VARIETAL PERFORMANCE OF BORO RICE UNDER NPK BRIQUETTE FERTILIZATION

A Thesis

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CERTIFICATE

This is to certify that the thesis entitled ***" VARIETAL PERFORMANCE OF BORO RICE UNDER NPK BRIQUETTE FERTILIZATION"*** *submitted to the* ***DEPARTMENT OF SOIL SCIENCE,*** *Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE (M.S.) in SOIL SCIENCE,*** *embodies the results of a piece of bonafide research work carried out by* **GM BADRUL HASAN,** *Registration No.* ***11-04299****, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.*

I further certify that any help or sources of information received during the course of this investigation have been duly acknowledged.

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ABSTRACT

A research work was carried out at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2016 to May 2017 in order to determine the suitable fertilizer doses to observe the growth performance with a view to increasing the grain yield of boro rice. The experiment consisted of two factors. Factor A: Variety (2 levels); V_1: BRRI dhan28, V_2: BRRI dhan29 and factor B: Fertilizer doses (5 levels); T_1= Control, T_2= Recommended Fertilizer Dose, T_3= 2 NPK briquette of 2.40 gm sized, T_4= 2 NPK briquette of 2.40 gm+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer, T_5= 1 NPK briquette of 2.40 gm + 1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer. The experiment was set up by following Randomized Complete Block Design with three replications. Experimental results showed that fertilizer doses had significant effect on plant height, tillers hill^{-1}, effective tillers hill^{-1}, non-effective tillers hill^{-1}, grains panicle^{-1}, unfilled grains panicle^{-1}, grain yield, straw yield, biological yield and harvest index. The application of T_4 treatment showed the highest grain yield (8.65 t ha^{-1}) and straw yield (10.41 t ha^{-1}) than any other sources of nitrogen treatments. All the studied characters except weight of thousand grains varied significantly due to varieties. BRRI dhan29 gave the higher grain yield (7.98 t ha^{-1}) than BRRI dhan28 (7.20 t ha^{-1}) which is mainly attributable to the highest number of grains panicle^{-1} (98.63). The combination of the 10 treatments and BRRI dhan29 had the higher performance in terms of producing the highest grain yield (9.34 t ha^{-1}) and straw yield (10.54 t ha^{-1}) among the interaction effects. The N, P and K uptake both in grain and straw of boro rice increased significantly due to application of nitrogen fertilizer. Research findings revealed that application of 2 NPK briquette of 2.40 gm sized in middle of 4 heel+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer showed the superiority over the other sources of nitrogen to produce higher grain yield of boro rice. In addition, interaction treatment of V_2 x T_4 i.e. application of 2 NPK briquette of 2.40 gm sized in middle of 4 heel+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer with BRRI dhan29 performed the best and interaction of T_4 treatment with other tested varieties were also promising in producing higher yield.

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LIST OF ACRONYMS

AEZ	= Agro- Ecological Zone
AIS	= Agricultural Information System
BARC	= Bangladesh Agricultural Research Council
BBS	= Bangladesh Bureau of Statistics
BTNA	= 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
° C	= Degree Centigrade
DF	= Degree of freedom
DAP	= Di-ammonium phosphate
DMA	= Dry matter accumulation
DMRT	= Duncan's Multiple Range Test
EC	= Emulsifiable Concentration
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	= Modem variety
MoP	= Muriate of potash
mm	= Millimeter
viz.	= Namely
N	= Nitrogen
NFAA	= Nitrogen fertilizer application amount

NS	= Non significant
%	= Percent
CV %	= Percentage of Coefficient of Variation
P	= Phosphorus
K	= Potassium
ppm	= Parts per million
PU	= Prilled urea
SAU	= Sher-e- Bangla Agricultural University
S	= Sulphur
SRDI	= Soil Resource Development Institute
SCU	= Sulphur coated urea
SHR	= Super hybrid rice
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 (*Oryza sativa* L) dominates the Bangladesh agriculture sector covering 80% of the total cropped area of the country. It is the most important food crop of the world and the staple food of more than 3 billion people or more than half of the world's population (IRRI, 2005). About 95% of the world rice is consumed in Asia (Rotshield, 1996), grown in wide range of climatic zones, to nourish the mankind (Chaturvedi, 2005). The area and production of total rice in Bangladesh is about 11.52 million hectares and 33.89 million tons, respectively where boro covers the production of 18.76 million tons. In boro season local & HYV rice covers about 41.6 lac hectares area with production of 157.4 lac metric tons and hybrid rice covers about 6.4 lac hectares area with production of 30.2 lac metric tons, respectively (BBS, 2012). Rice is also the main food crop of Bangladesh and it covers about 80% of the total cropped area of the country (AIS, 2013). But the grain yield per hectare is still low compared to other major rice growing countries of the world. Rice provides nearly 48% of rural employment, about two-third of total calorie supply and about one-half of the total protein intakes of an average per person in the country. About 75% of the total cropped area and over 80% of the total irrigated area is covered by rice. Thus, rice plays a vital role in the livelihood of the people of Bangladesh. Total rice production in Bangladesh was about 10.97 million tons in the year 1971 when the country's population was only about 70.88 millions. At present the country is now producing about 34.45 million tons to feed her 156.6 million people (BBS, 2013). This indicates that the increase of rice production was much faster than the increase of population. This increased rice production has been possible largely due to the adoption of modern rice varieties on around 70.24% of the rice land which contributes to about 83.39% of the country's total rice production (BBS, 2012). However, there is no reason to be complacent. Population growth rate in Bangladesh is two million people per year and the population will reach 233.2 million by 2050, going by the current trend (BBS, 2012). Bangladesh will require more than 55.0 million tons of rice per year to feed its people by the year 2050. Bangladesh will require about 31.3 to 42.0 million tons of rice for the year 2030 (IFPRI, 2012).

Plant nutrients are essential for the cultivation of crops. Among the nutrients N, P& K is the most important key input for rice production all over the world for its large requirement and instability in soil. In most cases, surface broadcasting of Urea, TSP & MP is practiced by farmers to meet up the N, P, K demand for boro rice crop. The lion part of those applied fertilizers is getting lost through a number of processes including volatilization, denitrification, run-off, leaching and fixation. These result in low crop yield.

NPK briquette are formed by dropping liquid urea, TSP & MoP from a prilling tower into droplets that dry into roughly spherical shapes of 1cm to 4 cm in diameter and increased efficiency of applied nutrients. The use of NPK granules, which is a mixture of urea, triple superphosphate and muriate of potash may help in reducing the loss of nutrients in flooded ecosystem. Farmers in Vietnam and Cambodia obtained 25% higher yields with deep placement of NPK granules over the broadcasting of fertilizers (IFDC, 2007). In Bangladesh yield of rice was increased by 15-25% while expenditure on commercial fertilizer was decreased by 24-32% when fertilizers granules were used as the source of N, P and K (IFDC, 2007). Islam *et al.* (2011) reported that application of NPK granules (2.4 g x 2) produced the highest rice grain yield of 7.47t ha^{-1} and demonstrated higher agronomic efficiency than PU(Granular urea) and USG(urea super granule). They also observed that NPK granules can save 33 kg Nha^{-1} compared to recommend PU. Kapoor *et al.* (2008) reported that broadcast application of N as urea resulted in an average 10 times higher amounts of ammonium N in flood water compared to deep placement of urea briquette and NPK briquette.

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 (Voushida, 1981). Among the fertilizers nitrogenous fertilizer has immense effect on the yield of rice. Proper application of urea supergranule (USG) and prilled urea is an important step towards augmentation of rice yields. Nitrogen is the top most important nutrient and it is a key input for rice production in the rice growing countries as well in Bangladesh (Hasan *et al.* 2002). Total N uptake by rice plant ha1 varies among rice varieties. Nitrogen is required in adequate amount at early, at mid-tillering and particle initiation stage for better grain development (Ahmed *et al.* 2005). Wani *et al.* (1999) revealed that 120 kg N h&' as LJSG 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%. Deep placement of fertilizer granules also offered environmental and economic benefits (IFPRI, 2004). Therefore the present experiment was undertaken with the following objectives:

i) To investigate the effect of NPK briquette on growth and yield of boro rice varieties; and

ii) To select the suitable dose of NPK briquette for maximum growth and yield of boro rice.

CHAPTER II
REVIW OF LITERATURE

The fertility status of Bangladesh soil is low due to poor organic matter content. Rapid degradation of organic matter occurs due to high rainfall and temperature. Productivity is intimately related with fertility of soil which supplies almost all of the essential nutrients to the crop. Hence improvement together with maintenance of a good supply of organic matter is essential for sustainable soil fertility and crop productivity. A number of research works on the response of rice to prilled urea and NPK granules have been carried out in the rice growing countries of the world including Bangladesh. In this chapter an attempt has been made to review some of available research findings in Bangladesh and elsewhere related to the effect of prilled urea combined with NPK granules on growth, yield, yield contributing characters and nutrient uptake by rice.

2.1 Effect of level of nitrogen on growth, yield and quality of rice

Nitrogen is the key element in the production of rice and gives by far the largest response. Most of the rice varieties are highly responsive to added nitrogen and they are not expected to produce their full yield potential without adequate fertilizers especially with nitrogen fertilizers. Available literatures, which are related to the level of nitrogen, are briefly reviewed in this section.

Chopra and Chopra (2004) showed that nitrogen had significant effects on yield attributes such as plant height, panicles plant^{-1} and 1000-grain weight. Cumulative effect of yield attributing characters resulted in significant increase in seed yield at 120 kg N ha^{-1} over 60 kg N ha^{-1} and the control. Different spacing did not affect seed yield. The relationship between seed yield and nitrogen was quadratic. The maximum response was observed at 60 kg N ha^{-1} and thereafter it decreases with increase in N rate. The optimum N rate was 141.9 kg ha^{-1}, recording an additional profit of Rs. 18607 over the control.

Namba (2003) showed in their experiment with rice cv. Giza 172 that grain yield ranged from 1470 to 1570 g m^{-2} when rice was grown at 55 hills m^{-2} and supplied with 15 or 20 g N m^{-2} or at 33 hills m^{-2} and supplied with 20 g N m^{-2}.

Lawal and Lawal (2002) conducted three field experiments during the rainy seasons of 1996, 1997 and 1998 in Nigeria to evaluate the growth and yield responses of lowland rice with 4 levels (0, 40, 60, and 80 kg N ha^{-1}). They concluded that grain yield increased significantly up to 80 kg N ha^{-1} and thousand grain weight (1000-grain) increased significantly up to 120 kg ha^{-1}.

Thakur (1993) showed that there was an increasing trend of 1000-grains weight with an increase level of N up to 80 kg ha^{-1}.

Munnujan *et al.* (2001) reported that the highest grain yield (3.8 t ha^{-1}) was obtained at 180 kg N ha^{-1}, which was similar to the yield obtained at 80 kg N ha^{-1} (3.81 t ha^{-1}).

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

Kim *et al.* (1999) stated that increases in tiller and panicle numbers were greater from increased N rate than higher plant density. Ripened grain ratio was slightly lower from dense planting. In brown rice 1000-grain weight was not significantly affected by treatment. Milled rice yield was highest from 165 kg N with standard planting for heavy panicle type rice, while yield for much panicle type rice was highest with 165 kg N and high density.

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

Castro and Sarker (2000) reported that the effect of N application as basal (80, 60 and 45 kg ha^{-1}) and top dressing (10, 30 and 45 kg ha^{-1}) on the yield and yield components of Japonica rice and obtained high effective tillers, percentage of ripened grains and high grain yields from 45 kg N ha^{-1} (basal) and 45 kg N ha^{-1} (top dressing).

Chopra and Chopra (2000) found that row spacing did not influence on yield components but seed and straw yields increased linearly up to 80 kg N ha^{-1} and there after a marginal reduction in seed yield was observed at 120 kg ha^{-1}.

Singh *et al.* (2000) stated that each incremental dose of N gave significantly higher grain and straw yields of rice over its preceding dose. Consequently the crop fertilized with 100 kg ha^{-1} gave the maximum grain yield (2647 kg ha^{-1}).

Chopra and Chopra (2000) reported that the application of N at the rate of 80 or 120 kg N ha^{-1} improved all the yield attributes compared with control treatment.

Neelam and Nisha (2000) stated that significant linear increase in seed yield was recorded up to 80 kg N ha^{-1} and thereafter a marginal reduction in seed yield was observed at 120 kg N ha^{-1} Straw yield increased up to the highest level of N. They recommended 98.5 kg N ha^{-1}.

Sahrawat *et al.* (1999) reported that N level significantly affected the straw yield.

Rajarathinam and Balasubrnianiayan (1999) observed that there was no appreciable change in the yield attributes due to application of higher dose of N above 150 kg ha^{-1}.

Singh *et al.* (1997) concluded that grain yield increased with up to 60 kg N ha^{-1} and was the highest at the sowing rate of 80 kg seed ha^{-1}.

Spanu and Pruneddu (1997) reported that rice yield increased with increasing N rates, ranging from 5.4 t ha^{-1} to 10.3 t ha^{-1}.

Singh *et al.* (1998) reported that rice cv. Pusa Basmati I and Kasturi grown in 2 seasons and found that Pusa Basmati was significantly superior for panicles $hill^{-1}$, rachille $panicle^{-1}$, weight of grains, grains $panicle^{-1}$ and gave 0.16 t ha^{-1} grain yield than that of Kasuri (3.31 t ha^{-1}). They found significantly linear increase in grain yield up to 100 kg N ha^{-1} beyond which the yields of both the varieties declined, and applying 100 kg N ha^{-1} gave 1.55, 0.25, 0.65 t ha^{-1} grain yields than those of 0, 50 and 150 kg N ha^{-1} respectively.

Maske *et al.* (1997) stated that plant height increased significantly with increased N level.

Chander and Pandey (1996) cited that application of 120 kg ha^{-1} resulted in significant increase in effective tiller m^{-2} compared to 60 kg N ha^{-1}.

BINA (1996) reported that the highest number of total and effective tillers was obtained from 120 kg ha^{-1} of N application. And they also stated that a significant increase in grains $panicle^{-1}$, tillers m^{-2} and grain yield was obtained from application of 120 kg N ha^{-1} compared to 60 kg N ha^{-1}.

Chander and Pandey (1996) noted that application of 120 kg N ha^{-1} gave significantly increased in grain yield compared with 60 kg N ha^{-1}.

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

Dahattonde (1992) concluded that N fertilizer significantly enhanced the plant height.

Hussain and Sharma (1991) reported that application of nitrogen up to 140 kg ha^{-1} increased plant height. At 80 kg and 120 kg N ha^{-1} the variation in plant height was no significant. The highest plant height was obtained from 120 kg N ha^{-1} and lowest one from the control.

Ali (1994) observed that weight of 1000-grains was higher when 100 kg N ha^{-1} was applied in three equal installments at basal, 30 days after transplanting.

Singh and Pillai (1994) reported that increased doses of nitrogen increased grain yield significantly up to 90 kg N ha^{-1} thereafter declined.

