INFLUENCE OF NITROGEN AND SEEDLING TYPE ON GROWTH AND YIELD OF *T. Aman* (cv. BRRI dhan46)

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CERTIFICATE

*This is to certify that the thesis entitled, "**Influence of Nitrogen and Seedling Type on Growth and Yield of T. Aman (cv. BRRI dhan46)** 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 bona fide research work carried out by **MD.NURUZZAMAN**, Registration No. 04-01473 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:

Place: Dhaka, Bangladesh

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

Dedicated

To

My Respected Parents

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ABSTRACT

A field experiment was conducted at the experimental field of Agronomy Department of Sher-e-Bangla Agricultural University, Dhaka during the period from August 2008 to January 2009, to study the influence of nitrogen levels and seedling types on growth and yield of *T. aman* rice (cv. BRRI dhan46). The experiment comprised five levels of nitrogen: 50% lower nitrogen than recommended dose (N_1), 25% lower nitrogen than recommended dose (N_2), recommended dose of nitrogen (N_3), 25 % higher nitrogen than recommended dose (N_4) and 50 % higher nitrogen than recommended dose (N_5) and three types of seedling: seedling grown in wet seedbed (S_1), seedling grown in floating seedbed (S_2) and seedling grown in dapog seedbed (S_3) in Split-Plot design. Twenty five percent higher nitrogen than recommended dose of nitrogen (N_4) showed highest grain yield (4.93t ha^{-1}), for highest dry matter $hill^{-1}$ (17.83 g, 33.50 g and 45.16g, respectively at 60 DAT, 90 DAT and harvest), effective tillers $hill^{-1}$ (10.38), filled grains $panicle^{-1}$ (88.55) and harvest index (47.27%). Seedling grown in wet seedbed (S_1) showed highest grain yield (4.73 t ha^{-1}), with highest tillers $hill^{-1}$ (5.57, 10.10, 13.04 and 14.24, respectively for 20, 40, 60 and 80 DAT), effective tillers $hill^{-1}$ (10.16), panicle length (24.21 cm), filled grains $panicle^{-1}$ (89.50), and harvest index (45.93%). The highest grain yield (5.60 t ha^{-1}) was obtained from 25% higher nitrogen than recommended dose of nitrogen along with seedlings of wet seedbed and at par with the yield (5.40 t ha^{-1}) from recommended dose of nitrogen with seedling from wet seedbed.

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LIST OF ABBRIVIATIONS

AEZ	=	Agroecological Zone
ANOVA	=	Analysis of variance
BRRI	=	Bangladesh Rice Research Institute
BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
^{0}C	=	Degree Celsius
DAT	=	Days after transplanting
et al.	=	and others
kg	=	Kilogram
g	=	gram (s)
LSD	=	Least Significant Difference
N	=	Nitrogen
MP	=	Muriate of Potash
m	=	Meter
P^{H}	=	Hydrogen ion conc.
TSP	=	Triple Super Phosphate
t/ha	=	ton/hectare
%	=	Percent

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the major crops of the world. Rice is a semi aquatic annual grass plant and is the most important cereal crop in the developing world. Ninety percent of all rice is grown and consumed in Asia. Rice feeds more a half of the people in the world. As the population rises, the demands for rice yields of the crop are leveling out. The current level of annual rice production is around 545 million tons which could be increased to about 700 million tons to feed an additional 650 million rice eaters by 2025 using less land indeed the great challenge in Asia (FAO, 2001). A study showed that most Asian countries will not be able to feed their projected populations without irreversibly degrading their land resources, even with high levels of management input (FAO, 1998). Bangladesh is mainly an agricultural country. Agriculture is the single largest producing sector of the economy and it contributes about 22 percent to the total Gross Domestic Product (GDP) of the country (BBS, 2008). Geographical and agronomic conditions of Bangladesh are favorable for rice cultivation. Rice is the leading food for more than two billion people in Asia and for hundreds of millions of people in Africa and Latin America. In Bangladesh rice occupies 10.58 million hectares of land which is about 77 percent of the cultivated area (BBS, 2008). The population of Bangladesh will increase to 173 million in 2020 which is 31 percent higher than the present level (FAO, 1998). About 47 million tons of rice will be needed to feed this people. For food security of the country, rice production is needed to be increased from 3 to 5 tons ha^{-1} in next 20 years (Mahbub *et al*., 2001).

Bangladesh is one of the poorer countries of the world due to its dense population and threatened by floods and storms. About 75% of the total cropped area and more than 80% of the total irrigated area of Bangladesh is planted to rice and there are three diverse growing seasons of rice namely *aus, aman* and *boro*. About 48.46% of the total rice area of Bangladesh is devoted to *aman* rice which contributes 33.4% to the national rice production (BBS, 2008). So, *aman* season is most important for our rice production. Our food security greatly depends on *aman* rice production. So we have to give more emphasis in this season for increasing rice production. On the other hand our population is increasing in an alarming rate and our cultivated land is decreasing at the same rate but we have to feed all of them.

The efficient use of nitrogen fertilizer can increase crop yield and reduce cost of production. The yield of the rice can be increased by even 50% through the use of optimum nitrogen fertilizer. An increase in yield of rice by 70-80% may be obtained from proper application of N-fertilizer (IFC, 1982). The efficiency of nitrogen use by rice plant is very low, the recovery being only 30-50% (Datta and Craswel, 1982). The effects of N fertilizer levels (0, 75, 150, 225 and 300 kg/ha) on japonica rice cv. 9325 grain yield and quality under water saving irrigation, the number of panicles/ha, head rice rate, protein content and gel consistency decreased, while chalkiness value and amylase content increased. Grain yield and rice quality were significantly correlated with variations of N absorption and utilization (You-Xiao Tao *et al*., 2006). A field trial in 1989-91 at Kolhapur, Maharashtra, India and found that rice cv. Jaya was given 50 or 100 kg N as a basal application at sowing or 50 kg N at sowing + 50 kg at 15 days after germination or after flood recession with N applied as urea or ammonium sulphate. A further treatment of 50 kg N as urea at 1st hoeing + 50 kg at 15 days after the 1st application was given. Average grain yield and uptake of N were highest with 50 kg N as ammonium sulphate at sowing + 50 kg after flood recession (Mahabari *et al.*, 1996). An experiment at Joydebpur, Bangladesh in 1991, rice cv. BR3 (dry season) and BR11 (wet season) were given 0, 29, 58 or 87 kg N/ha as prilled urea broadcast in 3 equal splits (after seedling establishment, at active tillering and 5-7 days before panicle initiation) or injected into the soil immediately after seedling establishment, or as urea super granules placed by hand at 8-10 cm depth after seedling establishment. Grain yield in both seasons was highest (4.8 and 3.8 t/ha in the dry and wet seasons, respectively, compared with 2.7 t in both seasons without applied N) when 87 kg N was applied as urea super granules, while broadcasting prilled urea gave the lowest grain yields and N use efficiency. N uptake was highest with the highest rate of urea super granules, while apparent N recovery was highest with the lowest N rate applied as urea super granules (Choudhury and Bhuiyan, 1994).

Seedlings from different seed bed are the more important for higher production of rice cultivation in *aman* season. Seedling age and seedling type varies rice production. Seedlings are grown in different seedbed, i.e. wet seedbed, floating seedbed and dapog seedbed. When flood occurs at low laying area, farmer cannot sow seed at proper time; have not any land for preparing seedbed. Immediately after flood water goes down farmer need seedlings for transplanting their main field. So seedbed has a great importance in rice cultivation in low land area. The more nitrogen fertilizer gives more yield in rice, this theory is not actually correct. So the proposed study was designed to find out the amount of nitrogen fertilizer, seedlings type and their interaction on growth and yield of *T. Aman* rice BRRI dhan46.

Therefore, the present experiment was conducted to achieve the following objectives:

- To identify the optimum Nitrogen level for higher yield,
- To identify the suitable seedling growing media for late *T. aman* rice cultivation, and
- To identify the interaction between seedling type and nitrogen level to get higher yield.

Chapter 2
Review of literature

CHAPTER 2

REVIEW OF LITERATURE

Yield and yield contributing characters of rice considerably depend on 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 Nitrogen fertilizer

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

2.1.1 Plant Height

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

Ahmed *et al.* (2005) observed that among 5 levels, 80 kg, N ha^{-1} gave the highest plant height (155.86 cm) and the height decreased gradually with decreased levels of nitrogen fertilizer application. Plants receiving no nitrogenous fertilizers were significantly shorter than other treatments. They also stated that nitrogen influences cell division and cell enlargement and ultimately increases plant height.

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

Ravisankar *et al.* (2003) conducted a field experiment during the 2000 and 2001 rainy seasons in Port Blari, Andaman and Nicobar Island, India to study the effect of rice cv. Mansarovar cultivated wider lowland conditions. The treatments comprised no nitrogen (T_1), 30 kg N ha^{-1} at basal, 30 and 70 days after planting (DAP) (T_2); 45 kg N ha^{-1} at 30 and 70 DAP (T_3), 32 kg N ha^{-1} at basal, 30 and 70 DAP and 25 kg N ha^{-1} at panicle initiation stage (T_4) 4.5% controlled release N at 60% of the recommended dose and 6.0% controlled release N at 60% of the recommended dose. The highest plant height at harvest (106 cm) was obtained with T_3 treatment.

Lawal and Lawal (2002) disclosed that N (120 kg ha^{-1}) significantly increased plant height. A basal N application increased the plant height significantly.

Ebaid and Ghanem (2000) conducted a field experiment at the Rice Research and Training Center (Etai El-Baroud Agricultural Research Station Farm) in Egypt during the year of 1996-97 to find out the productivity and also the plant height of Gila 177 rice (*Oryza sativa*). Nitrogen fertilizer was applied to the rice crop at the rate of 0, 96 and 144 kg N ha^{-1} in urea form and they found that increasing nitrogen level up to 144 kg ha^{-1} significantly increased 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.

Rajendran and Veeraputhiran (1999) conducted an experiment during the kharif season of 1996 and 1997 to study the effect of 4 nitrogen levels (0, 75, 150 and 225 kg ha^{-1}) and 3 sowing rates in the nursery (10, 20 and 30 g) on hybrid rice ADTRH1. Nitrogen was applied at 3 equal split namely, 7 days after transplanting, active tillering and panicle initiation stages. They found that the highest plant height was observed in hybrids supplied with 225 kg N ha^{-1}.

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

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

Vijaya and Subbaiah (1997) showed that plant height, number of tillers, 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.

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

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

Idris and Matin (1990) noted that plant height of rice increased up to 120 kg N ha^{-1}compared to the control and there after the height declined at 140 kg N ha^{-1}.

Reddy *et al*. (1990) noticed positive effect of nitrogen on plant height in rice. Taller plants were produced by higher amount of nitrogen application. Plant height decreased significantly with the reduction in the amount of nitrogen top dressings.

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.

2.1.2 Number of Tillers hill^{-1}

Tillering of rice is strongly influenced by nitrogen supply (IRRI, 1968, BRRI, 1989, 1990). BRRI (2000) reported that the maximum tillers hill^{-1} (10.2) was produced with 120 kg ha^{-1} N compared to 90 and 0 kg ha^{-1} N application.

Lawal and Lawal (2002) carried out 3 field experiments during the rainy season of 1996, 1997 and 1998 in Nigeria to evaluate the growth and yield response of low land rice to varying N rates and placement methods. The treatment consisted of 4 N rates (0, 40, 80 and 120 kg ha^{-1}) and 2 fertilizer placement method of (deep and surface placement). They found that application of 80 kg N ha^{-1} significantly increased the number of tiller hill^{-1}.

Ehsanullah *et al*. (2001) carried out a field experiment to determine the effect of various methods of nitrogen application for increasing nitrogen use efficiency in aus rice (*Oryza sativa* L.) using cv. Supper Basmati. They found that the application of 100 kg N ha^{-1} showed the maximum number of tillers hill^{-1} and 75 kg N ha^{-1} showed minimum tillers hill^{-1}. Similarly application of nitrogen by incorporating in between hills wrapped tissue paper produced more tillers hill^{-1} than other treatments and the differences were significant.

Devasenamma (2001) conducted a field experiment in Andhra Pradesh, India during the rabi season of 1996-97 to study the performance of rice hybrids (APHR-2, DRRH-1, MGR-1, TNRH-16 and NI-R-33358) at various nitrogen fertilizer rates (0, 60, 120, 180 kg ha^{-1}). They found that the highest number of tillers (464 m^{-2}) and panicles (458 m^{-2}) were produced by ARHR-2.

Munnujan *et al*., (2001) conducted a field experiment at Gazipur in 1993 to determine the effects of nitrogen (N) fertilizer and planting density on growth and yield of long grain rice. Tiller per plant increased linearly with the increase in N fertilizer levels.

Sahrawat *et al*., (1999) also observed that nitrogen level significantly affected tillering in rice. The number of tiller hill^{-1} increased significantly with increased nitrogen level.

Hari *et al.* (1997) carried out an experiment with rice hybrids PMS 2A/IR 30802 to study the effect of different levels of nitrogen and observed significant increase in productive tillers hill^{-1} with increasing levels of nitrogen from 0 to 150 kg ha^{-1}.

Chander and Pandey (1996) found that application of 120 kg N ha^{-1} resulted in significant increase in number of productive tillers hill^{-1} compared to 60 kg N ha^{-1}.

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

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

Pandey *et al*. (1991) concluded that higher grain yield from the increase in nitrogen level might be attributable to increase in productive tiller $hill^{-1}$. The application of 90 kg N ha^{-1} resulted in higher number of productive tiller $hill^{-1}$.

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 $hill^{-1}$.

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 Number 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}.

Chander and Pandey (1996) found that application of 120 kg N ha^{-1} resulted in significantly increased number of productive tillers $hill^{-1}$ of rice compared to 60 kg N ha^{-1}.

Ahsan (1996) in an experiment noted that the highest percentages of effective tillers (82.88% and 74.40%) of K inuhikari and Ohchikara varieties of rice were obtained with the application of control dose of N compared to 30, 100 and 150 kg) N respectively.

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.

