EFFECT OF NITROGEN SOURCES AND SPACING ON THE GROWTH AND YIELD OF T-AMAN RICE CV. BRRI dhan 31

BY

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CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF NITROGEN SOURCES AND SPACING ON THE GROWTH AND YIELD OF T-*AMAN* RICE CV. BRRI dhan 31"** 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. ROKIBUL HASAN, Registration No. 00889,*** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

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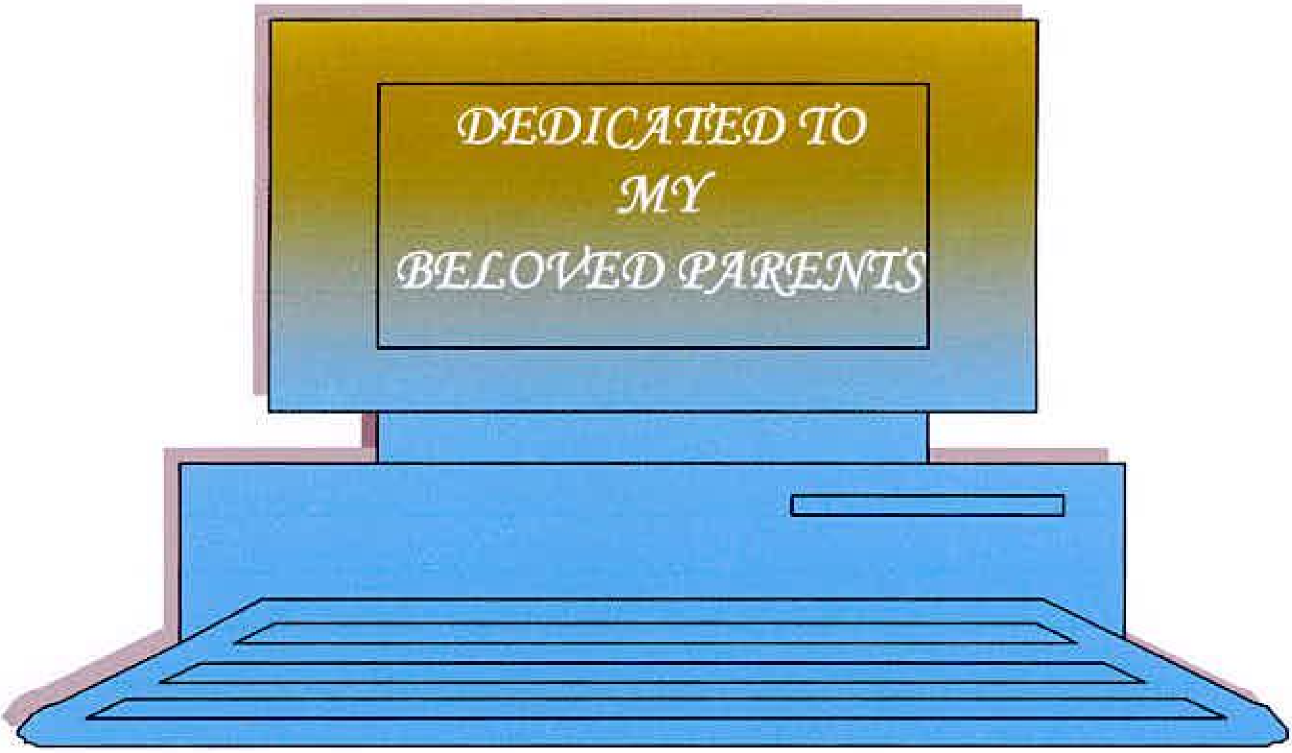
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ABSTRACT

The experiment was conducted at the Agronomy Field, Sher-e-Bangla Agricultural University, Dhaka from June to November 2007 to evaluate the effect of nitrogen sources and spacing on the growth and yield of T-*aman* rice of BRRI dhan 31. The experiment comprised of three nitrogen sources viz. prilled urea (PU), Urea super granules (USG) and foliar application of urea, and five spacing viz. 15 cm × 15 cm, 20 cm × 15 cm, 25 cm × 15 cm, 30 cm × 15 cm and 35 cm × 15 cm. The experiment was laid out in a split plot design with three replications assigning nitrogen sources in the main plot and spacing in the sub-plots. Nitrogen sources significantly changed all growth characters and yield attributes except 1000-grain weight. The highest plant height (105.70 cm at harvest), number of tillers $hill^{-1}$ (11.03 at 60 DAT), dry weight $plant^{-1}$ (101.95 g at harvest) were obtained from USG. The maximum grain yield (4.58 t ha^{-1}) was obtained from USG, which was attributed of higher number of effective tillers $hill^{-1}$ (7.55), the highest number of filled grains $panicle^{-1}$ (92.60) and highest panicle length (26.19 cm). The minimum grain yield (3.53 t ha^{-1}) was obtained from foliar application of urea. The effect of spacing was significant for all the crop characters except 1000-grain weight. Plant height, number of tillers $hill^{-1}$, dry weight $plant^{-1}$, effective tillers $hill^{-1}$, straw yield and biological yield were higher with widest spacing (35 cm × 15 cm). But number of filled grains $panicle^{-1}$ (102.2), panicle length (27.17 cm), grain yield (4.76 t ha^{-1}) and harvest index (45.97 %) were maximum in 25 cm × 15 cm spacing. The interaction between nitrogen sources and plant spacing had significant effect of crop characters except 1000-grain weight. Plant height, number of tillers $hill^{-1}$ and dry weight showed higher with the interaction of USG and 35 cm × 15 cm spacing. Number of effective tillers $hill^{-1}$, number of filled grains $panicle^{-1}$, panicle length, grain yield, biological yield and harvest index were found highest with the combination effect of USG and 25 cm × 15 cm spacing. On the other hand, lowest grain yield and straw yield was obtained from the interactions effect of foliar urea with 35 cm × 15 cm spacing and USG with 15 cm × 15 cm spacing, respectively.

