'INFLUENCE OF DIFFERENT FORMS OF NITROGEN ON THE PERFORMANCE OF SOME INBRED AND HYBRID VARIETIES OF RICE'

BY

MD. KHODADAD HOSSAIN

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Approved by:

(Prof. Dr. A.K.M. Ruhul Amin)	**(Prof. Dr. Md. Hazrat Ali)**
Supervisor	**Co-Supervisor**

(Prof. Dr. A.K.M. Ruhul Amin)
Chairman
Examination Committee
Dept. of Agronomy
SAU, Dhaka

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
PABX: 9110351 & 914427-79

CERTIFICATE

This is to certify that thesis entitled **"INFLUENCE OF DIFFERENT FORMS OF NITROGEN ON THE PERFORMANCE OF SOME INBRED AND HYBRID VARIETIES OF RICE"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) IN AGRONOMY embodies the result of a piece of *bona fide* research work carried out by MD.KHODADAD HOSSAIN, Registration No. 05-01725 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 05.05.2013
Dhaka, Bangladesh

(Prof. Dr. A.K.M. Ruhul Amin)
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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INFLUENCE OF DIFFERENT FORMS OF NITROGEN ON THE PERFORMANCE OF SOME AND HYBRID VARIETIES OF RICE

Abstract

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November, 2011 to May, 2012 to study the `Influence of Different from of Nitrogen on the Performance of Some Indred and Hybrid Varieties of Rice'. The experiment comprised of two factors viz. Factor A- source of N: (i) N_0 = Control (No Urea application) (ii) N_1 = 2.7 g size. N_2= Prilled Urea (PU) at three installments and (iv) N_3= NPK Super Granule. Factor B-Variety: (i) V_1= BRRI hybrid dhan 2 (ii) V_2= ACI hybrid dhan 1 (iii) V_3 = Hybrid Hira Rice and (iv) V_4=BRRI dhan. Analysis is done considering the factors viz. Effect of variety, forms of N and their interaction. From the experimental analysis it can be Concluded that among the four varieties, Results showed that BRRI Dhan29 (inbred) (V_4) Showed the highest grain yield (6.74 t ha^{-1}), biological yield (15.32 t ha^{-1}) and highest Harvest index (43.49%) where hybrid hira dhakn (v_3) showed the lowest grain yield (6.22), lowest biological yield (14.49 t ha^{-1}) and lowed Harvest index (42.29%). But BRRI hybrid dhan 2 (V_1) Showed the highest straw yield (8.59 t ha^{-1}) and ACI hybrid rice (V_2) showed the lowest straw yield (8.42 t ha^{-1}). Among the treatments, N_3 (NPK Super Granule) Showed the highest number of effective tillers $hill^{-1}$ (18.25), lowest number of non-effective tillers $hill^{-1}$ (2.12), highest number of panicle (18.65), highest number of grains $panicle^{-1}$ was recorded by N_3 (NPK Super Granule) (174.60), Highest 1000 seed weight was recorded N_3 (NPK Super Granule) (27.85 g), highest grains yield (7.87 t ha^{-1}), highest straw yield (9.00 t ha^{-1}), highest biological yield (16.80 t ha^{-1}), and highest Harvest index ((46.65%) where N_0 (Control) treatment showed the lowest number of effective tillers $hill^{-1}$ (9.05), highest number of non-effective tillers $hill^{-1}$ (3.84), lowest number of panicle at harvest (9.56), lowest number of grains $ppanicle^{-1}$ (140.30) lowest 1000 seed weight (21.22g), lowest grain yield ha^{-1} (4.18 t ha^{-1}), the lowest straw ha^{-1}(7.37 t ha^{-1}), lowest biological yield ha^{-1} (11.53 t ha^{-1}) and lowest Harvest index (36.16%), The combination effect study N_3V_4 (BRRI dhan29 × NPK Super Granule) Showed the best performance regarding growth, yield and yield contributing. So, N_3V_4 (BRRI Dhan29 × NPK Super Granule) was the best treatment for the present study.

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BRRI	=	Bangladesh Rice Research Institute
cm	=	Centimeter
^0C	=	Degree Centigrade
DAS	=	Days after sowing
et al.	=	and others *(at elli)*
Kg	=	Kilogram
Kg ha^{-1}	=	Kilogram $hectare^{-1}$
g	=	gram (s)
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
P^H	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t ha^{-1}	=	ton $hectare^{-1}$
%	=	Percent

Chapter 1

Introduction

In Bangladesh majority of food grains come from rice. Rice is a crop of graminae family. About 77% of cropped areas in our country is used for rice cultivation with annual production of 47.7 million tons from 11.5 million hectare (ha) of land (IRRI, 2010). The average yield of rice in Bangladesh is 2.23 ton ha^{-1} (BRRI, 2010). The average yield is almost less than 50% of the world average rice yield. Bangladesh will need to increase its rice production by over 80% in the next 20 years to feed the growing population (Zaman, 1996).

Thus rice plays a vital role in the livelihood of the people of Bangladesh. The increased rice production has been possibly largely due to the adoption of modern rice varieties. Rice yield increases in many ways of them developing new high yielding variety and adoption of proper agronomic practices.

Rice is the main food crop of an estimated 40% of the world's population (Buresh and De Datta 1990). The rice crop removes large amounts of N for its growth and grain production. The estimated amount of N removal ranges from 16 to 17 kg for the production of one ton of rough rice, including straw (Choudhury*et al.,* 1997; Ponnamperuma and Deturck 1993; Sahrawat, 2000). Total N uptake by rice plant per hectare varies among rice varieties. Most of the rice soils of the world are deficient in N, and biological nitrogen fixation by cyanobacteria and diazotrophic bacteria can only meet a fraction of the N requirement (Baldani*et al.,* 2000; Tran Van *et al.,*2000). Fertilizer N applicationis thus necessary to meet the crop's demands.

Generally urea is the most convenient N source for rice. The efficiency of the urea-N in rice culture is very low, generally around 30–40%, and in some cases even lower (Cao *et al.,* 1984; Choudhury and Khanif 2001, 2004; Choudhury*et al.,* 2002).

Many hybrid rice varieties are out yielded compare to standard check variety with same growth duration by more than one ton ha^{-1} (Julfiquar*et al.*, 1998). The heterosis for higher yield in hybrid rice comes from vegetative growth. The life cycles of hybrid and inbred rice are almost similar, but hybrid rice is more vigorous in the vegetative phase, especially at seedling stage. Hybrid rice has higher seedling dry matter content, thicker leaves, larger leaf area and longer root system (BRRI, 2000). Hybrid rice can give 10-15% yield advantage over modern inbred varieties through vigorous growth, extensive root system, efficient and greater sink size, higher carbohydrate translocation from vegetative parts to spikelet and larger leaf area index during the grain filling stage (Peng*et al.,* 1998).

Responses of modern rice to applied nitrogen have been studied extensively throughout the country by a series of fertility trials. The average yield increase due to fertilizer N varies from 30 to 75%. In some cases, without applied N modern rice showed almost complete failure, while application of 100 kg N ha^{-1} along with other nutrients resulted in a very successful crop yielding 6-7 ton ha^{-1}.

To obtain high yield from a rice crop, balanced fertilization should be made in time. The use of urea should not be over-emphasized. Other fertilizers such as TSP, MP, gypsum, zinc and boron fertilizer need to be applied according to their needs.

If urea super granule (USG) technology is followed; then one 3.0g mega granule or three 1.0g granules is to be placed in the center of four hills at two alternate rows at a depth of 6-8 cm after eight to ten days of transplanting (DAT). USG should be applied when there will be 2-3 cm standing water in the field. After USG application the water level should be raised to 4-5 cm.The best soils suitable for USG technologies are clay, silty clay and clay loam.

Deep placement of N fertilizers into the anaerobic soil zone is an effective method to reduce volatilization loss (Mikkelsen*et al.,* 1978). Urea can be placed deep into the reduced soil layer at 8–10-cm soil depth by an instrument called "pneumatic urea injector" developed in the Netherlands. Field experimental results conducted at Bangladesh Rice Research Institute (BRRI) showed the superiority of this method of urea application over the conventional split broadcast method (Choudhury and Bhuiyan 1994).

The low N-use efficiency is attributed mainly to ammonia volatilization, denitrification, leaching, and runoff losses (Cho, 2003; Freneyet *al.,* 1990; Ponnamperuma, 1972; Singh *et al.,* 1995). However, the magnitude of N loss by different ways varies depending on environmental conditions and management practices. Volatilization and denitrification cause atmospheric pollution through the emission of gases like nitrous oxide, nitric oxide, and ammonia (Azamet *al.,* 2002; Reeves *et al.,* 2002).

Generally, the farmers of our country use non urea fertilizer as basal during final land preparation. Deep placement of all essential fertilizers may be more efficient and farmers can be more benefited from this compared to broadcast method. The use of NPK briquette, which is a mixture of urea, triple super phosphate (TSP) and muriate of potash (MOP) may help to reduce the loss of nutrients.

The nature and degree of losses depends upon soil and climatic conditions as well as N and floodwater management practices. The major loss processes are dependent upon the concentrations and quantity of ammoniacal N present in floodwater or at the soil-water interface in a flooded situation. Deep placement of N in the reduced zone and proper coverage is the best method that can minimize N losses. Application of urea super granules is made in the center of four hills at alternate two rows at a depth of 6-8 cm with two 1g granules for T Aman and T Aus rice and with three 1g granules or one 3g mega granule for Boro rice. This application is equivalent to 113 kg USG ha^{-1} for T Aman and T Aus, and 170 kg USG ha^{-1} for Boro rice.

USG should be applied when there will be 2-3 cm standing water in the field. After USG application the water level should be raised to 4-5 cm. One should not enter into the rice field before one month's time. The best soils suitable for USG technology are clay, silty clay and clay loam.

An attempt was taken whether this granule can save nitrogen from undesirable losses by its slow releasing capacity and the present study was under taken with the following objectives:

1. **To find out the appropriate form of N application**
2. **To assess the response of varieties against the forms of N and**
3. **To find out the interaction effect of variety and form of N application.**

Chapter 2

Review of literature

Rice is the principal food crop for the people of Bangladesh. A good number of research works have been done on various aspects of its growth and yield at different ecological situations. Nitrogen fertilizer plays a significant role on growth and yield of transplant boro rice. Variety of a crop is also an important factor for achieving better yield. During urea use in the crop field by different crop variety, losses of urea is occurred due to different process like leaching loss, volatilization, washes out with water etc. Urea consumption capacity at different forms of urea is also different according to different crop variety. Considering this aspect, in this chapter, some research works relating to the effect of different form of nitrogen and different variety on growth and yield component of transplanted rice are reviewed and discussed.

Rice is our principal food crop. That is why food security is directly related to the production of Boro rice. There is no alternative but to increase the production of Boro rice, adopting the advanced technologies as recommended by the agricultural scientists. Hybrid rice technology is one of the alternative means to meet the challenge of food security for the increasing population in Bangladesh. Chinese rice scientists 20% over the semi-dwarf varieties (Yuan *et al.,* 1994).

The present study was undertaken to evaluate the growth and yield behaviour of a few selected hybrid and inbred rice varieties in wet season under controlled condition.

2.1 Effect of variety

The physiological basis for heterosis remains unknown. Again the inbred is normally sink limiting and hybrids are source limiting. For high yield of hybrid rice, sink is not the limiting factor as it is in inbred rice (Yan, 1988). Two-step grain filling is observed in hybrid rice, which means that pollinated spikelets stop development for several days but maintain the ability to fill later (Wen, 1990). During vegetative growth, hybrid rice accumulates more dry matter which results in higher spikelets/panicle, whereas inbred rice depends basically on the accumulation of assimilates after heading (Yan, 1988). The main reason for higher yield of hybrid rice is vigorous seedlings with tillers. The tillers that emerge in the seedbed produce more spikelets/panicle than the tillers that emerge after transplanting (Wen, 1990).

The common properties of modern inbred and hybrid rice varieties are , high nitrogen response, erect and thick leaves which remain green till maturity, short satured and high harvest index. Dry matter production at different growth stages shows different patterns for hybrid and inbred rice. While hybrid rice has more dry matter accumulation in the early and middle growth stages, inbred rice has more in the late growth stages (Yan, 1988). High grain yield of hybrid rice is attributed to high vegetative biomass production, high leaf area, large panicles and high tillering capacity in some cases (Peng*et al.,* 1998).

The present study was undertaken to evaluate the growth and yield behaviour of a few selected hybrid and inbred rice varieties in wet season under controlled condition.

Bisne*et al.* (2006) conducted an experiment with eight promising varieties using four CMS lines and showed that plant height, tiller number hill^{-1}and grain yield differed significantly among the varieties and Pusa Basmati gave the highest plant height tiller number hill^{-1} and grain yield in each line.

Myung (2005) worked with four different panicle types of rice varieties and observed that the primary rachis branches (PRBs) panicle^{-1} and grains were more on Sindongjinbyeo and Iksan#467 varieties, but secondary rachis branches (SRBs) were fewer than in Dongjin#1 and Saegyehwa varieties.

Bokyeong*et al.* (2003) reported that applied with same nitrogen dose Sindongjinbyeo and Iksan#467 gave high primary rachis branches than Sindongjinbyeo and Dongjin No. 1 varieties.

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers. They observed that CNHR2 produced more number of productive tillers (413.4 m^{-2}) and filled grains panicle^{-1} (111.0) than other varieties, whereas IR36 gave the highest 1000-grain weight (21.07g) and number of panicles m^{-2} than other tested varieties.

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

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

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

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

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

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

Sumit*et al.* (2004) worked with newly released four commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant SankarDhan 1) and two high yielding cultivars (HYV) as controls (Pant Dhan 4 and Pant Dhan 12) and reported that KHR 2 gave the best yield (7.0 t/ha) among them.

Devaraju*et al.* (1998) in a study with hybrid rice cultivar KRH2 and 1R20 as a check variety having different levels of N from 0 to 200 kg N ha^{-1} found that KRH2 out yielded IR20 at all levels of N. The increased grain yield of KRH2 was mainly attributed to the higher number of productive tillers $hill^{-1}$, panicle length, weight and number filled grains $panicle^{-1}$.

Dongarwar *et al.* (2003) conducted an experiment to investigate the response of hybrid rice KJTRH-1 in comparison with 2 traditional cultivars, Jaya and Swarna, to 4 fertilizer rates, i.e. 100:50:50, 75:37.5:37.5, 125:62.5:62.5 and 150:75:75 kg NPK ha^{-1} and reported that KJTRH-1 produced significantly higher yield (49.24 q ha^{-1}) than Jaya (39.64 q ha^{-1}) and Swarna (46.06 q ha^{-1}).