Srivastava and Solanki (1993) in yield trials with rice cultivar Kranti giving 0-150 kg N ha^{-1} found that grain yield and net returns increased with increasing N application.

Dahattonde (1992) reported from a field trial on four rice cultivars with nitrogen applied from 0-120 kg N ha^{-1} and yield increased up to 100 kg N ha^{-1}.

Hussain and Sharma (1991) reported that application of nitrogen increased grain number $panicle^{-1}$ up to 80 kg ha^{-1}. Nitrogen application at the rate of 120 kg ha^{-1} did not significantly affect the grains $panicle^{-1}$. The highest number of grains $panicle^{-1}$ was produced by 80 kg N ha^{-1} and the lowest was produced by the control treatment.

Thakur (1991) observed that there was an increasing trend of 1000-grain weight with an increase in levels of nitrogen up to 80 kg ha^{-1}. Similar result was also reported by Thakur (1993).

Islam *et al* (1990) noted that there was an increasing trend of 1000-grain weight with an increase in levels of nitrogen up to 80 kg ha^{-1}.

Idris and Matin (1990) observed that the grain yield increased gradually with an increase in N and *was* the maximum at 120 kg N ha^{-1}.

IRRI (1990) reported that the application of N fertilizer in transplant aman rice at doses of 30, 60, 90 and 120 kg N ha^{-1} gave the grain yield of 3.48, 4.41, 4.82 and 4.63 t ha^{-1} respectively.

Bhuiyan *et al.* (1990) reported that taller plants were produced by higher amount of nitrogen applications.

Biswas and Bhattacharya (1989) observed that increasing nitrogen rates from 0 to 100 kg ha^{-1} increased the rice yield from 0.5 to 5.0 t ha^{-1} in wet season and from 2.7 to 3.7 t ha^{-1} in dry season. Further increase in N up to 150 kg ha^{-1} did not produce significant variation in rice yield. The experimental results indicate that higher N application *(150* kg ha^{-1}*)* is required to achieve higher grain yields in hybrid rice (Singh *el al.* 1998).

Wang and Thorat (1988) reported from an experiment with rice cv.R-24 grown under different hill spacings and N rates that N application significantly increased the tiller number over all hill spacings. Nitrogen application from 0 to 120 kg ha^{-1} in three split dressings increased number of tillers $hill^{-1}$ (Reddy *et al.* 1986).

Kamal *et al.* (1988) observed that the highest rate of nitrogen fertilizer have maximum tillers $hill^{-1}$, which was significantly greater than any of other treatments.

Kehinde and Fagande (1987) reported that higher N level did not increase yield significantly compared to lower level. Both the level increased yield compared to the control.

Reddy *et al.* (1986) observed that application of 30, 60 and 90 kg N ha^{-1} to rice produced paddy yields of 2.89, 3.77 and 4.39 t ha^{-1} respectively.

Maskina and Singh (1987) studied the performances of three rice cultivars giving 90, 120 or 150 kg N ha^{-1} and noted that yield and yield components of all the cultivars increased upto 150 kg N ha^{-1}.

Mondal *et al.* (1987) stated that increasing rate of N from 40 to 160 kg ha^{-1} increased the number of productive tiller $hill^{-1}$. The plant height number of productive tillers $hill^{-1}$ and grain yield increased with increasing nitrogen application and were found the highest with 120 kg N ha^{-1}.

Kumar *et al.* (1988) reported that increasing rates of N from 0 to 80 kg ha^{-1} increased yields to 3.94 and 4.7 t ha^{-1} respectively increased dose of N from 0 to 80 kg ha^{-1} increased the no. of tillers $hill^{-1}$, number of grains $panicle^{-1}$ and weight of 1000-grain in rice. Grain and straw yields increased from 6.99 to 8.26 and 8.91 to 11.14 t ha^{-1} respectively.

2.2 Effects of phosphorus on growth and yield of rice

A field experiment was conducted by Srivastava *et al.* (2014) on basmati rice-wheat rotation with combinations of Zn levels (0, soil application of 2.5 kg Zn ha^{-1} and two foliar applications of 2.0 kg Zn ha^{-1}) and P levels (0, soil application of 8.7, 17.5 and 26.2 kg P ha^{-1}). The highest pooled grain yields of basmati rice and wheat were obtained with soil application of 17.5 kg P ha^{-1} and foliar application of 2 kg Zn ha^{-1}.

In order to investigate the effect of nitrogen and phosphorus fertilizer on spikelet structure and yield in rice (*Oryza sativa*), an experimental design in north of Iran in 2011 cropping season (Yosef, 2013). Nitrogen fertilizer at 50 and 150 kg ha^{-1} was main plot and phosphorus fertilizer at 4 level 0 (control), 30, 60 and 90 kg ha^{-1} as sub plot. Using randomized complete block design (RCBD) with 3 replications. The effect of phosphorus fertilizer on spikelet number and yield was significant in 1% probability level. Fertile spikelet, fertile spikelet percentage (%), sterile spikelet percentage (%) and biological yield were significant in 5% probability level. Spikelet number under phosphorus fertilizer treatment in P_1 and P_4 was (89.63), (90.54), (96.67) and (97.41) respectively. Increasing the level of P up to 26.4 kg ha^{-1} also significantly increased ($p<0.01$), the number of spikelets $panicle^{-1}$. Application of P increases the total number of spikelets $panicle^{-1}$ in rice thereby contributing to increment in grain yield (Gebrekidan and Seyoum 2006).

Fertile spikelet percentage (%) under phosphorus fertilizer treatment in p_1 and P_4 was (74.29), (77.80), (83.08) and (82.04) respectively. Maximum grain and biological yield was (44.70) and (91.20) respectively that observed for 90 kg ha^{-1} phosphorus fertilizer and minimum of these was (36.50) and (76.38) respectively obtained for (control) 0 kg ha^{-1} phosphorus fertilizer. Maximum harvest index was 47.92 observed for 90 kg ha^{-1} phosphorus fertilizer and minimum of that was 47.79 obtained for (control) 0 kg P ha^{-1}. Application of 13.2 kg P ha^{-1} significantly ($p<0.01$) increased harvest index of rice, according harvest index of the rice crop was negatively and significantly correlated with plant height, panicle length, number of panicle m^{-2} and straw yield.

Alinajoati sisie & Mirshekari (2011) said that phosphorus deficit is a most important restrictive factor in plant growth and recognition of mechanisms that increase plant phosphorus use efficiency is important. Phosphorus is a major component in ATP, the molecule that provides “energy” to that plant for such processes as photosynthesis, protein synthesis, nutrient translocation, nutrient uptake and respiration.

Wilson *et al.* (2006) reported that phosphorus is also a component of other compounds necessary for protein synthesis and transfer of genetic material DNA, RNA.

Delong *et al.* (2002) said that phosphorus application to rice increased P accumulation but did not consistently increase rice yields because flooding decreased soil P sorption and increased P diffusion. Resulting in higher P supply to rice relative to wheat.

2.3 Effects of potassium on growth and yield of rice

Tiwari (1985) reported that the K reserve of any soil is certainly limited, and no soil can supply K to crops adequately for an indefinite period of time. Some studies on K buffering capacity, K depletion, K release pattern and relationships of some soils indicated that there is a difference in soils in immediate and long-term availability of K. Intensive cropping and use of modern rice varieties for high yield caused heavy depletion of K in soils particularly in the absence of K application.

Mohanty and Mondal (1989) reported a negative K balance in rice systems at many sites in India.

Ahsan *et al.* (1997) said that a negative K balance even up to 60 kg/ha applied K level with diminishing magnitude was observed in a recent study of BRRI and suggested that an amount of about 60 kg K/ha would be required to sustain soil native K for rice cropping. Recent study indicated that about 60% cultivable land of Bangladesh is deficient in N, P and K. Most of the area of the North Western part of the country is deficient in K.

Miah (2005) showed that light textured soils of these areas has low exchangeable K and farmers also use low amount of K fertilizer. As the pressure to grow more food from the same piece of land increases, the soils come under the threat of nutrient depletion. Nutrient balance study indicated a negative balance for N and K and the mining of K from Bangladesh soil is now in alarming situation.

Rijmpa and Islam (2002) said that the value varied between 0-50 kg/ha/yr for N and 100-225 kg/ha/yr for K. Rice is the staple food of Bangladeshi people. Wheat is relatively a new crop and growing wheat in a rice-wheat cropping pattern has been getting importance as a promising system for increasing food production in the country. Rice-wheat cropping system draws a lot of potassium from the soil and taking into consideration inadequate potash fertilizer inputs, soils are often single supplier of K to plants in the Indo-Gangetic Plains.

As recently reviewed by Bijay Singh *et al.* (2004) K removal by rice wheat cropping system in the Indo-Gangetic Plains and in China ranges from 132 to 324 kg/ha in dependence from the cropping system and the productivity.

Long-term on-farm experiments conducted in different Asian countries indicated that initial rice yield increase due to K application was not significant (Witt *et al.* 2004).

Over 16 year period, the omission of K fertilizer significantly decreased the yield of rice and the yield gap between the balanced treatment and the zero K treatment widen sharply with time (BRRI, 2001).

Diba *et al*. (2005) reported a positive effect of K fertilizer use on rice yield contributing parameters.

The response to K fertilizer on cereal crops like wheat was reported by Shaha *et al.* (2001) and rice by Ahsan *et al.* (1997).

Timsina and Connor (2001) reported that intensive rice-based cropping system including wheat may cause heavy depletion of soil K.

2.4 Effects of NPK granules on yield of rice and nitrogen uptake by rice plant

Shah *et al.* (2012) reported that deep placement of NPK briquette (2 × 2.4 gm) increase rice yield about 10 percent and it saved 37 percent nitrogen than BRRI fertilizer recommended rate in Boro season. Similarly, NPK briquette (1 × 3.4 gm) produced 28 percent and 18 percent more rice yield than BRRI fertilizer recommended rate for T. Aus and T. Aman respectively and also resulted in savings of 26-39 percent nitrogen.

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

Kapoor *et al*. (2008) reported that significantly higher grain yield was observed with deep placement of NPK briquette compared to broadcast application.

Durguda *et al*. (2008) also reported that higher grain yield was observed in rice with DAP briquettes compared to urea.

Bulbuale *et al*. (2008) reported that grain yield of grain yield of rice significantly increased when the crop was fertilized through briquettes (100-50-30 kg NPK ha^{-1}) as compared to the application of conventional fertilizers (100-50-50 kg NPK ha^{-1}).

Upendra Singh *et al.* (2008) reported that the deep point placement of NPK briquettes significantly increased grain and straw yields, total N, P and K uptake, also N and P use efficiencies compared to broadcast incorporation of N, P and K in rice.

Vibhu Kapoor *et al.* (2008) recorded that deep placed NPK briquettes gave significantly higher grain yield, straw biomass, total P and K uptake, apparent P recovery, and agronomic N and P use efficiencies, when plant spacing was reduced from 20cm × 20 cm to 20 × 10 cm. Closer plant spacing led to better utilization of P and K and provided opportunities for deep placement of N or NPK briquettes in soils with low available P. Combining site specific characteristics viz., high soil pH, low percolation rate, high rainfall and surface runoffs with plant spacing and N–P–K briquettes prepared based on site-specific nutrient requirements offered potential for higher yields, improved fertilizer use efficiency, balanced fertilization and reduced nutrient losses.

IFDC (2007) reported that farmers in Vietnam and Cambodia obtained 25% higher yields with deep placement of NPK briquettes over the broadcasting of fertilizer.

Peterson (2007) found that placement of compound NPK fertilizer increased the grain yield and the quality parameters like grain size and the effect of fertilizer placement on grain yield and quality decreased in the order NPK> NP> N> P.

IFDC (2007) reported that deep placement of fertilizers had increased rice yield by 22 % over broadcasting and decreased urea use by 47 %.

Siddika (2007) conducted an experiment by using PU and USG and found that N use efficiency was higher from USG in compared to PU.

IFPRI (2004) reported that in Bangladesh, yield of rice was increased by 15-25 %, while expenditure on commercial fertilizer was decreased by 24-32 % when fertilizer briquettes were used as the source of plant nutrients. Deep placement of fertilizer briquettes also offered environmental and economic benefits.

Neubauer *et al*. (2002) and Chandrajith *et al*. (2008) found that in tidal ecosystem, nutrient management strategies would be different from other ecosystem. Because applied N, P and K fertilizers are washed-out from rice field during tidal flood. So, deep placement of all fertilizers would be effective rather than broadcasting.

Kadam *et al.* (2001) reported that urea briquettes increased grain yield of rice over split application of urea and the additional yield increased from 5 to 83 %.

Prasad and Prasad (1983) reported that the use of urea briquettes gave higher yields and resulted in greater removal of NPK briquette than prilled urea.

2.5 Effect of NPK granules compared with Urea on crops

Peterson (2007) found that placement of compound NPK fertilizer increased the grain yield and the quality parameters like grain size and grade when weeds are controlled mechanically by harrowing in barley. The effect of fertilizer placement on grain yield and quality decreased in the order NPK> NP> N> P.

Bulbule *et al.* (2008) carried out an experiment to study the effects of NPK briquettes on yield and nutrient content of rice. The results showed that grain yield of rice significantly increased when the crop was fertilized through briquettes (56-30-30 kg NPK ha^{-1}) as compared to the application of conventional fertilizers (100-50-50 kg NPK ha^{-1}).

Singh *et al.* (2008) reported that the deep-point placement of NPK briquettes significantly increased grain and straw yields, total N, P and K uptake, also N and P use efficiencies compared to broadcast incorporation of N, P and K in rice.

Kapoor *et al.* (2008) recorded that deep placed N–P briquettes gave significantly higher grain yield, straw biomass, total P and K uptake, apparent P recovery and agronomic N and P use efficiencies, when plant spacing was reduced from 20 x 20 cm to 20 x 10 cm. Closer plant spacing led to better utilization of P and K and provided opportunities for deep placement of NP or NPK briquettes in soils with low available P. Combining site specific characteristics viz. high soil pH, low percolation rate, high rainfall and surface runoffs with plant spacing and NPK briquettes prepared based on site specific nutrient requirements offered potential for higher yields, improved fertilizer use efficiency, balanced fertilization and reduced nutrient losses.

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

Choudhury *et al.* (2013) carried out three different experiments in three locations in Bangladesh (Jessore, Patuakhali and Mymensingh) to evaluate the performance of deep placement of NPK briquette compared to broadcast incorporation of N, P and K on vegetables like cucumber, taro and bitter gourd.

Shah *et al.* (2013) carried out twelve experiments at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur, BRRI regional station Sagordi, Barisal and farmers' field in 2012 to evaluate the NPK briquette efficacy in rice production. Experimental results revealed that deep placement of NPK briquette (2 x 2.4gm) increased rice yield about 10 percent and it saved 37 percent N, 30 percent P and 44 percent K than BRRI fertilizer recommended rate in boro season. Similarly, NPK briquette (1 x 3.4gm) produced 28 percent and 18 percent more rice yield than BRRI fertilizer recommended rate for T. aus and T. aman respectively. Thus, use of NPK briquette over NPK broadcast and incorporation was very much efficient for rice cultivation.

