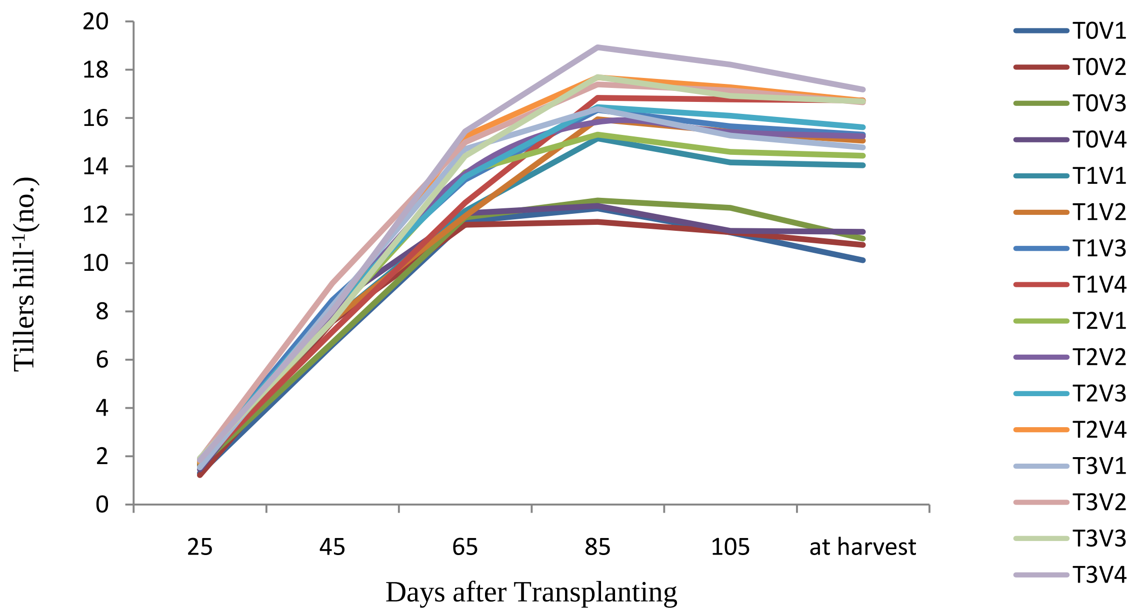
4.1.2.3 Interaction effect of nitrogen sources and variety

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 $hill^{-1}$ (18.93) was found in the interaction of the USG $\times$ BRRI dhan29 treatment followed by USG $\times$ BRRI dhan58 (17.70) interaction treatment and mixed NPK $\times$ BRRI dhan29 (17.68) interaction treatment. The lowest number (11.70) of tillers $hill^{-1}$ was found in the interaction of no nitrogen $\times$ SL8H.

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
Heera	1.57	7.55	13.09	14.78 b	13.83 d	13.35 c
SL 8H	1.68	8.07	13.05	15.22 b	14.81c	14.42 b
BRRI dhan 58	1.81	7.73	13.34	15.77 ab	15.25 b	14.66 b
BRRI dhan 29	1.69	7.86	13.81	16.45 a	16.15 a	16.03 a
S$\bar{x}$ Value	**NS**	**NS**	**NS**	**0.31**	**0.09**	**0.3**
CV (%)	**10.14**	**9.52**	**9.87**	**10.02**	**10.09**	**7.42**

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=Heera	V_2=SL8H	V_3=BRRI dhan58	V_4=BRRI dhan29
T_0=Control	T_1=Prilled Urea	T_2=Mixed Urea	T_3=USG

Fig. 2. Interaction Effect of Nitrogen Sources and Variety on tiller number hill^{-1} of boro rice at different days after transplantation of boro rice. (**S$\bar{x}$=**0.15, 0.35, 0.45, 0.57, 0.53 and 0.46 for 25,45, 65, 85,105 and At Harvest.

4.2 Yield components of boro rice

4.2.1 Effective tillers hill^{-1}

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, prilled urea and mixed NPK showed intermediate and similar level of effective tillering and its peak with USG. The highest number of effective tillers (15.81) hill^{-1} was obtained due to application of USG and the lowest number of effective tillers was obtained (9.25) hill^{-1} was obtained due 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.

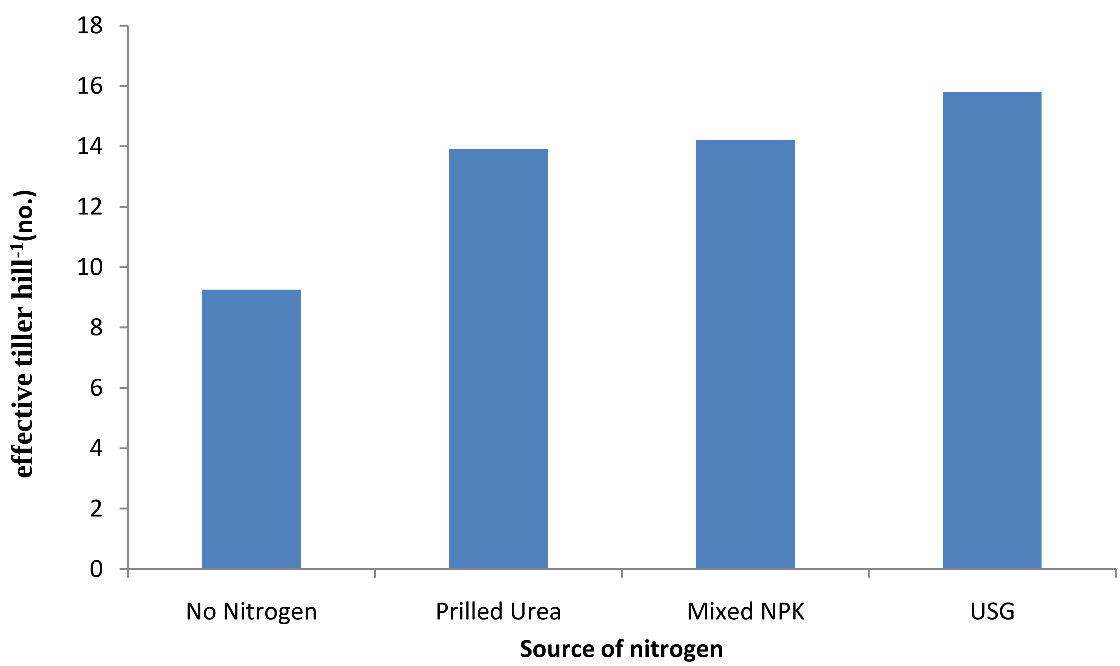


Fig. 3. Effect of nitrogen sources on effective tiller hill^{-1} of boro rice. ($S\bar{x}$=0.16)

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} (14.25) was found in BRRI dhan29 followed by BRRI dhan58 (13.55) and SL8H (13.25). The lowest number of effective tillers hill^{-1} was obtained in Heera. The result indicated that BRRI dhan29 produced 4.91%, 7.01% and 14.66% higher effective tillers hill^{-1} than BRRI dhan58, SL8H and Heera 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.

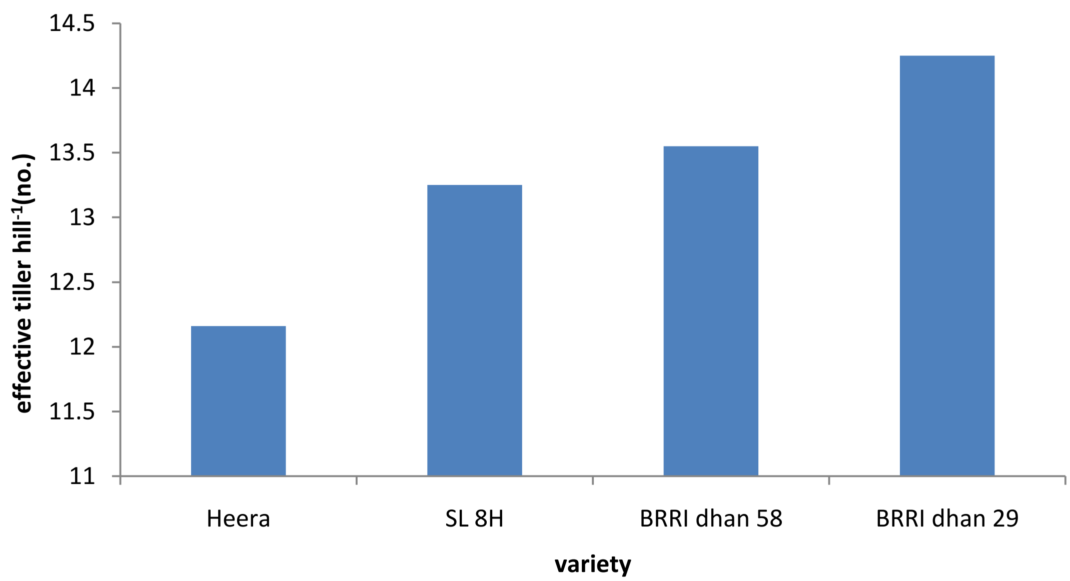


Fig. 4. Effect of variety on effective tiller hill^{-1} of boro rice. ($S\bar{x}$=0.24)

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 (14.17-16.93) than no nitrogen ranged (8.56 -9.87). The highest number of effective tillers hill^{-1} (16.93) was counted in the interaction of USG$\times$BRRI dhan29 treatment which was statistically similar with USG$\times$SL8H treatment and USG$\times$BRRI dhan58 treatment. The lowest number of effective tillers hill^{-1} (8.56) was counted in no nitrogen$\times$Heera interaction treatment.

4.2.2 Non-effective tillers hill^{-1}

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} (0.64) was found due to the application of USG by BARC recommended dose i.e. 66 kg N Ha^{-1}. prilled urea (1.46) and mixed NPK (1.39) produced the statistically similar non-effective tillers hill^{-1}.