Dwivedi (1997) in a field experiment found that scented genotypes, Kamini and Sugandha gave higher grain and straw yields than four other cultivars RP615, Harban, Basmati and Kasturi with 60 kg N ha^{-1} under midupland sandy loam soil conditions of Agwanpur (Bihar).

Munoz *et al.* (1996) noted that IR8025a hybrid rice cultivar produced an average yield of 7.1 t ha^{-1} which was 16% higher than the commercial variety Oryzica Yacu-9.

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

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

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

BINA (1992) reported that under transplanting conditions the grain yield of BINA13 and BINA19 were 5.39 and 5.57 t ha^{-1} respectively and maturity of the above strains were 160 days and 166 days, respectively.

Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (*viz.*Jharapajam, Lalmota, BansfulChikon) was compared with that of a modern variety (*viz.* KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

Wang *et al.* (2006) studied the effects of plant density and row spacing (equal row spacing and one seedling $hill^{-1}$, equal row spacing and 3 seedlings $hill^{-1}$, wide-narrow row spacing and one seedling $hill^{-1}$, and wide-narrow row spacing and 3 seedlings $hill^{-1}$) on the yield and yield components of hybrids and conventionalcultivars of rice.

Compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27%.

Xu and Wang (2001) evaluated ten restorer and ten maintainer lines. They observed that the restorer lines showed more spikelet fertility than maintainer lines. They studied growth duration, number of effective tillers, number of spikelets per panicle and adaptability.

Patel (2000) studied that the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36. The mean yield increased with Kranti over IR36 was 7.1 and 10.0% for grain and straw, respectively. Molla (2001) reported that Pro-Agro6201 (hybrid) had a significant higher yield than IET4786 (HYV), due to more mature panicles m^{-2}, higher number of filled grains $panicle^{-1}$ and greater seed weight.

Chen-Liang *et al*. (2000) showed that the cross between Peiai 64s and the new plant type lines had strong heterosis for filled grains per plant, number of spikes per plant and grain weight per plant, but heterosis for spike fertility was low.

Julfiquar*et al*. (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during *boro*season 1994-95 as preliminary yield trial at Gazipur and it was reported that five hybrids (IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. They also reported that thirteen rice hybrids were evaluated in three locations of BADC farm during the boro season of 1995-96. Two hybrids out yielded the check variety of same duration by more than 1 t ha^{-1}. Rajendra*et al.* (1998) carried out an experiment with hybrid rice cv. Pusa 834 and Pusa HR3 and observed that mean grain yields ofPusa 834 and Pusa HR3 were 3.3 t $ha^{-1}$and 5.6 t ha^{-1}, respectively.

Xu and Li (1998) observed that the maintainer lines were generally shorter than restorer line. Roy *et al*. (1995) observed that the plants, which needed more days for 50% flowering generally, gave more yield.

Son *et al.* (1998) reported that dry matter production of four inbred lines of rice (low-tillering large panicle type), YR15965ACP33, YR17104ACP5, YR16510-B-B-B-9, and YR16512-B-B-B-10, and cv. Namcheonbyeo and Daesanbyeo, were evaluated at plant densities of 10 to 300 plants m^{-2} and reported that dry matter production of low-tillering large panicle type rice was lower than that of Namcheonbyeo regardless of plant density.

Devarajuet *al.* (1998) in a study with two rice hybrids such as Karnataka Rice Hybrid 1 (KRH1) and Karnataka Rice Hybrid-2(KRI42) using HYV IR20 as the check variety and found that KRH2 out yielded than IR20. In IR20, the tiller number was higher than that of KRH2.

Mishra and Pandey (1998) evaluated standard heterosis for seed yield in the range of 44.7 to 230.9% and 42.4 to 81.4%, respectively. Plant height, panicle per plant, grain per panicle and 1000 grain weight increase the yield in modern varieties.

Associations of various yield components in rice (Padmavathi*et al.*, 1996) indicate that the plants with large panicles tend to have a high number of fertile grains. Similarly, a positive correlation was observed between number of panicle/plant and panicle length.

Islam (1995) in an experiment with four rice cultivars *viz.* BR10, BR11, BR22 and BR23 found that the highest number of non bearing tillers $hill^{-1}$ was produced by cultivar BR11 and the lowest number was produced by the cultivar BR10.

BRRI (1994) studied the performance of BR14, BR5, Pajam, and Tulsimala and reported that Tulsimala produced the highest number of filled grains $panicle^{-1}$ and BR14 produced the lowest number of filled grains $penicle^{-1}$. BINA (1993) evaluated the performance of four varieties IRATOM 24, BR14, BINA13 and BINA19. They found that varieties differed significantly on panicle length and sterile spikelets $panicle^{-1}$. It was also reported that varieties BINA13 and BINA19 each had better morphological characters like more grains panicle^{-1} compared to their better parents which contributed to yield improvement in these hybrid lines of rice.

Hossain and Alam (1991) found that the growth characters like total tillers hill^{-1} differed significantly among BR3, BR11, Pajam and Jaguli varieties in *boro*season. Ahmed *et al.* (1997) conducted an experiment to compare the grain yield and yield components of seven modern rice varieties (BR4, BR5, BR10, BR11, BR22, BR23, and BR25) and a local improved variety, Nizersail. The fertilizer dose was 60-60-40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively for all the varieties and found that percent filled grain was the highest in Nizersail followed by BR25 and the lowest in BR11 and BR23.

Rice tillering is a major determinant for panicle production (Miller *et al.*, 1991) and as a consequence affects total yield (Gallagher and Biscoe, 1978). The high tillering capacity is considered as a desirable trait in rice production, since number of tillers per plant is closely related to number of panicles per plant. To some extent, yield potential of a rice variety may be characterized by tillering capacity. On the other hand, it was reported that the plants with more tillers showed a greater inconsistency in mobilizing assimilates and nutrients among tillers. Moreover, grain quality could be also affected by tillering ability due to different grain development characteristics. It has been well documented that either excessive or insufficient tillering is unfavorable for high yield. Ghose and Ghatge (1960) stated that tiller number, panicle length contributed to yield. Ghosh and Hossain (1988) reported that effective tillers/plant, number of grains/panicle and grain weight as the major contributory characters for grain yield it had positive correlations with number of productive tillers/plant.

Miah*et al.* (1990) conducted an experiment where rice cv. Nizersail and mutant lines Mut. NSI and Mut. NSS were planted and found that plant height were greater in Mut. NSI than Nizersail.

Patnaik*et al*. (1990) reported that in hybrids, yield was primarily influenced by effective tillers per plant and fertile grains per panicle, whereas in parents it was panicle length, maturity and effective tillers per plant. Number of effective tillers per plant and fertile grains per panicle remained constant and common in explaining heterosis for yield of most of the hybrids. The heterosis for grain yield was mainly due to the significant heterosis for the number of spikelets/panicle, test weight and total dry matter accumulation.

Saha*et al*. (1989) studied the characteristics of CMS lines V20A, 279A, V41A and P203A with their corresponding maintainer (B) lines and two restorer (R) lines IR50 and IR54. In maintainer lines tiller number were recorded highest in V20B.

Shamsuddin*et al*. (1988) conducted a field trial with nine different rice varieties and observed that plant height differed significantly among varieties. Sawant*et al*. (1986) conducted an experiment with the new rice lines R-73-1-1, R-711 and the traditional cv. Ratna and reported that the traditional cv. Ratna was the shortest.

Dwarfness may be one of the most important agronomic characters, because it is often accompanied by lodging resistance and thereby adapts well to heavy fertilizer application (Futsuhara and Kikuchi, 1984). Prasad *et al*. (2001) observed that days to flowering are negatively correlated with plant height. Grain yield is negatively correlated with plant height (Amirthadevarathinam, 1983). Patnaik*et al*. (1990) found that hybrids with intermediate to tall plant height having non-lodging habit could be developed gave more than 20% grain yield than the standard checks.

Improvement of rice grain yield is the main target of breeding program to develop rice varieties for diverse ecosystems. However, grain yield is a complex trait, controlled by many genes and highly affected by environment (Jennings *et al*., 1979). In addition, grain yield also related with other characters such as plant type, growth duration, and yield components (Yoshida, 1981). Rice yield is a product of number of panicles per unit area, number of spikelets per panicle, percentage of filled grains and weight of 1000 grains (Yoshida, 1981; De Datta, 1981). Improving rice (*Oryza sativa* L.) grain yield per unit land areais the only way to achieve increased rice production becauseof the reduction in area devoted to rice production (Cassman, 1999).

2.2Different methods of urea application

Nitrogen being the most important nutrient element in soils plays the most vital role in crop production in Bangladesh. Except few leguminous crops, all other crops respond dramatically to applied nitrogen irrespective of soil types, growing seasons and cultivars used. Practically high yielding varieties of different crops such as wheat, maize, potato, sweet potato, cabbage, brinjal, tomato, cauliflower and banana are highly responsive and need ample supply of fertilizer nitrogen to express their yield potentials; while cotton, tobacco, mustard and sugarcane are substantially responsive. Pulses and other legumes are less responsive to applied nitrogen in Bangladesh soils. For some leguminous crops a starter nitrogen dose is considered essential for higher nodulation and production.

The low N-use efficiency is attributed mainly to ammonia volatilization, denitrification, leaching, and runoff losses (Cho, 2003; Freney*et al.*,1990; Ponnamperuma, 1972; Singh *et al.,* 1995). However, the magnitude of N loss by different ways varies depending on environmental conditions and management practices. Volatilization and denitrification cause atmospheric pollution through the emission of gases like nitrous oxide, nitric oxide, and ammonia (Azam*et al.*,2002; Reeves *et al.,* 2002).

Nitrous oxide absorbs infrared radiation contributing to the greenhouse warming and the depletion of the stratospheric ozone layer (Bohlool*et al.,* 1992). Nitric oxide contributes to the formation of tropospheric ozone, a major atmospheric pollutant that affects human health, agricultural crops, and natural ecosystems (Chameides*et al.,* 1994). Nitric oxide is also a precursor to nitric acid, a principal component of acid deposition (Kennedy, 1992). The deposition of nitric oxide and ammonia in terrestrial and aquatic ecosystems can lead to acidification, eutrophication, shifts in species diversity, and effects on predators and parasite systems (Reeves *et al.*,2002; Vitousek*et al.*, 1997).

Leaching of nitrate causes groundwater toxicity (Shrestha and Ladha 1998). Excess amounts of nitrate in drinking water and food may cause methemoglobinemia in infants, respiratory illness, and decreased content of vitamin A in the liver (Bohlool*et al.*,1992; Phupaibul*et al.*,2002).

Chien*et al.* (2009) provided information on some recent developments of fertilizer production and use that improve nutrient efficiency and minimize environmental impact. The nutrients are mainly N, P, and S. Improving N nutrient efficiency includes use of (1) controlled-release coated urea products, (2) slow release urea–aldehyde polymer products, (3) urea supergranules for deep placement, (4) nitrification inhibitors to reduce nitrate leaching and denitrification, (5) urease inhibitors to reduce ammonia volatilization from urea, and (6) ammonium sulfate to enhance N efficiency of urea. Improving efficiency of conventional P fertilizers includes use of (1) coated water-soluble P fertilizers, (2) urea supergranules containing P and K nutrients, and (3) fluid P fertilizers. Use of nonconventional P fertilizers includes (1) phosphate rock (PR) for direct application with a newly developed computer-based phosphate rock decision support system (PRDSS), (2) a mixture of PR and water-soluble P sources, (3) calcinednonapatite PR for direct application, and (4) nonconventional acidulated P fertilizers containingwater-insoluble but citrate-soluble P compounds. The agronomic effectiveness of newly developed granular NP fertilizers containing elemental S to provide S nutrient is discussed. Two processes of producing (1) partially acidulated P fertilizers and (2) compound fertilizers of NP and K by bulk blending are recommended for reducing Cd uptake from P fertilizers by crops. The use of these nonconventional fertilizers may result in an increased relative economic benefit with respect to the use of conventional fertilizers in terms of saving fertilizer cost, enhancing nutrient efficiency, or increasing crop yield.

Kolhe and Mittra (1987) conducted field experiments for three consecutive years during 1979—80 to 1981—82 to find out the relative efficiency of different forms of urea fertilizer for rice and their residual effect on the succeeding crop of wheat. In rice crop, root zone placement of nitrogen as urea super granule 1.0 g size (USG) under puddled field condition was proved to be superior to other sources. The relative efficiency of USG, urea in splits and sulphur coated urea (SCU) was 116.92%, 107.71% and 101.41% respectively as compared to ordinary urea at planting. Significant residual effect on succeeding crop of wheat was recorded in case of SCU which was followed by USG, urea in splits and urea at planting.

Another instrument called "liquid urea injector" is used to inject dissolved urea into the upper soil layer at 5–6 cm soil depth as band placement between alternate rice rows (Schnier*et al.* 1988, 1993). This method of N application was found effective in reducing ammonia volatilization loss resulting in increase in grain yield and fertilizer N recovery of the 15N labeled urea in several field experiments (Schnier 1995).

USG has been developed at the International Fertilizer Development Centre, United States. The superiority of USG over PU in rice culture has been found in many investigations (Craswell*et al.* 1985; Kannaiyan 2002). Field studies using 15N-labeled urea at IRRI showed that fertilizer N recovery with USG point placement was 65–96% while it was only 32–55% with the conventional PU broadcasting due to lower amount of ammonia volatilization loss (Cao et al. 1984). Urea large granule + (ULG), another modified form of urea having an average diameter of 7 mm, has been developed in the Netherlands. This modified form of urea, because of its larger granule size, may go deeply into the mud simply by force throwing, and thus may be expected to be more efficiently used than PU.

Idris and Matin (1990) noted that plant height increased up to 120 kg N ha^{-1} compared to the control and there after the height declined at 140 kg N ha^{-1}. They also noted that the length of panicle was highly related with the application of increased level of nitrogen. They also stated that panicle formation and elongation is directly related with the contribution of nitrogen. The maximum number of tiller $hill^{-1}$ was produced with 140 kg N ha^{-1} which was statistically similar to 60, 80, 100 and 120 kg N ha^{-1}. The minimum number of tiller $hill^{-1}$ was obtained from the control treatment (0 kg ha^{-1}).

Azollon, a slow-release nitrogen fertilizer, has been developed in Germany. It is a urea-formaldehyde condensation product containing 38% N. The relative performances of PU, ULG, USG, and Azollon in wetland rice culture were evaluated in a field experiment at BRRI (Choudhury *et al.* 1994). Considering grain yield, USG was significantly superior to PU and azollon, whereas ULG had a slight edge over PU but was not statistically different. Total N uptake increased significantly in ULG- and USG-treated plots compared to the conventional PU-treated plots. Agronomic efficiency and apparent recovery of added N were considerably higher with USG and ULG compared to PU (Choudhury et al. 1994).