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

2.1.4 Panicle length

Sarkar *et al.* (2001) conducted a field experiment during the kharif 1995 in West Bengal, India to evaluate the performance of 3 rice cultivars (IET 12199, IET 10664 and IET 15914) treated with 5 different nitrogen fertilizer levels (0, 40, 80, 120 and 160 kg ha^{-1}). IET 12199, treated with 80 kg N ha^{-1} gave the highest values for panicle length (25.77 cm); IET 10664 and IET 15914 also performed well.

Freitas *et al*. (2001) conducted a field experiment in Mococa, Sao, Paulo, Bazil during 1997-98 and 1998-99 to evaluate the response of three new rice cultivars (IAC- 10 1, IAC-102 and IAC 104) grown under irrigated conditions N fertilizer was applied as urea (at the rate of 0, 50, 100 and 150 kg ha^{-1}) 33% at seedling transplantation, and 33% at 20 and 40 days. They found that panicle length of three cultivars was significantly affected by N treatments.

Ebaid and Ghanem (2000) indicated that increasing nitrogen levels up to 144 kg N ha^{-1} significantly increased plant height, panicle length, straw yield and grain yield of rice.

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.

Azad *et al*. (1995) stated that the panicle length of rice increased significantly with the incremental level of N from 0 to 75 kg ha^{-1}.

Patel and Mishra (1994) carried out an experiment with rice cv. IR36 and were given 0, 30, 60 or 90 kg N ha^{-1} as Muossorie rock phosphate-coated urea, neem cake-coated urea, gypsum coated urea and 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.

Singh and Singh (1993) observed that panicle m^{-2}, panicle length and grains $panicle^{-1}$ of rice increased due to application of 60 kg N ha^{-1}.

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

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.

Kumar *et al*. (1986) observed that the highest panicle length was recorded with 80 kg N ha^{-1} which was significantly superior to 40 kg $ha^{-1.}$

2.1.5 Number of grains $panicle^{-1}$

BRRI (2006) found that increasing level of N increased the number of spikelet $panicle^{-1}$ of rice and the highest number of spikelet $panicle^{-1}$ (82.2) was obtained with 120 kg ha^{-1} compared to 90 and 0 kg ha^{-1}, respectively.

Subhendu *et al*., (2003) conducted an experiment to evaluate the effect of N split application (during transplanting, tillering and panicle initiation, transplanting, tillering, panicle initiation and 50% flowering and 10 days after transplanting, panicle initiation and botting) on the yield and yield components of rice cultivars BRT-5204, MTU-1010 and IR-64 in Rajendranagar, Hyderabad, Andhra Pradesh, India. They found that the application N (120 kg ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and tillering flowering resulted in the highest number of grains per panicle (89.8) in MTU-1010.

Rajarathinum and Balasubramaniyan (1999) reported that application of 150 kg N ha^{-1} produced higher number of grains $panicle^{-1}$ of rice than 250 kg, N ha^{-1}. They also noticed that the reduction of grains $panicle^{-1}$ was occurred at higher nitrogen dose due to the production of higher vegetative parts of plant.

Chowdhury *et al*. (1998) reported that increasing level of N increased the number spikelet $panicle^{-1}$ of rice and the highest number of panicle was obtained with the application of 75 kg ha^{-1} but after this dose the number of spikelet become reduced.

Chander and Pandey (1996) stated that a significant increase in grains panicle^{-1}, tillers m^{-2} and grain yield of rice were obtained from application of 120 kg N ha^{-1}compared to 60 kg N ha^{-1}.

Kapre *et al*. (1996) reported that USG has favorable effects on rice. They also observed from a study with 8 slow releasing fertilizers that grain yield, straw production, panicle hill-, 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 g 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}.

Hussain and Sharma (1991) stated that application of nitrogen increased the number of spikelets panicle^{-1} of rice up to 80 kg N ha^{-1}. The highest number of spikelets panicle^{-1} was produced at 80 kg N ha^{-1} and the lowest was produced in the control.

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 *aman* 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.

Masknia and Singh (1987) stated that nitrogen fertilizer application at 90, 120 and 150 kg ha^{-1} influenced number of grains panicle^{-1} in rice.

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}.

2.1.6 Dry matter weight hill^{-1}

Xie *et al*. (2007b) 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 in higher accumulation 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.

2.1.7 Weight of 1000-grain (g)

BRRI (2006) reported that the weight of rice 1000-grain was increased up to 90 kg ha^{-1} and after that the weights declined.

Ibrahiem *et al*. (2004) found that number of grains $panicle^{-1}$, 1000-grain weight, panicle weight and grain and straw yields ha^{-1} of rice were not significantly affected by increasing nitrogen levels from 30 to 60 kg N ha^{-1}.

Subhendu *et al*. (2003) conducted a field experiment during *aman* 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).

Lawal and Lawal (2002) conducted three field experiments during the rainy season of 1996, 1997 and 1998 in Nigeria to evaluate the growth and yield responses of lowland rice to varying N rates and placement methods. The treatment consisted of four N rates (0, 40, 80 and 120 kg ha^{-1}) and two fertilizer placement method (deep and surface placement). They found that the nitrogen rate up to 120 kg ha^{-1} has a positive effect on the 1000-grain weight.

Rodriguez *et al*. (2002) carried out an experiment in Araure, Portuguesa (Venezuela) during the rainy season of 1998 to evaluate the response of rice cultivars Fouaiapl and Cimarron at two different rates of nitrogen (150 and 200 kg N ha^{-1}). They found that nitrogenous fertilizer supplied @ (150 and 200 kg ha^{-1}) has a positive effect on 1000-grain weight of both cultivars.

Ehsanullah *et al*. (2001) conducted a field experiment to evaluate the effect of split application of nitrogen at three different stages like sowing, tillering and panicle emergence @ 125 kg N ha^{-1}. They found that the split application of N fertilizer at different growth stages significantly affected the 1000 grain weight.

Deva Senamma *et al*. (2001) conducted a field experiment in Andhra Prodesh, India during the rabi season of 1996-97 to study the performance of rice hybrids (APHR 2, DRRH 1, MGR 1, TNRH 16 and NLR 33358) at various N fertilizer rates (0, 60, 120 and 180 kg N ha^{-1}). They found that the TNRH 16 exhibits the highest 1000-grain weight (20.50 g) than others.

Bindra *et al*. (2000) conducted a field experiment in Malan, Himachal, Pradesh, India during the rainy season of 1996 and 1997 to determine the effect of 4 N rates (0, 30, 60 and 90 kg ha^{-1}) and 2 transplanting dates (7 and 14 July) oil scented rice cv. Kasturi. They found that crop transplanted on 7 July give 2.26% higher 1000-grain weight, respectively than those that transplanted oil 14 July. The higher N response was observed with 30 kg ha^{-1} during 7 July transplanting, followed by 60 kg ha^{-1}.

Ahsan (1996) in an experiment showed that higher level of N decreased the weight of 1000 grains of rice due to smaller size. He also stated that among 4 doses of N, 150 kg ha^{-1} gave the lowest weight of grain yield and the weight was increased gradually from 150 to 0 kg ha^{-1} and finally 0 kg ha^{-1} gave the highest weight of 1000 grains.

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

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.

Thakm (1991) concluded that the 1000 grain weight of rice was increasing with the increasing level of N up to 80 kg ha^{-1}.

Sadeque *et al*. (1990) conducted an experiment with 50, 100 and 120 kg N ha^{-1} and reported that 50 kg N ha^{-1} gave the maximum 1000-grain weight.

There was an increased trend of 1000-grain weight with an increased level of nitrogen up to 80 kg ha^{-1} (Islam *et al*. 1990).

Bhuiya *et al*., (1989) reported that application of N at 0-60 kg ha^{-1} increased the weight of 1000-grain. Increasing N levels from 40 to 160 kg ha^{-1} significantly increased the 1000-grain weight (Mondal *et al*. 1987).

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

Xie *et al*. (2007a) in his experiment found that the level of nitrogen application depends on the variety for obtaining the highest grain yield. They also reported Shanyou63 variety gave the highest yield (12 t ha^{-1}) with the application of 150 kg N ha^{-1} whereas 120 kg N ha^{-1} for Xieyou46 variety (10 t ha^{-1}).

Bowen *et al*. (2005) conducted 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.

Zayed *et al*. (2005) found that increasing nitrogen levels up to 165 kg N ha^{-1} significantly increased growth and yield of rice and its components.

Elbadry *et al*. (2004) in pot and lysimeter experiment showed that the increasing level of N had statistically significant difference on growth parameters and yield attributes like dry weight, number of productive tillers, grain and straw yields of rice. They also noted that after inoculation the grain yields of Giza 176 were 0.63, 0.93 and 1.22 t ha^{-1} at 0, 47.6 and 95.2 kg N ha^{-1}, respectively.

Sidhu *et al*. (2004) conducted field experiment from 1997 to 2001 in Indian Punjab, India to determine the optimum N requirement of Basmati rice in different cropping sequences i.e. fallow-Basmati rice-wheat, green manuring (GM; 50-days-old *Sesbania aculeata*), Basmati rice-wheat and GM-Basmati rice-sunflower. N fertilizers were applied at 0, 20, 40 and 60 kg ha^{-1}. Nitrogen fertilizers substantially increased the mean grain yield of Basmati up to 40 kg N ha^{-1} in the fallow Basmati-wheat sequence while 60 kg N ha^{-1} reduced Basmati yield.

Singh *et al*. (2004) conducted a field experiment during the rainy (*aman*) season, in New Delhi India, to study the effect of nitrogen levels (0, 60, 120 and ISO kg ha^{-1}) on the yield nitrogen use efficiency (NUE) of the rice cultivars Pusa Basmati-I (traditional high avidity aromatic rice) and pusa ricehybrid (aromatic hybrid rice). They found that Pusa rice hybrid -10 had given the significantly higher value for the yield attributes and nutrient accumulation than the non hybrid Pusa Basmati-I. The Maximum grain yield (5.87 t ha^{-1}) was recorded at the highest level of N nutrient (180 kg N ha^{-1}) and was 4.2, 15.5 and 39.3% higher than in the 120, 60 and 0 kg N ha^{-1} treatments respectively.

Yang *et al*. (2003) conducted an experiment with two varieties and three levels of nitrogen and observed that four times split application of 160 kg N ha^{-1} gave the highest yield about 5,916 kg ha^{-1}.

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. 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.

El-Rewainy (2002) recorded that applying 40 kg N ha^{-1} caused significant increase in plant height, number of panicles m^{-2}, panicle length, and panicle weight, number of filled grains $panicle^{-1}$ as well as grain and straw yields.

Choudhury and Khanif (2002) pointed out that yield of rice significantly increase with application of 120 kg N ha^{-1} over farmers practice (80 kg N ha^{-1}).

Fageria and Baligar (2001) conducted a field experiment during three consecutive years (1995-96, 1996-97 and 1997-98) in Goias, Central Part of Brazil on a Haplaquept inceptisol. The nitrogen levels used were 0, 30, 60, 90, 120, 150, 180 and 210 kg N ha^{-1}. They found that nitrogen fertilizer application significantly increased grain yield. Ninety percent of the maximum grain yield (6400 kg ha^{-1}) was obtained with the application of 120 kg N ha^{-1} in the first year, and in the second and third years 90% of the maximum yields (6345 and 5203 kg ha^{-1}) were obtained at 90 and 78 kg N ha^{-1}, respectively.

Sudhakar *et al*. (2001) carried out an experiment to evaluate the effects of various rice cultivars and nitrogen levels on yield and economics of direct sown semidry rice during *aman* 1996 and 1999. They found that cultivar PMK-1 show the maximum grain and straw yields, net return and B:C ratio. There was a significant increase in grain yield, straw yield, net return and B:C ratio with each increment of nitrogen application up to 125 kg ha^{-1}.

Ehsanulla *et al*. (2001) pointed out that the nitrogen level of 125 kg ha^{-1} produced maximum number of grains $panicle^{-1}$. The number of grains $panicle^{-1}$ increased with increasing rate of nitrogen from 0 to 60 kg ha^{-1}.

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}).

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

BRRI (2000) conducted an experiment with three levels of N doses from which the results revealed that the highest grain yield was obtained with 120 kg ha^{-1} compared to the lower level of N kg ha^{-1}.

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

Hari *et al.* (2000) showed that there was a significant increase in grain yield and its attributes with each additional nitrogen application up to 150 or 200 kg ha^{-1}.

Rajarathinam and Balasubramaniyan (1999) reported that the higher grain yield of hybrid rice CoRH-2 was produced to the application of 200 kg N ha^{-1}. However, application of 250 kg N ha^{-1} reduced the grain yield significantly.

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.

Devaraju *et al*. (1998) reported that KHR2 out yielded to IR 20 at all levels of N application ranging from 0 to 100 kg ha^{-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.

Singh *et al*. (1998) evaluated the performance of three rice cultivars (KHRI, Pro. Agro.103 and MGRI) using Jaya and Rasi as standard check giving four levels of N (0, 60, 120 and 180 kg ha^{-1}) and noticed that grain yield increased linearly with increased N level up to 120 kg ha^{-1}.

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 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}.

Singh (1997) found that the grain yield increased with each increment of N up to 80 kg ha^{-1} which registered the maximum yield.

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}).

Hossain *et al*. (1995) observed that application of nitrogen up to 120 kg ha^{-1} increased the grain yield of rice. Increased in yield with 40, 80 and 120 kg N ha^{-1} over the control was 24, 33 and 34%, respectively. He noted significantly higher yields with 80 and 120 kg N ha^{-1} than 0 and 40 kg N ha^{-1}.

Thakur *et al*. (1995) found that grain yield of rice increased up to 120 kg N ha^{-1}. The performances of genotypes IET 6760 and IET 8002 were evaluated against national check Pankij and local checks Radha and Rajashree at five levels of N (0, 10, 40, 80, 120 and 160 kg ha^{-1}) and observed that the genotype IET 8002 gave significantly higher grain and straw yields than the other genotypes.

Kumar *et al*. (1995) reported that an increase in N level from 80 to 120 kg ha^{-1} significantly increased the grain and straw yields, decreased the sterility percent.