CHAPTER III
MATERIALS AND METHODS

This chapter highlighted the experimental work. The experiment was conducted at Sher-e-Bangla Agricultural University (SAU) Farm, Sher-e-Bangla Nagar, Dhaka. A brief description about the experimental site and season, soil, climate, crops, treatments, experimental design followed, land preparation, seedling transplanting, intercultural operations, harvesting, data recording, collection and preparation of soil and plant samples and the methods for the chemical and statistical analysis are presented in this section.

3.1 Description of experimental site

3.1.1 Geographical location

The experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka, during the period from 10 November 2016 to 10 June 2017. The experimental area was situated at 23°77 N latitude and 90°33 E longitude at an altitude of 9 meter above the sea level (Anon. 2004).

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of “The Modhupur Tract”, AEZ-28 (Anon. 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where flood plain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon. 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix III.

3.1.3 Climate

The experimental area has sub-tropical climate which is characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds in Kharif season (16 March-15 October) and scantly rainfall associated with moderately low temperature during Rabi season (16 October-15 March). Weather information regarding temperature, relative humidity, total rainfall and sunshine hours prevailed at the experimental site during the study period were presented in Appendix II.

3.1.4 Soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 5.6-6.5 and had organic matter 1.1-1.99%. The experimental area was flat having available irrigation and drainage system and above food level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by soil Resource Development Institute (SRDI), Dhaka. The morphological, physical and chemical characteristics of the soil were presented in Appendix I.

3.2 Details of the experiment

3.2.1 Treatments

The experiment comprised of two factors:

Factor A: Variety (2):

V_1= BRRI dhan28

V_2= BRRI dhan29

Factor B: Fertilizer doses (5):

T_1=No nitrogen& other Fertilizer

T_2=Recommended Fertilizer Dose (N-120 kg/ha, P-30 kg/ha, K-50kg/ha)

T_3=2 NPK briquette of 2.40 gm sized in middle of 4 heel

T_4=2 NPK briquette of 2.40 gm sized in middle of 4 heel + 1 top dressing at tiller stage @ (1⁄4) of nitrogenous fertilizer

T_5=1 NPK briquette of 2.40 gm sized in middle of 4 heel + 1 top dressing at tiller stage @ (1⁄4) of nitrogenous fertilizer

3.3 Crop/ planting Material

Seeds of BRRI dhan28 and BRRI dhan29 were collected from Bangladesh Rice Research Institute, Gazipur.

3.3.1 Description of crop: Variety (BRRI dhan28)

BRRI dhan28 the test crop. This variety was developed at the Bangladesh Rice Research Institute from the cross between BG 90-2 and BR 51-46-5 in 1994. It is recommended for Boro season. Average plant height of the variety is 90-95 cm at the ripening stage. The grains are medium fine and white. It requires about 155-160 days completing its life cycle with an average grain yield of 6.0-6.5 t ha^{-1} (BRRI, 2004).

3.3.2 Description of crop: Variety (BRRI dhan29)

BRRI dhan29 was also used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute from Origin BR 802-118-4-2 in 1994. It is recommended for Boro season. Average plant height of the variety is 95 cm at the ripening stage. The grains are medium slender and white. It requires about 160 days completing its life cycle with an average grain yield of 7.5 t ha^{-1} (BRRI, 2004).

3.4 Land preparation

The experimental field was first ploughed on December 10, 2016 with the help of a tractor drawn rotary plough, later on December 12, 2016 the land was irrigated and prepared by three successive ploughing and cross ploughing with a tractor drawn plough and subsequently leveled by laddering. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on December 15, 2016 according to experimental specification.

3.5 Experimental design and lay out

The experiment was laid out in a Randomized Complete Block Design (RCBD), where the experimental area was divided into 3 blocks representing the replications to reduce the heterogeneous effects of soil. Each block was divided into 10 unit plots with raised bunds as treatments. Thus the total number of unit plots was 30. The unit plot size was 3.8 m x 2.1 m and plots to plot distance was 50 cm and row to row was 1 m. Treatments were randomly distributed within the block.

3.6 Manure and fertilizer application

The fertilizers were applied as per treatment. All the treatments except T_3, T_4 and T_5 received 52 kg P and 64 kg K ha^{-1} from TSP and MoP, respectively. In T_3, T_4 and T_5 treatments, P and K were supplied from NPK briquettes. Sulphur and zinc were applied to all plots as basal dose from gypsum and zinc oxide respectively. Prilled urea was applied in three splits. The first dose of PU was applied 15 days after transplanting (DAT), the second dose was added as top dressing at 35 DAT (active tillering stage) and the third dose was top-dressed at 55 DAT (panicle initiation stage). NPK briquettes were applied on 10 DAT and the briquettes were placed at 8-10 cm depth between four hills at alternate rows. Before application of N fertilizers, the water in the rice plot was drained out.

3.7 Transplanting of seedling

Thirty-five day old seedlings were carefully uprooted from a seedling nursery bed and transplanted in the plots on 11 January 2017 maintaining a spacing of 20 cm x 20 cm. Three seedlings were transplanted in each hill.

3.8 Intercultural operations

Intercultural operations were done as and when necessary for ensuring and maintaining the favorable environment for normal growth and development of crop. The following operations were performed:

3.8.1 Irrigation

Irrigation was provided to the plots from deep tube well to maintain continuous flooding condition during the growing period of the crop.

3.8.2 Weeding

The experimental plots were infested with some obnoxious weeds, which were controlled by uprooting and removing as many as three times from the field.

3.8.3 Insect and pest control

There was an infestation of Rice Hispa in the crop which was controlled by the application of Diazinon 60 EC.

3.9 Harvesting

Maturity of crop was determined when 90% of the grains become golden yellow in color. The harvesting of BRRI dhan28 was done on May 07, 2017. The harvesting of BRRI dhan29 was done on May 18, 2017. Hills from the central 1m^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.

3.10 Recording of yield components and yields

The data on yield components including plant height, effective tillers per hill, panicle length, grains panicle^{-1} and 1000-grain weight as well as grain and straw yields of BRRI dhan28 and BRRI dhan29 were recorded.

3.10.1 Plant height

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

3.10.2 Number of effective tillers hill^{-1}

The measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 5 hills.

3.10.3 Panicle length

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

3.10.4 Number of grains panicle^{-1}

Five panicles were taken at random hill^{-1} and the grains panicle^{-1} were counted and averaged.

3.10.5 1000-grain weight

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.

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

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

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

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

3.10.8 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})

3.10.9 Harvest index (%)

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

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

3.11 Collection and preparation of soil samples

Initial soil samples were collected at a depth of 0-15 cm from the surface. After removing weeds, plant roots, stubbles, stones, etc. the samples were air dried and ground to pass through a 2 mm (10 mesh) sieve. The samples were then stored in clean plastic bags for mechanical and chemical and analyses.

3.12 Analyses of soil samples

Initial soil samples were analyzed for both physical and chemical properties such as soil texture, soil pH, EC, organic carbon, total nitrogen, available P, exchangeable K and available S. The soil samples were analyzed following standard methods as follows:

3.12.1 Textural class

Particle size analysis of soil was done by hydrometer method (Boyoucos, 1926) and the textural class was determined by plotting the values of % sand, %silt and % clay in the Marshall's Triangular Co-ordinate following the USDA system.

3.12.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter using soil: water ratio of 1: 2.5 as described by Michael Peech (1965).

3.12.3 Soil EC

The EC of soil extract was measured by conductivity meter method (1:5 soil-water ratio at 25°C). Ten gm soil was taken into a 100 ml beaker and 50 mL water was added to it. The soil water suspension was stirred with a glass rod for 15 minutes and the suspension was settled down for 30 minutes. Then the EC of soil extract was measured with a conductivity meter at 25°C.

3.12.4 Organic matter content

Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). The oxidization of organic C was done with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and the excess $K_2Cr_2O_7$ solution was titrated with 1N $FeSO_4$. The organic matter content was calculated by multiplying the percent organic carbon with the van Bemmelen factor 1.73.

3.12.5 Total nitrogen

One gram of oven dry ground soil sample was taken into micro-kjeldahl flask to which 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. 5 H_2O: Se = 100: 10: 1), 2 ml 30% H_2O_2 and 3 ml H_2SO_4 were added. The flasks were swirled and allowed to stand for about 30 minutes. Then heating (380°C) was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. This digest was used for nitrogen determination.

After completion of digestion, 40% NaOH was added with the digest for distillation. The evolved ammonia was trapped into 4% H_3BO_3 solution and 5 drops of mixed indicator of bromocresol green ($C_{21}H_{14}O_5Br_4S$) and methyl red solution. Finally the distillate was titrated with standard 0.01 N H_2SO_4 until the color changed from green to pink (Bremner and Mulvaney, 1982). The amount of N was calculated using the following formula:

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

Where,

T = Sample titration value (ml) of standard H_2SO_4

B = Blank titration value (ml) of standard H_2SO_4

N = Strength of H_2SO_4

S = Weight of soil sample in gram.

3.12.6 Available phosphorus

Available phosphorus was extracted from the soil samples by shaking with 0.5 M $NaHCO_3$ solution at pH 8.5 following Olsen method (Olsen *et al.* 1954). The extracted phosphorus was determined by developing blue color by SnC_{l2} reduction of phosphomolybdate complex and measuring the intensity of color spectrophotometrically at 660 nm wavelength and the readings were calibrated to the standard P curve.

3.12.7 Exchangeable potassium

Exchangeable potassium was extracted from the soil samples with 1.0 N NH_4OAc (pH 7) as outlined by Knudsen *et al.* (1982) and K was determined from the extract by flame photometer.

3.13 Statistical analysis

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C (Russell, 1986).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter presents the effects NPK briquette on yield and yield contributing characters, nitrogen content and uptake by BRRI dhan28 and BRRI dhan29 rice. The results have been presented in various tables and figures and discussed below under the following sub-headings.

4.1. Growth Performance

4.1.1 Plant height (cm)

4.1.1.1 Effect of fertilizer dose

Effect of fertilizer dose showed a significant variation on plant height for all growth stages except 45 DAT (Table 1). At harvest, the tallest plant (99.77 cm) was recorded from T_4 treatment (2 NPK briquette of 2.40 gm sized in middle of 4 heel + 1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer) and the shortest plant (87.04 cm) was recorded from the control condition (T_1) 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.

Table 1: Effect of fertilizer doses on plant height (cm) at different days after transplantation of boro rice

Treatment	Days after transplanting (DAT) (cm)					
	25	45	65	85	105	at harvest
T_1	14.83 c	44.83	65.07 c	78.01 b	85.24 b	87.04 b
T_2	16.06b	47.61	67.35b	81.61 b	89.95ab	91.66ab
T_3	17.85 a	50.31	69.85 ab	86.23 a	94.79 a	96.77 a
T_4	18.85 a	52.56	72.85 a	89.23 a	97.81 a	99.77 a
T_5	17.09 ab	48.47	68.48 ab	81.96 b	90.48 ab	92.07 ab
SE Value	0.58	NS	2.18	1.4	1.51	1.57
LSD (%)	11.7	11.78	9.99	14.74	9.68	8.16

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

Here,

T_1= No nitrogen& other Fertilizer, T_2= Recommended Fertilizer Dose, T_3= 2 NPK briquette of 2.40 gm sized in middle of 4 heel, T_4= 2 NPK briquette of 2.40 gm sized in middle of 4 heel+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer, T_5= 1 NPK briquette of 2.40 gm sized in middle of 4 heel+ 1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer, V_1: BRRI dhan28, V_2: BRRI dhan29

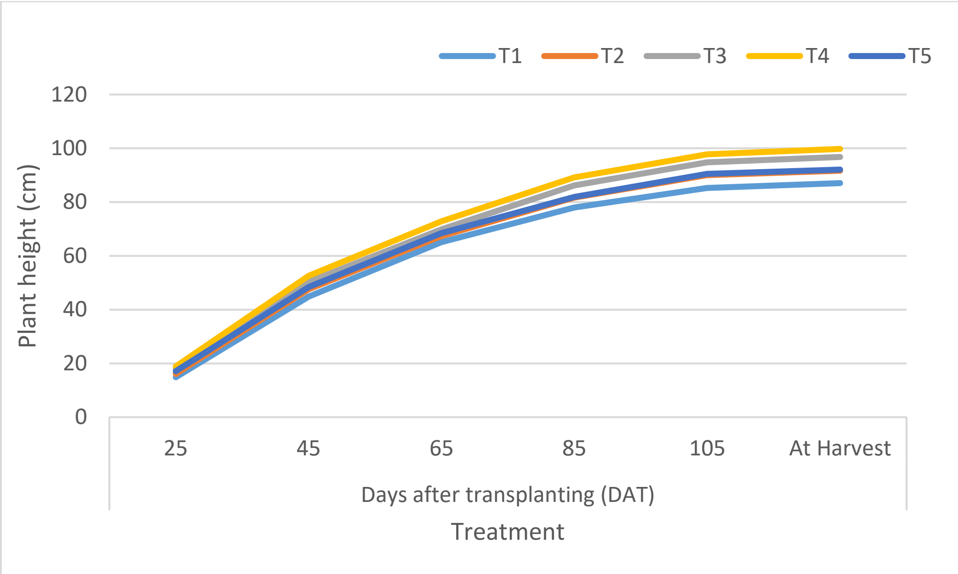


Figure 1: Effect of fertilizer doses on plant height (cm) of boro rice at different days after transplantation.

4.1.1.2 Effect of variety

Boro rice variety exhibited significant difference on plant height at different growth stages except 45 DAT (Table 2). Among the varieties, BRRI dhan29 showed significantly the tallest plant followed by BRRI dhan28 at all the growth stages (25, 45. 65, 85 and 105 DAT) and at harvest. Significantly the shortest plant was found in BRRI dhan28 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 2: Effect of variety on plant height (cm) at different days after transplantation of boro rice

Variety	Days after transplanting (DAT) (cm)					
	25	45	65	85	105	at harvest
V_1	16.12 b	48.16	65.69 b	79.90 b	87.86 b	89.57 b
V_2	17.75 a	49.35	71.80 a	87.01 a	95.57 a	97.38 a
SE Value	0.31	NS	0.95	1.10	1.19	0.92
LSD (%)	0.73	1.47	2.25	2.63	2.83	2.17

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

Here, V_1: BRRI dhan28, V_2: BRRI dhan29

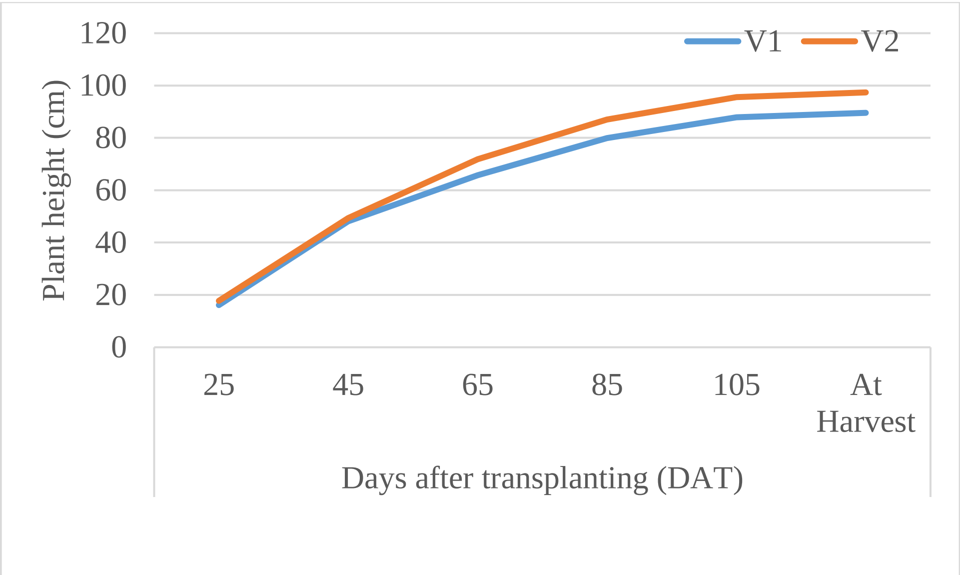


Figure 2: Effect of variety on plant height (cm) of boro rice at different days after transplantation.

