GROWTH AND YIELD OF BORO RICE BRRI dhan 29 AS INFLUENCED BY NITROGEN APPLICATION AND SEEDLING TYPES

BY

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CERTIFICATE

This is to certify that the thesis entitled "**Growth and Yield of Boro Rice BRRI dhan29 as Influenced by Nitrogen Application and Seedling Types**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRONOMY**, embodies the result of a piece of bonafide research work carried out by **Jamil Hossain**, Registration No. **07-02586** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 27.12.08
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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

A field experiment was carried out at Agronomy Field of Sher-e-Bangla Agricultural University, Dhaka during the period from December 2007 to May 2008 to study the growth and yield of *Boro* rice BRRI dhan29 as influenced by N application and seedling types. The experiment was conducted with two levels of treatments viz. A. N application : No nitrogen (control) (N_0), 2 splits at ½ at active tillering stage + ½ at panicle initiation stage (N_1), 3 splits at 1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage (N_2), 3 splits at 1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage+ additional 10 kg N ha^{-1} at flowering stage (N_3) and Urea Super Granules (N_4) and B. Seedling types: normal seedling as produced using farmers' practices (S_1), seedling produced following BRRI recommendation (S_2) and robust seedling from modified mat nursery (S_3). The experiment was laid out in split-plot design with 3 replications. Experimental result showed that N application had significant effect on the studied parameters like plant height, number of tillers $hill^{-1}$, dry matter weight $plant^{-1}$, number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, total grains $panicle^{-1}$, filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, 1000-grains weight, grain yield, biological yield and harvest index. The highest grain yield (7.27 t ha^{-1}) was obtained from the Urea Super Granules (N_4) and control (N_0) gave the lowest grain yield (3.02 t ha^{-1}). Seedling types also significantly influenced all the growth and yield attributes. The highest grain yield (6.27 t ha^{-1}) was obtained from robust seedling from modified mat nursery and the lowest grain yield (5.10 t ha^{-1}) was recorded from normal seedling as produced using farmers' practices (S_1). The combined effect of N application and seedling types had also significant effect on growth, yield attributes and yield. The interaction of Super Granule Urea (N_4) with robust seedling from modified mat nursery (S_3) gave the highest grain yield (7.84 t ha^{-1}).

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AEZ	Agro- Ecological Zone
atm.	Atmospheric
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
IRRI	International Rice Research Institute
cm	Centimeter
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
et al.	And others
FAO	Food and Agriculture Organization
i.e.	That is
µg	Microgram
EC	Emulsifiable Concetrate
Ml	Millimeter
g	Gram (s)
HI	Harvest Index
K_2O	Potassium Oxide
Kg	Kilogram (s)
LSD	Least Significant Difference
m^2	Meter squares
mm	Millimeter
MP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Non significant
P_2O_5	Phosphorus Penta Oxide
S	Sulphur
SAU	Sher-e- Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM/ TDW	Total Dry Matter/ Total Dry Weight
TSP	Triple Super Phosphate
USG	Urea Super Granule
PU	Prilled Urea
@	At the rate of
Viz.	Namely
var.	Variety
Wt.	Weight
t ha-1	Ton per hectare
0 C	Degree Centigrade
%	Percentage

CHAPTER 1

INTRODUCTION

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INTRODUCTION

The geographical, climatic and edaphic conditions of Bangladesh are favorable for year round rice cultivation. However, the national average rice yield (2.34 t ha^{-1}) is very low compared to that of other rice growing countries of the world. For instance, the average rice yield in China is about 6.3 t ha^{-1}, Japan is 6.6 t ha^{-1} and Korea is 6.3 t ha^{-1} (FAO, 2002). The population of Bangladesh is increasing at an alarming rate and the cultivable land is reducing due to urbanization and industrialization resulting in more shortage of food. It is not possible to have horizontal expansion of rice area, rice yield $unit^{-1}$ area should be increased to meet this ever-increasing demand of food in the country.

Among the production factors affecting crop yield, nutrient is the single most important factor that plays a dominant role in yield increase if other production factors are not limiting. It is reported that chemical fertilizers today hold the key role to success of production systems of Bangladesh agriculture being responsible for about 50% of the total crop production (BARC, 1997). Nutrient imbalance can be minimized by judicious application of different fertilizers. There is need to develop appropriate management technique to evaluate the performance and to assess the nutrient requirement for rice cultivation in the country. Among the fertilizers, nitrogen is essential for vegetative growth but excess nitrogen may cause excessive vegetative growth, prolong the growth duration and delay crop maturity with reduction in grain yield.

Among the different elements nitrogen is universally needed for all crops. Many workers have reported a significant response of rice to nitrogen fertilizer in different soils (Bhuiya *et al*., 1989; Hussain *et al*., 1989 and Islam *et al*., 1990). The efficient nitrogen management can increase crop yield and reduce production cost. An increase in the yield of rice by 70-80% may be obtained from proper application of N-fertilizer (IFC, 1982). Inadequate and improper applications of N are now considered one of the major reasons for low yield of rice in Bangladesh. The utilization efficiency of applied N by the rice plant is very low. The submerged condition of wetland soils produces N losses through NH_3-volatilization, denitrification, leaching, surface runoff, and chemical fixation. The efficiency of nitrogen use by rice plants is very low, the recovery being only 30-50% (Datta and Craswell, 1982). It is presently thought that different growth stages may be important from the standpoint of development of yield components and that one stage may be more critical than the other. Therefore, nitrogen should be applied in rice in such a way that the minimum is leached or washed away and the maximum is utilized for plant growth and grain production.

The split application of nitrogenous fertilizers is important aspect in overall nitrogen management in rice specially *Boro* rice from the viewpoint of its efficient utilization. Different splitting of nitrogen application may reduce the loss of nitrogen in the rice field and improve environmental condition. In most cases, surface broadcasting of prilled urea is practiced by farmers to meet the N demand for rice crop. But by this application, a large amount of applied N is being lost through NH_3 volatilization, leaching, denitrification and surface runoff, consequently N fertilizer use efficiency decreases. On the other hand, deep point placement of USG (Urea super granule) increases N fertilizer use efficiency in wetland rice. The placement of USG at 8-10 cm depth of soil can save 30% nitrogen than prilled urea, increases nutrient absorption, improves soil health and ultimately increases the yields.

Seedling types are also important in rice production. There is different type of seedling that are commonly used for rice cultivation. They are normal seedlings that are produced from farmers' level, seedling as recommended by BRRI, robust seedling from modified mat nursery etc. Producing young and robust rice seedlings is a challenge for rice farmers everywhere. To meet up this challenge, scientists from the International Rice Research Institute (IRRI) and the Tamil Nadu Agricultural University (TNAU) in India have developed an improved method in crop establishment: growing seedlings in a modified mat nursery (IRRI, 2007). But the information related to the effectivity of this method not to be well known to the farmers of our country. Considering the present situation the present experiment was conducted with the following objectives-

1. To find out the effect of split application of nitrogen fertilizer on growth, yield and yield attributes of BRRI dhan29,
2. To evaluate the effect of seedling types on growth, yield and yield attributes of BRRI dhan29, and
3. To study the interaction effect of seedling types and split application of nitrogen fertilizer on growth, yield and yield attributes of BRRI dhan29.

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Yield and yield contributing characters of rice considerably depend on manipulation of basic ingredients of agriculture. The basic ingredients include variety, environment and agronomic practices (planting density, fertilizer, irrigation, seedling types etc.). Among the above factors N application and seedling types are more responsible for the growth and yield of rice. High yielding varieties (HYV) are generally more adaptive to nitrogen application and they produce higher yield with increasing nitrogen levels up to a certain end. The available relevant reviews of literature on the related works done in the recent past have been presented and discussed in this chapter.

2.1 Effect of nitrogenous fertilizer on plant characters

Among the factors that are responsible for growth, yield and yield contributing characters of rice, split application of nitrogen fertilizers is very important, especially for the production of modern varieties of *Boro* rice. Some information regarding the effect of nitrogenous fertilizer on different yield attributes of rice are reviewed.

2.1.1 Plant height

Mishra *et al.* (2000) carried out a field experiment in 1994-95 in Bhubaneswar, Orissa, India, and reported that rice cv. Lalate was given 76 kg N ha^{-1} as USG at 0, 7, 14 for 21 days after transplanting (DAT), and these treated control. N increased plant height, panicle length, N up take and consequently the grain and straw yields of lowland rice. Best results were obtained with USG applied 14 DAT.

Prasad *et al.* (1999) conducted an experiment on growth of rice plants as influenced by the method of seeding, seed rate and split application of nitrogen and reported that plants were generally tallest with N applied 25% at 15 days after sowing, 50% at active tillering and 25% at panicle initiation stages.

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

Sharma (1995) reported in an experiment that split application of nitrogenous fertilizer increased the plant height significantly compare to the basal nitrogen application.

Akanda *et al.* (1991) pointed out that split application of nitrogen had no significant effect on plant height.

Reddy *et al.* (1990) reported a significant effect of nitrogen on plant height in rice with 120 kg N ha^{-1} in three split dressings at tillering, panicle initiation and booting stages.

Wagh and Thorat (1988) observed that (30+30+10+10) kg N ha^{-1} applied at 4 days after transplanting, maximum tillering, primordial initiation and flowering, respectively produced the longest plant.

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

Akanda *et al.* (1986) at the Bangladesh Agricultural University, Mymensingh observed that applying nitrogen in three splits 20 kg at basal, 40 kg at active tillering and 20 kg at panicle initiation stage had no significant effect on plant height.

Akanda *et al.* (1986) found that the tallest plants were produced when 80 kg N ha^{-1} was applied in three splits (20 kg at basal, 40 kg at active tillering and 20 kg at maximum tillering).

Reddy *et al.* (1985) reported that 120 kg N ha^{-1} applied in three split dressings at transplanting (50%), tillering (25%) and panicle emergence stage (25%) gave longer plant in two equal split dressings at transplanting and tillering or in a single dressing at transplanting.

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

Geethadevi *et al.* (2000) conducted an experiment with four splits application of nitrogen and found that higher number of tillers, filled grains $panicle^{-1}$ and higher grain weight $hill^{-1}$ for split application of nitrogenous fertilizer.

Islam *et al.* (1996) reported that number of effective tillers $hill^{-1}$ increased with increasing nitrogen level and split application was more effective compare to basal application during transplanting.

Shoo *et al.* (1989) reported that nitrogen application at transplanting or in two equal split dressing at transplanting and tillering stages increased the total number of tillers $hill^{-1}$.

Hussain *et al.* (1989) reported that 150 kg N ha^{-1} in split application increased the number of total tillers $hill^{-1}$. They also observed that nitrogen application date had significant effect on tillers production of aman rice.

Wagh and Thorat (1988) reported that 30+30+10+10 kg N ha^{-1} applied at 8 days after transplanting, maximum tillering, primordial initiation and flowering, respectively produced the highest number of tillers $hill^{-1}$.

Akanda *et al.* (1986) observed that application of nitrogen in three splits 20 kg at basal, 40 kg at active tillering and 20 kg at panicle initiation stage gave the highest number of total tillers $hill^{-1}$.

Singh and Singh (1986) worked with different levels of nitrogen as USG, sulphur coated and PU @ 27, 54 and 84 kg ha^{-1}. They reported that number of tillers m^{-2} increased with the increasing nitrogenous fertilizer. The number of tillers m^{-2} was significantly greater in USG than PU in all levels of nitrogen.

Reddy *et al.* (1985) reported that 120 kg N ha^{-1} applied in three split dressing at transplanting (50%), tillering (25%) and panicle emergence stage (25%) gave higher number of total tillers $hill^{-1}$ than in two equal split dressings at transplanting and tillering or in a single dressing at transplanting.

2.1.3 Dry matter weight hill^{-1}

Xie *et al.* (2007) reported that increased split application of nitrogen from control to 140 kg ha^{-1} increased dry matter accumulation (DMA) of different growth stages of Jinzao22 and Shanyou63 rice varieties and after that dose the DMA reduced due to the losses of nitrogen by volatilization.

Singh and Modgal (2005) noted that dry-matter accumulation (DMA) and concentration and uptake of nitrogen increased with increasing level of nitrogen at all the stages of crop growth. Split application of nitrogen with its heavier fractions (1/3+1/3+1/3) at tillering and panicle initiation stages resulted in higher dry-matter accumulation, and higher nitrogen concentration of rice. They also noted that the rice plants accumulated nearly 15% of the total absorbed nitrogen, up to tillering, 50% up to panicle initiation and 85–90% up to heading.

2.1.4 Number of effective tillers hill^{-1}

Bayan and Kandasamy (2002) noticed that the application of recommended rates of N in four splits at 10 days after sowing, active tillering, and panicle initiation and at heading stages recorded significantly lower dry weight of weeds and increased crop growth viz. effective tillers m^{-2}.

Islam *et al.* (1996) reported that number of effective tillers hill^{-1} increased with the increasing nitrogen level and split application was more effective compared to basal application during transplanting.

Shoo *et al.* (1989) reported that the number of effective tillers $hill^{-1}$ was the highest with N applied in 2-3 splits at tillering, panicle emergence and flowering stages.

Wagh and Thorat (1988) reported that nitrogen 30+30+10+10 kg N ha^{-1} applied at 8 days after transplanting, maximum tillering, primordial initiation and flowering, respectively produced the highest number of effective tillers $hill^{-1}$.

Akanda *et al.* (1986) observed that applying nitrogen in three splits 20 kg at basal, 40 kg at active tillering and 20 kg at panicle initiation stage gave the highest number of tillers $hill^{-1}$.

2.1.5 Panicle length

Rao *et al.* (1997) showed that nitrogen application at 50 kg ha^{-1} at tillering, 25 kg ha^{-1} at panicle initiation and 25 kg ha^{-1} at booting stage produced the longest panicle.

Patel and Mishra (1994) carried out an experiment with rice cv. IR36 and was given 0, 30, 60 or 90 kg N ha^{-1} as Muossorie rock phosphate-coated urea, neem cake-coated urea, gypsum coated urea, USG or PU. The coated materials as incorporated before transplanting and USG as placed 5-10 deep a week after transplanting and urea as applied in 3 split doses. They showed that N rate had no significant effect on panicle length, percent sterility and harvest index.

Sen and Pandey (1990) reported that the application of USG or PU @ 38.32 kg N ha^{-1} gave higher yield than broadcast PU and there were no significant differences in panicle length.

Reddy *et al.* (1987) observed from an experiment that panicle length increased with 120 kg N ha^{-1} in three split at tillering, panicle initiation and booting stages.

Latchanna and Yogeswara (1977) reported that the longest panicle was obtained when N was applied in three split dressings 1/3 at planting, 1/3 at tillering and 1/3 at panicle initiation.

2.1.6 Number of grains panicle^{-1}

Faraji and Mirlohi (1998) reported that plant height, number of tillers per unit area and days to heading and maturity increased with the increase of rate of N fertilizer application at 60, 90, 120 or 150 kg N ha^{-1}, were given before transplanting or in 2 or 3 splits while grain yield and panicle number increased up to 120 kg N ha^{-1} but decreased were decreased with increasing N rate.

Kapre *et al.* (1996) reported that USG has favourable effects on rice. They also observed from a study with 8 slow releasing fertilizers that grain yield, straw production, panicle $hill^{-1}$, grains $panicle^{-1}$ and 1000-grain weight increased significantly with USG and sulphur coated urea (SCU).

Surendra *et al.* (1995) conducted an experiment during rainy season with nitrogen level @ 0, 40, 80, 120 kg ha^{-1} and sources, of nitrogen, USG and urea dicyandiamide @ 80 kg ha-^{1}. They showed that USG and urea dicyandiamide produced more panicle $hill^{-1}$, filled grains $panicle^{-1}$, panicle weight and grain yield than PU @ 80 kg N ha^{-1}.

Nassem *et al.* (1995) indicated that percent grains remained unchanged in response to different levels but a significantly lower 1000-grain weight was recorded in the control treatment than in the plots received nitrogen fertilizer.

Tantawi *et al.* (1991) stated that split application of nitrogen markedly increased yield and the highest yield obtained from the triple splits. They also observed that split application resulted in greater number of panicles, heavier grains and more grains $panicle^{-1}$.

Thakur (1991) reported that total spikelets $panicle^{-1}$ was the highest when 40%, 30% and 20% nitrogen was applied as basal, at maximum tillering and panicle initiation stages, respectively.

Thakur (1991) studied the influence of levels, forms of urea and method of application of nitrogen in rice during *Kharif* season. He observed that yield attributes and grain yield differed significantly due to the levels and sources of nitrogen applied. Placement of nitrogen at 60 kg ha^{-1} through USG produced the highest number of panicle $unit^{-1}$area.

Kamal *et al.* (1991) conducted a field experiment in *Kharif:* season of 1985 and 1986 on rice cv. Joya with different forms of urea and level of nitrogen @ 29.58, 87 kg ha^{-1}. They reported that total tiller varied significantly due to forms of urea in 1995, but during 1996 there was no significant variation. PU was significantly inferior to the other forms. The highest number of tillers was produced in the treatment where USG was applied.