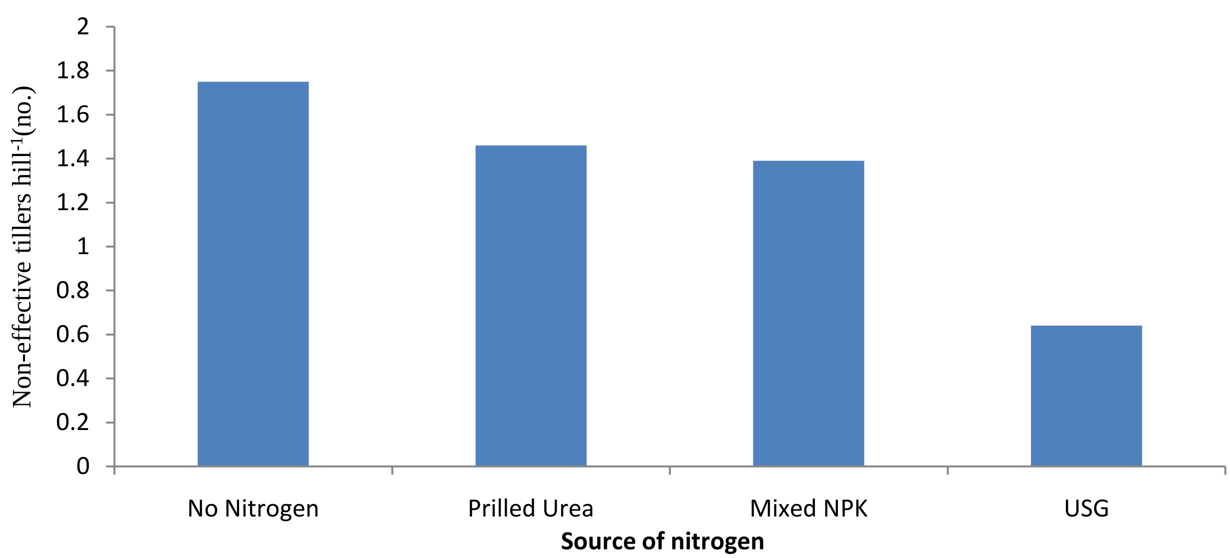


Fig. 5. Effect of nitrogen sources on non-effective tiller hill^{-1} of boro rice. ($S\bar{x}$=0.03)

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 $hill^{-1}$ (1.78) was obtained in BRRI dhan29 followed by Heera (1.18) and Sl8H (1.17). The lowest number of non-effective tillers $hill^{-1}$ was produced by BRRI dhan 58 (1.11) which is statistically similar with Heera (1.18) and Sl 8H (1.17).

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 no nitrogen $\times$ BRRI dhan29 and the lowest number of non-effective tillers $hill^{-1}$ (0.52) was recorded from the interaction of USG $\times$ SL8H.

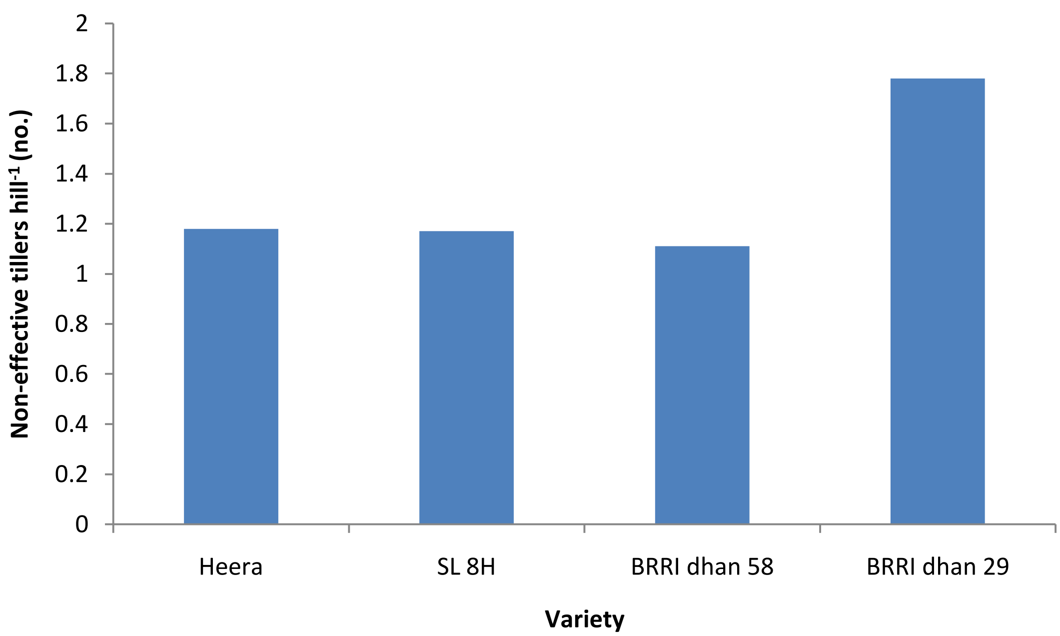


Fig. 6. Effect of variety on non-effective tiller $hill^{-1}$ of boro rice. ($S\bar{x}$=0.03)

4.2.3 Filled grains panicle^{-1}

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 USG. USG produced 10.12 % and 11.04 % higher number of grains panicle^{-1} number of grains panicle^{-1} than mixed NPK and prilled urea 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}.

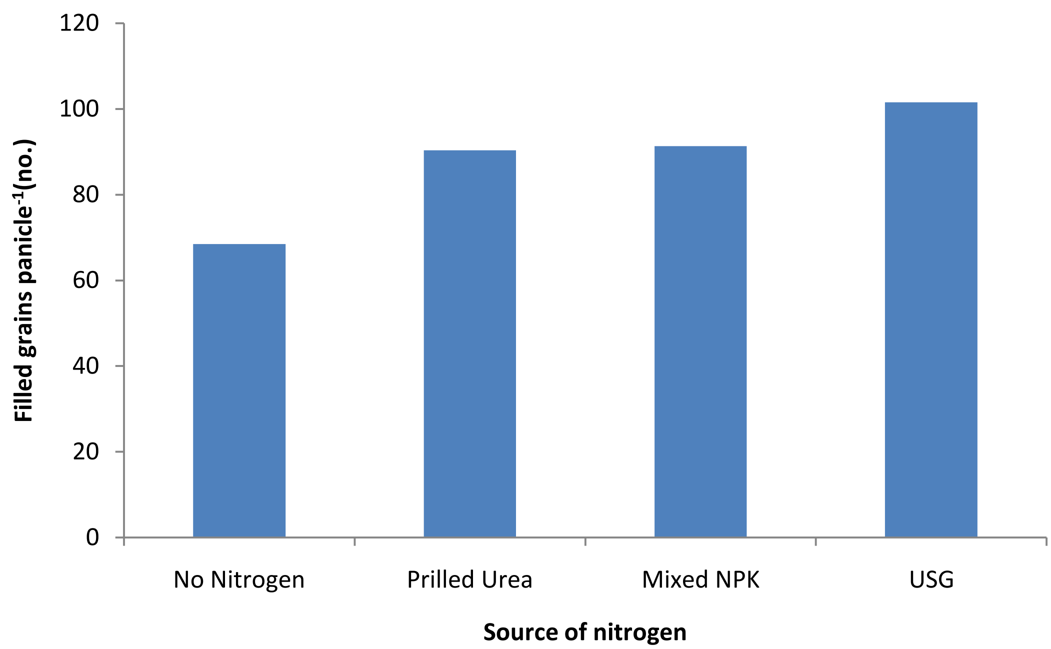


Fig. 7. Effect of nitrogen sources on filled grain panicle^{-1} boro rice. ($S\bar{x}$=2.1)

4.2.3.2 Effect of variety

Variety differed significantly in production of number of grains panicle^{-1}(Fig. 8). The highest number of grains panicle^{-1} (98.57) was observed in BRRI dhan29 followed by BRRI dhan58 (86.33) and Heera (84.69). The lowest number of grains panicle^{-1} (82.12) was obtained in SL 8H. The result showed that BRRI dhan29 produced 12.41%, 14.08% and 16.68% higher grains panicle^{-1} than BRRI dhan58, Heera and SL8H respectively.

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 USG with all the varieties showed higher number of grains panicle^{-1} than the interactions comprised with no nitrogen

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

Variety	Filled grains panicle^{-1}
Heera	84.69 b
SL 8H	82.12 c
BRRI dhan 58	86.33 b
BRRI dhan 29	98.57 a
Sx Value	2.07
CV (%)	9.93

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

and prilled urea with all the varieties (Table 13). The highest number of filled grains panicle^{-1} (115.12) was noted in the interaction of USG $\times$ BRRI dhan29 treatment followed by prilled urea $\times$ BRRI dhan29 (105.12) interaction treatment, Mixed NPK $\times$ BRRI dhan29 (103.16) interaction treatment and USG $\times$ BRRI dhan58 (101.53) treatment. The lowest number of grains panicle^{-1} (63.2) was obtained in the interaction treatment of no nitrogen $\times$ SL8H.

4.2.4 Unfilled grains panicle^{-1}

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 (5.97) number of unfilled grain was obtained due to the application of USG followed by (10.98) Mixed NPK and (11.84) Prilled urea. The highest (14.7) number of unfilled grain panicle^{-1} was obtained due to no nitrogen i.e. controlled condition. The result was supported by BRRI (2006) that no nitrogen produced the highest number of unfilled grains panicle^{-1} in boro season.