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ACRONYMS AND ABBREBIATIONS

AEZ	Agro- Ecological Zone
Anon.	Anonymous
ANOVA	Analysis of variance
Atm.	Atmospheric
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
DMRT	Duncan's Multiple Range Test
e.g.	Example given
et al.	et alia (and others)
FAO	Food and Agriculture Organization
Fig.	Figure
g	Gram (s)
HI	Harvest Index
hr	Hour(s)
$Hill^{-1}$	Per hill
IRRI	International Rice Research Institute
IFDC	International Fertilizer Development Centre
i.e.	That is
K_2O	Potassium Oxide
kg	Kilogram (s)
LSD	Least Significant Difference
lb	Pound
m^2	Square meter
m^{-2}	Per square meter
mm	Millimeter
MP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Non Significant
PU	Prilled Urea
P_2O_5	Phosphorus Penta Oxide
S	Sulphur
S_x	Standard error of means
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
SCU	Sulphur Coated Urea
TDM/ TDW	Total Dry Matter/ Total Dry Weight
TSP	Triple Super Phosphate
USG	Urea Super Granule(s)

ACRONYMS AND ABBREBIATIONS

var.	Variety
Viz.	Namely
wt.	Weight
t ha^{-1}	Ton per hectare
^{0}C	Degree Centigrade
%	Percentage

Chapter 1
Introduction

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important crop of the tropical countries. There are 111 rice-growing countries in the world that occupy about 146.5 million hectares of land, more than 90% of which is in Asia (Anon. 2006). Rice is the staple food for more than two billion people in Asia and many millions in Africa and Latin America. Bangladesh is an agro-based country and predominantly rice based one as she earns about 23.08% of her gross domestic product (GDP) from agriculture. The area and production of rice in Bangladesh are about 10.37 million ha and 25.16 million tons, respectively, with an average yield of only 2.43 t ha^{-1}(BBS, 2006). In Bangladesh there are three diverse growing seasons of rice namely Aus, Aman and Boro. About two-thirds of the cultivated land area of Bangladesh is occupied by rice. Increased rice production in this country is essential to meet the food demand of the teeming population. Unfortunately, the yield of rice is very low in Bangladesh (2.43 t ha^{-1}) compared to Australia (9.65 t ha^{-1}), Korean Republic (6.59 t ha^{-1}), Japan (6.70 t ha^{-1}) and Spain (6.59 t ha^{-1}) respectively (FAO, 2004). The transplant *aman* rice covers about 50.92% of total rice area and contributes about 39.03% of total rice production in the country (BBS, 2006). The yield of *aman* rice is lower than that of *boro* rice. T-*aman* is the most important rice of the country in order to increase the national production. Aman rice is more popular in Bangladesh and farmers cultivate this crop more than the other season's rice. As Bangladesh has attained near self-sufficiency in food a continuous grain in rice production is essential. To meet the demand of the increasing population Bangladesh has doubled its rice production during the next 20 years. Since the land area is constant as well as a gradual decline in per capital land area in facts the only option remaining is to increase production per unit area.

Among the different factors for rice productivity, nutritional requirements especially nitrogen is the key element for its significant role in rice physiology.

Incase of modern variety of rice the requirement of nitrogenous fertilizer varies from variety to variety. The deficiency of nitrogen may cause severe adverse effect on the growth and development of the rice plants. Miyoshi (1991) indicated that yield of modern varieties of rice in Bangladesh usually lower compared to that obtained in other rice growing countries. Inadequate amount and appropriate method of nitrogenous fertilizer management might be the reasons behind such lower response. Adequate supply of nitrogen at all growth stages ensure proper development of the rice plant characterized by prolific tillering, satisfactory panicle formation, proper spikelet development and grain filling (Van Keulen, 1997).

The predominant form of nitrogen fertilizer granular urea is used in Bangladesh as prilled urea. The efficiency of nitrogen fertilizer is very low in rice. Nitrogen use efficiency for rice crop largely ranges between 25% and 35% and seldom exceeds 50% (Singh and Yadav, 1985). Stangel (1976) has estimated that 10% improvement of nitrogen fertilizer use efficiency would result in savings of US 3.2 billion dollar year^{-1} at farm level in the world. Modifying urea sources is an important aspect of nitrogen management in rice from the view point of its efficient utilization. Prilled urea application have been shown to be highly inefficient with nitrogen losses approaching 60-70% of the nitrogen applied (De Datta and Buresh, 1989; Cassman *et al.*, 2002). Because of the dynamic and reactive nature of nitrogen compounds, losses by ammonia volatilization, denitrification, run off and leaching can greatly reduce the plant availability of nitrogen from prilled urea. Such losses represent not only an economic drain for farmers but also have negative impaction on the environment since the reactive compounds of nitrogen decrease water quality and contribute to global climate change (Gallowya *et al.*, 2003). Placement of urea super granules (USG) in the root zone of rice 8-10 cm depth of the soil (reduce zone of rice soil) is the most effective method for increasing the nitrogen use efficiency by keeping most of the urea nitrogen in the soil close to the plant roots and out of the flood water where it is more susceptible to loss as gaseous compounds or run off (Mohanty *et al*., 1999). It is noted that using urea super granules (USG) can save 30% nitrogen than prilled urea, increase absorption rate, improve soil health and ultimately increase the rice yield (Savant *et al*., 1991). The recent literatures on nitrogen use efficiency of rice in general, would indicate the superiority of root zone placement of urea super granules (USG) as it could reduce the magnitude of nitrogen losses to a considerable extent and improve its use efficiency for better grain production (Crasswell and De Datta, 1980 and Pallai, 1981).