Rama *et al.* (1989) observed that the number of grains $panicle^{-1}$ were significantly higher @ 40, 80 or 120 kg N ha^{-1} as USG applied as deep out a field trial to study the effect of placement of USG (5, 10 or 15 cm deep) and broadcast PU on rice yields of tall long duration Mashuri and dwarf, short duration Mashuri. They revealed that Mashuri had significantly higher yield, panicles m^{-2}, panicle length and weight, grains $panicle^{-1}$ and 1000-grain weight than Mashuri, probably due to Mashuri's long duration. All depths of USG placement resulted in higher yield characters than broadcast PU; however, differences except for panicle lengths were not significant.

Rama *et al.* (1989) mentioned form their earlier study that the Urea super granules (USG) significantly produced higher number grains $panicle^{-1}$ than split application of prilled urea.

Reddy *et al.* (1987) reported that total number of spikelets $panicle^{-1}$ increased with 120 kg with N ha^{-1} in three split dressings at tillering, panicle initiation and booting stages.

Akanda *et al.* (1986) observed that applying nitrogen in three splits 20 kg at basal, 40 kg at active tillering and 20 kg at panicle initiation stage gave the highest number of grains panicle^{-1}.

2.1.7 Weight of 1000 grains

Subhendu *et al.* (2003) conducted a field experiment during *kharif* season at Hyderabad, India. They found that the application of nitrogen (120 kg N ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and 50% flowering resulted in the highest 1000 grain weight (22.57 g).

Ali *et al.* (1992) reported from their earlier findings that 1000 grain weight was the highest when 100 kg N ha^{-1} was applied in three equal splits at basal, 30 and 60 days after transplanting.

Akanda *et al.* (1986) at the Bangladesh Agricultural University reported that the weight of 1000-grain was the highest when 80 kg N ha^{-1} was applied in three splits such as 20 kg ha^{-1} basal, 40 kg ha^{-1} at active tillering and 20 kg ha^{-1} at panicle initiation stages.

2.1.8 Grain yield

Bowen *et al.* (2005) conducted 531 on-farm trials during the *boro* and *aman* seasons in 7 districts of Bangladesh from 2000-2004. The results showed that UDP (Deep placement of urea super granule) increased grain yield by 1120 kg ha^{-1} and 890 kg ha-1 during the *boro* season and *aman* season, respectively.

Miah *et al.* (2004) carried out an experiment with transplanted rice cv. BINA dhan4. They found that the values of the parameters of urea. Rahman (2003) worked out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during aman season with three levels of USG viz. one, two and three USG/4 hills providing 40, 80 and 120 kg N ha^{-1}. He found that two USG/4 hills produced the higher grain and straw yield (5.22 and 6.09 t ha^{-1}, respectively).

Ikeda *et al.* (2003) stated the efficiency of the non-split fertilizer application to the rice variety 'Koshihikari' was evaluated in order to dispense with top dressing and improve the recovery rate of fertilizer in pneumatic direct sowing culture of rice on a submerged paddy field in Aichi Prefecture, Japan. The fertilizer used in this study, which was a combination of a linear-type coated urea and a sigmoidal-type coated urea, was found effective in this cultivation system. Results also showed that nitrogen recovery rate, yield rate and quality were improved with this system. The accumulative nitrogen release rates of the combined fertilizer were 40% at panicle formation stage, 80% at heading stage and 95% at maturity stage. Furthermore, the nitrogen release pattern was adapted for the growth phase of this cultivation system.

Jaiswal and Singh (2001) conducted an experiment with USG and PU both at 60 and 120 kg ha-1 under different planting methods. They found that transplanting method with urea super granules proved to be the best for maximum grain yield (4.53 t ha^{-1}).

Angayarkanni and Ravichandran (2001) conducted a field experiment at Tamill Naru from July to October, 1997 and found that split application of nitrogen for rice cv. IR20, treatment applying 16.66% of the recommended N as basal, followed by 33.33% N at 10 DAT, 25% N at 20 DAT and 25% N at 40 DAT recorded the highest grain yield e.g. 6189.4 kg ha^{-1}.

Ehsanullah *et al.* (2001) when work with split application of nitrogenous fertilizer and reported that nitrogen as split application at different growth stages significantly affected grain yield.

Ahmed *et al.* (2000) revealed that USG was more efficient than PU at all respective levels of nitrogen in producing all yield components and in turn, grain and straw yields. Placement of USG @ 160 kg N ha^{-1} produced the highest grain yield (4.32 t ha^{-1}) which was statistically identical to that obtained from 120 kg N ha^{-1} as USG and significantly superior to that obtained from any other level and source of nitrogen.

Geethadevi *et al.* (2000) showed that four split applications of nitrogen in KRH-1 recorded the maximum yield, as well as increased growth and yield components.

Suerkha *et al.* (1999) found that N application in four equal splits, the last at flowering improved the grain yield as well as nutrient uptake.

Asif *et al.* (1999) noticed that application of 60 : 67 : 67 or 180 : 90 : 90 kg NPK ha^{-1}, with N at transplanting and early tillering or a third each at transplanting, early tillering and panicle initiation resulted in higher grain yield with the higher NPK rates. Split application of N gave higher yields than a single application.

Thakur and Patel (1998) reported that the highest grain yield (3.84 t ha^{-1}) was recorded with the application of 80 kg N ha^{-1} in three split rates with 5 t FYM ha^{-1} and 60 kg N ha^{-1} in three split rates with 5 t FYM gave 3.81 t ha^{-1}.

Islam *et al.* (1996) reported that grain yield was increased with increasing nitrogen level and split application was more effective compare to basal application during transplanting.

Vaiyapuri *et al.* (1995) stated that application of 100 kg N ha^{-1} in three splits 25% basal + 50% tillering stage +25% panicle initiation gave the highest yield (5.88 t ha^{-1}).

Panda and Mphanty (1995) observed that grain yield was the highest with 60 $kgha^{-1}$ applied 30 kg at transplanting and 15 kg each at 21 and 75 days after transplanting.

Das and Singh (1994) reported that grain yield and N use efficiency by rice were greater for deep placed USG than for USG broadcast and incorporated or three split applications of PU.

Chaudhary *et al.* (1994) reported that Basmati rice gave the highest grain yield when fertilized with 124 kg N ha^{-1} in three equal split dressings at transplanting, 20-25 days after transplanting and 40-45 days after transplanting.

Channabasavanan and Setty (1994) found that rice yield was the highest when N was applied in different splits between sowing, tillering, panicle initiation and panicle emergence.

Avasthe *et al.* (1993) reported that the highest grain yield of 5.64 t ha^{-1} was obtained when N was applied in two equal split at transplanting and 7 days before panicle initiation or half of the N at transplanting + ¼ at late tillering + ¼ at panicle initiation.

Rabinson (1992) reported that among 12 different split application treatments, grain yield ranged 4.2-5.9 t ha^{-1} and was the highest with application of three equal splits (Basal application, panicle initiation stages and heading stages).

Nair and Gautam (1992) found that grain yield was higher when 60 kg N was applied at initiation, or 50% at transplanting + at tillering + 25% at panicle initiation stages than when all was applied at transplanting or at tillering.

Mongia (1992) reported that grain yield was the highest with 60 kg N ha^{-1} with the application in three split application (50% basal + 25% at flowering + 25% at the flag leaf stage).

Roy and Peterson (1990) reported that application of 40 to 50 percent N at ten days after transplanting, 25-30% at 21 days after transplanting and the rest at the panicle initiation stage were desirable.

Wagh and Thorat (1988) observed that N application date had significant effect on grain yields. Nitrogen application as 30+30+10 kg N ha^{-1} applied at 8 days after transplanting, maximum tillering, primordial initiation and flowering, respectively, produced the highest grain yield.

Park and Lee (1988) reported that brown rice yield of cv. Seomginbyeo increased significantly with up to 100 kg N and was the highest with 20% of N applied 25 days before heading.

Kim *et al*. (1987) stated that the highest rice grain yield was obtained from a basal application of 30 kg N ha^{-1}, three top dressing 32 and 15 days before heading and a final topdressing of 10 kg N ha^{-1} 10 days after heading.

Khander *et al*. (1987) stated that 90 kg N ha^{-1} as application in two split dressing and in a single dressing at transplanting gave yields of 5.47, 5.19 and 4.16 t ha^{-1}, respectively.

Paturde and Rahate (1986) observed significant increase in grain yield of rice with the split application of N as 40 kg N ha^{-1} at transplanting, 20 kg N ha^{-1} at panicle initiation and 20 kg N ha^{-1} at the heading stage.

2.1.9 Straw yield

Subhendu *et al*. (2003) conducted a field experiment during *kharif* season at Hyderabad, India. They found that the application of nitrogen (120 kg Nha^{-1}) as urea in equal split during transplanting, tillering, panicle initiation and 50% flowering resulted straw yield is 5322 kg ha^{-1}.

Ehsanullah *et al.* (2001) conducted an experiment with the application of nitrogenous fertilizer as split at different growth stages and reported that split application significantly affected straw yield.

Hussain *et al.* (1989) stated from their study that straw yield was increased with split application of nitrogenous fertilizer in rice filed compare to basal application of nitrogen.

Salam *et al.* (1988) reported that straw yield was the highest with split application of nitrogen and also application of nitrogen at tillering stage it was more effective than basal application.

Paturde and Rahate (1986) reported that straw yield was the highest due to N application in split, the rates of 40 kg N ha^{-1} at transplanting, 20 kg N ha^{-1} at panicle initiation and 20 kg ha^{-1} at heading stage.

2.1.10 Harvest index

Mondal and Swamy (2003) found that application N (120 kg ha^{-1}) as urea in equal split during transplanting, tillering, panicle initiation and flowering resulted in the highest number of panicles, number of filled grain $panicle^{-1}$, 1000-grains weight, straw yield and harvest index.

From the above presentation of the review of literatures it may be said that rates of nitrogen fertilizer and split application of nitrogen fertilizer have decisive influence on the crop performance of rice. The above review suggested that a considerable amount of work is still to be carried out in order to evaluate the effect of rate and split application of nitrogen fertilizer on the performance of rice.

2.2 Effect of seedling types

Seedlings can be grown in different ways. There is different types of seedling that are commonly used for rice cultivation. They are normal seedlings that are produced from farmers' level, seedling as recommended by BRRI, robust seedling from modified mat nursery and so on.

Producing strong and stout rice seedlings is a challenge for rice farmers everywhere. To meet this challenge, scientists from the International Rice Research Institute (IRRI) and the Tamil Nadu Agricultural University (TNAU) in India have developed an improved method in crop establishment: growing seedlings in a modified mat nursery.

The technology established for producing modified mat nursery seedlings is a layer of soil mixture, arranged on a firm surface. It uses less land and requires fewer seeds and inputs, such as fertilizer and water, reducing nursery costs by up to 50%. After 15–20 days, the seedlings reach the four-leaf stage which favors quick establishment in the field and rapid growth and are ready for transplanting. This is much quicker than the 25–35 days required for traditional wet-bed nurseries.

Rajendran *et al.* (2007) conducted an experiment at Soil and Water Management Research Institute (SWMRI), Thanjavur, Tamil Nadu, India on nursery technology for early production of robust rice seedlings to transplant under integrated crop management. A modified rice mat nursery (MRMN) was developed to produce robust, healthy rice seedlings in 15 days under different soil + manure + rice husk mixes as medium. Details such as thickness of the medium, lining of the seedbed, seed rate and nutrient requirements were standardized. Three field trials conducted at Thanjavur and Aduthurai, Tamil Nadu, India indicated the efficiency of the MRMN. Soil alone, soil + rice husk (9:1 w/w) or soil + press mud [filter cake] (1:1, w/w) were identified as the best medium for MRMN on the basis of seedling growth and vigour characteristics. Seedlings reached a height of 18-20 cm with 4 leaves in 15 days. These seedlings can be easily transported to the main field for transplanting.

Pasuquin *et al.* (2007) conducted an experiment with transplanting rice seedlings 20 days old or older has been commonly reported to generate an increase in grain yield as a result of higher tiller production. A series of experiments was conducted at the IRRI farm during the dry and wet seasons to quantify, in a range of plant types, the impact of even younger seedlings and contrasting nursery management on grain yield and to identify plant traits supporting high performance under a given establishment technique. Seedling age at transplanting, ranging from 7 to 21 days, and contrasting nursery types (seedling tray, dapog, mat nursery, and traditional wet-bed seeding) were evaluated for an elite line, a new plant type and hybrid rice. To avoid any confounding effect, sowing date in the nursery, seed rate and crop management in the main field were all the same. In the two seasons, and for all genotypes and nursery types, transplanting older seedlings induced a delay in the onset of linear dry matter accumulation and tiller emergence, while the rate of dry matter accumulation and tiller emergence was unchanged. This delay reduced nitrogen content in the seedlings. Plants recovered quickly, however, after transplanting. The delay also reduced maximum tiller number, and extended crop duration with delayed maximum tillering, flowering and maturity. Grain yield was consistently higher for younger seedlings, with, in some cases, a difference as large as 1 t ha^{-1} between 7- and 21-day transplanting. This result was valid for the four genotypes evaluated, with a higher impact during dry season. In contrast, no significant difference was observed for the influence of nursery type on the timing of tiller emergence and on grain yield. Some differences in seedling vigor (plant dry weight, specific leaf area, N content), higher in the case of dapog and wet bed, and in maximum tillering, higher in the case of the seedling tray, however, were observed. But these differences did not have a significant impact on the late increase in crop dry matter and on panicle number at maturity. No significant interaction between seedling age and nursery management for all genotypes and for all the parameters measured was found. Promoting early tiller emergence as a response to transplanting young seedlings increased grain yield in all cases despite the associated decrease in tillering efficiency. Extended growth inside the nursery, rather than transplanting shock per se, appeared to be the main reason for delayed tiller emergence in late transplanting.

From the above presentation of the review of literatures it may be said that there were very little information available regarding seedling type for rice cultivation which have significant influence on the crop performance. The above review suggested that there is need to carry out more study in order to evaluate the effect seedling type on performance of rice

CHAPTER 3

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207 during December 2007 to May 2008 to study the growth and yield performance of *Boro* rice as influenced by N application and seedling types. The details of the materials and methods applied in this experiment have been presented below:

3.1 Description of the experimental site

3.1.1 Location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site was $23^{0}74'$ N latitude and $90^{0}35'$ E longitude with an elevation of 8.2 meter from sea level. For better understanding the location of the experimental site has been shown in the AEZ map (Appendix I).

3.1.2 Soil

The soil of the experimental area was clay loam belonging to the Madhupur Tract (UNDP, 1988) under AEZ 28. The selected plot was medium high land. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. Details of the soil analysis result have been presented in Appendix II.

3.1.3 Climate

The geographical situation of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February, the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al.*, 1979). Metrological data of air temperature, relative humidity, rainfalls and sunshine hour during the period of the experiment were collected from the Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka presented in Appendix III.

3.2 Test crop and its Characteristics

BRRI dhan29 was used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute from the cross between BG 90-2 and BR51-46-5 in 1994. It is recommended for *Boro* season. Average plant height of the variety is about 95 cm at the ripening stage. The grains are medium fine and white. It requires about 160 days for completing its life cycle with an average grain yield of 7.5 t ha^{-1} (BRRI, 2000).

3.3 Experimental details

3.3.1 Treatments

The experiment considered two factors.

Factor A: N application -5

i. N_0 = No nitrogen (control)

ii. N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

iii. N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

iv. N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

v. N_4 = Urea Super Granules (Guti urea)

Factor B: Seedling types - 3

i. S_1 = Normal seedling (produced following farmers' practices)

ii. S_2 = Seedling produced as recommended by BRRI

iii. S_3 = Robust seedling from modified mat nursery

3.3.2 Experimental design and layout

The experiment was laid out following Split Plot Design with three replications. The layout of the experiment was prepared as per treatment, where nitrogen was assigned in the main plot and seedling type in the sub-plots. There were 15 plots, each measuring 4m × 2.5 m in each block. The total number of plots were 45. The distances between plot to plot and replication to replication were .75 m and 1 m, respectively. The layout of the experiment has been shown in Appendix IV.

3.4 Growing of crops

3.4.1 Raising seedlings

3.4.1.1 Seed collection

The seeds of the test crop i.e. BRRI dhan29 were collected from Bangladesh Rice Research Institute, Joydevpur, Gazipur.

3.4.1.2 Seed sprouting

Healthy seeds were selected by specific gravity method and then immersed in water in a bucket for 24 hours. Then the seeds were taken and kept thickly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

3.4.1.3 Preparation of nursery bed and seed sowing

A. Normal seedling (Produced following farmers' practices)

The common procedure was followed in raising seedlings in the seedbed. The seedbed was prepared by puddling with repeated ploughing followed by laddering. Weeds were removed and irrigation was gently provided to the bed as and when necessary. No fertilizer was used in the nursery bed. The sprouted seeds were sown on the seedbed on December 02, 2007(Plate 1).