Nitrogen use efficiency is usually low. Dobermann (2005) used data from over 800 experiments to estimate that, on average, only 51% of the N applied was recovered by the aboveground parts of cereals. Similar results were compiled by Cantarella (2007) using 15N data for maize in Brazil.However, N recovery may be even lower under certain management conditions. Fan *et al.* (2004) reported that the average N fertilizer recovery in cereals in China was 30–35%. Available data for perennial crops, such as citrus, show the same range of results; between 25% and 50% of the applied N was taken up by the plants (Quaggio*et al.*, 2005). Nitrogen derived from fertilizers and not taken up by plants may be immobilized in soil organic matter or may be lost to the environment. In this case, it has the potential to become a pollutant of ground or surface waters or to contribute to the greenhouse effect. Loss of N to the environment usually takes place when high concentrations of soluble N forms are present in the soil solution in excess compared to the amount that plants can take up or when in periods or positions in the soil profile where there are no plants or roots to make use of the available N. These problems can be largely overcome with good management practices, which include selecting a rate of application compatible with plant needs, placing the fertilizer where plants can easily reach the nutrients, and choosing the right application time. In many cases for N, this implies splitting the application in two or more time intervals. Management practices will not be discussed in this text, except urea supergranules (USG) for deep placement in lowland rice soils.

Works done by many researchers, especially by the International Fertilizer Development Center (IFDC), have conclusively demonstrated that compacted USG, that is, urea with 1–3 g granules, are an effective N source (Savant and Stangel, 1990). In general, one or more USG are deep placed (7–10 cm depth) by hand at the center of every four rice seedling hills in rice soils during or after rice transplanting. Savant and Stangel (1998) have shown that N loss is significantly reduced, which results in a significant increase in rice grain yield under flooded conditions compared with splitapplied PU. For example, the average rice grain increase over control with USG was significantly greater than that with split-applied PU in 29 irrigated rice trials. Deep placement of USG essentially cuts off NH_3 volatilization and also significantly reduces denitrification N loss compared to surface application of PU. Furthermore, the N concentration of flooded water is greatly reduced when USG is deep placed, so that any water runoff from rice paddies does not contribute to N loss or to potential eutrophication problems (Savant and Stangel, 1990). The reason for producing USG is that it makes it easier for farmers to apply USG by hand. Use of USG has one great advantage in that it requires only one-time application after rice transplanting, whereas surface application of PU requires two to three split applications that can still result in significant N loss through NH3 volatilization.

One drawback of applying USG is that it is a labor-intensive practice that some rice farmers in developing countries are not willing to adopt, for example, China. Also, it is not an alternative to commercial rice farms in the USA, Europe, and Latin America due to high labor costs. However, the use of USG has been successfully promoted in several Asian countries, notably in Vietnam and Bangladesh. The Government of Bangladesh has announced that it will expand the use of USG to almost 1 million hectares of rice land, reaching about 1.6 million farm families (IFDC, 2007).

In contrast to flooded rice, little study has been done on the use of USG for upland crops, presumably due to difficulty in deep placement of USG in upland soils. Nevertheless, supergranules of NPK compound fertilizers containing urea have been commercially marketed by some fertilizer companies for tree crops, particularly fruits. Once the problem of deep placement in upland soils is solved, it is expected that deep placement of USG should also perform well as an N source for upland food crops.

In the zone of USG placement, a high-localized urea/NH4+ concentration develops followed by an increase in soil pH through enzyme-catalysed hydrolysis (Singh *et al.*, 1994). However, dissolution of deep-placed USG occurs slowly and inhibits both urease and nitrifier activity, and molecular diffusion is likely the predominant mechanism for the movement of dissolved urea (Shah andWolfe, 2003). Tenuta and Beauchamp (2000) showed that use of USG increased N_2O production to a maximum of 1.24% of the added urea-N, with the presence of NO_2- being the dominant factor influencing its release.

Deeper placement of USG is technologically and agroeconomically advantageous in improving N use efficiency in lowland rice fields (Savant and Stangel, 1990; Mohanty *et al.,* 1999). This technology might be effective agronomically for up/dryland cropping systems (Mohanty *et al.*, 1999), but uncertainty prevails with regard to the environmental consequences. High NH_3 volatilization from sandy and

N_2O emission from silt loam soils treated with USG have been reported (Buresh, 1987). Further interest in the emission potentials of gaseous N species from agricultural soils treated with USG to the atmosphere, their interactions and possible environmental consequences has called for technological decision supports. Thus, we carried out experiments (a) to investigate the influence of various urea granule sizes on N_2O, NH_3 and NOx emissions from a silt loam soil, (b) to determine the role of contrasting soil types with point-placed USG on N_2O, NH_3 and NOx emissions, and (c) to elucidate the interrelations between the gaseous N species over time and the factors affecting their emissions.

Rahman (2003) observed that plant height was not affected by the different level of USG in rice. He carried out an experiment with two levels of urea supergranules (USG) in rice field as 50 and 75 kg N ha^{-1} in *kharif* season. He found that the highest plant height (83cm) was obtained with 75 kg N ha^{-1} as USG. But highest tiller number (14.32), panicle length (20.24 cm), grains $panicle^{-1}$ (91.44), 1000 seed weight (22.58 g), grain yield (3.12 t ha^{-1}) and straw yield (5.34 t ha^{-1})

Alam (2002) found that plant height and tiller number increase significantly with the increased level of USG/4 hill. They also reported that growth and yield parameters were increasedwith the increased level of nitrogen from 27-87 kg N ha^{-1}. Deep placement of urea supergranules (USG) resulted in the highest plant height, tillers $hill^{-1}$, biological yield, grain yield and harvest index than prilled urea.

Patel (1997) conducted an experiment and studied the effect of doses, forms of nitrogen fertilizer in rice and he found highest grain yield with 58 kg N ha^{-1} as urea supergranules(USG) applied 7 days after transplanting and were much lower with all rates of prilled urea.

Urea supergranules gave 14.9% higher yield, than applying 3 split applications of prilled urea (Mahalle and Throat, 1995). The same also observed by Patel and Mishra (1994), they placed urea supergranules 5-10 cm deep a week after transplanting.

Choudhury and Bhuiyan (1994) reported that 87 kg N ha^{-1} as urea supergranules gave highest yields compared with prilled urea applied as 3 equal splits. USG placed by hand at 8-10 cm depth after seedling establishment. Grain yield was highest when 112 kg N ha^{-1} was applied as large granular urea in 3 split dressing than prilled urea applied in 3 splits (Raja *et al*., 1994).

Bhuiyan*et al.* (1998) conducted experiments at BRRI during the period from 1975-1985 on USG and reported that deep placement of urea for rice was superior to split broadcast application during the dry season and the economics of use appeared favorable.

Pandey and Tiwari (1996) carried out a field trial with 87 kg N ha^{-1} as basal application of USG, PU, mussoorie rock phosphate urea (MRPU), large granule urea (LGU) or neem coated urea (NCU) or 66% basal incorporation + 33% top dressing at panicle initiation and found that grain yield and N use efficiency were highest with N given as a basal application of USG or MRPU applied in 2 split applications. Kumar *et al*. (1996) reported that application of urea supergranules in the sub-soil gave 22% higher grain yield than control.

Basti and Sarker (1995) conducted a field trail in kharif season with rice cv. Jagnnath and observed that grain yield and N content were 4.07 ton ha^{-1} and 1.43% respectively with USG and the lowest 2.66 t ha^{-1} and 1.31% with PU.

Dwivedi and Bajpai (1995) observed through using 0-90 kg N ha^{-1} as urea, USG + urea or urea spray that grain yield net returns increased with the increased rate of N application and the yield was highest with USG and lowest with urea spray.

Swain *et al*. (1995) evaluated the performance of USG application methods in low land transplanted rice. They have reported that USG gave higher grain and straw yield.

Jaiswal and Singh (2001) carried out a field experiment on the comparative efficiency of urea supergranules and prilled urea, both at 60 and 120 kg ha^{-1} on rice cultivation under different planting method during 1996-97 and 1997-98, in Faizabad, Uttar Pradesh, India. They stated that transplanting method with USG placement proved to be best for maximum grain yield (4.53 t ha^{-1}) and deep placement of USG increased N use efficiency (31.7%) compared to conventionally applied urea.

Mishra *et al.* (1999) conducted a field experiment with urea supergranules (USG) in wet land rice (*Oryza sativa* cv. Lalat) in affine textured soil. USG was applied at 76 kg N ha^{-1} along with prilled urea (PU) split. They found that placement of USG significantly increased both the grain and straw yield of rice compared to PU. Rice showed a greater response to N upon USG placement than split application of PU.

Harun*et al.* (1993) compared the benefits of USG application over PU and they found that USG produces at least 25% higher yield than PU and the marginal rate of return was highest for USG at 58kg N ha^{-1}.

Zaman*et al.* (1993) found that USG consistently produces significantly higher grain yield than PU. Also the total N uptake, apparent N recovery and agronomic efficiency N were higher with USG than PU.

An experiment was carried out at the Agronomy Field Laboratory, BAU, Mymensingh to investigate the effect of cultivar, depth of transplanting and sources of N fertilizer on the growth and yield of transplant *aman* rice and Kabir (1992) found that the grain yield of transplant *aman* rice can be maximized by maintaining a transplanting depth of 3 cm and applying USG instead of conventional PU.

Singh and Singh (1992) studied about the nitrogen economy through modified forms of urea application in rice and found that the grain yield increased with increasing nitrogen rates. Urea super granule produced significantly higher yields than the other sources.

Sahu*et al.* (1991) worked on the method of application of USG in low land rice soil and showed that USG gave higher yields than PU when USG was placed at midway between every alternate 4 hills.

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

Sahu and Mitra (1989) reported that higher grain yields were obtained with large granular urea @ 60 or 90 kg N ha^{-1} applied in two splits (7 days after transplanting and panicle initiation stage) than with PU. USG gave higher yields than large granular urea or PU.

Ali (1985) carried out an experiment with PU, USG on rice *cv.* BR3 and found that deep placement of USG was superior to 2 or 3 split application of PU. He had also found that USG was superior at all N rates where 62 kg N ha^{-1} gave the highest grain yield and it was increased with increasing N application up to 124 or 155 kg N ha^{-1} regardless of management.

Juang (1980) stated that the performance of USG was superior in rice yields and fertilizer N efficiency had shown the new product to be highly suitable for rice in many Asian countries, where urea is already a common fertilizer for rice. This product is to 40 to 50% more efficient than conventional urea.

De Datta and Crasswell (1980) showed that evaluation of rice program during 1975 to 1978 and he found that deep placement of USG is an effective means of increasing rice yields compared with traditional split application of PU.

From an international trial in eight countries under INPUTS project Yoshida *et al.* (1978) found that deep placement of USG was superior both for yield and nitrogen recovery to the conventional method of urea application. They achieved 1 tha^{-1}

increased yield by 41 kg N ha^{-1} in USG but the rate was 60 kg N ha^{-1} of increased yield case of urea.

Juang and Tann (1978) studied that the effect of form and rate of nitrogen fertilizer on yield and nitrogen content of rice under subtropical conditions using urea and USG at 44, 66, 88, and 132 kg N ha^{-1} and found that USG was very effective for increasing grain yield of rice than urea in the subtropics, but the optimum rate of this fertilizer might vary with the nitrogen fertility of the rice soils.

Vijaya and Subbaiah (1997) showed that plant height, number of tillers, root length, number and weight of panicles, dry matter and grain yield of rice increased with the increasing urea super granule size and were greater with the deep placement method of application both N and P compared with broadcasting.

Kamal *et al.* (1991) conducted a field experiment in *kharif* season of 1985 and 1986 on rice cv. Joya with different level of nitrogen @ 29, 58, 87, kg ha^{-1} as urea super granules (USG). Among the three doses of nitrogen, total tillers was the highest when 87 kg N ha^{-1} was applied, productive tillers also followed a similar trend.

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

Rama *et al.* (1989) mentioned that the number of panicles m^{-2} increased significantly when nitrogen level increased from 40 to 120 kg N ha^{-1} as urea super granule (USG).

Thakur (1991) studied the influence of levels, forms and method of application of urea in rice during *kharif* season. He observed that grain yield differed significantly due to the levels and sources of applied. Placement of nitrogen at 60 kg ha^{-1} through urea super granules produced the highest number of panicle $unit^{-1}$ area, panicle weight, number of grains $panicle^{-1}$ and 1000-grain weight which ultimately gave the grain yield 4.77 t ha^{-1} in 1987 and 4.94 t ha^{-1} in 1988.

Kumar and Singh (1983) carried out an experiment with rice cv. Hindham grown by applying 29-116 kg N ha^{-1} under flooded condition and stated that 87 kg N ha^{-1} in the form of USG gave the highest yield.

Miah*et al.* (2004) found that the values of the parameters measured were higher with application of urea super granules compared to application of urea. Patel and Desai (1987) found that rate of 58 kg N ha^{-1} as urea super granules placed at 10-12 cm depth gave the highest yield (4.34 t ha^{-1}) compared to any other rate.

Setty*et al.* (1987) reported that the grain yield increased significantly with increase N rate up to 87 kg ha^{-1} as urea super granules (USG). A similar effect of nitrogen as urea super granules (USG) was reported that Tomar (1987). Raja *et al.* (1987) conducted an experiment with rice cv. Pravath and urea super granules (USG). The USG at 75 kg N ha^{-1} gave the highest yield of 7.2 t ha^{-1}.

Bastia and Sarker (1995) reported that grain yield and N content were the highest with USG (4.07 t ha^{-1} and 1.31%, respectively). Reddy *et al.* (1986) reported that increasing N rates from 30 to 60 and 90 kg ha^{-1} increased paddy yields of wet land rice from 2.89 to 3.77 and 4.39 tha^{-1}, respectively when N applied as urea super granules (USG) and placed in the root zone in soil.

Johnkutty and Mathew (1992) conducted an experiment on rice cv. Jyoth during rainy season and reported that 84 kg N ha^{-1} as urea super granules (USG) gave higher yield.

In trials with rice variety 'Sabarmati' grown in *kharif* season, Jagdish*et al.* (1972) obtained higher rice yields by the foliar application of N as urea than by soil application with N rates being the same in both treatments.

Narayanan *et al.* (1958) conducting an experiment reported that spraying urea on rice at the of 15 lb/ac as a solution at the pre flowering stage gave 6% more grain and 50% more straw.

De *et al.* (1971) found in trials with rice applying 17.8 kg urea ha^{-1} as a 20% foliar spray that paddy yield was increased by 15.4% and the yield on unsprayed plots was 2.05 tha^{-1}.