4.1.1.3 Interaction effect of fertilizer doses and variety

Interaction of fertilizer doses and variety showed an increasing trend with advances of growth period in respect of plant height (Fig-3). The rate of increase was much higher in the early stages of growth 25 DAT to 85 DAT. After that the increasing rate was much slower up to 105 DAT. However, the tallest plant (99.85 cm) was found in the V_2 x T_4 interaction followed by V_1 x T_4 interaction (99.77 cm), V_2 x T_3 interaction (96.85 cm) and V_1 x T_3 interaction (96.77 cm) at harvest. The shortest plant (80.50 cm) was found in V_1 x T_1 interaction at harvest.

Table 3: Interaction effect of fertilizer doses and variety on plant height (cm) of boro rice at different days after transplantation.

Treatment	Days after transplanting (DAT) (cm)					
	25	45	65	85	105	At Harvest
V_1T_1	14.86 e	44.86 e	65.07 e	78.04 e	85.24 e	87.11 d
V_1T_2	16.16 d	47.61 d	67.35 d	81.61 d	89.95 d	91.77 d
V_1T_3	17.85 b	50.31 b	69.90 b	86.36 b	94.85 b	96.77 b
V_1T_4	18.85 a	52.62 a	72.88 a	89.23 a	97.81 a	99.85 a
V_1T_5	17.09 c	48.47 c	68.48 c	81.96 c	90.48 c	92.10 c
V_2T_1	14.83 e	44.83 e	65.19 e	78.01 e	85.24 e	87.36 d
V_2T_2	16.06 d	47.61 d	67.38 d	81.71 d	89.96 d	91.66 d
V_2T_3	17.90 b	50.34 b	69.85 b	86.23 b	94.79 b	96.85 b
V_2T_4	18.90 a	52.56 a	72.85 a	89.26 a	97.87 a	99.77 a
V_2T_5	17.12 c	48.50 c	68.51 c	81.96 c	90.51 c	92.07 c
SE Value	0.05	0.02	0.03	0.04	0.03	0.16
LSD (%)	0.17	0.14	0.13	0.14	0.13	0.58

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

Here,

T_1=No nitrogen& other Fertilizer, T_2=Recommended Fertilizer Dose, T_3=2 NPK briquette of 2.40 gm sized in middle of 4 heel, T_4=2NPK briquette of 2.40 gm sized in middle of 4 heel+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer, T_5=1 NPK briquette of 2.40 gm sized in middle of 4 heel+ 1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer, V_1: BRRI dhan28, V_2: BRRI dhan29

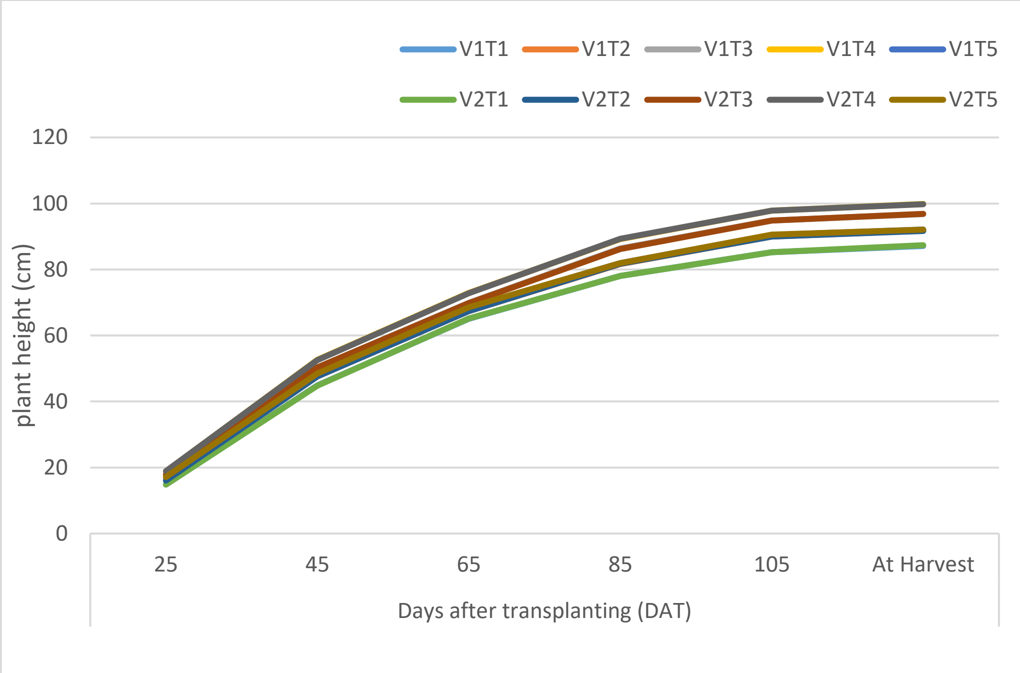


Figure 3: Interaction effect of fertilizer doses and variety on plant height (cm) of boro rice at different days after transplantation.

4.2 Yield components of boro rice

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

4.1.2.1 Effect of fertilizer dose

Number of effective tillers hill^{-1} was significantly affected due to different fertilizer doses at 5 % level of significance (Figure 4). All the treatments caused an increasing effect on the number of effective tillers hill^{-1} over control. The number of effective tillers hill^{-1} due to different treatments ranged from 9.79 in T_1 (control) to 16.42 in T_4 (2 NPK briquette of 2.40 gm sized in middle of 4 heel+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer). The highest number of effective tillers hill^{-1} in T_4 (2 NPK briquette of 2.40 gm sized in middle of 4 heel+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer) was 16.42 which was statistically identical to T_3 (2 NPK briquette of 2.40 gm sized in middle of 4 heel), T_5 (1 NPK briquette of 2.40 gm sized in middle of 4 heel+ 1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer) and T_2 (Recommended Fertilizer Dose) with the value of 16.42, 15.62, 14.35, 13.38 & 9.79 respectively. The lowest number of effective tillers hill^{-1} 9.79 was found in treatment T_1 (control) which was significantly lower than all other treatments.

The treatments may be ranked in the order to $T_4 > T_3 > T_5 > T_2 > T_1$ in terms of effective tiller hill^{-1}. Das (2011) observed that the highest number of total tillers hill^{-1} (13.14) was produced in treatment U_3 (1.8 g USG 4 hill^{-1}) and the lowest number of total tillers (8.57) was produced in treatment U_1 (no application of nitrogenous fertilizer). Hasan (2007) conducted an experiment during the boro season of 2006 and recorded the increased number of tillers hill^{-1} with increased nitrogen level as USG. Singh and Shivay (2003) evaluated that the effective tillers hill^{-1} was significantly affected by the level of nitrogen and increasing levels of nitrogen significantly increased the number of effective tillers hill^{-1}. These results are well corroborated with the findings of Rajni *et al.* (2001) who found increased number of effective tiller hill^{-1} with the integrated use of PU and NPK briquette fertilizers.

Figure 4: Effect of fertilizer doses on effective tiller hill^{-1} of boro rice.

4.1.2.2 Effect of variety

Variety exerted significant effect on the number of tillers hill^{-1} at 5% level of significance (Figure 5). The highest number of tillers hill^{-1} was produced by BRRI dhan29 (14.95) whereas the lowest number of tillers hill^{-1} was produced by BRRI dhan28 (13.63). 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.

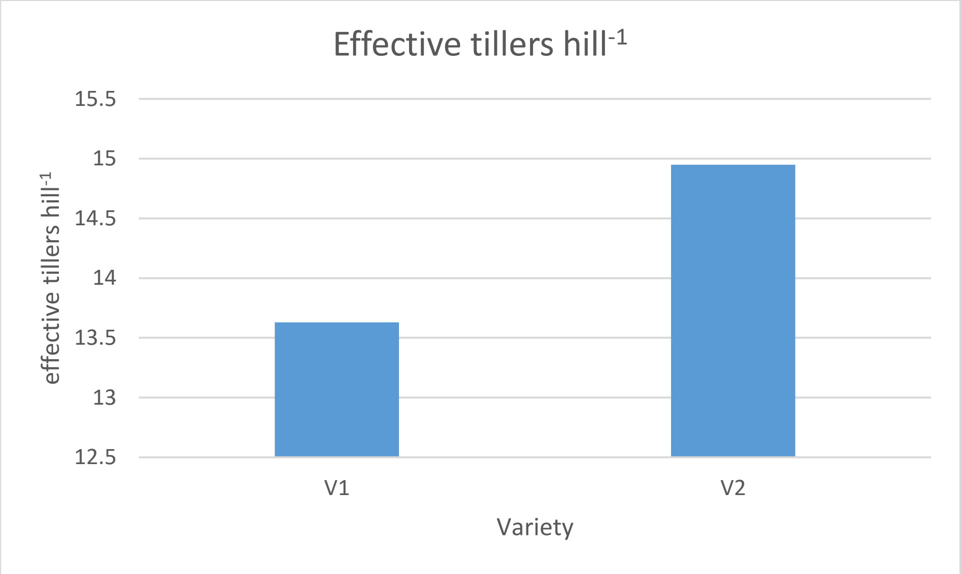


Figure 5: Effect of variety on effective tiller hill^{-1} of boro rice.

4.1.2.3 Interaction effect of fertilizer doses and variety

Effective tillers number hill^{-1} was significantly influenced by the interaction of fertilizer doses and variety at all sampling days (Figure 6). At harvest the highest number of tillers hill^{-1} (17.36) was found in the interaction of the V_1 x T_4, treatment followed by V_1 x T_3 (15.78) interaction treatment and V_1 x T_4 (15.48) interaction treatment. The lowest number (9.10) of tillers hill^{-1} was found in the interaction of V_1 x T_1.

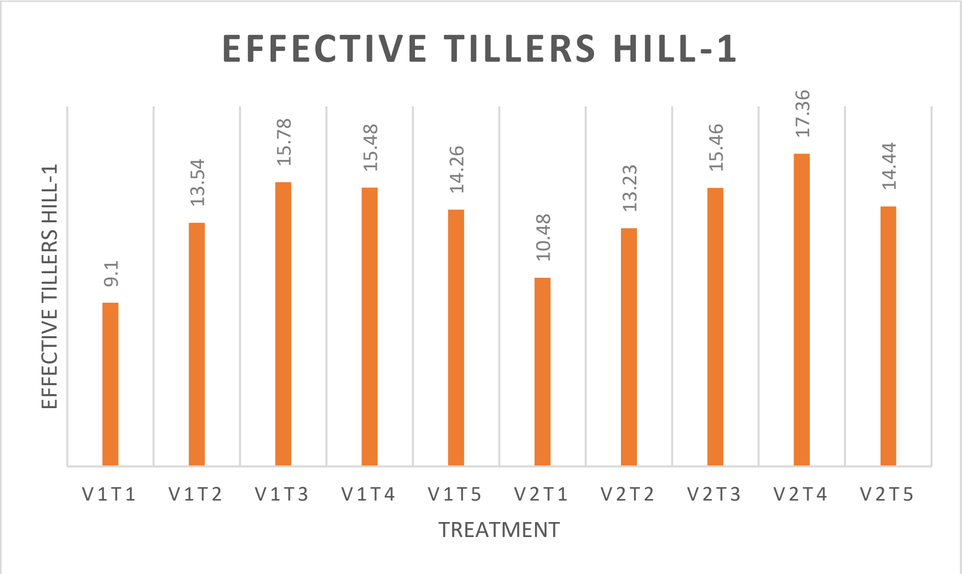


Figure 6: Interaction effect of fertilizer doses and variety on effective tiller hill^{-1} of boro rice.

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

4.2.2.1 Effect of fertilizer doses

Number of non-effective tillers hill^{-1} was significantly affected due to different fertilizer doses at 5 % level of significance (Table 4). The highest number of non-effective tillers hill^{-1} (3.37) was found at T_1 and the lowest number of non-effective tillers hill^{-1} (0.68) was found in T_4 treatment. Application of T_2 treatment (1.76) and T_3 treatment (1.52) produced the statistically similar non-effective tillers.

4.2.2.2 Effect of variety

Non-effective tillers hill^{-1} exerted significant difference among the varieties (Table 5). The highest number of non- effective tillers hill^{-1} (2.27) was obtained in BRRI dlian28. The lowest number of non-effective tillers hill^{-1} was produced by BRRI dhan29 (1.26) which is statistically similar with BRRI dhan28.

4.2.2.3 Interaction effect of fertilizer doses and variety

Significant interaction between fertilizer doses and variety was found on non-effective tillers hill^{-1} (Table 6). The highest number of non-effective tillers hill^{-1} (4.27) was recorded from the interaction of V_1 x T_1, and the lowest number of non-effective tillers hill^{-1} (0.23) was recorded from the interaction of V_1 x T_4.

4.2.3 Length of flag leaf

4.2.3.1 Effect of fertilizer doses

The length of flag leaf was significantly influenced by the application of fertilizer doses (Table 4). All the treatments gave significantly higher leaf length over the control (T_1). The highest length of flag leaf (30.02 cm) was found in T_4 (2 NPK briquette of 2.40 gm sized in middle of 4 heel+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer) which was identical with T_2 (Recommended dose) and the lowest flag leaf length (19.00 cm) was observed in T_1. The treatment T_5 (1 NPK briquette of 2.40 gm sized in middle of 4 heel+ 1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer) and T_3 (2 NPK briquette of 2.40 gm sized in middle of 4 heel) demonstrated statistically similar length of flag leaf.