On the other hand, urea super granules (USG) dissolve slowly in the soil providing a steady supply of available nitrogen throughout the growing period of the crop. Using urea super granules (USG) to transplant *aman* rice in Bangladesh can offer a compelling example of effective approach to managing urea fertilizer that results not only improved efficiency but also greater yield with less urea fertilizer.

Feeding plant through the soil is a slow process. Nutrient solution sprayed on plant leaves can in some cases, be quickly absorbed and that relatively much smaller quantities of nutrients may be required for normal growth as against the large quantities of the same required for soil application. Fertilizer application to crops growing on water logged soil becomes extremely difficult mainly due to placement problems. Scientist has demonstrated that stems, leaves, fruits and flowers are able to take up nutrients although roots are the principal nutrient absorbing organ of a plant. The phenomenon has been termed as foliar-feeding that is uptake of nutrient by above ground or aerial parts of plants.

Rate of absorption is generally higher by younger leaves which are closer to the growing points than that of leaves away from them. Moreover in younger leaves the absorption is higher from the back side of the leaves than that from the face. In older leaves the absorption is generally less and less difference is observed between the sides of a leaf. Urea is generally absorbed from the back side of the leaves rather from the face (Mitsui, 1967).

Spacing is one of the key factors that need to be considered for transplant *aman* rice. Optimum plant spacing enhances proper growth of plants both their aerial and underground parts through efficient utilization of solar radiation, nutrient and ultimately the yield (Miah *et al.*, 1990). In case of too wide spacing, the desired number of hills unit^{-1} area is not attained and this can reduce the yield. In closer spacing, more seedlings and laborers are needed which can increase the production cost and is a losing concern (Uddin, 1989). Therefore, optimum spacing must be maintained for higher yield of rice.

So in view of the above discussion the present study was designed and carried out with the following objectives:

1. To find out the effect of prilled urea (PU), urea super granular (USG) and foliar spray of urea on the growth and yield of transplant *aman* rice,
2. To find out the optimum spacing for higher yield of transplant *aman* rice, and
3. To observe the interaction effect of nitrogen sources and spacing on the growth and yield of transplant *aman* rice.

Chapter 2

Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

Rice is the principal food crop for the people of Bangladesh. A number of research works have been done on various aspects of its growth and yield at different ecological situations. Nitrogen fertilizer plays a significant role on growth and yield of transplant *aman* rice. Spacing is one of the factors that affect the yield of transplant *aman* rice. In this chapter, some research works relating to the effect of different form of nitrogen and spacing on growth and yield component of transplanted rice are reviewed and discussed.

2.1 Effect of different forms of nitrogen on plant characters and yield of rice

2.1.1 Plant height

Rajagopalam and Palaniasamy (1985) carried out an experiment with two levels of urea supergranules (USG) as 50 and 75 kg N ha^{-1} in *kharif* season. They found that the highest plant height (83cm) was obtained with 75 kg N ha^{-1} as USG.

Rahman (2003) stated that plant height did not affected by the different level of USG. He also found that different level of USG did not have any significant effect on 1000-grain weight of two *aman* rice cultivars.

Alam (2002) conducted an experiment at the agronomy field laboratory, BAU, Mymensingh during the *boro* season with three varieties and four level of USG. He observed that 1000-grain weight was not influenced by level of USG. He also found increased plant height with the increase of level of USG/4 hill.

Singh and Singh (1986) observed that plant height increased with the increased level of nitrogen fertilizer from 27-87 kg N ha^{-1}. They also found that deep placement of urea super granules (USG) resulted in the highest plant height than prilled urea.

2.1.2 Tillering pattern

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

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

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

2.1.3 Panicle length

Patel and Mishra (1994) carried out an experiment and found that different rate of N (0, 30, 60 or 90 kg ha^{-1}) as USG had no significant effect on panicle length and percent sterility.

2.1.4 Grains panicle^{-1} and 1000-grain weight

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

Nassem *et al.*, (1995) conducted an experiment and found that percent grain remain unchanged in response to different levels of nitrogen but a significantly lower 1000-grain weight was recorded in the control treatment than in the plots received nitrogen fertilizer.

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

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

2.1.5 Grain yield and straw yield

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

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

Urea super granules gave 14.9% higher yield than prilled urea applied 3 split applications (Mahalle and Throat, 1995; and Patel and Mishra, 1994). Choudhury and Bhuiyan (1994) reported that 87 kg N ha^{-1} as urea super granules gave highest yields compared with prilled urea applied as 3 equal splits. USG placed by hand at 8-10 cm depth after seedling establishment. Grain yield was highest when 112 kg N ha^{-1} was applied as large granular urea in 3 split dressing than prilled urea applied in 3 splits (Raja *et al.*, 1994).

Bhuiyan *et al.*, (1998) carried out an experiment at BRRI during 1975-1985 on USG and reported that deep placement of urea for rice was superior to split broadcast application of prilled urea during the dry season and the economics of use appeared favorable.

Pandey and Tiwari (1996) conducted a field trial with 87 kg N ha^{-1} as basal application of USG, PU, mussoorie rock phosphate urea (MRPU), large granule urea (LGU) or neem coated urea (NCU) or 66% basal incorporation + 33% top dressing at panicle initiation and found that grain yield and N use efficiency were highest with N given as a basal application of USG or MRPU applied in 2 split applications.