Le *et al.* (1968) conducted an experiment on rice grown under different fertilizer regions and on soil of varying fertility with 1.5-3% urea solution, where fertilizer was sprayed 18 and 15 days before flowering. They found that foliar application of urea increased grain yield by an average of 10%.

Rao and Padmanabham (1971) reported that 3 rice varieties were tried with 75, 100, or 125 kg N ha^{-1} in 3 split dressing, where application of 100 kg N ha^{-1} in 3 split dressing (50% before sowing, 25% in foliar spray at 7 days intervals being from 28 days after sowing and 25% a top dressing at the panicle iniciation stage) gave the highest average paddy yield of 5.61t ha^{-1} in other treatments.

Bhaskaran and De (1971) tested 4 rice varieties with 50, 100, 150, or 200 kg N ha^{-1}. In each treatment 80% of the N was applied at transplanting and the remainder either as a top dressing or as 1-4 foliar sprays at the ear emergence stage. When fertilizer was applied at transplanting and as a top dressing, the highest paddy yield was obtained with 150 kg N ha^{-1} whereas similar yield was obtained with 100 kg N ha^{-1} applying at transplanting and as foliar application of N at the higher rates.

Venkateswarlu and Rao (1965) found that yield of rice increased significantly with increasing spray concentration and with increasing basal dressing of N. Absorption of sprayed N was generally greatest from the first spraying by young leaves and greatest by the inflorescence at the third spraying and was increased with increased spray concentration. The grain protein content increased with increasing concentration and frequency of spraying but was not increased by basal N dressing.

Delafuente and Velasco (1955) found that during vegetative stage of rice plants, urea fertilizer as a foliar spray was less effective than as a soil top dressing. Urea top dressing in turn was less effective than a top dressing of ammonium sulphate. During the booting stage, urea spray on the leaves was as effective as a top dressing of ammonium sulphate.

Finney *et al.* (1957) observed that when wheat was sprayed a number of times with urea solution at 3 concentration at different times before, at and after flowering, the yield was increased with the high concentration applied at the rate of 50 lb N ac^{-1} seven weeks before flowering. The yield was reduced after spraying 15 times at the rate of 50 lb N ac^{-1} through the fruiting period but the protein content was increased from 10.8-21% and one spraying at flowering also increased the protein content by 4.4%.

Narayan *et al.* (1958) reported that the spraying of nitrogen at the rate of 16.80 kg ha^{-1} as a solution of rice plants at the pre-flowering stage gave 60% more grain yield and 50% more straw yield than soil application.

Anonymous (1969) reported that foliar application of nitrogen as 2% urea solution in two or more splits at weekly intervals, beginning from active tillering phase over a basal application of 50 kg N ha^{-1} as ammonium sulphate effect economy in fertilizer requirement besides causing mark improvement in yield. It was also reported that urea is compatible with folidol, coppersan and 2, 4-D and thus no extra cost was involved in restoring to foliar application of urea.

Narayan and Vasudevan (1959) observed that the heights of maize plants were increased by leaf feeding of fertilizers. Yield increase of grains was also greater in maize but the straw yield was less. Urea spray of 0.5% concentration increased the grain yield of maize by 5.3%. The cob-weight of maize was increased by 30% when sprayed with urea and potassium sulphate and that was increased 18% when sprayed with super phosphate.

Sharma *et al.* (1966) observed that the average grain yield of wheat was increased by 40 and 60% with application of 44.86 and 67.26 kg N ha^{-1} respectively and the application of N half to the soil at sowing and half as sprays (6% solution) at 7 and 11 weeks stage of growth gave higher yield than full soil application.

Foy *et al.* (1954) observed that in corn the severity of marginal leaf burn caused by spraying with urea increased as the concentration of the spray solution and the rate of application increased. Yield response to sprays was not greater than soil dressing. A dilute spray containing 5 lb urea 100 $gallons^{-1}$ of water (approximately 5%) at the rate of 20 lb N ac^{-1} produced little injury to the leaves and gave the same yield response with side dressing and at the rate of 40 lb N ac^{-1} was less effective than ground application.

Barat and Das (1962) observed that the efficiency of soil and foliar application of urea and super phosphate in the production of dry matter of kanas maize. They reported that the uptake of N and P from sprays was significantly greater than that from the soil. Application of N increased dry matter production irrespective of concentration. Soil application of P at the lower level increased dry matter production while spraying decreased it non-significantly.

Mukherjee *et al.* (1966) in a field experiment found that the 18% increase of potato yield when half the fertilizer was applied as a foliar spray and half to the soil at planting instead of full application to the soil at planting.

Rajat and Singh (1963) conducted an experiment on potatoes and reported that the foliar application of one-fifth or quarter of the usual quantity of nutrient was as effective as the full dose of nutrient applied to the soil.

Considering above review of literature it can be mentioned that limited researches have been done before and many other such type of researches can be held in respect of the present study. Different locations can be selected at home and abroad with different rice variety with many other different forms of urea along with USG.

2.3 Combined effect of different forms of nitrogen and variety

Farmers in Vietnam and Cambodia obtained 25 % higher yields with deep placement of NPK briquettes over the broadcasting of fertilizer (IFDC, 2007). 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 (IFPRI, 2004). A national survey conducted in Bangladesh during 2004 showed that more than 1800 briquette-making machines had been manufactured and sold and about 550000 rice farmers were using the technology in their fields (IFDC, 2007).

Islam*et al*. (2011) conducted an experiment at the Bangladesh Rice Research Institute, R/S Sagordi farm, Barisal to evaluate the effectiveness of NPK briquette on rice in tidal flooded soil condition during Boro season, 2010. NPK briquettes of size 2.4 g and 3.4 g were compared with urea super granules (USG) and prilled urea (PU), each supplemented with PKS. The results showed that NPK briquettes, USG and PU produced statistically similar grain yield. N-treated plots (briquettes, USG and PU) gave significantly higher grain yield than N control. The highest grain yield (7.47 t ha^{-1}) was observed in NPK briquette (2.4 g × 2) followed by PU. There was no significant difference between N control and absolute control plots in respect of yield indicating that N was the only yield limiting factor under that condition. The NPK briquettes showed higher agronomic efficiency than PU and USG. The small size briquettes (2.4 g) could save 33 kg N ha^{-1} compared to recommend PU. There was no residual effect of NPK briquettes on soil chemical properties. The NPK briquettes were found beneficial to the farmers in tidal ecosystem.

Chapter 3

Materials and Methods

The experiment was conducted of the Agronomy field at Sher-e-Bangla Agricultural University, Dhaka during the period from November,2011 to May, 2012. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations.

3.1 Site description

The present study was conducted in the Sher-e-Bangla Agricultural University farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28.The location of the experimental site is $23^0 74^{\prime}$N latitude and $90^0 35^{\prime}$E longitude with an elevation of 8.2 meter from sea level (Appendix I).

3.2 Climate and weather

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris*et al*., 1979).Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Meteorological department of Bangladesh, Sher-e Bangla Nagar, presented in Appendix II.

3.3 Soil

The soil belongs to "The Modhupur Tract", AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details have been presented in Appendix III.

3.4Plant materials and features

ACI hybrid dhan1, BRRI dhan29 and BRRI hybrid dhan2were used as plant materials for the present study. These three varieties are recommended for boroseason. The features of these three varieties are presented below:

BRRI hybrid dhan 2: BRRI hybriddhan 2 variety is grown in boro season. This variety is recommended for cultivation in medium high and medium low land. The cultivar mature at 145-150 days of planting. It attains at a plant height of 120-125 cm.The cultivar gives an average yield of 12-14t ha^{-1} .

ACI hybrid dhan 1: ACI hybrid dhan 1 variety is grown in boro season. This variety is recommended for cultivation in medium high and medium low land. The cultivarmature at 140-145 days of planting. It attains at a plant height of 115-120 cm.The cultivar gives an average yield of 10-12t ha^{-1} .

BRRI dhan29: Average plant height of the BRRI dhan29 variety is 100 cm at the ripening stage. The grains are medium fine and white. It requires about 155-160 days for completing its life cycle with an average grain yield of 6.5 t ha^{-1} (BRRI, 2010).

3.5Experimental details

3.5.1Treatments

Factor A: Different source of N application

i. N_0 =Control (No Urea application)

ii. N_1=2.7 g size Urea Super Granule (USG) placement at 7-10 DAT

iii. N_2= Prilled Urea (PU) at three installments

iv. N_3=NPK Super Granule

Factor B: Variety

i. V_1 = BRRI hybrid dhan 2

ii. V2 = ACI hybrid dhan 1

iii. V3 = Hybrid Hira Rice

iv. V4 = BRRI dhan29

Combined effect of different forms of nitrogen and variety

1) N_0V_1 = BRRI hybrid dhan 2 × Control
2) N_0V_2 = ACI hybrid dhan 1 × Control
3) N_0V_3 = Hybrid Hira Rice × Control
4) N_0V_4 = BRRI dhan29 × Control
5) N_1V_1 = BRRI hybrid dhan 2× 2.7 g size Urea Super Granule
6) N_1V_2 = ACI hybrid dhan 1× 2.7 g size Urea Super Granule
7) N_1V_3 = Hybrid Hira Rice × 2.7 g size Urea Super Granule
8) N_1V_4 = BRRI dhan29 × 2.7 g size Urea Super Granule
9) N_2V_1= BRRI hybrid dhan 2 × Prilled Urea
10) N_2V_2 = ACI hybrid dhan 1× Prilled Urea
11) N_2V_3 = Hybrid Hira Rice × Prilled Urea

12) N_2V_4 = BRRI dhan29 × Prilled Urea

13) N_3V_1 = BRRI hybrid dhan 2 × NPK Super Granule

14) N_3V_2 = ACI hybrid dhan 1× NPK Super Granule

15) N_3V_3 = Hybrid Hira Rice × NPK Super Granule

16) N_3V_4 = BRRI dhan29 × NPK Super Granule

3.5.2 Experimental design

The experiment was laid out in split plot design with three replications. The layout of the experiment was prepared for distributing the combination of variety and different methods of urea application. There were 48 plots of size 2.5 m × 4 m ($10m^2$) in each of 3 replications. The treatments of the experiment were assigned at random into each replication following the experimental design where forms of N was in main plot and variety was in sub-plot.

3.6 Growing of crops

3.6.1 Raising seedlings

3.6.1.1 Seed collection

The seeds of the test crop i.e. BRRI hybrid dhan 2 and BRRI dhan29 were collected from Bangladesh Rice Research Institute (BRRI), Joydevpur, Gazipur.Hybrid Hira rice and ACI hybrid dhan 1were collected from Supreme seed company and ACI Agribusiness respectively.

3.6.1.2 Seed sprouting

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

3.6.1.3 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbeds were prepared with 1 m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed beds on November 27,2011, in order to transplant the seedlings in the main field.

3.6.2 Preparation of the main field

The plot selected for the experiment was opened in 15December 2011 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed, and finally obtained a desirable tilth of soil for transplanting of seedlings.

3.6.3 Fertilizers and manure application

The fertilizers P, K, S and Zn in the form of TSP, MoP, Gypsum and $ZnSO_4$, respectively were applied. The entire amount of TSP, MoP, Gypsum andZinc sulphate were applied during the final preparation of land. Urea was applied as per treatment i.e. for the treatment of N_1, USG was used at 7 days after transplanting (DAT) and there was no split application of urea and for the treatment of N_2, three top dressing of prilled urea was applied.TSP, MoP, Gypsum andZinc sulphate were applied at the rate of 165 kg ha^{-1}, 180 kg ha^{-1}, 90 kg ha^{-1} and 15 $kgha^{-1}$ respectively for the treatment of N_0 and N_2. But for the treatment of N_4only NPK super granule was applied; there was no other prilled urea, TSP and MoP were used.

3.6.4 Uprooting seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on January11, 2012 without causing much mechanical injury to the roots.

3.6.5 Transplanting of seedlings in the field

The seedlings were transplanted in the main field on January 12, 2012 and the rice seedlings were transplanted in lines maintainingspacing of 20cm×15cm for BRRI hybrid dhan 2, ACI hybrid dhan 1,andHybrid Hira Rice,and for BRRI dhan 29 spacing was 20cm×15cm as per BRRI recommendation.

3.6.6 Cultural operations

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

3.6.6.1 Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water up to 6 cm in the early stages to enhance tillering and 10-12 cm in the later stage to discourage late tillering. The field was finally dried out at 15 days before harvesting.

3.6.6.2 Gap filling

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

3.6.6.3 Weeding

Two hand weeding was done at 40 and 65 DAT to keep the field weed of free.

3.6.6.4 Plant protection

Furadan 57 EC was applied at the time of final land preparation and later on other insecticides were applied as and when necessary.

3.7 Harvesting, threshing and cleaning

The rice plant was harvested depending upon the maturity of plant and harvesting was done manually from each plot. BRRI hybrid dhan 1, ACI hybrid dhan 1 and Hybrid Hira Ricewere harvested onApril 20, 2012 and BRRI dhan 29 onMay 6, 2012. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of riceseed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of grain and straw plot^{-1} were recorded and converted to t ha^{-1}.

3.8 Data recording

The following data were collected during the study period:

3.8.1 Data on growth parameters

1. Plant height (cm)
2. Number of tillers $hill^{-1}$
3. Dry weight $hill^{-1}$ (g)
4. Leaf area index

3.8.2 Data on yield and yield contributing parameters

1. Number of panicle
2. Panicle length (cm)
3. Grains $panicle^{-1}$
4. Weight of 1000 seed (g)
5. Grain yield (t ha^{-1})
6. Straw yield (t ha^{-1})
7. Biological yield (t ha^{-1})
8. Harvest index (%)

3.8.3Procedure of recording data

3.8.3.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 25, 50, 75DAT (days after transplanting) and at harvest. Data were recorded as the average of same 5 plants pre selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

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

The number of tillers $hill^{-1}$ was recorded at 25, 50,75 DAT and at harvest by counting total tillers as the average of same 5 hills pre selected at random from the inner rows of each plot.

3.8.3.3 Dry weight hill^{-1}

Total dry matter hill^{-1} was recorded at the time of 25, 50, 75 DAT and at harvest by drying plant sample. Data were recorded as the average of 3 sample hill plot^{-1} selected at random from the outer rows of each plot leaving the boarder line and expressed in gram.

3.8.3.4Leaf area index

Leaf area index was estimated measuring the length and width of leaf and multiplying by a factor 0.75 as suggested by Yoshida (1981).

3.8.3.5 Length of panicle

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

3.8.3.6Number of grains panicle^{-1}

The total number of grains were collected randomly from panicles selected 5 plant of each plot and then average number of grains panicle^{-1} was calculated.