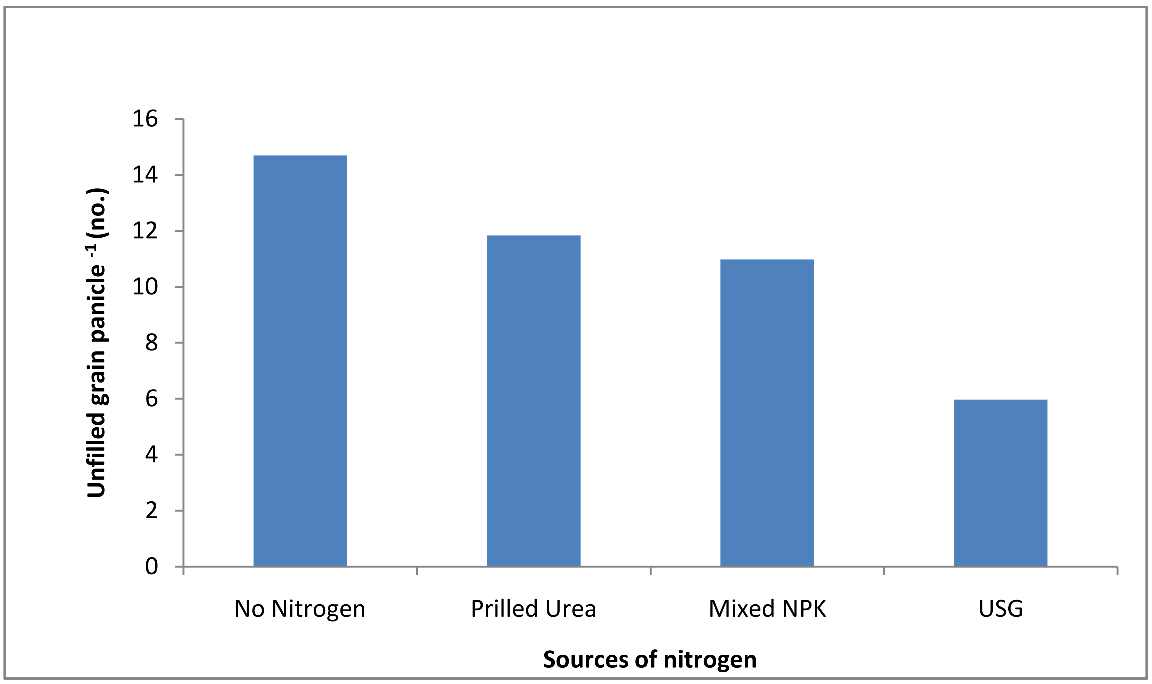


Fig. 8. Effect of nitrogen sources on unfilled grain panicle^{-1} boro rice. ($S\bar{x}$=0.5)

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} (13.71) was obtained in BRRI dhan29 followed by BRRI hybrid dhan58 (12.77) and SL 8H (9.49). The lowest number of unfilled grains panicle^{-1} (7.51) was obtained in

Heera. BINA (1993) observed the similar result that the production of unfilled grains panicle differed with variety to variety.

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 4.97-19.69) 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 no nitrogen $\times$ BRRI dhan29 interaction and the lowest number of unfilled grains panicle^{-1} (4.97) was counted in the interaction of USG $\times$ BRRI dhan29.

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

Variety	Un-filled grains panicle^{-1}
Heera	7.51 d
SL 8H	9.49 c
BRRI dhan 58	12.77 b
BRRI dhan 29	13.71 a
$S\bar{x}$ Value	0.46
CV (%)	12.58

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

4.2.5 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 (22.67 g) of 1000-grains was recorded due to application of USG followed by mixed NPK (22.28 g). The lowest weight (21.50 g) of 1000-grain was recorded from the No 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 (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

Source of nitrogen	**Weight of 1000 grains (g)**
No Nitrogen	21.50 c
Prilled Urea	21.95 bc
Mixed NPK	22.28 ab
USG	22.67 a
Sx Value	**0.16**
CV(%)	**8.49**

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

4.2.5.2 Effect of Variety

Variety had significant effect on the weight of 1000-grains. The highest weight (23.05 g) was observed in SL8H followed by Heera (22.51 g) and the lowest weight (20.77 g) was observed in BRRI dhan29 (Fig. 9). The result showed that SL8H produced 9.89%, 4.2% and 2.3% heavier seed than BRRI dhan29 BRRI hybrid dhan58 and Heera respectively.

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 (23.8 g) was obtained in the interaction of USG × Heera treatment that was statistically similar with the interaction of USG × SL8H (23.49g) treatment and mixed NPK × SL8H (23.15 g) treatment. The minimum weight of 1000-grains (20.40 g) was obtained in the interaction of no nitrogen × BRRI dhan29 treatment. The result also showed that SL8H produced higher level of 1000-grains weight than other interactions irrespective of nitrogen levels.

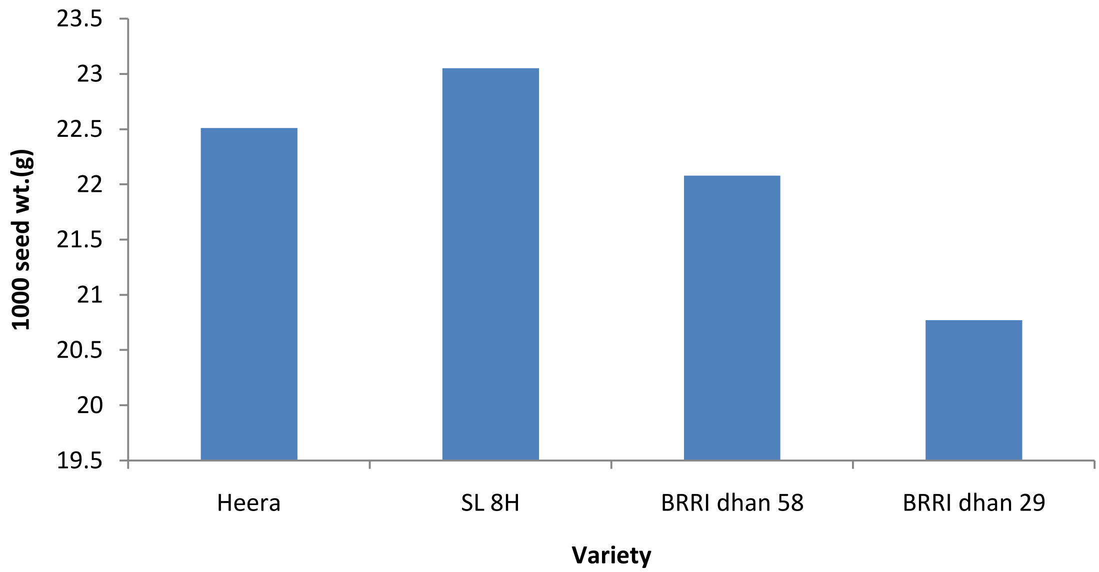


Fig. 9. Effect of variety on weight of 1000 grains of boro rice. ($S\bar{x}$=0.18)

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

Interaction Nitrogen source × Variety	Effective tillers^{-1} (no.)	Non-Effective tillers^{-1} (no.)	1000 Seed wt. (g)	Filled Grain Panicle^{-1}	Un-filled Grain Panicle^{-1}
No Nitrogen × Heera	8.56 j	1.56 cd	21.66 e-g	73.13 h	9.26 e
× SL 8H	9.02 ij	1.73 c	22.53 b-e	63.2 i	12.98 cd
× BRRI dhan58	9.55 ij	1.46 de	21.42 f-h	66.68 i	16.88 b
× BRRI dhan29	9.87 i	2.28 a	20.40 h	70.87 i	19.69 a
Prilled urea × Heera	12.76 h	1.29 ef	21.77 d-g	85.39 f	8 f
× SL 8H	13.78 fg	1.28 ef	23.03 a-c	83.12 fg	9.96 e
× BRRI dhan58	14.13 d-g	1.18 f	22.18 c-f	87.78 ef	13.67 c
× BRRI dhan29	15.03 c-e	2.09 b	20.82 gh	105.12 b	15.75 b
Mixed NPK × Heera	13.15 gh	1.27 ef	22.81 a-d	87.12 ef	7.16 g
× SL 8H	14.07 e-g	1.16 f	23.15 a-c	85.63 f	9.64 e
× BRRI dhan58	14.47 d-f	1.16 f	22.24 c-f	89.31e	12.64 d
× BRRI dhan29	15.17 b-d	1.98 b	20.92 gh	103.16 bc	14.48 bc
USG × Heera	14.17 d-g	0.62 gh	23.80 a	93.12 c-e	5.63 h
× SL 8H	16.13 ab	0.52 h	23.49 ab	96.54 d	5.38 h
× BRRI dhan58	16.03 a-c	0.66 gh	22.48 b-e	101.53 c	7.93 g
× BRRI dhan29	16.93 a	0.77 g	20.93 gh	115.12 a	4.97hi
$S\bar{x}$	**0.33**	**0.06**	**0.32**	**4.2**	**1.02**
CV (%)	**9.48**	**10.72**	**7.46**	**11.12**	**10.46**

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 Spikelet Sterility

4.2.6.1. Total Spikelet Sterility (%)

4.2.6.1.1 Effect of nitrogen sources

Nitrogen source exerted significant variation on spikelet sterility (%) (Table 9) Result showed that sources of nitrogen reduced the spikelet sterility (%) significantly. The spikelet sterility (%) was lowest (5.04) due to the application of USG and the highest spikelet sterility (14.92%) was observed in no nitrogen treatment i.e. control condition. USG, mixed NPK and prilled urea reduced the sterility of 9.88 %, 5.34% and 4.66%, respectively over control treatment.

4.2.6.1.2 Effect of variety

Variety exerted significant spikelet sterility (%) of rice (Table 10). BRRI dhan58 showed the highest spikelet sterility (11.71 %) compared to other tested varieties followed by BRRI dhan29 (11.13%) and SL 8H (9.65%) The lowest spikelet sterility was found in Heera (7.31%). The result indicated that Heera showed 4.4%, 3.82% and 2.34% lower spikelet sterility than BRRI dhan58, BRRI dhan29 and SL8H, respectively.

4.2.6.1.3 Interaction effect of nitrogen sources and variety

The interaction between nitrogen sources and variety exerted significant effect on spikelet sterility (%) of rice (Table 11). The highest spikelet sterility (18.07 %) was observed in no nitrogen $\times$ BRRI dhan29 interaction treatment followed by the interaction no nitrogen x BRRI dhan58 (16.97 %) and the lowest sterility (4.07 %) was observed in the interaction of USG $\times$ BRRI dhan29 treatment. Table showed that Heera and SL8H when interact with USG showed lower level of sterility than other interactions.

4.2.6.2 Sterility (%) at the top, middle and bottom portion of panicle

4.2.6.2.1 Effect of nitrogen sources

Nitrogen source showed significant variation in producing spikelet sterility (%) at top, middle and bottom portion of panicle (Table 9). The results showed that the highest sterility (%) was found at bottom portion of panicle and the lowest sterility (%) was found at top portion of panicle and middle portion of panicle showed intermediate level of sterility. However, USG showed the lowest spikelet sterility (%) than mixed NPK and prilled Urea for all the portion of the panicle. In top portion of panicle, USG showed 2.19% lower sterility over control, 1.03% lower sterility than prilled Urea and 0.89% lower sterility than mixed NPK. At middle portion of panicle USG showed 3.88%, 2.47% and 1.98% lower sterility than no nitrogen, prilled Urea and Mixed NPK, respectively. That of at bottom portion of panicle showed 3.71%, 2.14% and 2.01% lower sterility over no nitrogen (control), mixed NPK and prilled Urea application respectively.