Singh and Pillar (1994) noted that increased doses of nitrogen increased grain yield of rice significantly up to 90 kg ha^{-1} after that it declined.

BRRI (1992) reported that both grain and straw yields of rice increased significantly up to 80 kg N ha^{-1} and after that the yield become reduced.

Jha *et al*. (1991) observed that a variety responded up to 60 kg ha^{-1}, but another two varieties up to 40 kg N ha^{-1}, beyond which the grain yield declined.

Mahayan and Nagar (1991) reported from a field experiment that yield of rice increased significantly through increasing of nitrogen rates from 50-150 kg N ha^{-1}.

Katayama *et al*. (1990) found that yield of Suweon 258 hybrid cultivar and IR 24 increased as N level increased.

Dalai and Dixit (1987) reported that nitrogen had marked effect both on yield and yield attributes of rice. They observed that grain and straw yields increased significantly at each successive level of N due to increase in the number of panicles m^{-2}, length of panicle, spikelet $panicle^{-1}$ and weight of 1000-grain.

Pandey *et al*. (1989) found that grain yield of rice increased with N application up to 90 kg ha^{-1}.

Singandhupe and Rajput (1989) from an experiment with four N levels (0, 50, 100 and 150 kg ha^{-1}) and two varieties of rice (PR 106 and PR 109) stated that application of nitrogen up to 150 kg ha^{-1} increased both the grain and straw yields significantly compared with the unfertilized control.

Mirza and Reddy (1989) concluded that increase in N level from 30 to 90 kg ha^{-1} significantly increased the grain and straw yields of rice which were similar with the finding of Reddy and Reddy, 1989.

Hussain *et al*. (1989) carried out an experiment with rice cultivars Basmati 370 on sandy clay loam soil with 0, 30, 60, 90, 120 and 150 kg N ha^{-1} and obtained grain yield 3.9 t ha^{-1} with the application of 150 kg N ha^{-1}.

Milam *et al.* (1988) conducted a field experiment with two rice cultivars Lemont mid Newbonnet found that grain yield for both cultivars increased from 4155 kg ha^{-1} without N to 6364 kg ha^{-1} with 168 kg N ha^{-1}.

Gill and Shahi (1987) concluded that the grain yield of rice increased significantly with an increase in N application from 60 to 150 kg ha^{-1} with significant difference between 60 and 120, 60 and 150 & 90 and 150 kg N ha^{-1}.

Katoch *et al.* (1987) observed that the increasing N levels raised the grain yield in general with 0 to 60 kg ha^{-1} of N but the straw yield did not differ significantly.

Nitrogen application delayed flowering but the yield attributes were improved significantly. Grain and straw yields were also increased with every increase in N level by 20 kg ha^{-1} (Rao and Raju, 1987).

Budhar *et al*. (1987) reported that grain yield of rice was higher at 150 kg N ha^{-1} than that at 100 kg N ha^{-1}.

Grain yield of rice significantly increased with increase in the level of N up to 100 kg ha^{-1}. The yield and yield attributes increased with increasing levels of N up to 100 kg ha^{-1} reflecting their effect on yield (Thakur and Singh, 1987).

Significant increase in grain yield (49%) was observed with increase in N from 0 to 20 kg ha^{-1}. There was no improvement in yield with further increase in upto 40 or 60 kg ha^{-1}. The effect of interaction between cultivars (CR 1016 and CR 1018) and N levels was significant in respect of grain yield (Gosh *et al*., 1987),

Reddy *et al*. (1986) observed that the grain yield of rice increased significantly with successive increment in the level of nitrogen from 30 to 90 kg ha^{-1}.

Kumar *et al*. (1986) stated that the grain yield attributes of rice were significantly influenced by nitrogen. The maximum grain yield recorded 80 kg N ha^{-1} was due to the highest number of panicles m^{-2}, increase in panicle length and filled grains particle^{-1} which was significantly superior to 40 kg N ha^{-1} and control.

Awan *et al*. (1984) reported that application of different levels of nitrogen increased grain and straw yields of rice significantly.

Subbiah (1983) obtained significantly higher grain yield of rice with 120 kg N ha^{-1} than 40 kg N ha^{-1}. Sadaphal *et al*., (1981) observed that the yield of grain increased with the increase in the rates of nitrogen.

The maximum grain yield of rice was, recorded with an application of 180 kg N ha^{-1}, which was followed by 120, 60 and control. The response per kg N application was 24.0, 14.2 and15.2 kg of rice at 60, 120 and 180 kg N ha^{-1}, respectively (Singh and Paliwal, 1980).

2.1.9 Harvest Index

Ahmed *et al.* (2005) conducted an experiment with five levels of nitrogen on aman rice and observed that the harvest index was significantly higher with 40kg N ha^{-1}, compared to that of other treatments except 20 kg N ha^{-1} and the lowest harvest index was produced with maximum N dose (80 kg ha^{-1}) that was statistically identical to 0 and 60 kg N ha^{-1}.

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.

2.2 Effect of seedling types

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

Rajendran *et al*. (2007) conducted an experiment at Soil and Water Management Rasearch Institute (SWMRI), Thanjavur, Tamil Nadu, India on nursery technology for early production of robust rice seedlings to transplant under integrated crop management. A modified 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 charecteristics. 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 experiment 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 eupporting heigh performance under a given establishment technique. In the two seasons and for all genotypes and nursery types, transplanting older seedlings included a delay in the onset of liner 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. 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. In contrast, no significant difference was observed for the influence of nursery type on the timing of tiller emergence and on grain yield. No significant interaction between seedling age and nursery management for all genotypes and for all the parameters measured was found. Extended growth inside the nursery, rather than transplanting shock per seed, 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 there is need to carry out more study in order to evaluate the effect of seedling type on performance of rice.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

The research work was carried out at the experimental field of Agronomy Department of Sher-e- Bangla Agricultural University, Dhaka during the period from August 2008 to January 2009 to evaluate the influence of nitrogen and seedling types on growth and yield of *T. aman* (cv. BRRI dhan46). 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 research work was conducted at the experimental field of Agronomy Department of Sher-e- Bangla Agricultural University, Dhaka. The location of the site was $23^{0}74'$ latitude and $90^{0}35'$ E longitude with elevation of 8.2 meter from sea level. The experimental site has been shown in the AEZ map of Bangladesh in Appendix I.

3.1.2 Soil

The soil of the experimental site was clay loam belonging to the Modhupur Tract (UNDP, 1988) under AEZ 28. The selected plot was medium high land. The land was above flood level. Soil samples from 0-15 cm depths were collected from experimental field. Details of the soil analysis have been shown in the (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.

3.1.4 Test crop and its characteristics

BRRI dhan46 was the test crop of this experiment. This variety was developed by Bangladesh Rice Research Institute (BRRI), Gazipur. It is an *aman* variety but can be cultivated as late *aman*. Average plant height of the variety is about 105 cm at the ripening stage. The grains are course and whitish golden in color. It requires about 124 days for completing its life cycle with an average yield of 6.5 ton per hectare.

3.2 Experimental details

3.2.1 Treatments

The experiment considered two factors

Factor A: Nitrogen dose (N)

N_1 = 50% lower nitrogen than recommended dose (30 kg N ha^{-1})

N_2 = 25% lower nitrogen than recommended dose (45 kg N ha^{-1})

N_3 = recommended dose of nitrogen (60 kg N ha^{-1})

N_4 = 25% higher nitrogen than recommended dose (75 kg N ha^{-1})

N_5 = 50% higher nitrogen than recommended dose (90 kg N ha^{-1})

Factor B: Seedling Type (S)

S_1 = seedlings grown in wet seed bed

S_2 = seedlings grown in floating seed bed

S_3 = seedlings grown in dapog seed bed

3.2.2 Experimental design and layout

The experiment was laid out following Split-Plot design with three replications. 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 size. The total number of plots was 45. The distance between plot to plot and replication to replication was 0.75 m and 1 m, respectively. The layout of the experiment has been shown in Appendix IV.

3.3 Growing of crops

3.3.1 Raising seedlings

3.3.1.1 Seed collection

The seeds of the test crop i.e. BRRI dhan46 were collected from Bangladesh Rice Research Institute, Joydevpur, Gazipur.

3.3.1.2 Seed sprouting

Healthy seeds were selected by specific gravity and 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.

3.3.2 Preparation of nursery bed and seed sowing

3.3.2.1 Wet seed bed

Common procedure was followed in raising seedling 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 seedbed on 10 August, 2008.

3.3.2.2 Floating seedbed

Floating seedbed is one of the special types of seedbed which is prepared by using banana plant. A number of banana plants were tied together with bamboo stick and rope. Then banana leaves were spread on it and mud was uplifted on it as 3-4 cm thick. Then sprouted seed were sown on 25 August, 2008 and taken care of until transplanting.

3.3.2.3 Dapog seedbed

Dapog seedbed is another type of seedbed which was prepared by using polythene sheet and bamboo. Polythene sheet was spread on earth and every side was lift with the pieces of bamboo for controlling water then sprouted seeds were spread on 25 August, 2008 on polythene sheet about ½ inch thick. Water was applied for every eight hours regularly until transplanting.

3.3.3 Preparation of main field

The plot for the experiment was opened in the third week of August 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.

3.3.4 Fertilization

Recommended fertilizer Dose:

Urea	: 130 kg ha^{-1} (60 kg N ha^{-1})
T.S.P	: 90 kg ha^{-1}
M.P	: 70 kg ha^{-1}
Gypsum	: 60 kg ha^{-1}
Zinc Sulphate	: 10 kg ha^{-1}

The rate of urea was as per treatment. Whole amount of TSP, MP and Gypsum were applied as basal dose with two third ($^1/_3$) amount of urea as per treatment during final land preparation. Rest amount of urea ($^1/_3$+$^1/_3$) were applied in two installment as top dressing at the time of 30 DAT and 60 DAT, respectively (BRRI, 2008).

3.3.5 Uprooting of seedlings

The nursery bed was made wet by the application of water one day before uprooting of seedlings. The seedlings were uprooted on 3rd September, 2008 without causing much mechanical injury to the roots and they were immediately transferred to the main field.

3.3.6 Transplanting of seedlings in the field

Transplanting was done on 3rd September, 2008 using 25 days of wet seedbed, 14 days of floating seedbed and 14 days of dapog seedbed (Seedlings from floating seedbed and dapog seedbed must be transplanted within 14 days after seed sowing because any type of fertilizer are not applied to this type of seedbed). Seedlings were transplanted in lines following line to line distance 20 cm and hill to hill distance 15 cm, respectively.

3.4 After care

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

3.4.1 Irrigation and drainage

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

3.4.2 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.

3.4.3 Weeding

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

3.4.4 Top dressing

Urea was top dressed as per treatment mentioned in section 3.3.4.

3.4.5 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 30 DAT and 50 DAT.

3.5 Harvesting, threshing and cleaning

The rice was harvested depending upon the maturity of the crop and was harvested manually from each plot on 1st January, 2009. 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 cleaning of rice seed. The grains were weighted 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}, and was converted to t ha^{-1}.

5.6 Data recording

The following data were recorded –

Growth parameters:

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

Yield contributing parameters:

- Number of non-effective tillers hill^{-1}
- Number of effective tillers hill^{-1}
- Total tiller hill^{-1} (no)
- Panicle length (cm)
- Number of fertile spikelets (filled grains) panicle^{-1}
- Number of sterile spikelets (unfilled grains) panicle^{-1}
- Weight of 1000-grain (g)

Yield and harvest index data:

- Grain yield (t ha^{-1})
- Straw yield (t ha^{-1})
- Harvest index (%)

3.6.1 Plant height

The plant height was recorded in centimeter (cm) at 20, 40, 60 and 80 DAT, and harvest. Data were recorded as the average of 5 hills selected 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}

Number of tillers hill^{-1} was recorded at 20, 40, 60 and 80 DAT, and harvest. Data were recorded as the average of 5 hills selected random from the inner rows of each plot.

3.6.3 Dry matter hill^{-1}

Dry matter hill^{-1} was recorded at 60 and 90 DAT, and harvest. Data were recorded as the average of 5 hills selected random from the inner rows of each plot. For drying randomly selected plant sample previously sliced into very thin pieces were put into envelop and placed in an oven maintained at 60^0C for 72 hours. The samples was then transferred into desiccators and allowed to cool down at room temperature. Then the final weight of sample was taken. The average weight of three hills was considered as dry matter hill^{-1}.

3.6.4 Effective tiller hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing plant hill^{-1}. Data on effective tillers hill^{-1} was counted from 5 randomly selected hills from inner side of the plot and the average value was recorded.

3.6.5 Non-effected tillers hill^{-1}

The number of non-effective tillers hill^{-1} was counted as the number of non panicle bearing plant hill^{-1}. Data on effective tillers hill^{-1} was counted from 5 randomly selected hills from inner side of the plot and the average value was recorded.

3.6.6 Total tillers hill^{-1}

Total number of tillers hill^{-1} was counted as the number of effective tillers hil^{-1} and non-effective tiller hill^{-1}. Data on total tillers hill^{-1} was counted from 5 selected hills and average value was recorded.

3.6.7 Panicle length

Panicle length was measured with a meter scale from the panicles of 5 randomly selected plants and the average value was recorded as panicle length plant^{-1}.

3.6.8 Filled grains panicle^{-1}

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}

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 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.

3.6.11 Grain yield

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

3.6.12 Straw yield

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

3.6.13 Harvest index (%)

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

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.7 Statistical analysis

The collected data on different parameters were statistically analyzed to obtain the level of significance using the computer based software MSTAT-C program devolved by Russel (1986). Mean differences among the treatments were tested with the Duncan's Multiple Range Test (DMRT) at 5% level of significance.