3.8.3.7 Weight of 1000 grains

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

3.8.3.8 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The central 6 lines from each plot were harvested, threshed, dried, weighed and finally converted to t ha^{-1} basis.

3.8.3.9 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of central 6 lines were harvested, threshed, dried and weighed and finally converted to t ha^{-1} basis.

3.8.4.1 Biological yield

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

Biological yield = Grain yield + Straw yield.

3.8.4.2 Harvest index

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

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

3.9 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means were estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and discussion

The experimental results regarding the 'Influence of different forms of Nitrogen on the performance of some inbred and hybrid varieties of rice' has been presented and discussed in this chapter. The effects of variety and forms of Napplication and their interaction on growth, yield and yield contributing characters have been presented below.

4.1 Growth parameters

4.1.1 Plant height

4.1.1.1 Effect of variety

Significant influence was remarked in terms of plant height under the present study as influenced by different varieties of inbred and hybrid rice at different growth stages (Table1). Results showed that BRRI Dhan29 (inbrid)(V_4) showed the highest plant height at 25 and 50 DAT (27.96 and 34.17cm, respectively) which was statistically similar with BRRI hybrid dhan 2 (V_1). But at 75 DAT and at harvest the tallest plant was achieved by BRRI Hybrid dhan 2 (V_1) (57.72 and 94.59 cm respectively). Comparison on plant height among the test varieties, the smallest plant was observed in Hybrid Hira dhan (V_3) at all growth stages (26.06, 32.94, 47.21 and 91.96 cm at 25, 50, 75 DAT and at harvest respectively) which was significantly similar with ACI hybrid dhan (V_2)at 25 and 50 DAT.The results obtained from other findings by Bisne *et al.* (2006), BINA (1993) and Hossain and Alam (1991) were similar and they stated that plant height significantly differed among different varieties.

4.1.1.2 Effect of different forms of nitrogen

Plant height influenced significantly by different forms of N application on different varieties of transplanted boro rice at different growth stages (Table 1). Results showed that at 25, 50, 75 DAT and at harvest, the tallest plant (28.76, 35.85, 54.88 and 95.29 cm, respectively) was recorded by N_1(Urea Super Granule; USG) which was significantly different from all other treatments. The results obtained from N_{0p}(Control) showed the shortest plant at all growth stages (25.23, 30.32, 52.68and 90.39 cm at 25, 50, 75 DAT and at harvest respectively) and at 75 DAT, significantly similar result was observed from N_2 (Prilled urea) compared to control treatment.The result under the present study was consistence with the findings Rahman (2003), Alam (2002) and Vijaya and Subbaiah (1997).

4.1.1.3 Interaction effect of different forms of nitrogen and variety

Interaction effect of variety and different forms of N application exerted significant influence on plant height at different growth stages of transplanted boro rice (Table 1). Result indicated that the tallest plant (37.00, 59.00 and 95.86 cm at 50, 75 DAT and at harvest respectively) was with N_3 V_4which was significantly similar with N_1V_2 at 75 DAT and at harvest and with N_1V_2 at the time of harvest. But at 25 DAT, the highest plant height (29.62 cm) was found with N_1V_1 which was significantly similar with N_2V_1, N_1V_2 and N_3V_4.On the other hand, N_3V_3showed the lowest plant height which was statistically different from all other treatment. But at 50, 75 DAT and at harvest, the shortest plant was achieved by N_0V_3 (29.35, 44.34 and 87.12 cm respectively) which was also significantly different from all other treatments.

Table 1:Effect on Plant height as influenced by different inbred and hybrid varieties of rice and different forms of N

Treatments	Plant height at different days after transplanting (DAT)			
	25	50	75	At harvest
Effect of different forms of nitrogen				
N_0	25.23 d	30.32 c	52.68 c	90.39 c
N_1	28.76 a	35.85 a	54.88 a	95.29 a
N_2	27.89 b	34.75 b	52.89 c	92.62 b
N_3	26.63 c	34.19 b	53.93 b	93.21 b
Sx□[1]	0.0404	0.0089	0.0082	0.0046
Effect of variety				
V_1	27.82 a	34.13 a	57.72 a	94.59 a
V_2	26.67 b	33.86 b	53.39 c	92.46 b
V_3	26.06 b	32.94 b	47.21 d	91.96 c
V_4	27.96 a	34.17 a	56.06 b	92.50 b
Sx□	0.0404	0.0089	0.0082	0.0046
Interaction effect of different forms of nitrogen and variety				
$N_0 V_1$	24.88 e	31.17 g	51.84 g	91.29 f
$N_0 V_2$	24.97 e	29.77 h	55.50 de	90.97 f
$N_0 V_3$	24.72 e	29.35 h	44.34 l	87.12 i
$N_0 V_4$	26.37 d	30.98 g	54.34 f	92.19 e
$N_1 V_1$	29.62 a	35.42 b	51.00 h	89.67 g
$N_1 V_2$	29.06 ab	35.50 b	58.69 ab	95.67 ab
$N_1 V_3$	28.88 b	35.60 b	49.80 i	91.26 f
$N_1 V_4$	27.47 c	35.39 bc	56.20 d	95.49 ab
$N_2 V_1$	29.30 ab	35.50 b	55.03 ef	94.40 d
$N_2 V_2$	26.21 d	34.83 d	58.02 bc	94.73 cd
$N_2 V_3$	27.10 c	33.83 e	49.03 j	95.23 bc
$N_2 V_4$	28.96 b	34.83 cd	55.70 de	94.82 cd
$N_3 V_1$	27.45 c	34.41 d	55.68 de	94.64 cd
$N_3 V_2$	26.45 d	33.83 e	57.70 c	88.46 h
$N_3 V_3$	23.55 f	33.00 f	45.68 k	94.23 d
$N_3 V_4$	29.06 ab	37.00 a	59.00 a	95.86 a
Sx□[1□]	0.0809	0.0178	0.0164	0.0091
CV(%)	7.282	8.599	10.748	9.674

N_0 = Control (No Urea application) V_1 = BRRI hybrid dhan 2

N_1 = 2.7 g size Urea Super Granule (USG)
N_2 = Prilled Urea (PU) at three installments
N_3 = NPK Super Granule

V_2 = ACI hybrid dhan 1
V_3 = Hybrid Hira Rice
V_4 = BRRI dhan29

4.1.2 Number of tillers/hill^{-1}

4.1.2.1 Effect of variety

Number of tillers hill^{-1} was significantly influenced by different varieties used in the present study (Table 2). Results showed that BRRI Hybrid Dhan 2 (V_1) showed the highest number of tillers hill^{-1}at 25 DAT (2.01). But at 50, 75 DAT and at harvest BRRI Dhan29 (inbrid) (V_4) showed the highest number of tillers hill^{-1} (5.96, 16.38 and 16.22, respectively).BRRI hybrid dhan2 (V_1) at 50 DAT and at harvestalso showed statistically similar results compared to BRRI Dhan29 (V_4). Comparing tiller producing capacity of tillers hill^{-1} among the four varieties, hybrid hira rice (V_3) showed the lowest number of tillers hill^{-1} (1.63, 4.92, 14.47 and 14.38 at 25, 50, 75 DAT and at harvest, respectively). ACI hybrid rice at 50 DAT and 75 DAT also showed significantly same results compared to hybrid hira rice (V_3), but at the time of harvest, this variety showed intermediate result compared to all other test varieties.The findings of Bisne *et al.* (2006), Devaraju *et al.* (1998), BRRI (1994), BINA (1993), Chowdhury *et al.* (1993) and Hossain and Alam (1991) was similar with the present finding.

4.1.2.2 Effect of different forms of N

Significantly different result was observed in case of number of tillers hill^{-1} as influenced by different forms of Napplication on transplanted boro rice at different growth stages (Table 2). Results indicated that at all growth stages the highest, number of tillers hill^{-1} (2.21, 6.95, 19.80 and 19.37 at 25, 50, 75 DAT and at harvest respectively) were recorded by N_3 (NPK Super Granule) which was similar identical with N_2 (Prilled urea)at 25 DAT. The results obtained from N_0 (Control) treatment showed the lowest number of tillers hill^{-1} (1.27, 3.47, 10.03 and 10.89 at 25, 50, 75 DAT and at harvest, respectively) which was significantly different from all other nitrogenous treatments of the experiment. The result under the present study was similar with the findings of Rahman (2003) and Alam (2002).

4.1.1.3 Interaction effect of different forms of nitrogen and variety

Interaction effect of variety and different forms of N application had significant influence on number of tillers $hill^{-1}$ at different growth stages of the four test varieties of transplanted boro rice (Table 2). Results indicated that the highest number of tillers $hill^{-1}$ (2.84, 8.13, 21.33 and 21.18 at 25, 50, 75 DAT and at harvest respectively) were with N_3V_4which was statistically similar with N_2V_2at 25DAT and N_3V_1 at the time of harvest and closely followed by N_3V_1 at 75 DAT.The results recorded from N_0V_3 showed the lowest number of tillers $hill^{-1}$ (1.00, 3.19, 10.00 and 11.47 at 25, 50 DAT and at harvest respectively) which was statistically identical with N_0 V_4at 25 DAT and N_0V_1, N_0 $V_2$and N_0V_4 at the time of harvest. But at 75 DAT the lowest number of tillers $hill^{-1}$ (8.02) was observed from N_0V_1 which was statistically different from all other treatment combinations. N_0V_1 and N_1V_3 at 25 DAT and N_0V_4 at DAT also showed lower number of tillers $hill^{-1}$ which was significantly similar with N_0V_3. The results obtained from all other treatments showed significantly different results compared to highest and lowest result of number of tillers $hill^{-1}$.

Table 2: Effect on Number of tillers hill^{-1} as influenced by different inbred and hybrid varieties of rice and different forms of N

Treatments	Number of tillershill^{-1} at different days after transplanting (DAT)			
	25	50	75	At harvest
Effect of different forms of nitrogen				
N_0	1.27 c	3.47 d	10.03 d	10.89 d
N_1	1.77 b	6.44 b	17.38 b	17.86 b
N_2	2.27 a	4.88 c	13.96 c	13.76 c
N_3	2.21 a	6.95 a	19.80 a	19.37 a
Sx□[1]	0.0131	0.0121	0.0104	0.2459
Effect of variety				
V_1	2.01 a	5.80 a	15.67 b	15.96 a
V_2	1.94 b	5.06 b	14.65 c	15.33 b
V_3	1.63 c	4.92 b	14.47 c	14.38 c
V_4	1.93 b	5.96 a	16.38 a	16.22 a
Sx□	0.0131	0.0121	0.0104	0.2459
Interaction effect of different forms of nitrogen and variety				
$N_0 V_1$	1.26 hi	3.68 e-g	8.02 j	11.71 e
$N_0 V_2$	1.83 ef	3.77 e-g	10.93 hi	12.20 e
$N_0 V_3$	1.00 i	3.19 g	10.00 i	11.47 e
$N_0 V_4$	1.02 i	3.27 fg	11.18 hi	12.16 e
$N_1 V_1$	2.00 de	6.67 bc	18.50 cd	15.97 cd
$N_1 V_2$	1.67 fg	6.25 b-d	16.83 de	15.72 cd
$N_1 V_3$	1.25 hi	5.92 cd	15.19 ef	15.77 cd
$N_1 V_4$	2.16 cd	6.93 b	19.00 bc	16.00 cd
$N_2 V_1$	2.32 bc	5.92 cd	15.50 ef	15.10 cd
$N_2 V_2$	2.83 a	4.08 e	12.17 gh	14.33 cd
$N_2 V_3$	2.17 cd	4.00 ef	14.18 f	14.10 d
$N_2 V_4$	1.75 ef	5.52 d	14.00 fg	15.53 cd
$N_3 V_1$	2.50 b	6.93 b	20.67 ab	21.07 a
$N_3 V_2$	1.42 gh	6.17 b-d	18.67 cd	19.06 b
$N_3 V_3$	2.11 cd	6.58 bc	18.52 cd	16.17 c
$N_3 V_4$	2.84 a	8.13 a	21.33 a	21.18 a
Sx□[1□]	0.0061	0.0052	0.1230	0.0051
CV(%)	5.32	8.35	9.24	11.36

N_0 = Control (No Urea application) V_1 = BRRI hybrid dhan 2

N_1 = 2.7 g size Urea Super Granule (USG)
N_2 = Prilled Urea (PU) at three installments
N_3 = NPK Super Granule

V_2 = ACI hybrid dhan 1
V_3 = Hybrid Hira Rice
V_4 = BRRI dhan29

4.1.3 Dry weight/hill^{-1}.

4.1.3.1 Effect of variety

Significant variation was observed by different varieties (four varieties) used in the present study in terms of dry weight hill^{-1} (Table 3). Results showed that inbreed variety BRRI Dhan29 (inbrid) (V_4)showed the highest dry weight hill^{-1} (9.77, 43.87, 56.46 and 84.70 g at 25, 50, 75 DAT and at harvest respectively). BRRI hybrid dhan2 (V_1) also showed statistically similar result compared to the inbreedvariety of BRRI Dhan29 (V_4) at 25 DAT. Among the four varieties, hybrid hira rice (V_3) showed the lowest number dry weight hill^{-1} (8.95, 40.47, 53.56 and 80.36 g at 25, 50, 75 DAT and at harvest respectively). ACI Hybrid dhan 1 (V_2) gave statistically similar result at the time of harvest compared to the lowest dry weight hill^{-1}. Similar result was found by Amin *et al.* (2006), Son *et al.* (1998) and Patnaik*et al*. (1990).

4.1.3.2 Effect of different forms of nitrogen

Significantly different result was observed in terms of dry weight hill^{-1} as influenced by different forms of N application among the four test varieties of transplanted boro rice at different growth stages (Table 3). Results showed that at all growth stages, the highest dry weight hill^{-1}(10.79, 47.95, 62.22 and 91.54 g at 25, 50, 75 DAT and at harvest respectively) was recorded by N_3 (NPK Super Granule) which was statistically similar with N_1 (Urea Super Granule; USG) at 25 DAT. The results obtained from N_0 (Control)showed the lowest dry weight hill^{-1} (7.39, 35.47, 45.79 and 70.40 g at 25, 50, 75 DAT and at harvest respectively). The results obtained from all other treatments showed significantly different results compared to highest and lowest result of dry weight hill^{-1}. The result under the present study was similar with the findings of Vijaya and Subbaiah (1997).