Table 4: Effect of fertilizer doses on growth of boro rice

Treatment	Effective tiller $hill^{-1}$	Non-effective tiller $hill^{-1}$	Length of flag leaf (cm)
T_1	9.79 e	3.37 a	19.00 d
T_2	13.38 d	1.76 b	25.58 c
T_3	15.62 b	1.52 b	26.64 b
T_4	16.42 a	0.68 c	30.02 a
T_5	14.35 c	1.48 b	25.63 c
SE Value	0.24	0.16	0.09
LSD (%)	0.72	0.49	0.21

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

Here,

T_1=No nitrogen& other Fertilizer, T_2=Recommended Fertilizer Dose, T_3=2NPK briquette of 2.40 gm sized in middle of 4 heel, T_4=2NPK briquette of 2.40 gm sized in middle of 4heel+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer, T_5=1 NPK briquette of 2.40 gm sized in middle of 4 heel+ 1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer

4.2.3.2 Effect of variety

Variety differed significantly due to length of flag leaf (Table 5). The highest length of flag leaf (26.81 cm) was observed in BRRI dhan29. The lowest length of flag leaf (23.94 cm) was obtained in BRRI dhan28.

Table 5: Effect of variety on growth of boro rice

Variety	Effective tiller $hill^{-1}$	Non-effective tiller $hill^{-1}$	Length of flag leaf (cm)
V_1	13.63 b	2.27 a	23.94 b
V_2	14.95 a	1.26 b	26.81 a
SE Value	0.15	0.102	0.06
LSD (%)	0.32	0.214	0.12

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

Here,

V_1: BRRI dhan28, V_2: BRRI dhan29

4.2.3.3 Interaction effect of fertilizer doses and variety

Significant interaction between fertilizer doses and variety was observed on length of flag leaf (Table 6). The highest length of flag leaf (32.04 cm) was noted in the interaction of V_2 x T_4 treatment followed by V_1 x T_4 (28.00 cm) interaction treatment, V_2 x T_3 (27.29 cm) interaction treatment, V_2 x T_2 (26.96 cm) interaction treatment and V_1 x T_3 (26.00 cm) treatment. The lowest length of flag leaf (16.00 cm) was obtained in the interaction treatment of V_1 x T_1.

Table 6: Interaction effect of fertilizer dose and variety on effective tiller hill^{-1}, Non-effective tiller hill^{-1} and length of flag leaf (cm) of boro rice

Treatment	Effective tiller hill^{-1}	Non -effective tiller hill^{-1}	Length of flag leaf (cm)
V_1T_1	9.10 h	4.27 a	16.00 i
V_1T_2	13.54 ef	2.30 b	24.19 g
V_1T_3	15.78 b	1.90 bc	26.00 e
V_1T_4	15.48 bc	1.13 c	28.00 b
V_1T_5	14.26 def	1.73 bc	25.50 f
V_2T_1	10.48 g	2.48 b	22.00 h
V_2T_2	13.23 f	1.23 c	26.96 d
V_2T_3	15.46 bcd	1.13 c	27.29 c
V_2T_4	17.36 a	0.23 d	32.04 a
V_2T_5	14.44 cde	1.23 c	25.75 ef
SE Value	0.34	0.23	0.14
LSD (%)	1.21	0.82	0.29

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

Here,

T_1=No nitrogen& other Fertilizer, T_2=Recommended Fertilizer Dose, T_3=2 NPK briquette of 2.40 gm sized in middle of 4 heel, T_4=2 NPK briquette of 2.40 gm sized in middle of 4 heel+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer, T_5=1 NPK briquette of 2.40 gm sized in middle of 4 heel+ 1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer, V_1: BRRI dhan28, V_2: BRRI dhan29

4.2.4 Panicle length

4.2.4.1 Effect of fertilizer doses

Panicle length showed non-significant variation due to the application of fertilizer doses (Table 7). The highest panicle length (23.18 cm) was found in T_3 (2 NPK briquette of 2.40 gm sized in middle of 4 heel. the lowest panicle length (21.70cm) was observed in T_1.

4.2.4.2 Effect of variety

Panicle length showed non-significant variation due to variety (Table 8).The highest length of panicle (21.82 cm) was observed in BRRI dhan28. The lowest length of panicle (19.83) was obtained in BRRI dhan29.

4.2.4.3 Interaction effect of fertilizer doses and variety

There is no significant interaction between fertilizer doses and variety was observed on length of panicle (Table 9). Interaction comprised with treatment T_4 with all the varieties showed higher length of panicle than the interactions comprised with T_1 treatment with all the varieties (Table 9). The highest length of panicle (23.33) was noted in the interaction of V_1 x T_4 treatment followed by V_1 x T_2 (22.14) interaction treatment, V_1 x T_5 (21.90) interaction treatment, V_2 x T_4 (21.81) interaction treatment and V_1 x T_3 (21.45) treatment. The lowest length of panicle (15.66) was obtained in the interaction treatment of V_2 x T_2.

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

4.2.5.1 Effect of fertilizer doses

Fertilizer doses showed significant variation on production of filled grains panicle^{-1} (Table 7). The table showed that the lowest number of grains panicle (74.93) was obtained from the no nitrogen i.e. control condition whereas the highest number of grains was obtained by the application of treatment T_4 (111.53). T_4 treatment produced 33.58%, 1.39%. 12.29% and 10.63% higher number of grains panicle^{-1} than treatment T_1 (68.47), T_3, (101.57), T_5 (90.35) and T_2 (92.05), respectively. The result agreed with the findings of Kumar *et al*. (1986) and Thakur *et al.* (1995) in that increasing level of nitrogen significantly increased the number of filled grains panicle^{-1}.

4.2.5.2 Effect of variety

Variety differed significantly in production of number of grains panicle^{-1} (Table 8).The highest number of grains panicle^{-1} (98.63) was observed in BRRI dhan29 followed by BRRI dhan28 (88.20). The lowest number of grains panicle^{-1} (88.20) was obtained in BRRI dhan28.

4.2.5.3 Interaction effect of fertilizer doses and variety

Significant interaction between fertilizer doses and variety was observed on filled grains Panicle^{-1} (Table 9). Interaction comprised with treatment T_4 with all the varieties showed higher number of grains panicle than the interactions comprised with T_1 treatment with all the varieties (Table 9). The highest number of filled grains panicle $^{-1}$ (122.29) was noted in the interaction of $V_{2\,x}$ T_4 treatment followed by $V_{1\,x}$ T_3 (102.18) interaction treatment, V_1 x T_4 (100.77) interaction treatment, V_2 x T_3 (97.12) interaction treatment and V_1 x T_5 (90.07) treatment. The lowest number of filled grains panicle^{-1} (663.29) was obtained in the interaction treatment of V_1 x T_1.

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

4.2.6.1 Effect of fertilizer doses

Fertilizer doses had significant influence on the unfilled grains panicle^{-1} (Table 7). The figure showed that highest (14.08) number of unfilled grain was obtained due to the application of treatment T_1 followed by treatment T_2 (11.50), T_5 (7.43) and T_3 (6.22). The lowest (5.15) number of unfilled grain panicic^{-1} was obtained due to T_4 treatment. The result was supported by BRRI (2006) that without nitrogen application increased the maximum number of unfilled grains panicle^{-1} in boro rice

4.2.6.2 Effect of variety

A significant variation was observed between the varieties due to the number of unfilled grains panicle^{-1} (Table 8). The highest number of unfilled grains panicle^{-1} (10.39) was obtained in BRRI dhan28 followed by BRRI dhan29 (7.36). The lowest number of unfilled grains panicle^{-1} (7.36) was obtained in BRRI dhan29. RENA (1993) observed the similar result that the production of unfilled grains panicle^{-1} differed with variety to variety.

4.2.6.3 Interaction effect of fertilizer doses and variety

A significant interaction between fertilizer doses and variety was observed on unfilled grains panicle^{-1} (Table 9). The interaction result showed that interaction of BRRI dhan28 with all the fertilizer doses produced higher number of unfilled grains panicle^{-1} (ranged 4.84-16.52) followed by BRRI dhan29 irrespective of all fertilizer doses. However, the highest number of unfilled grains panicle^{-1} (15.20) was found in V_1 x T_1 interaction and the lowest number of unfilled grains panicle^{-1} (1.93) was counted in the interaction of V_2 x T_4.

4.2.7 Weight of 1000 grains (gm)

4.2.7.1 Effect of fertilizer doses

The weight of 1000 grains showed non-significant variation due to different levels of fertilizer doses (Table 7). The highest weight (23.18 gm) of 1000-grains was recorded due to application of treatment T_3 (23.18) followed by treatment T_2 (22.77 g) and T_4 (22.74). The lowest weight (21.70 g) of 1000-grain was recorded from the T_1 treatment i.e. no fertilizer treatment. The result fairly agreed with the findings of Mohaddesi *et al.* (2011) that 1000 grain weight had significant effect with increasing nitrogen levels but Rahman (2003) and Azad *et al.* (1995) found that the level of nitrogen didn't influence the weight of 1000-grain weight significantly which is similar with this findings.

Table 7: Effect of fertilizer doses on yield components of boro rice

Treatment	Panicle length	Filled grain panicle^{-1} (no.)	Unfilled grain panicle^{-1} (no.)	Weight of 1000 grains (gm)
T_1	20.08	74.93 d	14.08 a	21.70
T_2	18.90	86.92 c	11.50 b	22.76
T_3	21.08	99.65 b	6.22 d	23.18
T_4	22.57	111.53 a	5.15 e	22.74
T_5	21.52	94.08 bc	7.43 c	22.00
SE Value	NS	4.37	0.32	NS
LSD (%)	4.78	9.18	0.67	1.32

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

4.2.7.2 Effect of Variety

Variety had non-significant effect on the weight of 1000-grains. The weight (22.64 g) was observed in BRRI dhan 29 followed by BRRI dhan28 (22.32 g) (Table 8).

Table 8: Effect of variety on yield components of boro rice

Treatment	Panicle length	Filled grain panicle^{-1} (no.)	Unfilled grain panicle^{-1} (no.)	Weight of 1000 grains (gm)
V_1	21.82	88.20 b	10.39 a	22.32
V_2	19.83	98.63 a	7.36 b	22.63
SE Value	NS	2.76	0.20	NS
LSD (%)	3.02	5.81	0.42	0.84

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

4.2.7.3 Interaction effect of fertilizer doses and variety

There was no significant interaction between fertilizer doses and variety due to the weight of 1000-grains (Table 9). The maximum weight of 1000-grains (24.07 g) was obtained in the interaction of V_2 x T_3 treatment that was statistically similar with the interaction of V_2 x T_4 (23.00 g) treatment, V_2 x T_2 (22.88 g) treatment and V_1 x T_5 (22.74 g) treatment. The minimum weight of 1000-grains (21.27 g) was obtained in the interaction of V_1 x T_2, treatment. The result also showed that BRRI dhan 29 produced higher level of 1000-grains weight than other interactions irrespective of nitrogen levels.

Table 9: Interaction effects of fertilizer doses and variety on yield components of boro rice

Treatment	Panicle Length (cm)	Filled Grain Panicle^{-1}	Un-filled Grain Panicle^{-1}	1000 seed weight (g)
V_1T_1	20.31	63.29 f	15.20 a	21.45
V_1T_2	22.14	84.71 e	13.00 b	22.65
V_1T_3	21.45	102.18 b	5.38 f	22.29
V_1T_4	23.33	100.77 bc	8.36 d	22.47
V_1T_5	21.30	90.07 bcde	10.00 c	22.74
V_2T_1	19.84	86.56 de	12.96 b	21.95
V_2T_2	15.66	89.12 cde	10.00 c	22.88
V_2T_3	20.72	97.12 bcde	7.07 e	24.06
V_2T_4	21.80	122.29 a	1.93 g	23.00
V_2T_5	21.14	98.09 bcd	4.86 f	21.27
SE Value	NS	6.18	0.45	NS
LSD (%)	6.72	12.99	0.95	1.87

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

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

4.2.8.1 Effect of different level of fertilizer doses

Grain yield was significantly influenced by different level of fertilizer doses (Table 10). The maximum grain yield (8.65 t ha^{-1}) was obtained due to application of treatment T_4 followed by treatment T_3 (8.45 t ha). Numerical value indicated that treatment T_4 yielded out by 7.34, 7.11 and 6.41 t ha^{-1} over T_2, T_5 and T_1 treatment, respectively. Improvement of yield component such as number of effective tillers hill^{-1} and number of grains panicle^{-1} in these treatments ultimately resulted in high yield of grains. Idris and Matin (1990) reported that application of nitrogen increased the yield of rice which supports the results.

4.2.8.2 Effect of variety

Varieties differed significantly in producing grain yield (Table 11). Between the two varieties BRRI dhan29 showed its superiority in producing highest grain yield which was 9.09% higher than BRRI dhan28 respectively. However, BRRI dhan29 produced the highest grain yield (7.98 t ha^{-1}). The lowest grain yield (7.20 t ha^{-1}) was found in BRRI dhan28. 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.

4.2.8.3 Interaction effect of fertilizer doses and variety

Grain yield influenced significantly by the interaction of fertilizer doses and variety (Table 12). Among the interaction treatments, the highest grain yield (8.9.34 t ha^{-1}) was recorded in the interaction of V_2 x T_4 followed by V_2 x T_3 (9.12 t ha^{-1}), V_1 x T_4 (7.95 t ha^{-1}) and V_1 x T_3 (7.78 t ha^{-1}) interaction treatments. The lowest grain yield (6.24 t ha^{-1}) was observed in V_1 x T_1.

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

4.2.9.1 Effect of fertilizer doses

Straw yield varied significantly with the different fertilizer doses (Table 10). Straw yield was significantly highest (10.41 t ha^{-1}) at treatment T_4 that followed by treatment T_3 (10.26 t ha^{-1}). The lowest straw yield (8.54 t ha^{-1}) was found in T_1 treatment. Elbadry *et al.* (2004). Meena *et al.* (2003) and El-Rewainy (2002) observed similar view on straw yield due to nitrogen application.

4.2.9.2 Effect of variety

Straw yield differed significantly due to varietals differences (Table 11). BRRI dhan29 gave the highest straw yield (9.82 t ha^{-1}) which was statistically similar with BRRI dhan28 (9.56 t ha^{-1}). The lowest straw yield was found in BRRI dhan28 (9.56 t ha^{-1}). The differences in straw yield among the varieties might be attributed to the genetic makeup of the varieties. Chowdhury *et al* (1993), Kumar *et al* (1996) and Patel (2000) reported variable straw yield among the varieties.

4.2.9.3 Interaction effect of fertilizer doses and variety

There observed a significant difference among the interactions of fertilizer doses and varieties in respect of straw yield (Table 12). The maximum straw yield (10.54 t ha^{-1}) was found from the interaction of V_2 x T_4, followed by V_2 x T_3, (10.37 t ha^{-1}) and V_1 x T_4 (10.29 t ha^{-1}) which are statistically similar with each other. The minimum straw yield (8.33 t ha^{-1}) was found from the interaction of V_1 x T_1.

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

4.2.10.1 Effect of fertilizer doses

Biological yield differed significantly due to the different sources of nitrogen treatments (Table 10). Application of treatment T_4 produced the highest biological yield (19.06 t ha^{-1}) than treatment T_3 (18.71 t ha^{-1}) and T_2 (17.31 t ha^{-1}) of fertilizer doses. The lowest biological yield (14.95 t ha^{-1}) was recorded at no fertilizer 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.