Chapter 4

Results and Discussion

CHAPTER 4

RESULT AND DISCUSSION

The experiment was conducted to determine the effect of N application and seedling type on the growth and yield of BRRI dhan46 as *T. aman* variety. Data on different growth parameters, yield attributes and yield were recorded. The analysis of variance (ANOVA) of the data on different parameters was presented in Appendices V-IX. The results have been presented and possible interpretations given under the following headings:

4.1 Plant height (cm)

Plant height at 20, 40, 60 and 80 DAT and harvest varied significantly due to the different nitrogen doses (Table 1). The tallest plants (39.41, 73.78, 86.22, 95.09, 103.4 cm, at 20, 40, 60 and 80 DAT and harvest, respectively) were recorded from N_5 (50% higher N than recommended dose) which was followed (37.12, 69.22, 83.99, 92.70, 100.5 cm, at 20, 40, 60 and 80 DAT and harvest, respectively) by N_4 (25% higher N dose than recommended dose). On the other hand, the shortest plants (35.19, 62.89, 74.56, 84.15 and 94.33 cm, at 20, 40, 60 and 80 DAT and harvest, respectively) were observed from N_1 (50% lower N than recommended dose). Meena *et al*. (2003) and Sahrawat *et al*. (1999) reported that, higher plant height was obtained with higher dose of nitrogen.

Plant height at 20, 40, 60 and 80 DAT and at harvest varied significantly due to the seedling types (Table 1). The tallest plants (41.01, 72.42, 84.01, 93.58 and 101.6 cm, at 20, 40, 60 and 80 DAT and harvest, respectively) were recorded from S_1 (seedlings grown in wet seedbed). On the other hand, the shortest plants (33.49, 64.90, 78.48, 87.11 and 96.51 cm, at 20, 40, 60 and 80 DAT and harvest, respectively) are obtained by S_3 (seedlings grown in dapog seedbed) treatment.

Statistically significant variation was found due to interaction effect of different nitrogen dose and seedling types in terms of plant height. Numerically the tallest plant were observed (44.22, 80.01, 90.55, 99.63 and 108.5 cm, at 20, 40, 60 and 80 DAT and harvest, respectively) by the interaction of N_5S_1 (50% higher N dose than recommended dose and seedlings grown in wet seedbed) and the smallest plant (28.22, 56.61, 70.17, 75.33 and 89.53 cm, at 20, 40, 60 and 80 DAT and at harvest, respectively) was observed from N_1 S_3 interaction (50% lower N than recommended dose and seedling grown in dapog seedbed) (Table 2).

Table 1. Effect of Nitrogen levels and seedling types on plant height of BRRI dhan46 at different days after transplanting

Treatment	Plant height (cm) at				
	20 DAT	**40 DAT**	**60 DAT**	**80 DAT**	**Harvest**
Nitrogen levels					
N_1	35.19 b	62.89 b	74.56 b	84.15 b	94.33 b
N_2	36.63 ab	67.41 ab	80.63 ab	89.27 ab	97.52 ab
N_3	39.28 a	68.85 ab	82.74 ab	91.67 ab	99.86 ab
N_4	37.12 ab	69.22 ab	83.99 ab	92.70 ab	100.5 ab
N_5	39.41 a	73.78 a	86.22 a	95.09 a	103.4 a
$S\bar{x}$	0.94	2.53	2.75	2.63	2.24
Seedling types					
S_1	41.01 a	72.42 a	84.01 a	93.58 a	101.6 a
S_2	38.0 8 ab	67.96 a	82.40 a	91.03 a	99.24 a
S_3	33.49 b	64.90 b	78.48 b	87.11 b	96.51 b
$S\bar{x}$	0.93	2.52	3.04	2.63	2.27
CV (%)	6.33	5.14	5.45	6.60	6.80

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

N_1 = 50% Lower nitrogen than recommended dose
N_2 = 25% Lower nitrogen than recommended dose
N_3 = Recommended dose of nitrogen
N_4 = 25% Higher nitrogen than recommended dose
N_5 = 50% Higher nitrogen than recommended dose

S_1 = Seedlings grown in wet seed bed
S_2 = Seedlings grown in floating seed bed
S_3 = Seedlings grown in dapog seed bed

Table 2. Interaction effects of nitrogen levels and seedling types on plant height of BRRI dhan46 at different days after transplanting

Interaction (Nitrogen levels × seedling types)	Plant height (cm) at				
	20 DAT	40 DAT	60 DAT	80 DAT	At harvest
$N_1 \times S_1$	39.78 bc	67.33 b	75.67 cd	89.00 b	96.97 b
$N_1 \times S_2$	37.57 c-f	64.72 b	77.83 b-d	88.11 b	96.49 b
$N_1 \times S_3$	28.22 h	56.61 c	70.17 d	75.33 c	89.53 c
$N_2 \times S_1$	39.11 b-e	71.89 b	82.78 a-c	91.07 ab	98.67 b
$N_2 \times S_2$	36.67 d-g	66.00 b	80.56 a-c	89.51 b	97.15 b
$N_2 \times S_3$	34.11 g	64.34 b	78.55 b-d	87.22 b	96.72 b
$N_3 \times S_1$	42.05 ab	71.56 b	84.56 a-c	92.94 a-b	101.7 a-b
$N_3 \times S_2$	39.56 b-d	68.22 b	83.87 a-c	91.72 a-b	100.1 b
$N_3 \times S_3$	36.22 e-g	66.77 b	79.79 b-d	90.36 b	97.79 b
$N_4 \times S_1$	39.89 bc	71.33 b	86.48 ab	95.28 ab	102.2 ab
$N_4 \times S_2$	37.58 c-f	69.11 b	85.05 a-c	92.27 ab	100.9 b
$N_4 \times S_3$	33.89 g	67.22 b	80.45 a-c	90.56 b	98.40 b
$N_5 \times S_1$	44.22 a	80.01 a	90.55 a	99.63 a	108.5 a
$N_5 \times S_2$	39.03 b-e	71.78 b	84.67 a-c	93.56 ab	101.5 ab
$N_5 \times S_3$	35.00 fg	69.56 b	83.44 a-c	92.08 ab	100.1 b
$S\bar{x}$	0.93	2.52	3.04	2.63	2.27
CV (%)	6.33	5.14	5.45	6.60	6.80

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

N_1 = 50% Lower nitrogen than recommended dose
N_2 = 25% Lower nitrogen than recommended dose
N_3 = Recommended dose of nitrogen
N_4 = 25% Higher nitrogen than recommended dose
N_5 = 50% Higher nitrogen than recommended dose

S_1 = Seedlings grown in wet seed bed
S_2 = Seedlings grown in floating seed bed
S_3 = Seedlings grown in dapog seed bed

4.2 Number of tillers hill^{-1}

Statistically significant variation was observed for number of tillers hill^{-1} at 20, 40, 60 and 80 DAT due to the different nitrogen doses (Table 3). The maximum number of tillers hill^{-1} (5.11, 10.10, 12.33 and 14.83, at 20, 40, 60 and 80 DAT, respectively) were recorded from N_5 (50% higher N than recommended dose) which was followed (5.62, 8.72, 12.26 and 13.84, at 20, 40, 60 and 80 DAT, respectively) by N_4 (25% higher N dose from recommended dose). On the other hand, the minimum number of tillers hill^{-1} (3.49, 7.51, 9.96 and 11.35, at 20, 40, 60 and 80 DAT, respectively) were observed from N_1 (50% lower N than recommended dose). The result was consistence with the findings of Singh and Singh (1986) who reported that the number of tillers m^{-2} increased with increasing dose of nitrogen.

Number of tillers hill^{-1} at 20, 40, 60 and 80 DAT varied significantly due to the seedling types (Table 3). The highest number of tillers hill^{-1} (5.57, 10.10, 13.04 and 14.24, at 20, 40, 60 and 80 DAT, respectively) was recorded from S_1 (seedlings grown in wet seedbed). The lowest number of tiller hill^{-1} (3.90, 6.99, 10.74 and 12.08, at 20, 40, 60 and 80 DAT, respectively) by S_3 (seedlings grown in dapog seedbed).

Interaction effect of different N dose and seedling types in terms of number of tiller hill^{-1} showed statistically significant variation at all sampling date (Table 4). The maximum number of tillers hill^{-1} (6.787, 12.33, 13.86 and 15.71, at 20, 40, 60 and 80 DAT, respectively) was recorded from the interaction of N_5S_1 (50% higher N dose than recommended dose and seedlings grown in wet seedbed) where as the minimum number of tillers hill^{-1} (2.49, 4.88, 8.22 and 9.72, at 20, 40, 60 and 80 DAT, respectively) was recorded from the interaction of N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed).

Table 3. Effect of nitrogen levels and seedling types on tillers $hill^{-1}$ of BRRI dhan46 at different days after transplanting

Treatment	Tillers $hill^{-1}$ at			
	20 DAT	**40 DAT**	**60 DAT**	**80 DAT**
Nitrogen levels				
N_1	3.499 b	7.519 b	9.967 b	11.35 b
N_2	3.876 b	8.316 b	12.10 a	12.82 ab
N_3	5.001 a	8.262 b	12.22 a	13.26 ab
N_4	5.622 a	8.723 ab	12.26 a	13.84 ab
N_5	5.111 a	10.10 a	12.33 a	14.83 a
$S\bar{x}$	0.21	0.40	0.44	0.80
Seedling types				
S_1	5.579 a	10.10 a	13.04 a	14.24 a
S_2	4.377 ab	8.657 ab	12.07 ab	13.34 ab
S_3	3.909 b	6.999 b	10.74 b	12.08 b
$S\bar{x}$	0.21	0.40	0.44	0.80
CV (%)	8.03	8.10	9.40	11.47

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

N_1 = 50% Lower nitrogen than recommended dose
N_2 = 25% Lower nitrogen than recommended dose
N_3 = Recommended dose of nitrogen
N_4 = 25% Higher nitrogen than recommended dose
N_5 = 50% Higher nitrogen than recommended dose

S_1 = Seedlings grown in wet seed bed
S_2 = Seedlings grown in floating seed bed
S_3 = Seedlings grown in dapog seed bed

Table 4. Interaction effect of nitrogen levels and seedling types on tillers hill^{-1} of BRRI dhan46 at different days after transplanting

Interaction (Nitrogen levels × seedling types)	Tillers hill^{-1} at			
	20 DAT	**40 DAT**	**60 DAT**	**80 DAT**
$N_1 \times S_1$	4.667 ef	9.393 bc	11.39 c-e	12.22 c-e
$N_1 \times S_2$	3.337 g	8.280 c-e	10.28 e	12.11 de
$N_1 \times S_3$	2.493 h	4.883 f	8.223 f	9.723 e
$N_2 \times S_1$	4.333 ef	9.257 bc	13.26 ab	13.76 a-d
$N_2 \times S_2$	3.997 f	8.540 cd	12.21 b-d	12.71 b-d
$N_2 \times S_3$	3.297 g	7.150 e	10.82 de	11.98 de
$N_3 \times S_1$	5.777 bc	9.277 bc	13.24 ab	14.28 a-d
$N_3 \times S_2$	4.663 d-f	8.183 c-e	12.14 b-d	13.18 a-d
$N_3 \times S_3$	4.563 ef	7.327 de	11.29 c-e	12.33 cd
$N_4 \times S_1$	6.333 ab	10.24 b	13.44 ab	15.24 ab
$N_4 \times S_2$	5.327 cd	8.777 c	12.65 a-c	13.78 a-d
$N_4 \times S_3$	4.753 de	7.157 e	10.69 e	12.49 cd
$N_5 \times S_1$	6.787 a	12.33 a	13.86 a	15.71 a
$N_5 \times S_2$	4.563 ef	9.507 bc	13.04 ab	14.90 a-c
$N_5 \times S_3$	4.437 ef	8.480 cd	12.67 a-c	13.87 a-d
$S\bar{x}$	0.21	0.40	0.44	0.80
CV (%)	8.03	8.10	9.40	11.47

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

N_1 = 50% Lower nitrogen than recommended dose
N_2 = 25% Lower nitrogen than recommended dose
N_3 = Recommended dose of nitrogen
N_4 = 25% Higher nitrogen than recommended dose
N_5 = 50% Higher nitrogen than recommended dose

S_1 = Seedlings grown in wet seed bed
S_2 = Seedlings grown in floating seed bed
S_3 = Seedlings grown in dapog seed bed

4.3 Dry matter hill^{-1}

Dry mater hill^{-1} at 60 DAT, 90 DAT and at harvest exerted significant variation due to different N dose (Table 5). In general, applications of higher nitrogen increase the growth of plant and enhanced the production of dry matter per plant. However, at 60 DAT, 90 DAT and at harvest the highest dry matter hill^{-1} 17.83, 33.50 and 45.16 g, respectively from N_4 (25% higher N than recommended dose). The lowest dry matter hill^{-1} (13.03, 21.60 and 29.71 g, at 60 DAT, 90 DAT and harvest, respectively) from N_1 (50% lower N than recommended dose).

Statistically non significant variation was found due to seedling types for dry matter hill^{-1} (Table 5). Numerically the highest dry matter (16.94, 31.29 and 41.90 g, at 60 DAT, 90 DAT and at harvest, respectively) was recorded from S_1 (seedling grown in wet seedbed) and lowest dry matter hill^{-1} (14.74, 26.57 and 37.86 g, at 60, 90 DAT and at harvest, respectively) was found from S_3 (seedling grown in dapog seedbed).

Dry matter hill^{-1} showed statistically significant variation due to interaction effect of different N dose and seedling type at every sampling date (Table 6). The interaction of N_4 S_1 (25% higher N than recommended dose and seedling grown in wet seedbed) seemed to be promising by producing dry matter hill^{-1} of 18.62, 37.53 and 47.94 g, at 60 DAT, 90 DAT and at harvest, respectively, which was significantly highest than all other interaction. The lowest dry matter hill^{-1} (11.90, 19.10 and 27.98 g at 60 DAT, 90 DAT and at harvest, respectively) was recorded from the combination of N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed).