4.2.6.2.2 Effect of variety

Significant variation was observed in top, middle and bottom portion of panicle among all the varieties. For all the varieties it was observed that top portion of panicle showed the lowest spikelet sterility (%) and bottom portion of the panicle showed the highest sterility (%) (Table 10).It can be inferred from the table that BRRI dhan29 showed significantly highest spikelet sterility (%) for all potion of the panicle than the other varieties except bottom portion. In bottom portion BRRI dhan58 showed the highest spikelet sterility (%). Hybrid Heera and SL8H showed the lower level of spikelet sterility (%) than inbred varieties BRRI dhan29 and BRRI dhan58.

4.2.6.2.3 Interaction effect of nitrogen dose and variety

Significant interaction between nitrogen sources and variety was observed in producing sterility (%) at top, middle and bottom portion of panicle (Table 11).

The highest sterility (%) was found in the bottom portion and the lowest sterility (%) was found in the top portion of panicle for all the interaction treatments. In top, middle and bottom portion of panicle, the highest sterility (%) was observed in the interaction between no nitrogen (control) $\times$ BRRI dhan29 treatment followed by no nitrogen $\times$ BRRI dhan58 treatment and no nitrogen $\times$ SL8H treatment. The lowest sterility (%) of top portion, middle portion and bottom portion was observed in the interaction effect of USG $\times$ BRRI dhan29 treatment which was statistically simillar to prilled urea $\times$ SL 8 H interaction treatments.

Table 9. Effect of nitrogen sources on spikelet sterility of boro rice

Source of Nitrogen	Spikelet Sterility (%)	Spikelet sterility (%) of panicle at the		
		Top portion	Middle portion	Bottom portion
No Nitrogen	14.92 a	3.44 a	5.09 a	6.32 a
Prilled Urea	10.26 b	2.28 b	3.68 b	4.31 b
Mixed NPK	9.58 c	2.14 b	3.19 c	4.18 b
USG	5.04 d	1.25 c	1.21 d	2.61 c
S$\bar{x}$	**0.1**	**0.05**	**0.05**	**0.07**
CV (%)	**8.49**	**8.38**	**11.91**	**9.37**

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 10. Effect of variety on spikelet sterility of boro rice

Variety	Spikelet Sterility (%)	Spikelet sterility (%) of panicle at the		
		Top Portion	Middle Portion	Bottom Portion
Heera	7.31 d	1.78 c	2.70 c	2.91 c
SL 8H	9.65 c	2.10 b	3.26 b	4.27 b
BRRI dhan 58	11.71 a	2.25 b	3.41 b	5.95 a
BRRI dhan 29	11.13 b	2.98 a	3.80 a	4.29 b
S$\bar{x}$	**0.05**	**0.05**	**0.06**	**0.02**
CV (%)	**8.49**	**8.38**	**11.91**	**9.37**

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 effect of nitrogen sources and variety on spikelet sterility of boro rice

Nitrogen Source × Variety	Spikelet Sterility (%)	Spikelet sterility (%) of panicle at the		
		Top Portion	Middle Portion	Bottom Portion
No Nitrogen				
× **Heera**	9.99 f	2.25 de	3.82 e	4.05 e
× **SL 8H**	14.66 c	3.36 b	5.08 c	6.12 c
× **BRRI dhan58**	16.97 b	3.05 b	5.51 b	6.87 b
× **BRRI dhan29**	18.07 a	5.11 a	5.95 a	8.27 a
Prilled urea				
× **Heera**	7.77 h	1.71 fg	3.30 f	2.89 f
× **SL 8H**	9.64 fg	2.05 ef	3.23 f	4.46 e
× **BRRI dhan58**	11.88 d	2.34 de	4.06 de	4.48 e
× **BRRI dhan29**	11.76 d	3.03 b	4.14 d	5.41 d
Mixed NPK				
× **Heera**	7.08 i	1.61 g	2.53 h	2.88 f
× **SL 8H**	9.36 g	1.81 fg	3.34 f	4.08 e
× **BRRI dhan58**	11.28 d	2.44 cd	2.92 g	4.07 e
× **BRRI dhan29**	10.62 e	2.70 c	3.98 de	5.41 d
USG				
× **Heera**	4.42 jk	1.55 g	1.16 i	1.82 h
× **SL 8H**	4.94 j	1.18 h	1.39 i	2.44 g
× **BRRI dhan58**	6.72 i	1.17 h	1.14 i	4.44 e
× **BRRI dhan29**	4.07 k	1.10 h	1.13 i	1.76 h
$S\bar{x}$	**0.2**	**0.11**	**0.09**	**0.14**
CV (%)	**8.49**	**8.38**	**11.91**	**9.37**

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

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

4.2.7.1 Effect of nitrogen sources

Grain yield was significantly influenced by different sources of nitrogen (Table 12). The maximum grain yield (8.64 t ha^{-1}) was obtained due to application of

USG treatment and followed by mixed NPK. Numerical value indicated that USG treatment out yielded by 2.59, 1.52 and 0.46 t ha^{-1} over no nitrogen, prilled urea and mixed NPK 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.

4.2.7.2 Effect of variety

Varieties differed significantly in producing grain yield (Table 13). Among the four varieties BRRI dhan29 showed its superiority in producing highest grain yield which was 17.03%, 10.21% and 7.90 % higher than BRRI dhan58, SL8H and Heera, respectively. However, BRRI dhan29 produced the highest grain yield (8.22 t ha^{-1}). Heera produced the second highest grain yield (7.57 t ha^{-1}) which was statistically similar with SL8H (7.32 t ha^{-1}). The lowest grain yield (6.82 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.

4.2.7.3 Interaction effect of nitrogen dose and variety

Grain yield influenced significantly by the interaction of nitrogen sources and variety (Table 15). Among the interaction treatments, the highest grain yield (9.32 t ha^{-1}) was recorded in the interaction of USG × BRRI dhan29 followed by USG x Heera (8.98 t ha^{-1}), USG × SL8H (8.75 t ha^{-1}), mixed NPK x Heera (8.24 t ha^{-1}) and Mixed NPK × SL8H (8.24 t ha^{-1}) interaction treatments. The lowest grain yield (5.93 t ha^{-1}) was observed in no nitrogen × Heera.

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

4.2.8.1 Effect of nitrogen source

Straw yield varied significantly with the different sources of nitrogen (Table 12). Straw yield was significantly highest (9.68 t ha^{-1}) at USG treatment that followed by mixed NPK sources of nitrogen treatment. The lowest straw yield (6.24 t ha^{-1}) was found in no nitrogen (N_0) treatment Elbadry *et al.* (2004), Meena *et al.* (2003) and El-Rewainy (2002) observed similar view on straw yield due to nitrogen application.

4.2.8.2 Effect of variety

Straw yield differed significantly due to varietals differences (Table 13) BRRI dhan29 gave the highest straw yield (8.86 t ha^{-1}) followed by Heera (8.03 t ha^{-1}) which was statistically similar with SL 8H (7.83 t ha) and BRRI dhan58 (7.72t ha^{-1}). The lowest straw yield was found in BRRI dhan58 (7.72t 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.

4.2.8.3 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 14). The maximum straw yield (9.93 t ha^{-1}) was found from the interaction of USG × BRRI dhan29 followed by USG× Heera (9.66 t ha^{-1}) and USG × BRRI dhan58 (9.64 t ha^{-1}) which are statistically similar with each other. The minimum straw yield (5.82 t ha^{-1}) was found from the interaction of no nitrogen × BRRI dhan58.

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

4.2.9.1 Effect of Nitrogen sources

Biological yield differed significantly due to the different sources of nitrogen treatments (Table 12) USG produced the highest biological yield (18.33 t ha^{-1}) than mixed NPK (16.78 t ha^{-1}) and prilled urea (15.06 t ha^{-1}) of nitrogen treatments. The lowest biological yield (12.30 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.

4.2.9.2 Effect of variety

Significant variation in biological yield was observed due to varietals difference and it ranges from 14.55 - 17.09 t ha^{-1} (Table 13). The highest and lowest biological yield was obtained from BRRI dhan29 and BRRI dhan58, respectively. Heera (15.61 t ha^{-1}) and SL 8H (15.22 t ha^{-1}) are statistically similar in case of biological yield.

4.2.9.3 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 14). The results showed that the interaction between USG × BRRI dhan29 gave the highest biological yield (19.26 t ha^{-1}) that similar with USG × Heera (18.65 t ha^{-1}), USG × SL 8H (18.25 t ha^{-1}) and mixed NPK× BRRI dhan29(18.32 t ha^{-1}) interactions. The lowest biological yield (11.68 t ha^{-1}) was found in no nitrogen × BRRI dhan58 interaction treatment.

4.2.10 Harvest Index

4.2.10.1 Effect of nitrogen source

Effect of nitrogen sources exerted significant variation on harvest index (Fig. 12) Harvest index was highest at USG (49.28%) which was similar with mixed NPK (48.79%) and the lowest harvest index (47.07%) was obtained from no nitrogen treatment.

4.2.10.2 Effect of variety

No significant difference was observed for harvest index (%) due to varietal differences (Table 13) However, SL 8H showed the maximum numerical harvest index (48.55%) followed by BRRI dhan29 (48.54%) and Heera (48.18%). The lowest harvest index was found in BRRI dhan58 (47.18%). Alam and *et al.* (2009) also found the similar findings.

4.2.10.3 Interaction effect of nitrogen sources and variety

Harvest index was significantly influenced by the interaction effect of nitrogen source and variety (Table 14). The maximum harvest index (50.27%) was observed in USG $\times$BRRI dhan58 interaction that followed by mixed NPK$\times$SL8H interaction (49.62%). The minimum harvest index (43.73%) was found in the interaction treatment effect of no nitrogen$\times$BRRI dhan58.