Kumar *et al.*, (1996) reported that application of urea supergranules in the sub-soil gave 22% higher grain yield than control.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Rao *et al.*, (1986) worked on the method of application of urea and reported that USG was the most effective in increasing TDM than split application of urea.

From an international trial in eight countries under INPUTS project Yoshida *et al.*, (1978) observed that deep placement of USG was superior both for yield and nitrogen recovery over conventional method of urea application. They achieved 1 t ha^{-1} increased yield by 41 kg N ha^{-1} in USG but the rate was 60 kg N ha^{-1} of increased yield in case of urea.

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

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

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

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

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

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

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

Narayanan *et al.*, (1958) carried out an experiment and reported that spraying urea on rice at the of 15 lb ac^{-1} as a solution at the pre flowering stage gave 6% more grain and 50% more straw.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.2 Effect of spacing on plant characters and yield of rice

2.2.1 Plant height

Haque (2002) carried out an experiment with the spacing of 20 cm × 20 cm, 30 cm × 30 cm, 30 cm × 40 cm and 40 cm × 40 cm and found tallest plant from wider spacing. Miah *et al.* (1990) reported that plant height was influenced significantly due to spacing at all days after transplanting (DAT) except 15 DAT. It was observed that the widest spacing (25 cm × 20 cm) produced the tallest plant (120.80 cm) at 90 DAT and the shortest plant stature (112.98 cm) was in the closest spacing (19 cm × 20.80 cm) at that DAT.

Akita and Tanaka (1992) found that panicle formation and plant height were more with 49 hills m^{-2} but at heading maturity the tallest plants were found at low plant density. When planted on square system the number of culm at panicle formation was the greatest at 100 hill m^{-2} but at heading it was greatest at 64 hills m^{-2}, total dry weight increased with planting density and was highest when planted on the square and in rows with 64 and 100 hills m^{-2}, respectively.

Khisha (2002) stated that the highest plant height (122.52 cm) was obtained from 12 days old single seedling $hill^{-1}$ with 40 cm × 35 cm spacing and lowest plant height (109.9 cm) was found in normal practice which was thirty days old 2 seedlings $hill^{-1}$ with 25 cm × 15 cm spacing.

Shah *et al.*, (1991) reported that, in a field trial in 1987 that rice cv. K39 was grown at 15 cm × 15 cm or 10 cm × 10 cm plant spacing. Plant height was the greatest with 15 cm ×15 cm spacing. Spacing has a remarkable influenced on the number of total tillers.

2.2.2 Tillering pattern

Miah *et al.*, (1990) conducted an experiment using rice cv. Nizersail and mutant lines Mut. NS1 and Mut. NS5 transplanted at 15, 20, 25 and 30 cm row spacing. Plant height and number of grains $panicle^{-1}$ were higher in Mut. NS1 than in Nizersail. Number of effective tillers $hill^{-1}$ was higher at wider row spacing.

Akhter (2003) conducted an experiment where three seedling ages viz. 8, 12 and 16-day-old, three hill spacing viz. 20 cm × 20 cm, 30 cm × 30 cm and 40 cm × 40 cm and two number of seedlings per viz. 1 and 2 seedlings $hill^{-1}$ were included as experimental treatments. It was found that the widest spacing 40 cm × 40 cm produced the tallest plants, the highest number of tillers $hill^{-1}$ and lowest number of non-effective tillers $hill^{-1}$.

Sarker (2003) carried out an experiment on rice *cv.* BRRI dhan 39 with three row arrangements viz. single, double and triple row and reported that leaf dry matter, stem dry matter and total dry matter were significantly highest in triple row arrangement. On the other hand, plant height and total tillers hill^{-1} were the highest in single row arrangement. But grain yield and harvest index were highest in double row arrangement.

Siddiqui *et al.*, (1999) reported that effective tillers were significantly more in closer spacing (10 cm × 10 cm). The closer spacing (10 cm × 10 cm) produce significantly higher grain yield over wider spacing (20 cm × 10 cm).

Chris (2002) reported that among three plant spacing 20 cm × 20 cm, 30 cm × 30 cm and 40 cm × 40 cm, the highest number of tillers hill^{-1} was recorded from 20 cm × 20 cm spacing. Mustapha (2002) reported that the widest spacing of 40 cm × 40 cm produces the highest number of tillers hill^{-1}. The lowest number of tillers hill^{-1} was founded in 20 cm × 15 cm spacing. In wider spacing plants received more nutrient, moisture and light which resulted on more number of tillers hill^{-1}.

Tsai (19870 conducted an experiment where rice cv. Pegonil and Tainung 67 grown at spacing of 30 cm × 15 cm or 30 cm × 7.5 cm with 1 or 4-6 plants hill^{-1} with the wider spacing and several seedlings hill^{-1} produced lower tiller than Tainung 67.

Hossain (2002) reported that the highest number of effective tillers hill^{-1} (11.31) was founded in SRI practice with 15 days old seedlings and 25 cm × 15 cm spacing in BRRI dhan 32. Verma *et al.*, (2002) found that seedlings planted at 20 cm × 20 cm and 20 cm × 15 cm spacing produces higher number of productive tillers than the seedlings planted at 20 cm × 10 cm gave higher sterility percentage than wider spacing.