Table 5. Effect of nitrogen levels and seedling types on dry matter hill^{-1} of BRRI dhan46 at different days after transplanting

Treatment	Dry matter hill^{-1} at		
	60 DAT	**90 DAT**	**Harvest**
Nitrogen levels			
N_1	13.03 b	21.60 c	29.71 c
N_2	15.31 ab	28.45 b	37.63 b
N_3	16.04 a	31.18 ab	44.18 a
N_4	17.83 a	33.50 a	45.16 a
N_5	16.20 a	29.80 ab	42.99 a
$S\bar{x}$	0.70	1.11	1.52
Seedling types			
S_1	16.94	31.29	41.90
S_2	15.37	28.86	40.05
S_3	14.74	26.57	37.86
$S\bar{x}$	NS	NS	NS
CV (%)	7.73	8.16	6.58

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 levels of probability as per DMRT. NS = Non significant

N_1 = 50% Lower nitrogen than recommended dose
N_2 = 25% Lower nitrogen than recommended dose
N_3 = Recommended dose of nitrogen
N_4 = 25% Higher nitrogen than recommended dose
N_5 = 50% Higher nitrogen than recommended dose

S_1 = Seedlings grown in wet seed bed
S_2 = Seedlings grown in floating seed bed
S_3 = Seedlings grown in dapog seed bed

Table 6. Interaction effect of nitrogen levels and seedling types on dry matter hill^{-1} of BRRI dhan46 at different days after transplanting

Interaction (Nitrogen levels × seedling types)	Dry matter hill^{-1} at		
	60 DAT	90 DAT	Harvest
$N_1 \times S_1$	14.61 d-f	23.65 fg	30.90 f
$N_1 \times S_2$	12.59 fg	22.06 gh	30.25 f
$N_1 \times S_3$	11.90 g	19.10 h	27.98 f
$N_2 \times S_1$	16.82 a-d	30.58 b-d	39.72 de
$N_2 \times S_2$	15.00 c-e	28.32 de	36.88 e
$N_2 \times S_3$	14.11 ef	26.46 ef	36.31 e
$N_3 \times S_1$	17.45 ab	33.26 b	46.25 ab
$N_3 \times S_2$	15.70 b-e	31.82 b-d	44.48 a-d
$N_3 \times S_3$	14.98 c-e	28.46 de	41.80 b-d
$N_4 \times S_1$	18.62 a	37.53 a	47.94 a
$N_4 \times S_2$	17.72 ab	32.56 bc	45.03 a-c
$N_4 \times S_3$	17.15 a-c	30.40 b-d	42.50 b-d
$N_5 \times S_1$	17.20 a-c	31.44 b-d	44.69 a-d
$N_5 \times S_2$	15.82 b-e	29.53 c-e	43.59 a-d
$N_5 \times S_3$	15.58 b-e	28.44 de	40.70 c-e
$S\bar{x}$	0.39	1.10	1.51
CV (%)	7.73	8.16	6.58

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

N_1 = 50% Lower nitrogen than recommended dose
N_2 = 25% Lower nitrogen than recommended dose
N_3 = Recommended dose of nitrogen
N_4 = 25% Higher nitrogen than recommended dose
N_5 = 50% Higher nitrogen than recommended dose

S_1 = Seedlings grown in wet seed bed
S_2 = Seedlings grown in floating seed bed
S_3 = Seedlings grown in dapog seed bed

4.4 Number of effective tillers hill^{-1}

Effective tiller hill^{-1} showed statistically significant variation due to different N dose (Table 7). The highest number of effective tiller hill^{-1} (10.38) was recorded from N_4 (25% higher N dose than recommended dose) followed by N_3 (recommended dose) treatment (9.53). On the other hand, the lowest number of tiller hill^{-1} (7.44) was obtained from N_1 (50% lower N than recommended dose) *Hari et al*. (1997) and Thakur (1991) reported the same result that increasing the level of nitrogen increased level of effective tillers hill^{-1}.

Number of effective tillers hill^{-1} exerted significantly difference due to different seedling type (Table 7). The maximum number of effective tillers hill^{-1} (10.16) was obtained from S_1 (seedling grown in wet seedbed) which was closely followed by S_2 (seedling grown in floating seedbed). However, the minimum number of effective tillers hill^{-1} (4.43) was observed from S_3 (seedling grown in dapog seedbed).

Statistically significant variation was observed in respect of number of tillers hill^{-1} due to interaction effect of N dose and seedling type (Table 8). The maximum number of effective tillers hill^{-1} (12.68) was recorded from the interaction of N_4 S_1 (25% higher N than recommended dose and seedling grown in wet seedbed) and the minimum number of effective tillers hill^{-1} (6.187) was recorded from the interaction of N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed).

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

Non-effective tiller hill^{-1} varied significantly due to different N dose (Table 7). The highest number of non-effective tillers hill^{-1} (4.68) was obtained from N_1 (50% lower N than recommended dose) followed by N_4 (25% higher N than recommended dose). The lowest number of non effective tillers hill^{-1} (3.51) was recorded from N_2 (25% lower N than recommended dose).

The number of non-effective tillers hill^{-1} differed significantly due to the different seedling type (Table 7). The maximum number of non-effective tillers hill^{-1} (4.52) was recorded from S_1 (seedling grown in wet seedbed) and the minimum number of non-effective tillers hill^{-1} (3.19) was recorded for S_3 (seedling grown in dapog seedbed).

Interaction effect of different N dose and seedling type showed significant variation in respect of non-effective tillers hill^{-1} (Table 8). The highest number of non-effective tillers hill^{-1} (5.30) was recorded from the combination of N_1 S_1 (50% lower N than recommended dose and seedling grown in wet seedbed) which was statistically similar with the interaction of N_1 S_2 (50% lower N than recommended dose and seedling grown in floating seedbed) and N_4 S_1 (25% higher N than recommended dose and seedling grown in wet seedbed). The lowest number of non-effective tillers hill^{-1} (1.99) was found from N_5 S_3 (50% higher N than recommended dose and seedling grown in dapog seedbed) combination.

Table 7. Effect of nitrogen levels and seedling types on yield contributing characters of BRRI dhan46

Treatment	Effective tillers $hill^{-1}$ (no)	Non effective tillers $hill^{-1}$ (no)	Panicle length (cm)	Filled grain $panicle^{-1}$ (no)	Unfilled grain $panicle^{-1}$ (no)	1000-grain weight (g)
Nitrogen levels						
N_1	7.44 b	4.68 a	20.83 b	71.07 b	30.26 a	22.24 ab
N_2	9.32 ab	3.51 c	21.51 ab	80.41 ab	22.36 b	23.76 ab
N_3	9.53 ab	3.72 bc	23.26 ab	87.55 a	19.46 b	24.80 a
N_4	10.38 a	4.20 ab	23.44 ab	88.55 a	21.46 b	22.82 ab
N_5	9.30 ab	3.63 bc	25.36 a	82.67 a	31.95 a	20.84 b
$S\bar{x}$	0.56	0.14	1.11	2.85	1.28	0.89
Seedling types						
S_1	10.16 a	4.52 a	24.21	89.50 a	22.27 b	24.05
S_2	9.00 a	4.13 a	22.84	81.38 ab	25.47 ab	22.95
S_3	4.43 b	3.19 b	21.59	75.26 b	27.30 a	21.68
$S\bar{x}$	0.54	0.14	NS	2.19	0.80	NS
CV (%)	10.35	6.55	10.90	6.02	8.89	6.79

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 levels of probability as per DMRT. NS = Non significant.

N_1 = 50% Lower nitrogen than recommended dose
N_2 = 25% Lower nitrogen than recommended dose
N_3 = Recommended dose of nitrogen
N_4 = 25% Higher nitrogen than recommended dose
N_5 = 50% Higher nitrogen than recommended dose

S_1 = Seedlings grown in wet seed bed
S_2 = Seedlings grown in floating seed bed
S_3 = Seedlings grown in dapog seed bed

Table 8. Interaction effects of nitrogen levels and seedling types on yield contributing characters of BRRI dhan46

Interaction (Nitrogen levels × seedling types)	Effective tillers hill^{-1} (no)	Non effective tillers hill^{-1} (no)	Panicle length (cm)	Filled grains panicle^{-1} (no)	Unfilled grains panicle^{-1} (no)	1000-seed weight (g)
$N_1 \times S_1$	8.59 b-d	5.30 a	23.01 bc	77.34 e-g	27.40 c	22.82 b
$N_1 \times S_2$	7.56 de	5.22 a	21.70 bc	69.20 gh	32.05 a	22.34 b
$N_1 \times S_3$	6.18 e	3.53 fg	17.79 d	66.67 h	31.33 a-c	21.57 b
$N_2 \times S_1$	9.79 bc	4.00 d-f	20.49 cd	87.65 b-d	17.17 f	24.14 b
$N_2 \times S_2$	9.47 bc	3.56 e-g	22.28 bc	80.72 c-f	22.30 d	23.98 b
$N_2 \times S_3$	8.69 b-d	2.96 h	21.75 bc	72.87 f-h	27.61 bc	23.16 b
$N_3 \times S_1$	10.4 b	3.83 e-g	24.53 b	98.30 a	17.55 f	26.82 a
$N_3 \times S_2$	9.67 bc	3.51 g	22.97 bc	84.57 c-e	19.67 d-f	24.02 b
$N_3 \times S_3$	8.49 cd	3.84 e-g	22.27 bc	79.77 d-f	21.17 d-f	23.55 b
$N_4 \times S_1$	12.68 a	4.89 ab	24.13 bc	94.25 ab	18.06 ef	23.85 b
$N_4 \times S_2$	9.63 bc	4.04 de	23.47 bc	86.61 b-e	21.77 de	22.35 b
$N_4 \times S_3$	8.82 b-d	3.66 e-g	22.74 bc	84.78 c-e	23.32 d	22.25 b
$N_5 \times S_1$	9.26 b-d	4.57 bc	28.90 a	89.97 a-c	31.20 a-c	22.59 b
$N_5 \times S_2$	8.67 b-d	4.33 cd	23.77 bc	85.80 b-e	31.58 ab	22.08 b
$N_5 \times S_3$	9.98 bc	1.99 i	23.41 bc	72.23 f-h	33.07a	17.85 c
$S\bar{x}$	0.54	0.14	1.10	2.19	0.80	0.89
CV (%)	10.35	6.55	10.90	6.02	8.89	6.79

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

N_1 = 50% Lower nitrogen than recommended dose
N_2 = 25% Lower nitrogen than recommended dose
N_3 = Recommended dose of nitrogen
N_4 = 25% Higher nitrogen than recommended dose
N_5 = 50% Higher nitrogen than recommended dose

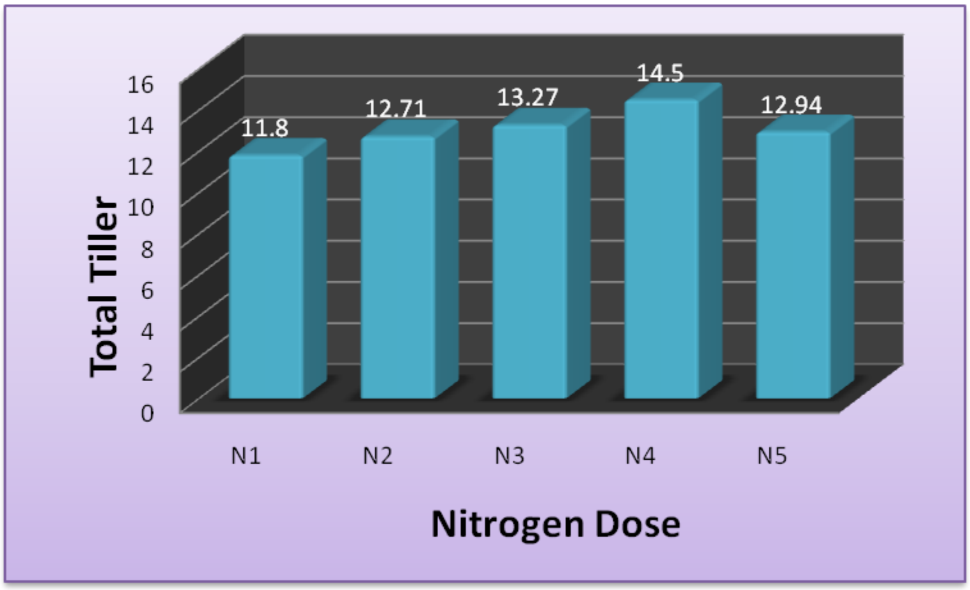
S_1 = Seedlings grown in wet seed bed
S_2 = Seedlings grown in floating seed bed
S_3 = Seedlings grown in dapog seed bed

4.6 Number of Total tillers hill^{-1}

Total tillers hill^{-1} exerted significant variation due to the different N dose (Figure 1). Figure shows that N_4 (25% lower N than recommended dose) treatment gives the highest number of total tillers hill^{-1} (14.5) which was closely followed by N_3 (recommended dose). The lowest number of total tillers hill^{-1} (11.8) was recorded from N_1 (50% lower N than recommended dose) treatment.

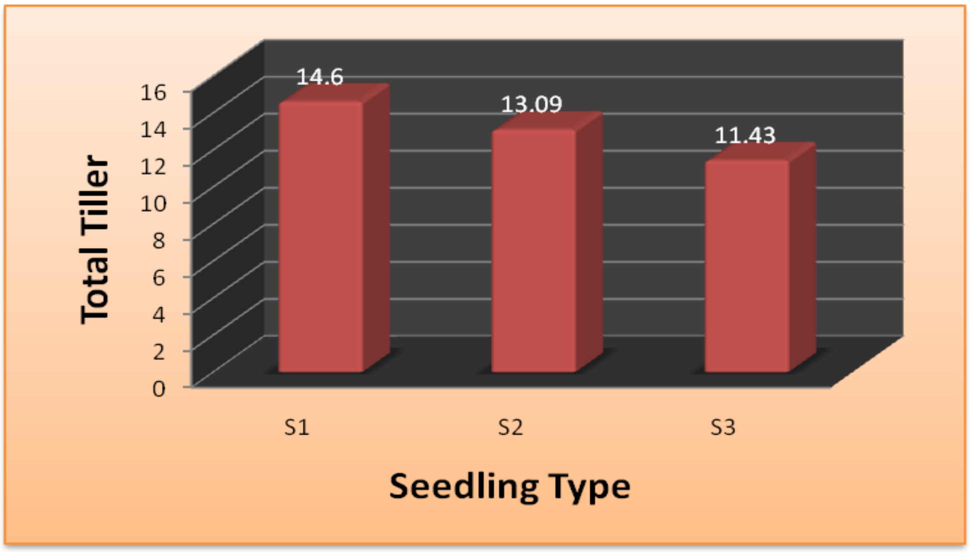
Statistically significant variation was found due to different seedling type for number of total tillers hill^{-1} (Figure 2). The maximum number of total tillers hill^{-1} (14.6) was recorded from S_1 (seedling grown in wet seedbed) which was followed by S_2 (seedling grown in floating seedbed). However the minimum number of total tillers hill^{-1} (11.43) was recorded from S_3 (seedling grown in dapog seedbed).