Table 12. Effect of nitrogen source on yield and harvest index of boro rice

Source of Nitrogen	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest Index (%)
No Nitrogen	6.05 d	6.24 d	12.30 d	47.07 c
Prilled Urea	7.12 c	7.93 c	15.06 c	47.31 bc
Mixed NPK	8.18 b	8.59 b	16.78 b	48.79 ab
USG	8.64 a	9.68 a	18.33 a	49.28 a
$S\bar{x}$	**0.13**	**0.13**	**0.2**	**0.55**
CV(%)	**9.12**	**11.42**	**9.58**	**11.32**

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 13. 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 (%)
Heera	7.57 b	8.03 b	15.61 b	48.18
SL 8H	7.38 b	7.83 b	15.22 b	48.55
BRRI dhan 58	6.82 c	7.72 b	14.55 c	47.18
BRRI dhan 29	8.22 a	8.86 a	17.09 a	48.54
$S\bar{x}$	**0.08**	**0.1**	**0.2**	**NS**
CV (%)	**11.11**	**8.37**	**7.76**	**10.51**

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

Table 14. Interaction Effects of nitrogen sources and variety on yield and harvest index of boro rice

Interaction Nitrogen Sources X Variety	Grain Yield ($t\ ha^{-1}$)	Straw Yield ($t\ ha^{-1}$)	Biological Yield ($t\ ha^{-1}$)	Harvest Index (%)
No Nitrogen				
× **Heera**	5.93 g	6.32 gh	12.26 gh	48.17 ab
× **SL 8H**	5.87 g	6.00 h	11.88 h	47.98 ab
× **BRRI dhan58**	5.85 g	5.82 h	11.68 h	43.73 c
× **BRRI dhan29**	6.56 fg	6.83 fg	13.40 fg	48.40 ab
Prilled urea				
× **Heera**	7.15 ef	7.45 ef	14.61 ef	48.95 ab
× **SL 8H**	6.66 e-g	7.44 ef	14.11 ef	47.19 a-c
× **BRRI dhan58**	6.57 fg	7.56 ef	14.13 ef	46.46 bc
× **BRRI dhan29**	8.12 b-d	9.28 ab	17.41 b-d	46.64 a-c
Mixed NPK				
× **Heera**	8.24 bc	8.69 bc	16.94 d	48.65 ab
× **SL 8H**	8.24 bc	8.37 cd	16.62 d	49.62 ab
× **BRRI dhan58**	7.35 d-f	7.88 de	15.24 e	48.25 ab
× **BRRI dhan29**	8.91 ab	9.41 ab	18.32 a-c	48.65 ab
USG				
× **Heera**	8.98 ab	9.66 a	18.65 ab	48.41 ab
× **SL 8H**	8.75 ab	9.49 ab	18.25 a-c	49.40 ab
× **BRRI dhan58**	7.50 c-e	9.64 a	17.15 cd	50.27 a
× **BRRI dhan29**	9.32 a	9.93 a	19.26 a	49.03 ab
$S\bar{x}$	**0.27**	**0.25**	**0.41**	**1.1**
CV (%)	**7.71**	**8.81**	**7.68**	**10.87**

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

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at the Agronomy Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2012 to May 2013 to determine the suitable nitrogen sources to growth performance and to increase the yield by reducing spikelet sterility in boro rice. The experiment comprised four sources of nitrogen viz. no nitrogen, BRRI recommended dose of prilled urea, recommended dose of mixed NPK and BARC recommended dose of urea super granule (USG), and four varieties viz. BRRI dhan29, BRRI dhan58, BADC SL8H and Heera. The experiment was set up following split-plot design with three replications.

Results revealed that nitrogen sources, variety and their interactions had significant effect on plant height at different days after transplanting. The tallest (97.68 cm) plant was recorded from USG treatment compared to the lower levels of nitrogen at harvest. At harvest, the tallest plant (96.77 cm) was observed in BRRI dhan29 and the shortest plant (87.04 cm) was observed in Heera. The tallest plant (100.2 cm) was found in the USG $\times$ BRRI dhan29 treatment and the shortest plant (80.50 cm) was found in no nitrogen $\times$ Heera interaction at harvest.

The highest number of tillers hill^{-1} (17.60) was found in USG treatment at 85 DAT. The highest and lowest number of tillers hill^{-1} (16.45) and (15.77) were recorded from BRRI dhan29 and BRRI dhan58, respectively. The interaction of USG $\times$ BRRI dhan29 was found promising in producing tillers hill^{-1}.

The highest number of effective tiller hill^{-1} (15.81) was counted USG treatment. BRRI dhan29 showed the highest number of effective tiller hill^{-1} (14.25) followed by BRRI dhan58 (13.55) and lowest number of effective tiller hill^{-1} (12.16) was recorded from Heera. The interaction of USG × BRRI dhan29 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} (1.78) was recorded in BRRI dhan29 whereas BRRI dhan58 produced the lowest number of non-effective tillers hill^{-1} (1.11). The highest number of non-effective tiller hill^{-1} (2.28) was found in the interaction of no nitrogen × BRRI dhan29 treatment and the lowest (0.52) was obtained from USG × SL8 H interaction treatments.

Nitrogen, variety and their interactions exhibited significant differences variation in producing filled grains panicle^{-1}. The highest number of filled grains panicle^{-1} (101.58) was counted at USG treatment whereas no nitrogen produces the lowest number of filled grains panicle^{-1}(68.47). The highest number of filled grains panicle^{-1} (98.57) was observed in BRRI dhan29 and the lowest number of filled grains panicle^{-1}(82.12) was observed in SL8H. The interaction of USG × BRRI dhan29 showed the highest number of filled grains panicle^{-1} (115.12) and the lowest number of filled grains panicle^{-1}(82.12) was observed in no nitrogen × SL8H 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} (13.71) and the lowest number of unfilled grains panicle^{-1} was observed in Heera. The highest number (19.69) and the lowest number (4.97) of unfilled grains panicle^{-1} was observed USG × BRRI dhan29 and no nitrogen × BRRI dhan29 interaction.

Nitrogen, variety and their interaction had significant effect on the production of spikelet sterility of rice. The lowest spikelet sterility (5.04%) obtained at USG and the highest (14.92%) obtained at no nitrogen treatment. The highest spikelet sterility (11.71%) was found in the inbred variety BRRI dhan58 and the lowest (7.31%) was found in Heera. The highest spikelet sterility (18.07%) was observed in the interaction of no nitrogen x BRRI dhan29 treatment and the lowest spikelet sterility (4.07%) was observed in the interaction of USG × BRRI dhan29 treatment. Bottom portion of panicle produced the maximum sterility (%) whereas, the top portion of panicle produced minimum sterility (%) for all nitrogen treatments.

Nitrogen, variety and their interaction was observed significant in case of weight of 1000 grain. The highest weight of 1000 seed weight (22.67) was found in USG treatment however the hybrid variety SL 8H and the inbred variety BRRI dhan29 showed significantly the highest (23.05 g) and the lowest (20.77 g) weight of 1000-gram, respectively. The interaction of USG × Heera treatment produced the maximum weight of 1000-grain (23.80 g) whereas, double of the recommended dose of nitrogen × BRRI dhan29 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 (8.64 t ha^{-1}) was obtained USG treatment and the lowest grain yield (6.05 t ha^{-1}) was obtained no nitrogen. The maximum grain yield (8.22 t ha^{-1}) was found in BRRI dhan29 and the lowest grain yield (6.82 t ha^{-1}) was found in BRRI dhan58. The interaction of USG × BRRI dhan29 treatment produced the highest (9.32 t ha^{-1}) grain yield and the interaction of no nitrogen × BRRI dhan58 treatment produced the lowest grain yield (5.85 t ha^{-1})

The highest straw yield (9.68 t ha^{-1}) and biological yield (18.33 t ha^{-1}) was obtained at USG treatment whereas the lowest straw yield (6.24 t ha^{-1}) and biological yield (12.30 t ha^{-1}) was obtained at no nitrogen. Both the highest straw yield (8.86 t ha^{-1}) and the biological yield (17.09 t ha^{-1}) were found in BRRI dhan29 whereas BRRI dhan58 showed the lowest straw yield (7.72 t ha^{-1}) and biological yield (15.22 t ha^{-1}). Both the highest straw (9.93 t ha^{-1}) and biological (19.26 t ha^{-1}) yield were obtained in the interactions of USG × BRRI dhan29 treatment and the lowest both straw yield (5.82 t ha^{-1}) and biological (11.68 t ha^{-1}) yield were obtained in the interactions of no nitrogen × BRRI dhan58 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 (49.28%) was obtained at USG treatment and the minimum (47.07%) was obtained at no nitrogen treatment. The significantly highest harvest index (50.27 %) was found in the interaction of USG × BRRI dhan58 treatment and the lowest harvest index (43.73%) was found in the interaction of no nitrogen × BRRI dhan58 treatment.

Reviewing above the results of the present study might be concluded as:

- ✓ USG showed the superiority over other sources of nitrogen to keep the spikelet sterility (%) at minimum level and to produce higher grain yield of rice.
- ✓ Hybrid variety Heera gave the lowest spikelet sterility (%), but inbred variety gave highest yield and medium level of spikelet sterility (%).
- ✓ Interaction of USG × BRRI dhan29 more superior and interaction of USG with other tested varieties were also found promising in producing high grain yield.

Chapter VI

REFERENCES

Ahmed, M., Islam, M. and Paul, S.K (2005) Effect of nitrogen on yield and other plant characters of local T. Aman Rice, Var. Jatai. Res. *J. Agric. Biol. Sci***. 1(2):** 158-161.

Ahmed, M.H., Islam, M.A., Kader, M.A. and Anwar, M.P. 2000. Evaluation of urea super granules as source of nitrogen in transplant *aman* rice. *Pakistan J. Biol. Sci.* **3(5):** 735-737.

Ahsan, K. (1996). Effect of rate of N fertilizer on growth and yield of Japonica and Japonica- indica Hybrid rice. *Bangladesh J. Agril.* **7 (1 &2):**17-21.

AIS (Agricultural Information Service), 2013. Khamar Bari, Farmgate, Dhaka. pp. 442-446.

Alam, B.M.R. (2002). Effect of different level of urea super granule on the growth and yield of three varieties of *boro* rice. MS (Ag.) Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. p. 119.

Ali, A., Khan, M.A., Hassan, G. Ali, A., Ali, S.S. and Majid, A. (1993) Rice grain quality as influenced by split application of nitrogenous fertilizer. *Intl. Rice Res. Newsl.* **17**(**3**)**:** 7.