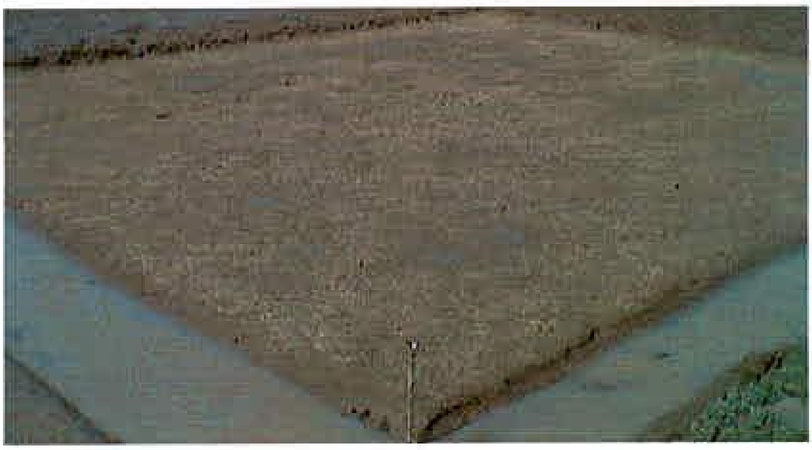


Plate 1. Photograph represents the farmers' practices nursery bed

B. BRRI recommended seedling

Seedbed was prepared as per BRRI recommendation(BRRI, 2007). The water was applied as per requirement in the bed and puddled with repeated ploughing followed by laddering. Weeds and stubbles were removed and well decomposed cow dung (2kg m^{-2}) was applied for vigorous growth of seedlings. The length and width of each bed was 10 m and 1.25m, respectively. The bed was raised 10cm and the distance between two beds was 0.5m. The sprouted seeds were sown as uniformly as possible on the seedbed on December 02, 2007 for raising seedling (Plate 2).

Plate 2. Photograph represents the BRRI recommended nursery bed

C. Modified mat nursery

For modified mat nursery seedling the following steps were taken:

1. Soil mixture was prepared with 7 parts soil (35 bucket), 2 parts well-decomposed chicken manure (10 bucket) and 1 part charred rice hull (5bucket) for preparation bed (1m wide and 10m length).

2. Polythene sheet was placed on the leveled land and the soil mixture was spreaded on the polythene sheet that was framed by banana stalks. The thickness of soil mixture was 4-5cm in the bed.

Plate 3 a. Placing polythene for bed preparation

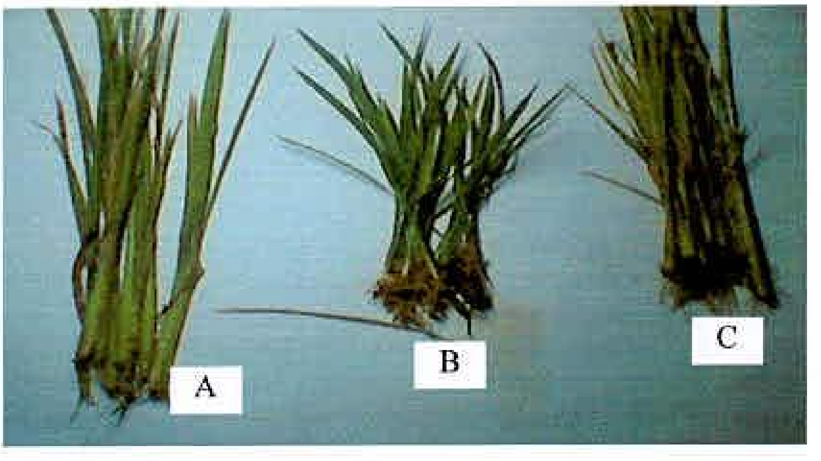
Plate 3 b. Soil mixture preparation for seed bed preparation

Plate 3 c. Photograph represents the modified mat nursery bed

3. Soaked the seeds for 24 hours. Drained the water after 24 hours and kept the seeds moist by covering them for another 24 hours for pre-germination.

4. The pre-germinated seeds were sown uniformly on December 20, 2007. The soil was sprinkled and pats gently to embed them at about 2–3 cm into the soil, and then water was sprinkled immediately.

5. Water was sprinkled the nursery twice a day for 5 days and kept it covered with rice straw to maintain moist condition to protect the nursery from heavy rains for the first 5 days after seeding.



A. Seedling recommended by BRRI;
B. Robust seedling from modified mat nursery; and
C. Normal seedling produced following farmers' practices

Plate 4. Seedlings from different seed bed

6. Five days after seeding, removed the cover and flooded the nursery. Maintained 1cm water level around the mats then, drained the water 2 days before removing the seedling mats for transplanting.

3.4.2 Preparation of the main field

The plot selected for the experiment was opened in the first week of December 2007 with a power tiller and was exposed to the sun for a week, after one week 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 for transplanting of seedlings.

3.4.3 Fertilization

The fertilizers N, P, K, S and B in the form of urea, TSP, MP, Gypsum and Zinc sulphate, respectively were applied. The entire amount of TSP, MP, Gypsum and Zinc sulphate were applied during the final land preparation. Urea was applied as per treatment mentioned in 3.3.1. But urea super granules (USG, 46% N, made from International Fertilizer Development Corporation, IFDC) weighing 1g each were placed 5-8 cm deep at 9 DAT in the centre of four hills in alternate rows at the rate of two granules to maintain 80 kg N ha^{-1}. The doses of fertilizer are shown in Table 1.

Table 1. Fertilizer dose of Boro rice

Fertilizers	Dose (kg ha^{-1})
Urea	270
TSP	130
MP	120
Gypsum	60
Zinc sulphate	10

Source: Adunik Dhaner Chash, BRRI, Joydebpur, Gazipur (2000)

3.4.4 Uprooting of seedlings

The nursery bed was made wet by the application of water one day before uprooting the seedlings. The seedlings were uprooted on January 08, 2008 without causing much mechanical injury to the roots and they were immediately transferred to the main field.

3.4.5 Transplanting of seedlings in the field

Transplanting was done on January 08, 2008 using 36 days old of normal, and BRRI recommended seedling and 18 days old seedling from modified mat nursery. Seedlings were transplanted in lines following line to line distance 25 cm and hill to hill distance 15 cm, respectively.

3.4.6 After care

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the rice seedlings.

3.4.6.1 Irrigation and drainage

Irrigation was given in each plot as per requirements. The field was finally dried out 15 days before harvesting.

3.4.6.2 Gap filling

Gap filling was done for all of the plots at 10 days after transplanting (DAT) with the same ages of seedlings from the same source.

3.4.6.3 Weeding

During plant growth period three weedings were done. First weeding was done at 20 days after transplanting, 2^{nd} and 3^{rd} weeding was done at 35 and 50 DAT.

3.4.6.4 Top dressing

Urea was top dressed as per treatment mentioned in chapter 3.3.1.

3.4.6.5 Plant protection

Plants were infested with rice stem borer and rice hispa to some extent which was successfully controlled by applying Diazinon(60 EC) two times @ 10 ml/10 liter of water for 5 decimal lands at tillering and before panicle initiation stage.

3.5 Harvesting, threshing and cleaning

The rice was harvested depending upon the maturity of the crop and was done manually from each plot on May 6, 2008. The harvested crop of each plot was bundled separately, properly tagged and brought to the threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice seed. The grains were weighed in plot wise and finally the weight was adjusted to a moisture content of 14%. The straw was also sun dried, and weighed the yields of grain and straw plot^{-1} was converted to t ha^{-1}.

3.6 Data recording

The following data were recorded –

A. Growth parameters

1. Plant height (cm)
2. Number of tillers hill^{-1}
3. Dry weight plant^{-1} (g)

B. Yield and yield component parameters

1. Effective tillers $hill^{-1}$ (no.)
2. Non-effective tillers $hill^{-1}$ (no.)
3. Total tillers $hill^{-1}$ (no.)
4. Length of panicle (cm)
5. Unfilled grains $panicle^{-1}$ (no.)
6. Total grains $panicle^{-1}$(no.)
7. Weight of 1000 grains (g)
8. Grain yield (t ha^{-1})
9. Straw yield (t ha^{-1})
10. Biological yield (t ha^{-1})
11. Harvest index (%)

3.6.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at the time of 30, 50, 70 and 90 DAT, and at harvest. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaf before heading and tip of the flag leaf after heading.

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

The number of tillers $hill^{-1}$ was recorded at the time of 30, 50, 70 and 90 DAT by counting tillers. Data were recorded as the average tillers of 10 hills selected at random from the inner rows of each plot.

3.6.3 Dry matter plant^{-1} (g)

Total dry matter plant^{-1} was recorded at 30, 50, 70 and 90 DAT, and at harvest by drying plant sample. Data were recorded as the average of 3 sample plants selected at random from the inner rows of each plot. For drying randomly, selected 100 g plant sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 60^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. Then the final weight of the sample was taken. The average weight of three plants was considered as dry matter plant^{-1}.

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

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing hill plant^{-1}. Data on effective tillers hill^{-1} was counted from 10 selected hills and average value was recorded.

3.6.5 Non-effective tillers hill^{-1} (no.)

The total number of non-effective tillers hill^{-1} was counted as the number of non- panicle bearing hill plant^{-1}. Data on non-effective tillers hill^{-1} was counted from 10 selected hills and average value was recorded.

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

The total number of tillers hill^{-1} was counted as the number of effective tillers hill^{-1} and non-effective tillers hill^{-1}. Data on total tillers hill^{-1} was counted from 10 selected hills and average value was recorded.

3.6.7 Panicle length (cm)

The length of panicle was measured with a meter scale from the panicles of 10 randomly selected plants and the average value was recorded as plant panicle length plant^{-1}.

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

The total number of filled grains panicle^{-1} was collected from 10 randomly selected plants of each plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} was recorded.

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

The total number of unfilled grains panicle^{-1} was collected from 10 randomly selected plants of each plot on the basis of unfilled grains in the spikelet and then averaged them to have unfilled grains panicle^{-1}.The grains which remained empty inside were considered as unfilled grains .

3.6.10 Total grains panicle^{-1}(no.)

The total number of grains panicle^{-1} was recorded from 10 randomly selected plants of each plot by adding filled and unfilled grains and then averaged the numbers to have total grains panicle^{-1}.

3.6.11 Weight of 1000- grains (g)

One thousand grains were counted randomly from the total cleaned harvested seeds from each plot and then weighted in grams to have weight of 1000-grains.

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

The dry weight of grains from central 3 m^2 area was taken from each plot and finally converted them to have t ha^{-1}. The grains weight was adjusted with 14% moisture basis.

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

The dry weight of straw of central 3 m^2 area from each plot was recorded and finally converted to t ha^{-1}.

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

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

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

3.6.15 Harvest index (%)

The harvest index was calculated on the ratio of economic yield (grain yield) to biological yield and expressed in terms of percentage. It was calculated by using the following formula (Gardner *et al.*, 1985).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (Grain + straw dry weight)}} \times 100$$

3.7 Statistical Analysis

The data collected on different parameters were statistically analyzed to obtain the level of significance using the MSTAT-C computer package program developed by Russel (1986). Mean differences among the treatments were tasted with the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was conducted to determine the effect of N application and seedling types on the growth and yield of *Boro* rice. Data on different growth parameters, yield attributes and yield were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendices V-IX. The results have been presented and possible interpretations given under the following headings:

4.1 Plant height

Plant height of BRRI dhan29 varied significantly due to different level of N application at 30, 50, 70 and 90 DAT, and at harvest (Table 2 and Appendix V). It can be inferred from the results that application of nitrogen (either spliting or Guti urea) enhanced the plant height over control for all sampling dates. At all sampling dates the tallest plants (24.29, 31.11, 45.09, 70.67 and 85.58 cm, respectively for 30, 50, 70 and 90 DAT, and at harvest) were recorded from N_4 (Urea Super Granules) which was followed (23.15, 30.03, 43.74, 65.69 and 85.58 cm, respectively for 30, 50, 70 and 90 DAT, and at harvest, respectively) by N_3 (3 splits of N + additional 10 kg N ha^{-1} at flowering stage). On the other hand, at the same DAT the shortest plants (19.56, 25.13, 38.47, 54.91 and 73.76 cm, respectively at 30, 50, 70 and 90 DAT, and at harvest) were observed from N_0 (No nitrogen) treatment. The present result is in contrast with the findings of Akanda *et al.* (1991), who stated that split application of nitrogen fertilizer had no significant effect on plant height.

Table 2. Effect of N application and seedling types on plant height of *Boro* rice

Treatment	Plant height (cm) at				
	30 DAT	50 DAT	70 DAT	90 DAT	Harvest
N application					
N_0	19.56 e	25.13 d	38.47 e	54.91 d	73.76 d
N_1	20.91 d	27.33 c	41.60 d	60.33 c	79.82 c
N_2	22.40 c	29.87 b	43.02 c	64.98 b	85.62 b
N_3	23.15 b	30.03 b	43.74 b	65.69 b	85.58 b
N_4	24.29 a	31.11 a	45.09 a	70.67 a	87.46 a
$LSD_{(0.05)}$	0.485	1.000	0.486	1.143	1.022
Level of significance	0.01	0.01	0.01	0.01	0.01
Seedling type					
S_1	20.39 c	26.46 c	40.66 c	60.77 c	80.68 c
S_2	22.01 b	28.87 b	42.29 b	63.61 b	82.68 b
S_3	23.78 a	30.75 a	44.20 a	65.56 a	83.98 a
$LSD_{(0.05)}$	0.313	0.524	0.375	0.696	0.717
Level of significance	0.01	0.01	0.01	0.01	0.01
CV (%)	6.86	9.40	11.16	5.44	10.14

In a column means having similar letter(s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

N_0 = No nitrogen (control)

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules (Guti Urea)

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

Plant height of BRRI dhan29 differed significantly due to the different seedling types at 30, 50, 70 and 90 DAT, and at harvest (Table 2 and Appendix V). Among the seedlings obtained from different beds, S_3 (Robust seedling from modified mat nursery) showed its superiority by producing taller plants for all sampling dates (at 30, 50, 70 and 90 DAT, and at harvest) over seedlings obtained from S_2 (Seedling produced as recommended by BRRI) and S_1 (Farmers' practiced nursery bed) beds. Seedlings obtained from S_1 (Farmers' practiced bed) showed significantly shortest plants 20.39 cm, 26.46 cm, 40.66 cm, 60.77 cm and 80.68 cm for 30, 50, 70 and 90 DAT, and at harvest, respectively. It is revealed that modified mat nursery produced healthy seedlings that ensure maximum vegetative growth with tallest plant. Pasuquin *et al.* (2007) reported that seedlings from modified mat nursery recovered quickly and produce tallest plant than other seedlings types which confirms the present result.

Statistically significant variation was found due to interaction effect of N application and seedling types in terms of plant height of BRRI dhan29 at 30, 50, 70 and 90 DAT, and at harvest (Table 3 and Appendix V). The highest plant height (25.67 cm, 33.60 cm, 47.20 cm, 75.60 cm and 87.20 cm) was observed from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) at 30, 50, 70 and 90 DAT, and at harvest, respectively where as the lowest plant height (17.40 cm, 23.27 cm, 35.74 cm, 52.60 cm and 72.60 cm) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices) combination for 30, 50, 70 and 90 DAT, and at harvest, respectively.

Table 3. Interaction effect of N application and seedling types on plant height of *Boro* rice

Treatment	Plant height (cm) at				
	30 DAT	50 DAT	70 DAT	90 DAT	Harvest
N_0S_1	17.40 i	23.27 g	35.74 i	52.60 j	72.60 j
N_0S_2	20.07 g	25.47 f	39.66 h	55.67 i	73.54 ij
N_0S_3	21.20 ef	26.67 e	40.00 h	56.47 i	75.13 hi
N_1S_1	19.27 h	24.71 f	39.80 h	58.93 h	76.60 h
N_1S_2	20.60 fg	27.13 de	41.00 g	60.60 g	80.40 g
N_1S_3	22.87 c	30.13 c	44.00 cd	61.47 g	82.46 f
N_2S_1	20.93 f	27.80 de	41.33 g	63.34 f	84.73 e
N_2S_2	21.93 de	30.13 c	42.93 ef	65.00 d-f	86.53 b-d
N_2S_3	24.33 b	31.67 b	44.80 bc	66.60 cd	85.60 c-e
N_3S_1	21.87 de	28.20 d	42.63 f	64.00 ef	85.34 de
N_3S_2	22.73 c	30.20 c	43.60 de	65.40 de	87.53 b
N_3S_3	24.84 b	31.69 b	45.00 b	67.67 c	89.50 a
N_4S_1	22.47 cd	28.34 d	43.80 de	65.00 d-f	84.13 e
N_4S_2	24.73 b	31.40 b	44.27 b-d	71.40 b	85.40 de
N_4S_3	25.67 a	33.60 a	47.20 a	75.60 a	87.20 bc
$LSD_{(0.05)}$	0.700	1.171	0.838	1.557	1.602
Level of significance	0.01	0.05	0.01	0.01	0.01
CV (%)	6.86	9.40	11.16	5.44	10.14

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

4.2 Number of tillers hill^{-1}

Statistically significant variation was observed for number of tillers hill^{-1} of BRRI dhan29 due to different forms of N application at 30, 50, 70 and 90 DAT (Table 4 and Appendix VI). In general, application of nitrogen enhanced the tillers production hill^{-1} over control. At the different days after transplanting (DAT) the maximum number of tillers hill^{-1} (5.79, 11.72, 23.10 and 18.31 for 30, 50, 70 and 90 DAT, respectively) was obtained from N_4 (Urea Super Granules). The second highest tillers hill^{-1} (4.96, 10.44, 19.82 and 16.13 for 30, 50, 70 and 90 DAT, respectively) was recorded by N_3 (3 splits of N + additional 10 kg N ha^{-1} at flowering stage). On the other hand, at the same DAT the minimum number of tillers hill^{-1} (3.38, 6.50, 14.05 and 11.36) was recorded from N_0 (control condition). Similar result was found by Singh and Singh (1986) who reported that number of tillers m^{-2} increased with the increasing nitrogen fertilizer.