Hu *et al.*, (1997) reported that among the spacing of 30 cm × 10 cm, 30 cm × 17 cm, 30 cm × 27 cm, 40 cm × 20 cm or 33 cm × 27 cm, the greatest number of tillers was reached with lower plant spacing (40 cm × 20 cm spacing).

Sarker (2001) reported that row spacing exerted significant effect on the production of tillers hill^{-1} at all sampling dates. There was in increasing trend of tiller production with the increase in spacing on all the dates of observation.

Shrirame *et al.*, (2000) reported that the widest spacing of 20 cm × 15 cm produces the maximum number of functional leaves hill^{-1}, maximum leaf area hill^{-1} and total number of tillers hill^{-1} but plant height, grain and straw yield and harvest index were not affected.

Srinivasan and Purushothamam (1990) reported in rice *cv.* Ponni and Bhavani when transplanted at 29 cm × 15 cm or 25 cm × 10 cm increased number of productive tillers at higher plant density in the main and ratoon crops but had no significant effect on grain and straw yield of ratoon crops.

2.2.3 Panicle length

Kalita *et al.*, (1997) observed that closer spacing decreased yield components including grains panicle^{-1}, panicle length and panicle weight but increased panicle numbers m^{-2}. Rekhashri *et al.*, (1997) reported that closer spacing decreased yield components including number of grains panicle^{-1}, panicle length and panicle weight but increased panicle numbers m^{-2} which slightly increased grain yield.

Liou (1987) reported that rice cultivars with closer spacing markedly decreased the panicle length, when grown at spacing 12.5 cm × 12.5 cm, 25 cm × 25 cm or 50 cm × 50 cm.

Shirakawa *et al.*, (1992) reported that in rice *cv.* Koshinikari, plant height and panicle length decreased with a decreased in grain yield as plant density increased from 6-32 plants m^{-2}.

2.2.4 Grains panicle^{-1} and 1000-grain weight

Ghosh *et al.*, (1998) obtained the highest number of grains panicle^{-1} at a spacing of 30 cm × 30 cm over closer spacing of 20 cm × 20 cm and 20 cm × 25 cm.

Yan (2002) reported that rice var. Yaza I gave maximum yield of 12.79 t ha^{-1}, had 240 effective panicles m^{-2} and 198 grains panicle^{-1} with a 1000-grains weight of 27.05 g when plant spacing was 50 cm × 50 cm. Wang *et al.* (2002) reported that 1000-grains weight were 26.53, 26.72, 26.96 and 26.7 (g) with spacing distance of 25 cm × 25 cm, 25 cm × 15 cm, 30 cm × 30 cm or 30 cm × 15 cm, respectively.

Halder *et al.*, (2000) stated that closer spacing produces higher number of panicle, higher 1000-grain weight and yield than wider spacing. Muhammad *et al.*, (1997) reported that 1000-grain weight decreased with increasing plant density.

2.2.5 Grain yield and straw yield

Wanjari *et al.*, (2006) found that a single seedling hill^{-1} with the spacing of 15 cm × 15 cm in hybrid rice gave the highest yield. Rahman (2005) conducted an experiment with rice *cv.* BR 26 with four spacing viz. 20 cm × 15 cm, 25 cm × 15 cm, 20 cm × 20 cm, 25 cm × 20 cm to find out the effect of spacing on yield attributes and yield and reported that the highest grain and straw yields were obtained from 20 cm × 15 cm spacing due to highest number of effective tillers m^{-2}.

Rajesh and Thanunathan (2003) observed that plant spacing of 40 days old seedlings at 2 seedlings hill^{-1} with a spacing of 20 cm × 25 cm recorded the maximum grain yield of 2.85 t ha^{-1} and 2.65 t ha^{-1} in experiment I and II, respectively.

Guilani *et al.*, (2003) observed that the effect of hills spacing (15 cm × 15 cm, 30 cm × 30 cm, 45 cm × 45 cm plots) on crop and yield components of rice cultivars were evaluated in Khusestan and Iran during 1997. They showed that the highest crop yield plot^{-1} (7.74 t ha^{-1}) was obtained with 15 cm × 15 cm spacing.

Santos *et al.*, (2002) observed the response of the rice cultivars on different hill spacing (20 cm, 30 cm and 40 cm). Hill spacing of 30 cm and 40 cm significantly increased crop yield. Haque (2002) conducted an experiment during *boro* season with *cv.* BINA dhan 6 and found that the highest biological yield (14.24 t ha^{-1}) was obtained from 45 days old seedling hill^{-1} with the spacing of 30 cm × 30 cm. The lowest biological yield (7.51 t ha^{-1}) was obtained from 45 days old seedling hill^{-1} with 40 cm × 40 cm spacing.

Neelam and Nisha (2000) conducted an experiment with scented rice *cv.* Pusa Basmati 1 cultivated under various plant spacing viz. 30 cm × 15 cm, 15 cm × 15 cm and 20 cm × 20 cm and found that spacing did not influence grain and straw yield.

BRRI (2000) reported that the effect of plant density at various nitrogen levels was studied to find out whether the loss of crop production in less fertile soil could be overcome by increasing plant density. Plant spacing were 40 cm × 20 cm, 25 cm × 25 cm, 25 cm × 10 cm and 20 cm × 10 cm. Grain yield increased with the increased in plant density up to 20 hills m^{-2}, further increasing plant density increase the transplanting cost by at least 65%.

Chavan *et al.*, (1989) found from an experiment at different spacing that grain yield and grain: straw ratio increased with wider spacing.

Patel (1999) found that higher plant density (20 cm × 10 cm) recorded appreciable increase in grain yield compared to that of 20 cm × 15 cm and 15 cm × 10 cm spacing.