4.1.1.3 Interaction effect of different forms of N and variety

Interaction effect of variety and different forms of N application exerted significant influence on dry weight hill^{-1} at different growth stages of boro rice (Table 3). Results indicated that the highest dry weight hill^{-1} (11.18, 50.37, 64.31 and 94.37 g at 25, 50, 75 DAT and at harvest respectively) was with N_3V_4which was statistically similar with N_3V_1 at 50 DAT and also closely followed by at 25 and75 DAT. The treatment combination of N_3V_2 also showed comparatively higher result at 25 DAT which was closely followed by N_3V_4.The result ondry weight hill^{-1} from N_3V_1, N_3V_2, N_3V_3 and N_1V_4also showedcomparatively higher dry weight hill^{-1}at harvest but significantly different from N_3V_4. The results recorded from N_0V_3 showed the lowest dry weight hill^{-1} (6.99, 34.18, 43.38 and 68.54 g at 25, 50, 75 DAT and at harvest respectively) which was closely followed by N_0V_2at 25, 50 DAT and at harvest. The treatment combinations of N_0V_1, N_2V_2, N_2V_3 and N_0V_4 also showed very poor results compared to N_3V_4at all growth stages of different rice varieties but significantly different from highest and lowest dry weight hill^{-1}.The results obtained from all other treatments at different growth stages also showed significantly different results compared to highest and lowest dry weight hill^{-1}.

Table 3: Effect on Dry weight $hill^{-1}$ as influenced by different inbred and hybrid varieties of rice and different forms of N

Treatments	Dry weight at different days after transplanting (DAT)			
	25	50	75	At harvest
***Effect of different* forms of N**				
N_0	7.385 c	35.47 d	45.79 d	70.40 d
N_1	10.29 a	45.16 b	58.45 b	86.02 b
N_2	8.958 b	40.09 c	53.68 c	80.79 c
N_3	10.79 a	47.95 a	62.22 a	91.54 a
Sx□[1]	0.0080	0.0041	0.3129	0.0051
Effect of variety				
V_1	9.507 a	42.95 b	55.86 b	82.50 b
V_2	9.198 b	41.38 c	54.26 c	81.19 c
V_3	8.952 b	40.47 d	53.56 d	80.36 c
V_4	9.773 a	43.87 a	56.46 a	84.70 a
Sx□	0.0080	0.0041	0.3129	0.0051
Interaction effect of different* forms of N *and variety				
$N_0 V_1$	7.547 hi	36.21 g	48.38 h	71.33 j
$N_0 V_2$	7.193 ij	35.16 gh	45.23 i	70.23 jk
$N_0 V_3$	6.993 j	34.18 h	43.38 j	68.54 k
$N_0 V_4$	7.807 h	36.33 g	46.16 i	71.50 j
$N_1 V_1$	10.37 cd	45.56 bc	58.38 de	85.12 e
$N_1 V_2$	9.993 d	44.39 c	58.01 e	84.88 e
$N_1 V_3$	10.18 d	43.81 c	57.24 e	84.07 ef
$N_1 V_4$	10.63 bc	46.87 b	60.17 cd	90.02 cd
$N_2 V_1$	9.107 f	40.58 de	53.82 fg	81.32 gh
$N_2 V_2$	8.793 fg	38.76 f	52.66 g	78.52 i
$N_2 V_3$	8.463 g	39.12 ef	53.06 g	80.40 h
$N_2 V_4$	9.470 e	41.89 d	55.19 f	82.89 fg
$N_3 V_1$	11.01 ab	49.46 a	62.87 ab	92.21 b
$N_3 V_2$	10.81 ab	47.20 b	61.12 bc	91.14 bc
$N_3 V_3$	10.17 d	44.78 c	60.58 c	88.44 d
$N_3 V_4$	11.18 a	50.37 a	64.31 a	94.37 a
Sx□[1]	0.0161	0.0082	0.6258	0.0101
CV(%)	6.389	9.466	10.286	9.122

N_0 = Control (No Urea application) V_1 = BRRI hybrid dhan 2

N_1 = 2.7 g size Urea Super Granule (USG)
N_2 = Prilled Urea (PU) at three installments
N_3 = NPK Super Granule

V_2 = ACI hybrid dhan 1
V_3 = Hybrid Hira Rice
V_4 = BRRI dhan29

4.1.4 Leaf area index

4.1.4.1 Effect of variety

Leaf area index was significantly influenced by varieties used in the present study (Table 4). Results showed that BRRI Dhan29 (V_4)showed the highest leaf area index (2.52, 6.80 and 7.62 cm^2 at 25, 75 DAT and at harvest respectively) which was statistically similar with BRRI hybrid dhan 2 (V_1) at 25 DAT. But at 50 DAT, the highest leaf area (6.94 cm^2) was observed byhybrid hira rice (V_3). Among the fourtest varieties, ACI hybrid rice (V_2) showed the lowest leaf area index(2.25 and 6.48 cm^2 at 25 and 50 DAT respectively). But at 75 DAT and at harvest, the lowest leaf area (7.43 and 7.06 cm^2 respectively) was obtained from hybrid hira rice (V_3) which was statistically similar with ACI hybrid rice (V_2) at 75 DAT.These results might be due to cause of proper nutrient supply from soil to the plants, light intensity and light holding capacity of a variety and above all phenotypic characters of the varieties.

4.1.1.2 Effect of different forms of nitrogen

Different forms of N application affected significantly on leaf area index of transplanted boro rice at different growth stages (Table 4). Results showed that at 25 DAT, N_2 (Prilled urea) gave the highest leaf area index(2.84 cm^2) but at 50, 75 DAT and at harvest with N_3 (NPK Super Granule) showed the highest leaf area (8.14, 9.28 and 8.96 cm^2 respectively). At all growth stages, N_0 (Control) treatment gave the lowest result at 25, 50, 75 DAT and at harvest (1.78, 5.80, 5.98 and 5.57 cm^2 respectively) which was closely followed by N_2 (Prilled urea) at 50 DAT. The results under the present study might be due to cause of nutritional balance fertilizer use in the crop field.

4.1.1.3 Interaction effect of different forms of N and variety

Interaction of variety and different forms of N application exerted had significant influence on leaf area index at different growth stages of boro rice (Table 4). Results indicated that the highest leaf area index (8.49, 9.84 and 9.55 cm^2 at 50, 75 DAT and at harvest respectively) was with N_3V_4which was closely followed by N_3V_1at 50, 75 DAT and at harvest. But at 25 DAT, N_2V_4 showed the highest leaf area which was closely followed by N_2V_1. These treatment combinations (N_1V_1, N_3V_2, $N_3V_3$and N_1V_4) showed intermediate level of leaf area index value at different growth stages compared to all treatment combinations. The results recorded from N_0 V_3showed the lowest leaf area index (1.70, 4.86, 5.83 and 5.45 cm^2 at 25, 50, 75 DAT and at harvest respectively) which was statistically similar with N_0V_1, N_0V_2, N_0V_3 and N_0V_4at all growth stages. The treatment combination of N_2V_1, N_2V_2, $N_2V_3$and N_2V_4also gave lower leaf area indexbut significantly higher than that of N_0V_3. The results obtained from all other treatment combinations at different growth stages showed significantly different results compared to highest and lowest area index.

Table 4: Effect on Leaf area $hill^{-1}$ as influenced by different inbred and hybrid varieties of rice and different forms of N

Treatments	Leaf area $hill^{-1}$ at different days after transplanting (DAT)			
	25	50	75	At harvest
***Effect of different* forms of N**				
N_0	1.78 d	5.80 c	5.98 d	5.57 d
N_1	2.36 c	7.17 b	8.27 b	8.00 b
N_2	2.84 a	5.84 c	7.15 c	6.82 c
N_3	2.56 b	8.14 a	9.28 a	8.96 a
Sx□[1]	0.0182	0.0625	0.1240	0.0066
Effect of variety				
V_1	2.51 a	6.74 b	7.77 b	7.46 b
V_2	2.25 b	6.48 c	7.52 c	7.21 c
V_3	2.26 b	6.94 a	7.43 c	7.06 d
V_4	2.52 a	6.80 b	7.96 a	7.62 a
Sx□	0.0182	0.0625	0.1240	0.0066
Interaction effect of different forms* of N *and variety				
$N_0 V_1$	1.77 f	5.20 f	6.00 h	5.64 g
$N_0 V_2$	1.93 f	5.02 f	5.95 h	5.50 g
$N_0 V_3$	1.70 f	4.86 f	5.83 h	5.45 g
$N_0 V_4$	1.70 f	5.05 f	6.15 h	5.70 g
$N_1 V_1$	2.55 cd	7.29 d	8.38 c-e	8.14 cd
$N_1 V_2$	1.97 ef	7.04 d	8.19 de	7.93 cd
$N_1 V_3$	2.33 de	6.92 d	7.97 ef	7.68 de
$N_1 V_4$	2.59 cd	7.42 cd	8.54 c-e	8.23 cd
$N_2 V_1$	3.02 ab	6.29 e	7.36 fg	7.03 ef
$N_2 V_2$	2.85 a-c	5.99 e	7.05 g	6.79 f
$N_2 V_3$	2.37 d	7.93 bc	6.88 g	6.47 f
$N_2 V_4$	3.14 a	6.22 e	7.30 fg	7.00 ef
$N_3 V_1$	2.70 b-d	8.15 ab	9.35 ab	9.04 ab
$N_3 V_2$	2.50 cd	7.88 bc	8.89 b-d	8.60 bc
$N_3 V_3$	2.41 d	8.04 ab	9.03 bc	8.63 bc
$N_3 V_4$	2.65 b-d	8.49 a	9.84 a	9.55 a
Sx□[1□]	0.0364	0.1250	0.2480	0.0131
CV(%)	7.548	8.566	11.247	10.184

N_0 = Control (No Urea application) V_1 = BRRI hybrid dhan 2

N_1	=	2.7 g size Urea Super Granule (USG)	V_2	=	ACI hybrid dhan 1
N_2	=	Prilled Urea (PU) at three installments	V_3	=	Hybrid Hira Rice
N_3	=	NPK Super Granule	V_4	=	BRRI dhan29

4.2 Yield contributing parameters

4.2.1 Number of effective tillers hill^{-1}

4.2.1.1 Effect of variety

Number of effective tillers hill^{-1} at harvest was significantly influenced by different varieties used in the present study (Table 5). Results showed that BRRI Dhan29 (V_4)showed the highest number of effective tillers hill^{-1} at harvest (14.64) which was statistically similar with BRRI hybrid dhan 2 (V_1) and closely followed by ACI hybrid rice (V_2). The other variety, hybrid hira rice (V_3) used for the present study showed the lowest number of effective tillers hill^{-1} at harvest. The result under the present study was similar with the findings ofBisne*et al.* (2006) and Bhowmick and Nayak (2000).

4.2.1.2 Effect of different forms of nitrogen

Number of effective tillers hill^{-1}was significantly influenced by different forms of urea application to the four test varieties used in the present study (Table 5). Result showed that N_3 (NPK Super Granule)showed the highest number of effective tillers hill^{-1} at harvest (18.25) which was significantly different from all other nitrogenous treatments. On the other hand, N_0 (Control) treatment showed the lowest number of effective tillers hill^{-1} at harvest (9.05) where N_1 (Urea Super Granule; USG) and N_2 (Prilled urea) treatments showed intermediate results regarding number of effective tillers hill^{-1} at harvest.

4.2.1.3 Interaction of different forms of nitrogen and variety

Different forms of Napplication to different variety had significant influence regarding number of effective tillers hill^{-1} at harvest (Table 5). Result indicated that the highest number of effective tillers hill^{-1} at harvest (20.32) was with N_3V_4which was statistically similar with N_3V_1. The results obtained from the treatment combination of N_3V_2 also gave comparatively higher number of effective tillers hill^{-1} at harvest but significantly different from N_3V_4.The results recorded from N_0V_1 showed the lowest number of effective tillers hill^{-1} at harvest (8.55) which was closely followed by N_0V_3. The results obtained from the treatment combination of N_0V_2, N_2V_3 and N_0V_4 also showed comparatively lower number of effective tillers hill^{-1} at harvest but significantly different from N_0V_1.The results obtained from all other treatments combinations in terms of number of effective tillers hill^{-1} at harvest showed medium level result compared to highest and lowest results.

4.2.2 Number of non-effective tillers hill^{-1} at harvest

4.2.2.1 Effect of variety

Number of non-effective tillers hill^{-1} at harvest was significantly influenced by different varieties used in the present study (Table 5). Results showed that BRRI hybrid dhan 2 (V_1)showed the highest number of non-effective tillers hill^{-1} at harvest (2.76) which was statistically similar with ACI hybrid rice (V_2). The BRRI Dhan29 (inbrid) (V_4)variety showed the lowest number of non-effective tillers hill^{-1} at harvest (2.58) which was statistically similar with hybrid hira rice (V_3).

4.2.2.2 Effect of different forms of N

Number of non-effective tillers hill^{-1} at harvest was significantly influenced by different forms of N application to the four test varieties used in the present study (Table 5). Results showed that N_3 (NPK Super Granule)showed the lowest number of non-effective tillers hill^{-1} at harvest (2.12) which was significantly different from all other fertilizer application treatments. On the other hand, N_0 (Control) treatment showed the highest number of non-effective tillers hill^{-1} at harvest (3.84).The nitrogenous treatment ofN_1

(Urea Super Granule; USG)) and N_2 (Prilled urea) showed intermediate results regarding number of non-effective tillers $hill^{-1}$ at harvest.

4.2.2.3 Interaction effect of different forms of N and variety

Different forms of N application to different variety had significant influence regarding number of non-effective tillers $hill^{-1}$ (Table 5). Results indicated that the lowest number of non-effective tillers $hill^{-1}$ at harvest (1.87) was with N_3V_4which was significantly different from all other treatments.The treatment combination of N_3V_3 also gave comparatively lower number of non-effective tillers $hill^{-1}$ at harvest but significantly different from N_3V_4. The results recorded from N_0 V_1 showed the highest number of non-effective tillers $hill^{-1}$ at harvest (4.16) which was statistically similar with N_0V_2. The results obtained from the treatment combination of $N_0V_3$and N_0V_4 also showed comparatively highernumber of non-effective tillers $hill^{-1}$ at harvest but significantly different from N_0V_1. Other treatments combinations in terms of number of non-effective tillers $hill^{-1}$ at harvest showed intermediate results compared to highest and lowest results.

4.2.3 Number of panicle at harvest/$hill^{-1}$

4.2.3.1 Effect of variety

Number of panicle $hill^{-1}$ was significantly influenced by different varieties used in the present study (Table 5). Results showed that BRRI Dhan29 (V_4)showed the highest number of panicle $hill^{-1}$ (15.40). But ACI hybrid rice (V_2) showed the lowest number of panicle at harvest (13.38) which was statistically similar with hybrid hira rice (V_3).The other variety, BRRI hybrid dhan 2 (V_1) showed the lowest number of panicle at harvest. The result under the present study was similar with the findings ofMyung (2005) and Bhowmick and Nayak (2000).