Number of tillers hill^{-1} of BRRI dhan29 varied significantly due to the different seedling types at different sampling days after transplanting of 30, 50, 70 and 90 DAT (Appendix VI). At 30, 50, 70 and 90 DAT, the maximum number of tillers hill^{-1} (5.07, 10.99, 20.28 and 16.81, respectively) were found from S_3 (Robust seedling from modified mat nursery) which was closely followed (4.54, 9.34, 18.75 and 14.79, respectively) by S_2 (Seedling produced as recommended by BRRI.

Table 4. Effect of N application and seedling types on number of tillers hill^{-1} of *Boro* rice

Treatment	Number of tillers hill^{-1} at			
	30 DAT	50 DAT	70 DAT	90 DAT
N application				
N_0	3.38 e	6.50 d	14.05 e	11.36 e
N_1	3.76 d	8.66 c	16.80 d	12.75 d
N_2	4.73 c	10.20 b	18.82 c	15.55 c
N_3	4.96 b	10.44 b	19.82 b	16.13 b
N_4	5.79 a	11.72 a	23.10 a	18.31 a
$LSD_{(0.05)}$	0.091	0.444	0.330	0.069
Level of significance	0.01	0.01	0.01	0.01
Seedling type				
S_1	3.97 c	8.17 c	16.53 c	12.86 c
S_2	4.54 b	9.34 b	18.75 b	14.79 b
S_3	5.07 a	10.99 a	20.28 a	16.81 a
$LSD_{(0.05)}$	0.048	0.280	0.213	0.034
Level of significance	0.01	0.01	0.01	0.01
CV (%)	7.44	5.87	12.51	10.33

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

Again, the minimum number of tillers hill^{-1} (3.97, 8.17, 16.53 and 12.86) at 30, 50, 70 and 90 DAT, respectively) was observed from S_1 as normal seedling of farmers' practices (Table 4). It was revealed that modified mat nursery produced healthy seedling that ensured maximum vegetative growth with maximum number of tillers. The result was in consistence with the findings of Pasuquin *et al.* (2007) that seedlings from modified mat nursery recovered quickly and produce maximum number of tillers than other seedlings types.

Interaction effect of N application and seedling types in terms of number of tillers hill^{-1} of BRRI dhan29 showed statistically significant variation at 30, 50, 70 and 90 DAT (Table 5 and Appendix VI). The maximum number of tillers hill^{-1} (6.60, 13.33, 25.26 and 20.86 at 30, 50, 70 and 90 DAT, respectively) was observed from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) where as the minimum number of tillers hill^{-1} (3.11, 5.80, 12.63 and 10.53) at 30, 50, 70 and 90 DAT, respectively) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices).

Table 5. Interaction effect of N application and seedling types on number of tillers $hill^{-1}$ of *Boro* rice

Treatment	Number of tillers $hill^{-1}$ at			
	30 DAT	50 DAT	70 DAT	90 DAT
N_0S_1	3.11 k	5.80 f	12.63 j	10.53 m
N_0S_2	3.23 j	6.40 f	14.23 i	11.16 l
N_0S_3	3.80 i	7.30 e	15.30 gh	12.40 k
N_1S_1	3.26 j	7.26 e	15.13 h	11.12 l
N_1S_2	3.90 i	8.26 d	17.16 f	12.60 j
N_1S_3	4.13 h	10.46 c	18.10 e	14.53 g
N_2S_1	4.12 h	8.73 d	15.70 g	13.06 i
N_2S_2	4.83 f	10.00 c	19.46 d	15.80 f
N_2S_3	5.23 d	11.86 b	21.30 c	17.80 d
N_3S_1	4.36 g	8.78 d	18.26 e	13.75 h
N_3S_2	4.92 ef	10.53 c	19.76 d	16.17 e
N_3S_3	5.60 c	12.00 b	21.43 c	18.47 b
N_4S_1	4.98 e	10.29 c	20.93 c	15.86 f
N_4S_2	5.80 b	11.53 b	23.12 b	18.22 c
N_4S_3	6.60 a	13.33 a	25.26 a	20.86 a
$LSD_{(0.05)}$	0.108	0.626	0.476	0.076
Level of significance	0.01	0.01	0.01	0.01
CV (%)	7.44	5.87	12.51	10.33

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

4.3 Dry matter plant^{-1}

Dry matter plant^{-1} of BRRI dhan29 exerted significant variation due to the application of different N application at 30, 50, 70 and 90 DAT, and at harvest (Appendix VII). In general, application of N at various forms enhanced the production of dry matter plant^{-1} over control treatment. However, for 30, 50, 70 and 90 DAT, and at harvest the highest dry matter plant^{-1} 0.524, 3.46, 15.29, 25.89 and 56.88 g, respectively were recorded from N_4 (Urea Super Granules). The treatment N_3 (0.458, 2.78 , 12.01 , 21.84 and 52.89 g at 30, 50, 70 and 90 DAT, and at harvest, respectively) and N_2 (0.382 , 2.19 , 9.36 , 19.60 and 40.52 g at 30, 50, 70 and 90 DAT, and at harvest, respectively) showed the statistically similar, and second and third highest dry weight plant^{-1} (Table 6). On the other hand, significantly the lowest dry matter plant^{-1} (0.333, 1.54, 6.74, 14.41 and 29.86 g at 30, 50, 70 and 90 DAT, and at harvest, respectively) was found from N_0 (No nitrogen) treatment.

Significant variation was found due to the different seedling types for dry matter plant^{-1} of BRRI dhan29 at 30, 50, 70, 90 DAT, and at harvest (Appendix VII). Seedlings obtained from modified mat nursery produced significantly highest dry matter plant^{-1} than other type of seedlings for all the days after transplanting (Table 6).

Table 6. Effect of N application and seedling types on dry matter plant^{-1} of *Boro* rice

Treatment	Dry matter plant^{-1} at				
	30 DAT	50 DAT	70 DAT	90 DAT	Harvest
N application					
N_0	0.333 d	1.54 d	6.74 d	14.41 d	29.86 d
N_1	0.382 c	2.19 c	9.36 c	19.60 c	40.52 c
N_2	0.448 b	2.69 b	11.89 b	21.56 b	52.40 b
N_3	0.458 b	2.78 b	12.01 b	21.84 b	52.89 b
N_4	0.524 a	3.46 a	15.29 a	25.89 a	56.88 a
$LSD_{(0.05)}$	0.034	0.168	0.486	0.284	1.368
Level of significance	0.01	0.01	0.01	0.01	0.01
Seedling type					
S_1	0.361 c	2.20 c	9.68 c	19.42 c	43.38 c
S_2	0.411 b	2.37 b	10.81 b	20.45 b	46.01 b
S_3	0.515 a	3.02 a	12.68 a	22.11 a	50.14 a
$LSD_{(0.05)}$	0.024	0.048	0.539	0.197	0.871
Level of significance	0.01	0.01	0.01	0.01	0.01
CV (%)	6.13	8.27	6.40	7.25	6.46

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

On the other hand, seedlings of farmers' practiced nursery bed produced the lowest values of dry matter plant^{-1} for all DAT. It can be inferred from the result that modified nursery bed seedling showed its superiority by producing 0.154 , 0.82, 3.00,2.69 and 6.76 g higher dry matter than farmers' practiced seedling and 0.104, 0.65, 1.87, 1.66 and 4.13 g higher than BRRI recommended practiced seedlings at 30, 50, 70 and 90 DAT, and at harvest, respectively. The highest dry matter plant^{-1} in modified nursery may perhaps produce healthy seedlings in this type of bed which ensure maximum vegetative growth with tallest plant and highest number of tillers plant^{-1}.

Dry matter plant^{-1} showed significant variation due to interaction effect of N application and seedling types of BRRI dhan29 at 30, 50, 70 and 90 DAT, and at harvest (Table 7and Appendix VII). The interaction of N_4S_3 seemed to be promising by producing highest dry matter plant^{-1} of 0.633, 4.31, 17.56, 27.44 and 59.94 g at 30, 50, 70 and 90 DAT, and at harvest, respectively which was significantly highest than all other interaction. The lowest dry matter plant^{-1} (0.293, 1.41, 5.92, 13.67 and 27.98 g at 30, 50, 70 and 90 DAT, and at harvest, respectively) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices) combination.

Table 7. Interaction effect of N application and seedling types on dry matter plant^{-1} of *Boro* rice

Treatment	Dry matter plant^{-1} at				
	30 DAT	50 DAT	70 DAT	90 DAT	Harvest
N_0S_1	0.293 g	1.41 j	5.92 i	13.67 l	27.98 k
N_0S_2	0.333 fg	1.44 j	7.04 hi	14.23 k	28.74 k
N_0S_3	0.373 ef	1.76 i	7.25 gh	15.33 j	32.87 j
N_1S_1	0.313 g	1.92 h	8.32 fg	18.45 i	37.82 i
N_1S_2	0.380 ef	2.12 g	9.23 ef	19.23 h	39.93 h
N_1S_3	0.453 cd	2.52 e	10.54 d	21.11 f	43.82 g
N_2S_1	0.370 ef	2.31 f	10.32 de	19.97 g	47.92 f
N_2S_2	0.420 de	2.54 e	11.46 d	21.52 ef	52.40 e
N_2S_3	0.553 b	3.22 bc	13.89 bc	23.19 d	56.88 b
N_3S_1	0.380 ef	2.40 f	10.38 de	20.24 g	48.47 f
N_3S_2	0.430 de	2.63 e	11.49 d	21.79 e	53.02 de
N_3S_3	0.563 b	3.31 b	14.15 bc	23.49 d	57.17 b
N_4S_1	0.450 cd	2.94 d	13.48 c	24.78 c	54.72 cd
N_4S_2	0.490 c	3.12 c	14.82 b	25.46 b	55.98 bc
N_4S_3	0.633 a	4.31 a	17.56 a	27.44 a	59.94 a
$LSD_{(0.05)}$	0.054	0.108	1.201	0.441	1.947
Level of significance	0.05	0.05	0.05	0.01	0.05
CV (%)	6.13	8.27	6.40	7.25	6.46

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

4.4 Number of effective tillers hill^{-1}

Effective tillers hill^{-1} of BRRI dhan29 showed statistically significant variation due to N applications (Appendix VIII). The trend of production of effective tillers hill^{-1} was that the control treatment (No nitrogen) showed the lowest number and then the number increases gradually with increases of nitrogen spliting. The highest increase (13.33) was found with the application of N_4 as Urea Super Granules treatment. The result also revealed that among the nitrogen spliting treatments N_3 (3 splits of N + additional 10 kg N ha^{-1}) showed higher effective tillers hill^{-1} (12.77). It was also observed that Urea Super Granules (N_4) produced 50.45, 36.86, 8.02, 4.93 % higher effective tiller hill^{-1} than N_0 (control), N_1 (2splits of N), N_2 (3 splits of N) and N_3 (3 splits of N + additional 10 kg N ha^{-1}) treatments respectively. The result was consistence with the findings of Bayan and Kandasamy (2002) who reported split application of N showed higher effective tilles hill^{-1}.

Number of effective tillers hill^{-1}of BRRI dhan29 exerted significant difference due to different seedling types (Appendix VIII). The maximum number of effective tillers hill^{-1} (12.46) was obtained from S_3 (Robust seedling from modified mat nursery) which was closely followed by S_2 (Seedling produced as recommended by BRRI). However, the minimum number of effective tillers hill^{-1} (10.63) was observed from S_1 as normal seedling of farmer's practices (Table 8). The result corroborates with the findings of Pasuquin *et al.* (2007) that seedlings from modified mat nursery produced higher tillers hill^{-1} than other seedlings which may perhaps due to modified mat nursery recovered quickly that ensure maximum vegetative growth and maximum number of effective tillers hill^{-1}.

Statistically significant variation was observed due to interaction effect of N application and seedling types in respect of number of effective tillers hill^{-1} of BRRI dhan29 (Table 9 and Appendix VIII). The maximum number of effective tillers hill^{-1} (14.14) was recorded from the interaction of N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) which was statistically similar with the interaction of N_3S_3 (3 splits of N + additional 10 kg N ha^{-1}× Robust seedling from modified mat nursery) and the minimum number of effective tillers hill^{-1} (8.08) was recorded from the interaction of N_0S_1 (control × normal seedling produced following farmers' practices).

4.5 Number non-effective tillers hill^{-1}

Non-effective tillers hill^{-1} varied significantly due of nitrogen application at different splitting (Table 8 and Appendix VIII). The maximum number of non-effective tillers hill^{-1} (4.45) was obtained from N_4 (Urea Super Granules) which was followed by N_3 (3 splits of N + additional 10 kg N ha^{-1} at flowering stage) 3.56 and 3.36, respectively and N_2 (3 splits of N). The minimum number of non-effective tillers hill^{-1} (2.25) was observed from N_0 (control condition) which was significantly lower than those of the nitrogen treatment.

Table 8. Effect of N application and seedling types on yield contributing characters of *Boro* rice

Treatment	Effective tillers $hill^{-1}$ (no.)	Non-effective tillers $hill^{-1}$ (no.)	Length of panicle (cm)	Number of filled grains $panicle^{-1}$	Number of unfilled grains $panicle^{-1}$	Weight of 1000 grains (g)
N application						
N_0	8.86 e	2.25 d	21.09 e	64.43 e	12.21 a	19.42 e
N_1	9.74 d	2.75 c	21.85 d	79.86 d	8.76 b	20.27 d
N_2	12.34 c	3.36 b	23.05 c	88.47 c	7.97 c	21.12 c
N_3	12.77 b	3.56 b	23.50 b	89.66 b	6.34 d	21.58 b
N_4	13.33 a	4.45 a	23.92 a	92.62 a	5.21 e	22.24 a
$LSD_{(0.05)}$	0.203	0.370	0.260	0.648	0.699	0.910
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
Seedling types						
S_1	10.63 c	2.64 c	21.41 c	80.68 c	9.34 a	20.56 c
S_2	11.13 b	3.20 b	22.72 b	83.27 b	8.20 b	20.98 b
S_3	12.46 a	3.98 a	23.92 a	85.06 a	6.75 c	21.24 a
$LSD_{(0.05)}$	0.162	0.225	0.170	0.321	0.487	0.108
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	7.86	9.00	10.99	8.51	7.89	9.68

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

Number of non-effective tillers hill^{-1} differed significantly due to the different seedling types of BRRI dhan29 (Table 8 and Appendix VIII). The maximum number of non-effective tillers hill^{-1} (3.98) was recorded from S_3 (Robust seedling from modified mat nursery) and that of second highest (3.20) was found in S_2 (Seedling produced as recommended by BRRI). Again, the minimum number of non-effective tillers hill^{-1} (2.64) was recorded from S_1 (normal seedling produced following farmer's practices).

Interaction effect of N application and seedling types showed statistically significant variation in respect of number of non-effective tillers hill^{-1} of BRRI dhan29 (Table 9 and Appendix VIII). The maximum number of non-effective tiller hill^{-1} (5.72) was recorded from the interaction of N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) and the minimum number of non-effective tiller hill^{-1} (2.10) was recorded from the interaction of N_0S_1 (No nitrogen × normal seedling produced following farmer's practices) which was statistically similar with the interaction of N_0S_2 (No nitrogen × seedling produced as recommended by BRRI), N_0S_3(No nitrogen × Robust seedling from modified mat nursery) and N_1S_1 (2 splits of N× normal seedling produced following farmers' practices).

4.6 Number of total tillers hill^{-1}

Total tillers hill^{-1} of BRRI dhan29 exerted significant variation due to the application of different N application (Appendix VIII and Figure 1). The figure shows that N_0 (No nitrogen) treatment gave the lowest number of total tillers hill^{-1} and the values of total tillers hill^{-1} increased gradually with the increases of nitrogen spliting and Guti urea application. The highest total tillers hill^{-1} (17.78) was counted in Guti urea application and that of second highest (16.33) recorded in N_3 (3 splits of N + additional 10 kg N ha^{-1} at flowering stage) treatment.