BRRI (1999) conducted an experiment with three rice varieties at different Regional Research Stations under different spacing of 10 cm x 10 cm to 30 cm × 30 cm using normal cultural practices and reported that grain yield, straw yield, total dry matter, leaf area index, specific leaf area and harvest index were varied significantly. Yield varied from 2.2 to 3.45 t ha^{-1} in closer spacing with an average of 3.04 t ha^{-1} whereas the yield varied from 2.27 to 4.89 t ha^{-1} in wider spacing with an average of 3.83 t ha^{-1}. Most of the varieties gave higher grain yield in wider spacing.

Rafiq *et al.*, (1998) carried out an experiment where rice *cv.* Basmati 385 were transplanted with 30 cm × 25 cm, 30 cm × 20 cm, 30 cm × 16 cm and 20 cm × 20 cm spacing and obtained the highest grain yield of 4.88 t ha^{-1} with 20 cm × 20 cm spacing.

Hegazy *et al.*, (1995) found in a trial where rice was planted in 15 cm × 15 cm, 20 cm × 20 cm or 20 cm × 25 cm that the yield was highest at 20 cm × 20 cm row spacing. Grain yield was not significantly affected by plant density.

Azad *et al.*, (1995) observed from an experiment with rice seedlings transplanted at 20 cm × 10 cm, 25 cm × 15 cm, 30 cm × 20 cm spacing. They have found that grain yield was decreased with the wider spacing.

Krishna *et al.*, (1994) conducted an experiment where rice *cv.* IR20 was grown at spacing of 20 cm × 10 cm or 15 cm × 10 cm and found that grain yield was higher with wider spacing.

Islam *et al.*, (1994) found that grain and straw yields increased with closer spacing in both row and hill direction. The closer spacing of 20 cm × 15 cm with six seedling hill^{-1} produced 61% and higher grain yield and straw yield, respectively over 40 cm × 30 cm spacing with 10 seedlings hill^{-1}.

Chowdhury *et al.*, (1994) conducted an experiment with three spacing of 15 cm × 15 cm, 20 cm × 15 cm and 20 cm × 20 cm with three varieties viz. BR 22, BR 23 and Nizersail and found that BR 23 and Nizersail performed better for seed yield and gross return.

Om *et al.*, (1993) studied the effect of spacing on grain yield of rice *cv.* Basmati and found that when transplanted at 15 cm × 15 cm, 22.5 cm × 15 cm or 30 cm × 15 cm and 30 cm × 15 cm produced grain yield of 4.80, 3.91 and 3.63 t ha^{-1}, respectively.

Ramakrishna *et al.*, (1992) conducted an experiment with rice *cv.* Jaya transplanted at 10 cm × 10 cm, 20 cm × 10 cm and 20 cm × 15 cm spacing and found that grain yield decreased with increasing plant spacing.

Reddy *et al.*, (2001) reported that planting of rice at a closer spacing of 15 cm × 10 cm resulted in higher grain yield (4.06 and 5.03 t ha^{-1} during 1996 and 1997, respectively) as compared to normal planting at a spacing of 20 cm × 10 cm (3.59 and 4.81 t ha^{-1} during 1996 and 1997, respectively) and recorded a mean increase of 7.6% higher grain yield over the normal spacing.

Mustapha (2001) claimed that differences in population density in rice cv. IET306 gave relatively similar yield between 20 cm × 15 cm and 30 cm × 15 cm spacing. Stover yield increased with an increase in spacing, but that did not correspond to an increase in grain yield. Transplanting at a spacing of 40 cm × 40 cm gave the highest stover mass, but the grain yield was the lowest.

Islam (1999) stated that plant spacing of 25 cm × 25 cm and 20 cm × 20 cm, yield the same (9.5 t ha^{-1} and 9.2 t ha^{-1} respectively) but with spacing of 30 cm × 30 cm the yield increase up to 10.5 t ha^{-1} which was 4.5 t ha^{-1} more than the current national highest average yield of 6 t ha^{-1}.

Budhar *et al.*, (1993) studied that rice cv. CR666-18 transplanted at a spacing of 10 cm × 8 cm with 2 or 4 seedlings $hill^{-1}$, gave paddy yields of 3.8 and 4.4 t ha^{-1}, respectively. There was no significant difference in respect to yield. Crops grown at a spacing of 10 cm × 10 cm with 2 or 4 seedlings $hill^{-1}$ yielded 3.0 t ha^{-1}.

Bisht *et al.*, (1991) reported that in hybrid rice cv. PRHI closer spacing increased the grain yield significantly by promoting panicle number m^{-2} and total spikelet m^{-2}.

Rao *et al.*, (1990) found that grain yields was highest (t ha^{-1}) at 20 cm × 15 cm spacing and decreased with closer spacing due to few filled spikelets $panicle^{-1}$ and lower panicle weight and yield was also found to be decreased at wider spacing despite of slightly higher panicle weight.

Karim *et al.*, (2002) conducted an experiment in *boro* season of 2000-2001. Spacing of 30 cm × 30 cm, 35 cm × 35 cm and 40 cm × 40 cm were tested and found that the highest, number of total tillers $hill^{-1}$ was produced in wider spacing of 35 cm × 35 cm or 40 cm × 40 cm.

Hasan and Sarker (2002) reported that CARE/Bangladesh conducted same 17 trials at Kishoregonj during *aman* season and found that the average yield of SRI plots was 6.5 t ha^{-1} which was 39% more than the farmer's conventional practices and the highest yield attained 7.5 t ha^{-1}.