Total number of tillers hill^{-1} gives statistically significant variation due to interaction effect of different N dose and seedling types (Figure 3). In respect of total tillers hill^{-1} interaction N_4 S_1 (25% higher N than recommended dose and seedling grown in wet seedbed) showed the highest value (17.24) and N_1 S_3 (50% higher N than recommended dose and seedling grown in dapog seedbed) combination showed the lowest value (8.71).



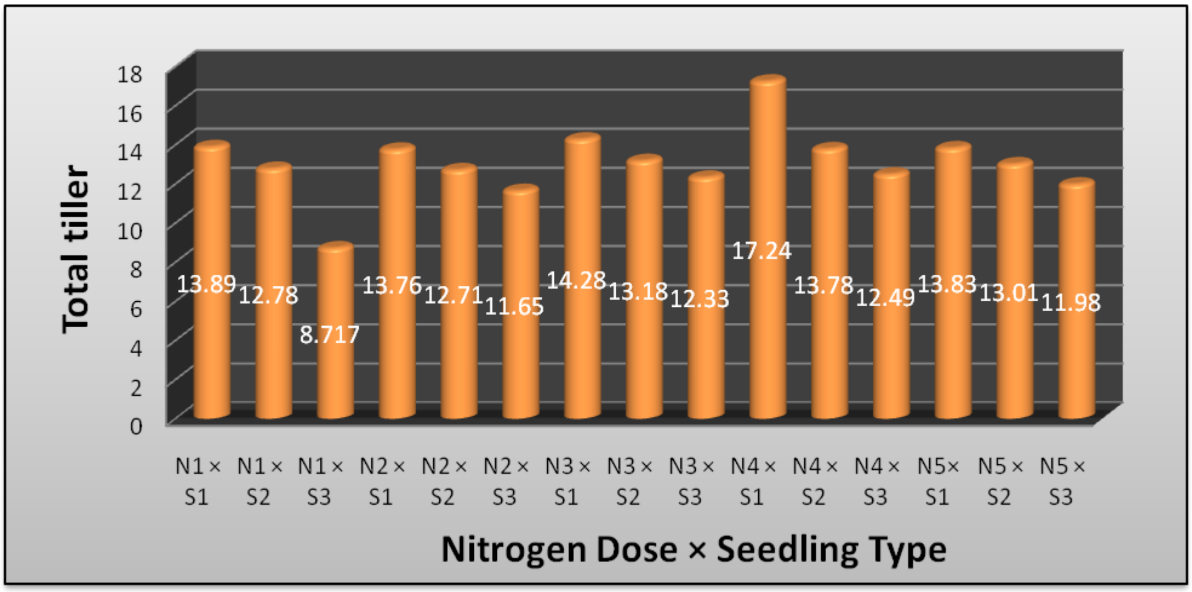
N_1 = 50% Lower nitrogen than recommended dose, N_2 = 25% Lower nitrogen than recommended dose, N_3 = Recommended dose of nitrogen, N_4 = 25% Higher nitrogen than recommended dose, N_5 = 50% Higher nitrogen than recommended dose

Figure 1. Effect of nitrogen levels on total tiller hill^{-1} of BRRI dhan46 ($S\bar{x}$ = 0.58)



S_1 = Seedlings grown in wet seed bed, S_2 = Seedlings grown in floating seed bed, S_3 = Seedlings grown in dapog seed bed

Figure 2. Effect of seedling types on total tiller hill^{-1} of BRRI dhan46 ($S\bar{x}$ = 0.54)



N_1 = 50% Lower nitrogen than recommended dose
N_2 = 25% Lower nitrogen than recommended dose
N_3 = Recommended dose of nitrogen
N_4 = 25% Higher nitrogen than recommended dose
N_5 = 50% Higher nitrogen than recommended dose

S_1 = Seedlings grown in wet seed bed
S_2 = Seedlings grown in floating seed bed
S_3 = Seedlings grown in dapog seed bed

Figure 3. Interaction effect of nitrogen levels and seedling types on total tiller hill^{-1} of BRRI dhan46 ($S\bar{x}$ = 0.93)

4.7 Panicle length (cm)

Panicle length of rice differed significantly due to different doses of nitrogen (Table 7). Highest panicle length (25.36 cm) was recorded from N_5 (50% higher N than recommended dose) which was closely followed by N_4 (25% higher N than recommended dose) and N_3 (Recommended dose). However, the lowest panicle length (20.83 cm) was recorded from N_1 (50% lower N than recommended dose). The result corroborates with the findings of Ebaid and Ghanem (2000), Azad *et al.* (1995) and Idris and Matin (1990), they reported that length of panicle was highly related with the application of increased level of nitrogen.

Statistically non significant variation was found in respect of panicle length due to seedling type (Table 7). However, the maximum panicle length (24.21 cm) was found in S_1 (seedlings grown in wet seedbed) followed by N_2 (seedling grown in floating seedbed). On the other hand, the minimum panicle length (21.59 cm) was recorded from N_3 (seedling grown in dapog seedbed).

Statistically significant variation was recorded due to interaction effects of different N dose and seedling type in terms of panicle length (Table 8). The interaction of 50% higher N than recommended dose and seedling grown in wet seedbed (N_5S_1) showed the longest panicle (28.90 cm) which was followed by combination of N_3S_1 (recommended dose and seedling grown in wet seedbed). The shortest panicle length (17.79 cm) was observed by interaction of 50% lower N than recommended dose and seedling grown in dapog seedbed (N_1S_3).

4.8 Number of filled grains panicle^{-1}

Different nitrogen dose showed statistically significant variation in producing number of filled grains panicle^{-1} (Table 7). The maximum number of filled grains panicle^{-1} (88.55) was recorded from N_4 (25% higher N than recommended dose) which was closely followed by N_3 (recommended dose). On the other hand, the minimum number of filled grains panicle^{-1} (71.07) was recorded from N_1 (50% lower N than recommended dose). The result was consistent with the findings of Kumar *et al.* (1995) and Thakur and Singh (1987). They reported that increasing the level of nitrogen significantly increased the number of filled grains panicle^{-1}.

Number of filled grains panicle^{-1} exerted significant variation due to different seedling type (Table 7). The highest number of filled grains panicle^{-1} (89.50) was recorded from S_1 (seedling grown in wet seedbed) and that of second highest (81.38) by S_2 (seedling grown in floating seedbed). The lowest number of filled grains panicle^{-1} (75.26) was recorded from S_3 (seedling grown in dapog seedbed). It is revealed that wet seedbed produced healthy seedling that ensure maximum vegetative growth with higher number of filled grains panicle^{-1}.

Statistically significant variation was recorded due to interaction effect of different N dose and seedling type in terms of number of filled grains panicle^{-1} (Table 8). N_3S_1 (recommended dose and seedling grown in wet seedbed) combination showed the higher number of filled grains panicle^{-1} (98.30) and the combination of N_1S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed) showed the lowest number of filled grains panicle^{-1} (66.67).

4.9 Number of unfilled grains panicle^{-1}

Different dose of nitrogen showed statistically significant variation on the number of unfilled grains panicle^{-1} (Table 7). The lowest number of unfilled grains panicle^{-1} (19.46) was recorded from N_3 (recommended dose) followed by N_4 (25% higher N than recommended dose) and N_2 (25% lower N than recommended dose). On the other hand, the highest number of unfilled grains panicle^{-1} (31.95) was recorded from N_5 (50% higher N than recommended dose) which was closely followed by N_1 (50% lower N than recommended dose). It was revealed that both lowest amount of nitrogen and high amount of nitrogen increased the unfilled grains panicle^{-1}.

Number of unfilled grains panicle^{-1} differed significantly due to seedling type (Table 7). The lowest number of unfilled grains panicle^{-1} (22.27) was observed from S_1 (seedling grown in wet seedbed) which was followed by S_2 (seedling grown in floating seedbed). On the other hand, the highest number of unfilled grains panicle^{-1} (27.30) was recorded from S_3 (seedling grown in dapog seedbed).

The interaction effects of different nitrogen dose and seedling type were found to be significant for unfilled grains panicle^{-1} (Table 8). The minimum number of unfilled grains panicle^{-1} (17.17) was recorded from N_2 S_1 (25% lower nitrogen than recommended dose and seedling grown in wet seedbed) combination which was statistically similar with N_3S_1, N_4S_1, N_3S_2 and N_4S_2. The maximum number of unfilled grain panicle^{-1} (33.07) was recorded from N_5S_3 (50% higher N than recommended dose and seedling grown in dapog seedbed) which was statistically similar with the combinations of N_1S_2, N_1S_3 N_5S_2, and N_5S_1.

4.10 Weight of 1000-grains (g)

Weight of 1000-grains showed significant variation due to application of different dose of nitrogen (Table 7). The highest weight of 1000-grains (24.80 g) was recorded from N_3 (recommended dose) treatment and the lowest weight of 1000-grains was found in N_5 (50% higher N than recommended dose) treatment. It is revealed that both higher dose of nitrogen and lower dose of nitrogen decrease the weight of 1000-grains.

Statistically non significant variation was found in terms of weight of 1000-grains due to different seedling type (Table 7). Numerically highest weight of 1000-grains (24.05 g) was found in S_3 (seedling grown in wet seedbed) treatment. The second height was recorded from S_2 (seedling grown in floating seedbed) treatment. However, the lowest weight of 1000-grains was found in S_3 (seedling grown in dapog seedbed) treatment.

Interaction effect of different dose of N and seedling type differed significantly on 1000-grains weight (Table 8). The highest weight of 1000-grains (26.82 g) was found in the combination of N_3S_1 (recommended dose and seedling grown in wet seedbed). The lowest weight of 1000-grains (17.85 g) was recorded from the combination of N_5S_3 (50% higher N than recommended dose and seedling grown in dapog seedbed). All other combination showed statistically similar level of 1000-seed weight.

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

Grain yield was influenced significantly by the different doses of nitrogen (Table 9). The treatment N_4 (25% higher N than recommended dose) showed the highest grain yield (4.93 t ha^{-1}) which was statistically similar with N_3, N_2 and N_5 treatments. On the other hand, the lowest grain yield (2.95 t ha^{-1}) was recorded from N_1 (50% lower N than recommended dose). The result agreed with the findings of Zayed *et al*. (2005), Hari *et al*. (2000) and Singh and Pillai (1994). They reported that the grain yield increased at certain increasing levels of nitrogen and after that the yield declined which support the findings.

There was a significant effect of seedling types on grain yield (Table 9). The table shows that seedling grown in wet seedbed (S_1) maintains its superiority by producing higher yield than other two (S_2 and S_3) seedling types. The highest grain yield (4.73 t ha^{-1}) was recorded from S_1 (seedling grown in wet seedbed) which was 13.86% and 33.99% higher than S_2 (seedling grown in floating seedbed) and S_3 (seedling grown in dapog seedbed), respectively. Again, the lowest grain yield (3.53 t ha^{-1}) was observed from S_3 (seedling grown in dapog seedbed).

Interaction effect of different dose of nitrogen and seedling types showed statistically significant variation on grain yield of rice (Table 10). The highest grain yield (5.60 t ha^{-1}) was found from N_4 S_1 (25% higher N than recommended dose and seedling grown in wet seedbed) and the lowest grain yield (2.50 t ha^{-1}) was recorded from N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed). It was observed that the interaction of N_2S_1 (25% lower N than recommended dose and seedling grown in wet seedbed) and N_3S_1 (recommended dose of N and seedling grown in wet seedbed) also produced statistically similar yield with the interaction of N_4S_1 (25% higher N than recommended dose and seedling grown in wet seedbed).

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

Straw yield exerted significant variation due to the application of different doses of nitrogen (Table 9). In general, increasing rate of nitrogen fertilizer increased the growth of rice plants. Treatment N_4 (25% higher nitrogen than recommended dose) showed the highest straw yield (5.89 t ha^{-1}) which was statistically at par with all other doses except N_1. The lowest straw yield (4.48 t ha^{-1}) was found in N_1 (50% lower N than recommended dose). Elbadry *et al*. (2004), Meena *et al*. (2003) and El-Rewainy (2002) observed similar trend of straw yield due to nitrogen application.

Statistically not significant variation was found in terms of straw yield due to seedling type (Table 9). However, the numerical values of highest straw yield (5.55 t ha^{-1}) was recorded from S_1 (seedling grown in wet seedbed) and that of lowest in S_3 (seedling grown in dapog seedbed).

Interaction effect of different dose of nitrogen and seedling type showed statistically significant variation in terms of straw yield (Table 10). The highest straw yield (6.02 t ha^{-1}) was found in N_4 S_3 (25% higher N than recommended dose and seedling grown in dapog seedbed) which was statistically at par with all other interaction except N_1S_1, N_1S_2, N_1S_3, N_2S_2 and N_2S_3. The lowest straw yield (4.14 t ha^{-1}) was recorded from N_1S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed) which was statistically similar with N_1S_1, N_1S_2, N_2S_2 and N_2S_3 interaction.

4.13 Harvest index (%)

Harvest index showed significant variation due to application of different doses of nitrogen (Table 9). The highest harvest index (45.81 %) was observed from N_4 (25% higher N than recommended dose) which was statistically similar with N_2, N_3 and N_5. On the other hand, the lowest harvest index (38.34 %) was observed from N_1 (50% lower N than recommended dose).

Harvest index differed significantly due to different seedling types (Table 9). The highest harvest index (45.93%) was found from S_1 (seedling grown in wet seedbed) which was 2.23% and 5.84% higher than S_2 (seedling grown in floating seedbed) and S_3 (seedling grown in dapog seedbed), respectively. However, the lowest harvest index (40.09%) was recorded from S_3 (seedling grown in dapog seedbed).