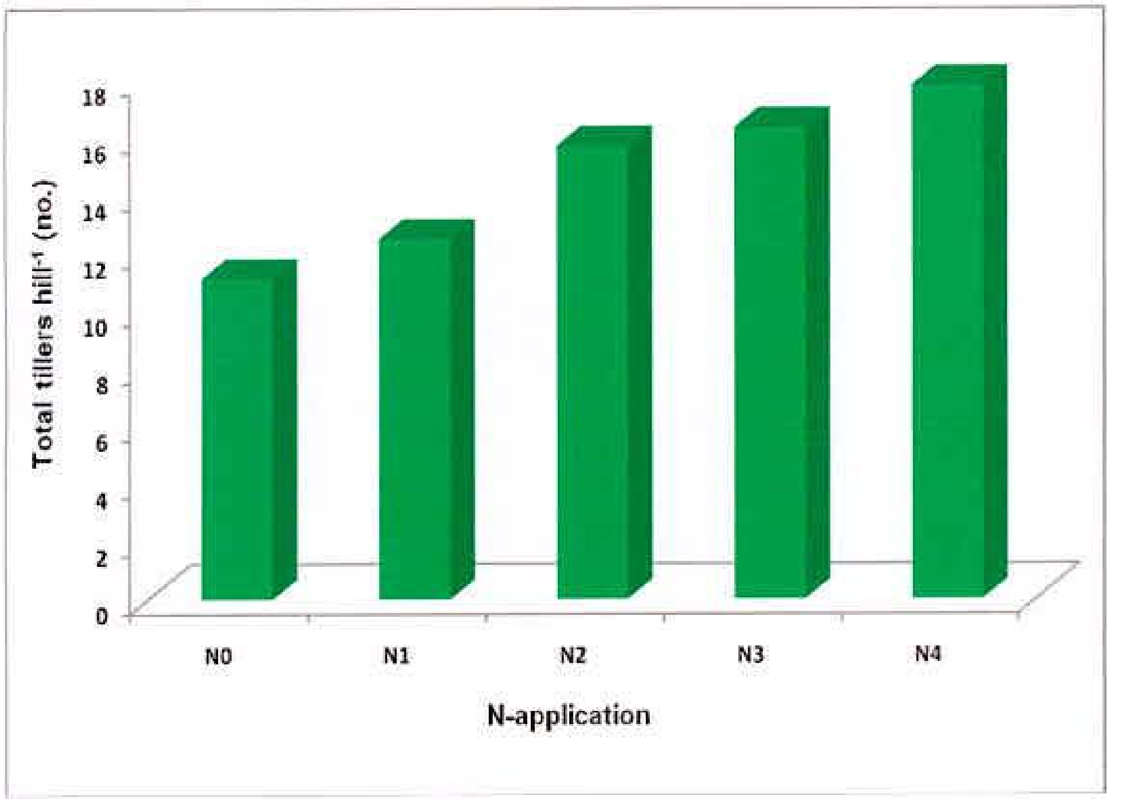


Figure 1. Effect of N application on number of total tillers hill^{-1} of *Boro* rice ($LSD_{0.05}$ = 0.501)

N_0 = No nitrogen
N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)
N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)
N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage + additional 10 kg N ha^{-1} at flowering stage)
N_4 = Urea Super Granules

Number of total tillers $hill^{-1}$ of BRRI dhan29 differed significantly due to the different seedling types (Figure 2 and Appendix VIII). The maximum number of total tillers $hill^{-1}$ (16.44) was recorded from S_3 (Robust seedling from modified mat nursery) which was followed by S_2 (Seedling produced as recommended by BRRI) treatment. However, the minimum number of total tillers $hill^{-1}$ (13.27) was obtained from S_1 (normal seedling produced following farmers' practices) treatment.

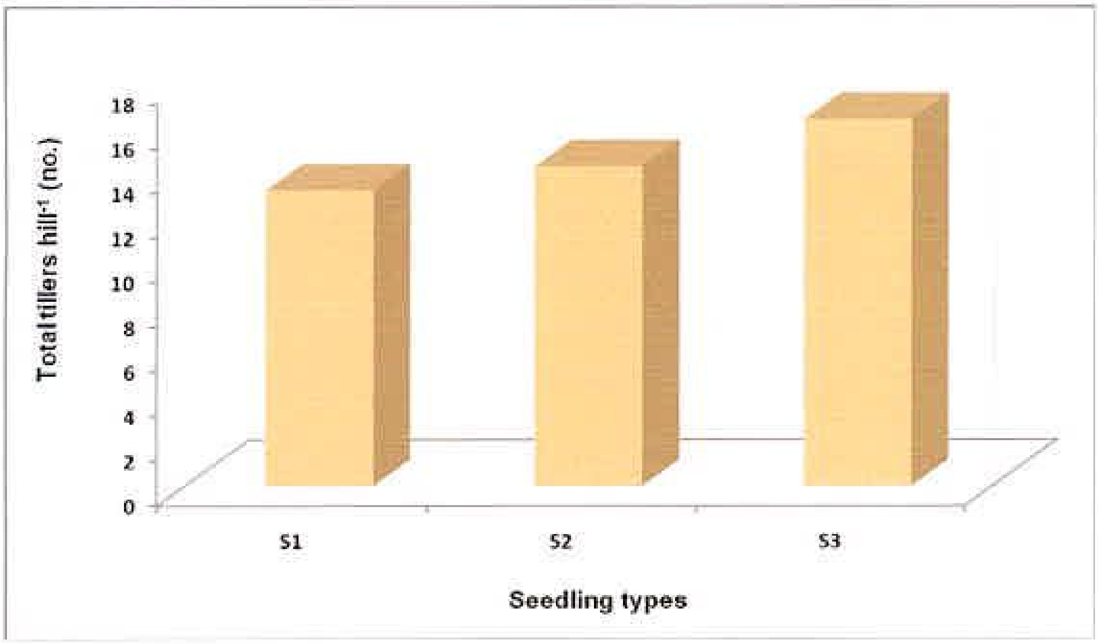


Figure 2. Effect of seedling types on number of total tillers $hill^{-1}$ of *Boro* rice ($LSD_{0.05}$ = 0.262)

S_1 = Normal seedling (produced following farmers' practices)
S_2 = Seedling produced as recommended by BRRI
S_3 = Robust seedling from modified mat nursery

Statistically significant variation was found in total tillers $hill^{-1}$ due to interaction effect of N application and seedling types (Appendix VIII). The interaction effect of N application and seedling types on total tillers $hill^{-1}$ has been presented in Figure 3. The figure shows that irrespective of seedling types the value of total tillers $hill^{-1}$ showed increasing trend with the increases of N spiliting and the highest increase was found in guti urea treatment. On the other hand, irrespective N application, robust seedling from modified mat nursery showed the highest tillers than others. The maximum number of total tillers $hill^{-1}$ (19.86) was found from the interaction of N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) and the minimum number of total tillers $hill^{-1}$ (10.18) was observed from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices)

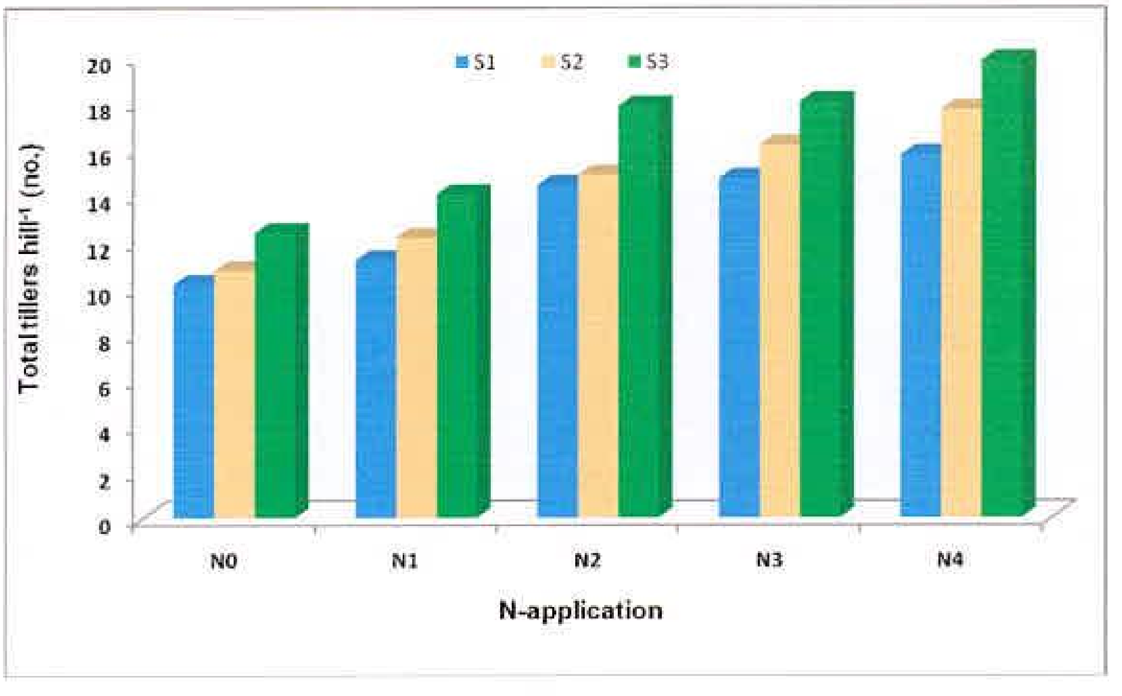


Figure 3. Interaction effect of N application and seedling types on number of total tillers $hill^{-1}$ of *Boro* rice ($LSD_{0.05}$ = 0.587)

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

4.7 Panicle Length (cm)

N splitting on length of panicle in rice was found significant (Appendix VIII). Application of nitrogen in spliting or Guti urea form enhanced panicle length over control (N_0) treatment which indicated that the treatment N_4 (Urea Super Granules), N_3 (3 splits of N + additional 10 kg N ha^{-1}), N_2 (3 splits of N) and N_1 (2 splits of N) increased 11.83, 10.25, 4.99 and 3.47 % higher panicle length than N_0 (No Nitrogen) application treatment (Table 8). These results were in agreement with the findings of Reddy *et al.* (1987) who observed that split application of nitrogen increased panicle length of rice.

The values of length of panicle of BRRI dhan29 differed significantly due to the different seedling types (Table 8 and Appendix VIII). It was observed that S_3 (Robust seedling from modified mat nursery) gave the longest panicle (23.92 cm). The shortest panicle (21.41 cm) was recorded from S_1 (normal seedling produced following farmers' practices). A panicle length increment of 2.51 cm and 1.20 cm were found in robust seedling over S_1 and S_2 types of seedlings.

Statistically significant variation was recorded due to interaction effect of N application and seedling types in terms of length of panicle in BRRI dhan29 (Table 9 and Appendix VIII). The interaction of Urea Super Granules × Robust seedling from modified mat nursery showed the longest panicle (24.83 cm) which was statistically similar with N_3S_3 (3 splits of N + additional 10 kg N ha^{-1}× Robust seedling from modified mat nursery). The shortest panicle (20.00 cm) was recorded from N_0S_1 (control × normal seedling produced following farmer's practices) which was significantly lowest other interaction.

Table 9. Interaction effect of N application and seedling types on yield contributing characters of *Boro* rice

Treatment	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Length of panicle (cm)	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Weight of 1000 - grains (g)
N_0S_1	8.08 j	2.10 i	20.00 k	62.00 n	14.61 a	19.20 h
N_0S_2	8.60 i	2.16 hi	20.87 i	64.83 m	12.50 b	19.37 h
N_0S_3	9.90 f	2.50 f-i	22.40 ef	66.47 l	9.53 c	19.70 g
N_1S_1	9.00 h	2.22 g-i	20.47 j	77.60 k	9.65 c	19.90 g
N_1S_2	9.43 g	2.76 e-g	21.43 h	79.73 j	9.23 c	20.20 f
N_1S_3	10.80 e	3.26 c-e	23.66 c	82.23 i	7.41 ef	20.70 e
N_2S_1	11.80 d	2.66 f-h	22.13 fg	85.93 h	8.88 cd	20.60 e
N_2S_2	11.57 d	3.27 c-e	23.12 d	88.93 f	7.90 de	21.20 d
N_2S_3	13.67 b	4.14 b	23.90 c	90.53 de	7.13 ef	21.57 c
N_3S_1	11.90 d	2.85 d-f	21.83 g	86.97 g	7.08 ef	21.20 d
N_3S_2	12.60 c	3.57 c	23.86 c	89.93 e	6.48 fg	21.70 bc
N_3S_3	13.80 ab	4.27 b	24.80 a	92.07 c	5.45 gh	21.83 b
N_4S_1	12.37 c	3.39 cd	22.63 e	90.90 d	6.48 fg	21.90 b
N_4S_2	13.47 b	4.25 b	24.30 b	92.93 b	4.91 hi	22.41 a
N_4S_3	14.14 a	5.72 a	24.83 a	94.02 a	4.25 i	22.41 a
$LSD_{(0.05)}$	0.361	0.502	0.381	0.717	1.088	0.241
Level of significance	0.05	0.01	0.01	0.05	0.01	0.05
CV (%)	7.86	9.00	10.99	8.51	7.89	9.68

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

4.8 Number of filled grains panicle^{-1}

Due to the application of N in different splitting showed statistically significant variation in producing number of filled grains panicle^{-1} (Table 8 and Appendix VIII). The maximum number of filled grains panicle^{-1} (92.62) was recorded from N_4 (Urea Super Granules) treatment and the second highest (89.66) was recorded from N_3 (3 splits of N + additional 10 kg N ha^{-1} at flowering stage). On the other hand the minimum number of filled grains panicle^{-1} (64.43) was observed from N_0 (No nitrogen). The result was in consistence with the findings of Kapre *et al.* (1996) that Urea Super Granules produced the highest level of grains panicle^{-1}.

Number of filled grains panicle^{-1} of BRRI dhan29 differed significantly due to the different seedling types (Table 8 and Appendix VIII). The maximum number of filled grains panicle^{-1} (85.06) was recorded from S_3 (Robust seedling from modified mat nursery) and that of second highest (83.27) by S_2 (Seedling produced as recommended by BRRI). Again, the minimum number of filled grains panicle^{-1} (80.68) was found from S_1 (normal seedling produced following farmer's practices). It is revealed that modified mat nursery produced healthy seedling that ensure maximum vegetative growth with maximum number of filled grains panicle^{-1}.

Statistically significant variation was recorded due to interaction effect of N application and seedling types in terms of number of filled grains panicle^{-1} of BRRI dhan29 (Table 9 and Appendix VIII). The maximum number of filled grains panicle^{-1} (94.02) was recorded from the interaction of N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) and the minimum number of filled grain plant^{-1} (62.00) was recorded from N_0S_1 (control × normal seedling produced following farmers' practices) combination.

4.9 Number of unfilled grains panicle^{-1}

Different forms of N application showed statistically significant variation on the number of unfilled grains panicle^{-1} of BRRI dhan29 (Appendix VIII). The minimum number of unfilled grains panicle^{-1} (5.21) was observed from N_4 as Urea Super Granules (Table 8). On the other hand, the maximum number of unfilled grains panicle^{-1} (12.21) was observed from N_0 (no nitrogen) condition.

Number of unfilled grains panicle^{-1} of BRRI dhan29 differed significantly due to seedling types (Table 8 and Appendix VIII). The minimum number of unfilled grains panicle^{-1} (6.75) was recorded from S_3 (Robust seedling from modified mat nursery) and the second highest was recorded from S_2 (Seedling produced as recommended by BRRI). Again, the maximum number of unfilled grains panicle^{-1} (9.34) was observed from S_1 (normal seedling of farmer's practices).

The interaction effect of N application and seedling types was found to be significant for unfilled grains panicle^{-1} (Table 9 and Appendix VIII). The minimum of number of unfilled grains panicle^{-1} (4.25) was found from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) which was statistically similar with N_4S_2 (Urea Super Granules × Seedling produced as recommended by BRRI) and N_3S_3 (3 splits of N + additional 10 kg N ha^{-1} at flowering stage × Robust seedling from modified mat nursery) the maximum number of unfilled grains $panicle^{-1}$ (14.61) was recorded from N_0S_1 (control × normal seedling produced following farmer's practices) combination.

4.10 Number of total grains panicle^{-1}

Significant variation was found in total number of grains $panicle^{-1}$ with different N application (Figure 4 and Appendix VIII). It can be inferred from the figure that application of N increased the total grains $panicle^{-1}$ at different levels. The maximum number of total grains $panicle^{-1}$ (97.83) was recorded from N_4 (Urea Super Granules) which was followed by N_2 (3 splits of N) and N_3 (3 splits of N + additional 10 kg N ha^{-1} at flowering stage). On the other hand, the minimum number of total grains $panicle^{-1}$ (76.65) was recorded from N_0 (No nitrogen). The similar results were also reported by Mondal and Swamy (2003) that split application of N increased the total grains $panicle^{-1}$.

The maximum number of grains $panicle^{-1}$ (91.82) was obtained from S_3 (Robust seedling from modified mat nursery) which was statistically similar with the S_2 (Seedling produced as recommended by BRRI). The treatment S_1 (normal seedling of farmers' field) gave the minimum number of total grains $panicle^{-1}$ (90.02) (Figure 5). For total grains $panicle^{-1}$, the seedling types may be graded as $S_3 > S_2 > S_1$.