Hossain (2002) conducted a field experiment during *aman* with cv. BRRI dhan 32. The result exposed that the highest biological yield (11.65 t ha^{-1}) was obtained from SRI planting method, with the 15 days old seedling $hill^{-1}$ with the spacing 25 cm × 25 cm. The lowest biological yield (7.94 t ha^{-1}) was obtained from conventional planting method which was 25 days old seedling $hill^{-1}$ through spacing of 25 cm × 15 cm.

Kim *et al.*, (1990) found that harvest index was increased by dense planting. Bhab *et al.*, (1987) found that harvest index was highest with 15 cm × 15 cm spacing.

From the reviews cited above it is clear that nitrogen sources and spacing have pronounced influence on the yield and yield contributing characters of rice plant. Thus there may have enough scope of investigating into the effect nitrogen sources and spacing in favor of yield improvement of transplant *aman* rice.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during June to November 2007. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recordings and their analyses.

3.1 Site description

The experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka under the Agro-ecological zone of Modhupur Tract, AEZ-28 during the Aman season of 2007. The land area was situated at 23°41′N latitude and 90°22′E longitude at an altitude of 8.6 meter above sea level. The experimental site has been shown in the AEZ Map of Bangladesh in Appendix I.

3.2 Climate

The experimental area was under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March). The weather data during the study period of the experimental site has shown in Appendix II.

3.3 Soil

The soil of the experimental field belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done from Soil Resources and Development Institute (SRDI), Dhaka. The physicochemical property of the soil has presented in Appendix III.

3.4 Crop/Planting materials

A high yielding variety of Aman rice BRRI dhan 31 was used as a test crop. The variety BRRI dhan 31 was developed from the cross between BR 11 and ARC10550 by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, Bangladesh. It inheritance number was BR1725-13-7-1-6. The height of the variety is 115 cm. it is characterized by deep green and erect leaves. The life cycle of this variety ranges from 140-145 days. Its grain size is medium-coarse and color of kernel is white. The variety was released in 1994 for cultivation in Aman season. BRRI dhan 31 is highly resistant to Brown plant hopper and moderately resistant to Leaf Blight and Tungro (BRRI, 2004).

3.5 Fertilization

Granular urea or prilled urea (PU), urea super granules (USG) and foliar spray of urea application were used as the source of nitrogen fertilizer.

Prilled Urea: It is the most common form of urea available in the market. It contains 46% N. The mean diameter of urea aggregates is 1.5 mm.

Urea super granule: Urea super granule fertilizer is manufactured by physical modification of granular urea. It has been developed by the IFDC, Muscle Shoals, Alabama and USA. It is well recognized as a slow release nitrogenous fertilizer containing 46% N. Its nature and properties are similar to that of urea but its granule size is bigger, condensed with some conditions for slow hydrolysis. It can easily be placed in reduce layer as deep placement. The weight of individual granule is 1 gm approximately.

Foliar application of urea

Urea is highly soluble fertilizer especially in water which can be used as spray form in the plant. It was sprayed by the knapsack sprayer.

3.6 Experimental treatments:

The experiment consisted of the following treatments:

Factor A: Nitrogen sources (3)

i) Prilled urea (PU) or granular urea (U_1)

ii) Urea super granules (USG) (U_2)

iii) Foliar spray of urea (U_3)

Factor B. Spacing (5)

i) 15 cm × 15 cm (S_1)

ii) 20 cm × 15 cm (S_2)

iii) 25 cm × 15 cm (S_3)

iv) 30 cm × 15 cm (S_4)

v) 35 cm × 15 cm (S_5)

3.7 Design and layout of the experiment

The experiment was laid out in a split-plot design with three replications. Each replication was divided into three main plots and each main plots were divided into five sub-plots where nitrogen sources were assigned in the main plot and row spacing in the sub plots at random. The total number of plot was 45 and the size of unit plot was 4.0 m × 3.0 m = 12 m^2. The distances between plot to plot and replication to replication were 1m and 1.5 m, respectively. The layout of the experiment has been shown in Appendix IV.

3.8 Collection and preparation of initial soil sample

The initial soil samples from the main field were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different locations covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves were picked up and removed. Then the sample was air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.9 Crop production practices

3.9.1 Nursery bed preparation and raising of seedlings

A piece of high land was selected for the nursery bed. The nursery bed was prepared well by puddling with repeated ploughing followed by laddering to level the soil. The nursery bed was cleaned properly by removing of weeds and stubble. Healthy and vigorous seeds of BRRI dhan31 were collected from BRRI. Seeds were than soaked in water in a bucked for 24 hours. Thereafter, the seeds were taken out of water and kept thickly in gunny bags for sprouting. After 48 hours, the sprouted seeds were sown in the finely prepared nursery bed on 22 June 2007. Care was taken to see that there was no damage by birds and no infestation of pest and diseases. Weeds were removed and irrigation was given in the nursery bed as and when necessary. Proper care was taken to raise healthy seedlings.

3.9.2 Preparation of main land for transplanting

The experimental field was first opened on July 07, 2007 with the help of a disc plough and later on, the land was irrigated and prepared by three successive ploughing and cross-ploughing. Each ploughing was followed by laddering to have a good puddled field. The corners of the land were spaded. All kinds of weeds and residues of previous crop were removed from the field. The field layout was made on July 25, 2007 according to design immediately after final land preparation. Individual plots were cleaned and finally leveled with the help of wooden ladder. The land was then ready for transplanting.