4.2.10.2 Effect of variety

Significant variation in biological yield was observed due to varietals difference and it ranges from 16.77-17.81 t ha^{-1} (Table 11). The highest and lowest biological yield was obtained from BRRI dhan29 and BRRI dhan28 respectively. BRRI dhan29 (17.81 t ha^{-1}) and BRRI dhan28 (16.77 t ha^{-1}) are statistically similar in case of biological yield.

4.2.10.3 Interaction effect of fertilizer doses and variety

Significant variation in biological yield (t ha^{-1}) was observed in the interaction effect of fertilizer doses and variety (Table 12). The results showed that the interaction between V_2 x T_4 gave the highest biological yield (19.88 t ha^{-1}) that similar with V_2 x T_3 (19.49 t ha^{-1}) and V_1 x T_4 (18.24 t ha^{-1}) interactions. The lowest biological yield (14.57 t ha^{-1}) was found in V_1 x T_1 interaction treatment.

4.2.11 Harvest Index

4.2.11.1 Effect of fertilizer doses

Effect of nitrogen sources exerted significant variation on harvest index (Table 10). Harvest index was highest at T_4 treatment (45.34%) and the lowest harvest index (41.947%) was obtained from T_1 no fertilizer treatment. Statistically similar harvest index was found from the application of treatment T_3 (45.04%) and T_5 (43.38%).

Table 10: Effect of fertilizer doses on yield of boro rice

Treatment	Grain yield (t ha^{-1})	Straw Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest Index (%)
T_1	6.41 e	8.54 e	14.95 e	41.94 e
T_2	7.34 c	9.56 c	17.31 c	42.52 d
T_3	8.45 b	10.26 b	18.71 b	45.04 b
T_4	8.65 a	10.41 a	19.06 a	45.34 a
T_5	7.11 d	9.29 e	16.41 e	43.38 c
SE Value	0.02	0.06	0.03	0.01
LSD (%)	0.06	0.11	0.08	0.03

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

4.2.11.2 Effect of variety

Significant difference was observed for harvest index (%) due to varietal differences (Table 11). However BRRI dhan29 showed the maximum numerical harvest index (44.68%). The lowest harvest index was found in BRRI dhan28 (42.61%). Alam *et al* (2009) also found the similar findings.

Table 11: Effect of variety on yield of boro rice

Treatment	Grain yield (t ha^{-1})	Straw Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest Index (%)
V_1	7.20 b	9.56 b	16.77 b	42.61 b
V_2	7.98 a	9.82 a	17.81 a	44.68 a
SE Value	0.02	0.03	0.02	7.68
LSD (%)	0.04	0.08	0.05	0.02

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

4.2.11.3 Interaction effect of fertilizer doses and variety

Harvest index was significantly influenced by the interaction effect of fertilizer doses and variety (Table 12). The maximum harvest index (47.05%) was observed in $V_2 \times T_4$ interaction that followed by $V_2 \times T_3$ interaction (46.74 %), $V_2 \times T_5$ interaction (43.92%) and $V_1 \times T_4$ (43.63%). The minimum harvest index (41.21%) was found in the interaction treatment effect of $V_1 \times T_1$.

Table 12. Interaction effects of fertilizer doses and variety on grain yield, straw yield, biological yield and harvest index of boro rice

Treatment	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest Index (%)
V_1T_1	6.24 j	8.33 i	14.57 j	41.21 j
V_1T_2	7.16 g	9.89 e	17.05 f	42.01 i
V_1T_3	7.78 d	10.15 cd	17.93 d	43.34 e
V_1T_4	7.95 c	10.29 bc	18.24 c	43.63 d
V_1T_5	6.88 h	9.16 g	16.04 h	42.83 g
V_2T_1	6.59 i	8.74 h	15.34 i	42.01 h
V_2T_2	7.53 e	10.02 de	17.56 e	43.04 f
V_2T_3	9.12 b	10.37 b	19.49 b	46.74 b
V_2T_4	9.34 a	10.54 a	19.88 a	47.05 a
V_2T_5	7.35 f	9.42 f	16.77 g	43.92 c
SE Value	0.04	0.08	0.06	0.02
LSD (%)	0.09	0.17	0.12	0.04

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

4.3 Soil Analysis

4.3.1 pH

There was no significant variation was recorded in post-harvest soil pH due to the application of different levels of nitrogen for BRRI dhan28 and BRRI dhan29 cultivation (Table 15). The highest pH of post-harvest soil (5.63) was found from V_2xT_4 (5.60) which was statistically identical with $V_1 \times T_4$ (5.60) and $V_2 \times T_3$ (5.60) treatments respectively and the lowest pH in post-harvest soil (5.10) was recorded from $V_1 \times T_1$ (Control) treatment (Table 13)

4.3.2 Organic matter

Organic manure in post-harvest soil showed no statistically differences due to the application of different levels of fertilizer doses in BRRI dhan28 and BRRI dhan29 cultivation (Table 13). The highest organic matter in post-harvest soil (1.58%) was recorded from V_1 x T_1 and the lowest organic matter in post-harvest soil (1.44%) was observed from V_1 x T_4 treatment (Table 15).

Table 13. Interaction effects of fertilizer doses and variety on pH and Organic carbon

Treatments	pH	Organic Carbon
V_1T_1	5.10	1.58
V_1T_2	5.30	1.48
V_1T_3	5.60	1.52
V_1T_4	5.60	1.44
V_1T_5	5.43	1.49
V_2T_1	5.13	1.57
V_2T_2	5.30	1.48
V_2T_3	5.60	1.52
V_2T_4	5.63	1.45
V_2T_5	5.40	1.49
SE(±)	NS	NS
LSD (%)	0.0925	0.0233

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

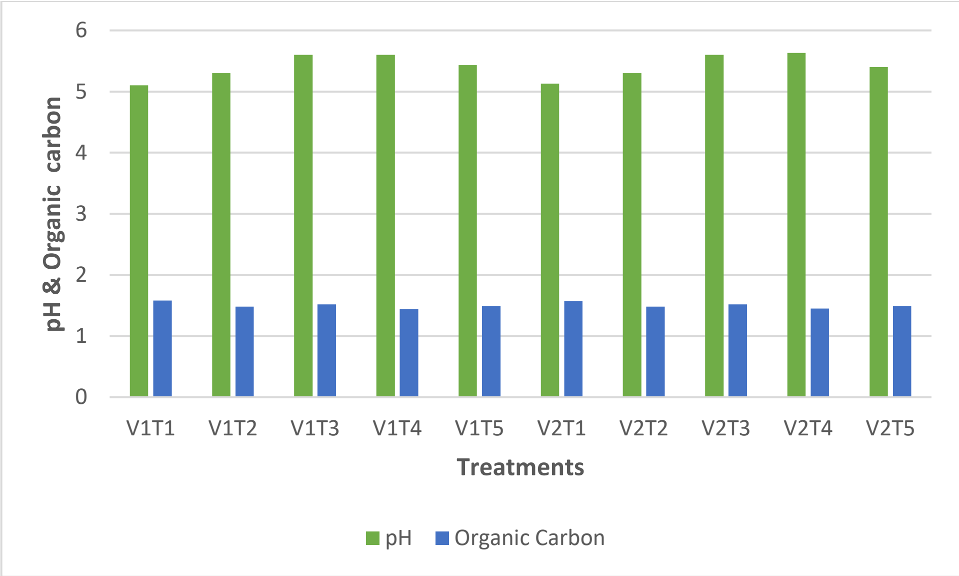


Figure 7: Interaction of fertilizer doses and variety on pH and Organic carbon

4.3.3 Total Nitrogen

Total nitrogen in post-harvest soil showed statistically significant differences due to the application of different levels of fertilizer for BRRI dhan28 and BRRI dhan28 cultivation (Table 14). The highest total nitrogen in post-harvest soil (0.058%) was recorded from $V_2 \times T_4$. On the other hand, the lowest total nitrogen in post-harvest soil (0.028%) was obtained from $V_1 \times T_1$ treatment (Table 14).

4.3.4 Exchangeable K

The application of different levels of fertilizer for rice cultivation had significant effect on exchangeable K in soil (Table 14). The highest exchangeable K in post-harvest soil (0.18 meq /100 g soil)) was recorded from $V_2 \times T_4$. On the other hand, the lowest exchangeable K in post-harvest soil (0.11 meq /100 g soil) was obtained from $V_1 \times T_1$ treatment (Table 14).

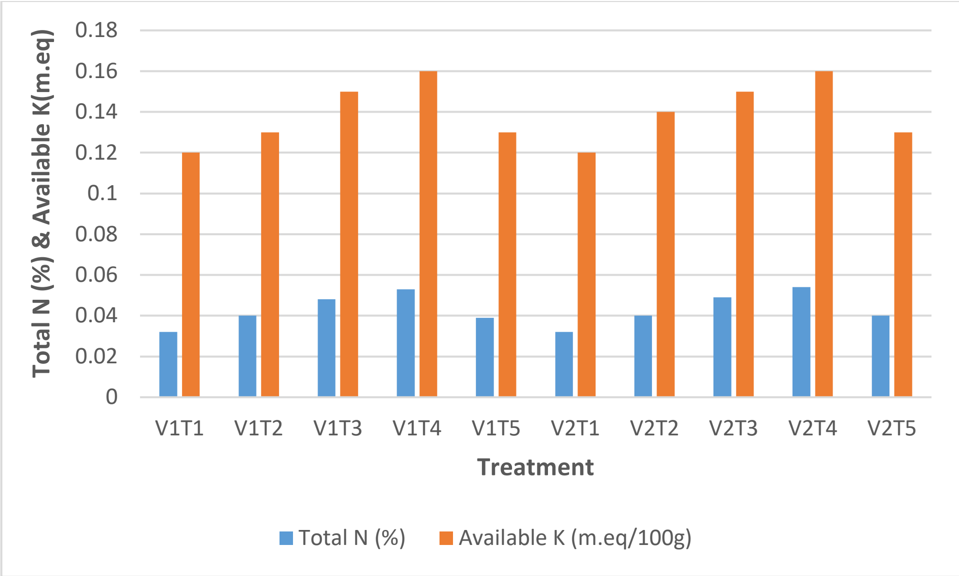


Figure 8: Interaction effects of fertilizer doses and variety on total nitrogen and available K

4.3.5 Available P

Available P in post-harvest soil showed statistically significant differences due to the application of different levels of fertilizer in BRRI dhan28 and BRRI dhan29 (Table 14). The highest available P in post-harvest soil (25.57 ppm) was recorded from $V_2 \times T_4$ and the lowest available P in post-harvest soil (19.45 ppm) was observed from $V_1 \times T_1$ level (Table 14).

4.3.6 Available S

Available S in post-harvest soil showed statistically significant differences due to the application of different levels of nitrogen in BRRI dhan28 and BRRI dhan29 (Table 14). The highest available S in post-harvest soil (20.65 ppm) was recorded from $V_2 \times T_4$ and the lowest available S in post-harvest soil (12.44 ppm) was observed from $V_1 \times T_1$ levels (Table 14).

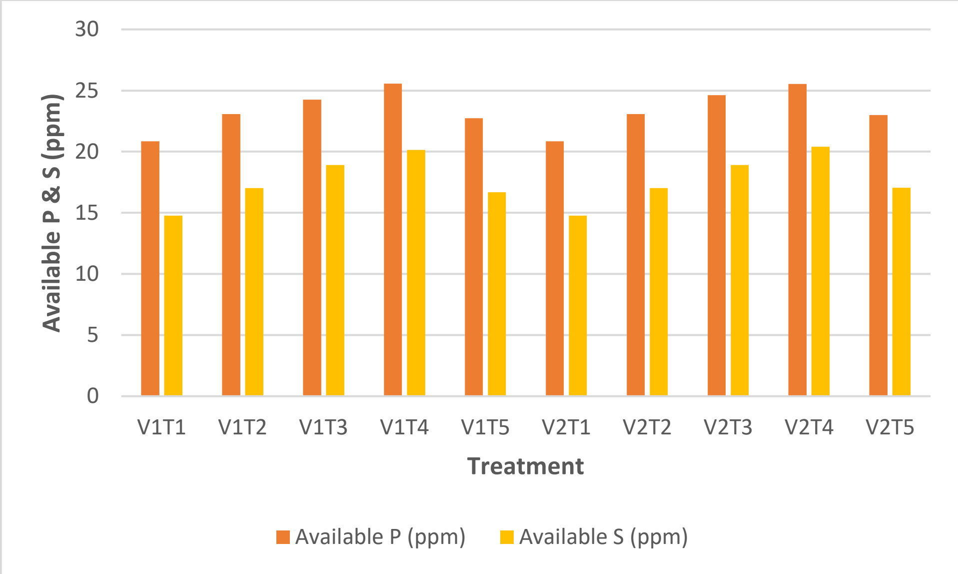


Figure 9. Interaction effects of fertilizer doses and variety on available p and available S

Table 14. Interaction effects of fertilizer doses and variety on Total N (%), Available P (ppm), Available K (meq/100g) and Available S (ppm)

Treatment	Total N (%)	Available P (ppm)	Available K (meq/100g)	Available S (ppm)
V_1T_1	0.028 h	19.45 j	0.11 e	12.44 e
V_1T_2	0.039 ef	23.07 f	0.13 c	17.02 c
V_1T_3	0.044 d	24.27 d	0.15 b	18.90 b
V_1T_4	0.053 b	24.53 c	0.16 b	19.07 b
V_1T_5	0.041 e	22.06 h	0.13 cd	16.67 c
V_2T_1	0.033g	20.85 i	0.12 d	14.78 d
V_2T_2	0.044 d	24.04 e	0.13 c	17.02 c
V_2T_3	0.049 c	24.63 b	0.15 b	18.91 b
V_2T_4	0.058 a	25.57 a	0.18 a	20.65 a
V_2T_5	0.037 f	22.72 g	0.13 cd	17.05 c
SE(±)	1.09	0.02	4.38	0.73
LSD (%)	2.30	0.04	9.21	1.53

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

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was carried out at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2015 to May 2016 to determine the suitable fertilizer doses for growth performance and to increase the yield of boro rice. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors. Factor A: Fertilizer doses (5 levels); T_1 (No nitrogen& other Fertilizer), T_2 (Recommended Fertilizer Dose), T_3 (2 NPK granule of 2.40 gm sized in middle of 4 heel), T_4 (2 NPK granule of 2.40 gm sized in middle of 4 heel+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer), T_5 (1 NPK granule of 2.40 gm sized in middle of 4 heel+ 1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer) and factor B: Variety (2 levels); V_1: BRRI dhan28, V_2: BRRI dhan29. The experiment was laid out following randomized complete block design with three replications where main plot was for variety (Factor B) and subplot was for treatment (Factor A). There were 10 treatment combinations. The total numbers of unit plots were 30. The size of unit plot was 7.98 m^2 (3.8 in x 2.1 m). Triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate was applied at the rate of 148-178-100-15 kg ha^{-1} as basal dose at final land preparation of individual plots.