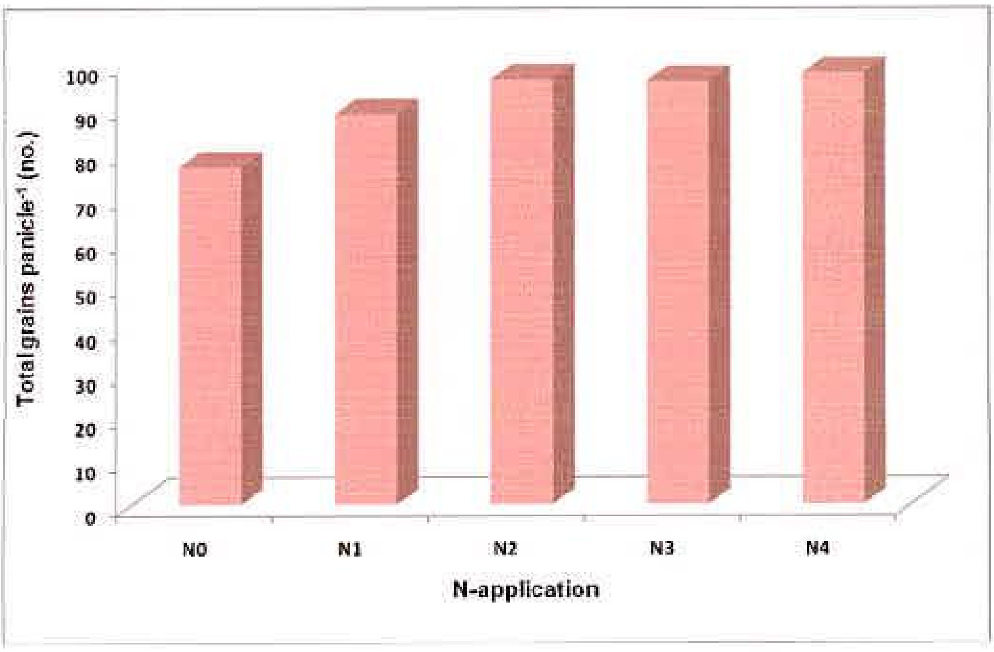


Figure 4. Effect of N application on number of total grains panicle^{-1}(LSD$_{0.05}$ = 0.923)

N_0 = No nitrogen
N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)
N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)
N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage + additional 10 kg N ha^{-1} at flowering stage)
N_4 = Urea Super Granules

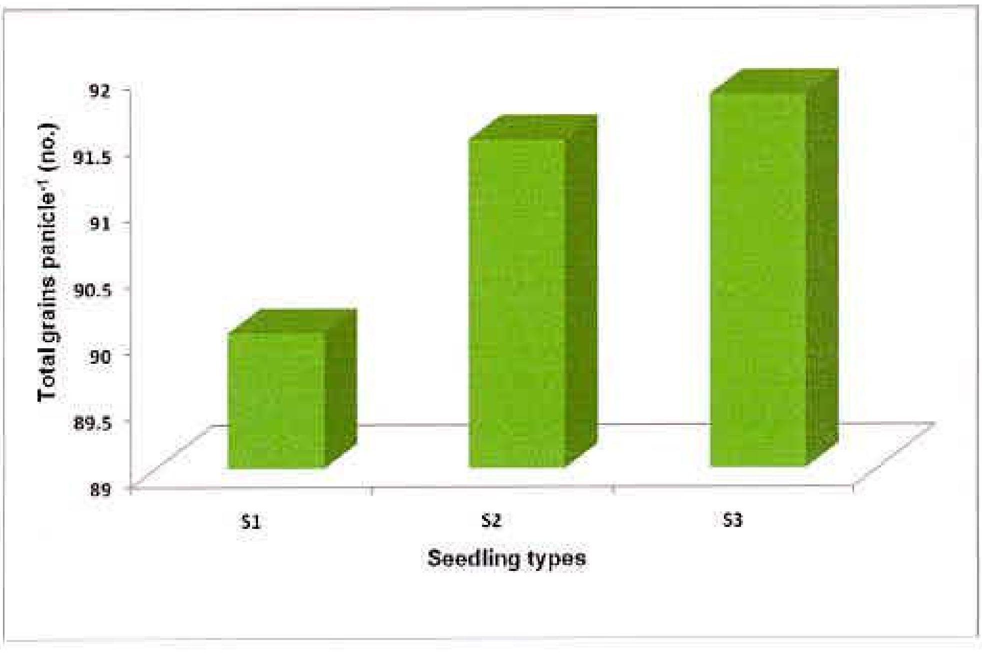


Figure 5. Effect of seedling types on number of total grains panicle^{-1} (LSD$_{0.05}$ = 0.629)

S_1 = Normal seedling (produced following farmers' practices)
S_2 = Seedling produced as recommended by BRRI
S_3 = Robust seedling from modified mat nursery

The total number of grains panicle^{-1} was influenced statistically by the interaction effect of N application and seedling types (Appendix VIII and Figure 6). The figure shows that total number of grains panicle^{-1} showed increasing trend due to split application of N for all seedling types. On the other hand, irrespective of nitrogen application with S_3 (Robust seedling from modified mat nursery) seedling produced higher level of total grains panicle^{-1} than other two (S_1 and S_2) seedling types except N_0S_3 interaction. However, the maximum number of total grains panicle^{-1} (98.27) was recorded from N_4S_3 (Urea Super Granules × robust seedling from modified mat nursery) and the minimum number of total grain panicle^{-1} (76.61) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices).

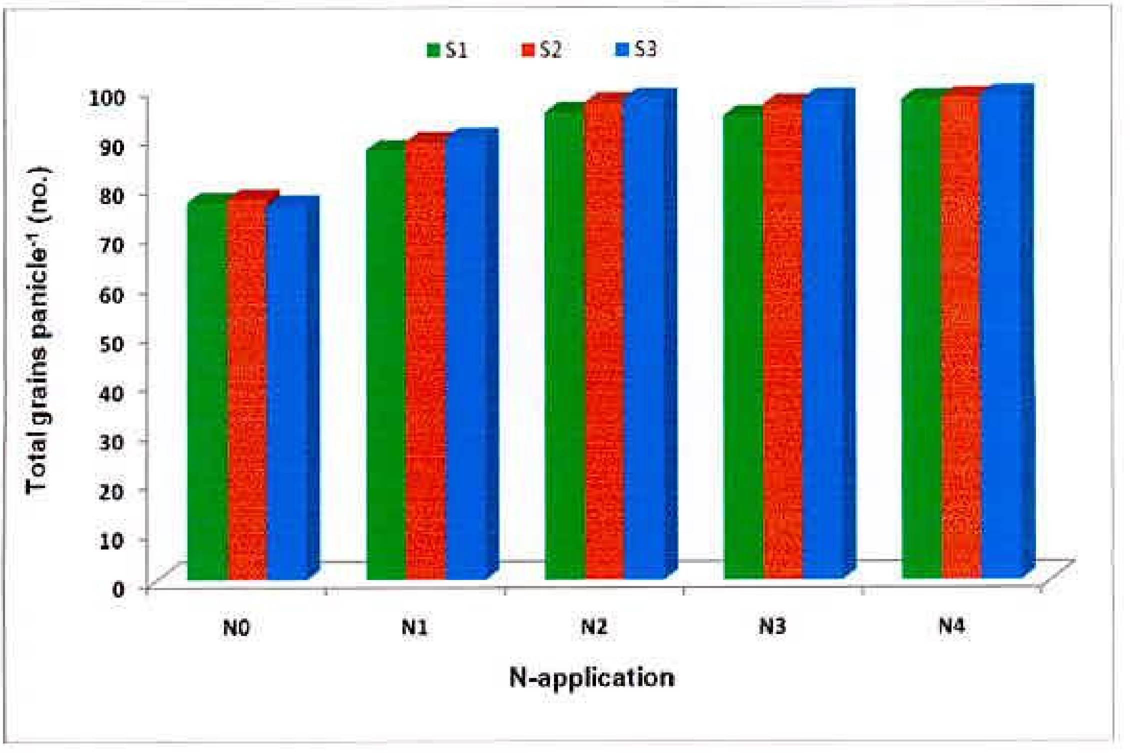


Figure 6. Interaction effect of nitrogen application and seedling types on number of total grains panicle^{-1} of *Boro rice* ($LSD_{0.05}$ =1.409)

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

4.11 Weight of 1000-grains (g)

Weight of 1000-grains of BRRI dhan29 showed significant variation due to the application of different N application (Appendix IX and Table 8). The result showed that application of N at various splitting along with Urea Super Granules increased the value of 1000-grains. The highest weight of 1000-grains (22.24 g) was recorded from N_4 (Urea Super Granules) treatment. Among the N splitting N_3 (3 splits of N+ additional 10 kg N ha^{-1}at flowering stage) showed the highest weight of 1000-grains and the values reduced with the reduced N splitting. The lowest weight of 1000-grains was found in N_0 (no nitrogen) treatment. Similar result was reported by Subhendu *et al.* (2003) that split application of N increased the weight of 1000-grains.

Weight of 1000-grains of BRRI dhan29 differed significantly due to the different seedling types (Table 8 and Appendix IX). The highest weight of 1000-grains (21.24 g) was observed from S_3 (Robust seedling from modified mat nursery) which was 3.30 and 1.24 % higher than S_1 (normal seedling of farmers' field) and S_2 (Seedling produced as recommended by BRRI) seedling types, respectively. However, the lowest 1000-grains weight (20.56 g) was recorded S_1 (normal seedling produced following farmers' practices).

Table 10. Effect of N application and seedling types on yield and harvest index contributing characters and yield of *Boro* rice

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
N application			
N_0	3.02 e	4.52 e	39.92 d
N_1	4.66 d	5.79 d	44.54 c
N_2	6.52 c	7.25 c	47.30 b
N_3	6.80 b	7.38 b	47.91 a
N_4	7.27 a	7.73 a	48.43 a
$LSD_{(0.05)}$	0.114	0.049	0.545
Level of significance	0.01	0.01	0.01
Seedling type			
S_1	5.10 c	6.22 c	44.26 c
S_2	5.60 b	6.45 b	45.67 b
S_3	6.27 a	6.92 a	46.93 a
$LSD_{(0.05)}$	0.064	0.042	0.341
Level of significance	0.01	0.01	0.01
CV (%)	7.50	6.78	8.98

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

Interaction effect of N application and seedling types differed significantly on 1000-grains weight (Table 9 and Appendix IX). The highest weight of 1000-grains (22.41 g) was found from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) which was statistically similar with N_4S_2 (Urea Super Granules × Seedling produced as recommended by BRRI) and the lowest weight of 1000-grains (19.20 g) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices) which was statistically similar with the interaction N_0S_2 (No nitrogen × Seedling produced as recommended by BRRI).

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

Grain yield was influenced significantly by the different N application (Table 10 and Appendix IX). Application of Urea Super Granules (N_4) treatment out yielded over N_0 (No nitrogen), N_1 (2 splits of N), N_2 (3 splits of N), and N_3 (3 splits of N + additional 10 kg N ha^{-1}at flowering stage) treatments by producing 4.25, 2.61, 0.75 t ha^{-1} higher yield, respectively. The highest grain yield (7.27 t ha^{-1}) was found from N_4 (Urea Super Granules) and the second highest (6.80 t ha^{-1}) was recorded from by N_3 (3 splits of N + additional 10 kg N ha^{-1} at flowering stage). On the other hand, the lowest grain yield (3.02 t ha^{-1}) was observed from N_0 (No nitrogen). These results were in agreement with the findings of Nair and Gautam (1992), Avasthe *et al.* (1993) and Panda and Mohanty (1995) that split application of N gave the highest grain yield.

Table 11. Interaction effect of N application and seedling types on yield and harvest index of *Boro* rice

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
N_0S_1	2.66 m	4.31 m	38.16 j
N_0S_2	2.84 l	4.32 m	39.66 i
N_0S_3	3.56 k	4.93 l	41.93 h
N_1S_1	4.12 j	5.43 k	43.14 g
N_1S_2	4.62 i	5.76 j	44.51 f
N_1S_3	5.25 h	6.17 i	45.97 e
N_2S_1	5.87 g	6.87 h	46.07 e
N_2S_2	6.46 e	7.22 f	47.22 cd
N_2S_3	7.24 c	7.66 c	48.59 ab
N_3S_1	6.18 f	7.01 g	46.85 d
N_3S_2	6.77 d	7.36 e	47.91 bc
N_3S_3	7.45 b	7.77 b	48.95 a
N_4S_1	6.65 d	7.48 d	47.06 d
N_4S_2	7.32 bc	7.61 c	49.03 a
N_4S_3	7.84 a	8.09 a	49.21 a
$LSD_{(0.05)}$	0.143	0.093	0.762
Level of significance	0.01	0.01	0.05
CV (%)	7.50	6.78	8.98

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

There was significance difference among the seedling types (Table 10 and Appendix IX).The table shows that robust seedling maintained its superiority by producing higher yield than other two(S_1 and S_2) seedling types. The highest grain yield (6.27 t ha^{-1}) was observed from S_3 (Robust seedling from modified mat nursery) which was 22.94 % higher than S_2 (Seedling produced as recommended by BRRI) and 11.96 % higher than S_1 (normal seedling produced following farmer's practices). Again, the lowest grain yield (5.10 t ha^{-1}) was observed from S_1 (normal seedling produced following farmers' practices).

Interaction effect of N application and seedling types showed statistically significant variation on grain yield of BRRI dhan29 (Table 11 and Appendix IX). The highest grain yield (7.84 t ha^{-1}) was found from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) and the lowest grain yield (2.66 t ha^{-1}) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices).

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

Straw yield of BRRI dhan29 showed statistically significant variation due to the application of different N application (Table 10 and Appendix IX). In general, application of N increased straw yield over no nitrogen (N_0) treatment. Urea Super Granules (N_4) showed highest straw yield (7.73 t ha^{-1}) than all other N spiliting treatments. Among the N splitting treatments, N_3 (3 splits of N + additional 10 kg N ha^{-1} at flowering stage) gave higher straw yield than N_1 (2 splits of N) and

N_2 (3 splits of N) treatments. The lowest straw yield (4.52 t ha^{-1}) was observed from N_0 (No nitrogen) treatment. The result corroborates with the finding of

Salam *et al.* (1988) that split application of nitrogen increased the straw yield of rice.

Straw yield varied significantly due to the different seedling types (Table 10 and Appendix IX). The trend of straw yield was similar with grain yield .The robust seedling from modified mat nursery produced the highest yield (6.92 t ha^{-1}) than other two seedling types. The result indicates that robust seedling from modified mat nursery showed higher yield than S_1 (normal seedling produced following farmer's practices) and S_2 (Seedling produced as recommended by BRRI), respectively. This result was consistent with the finding of Pasuquin *et al.* (2007) who reported that seedlings from modified mat nursery recovered quickly that ensure maximum vegetative growth and highest straw yield.

Statistically significant variation was recorded due to interaction effect of N application and seedling types in terms of straw yield of BRRI dhan29 (Table 11 and Appendix IX). The highest straw yield (8.09 t ha^{-1}) was recorded from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) and the lowest straw yield (4.31 t ha^{-1}) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices).

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

Biological yield of BRRI dhan29 showed statistically significant variation due to the application of different N application (Figure7 and Appendix IX). The trend of biological yield production was that the no nitrogen treatment (N_0) showed the lowest biological yield after that it had an increasing trend with the increases of nitrogen splitting and the highest increase was found in Urea Super Granules (N_4) treated treatment.

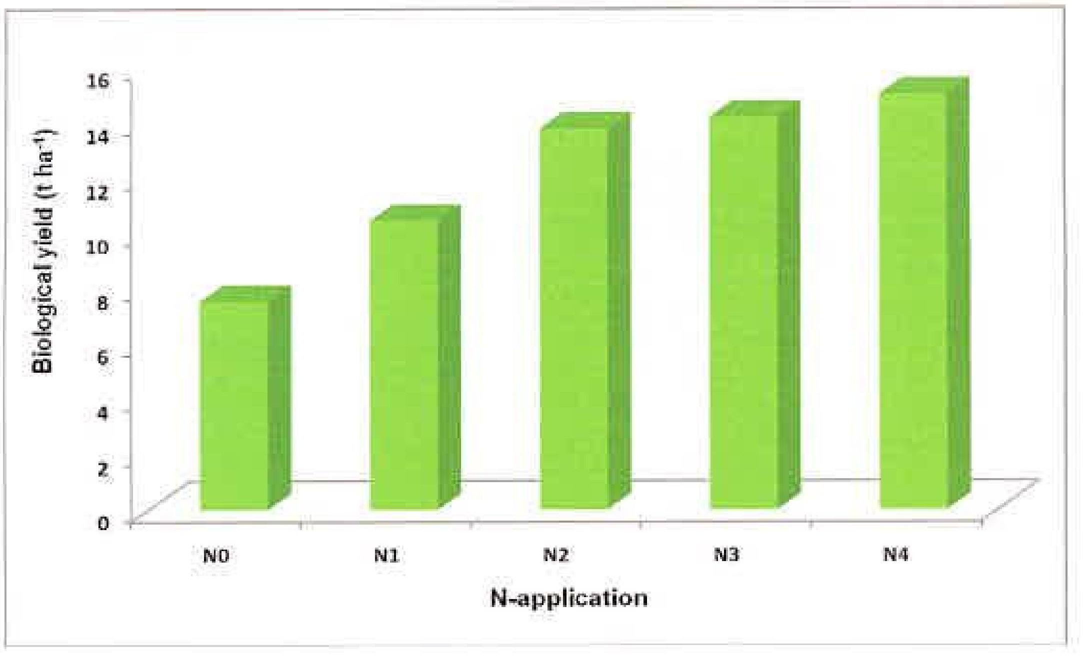


Figure 7. Effect of N application on biological yield (t ha^{-1}) of *Boro* rice ($LSD_{0.05}$ = 0.119)

N_0 = No nitrogen
N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)
N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)
N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage + additional 10 kg N ha^{-1} at flowering stage)
N_4 = Urea Super Granules

Biological yield was significantly influenced by the different seedling types (Figure 8 and Appendix IX). The highest biological yield (13.19 t ha^{-1}) was found from S_3 (Robust seedling from modified mat nursery) which was followed by S_2 (Seedling produced as recommended by BRRI). Again, the lowest biological yield (11.32 t ha^{-1}) was observed from S_1 as normal seedling of farmers' field. So the biological yield may be graded as $S_3 > S_2 > S_1$.