Azad, A. K., Gaffer. M. A., Samanta, S. C, Kashem, MA. and Islam, M.T. (1995) Response of BR10 rice to different levels of nitrogen and spacing. *Bangladesh J. Sci. Ind. Res.* **30(1):** 31-38.

Azam, S.M.G. (2009). Evaluation of urea super granule as a source of nitrogen in transplant *aman* rice. MS (Ag.) Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh, pp. 28-41.

BBS (Bangladesh Bureau of Statistics). 2011. Statistical Year Book of Bangladesh. Stat. Div., Minis. Plan., Govt. People's Repub. Bangladesh, Dhaka. p. 136-140.

Bhowmick, N. and Nayak, R. L. (2000). Response of hybrid rice *(Oryza saliva)* varieties to nitrogen, phosphorus and potassium fertilizers during dry (boro) season in West Bengal. *Indian J. Agron.* **45 (2):** 323-326.

Bisne, R.; Sarawgi, A.K. (2008). Agro-morphological and quality characterization of Badshah Bhog group from aromatic rice germplasm of Chhattisgarh. *Bangladesh Journal of Agricultural Research* **33:** 479-492.

BINA (Bangladesh Institute of Nuclear Agriculture) (1992). Annual Report for 1990-91. Bangladesh Inst. Nucl Agric, Mymensingh. p. 6.

BINA (Bangladesh Institute of Nuclear Agriculture) (1993). Annual Report for 1992-93 Bangladesh Inst. Nucl. Agric , Mymensingh p. 143 - 147

BINA (Bangladesh Institute of Nuclear Agriculture). (1998). Technical report on hybrid rice Alok 6201. Div. Agron., Bangladesh Inst. Nuc. Agric., Mymensingh. p. 1-3.

BINA (Bangladesh Institute of Nuclear Agriculture). (2001). Annual Report for 1998-99. Bangladesh Inst. Nuc. Agric., Mymensingh. p. 334.

Bokyeong, K, Kiyoung, K., Myungkyu, O., Jaekii, Jaekwon, K and Heekyoung, K. (2003). Effects of nitrogen level and seedling number on panicle structure in japomca rice. *Korean J. Crop Sci.* **48 (2):** 120-126.

BRKB (Bangladesh Rice Knowledge Bank) (2007). Rice in Bangladesh File://K:\Bangladesh Rice Knowledge Bank. html. Last updated July 1, 2007.

BRRI (Bangladesh Rice Research Institute). (2006) Annual Report for 2005-2006 Bangladesh Rice Res. Inst, Joydebpur, Gazipur, Bangladesh. pp. 63-67

BRRI (Bangladesh Rice Research Institute). (1995) Annual Report for 2005-2006 Bangladesh Rice Res. Inst, Joydebpur, Gazipur, Bangladesh. pp. 33-39

BRRI (Bangladesh Rice Research Institute). (1980). Annual Report for 1990. Bangladesh Rice Res. Inst., Joydebpur, Gazipur. pp. 61-73.

BRRI (Bangladesh Rice Research Institute). (1988). Annual Report. Soil and Fertilizer Management Programme, Bangladesh Rice Res. Inst, Joydebpur, Gazipur. 2:1-20.

BRRI (Bangladesh Rice Research Institute). (1989). Annual International Review Report for 1988. Soil and Fertilizer Management Programme, Bangladesh Rice Res. Inst, Joydebpur, Gazipur. 2:2-15.

BRRI (Bangladesh Rice Research Institute). (2013). Adunik Dhaner Chash (in Bangla). 17th Edn. Bangladesh Rice Res. Inst., Joydebpur, Gazipur. pp. 17-33.

BRRI 1976, Annual Report (1976) Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh pp. 67-105.

Chaturvedi, I. (2005). Effect of nitrogen fertilizers on growth, yield and quality of hybrid rice (Oryza sativa L.). *Journal of Central European Agricultural*, **6(4):** 611-618.

Chowdhury, M.J.U, Sarkar, A. U. Sarkar, M.A.R. and Kashem, M.A. (1993) Effect of variety and number of seedlings hill^{-1} on the yield and its components on late transplanted aman rice. *Bangladesh J. Agril. Sci.* **20 (2):** 311-316.

Chowdhury, M.M.U., Ullah, M.H. Islam, M.S., Nabi, S.M and Hoque, A.F.M. E. (1998). Rice cultivation in hill valley after dhaincha manuring as affected by different levels of nitrogen. *Bangladesh J. Agril. Sci.* **23 (2):** 299-306.

Dalai, P.K. and Dixit, L. (1987) Response of medium rice varieties (dwarf indica) to different levels of N. *Indian J. Agron.* **32 (3):** 286-287

Das, D.K. (1989). Efficiency of different urea materials for rainy season rice (*Oryza sativa*). *Indian J. Agril. Sci.* **59 (8):** 534-536.

Dash, A.K., Mishra, B.K., Jena, M.K. and Jena, D. (2003). Effect of dose and application methods of different urea based fertilizers on yield of lowland rice. *Annuals of Agril. Res.* **24(2):** 308-313.

Ebaid, R. A. and Ghanem, S.A. (2000) Productivity of Giza 177 rice variety grown after different winter crops and fertilized with different nitrogen levels. *Egypt J. Agric Res,* **78**: 717-731.

Elbadry, M., Gamal-Eldin, H and Elbanna, K. (2004) Effect of Rhodobacter capsulatus inoculation in combination with graded levels of nitrogen fertilizer on growth and yield of rice in pots and lysimeter experiments. *World J. Microbiol. Biotech.* **15 (3):** 393-395.

El-Rewainy, I. M.O. (2002). The effect of different nitrogen fertilizer source on yield and some agricultural characters in rice Ph.D., Thesis, Fac. Agric. Shebin El-Kom, Menofia Univ., Egypt.

Evant, N.S., Johson. T.H. and Beachell, H.M. (1960). The response of short – straw rice varieties to heavy levels of nitrogen fertilization. *Intl. Rice Comm. Newsl.* **(3):**5-12.

Gunawardena, T.A., Fukai, S. and Blarney, F.P.C. (2003) Low temperature induced spikelet sterility in rice. I. Nitrogen fertilization and sensitive reproductive period *Australian. J.Agril. Res* **54 (10):** 937-946.

Hari, O.M., Katyal, S.K. and Dhiman, S.D (2000) Response of two nee hybrids to graded levels of nitrogen *Indian J. Agric. Sci.,* **70**: 140-142.

Hari. O.K., katyal, S.K. and Dhiman, S.D. (1997). Effect of nitrogen and seed rate in nursery on growth and yield of hybrid rice *{Oryza sativa). Indian J. Agron.* **42 (2):** 275-277.

Hasan, M.S., Hossain, S.M.A., Salim, M., Anwar, M.P. and Azad, A.K.M. 2002. Response of hybrid and inbred rice varieties to the application methods of urea supergranules and prilled urea. *Pakistan J. Biol. Sci.* **5(7):** 746-748.

Hasanuzzaman, M., Nahar, K., Alam, M. M., Hossain, M. Z., & Islam, M. R. (2009). Response of transplanted rice to different application methods of urea fertilizer. *International Journal of Sustainable Agricultural,* **1(1):** 01-05.

Hasan, S.M. (2007), Effect of level of urea supergranules on the performance of T.Aman rice. M. Sc. .Ag.thesis in agronomy BAU,Mymensingh.

Hall, Vernon L., and Robert M. Railey. 1964. Timing nitrogen fertilization of rice with morphological development of the plant. Rice Journal 67(1):6-9.

Hossain M, Lewis D, Bose ML and Chowdhury A. 2003. Rice research, technological progress, and impacts on the poor: the Bangladesh case. Discussion Paper 110. *International Food Policy Research Institute (IFPRI),* Washington, DC.

Hossain**,** S.M.A. and Alam, A. B. M.M. (1991). Productivity of cropping patterns of participating farmers. In Fact searching and intervention in two FSRDP sites, activities. 1989-90. Farming Systems Research and Development Programme. BAU, Mymensingh. pp. 44-48.

Hossain, M.S. (2007). Grain yield and protein content of transplant *aman* rice as influenced by variety and rate of nitrogen. M. Sc. (Ag.) Thesis in Agron., BAU, Mymensingh, pp. 51-55.

Hossain. S.M. (2007). Effect of level of urea super granules on the performance of T. *aman* rice. M. Sc. Ag. *Thesis in Agron.,* BAU, Mymensingh.

Hussain, J. (2008). Evaluation of nitrogen use efficiency using prilled urea and urea super granules on transplant *aman* rice. M. Sc. (Ag.) *Thesis in Agronomy*,BAU, Mymensingh, p. 43.

Idris, M. and Matin, M.A. (1990) Response of four exotic strains of aman rice to urea. *Bangladesh J. Agril. Sci.* **17 (2)**: 271 -275.

IFPRI (International Food Policy Research Institute). 2007. *The world food situation: new driving forces and required actions*. December, Beijing, CGIAR Annual General Meeting.

Iqbal (2011). Detection of suitable soils for Zero-Till wheat sowing in Gujranwala using GITs, MS Thesis. National University of Sciences and Technology, Pakistan.

IFDC, (2007) (International Fertilizer Development Center) 2007. http://www.ifdc.org/changing_lives/bangladesh/fertilizer-system

IRRI (International Rice Research Institute) (1968). Annual report 1968. IRRI Almanac. *Intl. Rice Res Inst.* Los Banos, Philippines pp. 301-303

IRRI (International Rice Research Institute) (1993) IRRI Almanac *Intl. Rice Res. Intl.* Los Banos, Philippines, p. 110.

IRRI (International Rice Research Institute) (2005) IRRI Almanac *Intl. Rice Res. Intl.* Los Banos, Philippines, p. 11.

Jaiswal, V. P. and G. R. Singh (201). Efect of planting methods, source and level of nitrogen on the growth and yield of rice (Oryza sativa L.) and on suceding wheat (Tritcum aestivum). *Indian J. Agron.* **46 (1):** 5–1.

Jee, R.C. and Mahapatra, A.K.I. 1989. Effect of time of application of some slow release N-fertilizers on rice. *Indian J. Agril. Sci*. **34(4):**435-436.