4.2.3.2 Effect of different forms of nitrogen

Number of panicles at harvest was significantly influenced by differentforms of Napplication to the four test varieties used in the present study (Table 5).Results showed that N_3 (NPK Super Granule)showed the highest number of panicles(18.65) which was significantly different from all other nitrogenous treatments. On the other hand, N_0 (Control) treatment showed the lowest number of panicle (9.56) where N_1 (Urea Super Granule; USG) and N_2 (Prilled urea) treatments showed intermediate results.

4.2.3.3 Interaction effect of different forms of N and variety

Variety and different forms of N application to different variety had significant influence regarding number of panicle hill^{-1}(Table 5). Results indicated that the highest number of panicles hill^{-1}(20.41) was with V_4N_3which was statistically similar with N_3V_1. The results obtained from the treatment combination of N_1V_1, N_3V_2, N_3V_3 and N_1V_4also gave comparatively higher number of panicle at harvest but significantly different from N_3V_4. Combination N_0V_1 showed the lowest number of panicle hill^{-1}(8.21) which was closely followed by N_0V_3. The treatment combination of N_0V_2, $N_0V_4$and N_2V_2also showed comparatively lower number of panicle at harvest but significantly different from N_0V_1. Other treatments combinations in terms of number of effective tillers hill^{-1} at harvest showed medium level of panicle hill^{-1} compared to highest and lowest results.

4.2.4 Number of grains panicle^{-1}

4.2.4.1 Effect of variety

Number of grains panicle^{-1} was significantly influenced by different varieties (Table 5). Results showed that BRRI Dhan29 (inbrid) (V_4)showed the highest number of grains panicle^{-1} (161.30) which was statistically similar with ACI hybrid rice (V_2) where hybrid hira rice (V_3) showed the lowest number of grains panicle^{-1} (156.70) which was statistically identical with BRRI hybrid dhan 2 (V_1).Supporting results were achieved by Bhowmick and Nayak (2000), Chowdhury*et al.* (1993) and Hossain and Alam (1991).

4.2.4.2 Effect of different forms of N application

Different forms of N application had significant effect on number of grains panicle^{-1} of transplanted boro rice (Table 5). Result showed that the highest number of grains panicle^{-1}was recorded by N_3 (NPK Super Granule) (174.60) where the lowest (140.30) was obtained from N_0 (Control).The result obtained from N_1 (Urea Super Granule; USG) and N_2 (Prilled urea) showed medium result compared to highest and lowest number of grains panicle^{-1}. The result under the present study was similar with the findings of Rahman (2003).

4.2.4.3 Interaction effect of variety and different forms of N application

Interaction effect of variety and different forms of Napplication had significant influence on number of grains panicle^{-1} of transplanted boro rice (Table 5). Result indicated that the highest number of grains panicle^{-1} (181.20) was with N_3V_4which was significantly different from all other treatment combinations. The combinnation N_3V_1, $N_3V_2$and N_3V_3 alsogave comparatively higher number of grains panicle^{-1} but significantly different from

N_3V_4. On the other hand the lowest result was recorded from N_0V_1 (130.50) which were also significantly different from all other treatment combinations. Again, N_0V_1, N_0V_2, and N_0 V_4also gave lower number of grains panicle^{-1} but comparatively higher than N_0V_1. The results obtained from all other treatments combinations was significantly different compared to highest and lowest number of grains panicle^{-1}.

4.2.5 Weight of 1000 seeds

4.2.5.1 Effect of variety

Weight of 1000 seed varied significantly among the varieties (Table 5). Hybrid hira rice (V_3)showed the highest 1000 seed weight (25.65 g) which was statistically sssimilar with BRRI hybrid dhan 2 (V_1) and ACI hybrid rice (V_2) where BRRI Dhan29 (inbrid) (V_4) showed the lowest 1000 seed weight (24.48 g) which was statistically similar with ACI hybreed rice. Bhowmick and Nayak (2000), Mishra and Pandey (1998) and Chowdhury*et al.* (1993) found similar results in respect of 1000 seed weight at different varieties of rice.

4.2.5.2 Effect of different forms of N application

Forms of N application treatment showed significant variation on 1000 seed weight of boro rice (Table 5) .NPK super granule applied treatment showed the highest weight of 1000 seed (27.85g).On the other hand, control treatment (no. N) give lowest 1000 seed weight (21.22g) that was 23.81% lower than N applied from NPK super granule. Other two N applied treatment showed the intermediate level of 1000 seed weight.

4.2.3.3 Interaction effect of different forms of nitrogen and variety

Interaction variety and from of N application showed significant variation in producing 1000 seed weight (Table 5). The highest 1000 seed weight was measured with N_3V_1 combination which was statistically highest than other combination. Second highest 1000 seed weight (27.699) with N_3V_2 interaction which was measured with N_0V_1 interaction which was closely followed by combination (20.33g).

Table 5: Effect of forms of Nitrogen and Variety and their interaction on yield contributing characters of boro rice

Treatments	Effective tillershill^{-1} at harvest (no.)	Non-effective tillers hill^{-1} (no.)	Number of panicle hill^{-1} (no.)	Panicle length (cm)	Grains Panicle^{-1} (no.)	Weight of 1000 seed (g)
Effect of different forms of N						
N_0	9.049 d	3.84 a	9.564 d	15.11 c	140.3 d	21.22 d
N_1	14.62 b	2.25 c	15.57 b	20.90 a	167.9 b	26.22 b
N_2	13.34 c	2.43 b	13.25 c	17.46 b	153.8 c	25.27 c
N_3	18.25 a	2.12 d	18.65 a	21.20 a	174.6 a	27.85 a
Sx□^{1}	0.126	0.0182	0.0417	0.0008	0.8637	0.2119
Effect of variety						
V_1	14.21 a	2.75 a	14.85 b	19.24 a	157.6 b	25.57 a
V_2	13.62 ab	2.71 a	13.38 c	17.82 b	161.0 a	24.86 ab
V_3	12.79 b	2.59 b	13.40 c	18.15 b	156.7 b	25.65 a
V_4	14.64 a	2.58 b	15.40 a	19.45 a	161.3 a	24.48 b
Sx□	0.126	0.0182	0.0417	0.0008	0.8637	0.2119
Interaction effect of different forms of N and variety						
$N_0 V_1$	8.54 h	4.16 a	8.213 g	15.98 h	135.8 h	19.51 k
$N_0 V_2$	9.21fg	3.99 a	10.22 ef	14.42 j	145.3 g	20.71 i
$N_0 V_3$	8.817 gh	3.66 b	9.543 fg	14.84 ij	130.5 i	24.32 h
$N_0 V_4$	9.617 f	3.55 b	10.28 ef	15.17 i	149.4 fg	20.33 j
$N_1 V_1$	14.72 c	2.26 de	17.28 b	20.93 c-e	167.2 c	26.84 c
$N_1 V_2$	14.42 c	2.31 de	14.28 c	19.92 f	170.5 bc	26.47 d
$N_1 V_3$	14.52 c	2.26 de	13.48 cd	21.12 b-d	166.6 c	26.08 e
$N_1 V_4$	14.82 c	2.19 de	17.21 b	21.62 b	167.4 c	25.50 fg
$N_2 V_1$	13.72 d	2.39 d	14.01 c	18.55 g	156.6 de	25.48 fg
$N_2 V_2$	13.02 e	2.32 de	11.81 de	16.18 h	152.8 ef	24.57 h
$N_2 V_3$	12.82 e	2.29 de	13.48 cd	16.27 h	158.6 d	25.76 ef
$N_2 V_4$	13.82 d	2.72 c	13.68 c	18.82 g	147.3 g	25.29 g
$N_3 V_1$	19.87 a	2.21 de	19.88 a	21.50 bc	170.8 bc	30.46 a
$N_3 V_2$	17.82 b	2.25 de	17.21 b	20.74 de	175.4 b	27.69 b
$N_3 V_3$	15.02 c	2.16 e	17.08 b	20.36 ef	170.9 bc	26.44 d
$N_3 V_4$	20.32 a	1.87 f	20.41 a	22.19 a	181.2 a	26.81 c
Sx□$^{1□}$	0.252	0.036	0.083	0.0017	1.72	0.42
CV(%)	9.244	11.38	8.07	9.34	8.24	7.11

N_0 = Control (No Urea application)
N_1 = 2.7 g size Urea Super Granule (USG)
V_1 = BRRI hybrid dhan 2
V_2 = ACI hybrid dhan 1

N_2 = Prilled Urea (PU) at three installments
N_3 = NPK Super Granule

V_3 = Hybrid Hira Rice
V_4 = BRRI dhan29

4.3 Yield parameters

4.3.1 Grain yield

4.3.1.1 Effect of variety

Grain yield was significantly influenced by different varieties (four varieties) used in the present study (Table 6). Results showed that BRRI Dhan29 (inbrid) (V_4)showed the highest grain yield (6.74 t ha^{-1}) which was statistically similar with BRRI hybrid dhan 2 (V_1) and ACI hybrid rice (V_2) where hybrid hira rice (V_3) showed the lowest grain yield (6.22 t ha^{-1}). The present finding was conformity with Bisne*et al.* (2006), Patel (2000), Devaraju*et al.* (1998), Dwivedi (1997) and Chowdhury*et al.* (1993).

4.3.1.2 Effect of different forms of N

Different forms of urea application had significant effect on grain yield among the four varieties of transplanted boro rice (Table 6). Result showed that the highest grain yield was recorded by N_3 (NPK Super Granule) (7.87 t ha^{-1}) which was closely followed by N_1 (Urea Super Granule; USG) where the lowest (4.18 t ha^{-1}) was obtained from N_0 (Control).The results obtained from N_2 (Prilled urea) showed medium result compared to highest and lowest grain yield. The result under the present study was similar with the findings Rahman (2003), Alam (2002), Savant and Stangel (1998), Patel (1997) and Choudhury*et al.* (1994).

4.3.1.3 Interaction effect of different forms of N and variety

Interaction effect of variety and different forms of N application had significant influence on grain yield of transplanted boro rice (Table 6). Results indicated that the highest grain yield (8.18 t ha^{-1}) was with N_3V_4 interaction which was statistically similar with N_3V_1 and N_3V_2interaction. The results from other treatment combinations like N_1V_1, N_1V_2, N_3V_3

and N_1V_4gave comparatively higher grain yield but significantly lower than N_3V_4, N_1V_1 and N_3V_2Again, the lowest result was recorded from N_0V_3 (3.85 t ha^{-1}) which was statistically similar with N_0V_2. The treatment combination of N_0V_1 and N_0V_4also gave lower grain yield but comparatively higher than N_0V_3. The results obtained from the rest of the treatment combinations showed intermediate level of grain yield compared to highest and lowest grain yield. The findings achieved from Islam*et al.* (2011) conformedthe findings of the present study.

4.3.2 Straw yield

4.3.2.1 Effect of variety

Straw yield was significantly influenced by different varieties (four varieties) used in the present study (Table 6). Results showed that BRRI hybrid dhan 2 (V_1) showed the highest straw yield (8.59 t ha^{-1}) which was closely followed byBRRI Dhan29 (inbrid) (V_4). Again, the lowest straw yield (8.42 t ha^{-1}) was achieved by ACI hybrid rice (V_2) and hybrid hira rice (V_3) showed intermediate results compared to highest and lowest straw yield ha^{-1}. Similar result was found by Patel (2000), Dwivedi (1997) and Chowdhury*et al.* (1993).

4.3.2.2 Effect of different forms of N

Different forms of N application exerted significant effect on straw yield among the four varieties of transplanted boro rice (Table 6). Results showed that the highest straw yieldwas recorded by N_3 (NPK Super Granule) (9.00 t ha^{-1}) which was closely followed by N_2 (Prilled urea) wherethe lowest (7.37 t ha^{-1}) was obtained from N_0 (Control).The results obtained from N_1 (Urea Super Granule; USG) showed medium result compared to highest and lowest straw yield. The result under the present study was similar with the findings of Rahman (2003), Mishra *et al.* (1999) and Swain *et al.* (1995).

4.3.2.3 Interaction effect of different forms of N and variety

Interaction effect of variety and different form of Napplication showed significant influence on straw yield of transplanted boro rice (Table 6). The highest straw yield (9.15 t ha^{-1}) was with N_3V_4 which was statistically similar with N_3V_1 and N_3V_2. The results from other treatment combinations like N_2V_1, N_1V_2, N_2V_2, N_1V_3 and N_2V_3 gave comparatively higher straw yield but significantly different from N_3V_4. Again, the lowest result was recorded from N_0V_2 (7.29 t ha^{-1}) which was statistically similar with N_0V_3. The treatment combinations of N_0V_1 and N_0 V_4alsogave lower straw yield but higher than that of N_0V_2. The results obtained from the rest of the treatment combinations showed intermediate level of straw yield compared to highest and lowest straw yield.

4.3.3 Biological yield

4.3.3.1 Effect of variety

Biological yield was significantly influenced by different varieties used in the present study (Table 6). Results showed that BRRI (V_4)showed the highest biological yield (15.32 t ha^{-1}) which was closely followed by BRRI hybrid dhan 2 (V_1) where the lowest biological yield (14.49 t ha^{-1}) was achieved by hybrid hira rice (V_3). Again, ACI hybrid rice (V_2) gave medium biological yield.

4.3.3.2 Effect of different forms of N

Different form of N application exerted significant effect on straw yield among the of transplanted boro rice (Table 6). Results showed that the highest biological yieldwas recorded by N_3 (NPK Super Granule) (16.80 t ha^{-1}) where the lowest (11.53 t ha^{-1}) was obtained from N_0 (Control).The results obtained from N_1 (Urea Super Granule; USG) and N_2 (Pilled urea) showed medium result compared to highest and lowest biological yield. The findings obtained by Alam (2002) was similar with the present finding.

4.3.3.3 Interaction effect of different forms of N and variety

Interaction effect of variety and different forms of N application showed significant influence on biological yield boro rice (Table 6). Results indicated that the highest biological yield (17.32 t ha^{-1}) was obtained from N_3V_4 which was statistically similar with N_3V_1 and N_3V_2.Other treatment combinations like N_1V_1, N_2V_1, N_1V_2, N_2V_2, N_1V_3, N_3V_3, N_1V_4 and N_2V_4gave comparatively higher biological yield but lower than that of N_3V_4. Again, the lowest result was recorded from N_0V_3 (8.50 t ha^{-1}) which was closely followed by N_0V_2. ButV_1N_0 and N_0V_4gave lower biological yield but significantly higher than that of N_0V_3. The results obtained from the rest of the treatment combinations showed intermediate level of biological yield compared to highest and lowest biological yield.