Results revealed that nitrogen sources, variety and their interactions had significant effect on plant height at different days after transplanting. The tallest (99.77 cm) plant was recorded from T_4 treatment compared to the lower levels of nitrogen at harvest. At harvest, the tallest plant (97.38 cm) was observed in BRRI dhan29 and the shortest plant (89.57 cm) was observed in BRRI dhan28. The tallest plant (99.85 cm) was found in the V_1 x T_4 interaction treatment and the shortest plant (87.11 cm) was found in V_1 x T_1 interaction at harvest.

The highest number of effective tillers hill^{-1} (16.42) was found in T_4 treatment. The highest and lowest number of tillers hill^{-1} (14.95) and (13.63) were recorded from BRRI dhan29 and BRRI dhan28 respectively. The interaction of V_2 x T_4 was found promising in producing tillers hill^{-1} (17.36).

Significant difference was observed in producing non-effective tillers hill^{-1} due to fertilizer dose, variety and their interactions. The highest number of non-effective tillers hill^{-1} (3.37) was counted from T_1 treatment. The highest number of non-effective tillers hill^{-1} (2.27) was recorded in BRRI dhan28 whereas BRRI dhan29 produced the lowest number of non-effective tillers hill^{-1} (1.26). The highest number of non-effective tiller hill^{-1} (4.27) was found in the interaction of V_1 x T_1 treatment and the lowest (0.23) was obtained from V_2 x T_4 interaction treatment.

The length of flag leaf was significantly influenced by the application of fertilizer doses. The highest length of flag leaf (30.02 cm) was found in T_4 and the lowest (19.00 cm) was observed in $T_{1.}$ The highest length of flag leaf (32.04 cm) was noted in the interaction of V_2 x T_4 treatment and the lowest length of flag leaf (16.00 cm) was obtained in the interaction treatment of V_1 x $T_{1.}$

Fertilizer, variety and their interactions exhibited significant differences variation in producing filled grains panicle^{-1}. The highest number of filled grains panicle^{-1} (111.53) was counted at T_4 treatment whereas no fertilizer produces the lowest number of filled grains panicle^{-1} (74.93). The highest number of filled grains panicle^{-1} (98.63) was observed in BRRI dhan29 and the lowest number of filled grains paniel^{-1} (88.20) was observed in BRRI dhan28. The interaction of V_2 x T_4 showed the highest number of filled grains panicle^{-1} (122.29) and the lowest number of filled grains panicle^{-1} (63.29) was observed in V_1 x T_1 interaction.

Without nitrogen produced the higher number of unfilled grains panicle^{-1} (14.08) compared to other fertilizer doses. BRRI dhan28 produced the highest number of unfilled grains panicle^{-1} (10.39) and the lowest number of unfilled grains panicle^{-1} was observed in BRRI dhan29 (7.36). The highest number (15.20) and the lowest number (1.93) of unfilled grains panicle^{-1} were observed V_1 x T_1 and V_2 x T_4 interaction.

Fertilizer, variety and their interaction was observed no significant in case of weight of 1000 grain. The highest weight of 1000 seed weight (23.18) was found in T_3 treatment however the variety BRRI dhan29 and the variety BRRI dhan28 showed similar (22.64 g) and (22.32 g) weight of 1000- gram respectively. The interaction of V_2 x T_3 treatment produced the maximum weight of 1000-grain (24.06 g) whereas, V_2 x T_5 interaction treatment produced the minimum weight of 1000 grains (21.27 g).

Grain yield varied significantly due to fertilizer doses, variety and their interaction. The highest grain yield (8.65 t ha^{-1}) was obtained T_4 treatment and the lowest grain yield (6.41 t ha^{-1}) was obtained T_1 (no fertilizer). The maximum grain yield (7.98 t ha^{-1}) was found in BRRI dhan29 and the lowest grain yield (7.20 t ha^{-1}) was found in BRRI dhan28. The interaction of V_2 x T_4 treatment produced the highest (9.34 t ha^{-1}) grain yield and the interaction of V_1 x T_1 treatment produced the lowest grain yield (6.24 t ha^{-1})

The highest straw yield (10.41 t ha^{-1}) and biological yield (19.06 t ha^{-1}) was obtained at T_4 treatment whereas the lowest straw yield (8.54 t ha^{-1}) and biological yield (14.95 ha^{-1}) was obtained at T_1 (no nitrogen). Both the highest straw yield (9.82 t ha^{-1}) and the biological yield (17.81 t ha^{-1}) were found in BRRI dhan29 whereas BRRI dhan28 showed the lowest straw yield (9.56 t ha^{-1}) and biological yield (16.77 t ha^{-1}). Both the highest straw (10.54 t ha^{-1}) and biological (19.88 t ha^{-1}) yield were obtained in the interactions of V_2 x T_4 treatment and the lowest both straw yield (8.33 t ha^{-1}) and biological (14.57 t ha^{-1}) yield were obtained in the interactions of V_1 x T_1 treatment.

The interaction of fertilizer doses and variety showed significant variation on harvest index. The maximum harvest index (45.34%) was obtained at T_4 treatment and the minimum (41.94%) was obtained at T_1 (no fertilizer treatment). The significantly highest harvest index (47.05%) was found in the interaction of V_2 x T_4 treatment and the lowest harvest index (41.21%) was found in the interaction of V_1 x T_1 treatment.

Reviewing above the results of the present study. It might be concluded that

- 2 NPK granule of 2.40 gm sized in middle of 4 heel+1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer showed the superiority over other sources and application methods of fertilizer to produce higher grain yield of rice.
- Sources and application methods of nitrogen as NPK granule showed the superiority over pilled urea.
- BRRI dhan29 showed the higher production than BRRI dhan28 variety of boro rice.
- Interaction treatment of T_4 (2 NPK granule of 2.40 gm sized in middle of 4 heel + 1 top dressing at tiller stage @ 1⁄4 of nitrogenous fertilizer) and V_2: BRRI dhan29 performed best; interaction of 10 treatment with other tested varieties were also promising in producing higher yield.

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

REFERENCES

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. M. L. (1994) Nutrient balance for sustainable Agriculture. Paper presented at the workshop on Integrated Nutrient Management for sustainable agriculture held at SRI). Dhaka. June. 26-28. 1994.

Alinajati Sisie and Mirshekari B, (2011) Effect of phosphorus fertilization and seed bio fertilization on harvest index and phoshorus use efficiency of wheat cultivars. Journal of Food, Agriculutral & Environment. vol9 (2):388-397.

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. 3. Agric, Blot Sci. 1(2): 158-161.

Ahsan K, Saleque M A, Abedin M J and Bhuiyan N I. (1997) Multiple year-response of wetland rice to potassium fertilizer and apparent potassium balance in soil. Thai J. Agric. Sci. 30: 501-509.

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

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

BBS (Bangladesh Bureau of Statistics). (2012) Agriculture crop cutting. Estimation of boro rice 2011-2012. Government of the People's Republic of Bangladesh. Web site: http://www.bbs.gov.bd.

Bhuiyan Lit., islam, N. and Mowla. C. (1990) Rice response to application with different irrigation schedules. Int. Rice Res. Newsl. 15(6): 18.

Biswas, C.R. and Bhattacharya, B. (1989) Optimum of N supplies and plant density for high yielding rice in Coastal Saline Soil. Rice .1. 24 (3): 231-235.

Bijay Singh, Yadvinder Singh, Imas P and Xie Jian-chang. (2004) Potassium nutrition of the rice-wheat cropping system. Advances in Agron. 81: 203-259.

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

BRRI (2001) Bangladesh Rice Research Institute Internal review. VIII. Soil Science Division. BRRI, Gazipur, Bangladesh. p 92.

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

Bulbule AV, Durgude AC, Patil VS, Kulkarni RV (2008) Fertilization of low land transplanted rice through briquettes. Journal of Crop Research J 35 1-5.

Bulbule AV, Durgude AG, Patil VS, Kulkarni RV (2008) Fertilization of low land transplanted rice through briquettes. Crop Research 35(1&2) 1-5.

Chopra, N. K. and Chopra, N. (2000) Effect of row spacing and nitrogen level on growth yield and seed quality of scanted rice (*Oryza sativa*) under transplanted condition. Indian. J. Agron., 45(2): 304-408.

Castro, R and Sarker, A. B. S. (2000) Rice growth response to different proportions of applied nitrogen fertilizer. Cultiva-Tropicales. 21(4): 57-62.

Chandcr, S. and Pandey, J. (1996) Effect of herbicide and nitrogen on yield of scented rice (*Oryza sativa*) under different rice cultures. Indian. .1 Agron. 41(2): 209-2 14.

Chowdhuiy, 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 amon rice. Bangladesh J. Agrit Sct 20(2): 311 -316.

Chaturvedi, L. (2005) Effect of nitrogen fertilizers on growth, yield and quality of hybrid rice (Oryza sativa L.). Journal of Central European Agricultural, 6(4): 61 1-618.

Choudhury AK, Sarker MJU, Rashid MH, Sarker MMR, Shahiduzzaman M, Islam MS, Bashar MK (2013) Response of vegetables to NPK briquette deep placement. Paper presented at the National Workshop on deep placement of NPK briquette, held at BARC, Dhaka on March 28, 2013 in collaboration with IFDC.

Dahattonde, B. N. (1992) Response of promising rice (Oryza sativa) varieties to graded level of nitrogen. Indian. I Agron. 37(4): 802-803.

Das KPB (2011) Effect of PM and nitrogenous fertilizer on the growth and yield of boro rice cv. BRRI dhan45, M.S. Thesis, Department of Agronomy, Bangladesh Agrilcultural University Mymensingh. pp. 31-45.

Delog RE, Slaton NA, Anders MM, Johnson JRWF, (2002) Phosphorus fertilization and previous crop effects nutrient uptake and grain yield of wheat. Arkansas soil Fertility Studies.1:28-31.

Diba F, Farukh M A, Islam N and Bhuiyan M S U. (2005) Effect of nutrition and potassium fertilizers on the performance of BRRI dhan28 and BRRI dhan29 in Boro season. Bangladesh J. Agric. and Environ. 1 (1): 57-64.

Durguda AG, Patil YJ, Bulbula AV, Patil VS (2008) Effect of fertilizer management through urea-DAP briquettes on lowland rice. An Asian Journal of Soil Science 3(1) 1-3.

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

El-Rewainy, I. M. 0. (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.

Hasan SM (2007) Effect of levels of urea super granules on the performance of T. aman rice, M.S. Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh.

Hussain, S. M. and Sharma. U. C. (1991) Response of rice to nitrogen fertilizer in acidic soil of Nagaland. Indian]. Agric. 61(9): 660-664.

Islam MSh, Rahman F, Hossain ATMS (2011) Effects of NPK Briquette on Rice (Oryza sativa) in Tidal Flooded Ecosystem. A Scientific Journal of Krishi Foundation 9(1&2) 37-43

Islam MS, Rahman F, Hossain ATMS (2011) Effects of NPK Briquette on Rice (Oryza sativa) in tidal flooded ecosystem. The Agriculturists 9(1&2) 37-43.

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

IFDC (2007) International Fertilizer Development Centre, Mitigating poverty and environmental degradation through nutrient management in South Asia IFDC Report, March (2007). International Fertilizer Development Centre.

IFPRI (2004) International Food Policy Research Institute, Annual Report, Production 2 Yearbook 74 IFPRI Wasington DC, United State of America.

IFDC (International Fertilizer Development Centre). (2007) Mitigating poverty and environmental degradation through nutrient management in South Asia. IFDC Report, March 2007.

IFPRI (2004) Annual Report, (2003-2004) International Food Policy Research Institute (IFPRI): Wasington, DC, USA. pp. 74.

Kadam JR (2001) Efficient use of NPK fertilizer briquettes on the yield and quality of crops. Indian Sugarcane 51(2) 115-118.

Kapoor V, Singh U, Patil SK, Magre H, Shrivastava LK, Mishra VN, Das RO, Samadhiya VK, Sanabria J, Diamond R (2008) Rice growth, grain yield, and floodwater nutrient dynamics as affected by nutrient placement method and rate. Agronomy Journal 100 526-536.

Kapoor V, Singh U, Patil SK, Magre H, Shrivastava LK, Mishra VN, Das RO Samadhiya VK, Sanabria J, Diamond R (2008) Rice Growth, Grain Yield and Floodwater Nutrient Dynamics as Affected by Nutrient Placement Method and Rate. Agronomy Journal 100(3) 526-536.

Kim, B. K., Kim. If. If., Ko, J. K. and Shin. I-I. T. (1999) Effect of planting density and nitrogen levels on growth and yield of heavy paniele weight type of Japonica rice. Korean J. Crop ScL 44 (2): 106-111.

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

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

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

Kehinde. J. K. and Fagande, S. 0. (1987) Response of upland rice to nitrogen. Intl. Rice Res. Newsl. 12 (4): 60.

Lawal, M. 1. and i.awal. A. B. (2002) Influence of nitrogen rate and placement method on growth and yield of rice at Kadawa. Nigeria. Crop Res. Hisar. 23(3): 403-411.

Maskina. M. A. and Singh. B. (1987) Response of new rice varieties to N. Intl. Rice. Res. Newsl. 12 (4): 8-9.

Maske, N. S., Norkar. S. L. and Rajgire. H. J. (1997) Effect of nitrogen levels on growth, yield and grain quality of rice. .1. Soils and &ops. 7 (I): 86.

Meena, S. L., Sundera. S., and Shivay. Y. S. (2003) Response to hybrid rice (Orvza saliva) to nitrogen and potassium application in sandy clay-loam soils. Indian., Agric. Set 73(1): 8-I1.

Miah M A M. (2005) Potassium status in Bangladesh soil and the efficiency of potash fertilizer in rice based cropping system. A seminar paper presented in Bangladesh Rice Research Institute. December 14.

Munnujan, K., Haniid, A., llashem, A., Hirota. 0. and Khanam. M. (2001) Effects of nitrogen fertilizer lcvels and planting density on growth and yield of long grain rice. Bulletin, Inst. Tropic. Agric. Kyushu Univ. 24:110.

Mohaddesi, A., Abbasian, A., Bakhshipour. S. and Aminpanah. 11. (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 and Environmental Sciences 10(5): 893- 900.

Mohanty S K and Mandal L N. (1989) Transformation and budgeting of N, P and K in soils for rice cultivation. Oryza. 26: 213-231.Namba, T. 2003. Optimum planting density and nitrogen application rate for maximizing rice yield in the Nile Delta. Japanese J. Crop ScL 72 (7):133-141.

Neelam, K. C. and Nisha. C. (2000) Effect of row spacing and N level on growth,yield and seed quality of scented (0.5.) under transplanted conditions. Indian. Agric. ScL 45 (2): 304-308.

Neubauer SC, Anderson IC, Constantine JA, Kuehl SA (2002) Sediment Deposition and Accretion in a Mid-Atlantic (U.S.A) Tidal Freshwater Marsh Estuarine. Coastal Shelf Science 54 713-727.

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

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

Peterson J (2007) Placement of Nitrogen, Phosphorus and Potassium fertilizers by drilling in spring barley grown for malt without use of pesticide. Plant and Soil Science 57 (1) 53-64.