Kamal, A.M.A., Azam, M.A. and Islam, M.A. 1988. Effect of cultivars and NPK combinations on the yield contributing characters of rice. *Bangladesh J. Agril. Sci.* **15(1):**105-110.

Kamal, J., Tomy, P.J. and Rajaappan Nair, N. 1991. Effect of sources and levels of nitrogen on the growth, yield and nitrogen use efficiency of wetland rice. *Indian J. Agron.* **36(l):** 40-43.

Khisha, K. 2002. An Evaluating of Madagascar System of Rice Production in aman Season with Three High Potential Rice Varieties. MS (Ag.) Thesis,Dept. Agron., Bangladesh Agril. Univ., Mymensingh. p. 98.

Kumar, G.H., Reddy, S.N. and Ikramullah, M. (1995). Effect of age of seedling and nitrogen levels on the performance of rice *(Oryza saliva)* under late planting *Indian J. Agric. Sci.* **65** (5): 354-355.

Kumar, S.R., Reddy, M.R., Reddy, T.M.M. and Reddy, BB. (1986), Nitrogen management in direct seeded and transplanted rice. *Indian J. Agron.* **31 (1):** 100-101.

Lal P., Gautam, R.C., Bisht, P.S. and Pandey, P.C. 1983. Effect of USG placement and planting geometry on yield of random planted rice. *Intl. Rice Res. Newsl.* **8(6):** 28.

Meena, S.L., Sundera, S., and Shivay, Y.S. (2003). Response to hybrid rice *(Oryza saliva)* to nitrogen and potassium application in sandy clay-loam soils. *Indian J. Agric.. Sci.* **73 (1)**: 8-11.

Mirzeo, W. A. and Reddy, S.N. (1989). Performance of modified urea materials at graded levels of nitrogen under experimental and farmers' management conditions in low land rice (*Oryza sativa*). *Indian J. Agril. Sci.* **59(3):** 154-160.

Mishra, B.K., Das, A.K., Dash, A.K., Jena,D. and Swin, S.K. (1999). Evaluation of placement methods for urea super granules in wetland rice (Oryza sativa) soil. *Indian J. of Agron.* **44(4):** 710-716.

Mishra, B.K., Mishra, S.,Das, A.K., and Jena,D. and (2000). Effect of time for urea super granule placement of lowland rice. *Ann. Res.* **20(4)**: 443-447.

Mohaddesi A, Abbasian A, Bakhshipour S, Aminpanah H. (2011). Effect of Different Levels of Nitrogen and Plant Spacing on Yield, Yield Components and Physiological Indices in High-Yield Rice (Number 843). *American-Eurasian Journal of Agricultural & Environmental Sciences* **10(5):** 893- 900

Mohanty, S.K., Chakravorti, S.K. and Bhadrachalan, A. (1989). Nitrogen balance studies in rice using 15 N-labelled urea and urea super granules. *J. Agric. Sci.* **113(l):** 119-121.

Munoz, D., Gutierrez., P. and Carredor, E. (1996). Current status of research and development of hybrid rice technology in Colombia. In. Abst., Proc. 3r Intl. Symp. On Hybrid Rice November 14-16. Directorate Rice Res., Hyderabad, India, p. 25.

Murthy, K.N.K., Shankaranarayana, V., Murah, K., Jayakumar, B.V (2004). Effect of different dates of planting on spikelet sterility in rice genotypes *(Oryza sativa L.) Res. Crops.* **5(2/3):** 143-147.

Myung, K. (2005). Yearly variation of genetic parameters for panicle characters of Japonica rice *(Oryza sahva* L.) E mail: Ind_Chaturvedi@vahoo.com. Accepted for publication: May 27, 2005.

Niu, I., Li, Y., Zhang, W., Niu, Z. and Zhou, M. (2001). High yielding and good quality Tianjin 1244. Japonica hybrid cultivar series. *Intl. Rice Res. Notes*. **26(1):** 12.

Nuruzzaman, M., Yamamoto, Y., Nitta, Y., Yoshida, T. and Miyazaki, A. 2000. Varietal differences in tillering ability of fourteen Japonica and Indica rice varieties. *Soil Sci. Plant Nutri.* **46(2):** 381-391.

Om, H, Dhiman, S. D., NandaL, D. P. and Verma, S.L. (1998). Effect of method of nursery raising and nitrogen on growth and yield of hybrid rice (Oryza sativa). *Indian J. Agron.* **43(l):** 68-70.

Ota, Y. and Yamada, N. (1965). Studies on sterility of mdica rice II Effect of nitrogen application and depletion at different stages of growth on sterility in mdica rice. *Japanese. J. Trap. Agric.* **9 (2):** 76-79.

Pandey, A. and Tiwari, K.L. (1996). Effect of prilled urea, modified urea and coated urea on transplanted rice. Adv. *Agril. Res. India*. 5: 83-88 [Field Crop Abst. 1998, **15**(2): 87].

Pandey, H.K and Khan, R.A. (1969). Effect of varying levels of fertility and moisture on the sterility of spikelets in two varieties of rice. *Riso.* **18**:43-46.

Patel, J.R. (2000). Effect of water regime, variety blue green algae on rice *(Oryza sativa)* hybrids. *Indian J. Agron.* **45(1):** 103-106.

Rahman, M.A. (2003). Effect of levels of urea supergranules and depth of placement on the growth and yield of transplant *aman* rice. MS (Ag.) Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. p. 100 .

Rahman, M.M. (2006). Effect of cultivar, depth of transplanting and depth of placement of urea supergranules on growth and yield of *boro* rice. MS (Ag.) Thesis, Dept. Agron., Bangladesh Agril. Univ.,Mymensingh. p.

Rahman, M.S., Miah, A.J. and Mansur, M.A. (1985). Agronomic performance of rice mutants with varying N fertilizer doses and plant spacing. *Bangladesh . J. Nucl. Agric.* **1(1):** 54-64.

Rama, S., Reddy, G. and Reddy, K. (1989). Effect of levels and sources of nitrogen on rice. *Indian J. Agron.* **34(3):** 364-366.

Rekhi, R.S., Bajwa, M.S. and Starr, J.L. (1989). Efficiency of prilled urea and urea supergranules in rapidly percolating soil. Punjab Agric. Univ., Ludhiana 141004, India. *Intl. Rice Res. Newsl*. **14(2):** 28-29.

Rotshield, G.H.L. (1996). Perspectives for rice production in Asia. Crop research in Asia:Achievements and perspectives. Proceedings of the 2nd Asian crop science conference. *Asian Crop Sci. Assoc.* Fukui. Pp. 12-17.

Sahrawat, K.L., Diatta, S. and Singh, B.N. (1999). Nitrogen responsiveness of lowland rice varieties under irrigated condition in West Africa. *Intl. Rice Res. Notes.* **24 (2):**30

Salem, A.K.M. (2006). Effect of nitrogen levels, plant spacing and time of farmyard manure application on the productivity of rice. *J. Appl Sci. Res.* **2(11):** 980-987.

Sawant, A.C., Thorat, S.T., Khadse, R.R. and Bhosale, R.J. (1986) Response of early rice varieties to nitrogen levels and spacing in coastal Maharastra. *J. Maharashtra Agril. Univ*. **11(2):** 182-184.

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

Singh, B. and Kumar, A. (2003). Effect of slow release fertilizers, biogass slurry BGA on yield, N- uptake and N- use efficiency in rice. *Farm sci.. J.* **12(2):**146-147.

Singh, B.K. and Singh, R.P. (1986). Effect of modified urea materials on rainfed low land transplanted rice and their residual effect on succeeding wheat crop. *Indian J. Agron.* **31(2):** 198-200.

Singh, C.M. and Kumar, N. (1983). Nitrogen fertilization in transplanted rice. *Intl. Rice. Res. Newsl.* **8(5):** 27.

Singh, D. and Om, H. (1993). Effect of time of nitrogen application on yield of short duration rice. Pussa 33. *Haryana. J. Agron.* **9(1):**88-89.

Srivastava, G.K. and Tripathi, R.S. (1998). Response of hybrid and composite rice to number of seedling and planting genometry. *Ann. Agril. Res. Newsl.* **19(2):** 235-236.

Sumit, C; Pyare, L; Singh, A. P. and Tripathi, M.K. (2004). Agronomic and morpho-physiological analysis of growth and productivity in hybrid rice *(Oryza sativa* L). *Annals Biol.* **20 (2):** 233-238.

Surendra, S., Prasad, R. and Sharma, S.N. (1995). Effects of blue green algae, nitrogen levels and modified urea materials on yield attributes and yield of low land rice (*Oryza sativa). Indian J. Agron.* **40(4):** 594-597.

Tanaka, A., Navasero, S.A., Garoia, C.V., Parao, F.T. and Ramirez, E. 1964. Growth habit of the rice plant in the tropics and its effect on nitrogen response. *Int. Rice Res. Inst. (IRRI). Tech. Bull*. p. 80.

Tanaka, S.A., Navasero, C.V., Garcia, P. T., Parao and Raamierz, E (1964). Growth habit of the rice plant in the tropics and its effects on nitrogen response, *Int. Rice Res. Inst. Tech. Bull.* **3:** 67-80.

Thakur, R.B. (1991 b). Effect of N levels and forms of urea on low land rice under late transplanting. *Indian J. Agron.* **36:**281-282.

Thakur, R.B. (1991a) Response of summer rice *(Oryza sativa)* to nitrogen. *Indian J. Agron.* **36**:229-230.

Thakur, R.B. (1993). Perfomiance of summer rice *(Oryza sativa)* to varying levels of nitrogen. *Indian J. Agron.* **38 (2).** 187-190.

Thakur, R.B. (1991). Relative efficiency of prilled urea and modified urea fertilizer on rainfed low land rice. *Indian J. Agron.* **36(1):** 87-90.

Wang, X. (2001) Personal communication, Human Academy of Agricultural Science P. R. China.

Wani, A.R., Hasan, B. and Bali, A.S. (1999). Relative efficiency of some modified urea materials in transplanted rice under temperate conditions of Kashmir. Oryza. **36(4):** 382-383.

Xie, W., Wang, G. and Zhang, Q (2007). Potential production simulation and optimal nutrient management of two hybrid rice varieties in Jinhua, Zhejiang Province. *J. Zhejiang Univ. Sci.* **8**(7): 486-492.