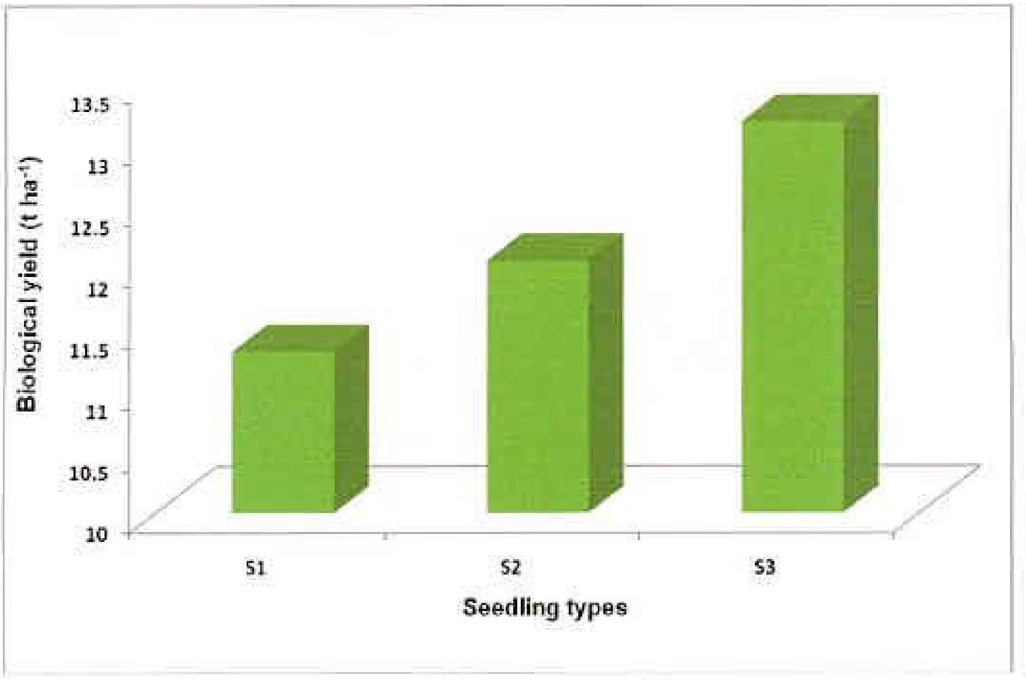


Figure 8. Effect of seedling types on biological yield (t ha^{-1}) of *Boro* rice (LSD$_{0.05}$ = 0.0.73)

S_1 = Normal seedling (produced following farmers' practices)
S_2 = Seedling produced as recommended by BRRI
S_3 = Robust seedling from modified mat nursery

Statistically significant variation was found due to interaction effect of N application and seedling types in terms of number of biological yield of BRRI dhan29 (Figure 9 and Appendix IX). The highest biological yield (15.93 t ha^{-1}) was recorded from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) and the lowest biological yield (6.97 t ha^{-1}) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices).

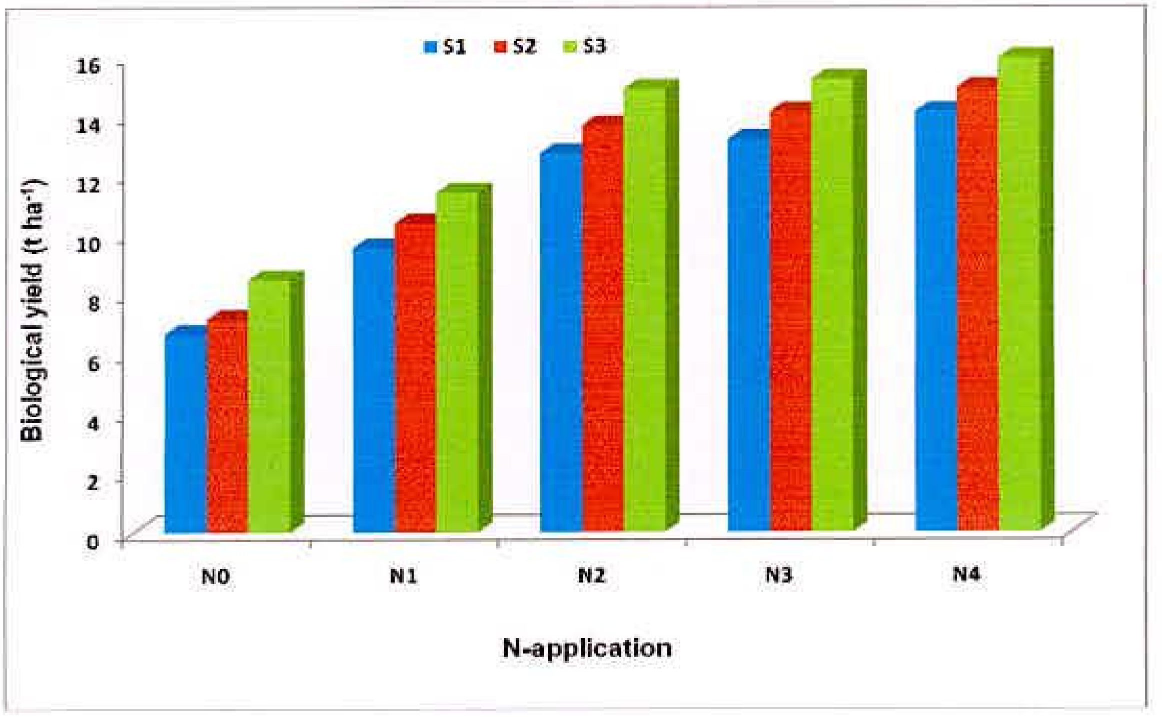


Figure 9. Interaction effect of nitrogen application and seedling types on biological yield of *Boro rice* ($LSD_{0.05}$ =0.162)

N_0 = No nitrogen

N_1 = 2 splits (½ at active tillering stage + ½ at panicle initiation stage)

N_2 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage)

N_3 = 3 splits (1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage) + additional 10 kg N ha^{-1} at flowering stage

N_4 = Urea Super Granules

S_1 = Normal seedling (produced following farmers' practices)

S_2 = Seedling produced as recommended by BRRI

S_3 = Robust seedling from modified mat nursery

4.15 Harvest index (%)

Harvest index of BRRI dhan29 showed statistically significant variation due to N application (Table 10 and Appendix IX). The highest harvest index (48.43%) was observed from N_4 (Urea Super Granules) which was statistically similar with N_3 (3 splits of N + additional 10 kg N ha^{-1} at flowering stage). On the other hand the lowest harvest index (39.92%) was observed from N_0 (No nitrogen) condition.

Harvest index differed significantly due to the different seedling types (Table 10 and Appendix IX). The highest harvest index (46.93%) was found from S_3 (Robust seedling from modified mat nursery) which was 1.26 % higher than S_2 (Seedling produced as recommended by BRRI) and 2.67% higher than S_1 (normal seedling produced following farmers' practices).

Statistically significant variation was observed on harvest index of BRRI dhan29 due to interaction effect of N application and seedling types (Appendix IX). The highest harvest index (49.21%) was recorded from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) interaction which was statistically similar with the interaction of N_4S_2 (Urea Super Granules× Seedling produced as recommended by BRRI). The lowest harvest index (38.16%) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices) interaction.

CHAPTER 5

SUMMARY AND CONCLUSION

CHAPTER 5

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The field experiment was conducted in the experimental field Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during on December 2007 to May 2008 to study the growth and yield of *Boro* rice BRRIdhan29 as influenced by N application and seedling types. The experiment considered two factors. Factor A: N application: N_0 (No nitrogen); N_1 (2 splits at ½ at active tillering stage + ½ at panicle initiation stage); N_2 (3 splits at 1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage); N_3 (3 splits at 1/3 at 15 DAT + 1/3 at active tillering stage + 1/3 at panicle initiation stage + additional 10 kg N ha^{-1} at flowering stage) and N_4 (Urea Super Granules) and Factor B: Seedling types: S_1(normal seedling produced following farmers' practices); S_2 (seedling produced as recommended by BRRI) and S_3 (robust seedling from modified mat nursery). The experiment was conducted following split plot design with three replications.

The data on crop growth parameters like plant height, number of tillers $hill^{-1}$, and dry weight $plant^{-1}$ at different growth stages; yield parameters like number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, panicle length, number of grains $panicle^{-1}$, filled and unfilled grains $panicle^{-1}$, 1000-grains weight, grain and straw yield(t ha^{-1}) were recorded after harvest. Data were analyzed using MSTAT-C package. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

At 30, 50, 70 and 90 DAT, and at harvest the tallest plant 24.29, 31.11, 45.09, 70.67 and 85.58 cm, respectively) were recorded from N_4 (Urea Super Granules) treatment and the shortest (19.56 cm, 25.13 cm, 38.47 cm, 54.91 cm and 73.76 cm, respectively) was observed from N_0 (No nitrogen). On the other hand, the highest plant height (23.78 cm, 30.75 cm, 44.20 cm, 65.56 cm and 83.98 cm) was found from S_3 (robust seedling from modified mat nursery), and the lowest (20.39 cm, 26.46 cm, 40.66 cm, 60.77 cm and 80.68 cm) was recorded from S_1 (normal seedling produced following farmers' practices) at 30, 50, 70and 90 DAT, and at harvest, respectively. The interaction of N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) gave the highest plant height (25.67 cm, 33.60 cm, 47.20 cm, 75.60 cm and 87.20 cm) where as the lowest plant height (17.40 cm, 23.27 cm, 35.74 cm, 52.60 cm and 72.60 cm) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmer's practices) at 30, 50, 70and, 90 DAT and at harvest, respectively.

The maximum number of tillers $hill^{-1}$ (5.79, 11.72, 23.10 and 18.31) was obtained from N_4 (Urea Super Granules) and the minimum (3.38, 6.50, 14.05 and 11.36) was observed from N_0 (No nitrogen) at 30, 50, 70and 90 DAT, respectively. At 30, 50, 70 and 90 DAT the maximum number of tillers $hill^{-1}$ (5.07, 10.99, 20.28 and 16.81) was found from S_3 (robust seedling from modified mat nursery) and that of minimum (3.97, 8.17, 16.53 and 12.86) was observed in S_1 (normal seedling produced following farmer's practices) at same DAT. At 30, 50, 70 and 90 DAT the maximum number of tillers $hill^{-1}$ (6.60, 13.33, 25.26 and 20.86, respectively) was observed from the interaction of N_4S_3

(Urea Super Granules × Robust seedling from modified mat nursery) where as the minimum (3.11, 5.80, 12.63 and 10.53, respectively) was found from N_0S_1 (control × normal seedling produced following farmer's practices) interaction.

At 30, 50, 70 and 90 DAT, and at harvest the highest dry matter plant^{-1} (0.524, 3.46, 15.29, 25.89 and 56.88 g, respectively) was recorded from N_4 (Urea Super Granules) and the lowest dry matter plant^{-1} (0.333, 1.54, 6.74, 14.41 and 29.86 g, respectively) was found from N_0 (No nitrogen). The highest dry matter plant^{-1} (0.515 g, 3.02 , 12.68 , 22.11 and 50.14 g , respectively) was observed from S_3 (robust seedling from modified mat nursery) and that of lowest (0.361 , 2.20 , 9.68 , 19.42 and 43.38 g, respectively) was observed from S_1 (normal seedling produced following farmers' practices) at 30, 50, 70 and 90 DAT, and at harvest. On the other hand, the highest dry matter plant^{-1} (0.633, 4.31, 17.56, 27.44 and 59.94 g respectively) was recorded from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) interaction where as the lowest dry matter plant^{-1} (0.293, 1.41, 5.92, 13.67 and 27.98 g, respectively) was recorded from N_0S_1 (control × normal seedling produced following farmers' practices) interaction at same days.

The maximum number of total tillers hill^{-1} (17.78) was found from N_4 (Urea Super Granules) and the minimum (11.11) was observed from N_0 (No nitrogen). Again, the maximum number of total tillers hill^{-1} (16.44) was recorded from S_3 (robust seedling from modified mat nursery) and the minimum (13.27) was obtained from S_1 (normal seedling produced following farmer's practices). The maximum number of total tillers hill^{-1} (19.86) was found from N_4S_3 (Urea Super

Granules × Robust seedling from modified mat nursery) and the minimum (10.18) was recorded from N_0S_1. (Control × normal seedling produced following farmers' practices) interaction.

The longest panicle length (23.92 cm) was recorded from N_4 (Urea Super Granules) and that of shortest (21.09 cm) was recorded from N_0 (No nitrogen). The robust seedling from modified mat nursery (S_3) showed the longest panicle (23.92 cm) and the shortest panicle (21.41 cm) was recorded from S_1 (normal seedling produced following farmers' practices). The highest length of panicle (24.83 cm) was recorded from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) and the lowest length of panicle (20.00 cm) was recorded from N_0S_1 (Control × normal seedling produced following farmers' practices) interaction.

The maximum number of total grains (97.83) was recorded from N_4 (Urea Super Granules) and the minimum (76.65) was recorded from N_0 (No nitrogen). S_3 (Robust seedling from modified mat nursery) gave maximum grains panicle^{-1} (91.82) and that of minimum (90.02) was observed from S_1 (normal seedling produced following farmers' practices). The interaction of N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) produced the maximum number of total grains panicle^{-1} (98.27) and that of minimum (76.61) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices) interaction.

The highest weight of 1000 grains (22.24 g) was obtained from N_4 (Urea Super Granules) and that of lowest (19.42 g) was observed from N_0 (No nitrogen).

Seedling types also influenced the weight of 1000 grains. The highest weight of 1000 grains (22.41 g) was found from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) and the lowest weight of 1000 grains (19.20 g) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices) interaction.

Grain yield varied significantly due to application of N splitting. The highest grain yield (7.27 t ha^{-1}) was found from N_4 (Urea Super Granules) and the lowest (3.02 t ha^{-1}) was observed from N_0 (No nitrogen). S_3 (Robust seedling from modified mat nursery) gave the highest grain yield (6.27 t ha^{-1}) where as S_1 (normal seedling produced following farmer's practices) produced the lowest grain yield (5.10 t ha^{-1}). The maximum grain yield (7.84 t ha^{-1}) was found from N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) and the lowest (2.66 t ha^{-1}) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices).

The highest straw yield (7.73 t ha^{-1}) and biological yield (15.00 t ha^{-1}) were obtained from N_4 (Urea Super Granules). The lowest straw yield (4.52 t ha^{-1}) and biological yield (7.54 t ha^{-1}) were observed from N_0 (No nitrogen). The maximum straw yield (6.92 t ha^{-1}) and biological yield (13.19 t ha^{-1}) were recorded from S_3 (Robust seedling from modified mat nursery) where as the lowest straw (6.22 t ha^{-1}) and biological yield (11.32 t ha^{-1}) was found from S_1 (normal seedling produced following farmer's practices). Interaction N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) produced the highest straw (8.09 t ha^{-1}) and biological yield (15.93 t ha^{-1}) and N_0S_1 (No nitrogen × normal seedling produced following farmers' practices) gave the lowest straw (4.31 t ha^{-1}) and biological yield (6.97 t ha^{-1}) .

The seedling types, N splitting and the interaction of N splitting with seedling types showed significant variation on harvest index. The maximum harvest index (48.43%) was obtained from N_4 (Urea Super Granules) and the minimum (39.92%) was observed from N_0 (No nitrogen). The highest harvest index (46.93%) was found from S_3 (Robust seedling from modified mat nursery) and the lowest harvest index (44.26%) was observed from S_1 (normal seedling produced following farmers' practices). The highest harvest index (49.21%) was found from the interaction N_4S_3 (Urea Super Granules × Robust seedling from modified mat nursery) and the lowest harvest index (38.16%) was recorded from N_0S_1 (No nitrogen × normal seedling produced following farmers' practices).

Based on the results of the present study, the following conclusions may be drawn-

- Urea Super Granules showed the higher yield than other forms of N application,
- Robust seedling from modified mat nursery gave highest yield than normal seedling or BRRI recommended nursery seedling,
- The interaction of Urea Super Granules with robust seedling from modified mat nursery was found promising for producing higher yield of rice.