Statistically significant variation was observed on harvest index due to interaction effects of different dose of nitrogen and seedling types (Table 10). The highest harvest index (49.43 %) was recorded from N_4 S_1 (25% higher N than recommended dose and seedling grown in wet seedbed) which was statistically at par with N_2S_1, N_3S_2 and N_3S_2 combination. Lowest harvest index (33.82%) was recorded from N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed) which was statistically similar with N_5S_3 interaction.

Table 9. Effect of nitrogen levels and seedling types on grain yield, straw yield and harvest index of BRRI dhan46

Treatment	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest index (%)
Nitrogen levels			
N_1	2.954 b	4.480 b	38.34 b
N_2	4.018 a	5.067 ab	43.73 ab
N_3	4.804 a	5.653 a	45.81 a
N_4	4.933 a	5.889 a	47.27 a
N_5	3.984 a	5.822 a	41.05 ab
$S\bar{x}$	0.24	0.29	1.77
Seedling types			
S_1	4.731 a	5.550	45.93 a
S_2	4.155 ab	5.345	43.70 b
S_3	3.531 b	5.251	40.09 c
$S\bar{x}$	0.24	NS	1.77
CV (%)	10.06	9.34	6.39

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 levels of probability as per DMRT. NS = Non significant

N_1 = 50% Lower nitrogen than recommended dose
N_2 = 25% Lower nitrogen than recommended dose
N_3 = Recommended dose of nitrogen
N_4 = 25% Higher nitrogen than Recommended dose
N_5 = 50% Higher nitrogen than Recommended dose

S_1 = Seedlings grown in wet seed bed
S_2 = Seedlings grown in floating seed bed
S_3 = Seedlings grown in dapog seed bed

Table 10. Interaction effects of nitrogen levels and seedling types on grain yield, straw yield and harvest index of BRRI dhan46

Interaction (Nitrogen levels × seedling types)	Grain weight (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
$N_1 \times S_1$	3.36 fg	4.81 d-f	41.09 c-e
$N_1 \times S_2$	3.00 gh	4.49 ef	40.12 de
$N_1 \times S_3$	2.50 h	4.14 f	33.82 f
$N_2 \times S_1$	4.84 a-c	5.29 a-e	46.21 a-c
$N_2 \times S_2$	4.05 d-f	5.02 b-f	44.58 b-d
$N_2 \times S_3$	3.15 gh	4.87 c-f	40.42 c-e
$N_3 \times S_1$	5.41 ab	5.85 ab	48.02 ab
$N_3 \times S_2$	4.86 bc	5.62 a-d	46.36 a-c
$N_3 \times S_3$	4.14 c-e	5.48 a-d	43.05 b-e
$N_4 \times S_1$	5.60 a	5.90 ab	49.43 a
$N_4 \times S_2$	4.82 bc	5.75 a-d	45.28 b-d
$N_4 \times S_3$	4.37 cd	6.01 a	45.16 b-d
$N_5 \times S_1$	4.43 cd	5.88 ab	42.97 b-e
$N_5 \times S_2$	4.03 d-f	5.84 a-c	42.16 b-e
$N_5 \times S_3$	3.48 e-g	5.74 a-d	38.01 ef
$S\bar{x}$	0.24	0.28	1.77
CV (%)	10.06	9.34	6.39

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

N_1 = 50% Lower nitrogen than recommended dose
N_2 = 25% Lower nitrogen than recommended dose
N_3 = Recommended dose of nitrogen
N_4 = 25% Higher nitrogen than recommended dose
N_5 = 50% Higher nitrogen than recommended dose

S_1 = Seedlings grown in wet seed bed
S_2 = Seedlings grown in floating seed bed
S_3 = Seedlings grown in dapog seed bed

Chapter 5

Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The field experiment was conducted in the experimental field of Agronomy Department of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during August 2008 to January 2009 to study the influence of nitrogen and seedling type on growth and yield of *T. aman* variety BRRI dhan46. The experiment comprised two factors. (A): Nitrogen dose: N_1 (50% lower N than recommended dose), N_2 (25% lower N than recommended dose), N_3 (recommended dose), N_4 (25% higher N than recommended dose) and N_5 (50% higher N than recommended dose) and (B): Seedling type: S_1 (seedling grown in wet seedbed), S_2 (seedling grown in floating seedbed) and S_3 (seedling grown in dapog seedbed). 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 matter weight hill^{-1} at different growth stages; yield parameters like number of effective tillers hill^{-1}, number of non-effective tillers hill^{-1}, number of total tillers hill^{-1}, panicle length, number of filled and unfilled grain panicle^{-1}, 1000-grains weight, grain and straw yield (t ha^{-1}) were recorded.

At 20, 40, 60, 80 DAT and harvest the tallest plant (39.41, 73.78, 86.22, 95.09, 103.4 cm, respectively) were recorded from N_5 (50% higher N than recommended dose) treatment and the shortest plant (35.19, 62.89, 74.56, 84.15 and 94.33 cm respectively) were observed from N_1 (50% lower N than recommended dose) treatment. On the other hand, the tallest plants (41.01, 72.42, 84.01, 93.58 and 101.6 cm respectively) were recorded from S_1 (seedlings grown in wet seedbed) and the shortest plants (33.49, 64.90, 78.48, 87.11 and 96.51 cm respectively) were recorded from S_3 (seedlings grown in dapog seedbed) at 20, 40, 60, 80 DAT and at harvest. The tallest plant (44.22, 80.01, 90.95, 99.65 and 108.5 cm, at 20, 40, 60 and 80 DAT, respectively) was observed by the interaction of N_5S_1 (50% higher N dose than recommended dose and seedlings grown in wet seedbed) and the smallest plant (28.22, 56.61, 70.17, 75.33 and 89.53 cm, at 20, 40, 60 and 80 DAT and at harvest, respectively) was observed from N_1S_3 interaction (50% lower N than recommended dose and seedling grown in dapog seedbed).

The maximum number of tillers hill^{-1} (5.11, 10.10, 12.33 and 14.83, respectively) were recorded from N_5 (50% higher N than recommended dose) and the minimum number of tillers hill^{-1} (3.49, 7.51, 9.96 and 11.35, respectively) were observed from N_1 (50% lower N than recommended dose) at 20, 40, 60 and 80 DAT. The highest number of tiller hill^{-1} (5.57, 10.10, 13.04 and 14.24, respectively) were recorded from S_1 (seedlings grown in wet seedbed) and the lowest tiller hill^{-1} (3.90, 6.99, 10.74 and 12.08, respectively) by S_3 (seedlings grown in dapog seedbed) at 20, 40, 60 and 80 DAT. The maximum number of tillers hill^{-1} (6.78, 12.33, 13.86 and 15.71, respectively) was recorded from the interaction of N_5 S_1 (50% higher N dose than recommended dose and seedlings grown in wet seedbed) and the minimum number of tillers hill^{-1} (2.49, 4.88, 8.22 and 9.72, respectively) from the interaction of N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed) at 20, 40, 60 and 80 DAT.

At 60 DAT, 90 DAT, and at harvest the highest dry matter hill^{-1} (17.83, 33.50 and 45.16 g, respectively) from N_4 (25% higher N than recommended dose) treatment and the lowest dry matter hill^{-1} (16.04, 31.18 and 44.18 g, respectively) from the treatment N_3 (recommended dose) treatment was recorded. Statistically no significant variation was found due to seedling types for dry matter hill^{-1}. The interaction of N_4 S_1 (25% higher N than recommended dose and seedling grown in wet seedbed) give the highest dry matter hill^{-1} (18.62, 37.53 and 47.94 g, respectively) and the lowest dry matter hill^{-1} (11.90, 19.10 and 27.98 g, respectively) was recorded from the interaction of N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed) at 60 DAT, 90 DAT and at harvest.

The highest number of effective tiller hill^{-1} (10.38) was recorded from N_4 (25% higher N dose than recommended dose) and the lowest number of tiller hill^{-1} (7.44) was obtained from N_1 (50% lower N than recommended dose). The maximum number of effective tillers hill^{-1} (10.16) was obtained from S_1 (seedling grown in wet seedbed) and the minimum number of effective tillers hill^{-1} (4.43) was observed from S_3 (seedling grown in dapog seedbed). The maximum number of effective tillers hill^{-1} (12.68) was recorded from the interaction of N_4 S_1 (25% higher N than recommended dose and seedling grown in wet seedbed) and the minimum number of effective tillers hill^{-1} (6.187) was recorded from the interaction of N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed).

The highest number of non-effective tillers hill^{-1} (4.68) was obtained from N_1 (50% lower N than recommended dose) and the lowest number of non effective tillers hill^{-1} (3.51) was recorded from N_2 (25% lower N than recommended dose). The maximum number of non-effective tillers hill^{-1} (4.52) was recorded from S_1 (seedling grown in wet seedbed) and the minimum number of non-effective tillers hill^{-1} (3.19) was recorded for S_3 (seedling grown in dapog seedbed). The highest number of non-effective tillers hill^{-1} (5.30) was recorded from the combination of N_1 S_1 (50% lower N than recommended dose and seedling grown in wet seedbed) and the lowest number of non-effective tillers hill^{-1} (1.99) was found from N_5 S_3 (50% higher N than recommended dose and seedling grown in dapog seedbed) combination.

The maximum number of total tiller hill^{-1} (14.5) was recorded from N_4 (25% higher N than recommended dose) treatment and the lowest number of total tiller hill^{-1}(11.8) was recorded from N_1 (50% lower N than recommended dose). Again, the highest number of total tiller hill^{-1} (14.6) was recorded from S_1 (seedling grown in wet seedbed) and that of lowest (11.43) was recorded from S_3 (seedling grown in dapog seedbed). Combination N_4 S_1 (25% higher N than recommended dose and seedling grown in wet seedbed) gives the highest number of total tillers hill^{-1} (17.24) and N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed) combination gave the lowest number of total tillers hill^{-1} (8.71).

The longest panicle length (25.36 cm) was recorded from N_5 (50% higher N than recommended dose) and shortest panicle length (20.83 cm) was recorded from N_1 (50% lower N than recommended dose). Again, the longest panicle (24.21 cm) was found in S_1 (seedlings grown in wet seedbed) and the shortest panicle (21.59 cm) was recorded from S_3 (seedling grown in dapog seedbed). The interaction of 50% higher N than recommended dose and seedling grown in wet seedbed (N_5 S_1) showed the longest panicle (28.90 cm) and that of shortest 17.79 cm was observed by interaction of 50% lower N than recommended dose and seedling grown in dapog seedbed (N_1 S_3).

The maximum number of filled grain panicle^{-1} (88.55) was recorded from N_4 (25% higher N than recommended dose) and the minimum numbers of filled grain panicle^{-1} (71.07) was recorded from N_1 (50% lower N than recommended dose). The highest number of filled grain panicle^{-1} (89.50) was recorded from S_1 (seedling grown in wet seedbed) and that of lowest 75.26 was recorded from S_3 (seedling grown in dapog seedbed). Combination of N_3 S_1 (recommended dose and seedling grown in wet seedbed) showed the higher number of filled grain panicle^{-1} (98.30) and N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed) combination showed the lowest number of filled grain panicle^{-1} (66.67).

The lowest number of unfilled grains panicle^{-1} (19.46) was recorded from N_3 (recommended dose) and the highest number of unfilled grains panicle^{-1} (31.95) was recorded from N_5 (50% higher N than recommended dose). The lowest number of unfilled grains panicle^{-1} (22.27) was observed from S_1 (seedling grown in wet seedbed) and the highest number of unfilled grains panicle^{-1} (27.30) was recorded from S_3 (seedling grown in dapog seedbed). The minimum number of unfilled grains panicle^{-1} (17.55) was recorded from N_3 S_1 (recommended dose and seedling grown in wet seedbed) combination and the maximum number of unfilled grains panicle^{-1} (32.05) was recorded from N_1 S_2 (50% lower N than recommended dose and seedling grown in floating seedbed).

The highest weight of 1000-grains (24.80 g) was recorded from N_3 (recommended dose) treatment and the lowest weight of 1000-grains was found in N_5 (50% higher N than recommended dose) treatment. The highest weight of 1000-grains (24.05 g) was found in S_3 (seedling grown in wet seedbed) treatment and the lowest weight of 1000-grains was found in S_3 (seedling grown in dapog seedbed) treatment. The highest weight of 1000-grains (26.82 g) was found in the combination of N_3 S_1 (recommended dose and seedling grown in wet seedbed) and the lowest weight of 1000-grains (17.85 g) was recorded from the combination of N_5 S_3 (50% higher N than recommended dose and seedling grown in dapog seedbed).

The treatment N_4 (25% higher N than recommended dose) showed the highest grain yield (4.93 t ha^{-1}) and the lowest grain yield (2.95 tha^{-1}) was recorded from N_1 (50% higher N than recommended dose). The highest grain yield (4.73 t ha^{-1}) was recorded from S_1 (seedling grown in wet seedbed) and the lowest grain yield (3.53 t ha^{-1}) was observed from S_3 (seedling grown in dapog seedbed). The highest grain yield (5.6 t ha^{-1}) was found from N_4 S_1 (25% higher N than recommended dose and seedling grown in wet seedbed) and the lowest grain yield (2.50 t ha^{-1}) was recorded from N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed).

Treatment N_4 (25% higher nitrogen than recommended dose) showed the highest straw yield (5.88 t ha^{-1}) and the lowest straw yield (4.48 t ha^{-1}) was found in N_1 (50% lower N than recommended dose). Statistically no significant variation was found in terms of straw yield due to seedling type. The highest straw yield (6.01 t ha^{-1}) was found in N_4 S_3 (25% higher N than recommended dose and seedling grown in dapog seedbed) and the lowest straw yield

(4.14 t ha^{-1}) was recorded from N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed).