Prasad M and Prasad R (1983) Removal of nitrogen, phosphorus and potassium by rice-wheat double cropping system as affected by duration of rice variety, methods of planting rice and levels and sources of nitrogen. Plant and Soil 70 287-295.

Rahman, M. A. (2003) Effect of levels of urea supergranules and depth of placement on the growth and yield of transplant aman rice. MS. Thesis, Dept. of Agronomy, Bangladesh Agril University Mymensingh P. 100.

Rajni Rani, Srivastava OP, Rani R (2001) Effect of integration of organics with fertilizer N on rice and N Uptake Fertilizer Newsletter 46(9)63-65.

Reddy. M. Ii, Panda, M. M., Ghosh, B. C. and Reddy. B. B. (1986) Effect of nitrogen fertilizer on yield and nitrogen concentration in grain and straw of rice under semi deep water condition. J. Agrit Sci. (UK.) 110 (1): 53- Im

Rijmpa J and Islam F. (2002) Nutrient mining and its effect on crop production and environment. In: Seminar on soil health management: DAE-SFFP experience. DAE-SFFP, Khamarbari, Dhaka, Bangladesh.

Rajarathinam, P. and Balasubrnianiayan (2007) of plant population and nitrogen on yield attributes and yield of hybrid rice (*Oryza cativa*). Indian J. Agron. 44 (4): 717-721.

Rotshield, G. H. L. (1996) Perspectives for rice production in Asia. Crop research in Asia: Achievements and perspectives. Asian Crop Sd. Assoc. Fukui. pp. 12-17.

Sahrawat, K. L. Datta, S. and Sing, B. N. (1999) Nitrogen responsiveness of low land rice varieties tinder irrigated conditions in West Africa Intl. Rice Res. Notes. 24 (2): 30.

Sarker, A. R. S., Kojims. N. and Amano. V. (2001) Effect of nitrogen rates on Japonica and Indica rice under irrigated ecosystem. Bangladesh .1 Sd. Tech.3 (I):49-53.

Saha P K, Saleque M. A., Panaullah G. M. and Bhuiyan N I. (2001) Response of wheat to potassium in deep tubewell project areas of North-western Bangladesh. Bangladesh J. Agric. Res., 26(4): 613-617.

Shah AL, Sarker A.B.S, Islam S.M.M., Mridha A.J. (2013) Deep placement of NPK briquette. Environment friendly technology for rice production. Paper presented at the National Workshop on deep placement of NPK briquette, held at BARC, Dhaka on March 28, 2013 in collaboration with IFDC.

Singh. M. K., Thakur. R., Verma. U. N., Upasani. R. It. and Pal. S. K. (2000) Effect of planting time and nitrogen on production potential of Basmati *me* rice *(Oryza saliva)* eultivars in l3ihar Plateau. *Indian .1. Agron. 45* (2): 300-303.

Singh, S. P. and Filial. K. G. (1994) Response to nitrogen in semi-dwarf scented rice varieties. Intl. Rice Res. Notes. 19 (4): 17.

Singh S, and Shivay YS (2003) Coating of prilled urea with eco-friendly neem (Azadirachta indica A. Juss.). Acta Agroninica, Hungarica 51(1) 53-59.

Srivastava, G. K. and Solanki. S. S. (1993) Effect of water regimes, nitrogen levels and weed control on growth and yield of low land rice. Mysore J. AgrL ScL 27 (2): 5-8.

Sahrawat, K. L. Datta, S. and Sing, B. N. (1999) Nitrogen responsiveness of 'low land rice varieties tinder irrigated conditions in West Africa Intl. Rice Res. Notes. 24 (2): 30.

Singh, M. V., Tripathi. H. N. and Tripathi. H. P. (1997) Effect of nitrogen and planting on yield and quality of scented rice (Oryza saliva). Indian J. Agron. 42 (4): 602-606.

Singh, S. P. and Filial. K. G. (1994) Response to nitrogen in semi-dwarf scented rice varieties. Intl. Rice Res. Notes. 19 (4): 17.

Shah AL, Islam SMM, Sarker ABS, Mridha AJ (2012) Deep placement of NPK Briquette. Bangladesh Rice Research Institute. Research Paper.pp. 1-14.

Siddika N (2007) Effect of nitrogen management with prilled urea, urea super granule and leaf color chart on the performance of transplant aman rice (cv. BR 14), MS Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh. pp. 35, 42-44.

Srivastava PC, Bhatt M, Pachauri SP and Tyagi AK (2014) Effect of zinc application methods on apparent utilization efficiency of zinc and phosphorus fertilizers under basmati rice-wheat rotation. Archived Agron. SoilSci., 60(1): 33-48.

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 saliva L). Annals BioL 20(2): 233-238.

Thakur. R. B. (1991) Effect of N levels and forms of urea on low land rice tinder late transplanting. Indian. Agron. 36: 28 1-282.

Thakur, R. B. (1993) Performance of summer rice to N. 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.

Tiwari V S, Raisadhan S R, Jagtap D D and Pujari C V. (1999) Effect of organic and inorganic fertilizer on yield and quality of Sweet orange. International symposium on Citriculture, Nagpur, Nov. 23-27. p 411.

Timsina J and Connor D J. (2001). Productivity and management of rice-wheat cropping systems: issues and challenges. Field Crop Res. 69: 93-132.

Upendra Singh, Patil KS, Vibhu K, Deborah H, Kovach S (2008) Improving Crop Yield and Fertilizer Use Efficiency with One-Time Nutrient Deep Placement. Joint Annual meeting 5 -9 675 - 17.

Vibhu Kapoor, Singh U, Patil SK, Magre H, Shrivastava LK, Mishra VN, Das RO, Samadhiya VK, Sanabria J, Diamond R (2008) Rice Growth, Grain Yield,and Floodwater Nutrient Dynamics as Affected by Nutrient Placement Method and Rate.

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. Sd. 8(7): 486492.

Wang, R. G. and Thorat, S. T. (1988) Tesponse of rice var. R-24 to different times of application of nitrogen and plant densities in coastal soils. J. Indian Soc. ('ousta/Agril. Res. 6(2): 1333-137.

Wilson CE, Bollich PK and Norman RJ, (1998) Nitrogen application timing effects on nitrogen efficiency of dry-seeded rice. Soil Sic .Soc.Am.J.62:959-964.

Witt C, Dobermann A, Buresh R and Abdulrachman S. (2004) Long-term phosphorus and potassium strategies in irrigation rice. Better Crops. 88 (4): 32-35.

APPENDICES

Appendix I. Physical and chemical properties of soil of the experimental plots

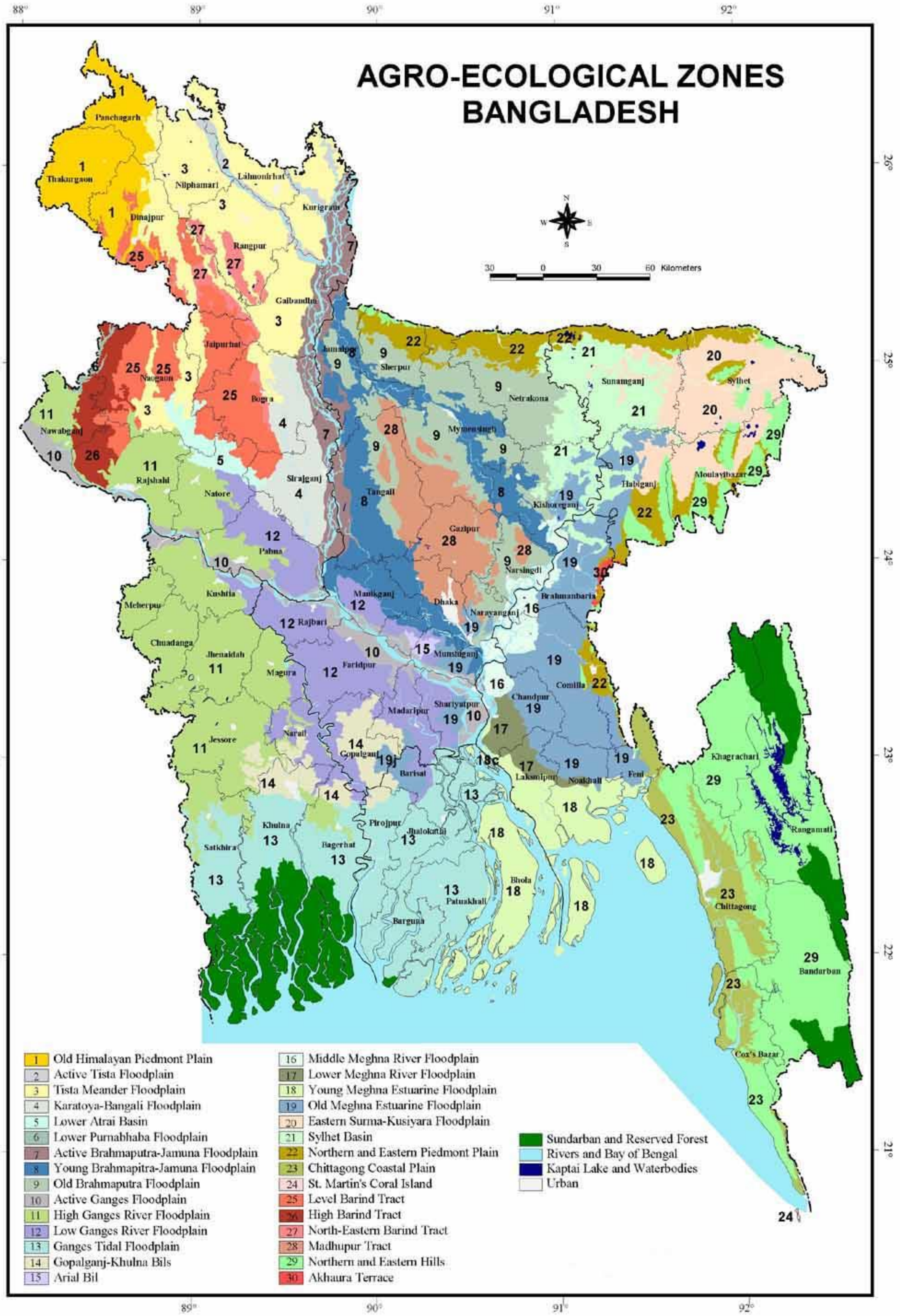
A. Physical properties of soil	
% sand (0.2-.02 mm)	24
% silt (0.02-.002 mm)	48
% clay (< 0.002 mm)	28
Textural class	Silty clay loam
Consistency	Granular
B. Chemical properties of soil	
Soil pH	5.63
Organic carbon (%)	0.74
Organic matter (%)	1.28
Total nitrogen (%)	0.058
Available phosphorus (ppm)	25.57
Exchangeable potassium (me/100 g soil)	0.18
Available sulphur (ppm)	20.65

Appendix II. Average monthly rainfall, air temperature and relative humidity during the experimental period between November 2015 to May 2016 at the SAU area, Dhaka

Month	Monthly average air temperature (^0C)			Average rainfall (mm)	Average relative humidity (%)	Average daily sunshine (hrs)
	Maximum	Minimum	Average			
October	31.27	24.14	27.71	18.0	86.2	8.65
November	29.49	19.55	24.52	00.0	84.3	8.45
December	26.52	13.19	19.85	00.0	80.8	6.67
January	23.43	12.93	18.18	00.0	78.0	7.20
February	27.34	16.41	21.87	06.6	73.9	8.18
March	29.61	20.57	25.09	13.6	80.6	7.66
April	30.56	22.14	26.35	96.6	78.57	7.42

Source: Weather Yard, SAU, Dhaka

Appendix III: Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix IV: The experimental site

Figure 10 : Seedling stage of BRRI dhan28

Figure 11 : Seedling stage of BRRI dhan29

Figure 12 : Transplant stage of BRRI dhan28

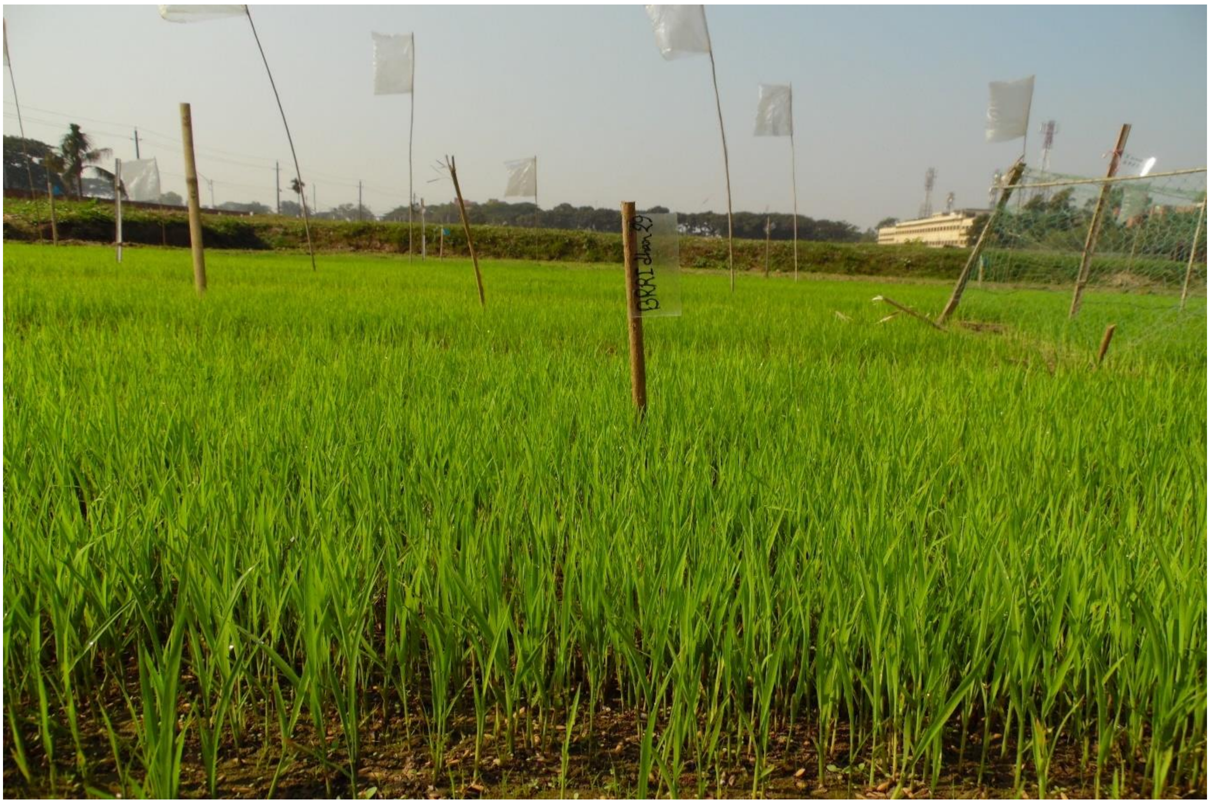


Figure 13 : Transplant stage of BRRI dhan29

Figure 14 : Field view of experiment plot

Figure 15 : Field view of experiment plot