However, to reach a specific conclusion and recommendation the same experiment need to be repeated and more research work should be done over different Agro-ecological zones of the country.

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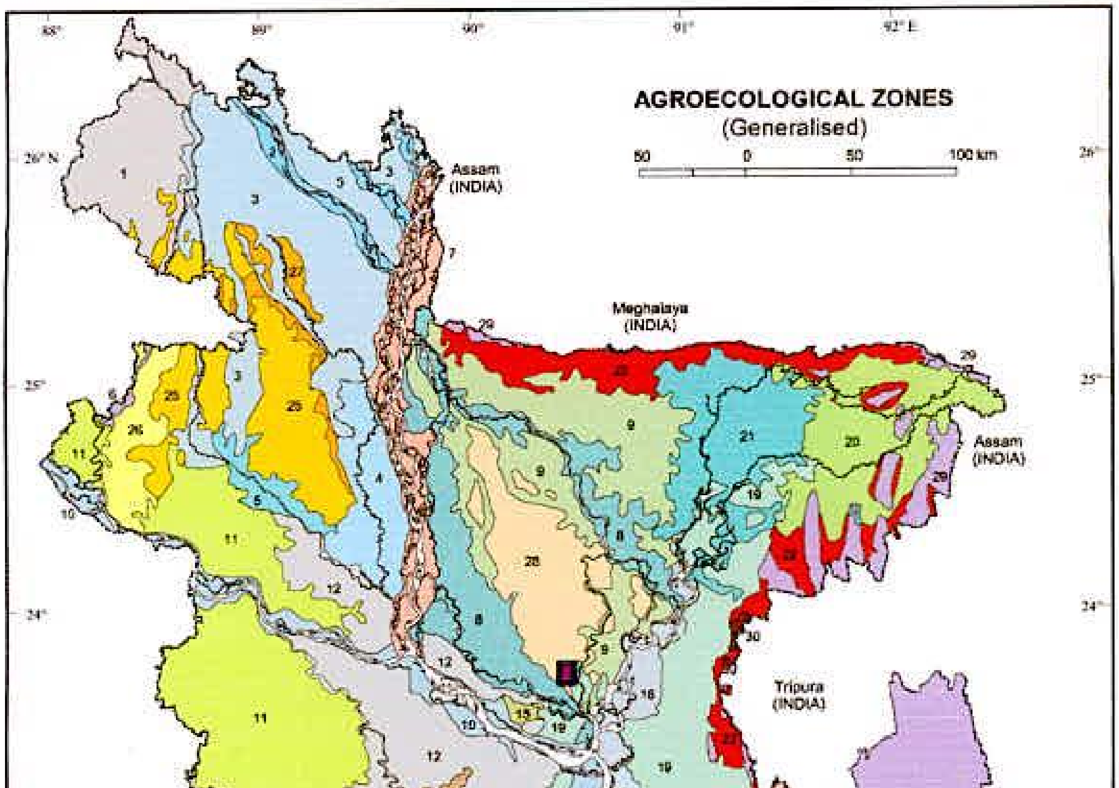
APPENDICES

APPENDICES

Appendix I. Map showing the experimental sites under study



The experimental site under study

Appendix II. Physical characteristics and chemical composition of soil of the experimental plot

Soil Characteristics	Analytical results
Agrological Zone	Madhupur Tract
P^H	5.47 – 5.63
Organic matter	0.80%
Potassium	0.15 meq/100 g soil
Calcium	3.60 meq/100 g soil
Magnesium	1.00 meq/100 g soil
Total N (%)	0.076%
Phosphorus	22.09 µg/g soil
Sulphur	25.96 µg/g soil
Boron	0.44 µg/g soil
Copper	3.56 µg/g soil
Iron	262.9 µg/g soil
Manganese	163.0 µg/g soil
Zinc	3.31 µg/g soil

Source: Soil Resource Development Institute (SRDI), Khamarbari, Dhaka.

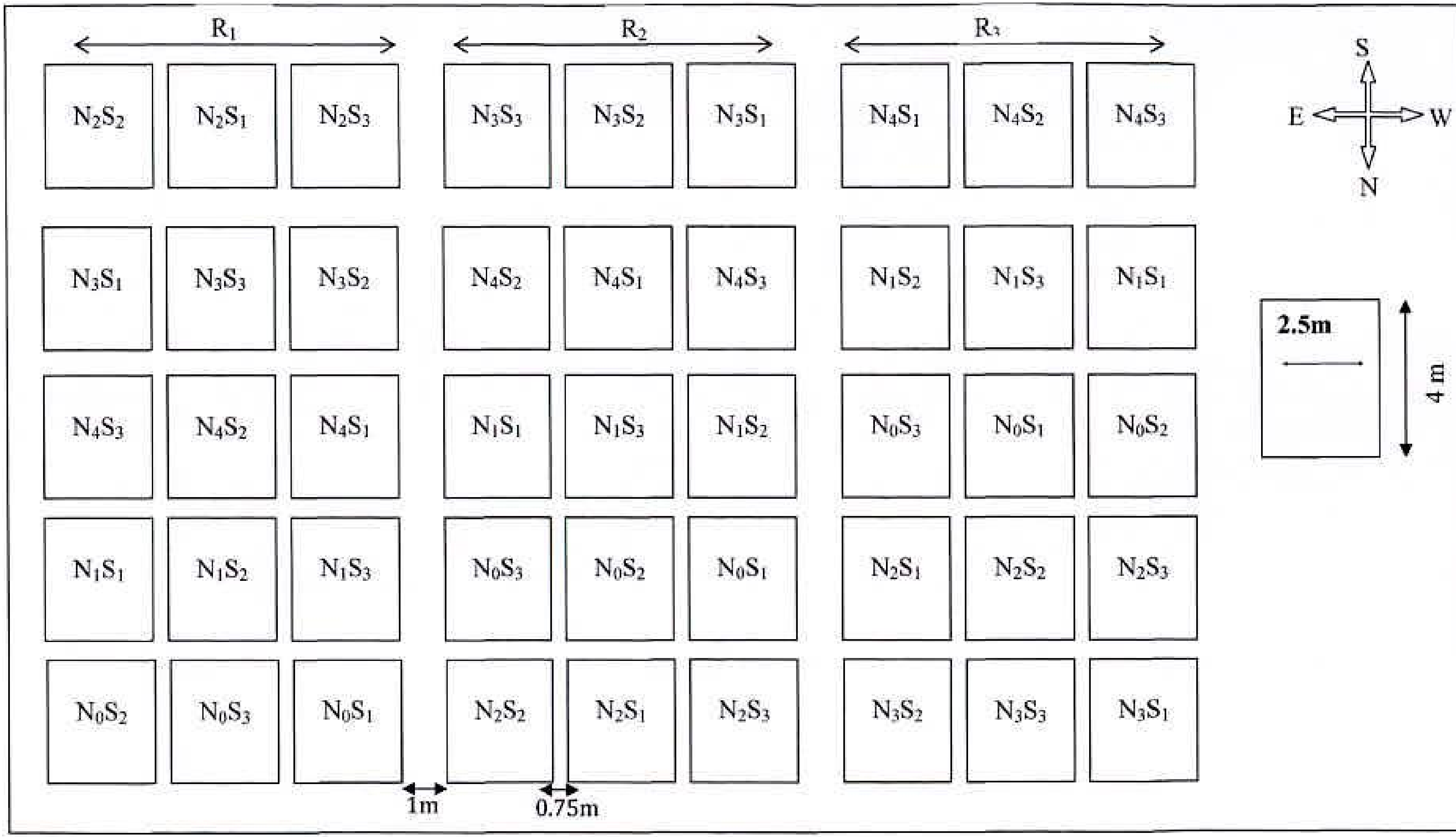
Appendix III. Monthly record of average air temperature, rainfall, relative humidity, soil temperature and sunshine of the experimental site during the period from December 2007 to April 2008

Month	*Air temperature (°c)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
December, 2007	22.4	13.5	74	00	6.3
January, 2008	24.5	12.4	68	00	5.7
February, 2008	27.1	16.7	67	30	6.7
March, 2008	31.4	19.6	54	11	8.2
April, 2008	33.6	23.6	69	163	6.4

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 1212

Appendix IV. Layout of the experimental plot



Appendix V. Analysis of variance of the data on plant height of boro rice as influenced by nitrogen application and seedling types

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		30 DAT	50 DAT	70 DAT	90 DAT	Harvest
Replication	2	0.400	0.410	0.182	0.396	0.935
Nitrogen (A)	4	31.200**	53.019**	57.440**	319.445**	286.611**
Error	8	0.199	0.847	0.200	1.105	0.884
Seedling (B)	2	43.240**	69.287**	47.090**	86.938**	41.404**
Interaction (A×B)	8	0.603**	7.071*	1.816**	8.575**	3.144**
Error	20	0.169	0.473	0.242	0.836	0.885

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on number of tillers hill^{-1} of boro rice as influenced by nitrogen application and seedling types

Source of variation	Degrees of freedom	Mean square			
		Number of tillers hill^{-1} at			
		30 DAT	50 DAT	70 DAT	90 DAT
Replication	2	0.005	0.015	0.031	0.003
Nitrogen (A)	4	8.392**	35.959**	102.846**	69.054**
Error	8	0.007	0.167	0.092	0.004
Seedling (B)	2	4.589**	30.060**	53.243**	58.462**
Interaction (A×B)	8	0.126**	0.483**	1.278**	1.374**
Error	20	0.004	0.135	0.078	0.002

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on dry matter plant^{-1} of boro rice as influenced by nitrogen application and seedling types

Source of variation	Degrees of freedom	Mean square				
		Dry matter weight plant^{-1} at				
		30 DAT	50 DAT	70 DAT	90 DAT	Harvest
Replication	2	0.0001	0.015	0.201	0.070	0.217
Nitrogen (A)	4	0.049**	4.616**	92.294**	157.013**	1115.65**
Error	8	0.001	0.024	0.200	0.068	1.583
Seedling (B)	2	0.092**	2.859**	34.311**	27.651**	173.837**
Interaction (A×B)	8	0.002*	0.135*	1.292*	0.384**	3.501*
Error	20	0.001	0.004	0.500	0.067	1.307

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on yield contributing characters of boro rice as influenced by nitrogen application and seedling types

Source of variation	Degrees of freedom	Mean square							
		Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Total tillers hill^{-1} (no.)	Panicle Length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Total grains panicle^{-1} (no.)	1000 grains Weight (g)
Replication	2	0.043	0.053	0.100	0.001	0.125	0.918	0.529	0.004
Nitrogen (A)	4	35.23**	6.303**	69.48**	12.49**	172.9**	64.84**	703.75**	10.993**
Error	8	0.035	0.116	0.212	0.057	0.355	0.413	0.720	0.007
Seedling (B)	2	13.42**	6.733**	38.91**	23.56**	72.88**	25.20**	13.682**	1.772**
Interaction (A×B)	8	0.250*	0.389**	0.581**	0.532**	0.536*	1.719**	2.174*	0.055*
Error	20	0.045	0.087	0.119	0.050	0.177	0.408	0.684	0.020

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data on yield and harvest index of boro rice as influenced by nitrogen application and seedling types

Source of variation	Degrees of freedom	Mean square			
		Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Replication	2	0.002	0.001	0.004	0.094
Nitrogen (A)	4	28.350**	16.347**	87.738**	111.656**
Error	8	0.011	0.002	0.012	0.251
Seedling (B)	2	5.183**	1.928**	13.394**	26.818**
Interaction (A×B)	8	0.039**	0.019**	0.088**	0.579*
Error	20	0.007	0.003	0.009	0.200

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

PLATES

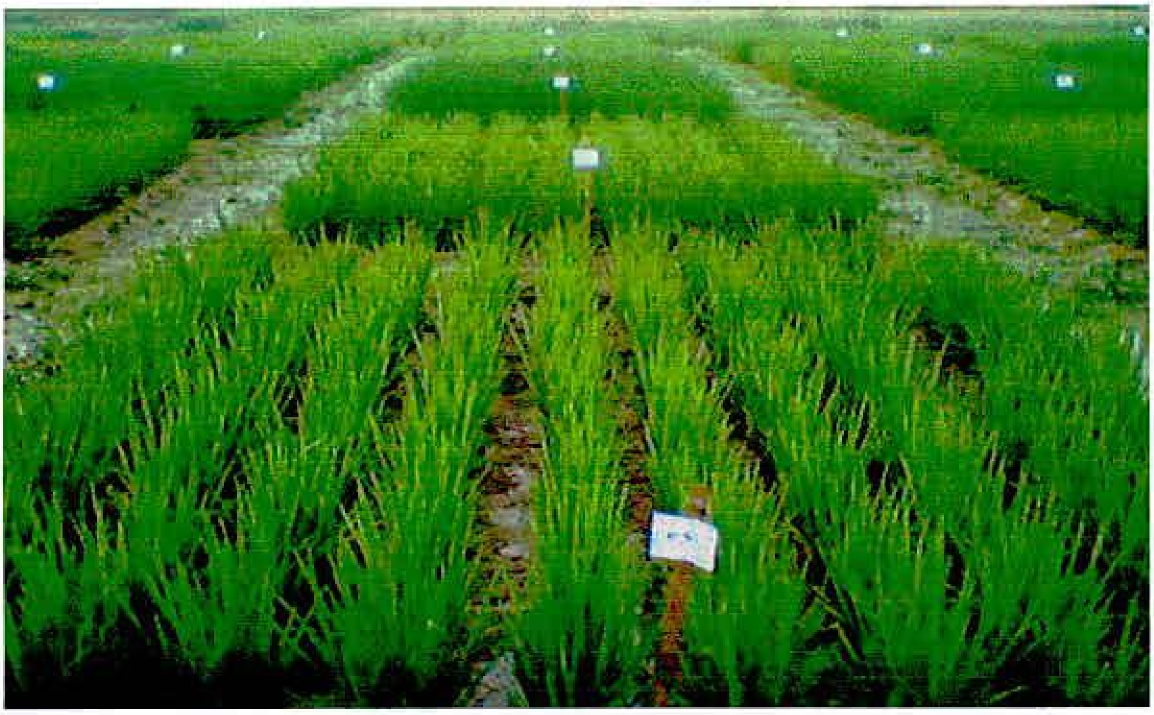


Plate5. Field view of the experimental plots at a glance

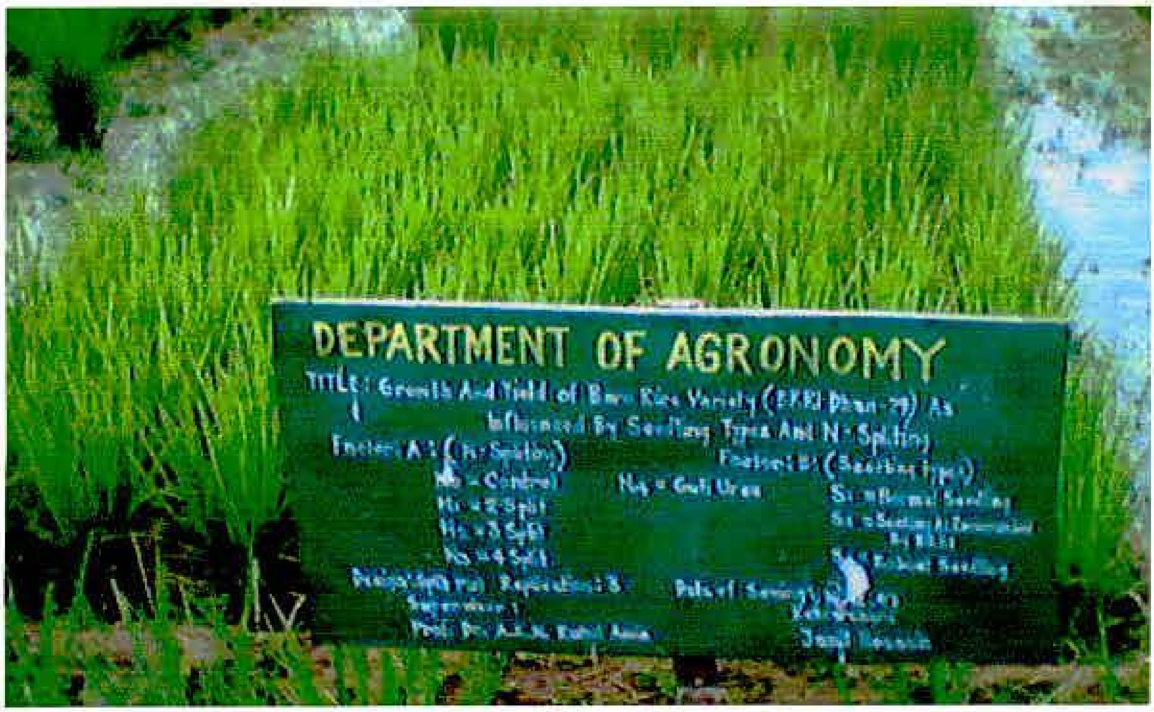


Plate 6. Field view of the experimental plots at tillering stage

Plate 7. Field view of the experimental plots at panicle initiation stage

Plate 8. Field view of the experimental plots at flowering stage

Plate 9. Close view of flowering stage

Plate 10. Field view of the experimental plots at ripening stage