The highest harvest index (45.81 %) was observed from N_4 (25% higher N than recommended dose) and that of lowest 38.34 % was observed from N_1 (50% lower N than recommended dose). The highest harvest index (45.93) was found from S_1 (seedling grown in wet seedbed) and the lowest harvest index (40.09%) was recorded from S_3 (seedling grown in dapog seedbed). The highest harvest index (49.43 %) was recorded from N_4 S_1 (25% higher N than recommended dose and seedling grown in wet seedbed) and the lowest harvest index (33.82%) was recorded from N_1 S_3 (50% lower N than recommended dose and seedling grown in dapog seedbed).

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

- Application of nitrogen at recommended dose showed economically higher yield than other dose, although 25% higher N than recommended dose showed slightly higher yield *T. Aman*.
- Seedling grown in wet seedbed gave the higher yield than floating seedbed and dapog seedbed. If any where wet seedbed cannot be prepared in case of flooding then floating seedbed and dapog seedbed may be prepared for transplanting of seedling at the right time in main field.
- Use of recommended dose of nitrogen and seedling grown in wet seedbed appeared as promising for producing higher yield of *T. Aman* 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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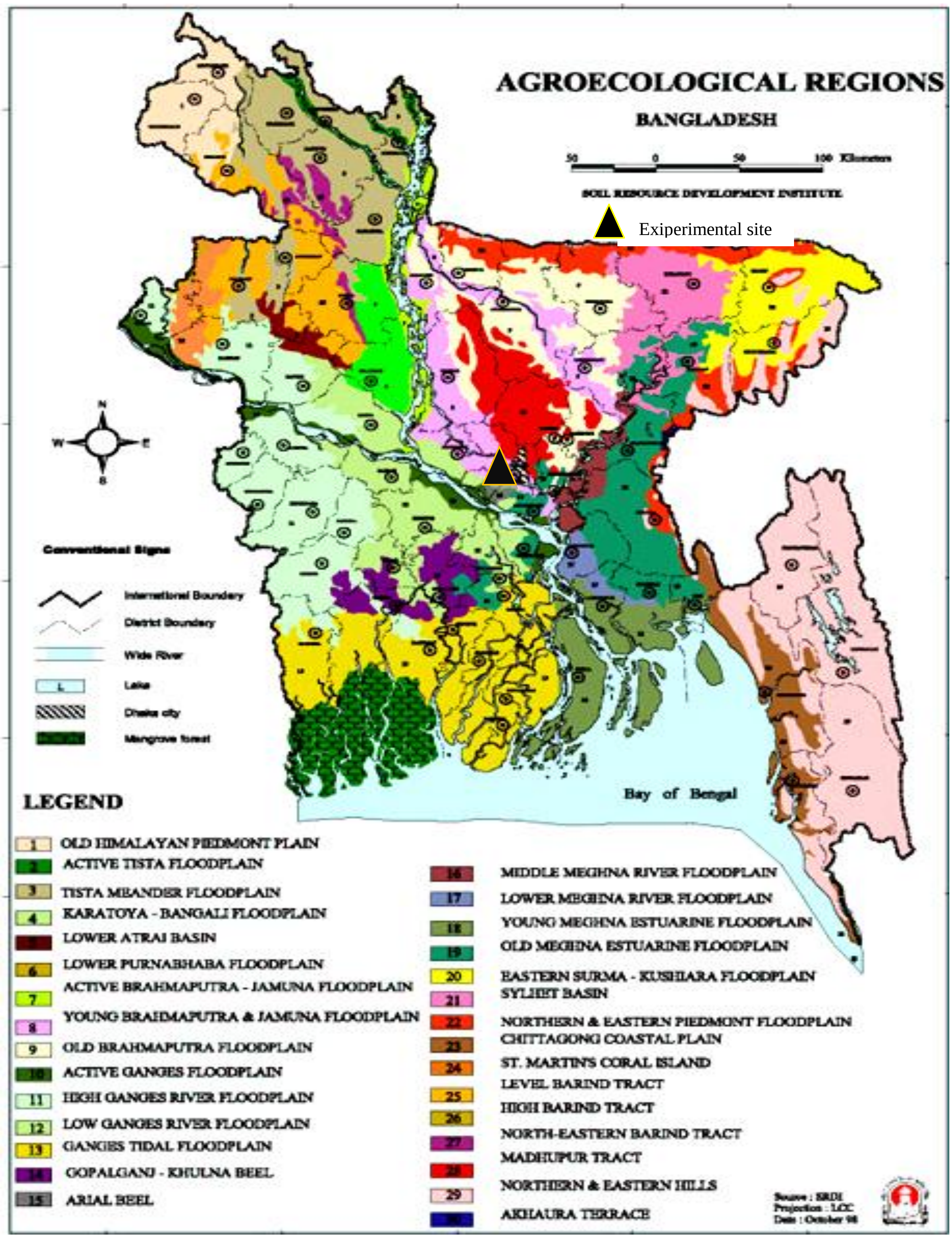
APPENDICES

Appendix I. Location of experimental site in agro ecological zone.



Appendix II. Chemical composition of soil of the experimental plot

Soil characteristics	Analytical results
Agro Ecological Zone	Madhupur Tract
P^H	5.47-5.63
Organic matter	0.85%
Potassium	0.13 meq/100 g soil
Calcium	3.50 meq/100 g soil
Megnesium	1.05 meq/100 g soil
Total N (%)	0.085%
Phosphorus	21.50 µg/g soil
Sulphur	24.96 µg/g soil
Boron	0.48 µg/g soil
Copper	3.55 µg/g soil
Iron	260.9 µg/g soil
Manganese	161.2 µg/g soil
Zinc	3.37 µg/g soil

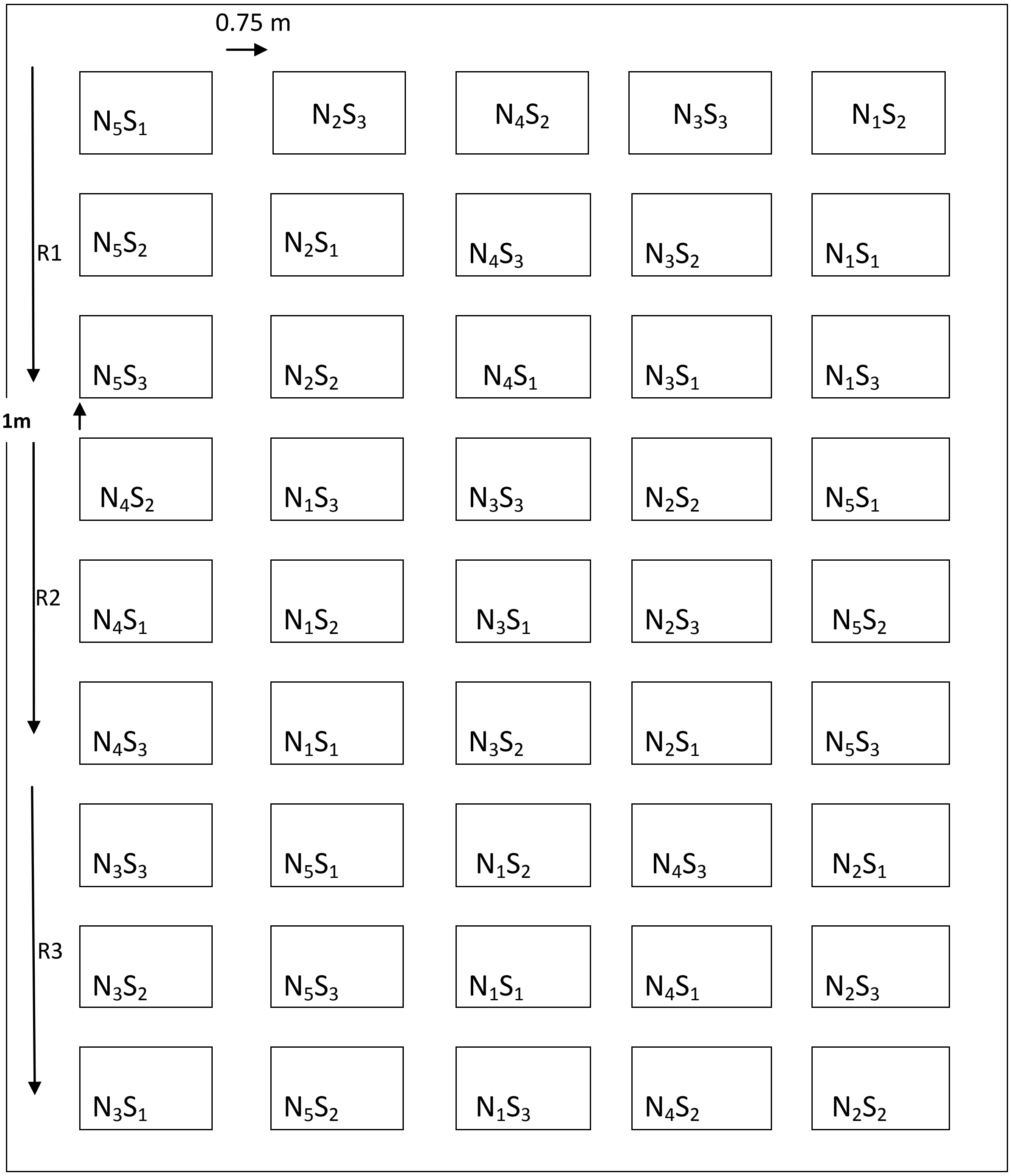
Source: Soil Resource Development Institute (SRDI), Khamarbari, Dhaka.

Appendix III. Monthly record of average air temperature, rainfall and relative humidity of the experimental site during the period from August 2008 to January 2009.

Month	Air temperature (^{0}C)		Relative humidity (%)	Rainfall (mm) (total)
	Maximum	Minimum		
August, 2008	28.10	17.23	76.20	50
September, 2008	27.50	16.05	74.90	35
October, 2008	27.05	15.25	74.20	20
November, 2008	26.50	14.90	72.52	Trace
December, 2008	25.90	14.13	68.59	00
January, 2009	24.85	13.85	70.26	00

Source: Bangladesh Meteorological Department (Climate and weather division), Agargoan, Dhaka

Appendix IV. Layout of the experiment



Appendix V. Analysis of variance (ANOVA) for plant height of BRRI dhan46 as influenced by nitrogen dose and seedling type

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		20 DAT	40 DAT	60 DAT	80 DAT	Harvest
Replication	2	5.20	208.29	164.68	344.62	446.87
Nitrogen (A)	4	29.35**	51.93*	76.38*	155.51*	103.78*
Error	8	2.64	19.18	27.75	20.75	15.00
Seedling (B)	2	215.71**	85.71*	71.65*	159.52*	97.27*
Interaction (A X B)	8	8.32^{NS}	3.29^{NS}	1.84^{NS}	24.34^{NS}	10.28^{NS}
Error	20	5.64	12.36	19.90	35.74	45.46

**: Significant at 0.01 level of probability
*: Significance at 0.05 level of probability
NS: Non Significant

Appendix VI. Analysis of variance (ANOVA) for tiller number $hill^{-1}$ of BRRI dhan46 as influenced by nitrogen dose and seedling type

Source of variation	Degrees of freedom	Mean square			
		Tiller number $hill^{-1}$ at			
		20 DAT	40 DAT	60 DAT	80 DAT
Replication	2	0.22	7.02	50.52	17.37
Nitrogen (A)	4	7.20**	8.19**	20.74*	15.77*
Error	8	5.18	2.84	0.582	1.94
Seedling (B)	2	11.13*	36.06**	19.54**	17.59**
Interaction (A X B)	8	0.33*	1.45*	0.73**	0.48**
Error	20	0.13	0.48	1.21	2.28

**: Significant at 0.01 level of probability
*: Significance at 0.05 level of probability
NS: Non Significant

Appendix VII. Analysis of variance (ANOVA) for dry matter $hill^{-1}$ of BRRI dhan46 as influenced by nitrogen dose and seedling type

Source of variation	Degrees of freedom	Mean square		
		Dry matter $hill^{-1}$ at		
		60 DAT	90 DAT	Harvest
Replication	2	19.29	0.33	57.31
Nitrogen (A)	4	27.37**	181.32**	370.11**
Error	8	1.46	3.68	6.90
Seedling (B)	2	19.23^{NS}	83.59^{NS}	61.36^{NS}
Interaction (A X B)	8	0.32*	2.59*	1.42*
Error	20	1.46	5.56	6.90

**: Significant at 0.01 level of probability
*: Significance at 0.05 level of probability
NS: Non Significant

Appendix VIII. Analysis of variance (ANOVA) for different yield contributing characters of BRRI dhan46 as influenced by nitrogen dose and seedling type

Source of variation	Degrees of freedom	Mean square					
		Different yield contributing characters at					
		Effective tiller hill^{-1} (no)	Non effective tiller hill^{-1} (no)	Panicle length (cm)	Filled grain panicle^{-1} (no)	Unfilled grain panicle^{-1} (no)	1000-grain weight (g)
Replication	2	3.09	0.51	12.54	2.00	11.57	1.52
Nitrogen (A)	4	10.36**	2.12**	7.63**	441.20**	290.72**	20.27**
Error	8	1.98	5.46	0.42	7.42	5.45	1.95
Seedling (B)	2	11.53**	6.93**	15.77^{NS}	765.07**	97.06**	21.05^{NS}
Interaction (A X B)	8	2.61**	1.09**	0.32**	25.84*	9.57*	3.25**
Error	20	0.90	0.06	6.38	24.42	4.94	2.42

**: Significant at 0.01 level of probability
*: Significance at 0.05 level of probability
NS: Non Significant

Appendix IX. Analysis of variance (ANOVA) for yield and harvest index of BRRI dhan46 as influenced by nitrogen dose and seedling type

Source of variation	Degrees of freedom	Mean square of		
		Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Replication	2	0.48	1.99	8.95
Nitrogen (A)	4	5.66**	3.23**	75.48**
Error	8	0.07	0.00	9.40
Seedling (B)	2	5.40**	0.35^{NS}	79.25**
Interaction (A X B)	8	0.09**	0.07*	2.15**
Error	20	0.17	0.25	7.66

**: Significant at 0.01 level of probability
*: Significance at 0.05 level of probability
NS: Non Significant