Xie, W., Wang, G., Zhang, Q and Guo, H. (2007). Effects of nitrogen fertilization strategies on nitrogen use efficiency in physiology, recovery and agronomy and redistribution of dry matter accumulation and nitrogen accumulation in two typical rice cultivars in Zhejiang, China . *J. Zhejiang Univ. Sci.* **8**(3): 208-216

Yoshida, S. (1981). Fundamentals of Rice Crop Science *lnt. Rice Res. Inst.* Manila, Philippines.

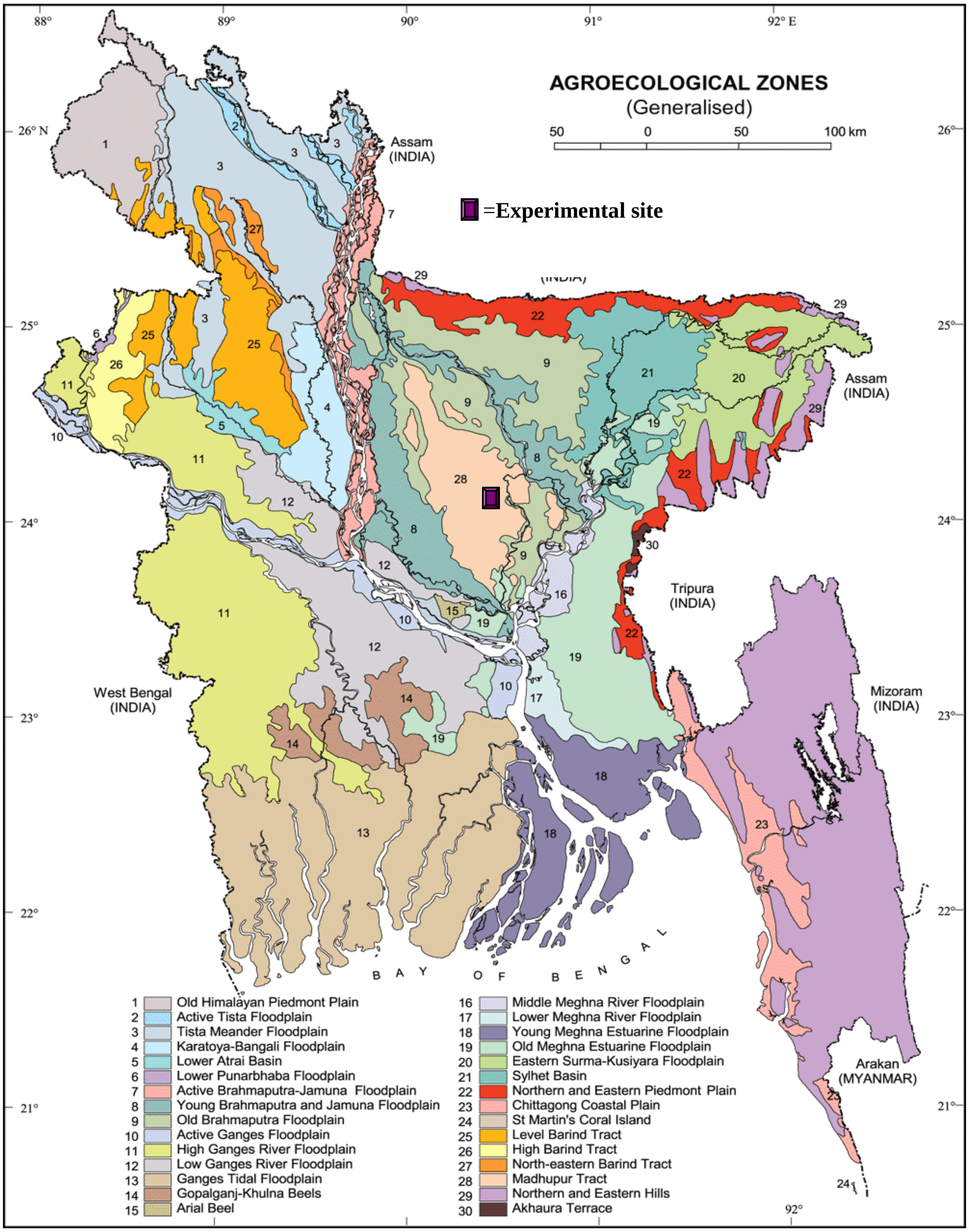
Yoshida, S., and Parao, F.T. (1976). Climatic influence on yield and yield components of lowland rice in the tropics. Climate and Rice, Los Banos, Philippines, pp. 471-494.

Zaman, S.K ., Razzaque, M.A., Karim, S.M.R. and Ahmed, A.U. (1993). Evaluation of prilled urea and urea super granules as nitrogen sources for upland aus rice.pp.42-46.

Zohra, F.T. (2012). Effect of level of urea super granules on the performance of transplant *aman* rice. M.Sc. (Ag) Thesis, Dept. Agron. Bangladesh Agril. Univ. Mymensingh. p. 23-34.

LIST OF APPENDICES

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



Appendix II. Layout for experimental field.

$R_1V_2\ T_1$	$R_1V_2\ T_0$	$R_1V_2\ T_3$	$R_1V_2\ T_2$
$R_1V_4\ T_0$	$R_1V_4\ T_2$	$R_1V_4\ T_1$	$R_1V_4\ T_3$
$R_1V_1\ T_3$	$R_1V_1\ T_1$	$R_1V_1\ T_2$	$R_1V_1\ T_0$
$R_1V_3\ T_2$	$R_1V_3\ T_3$	$R_1V_3\ T_0$	$R_1V_3\ T_1$
$R_2V_4\ T_1$	$R_2V_4\ T_0$	$R_2V_4\ T_3$	$R_2V_4\ T_2$
$R_2V_2\ T_0$	$R_2V_2\ T_2$	$R_2V_2\ T_1$	$R_2V_2\ T_3$
$R_2V_3\ T_3$	$R_2V_3\ T_1$	$R_2V_3\ T_2$	$R_2V_3\ T_0$
$R_2V_1\ T_2$	$R_2V_1\ T_3$	$R_2V_1\ T_0$	$R_2V_1\ T_1$
$R_3V_3\ T_1$	$R_3V_3\ T_0$	$R_3V_3\ T_3$	$R_3V_3\ T_2$
$R_3V_4\ T_0$	$R_3V_4\ T_2$	$R_3V_4\ T_1$	$R_3V_4\ T_3$
$R_3V_1\ T_3$	$R_3V_1\ T_1$	$R_3V_1\ T_2$	$R_3V_1\ T_0$
$R_3V_2\ T_2$	$R_3V_2\ T_3$	$R_3V_2\ T_0$	$R_3V_2\ T_1$

North →

Appendix III. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0- 15 cm depth).

Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17meq/100 g soil
Boron	0.88 µg/g soil
Copper	3.54 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 µg/g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka

Appendix IV. 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
	January	24.57	14.53	65
	February	26.67	15.1	155
	March	31.15	21.45	184
	April	34.35	24.5	281
2013	May	33.53	22.57	269

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

Appendix IV .Analysis of variance of the data on plant height of rice as influenced by nitrogen and variety

Source Of variation	Degrees of freedom	Mean square values at					
		25DAT	45DAT	65DAT	85DAT	105DAT	At Harvest
Replication	2	28.43	148.79	48.79	3.324	33.08	32.313
Factor A	3	20.44	62.30^{NS}	48.88*	135.761*	182.90*	189.66*
Error (a)	6	18.982	115.60	30.60	15.69	17.62	20.79
Factor B	3	10.52^{NS}	59.10^{NS}	182.74^{NS}	244.42*	314.82*	315.75*
AB	9	1.030^{NS}	1.16^{NS}	2.75^{NS}	6.28*	8.92*	8.03*
Error (b)	24	15.583	55.47	56.54	23.72	27.14	29.13

* = Significant at 5% level of probability

Appendix V.Analysis of variance of the data on total tillers hill^{-1}of rice as influenced by nitrogen and variety

Source Of variation	Degrees of freedom	Mean square values at					
		25DAT	45DAT	65DAT	85DAT	105DAT	At Harvest
Replication	2	0.037	0.186	0.120	0.672	0.909	1.858
Factor A	3	0.114*	0.582*	1.473*	6.303*	11.134*	14.628*
Error (a)	6	0.0112	1.428	1.013	1.159	0.119	1.107
Factor B	3	0.466*	2.030*	23.875*	64.411*	70.073*	83.539*
AB	9	0.031*	1.176*	0.809*	0.699*	1.573*	0.93*
Error (b)	24	0.068	0.362	0.598	0.982	0.836	0.645

* = Significant at 5% level of probability

Appendix VI. ANOVA showing the mean square values of effective tiller no., non-effective tiller no., filled grains per panicle, unfilled grains per panicle, total grains per panicle and 1000grain weight of rice as influenced by nitrogen and variety

Source Of variation	Degrees of freedom	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Filled grains panicle^{-1}	Unfilled grains Panicle^{-1}	1000 grain weight (gm)
Replication	2	22.27	0.052	1296.404	0.299	18.837
Factor A	3	9.04*	1.167*	658.986*	99.59*	11.36*
Error (a)	6	0.71	0.008	5.895	0.720	0.388
Factor B	3	95.71*	2.712*	2435.941*	158.34*	2.966*
AB	9	0.27*	0.087*	51.961*	11.993*	0.450*
Error (b)	24	0.33	0.011	8.938	0.335	0.308

* = Significant at 5% level of probability

Appendix VII. Analysis of variance of the data on yield of rice as influenced by nitrogen and variety

Source Of variation	Degrees of freedom	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.312	0.021	0.162	18.508
Factor A	3	4.050*	3.204*	62.835*	149.063*
Error (a)	6	0.085	0.140	4.638	10.459
Factor B	3	15.996*	24.863*	4.504*	3.141*
AB	9	0.304*	0.383*	1.287*	6.151*
Error (b)	24	0.214	0.194	1.575	4.982

* = Significant at 5% level of probability

LIST OF PLATES

1. Field view of experimental field

2. Field view of the difference between Controlled Plot and USG treated plot

3. Field view of best variety at vegetative stage (BRRI Dhan29)

4. Field view of USG treated plot with Heera variety

5. Field view at ripening stage

6. Field view of best Interaction (BRRI dhan29X USG)