4.3.4 Harvest index

4.3.4.1 Effect of variety

Harvest index was significantly influenced by different varieties (Table 6). BRRI Dhan29 (V_4)showed the highest Harvest index (43.49%) which was statistically similar withBRRI hybrid dhan 2 (V_1) whereas the lowest Harvest index (42.29%) was achieved by hybrid hira rice (V_3). Again, ACI hybrid rice (V_2) gave medium value of Harvest index.

4.3.4.2 Effect of different forms of N

Different forms of N application had significant effect on Harvest index of transplanted boro rice (Table 6). The highest Harvest indexwas recorded by N_3 (NPK Super Granule) (46.65%) whereas the lowest (36.16%) was obtained from N_0 (Control).The results obtained from N_1 (Urea Super Granule; USG) and N_2 (Prilled urea) showed medium result compared to highest and lowest Harvest index. This result was conformity with the findings of Alam (2002).

4.3.4.3 Interaction effect of different forms of N and variety

Interaction effect of variety and different forms of N application had significant influence on Harvest index among the treatment combinations (Table 6). The highest Harvest index (47.21%) was with N_3V_4 which was closely followed by N_3 $V_1$and N_3V_2. Other treatment combinations like, N_1V_1, N_1V_2, N_3V_3 and N_1V_4gave comparatively higher Harvest index but lower than that of N_3V_4. Again, the lowest result was recorded from N_0V_1 (36.77%) which was significantly different from all other treatment combinations. The treatment combination of N_0V_2, N_0V_3 and N_0V_4gave comparatively lower Harvest index but significantly higher than that of N_0V_1. The results obtained from the rest of the treatment combinations showed intermediate level of Harvest index value compared to highest and lowest Harvest index result.

Table 6: Effect on Yield parameters as influenced by different inbred and hybrid varieties of rice and different forms of N

Treatments	Grain yield (ha^{-1})	Straw yield (ha^{-1})	Biological yield (ha^{-1})	Harvest index (%)
***Effect of different* forms of N**				
N_0	4.18 c	7.36 c	11.53 c	36.16 d
N_1	7.13ab	8.65 b	15.75 b	45.23 b
N_2	6.84 b	8.44ab	15.62 b	43.81 c
N_3	7.87 a	9.03 a	16.80 a	46.65 a
Sx□[1]	0.0120	0.0840	0.0252	0.0260
Effect of variety				
V_1	6.62 a	8.59 a	15.04 ab	43.30 a
V_2	6.46 ab	8.28 c	14.86 b	42.77 b
V_3	6.22 b	8.42 b	14.49 c	42.29 c
V_4	6.74 a	8.48ab	15.32 a	43.49 a
Sx□	0.0120	0.0840	0.0252	0.0260
Interaction effect of different* forms of N *and variety				
$N_0 V_1$	4.34 f	7.43 f	11.79 de	36.77 g
$N_0 V_2$	4.01 g	7.29 g	11.29 ef	35.47 h
$N_0 V_3$	3.85 g	7.17 g	11.01 f	34.92 h
$N_0 V_4$	4.51 f	7.53 f	12.03 d	37.45 f
$N_1 V_1$	7.18bc	8.49 e	15.66 bc	45.82 b
$N_1 V_2$	7.03 cd	8.55 e	15.57 bc	45.13 c
$N_1 V_3$	6.96 de	8.74 cd	15.67 bc	44.33 d
$N_1 V_4$	7.34 b	8.75 cd	16.08 b	45.62 bc
$N_2 V_1$	6.87 de	8.87bc	15.73 bc	43.65 e
$N_2 V_2$	6.76 e	8.75 cd	15.50 bc	43.59 e
$N_2 V_3$	6.84 de	8.59 de	15.42 c	44.33 d
$N_2 V_4$	6.91 de	8.92 b	15.82 bc	43.65 e
$N_3 V_1$	8.06 a	9.11 a	16.96 a	46.95 a
$N_3 V_2$	8.01 a	9.03 a	17.08 a	46.88 a
$N_3 V_3$	7.23 bc	8.63 de	15.84 bc	45.56 bc
$N_3 V_4$	8.18 a	9.15 a	17.32 a	47.21 a
Sx□[1]	.0240	.1760	.0504	.0520
CV(%)	8.63	9.12	7.36	10.11

N_0 = Control (No Urea application) V_1 = BRRI hybrid dhan 2

N_1	=	2.7 g size Urea Super Granule (USG)	V_2	=	ACI hybrid dhan 1
N_2	=	Prilled Urea (PU) at three installments	V_3	=	Hybrid Hira Rice
N_3	=	NPK Super Granule	V_4	=	BRRI dhan29

Chapter 5

Summary and Conclusion

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November, 2011 to May, 2012 to study the 'Influence of forms of Nitrogen on the performance of some inbred and hybrid varieties of rice'.

The experiment comprised of two factors viz. (1) Factor A – Variety: (i) V_1 = BRRI hybrid dhan 2 (ii) V_2 = ACI hybrid dhan 1 (iii) V_3 = Hybrid Hira Rice and (iv) V_3 = BRRI dhan29 and (2)Factor B –source of N:(i) N_0= Control (No Urea application) (ii) N_1= 2.7 g size Urea Super Granule (USG) (iii) N_2= Prilled Urea (PU) at three installments and (iv) N_3= NPK Super Granule.

The size of the unit plot was 10 m^2.There were 16 treatment combinations for the present study with three replications. The experiment was laid out in Split plot Design.Significant variation was recorded for data on growth, yield and yield contributing parameters of experiment.

Data was collected on plant height (cm), number of tillers $hill^{-1}$, dry weight $hill^{-1}$ (g), leaf area index (cm^2), number of panicle $hill^{-1}$, panicle length (cm), number of grains $panicle^{-1}$, 1000 seed weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%).

There were three factors were considered for analyzing the data viz. effect of variety, different source of N use and their interaction.Different variety showed dissimilar plant height at different growth stages.

BRRI Dhan29 (inbrid)(V_4) showed the highest plant height at 20 and 45 DAT (27.96 and 34.17cm, respectively) but at 70 DAT and at harvest the tallest plant was achieved from BRRI Hybrid Dhan 2 (V_1) (57.72 and 94.59 cm, respectively). The shorter plant height was observed in Hybrid Hira dhan (V_3) at all growth stages (26.06, 32.94, 47.21 and 91.96 cm at 20, 45, 70 DAT and at harvest, respectively).

At 50, 75 DAT and at harvest BRRI Dhan29 (inbrid) (V_4) showed the highest number of tillers hill^{-1} (5.96, 16.38 and 18.22 respectively), highest dry weight hill^{-1} (9.77, 43.87, 56.46 and 84.70 g at 25, 50, 75 DAT and at harvest, respectively) and highest leaf area index (2.52, 6.80 and 7.62 cm^2 at 25, 75 DAT and at harvest, respectively)where hybrid hira rice (V_3) showed the lowest number of tillers hill^{-1} (1.64, 4.92, 14.47 and 16.38 at 25, 50, 75 DAT and at harvest, respectively) and lowest number of dry weight hill^{-1} (8.95, 40.47, 53.56 and 80.36 g at 25, 50, 75 DAT and at harvest, respectively). Butat 50 DAT, the highest leaf area (6.94 cm^2) was observed by hybrid hira rice (V_3). ACI hybrid rice (V_2) showed the lowest leaf area index(2.25 and 6.48 cm^2 at 25 and 50 DAT, respectively) but at 75 DAT and at harvest, the lowest leaf area (7.43 and 7.06 cm^2,respectively) was obtained from hybrid hira dhan(V_3).

Results also showed that at the time of harvest, BRRI Dhan29 (inbrid) (V_4)showed the highest number of effective tillers hill^{-1}, lowest number of non-effective tillers hill^{-1} (2.58), highest number of panicle (15.40) and highest number of grains panicle^{-1} (161.30).On the other hand, hybrid hira dhan(V_3) showed the lowest number of effective tillers hill^{-1} and lowest number of grains panicle^{-1} (156.70) at harvest.BRRI hybrid dhan 2 (V_1)showed the highest number of non-effective tillers hill^{-1} at harvest (2.76) and ACI hybrid rice (V_2) showed the lowest number of panicle at harvest (13.38).In terms of 1000 seed weight, the highest (25.65 g) and lowest (24.48 g) were achieved from hybrid hira dhan(V_3) and BRRI Dhan29 (inbrid) (V_4), respectively.

Results showed that BRRI Dhan29 (inbrid) (V_4)showed the highest grain yield (6.74 t ha^{-1}), biological yield (15.32 t ha^{-1}) and highest Harvest index (43.49%) where hybrid hira dhan(V_3) showed the lowest grain yield (6.22 t ha^{-1}), lowest biological yield (14.49 t ha^{-1}) and lowest Harvest index (42.29%). But BRRI hybrid dhan 2 (V_1) showed the highest straw yield (8.59 t ha^{-1}) and ACI hybrid rice (V_2) showed the lowest straw yield (8.42 t ha^{-1}).

In terms of different source of N application considering growth parameters, results showed that, the tallest plant (28.76, 35.85, 54.88 and 95.29 cm at 25, 50, 75 DAT and at harvest, respectively) was recorded by N_1 (Urea Super Granule; USG) which was also showed the highest number of tillers $hill^{-1}$ (2.22, 6.95, 19.80 and 21.37 at 25, 50, 75 DAT and at harvest, respectively), highest dry weight $hill^{-1}$ (10.79, 47.95, 62.22 and 91.54 g at 25, 50, 75 DAT and at harvest, respectively) and the highest leaf area (8.14, 9.28 and 8.96 cm^2 at 50, 75 DAT and at harvest, respectively) but at 25 DAT, N_2 (Prilled urea) gave the highest leaf area index(2.84 cm^2). The results obtained from N_0 (Control) showed the shortest plant (25.23, 30.32, 52.68 and 90.39 cm at 25, 50, 75 DAT and at harvest, respectively), lowest number of tillers $hill^{-1}$ (1.28, 3.48, 10.03 and 13.89 at 25, 50, 75 DAT and at harvest, respectively) lowest dry weight $hill^{-1}$ (7.39, 35.47, 45.79 and 70.40 g at 25, 50, 75 DAT and at harvest, respectively) and lowest leaf area index (1.78, 5.80, 5.98 and 5.57 cm^2 at 25, 50, 75 DAT and at harvest, respectively).

Again, considering yield and yield contributing characters, it was also observed that at the time of harvest, N_3 (NPK Super Granule)showed the highest number of effective tillers $hill^{-1}$(18.25), lowest number of non-effective tillers $hill^{-1}$(2.12), highest number of panicle (18.65), highest number of grains $panicle^{-1}$was recorded by N_3 (NPK Super Granule) (174.60), highest 1000 seed weightwas recorded by N_3 (NPK Super Granule) (27.85 g),highest grain yield (7.87 t ha^{-1}), highest straw yield (9.00 t ha^{-1}), highest biological yield(16.80 t ha^{-1}) and highest Harvest index(46.65%) where N_0 (Control) treatment showed the lowest number of effective tillers $hill^{-1}$ (9.05), highest number of non-effective tillers $hill^{-1}$ (3.84), lowest number of panicle at harvest (9.56), lowest number of grains $panicle^{-1}$ (140.30), lowest 1000 seed weight (21.22 g), lowest grain yield ha^{-1} (4.18 t ha^{-1}), the lowest straw ha^{-1} (7.37 t ha^{-1}), lowest biological yield ha^{-1} (11.53 t ha^{-1}) and lowest Harvest index (36.16%).

In terms of combined effect of variety and different source of N application on growth parameters, the longest plant (37.00, 59.00 and 95.86 cm at 50, 75 DAT and at harvest, respectively) was with N_3V_4, where the lowest was achieved by N_0V_3 (29.35, 44.34 and 87.12 cm at 50, 75 DAT and at harvest, respectively) but at 25 DAT, the highest and lowest plant (29.62 cm and 23.55 cm, respectively) were obtained from N_1V_1 and N_3V_3 combination.Results also indicated that the highest number of tillers $hill^{-1}$ (2.84, 8.13, 21.33 and 23.18 at 25, 50, 75 DAT and at harvest, respectively), highest dry weight $hill^{-1}$ (11.18, 50.37, 64.31 and 94.37 g at 25, 50, 75 DAT and at harvest, respectively) and highest leaf area index (8.49, 9.84 and 9.55 cm^2 at 50, 75 DAT and at harvest, respectively) were with the treatment combination of $N_3V_4$where the lowest number of tillers $hill^{-1}$ (1.00, 13.19 and 13.47 at 25, 50 DAT and at harvest, respectively), lowest dry weight $hill^{-1}$ (6.99, 34.18, 43.38 and 68.54 g at 25, 50, 75 DAT and at harvest, respectively) and leaf area index (1.70, 4.86, 5.83 and 5.45 cm^2 at 25, 50, 75 DAT and at harvest, respectively) were with the treatment combination of N_0V_3.

Again, in case of yield contributing characters, the treatment combination of N_3V_4 represented the highest number of effective tillers $hill^{-1}$(20.32), lowest number of non-effective tillers $hill^{-1}$(1.87), highest number of panicles $hill^{-1}$(20.41) and highest number of grains $panicle^{-1}$ (181.20) at the time of harvest but the highest 1000 seed weight (30.46 g) was found in the treatment combination of N_3V_1. On the other hand, the results recorded from N_0V_1at harvestshowed the lowest number of effective tillers $hill^{-1}$(8.55), highest number of non-effective tillers $hill^{-1}$(4.16), lowest number of panicle (8.21), lowest number of grains panicle-1(130.50) and lowest 1000 seed weight (19.51 g).

Considering yield parameters, it was found that the highest grain yield (8.18 t ha^{-1}), highest straw yield (9.15 t ha^{-1}), highest biological yield (17.32 t ha^{-1}) and the highest Harvest index (47.21%) were with the treatment combination of N_3V_4. On the other hand, the lowest grain yield (3.85 t ha^{-1}) and lowest biological yield (8.50 t ha^{-1}) were obtained from N_0V_3 but the lowest straw yield (7.29 t ha^{-1}) and lowest harvest index (36.77%) were achieved from the treatment combination of N_0V_2 and N_0V_1, respectively.

From the above discussion it can be concluded that among the four varieties for the present study, BRRI dhan29 showed higher efficiency regarding different growth, yield and yield contributing characters. Again, among the different four source of N application, NPK Super Granule (N_3) showed the best performance where Control (No Urea application) gave the lowest efficiency considering growth, yield and yield contributing characters. As combined effect of the present study N_3 V_4 (BRRI dhan29 × NPK Super Granule) showed the best performance regarding growth, yield and yield contributing characters of the four test boro rice varieties. So, N_3V_4 (BRRI dhan29 × NPK Super Granule) was the best treatment for the present study.

However, to reach a specific conclusion more experiments should be repeated in different agro-ecological zone of the country taking more varieties and source of N.

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