3.9.3 Fertilizer application

3.9.3.1 Basal application

At the time of first ploughing cowdung at the rate of 10 t ha^{-1} was applied. The experimental field was fertilized with 120, 80, 120, 55 and 10 kg ha^{-1} N, P_2O_5, K_2O, S and Zn applied in the form of urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum and zinc sulphate respectively. The whole amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at final land preparation as a basal dose. Urea was applied in two equal installments. The first one-half of urea was applied after recovery at 7 days after transplantation; second one-half was applied at maximum tillering stage.

3.9.3.2 Placement of urea super granules

After 7 DAT, nitrogen applied in the form of urea super granules (One USG) treatment at the rice root zone i.e., at 6-9 cm depth of the soil.

3.9.3.3 Foliar application of urea

After 7 DAT and maximum tillering stage, nitrogen was applied in the form foliar spray 800 liter ha^{-1} of water @20 kg N ha^{-1} or 25000 ppm N ha^{-1} of the rice plant leaves. The total volume was allowed for half an hour to dissolve the urea completely. The suspension was filtered with cloth so that no dust remained in the solution and to ensure easy passing through the nozzle of sprayer (Ali *et. al.*, 1996).

3.9.4 Uprooting of seedlings

The nursery bed was made wet by applying water in the morning and evening on the previous day before uprooting the seedlings to reduce mechanical injury to the roots. The seedlings were uprooted and kept on soft mud in shade before they were transplanted. The seedlings similar in size having no injury were only used for transplanting.

3.9.5 Transplanting of seedlings

Thirty-two day old seedlings were transplanted on well puddle plots on 27 July 2007 according to the experimental design by maintaining five different row spacing as per treatments. Transplanting was done by using 2 seedlings $hill^{-1}$.

3.9.6 Intercultural operations

The following intercultural operations were done for ensuring normal growth of the crop.

Gap filling

After one week of transplanting, a minor gap filling was done where it was necessary using the seedling from the same source.

Weeding

During plant growth period three hand weeding were done. First weeding was done at 20 days after transplantation followed by second weeding at 15 days after first weeding and third weeding at 15 days after second weeding.

Irrigation and drainage

Irrigation water was added to each plot as per requirements. Before ripening, the field was allowed to become dry for all the treatments. The drainage system was good and the ails of individual plot was high because it was the time of rainy season.

Plant protection measures

During the growth period some plants were infested with rice stem borer (*Scirpophaga incertulus*) and rice hispa (*Dicladispa armigera*) to some extent which were successfully controlled by applying Diazinon two times @ 10 ml/ 10 liter of water for 5 decimal lands and by Ripcord one time @ 10 ml/ 10 liter of water for 5 decimal lands. Crop was protected from birds and rats during the grain filling period. Field trap and poisonous bait were used to control the rat. For controlling the birds watching was done properly, especially during morning and afternoon.

3.9.7 General observation of the experimental field

The field looked nice with normal green plants. The plants in the wider spacing appeared to be more vigorous and luxuriant than that of closer spacing. Field was observed time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest was minimized. Incidence of stem borer, leaf roller and rice hispa (*Dicladispa armigera*) was observed during tillering stage but controlled properly.

3.9.8 Sampling and harvesting:

Ten hills (excluding border hills) from each plot were randomly selected from which different growth and yield attributes data were collected and 3 m^2 areas from middle portion (pre-marked) of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Maturity of crop was determined when 90% of the grains became golden yellow in color. The harvesting was done at full maturity on 26 November 2007. Threshing was done by using pedal thresher. The grains were cleaned and sun dried to a moisture content of 12 %. Straw was also sun dried properly. Grain and straw yields $plot^{-1}$ were converted to t ha^{-1}.

3.10 Collection of data

Experimental data (Growth and yield) were collected from 20, 40 and 60 days after transplanting and at harvest. The following data were recorded during the experimentation.

A. Growth data:

1. Plant height (at 20, 40, 60 DAT and at harvest)
2. Number of tillers hill^{-1} (at 20, 40 and 60 DAT)
3. Dry weight of plant (at 20, 60 DAT and at harvest)

B. Plant, yield components and yield data:

1. Number of effective tillers hill^{-1} (At harvest)
2. Number of non-effective tillers hill^{-1} (At harvest)
3. Length of panicle (cm)
4. Number of fertile spikelets panicle^{-1} (Filled grain)
5. Number of sterile spikelets panicle^{-1} (Unfilled grain)
6. Number of total grains panicle^{-1}
7. Weight of 1000-grains (g)
8. Grain yield (t ha^{-1})
9. Straw yield (t ha^{-1})
10. Biological yield (t ha^{-1})
11. Harvest Index (%)

3.10.1 Procedures of recording data

A brief outline of the data recording procedure is given below:

A. Crop Growth data

Plant height (cm)

The height of the preselected 10 hills were taken by measuring the distance from the base of the plant to the tip of the leaf before heading, and to the tip of flag leaf after heading. The collected data were finally averaged.

Number of tillers hill^{-1}

Number of tillers hill^{-1} was counted from 10 preselected hills at 20, 40 and 60 DAT. Tillers, which had at least one visible leaf, were counted. Finally average them to have numbers of tillers hill^{-1}.

Dry weight hill^{-1} (g)

Five hills plot^{-1} were uprooted from second line of each plot at 20 DAT, 60 DAT and at harvest for measuring dry weight. The samples were oven dried until a constant weight from which the weights of dry matter were recorded and averaged then to get dry weight hill^{-1}.

Time of flowering

Time of flowering was recorded when about 90% of the plants within a plot emerged flowering. The number of days for flowers was recorded.

B. Yield components and yield data

Number of effective tillers hill^{-1}

The effective tillers from ten hills were counted and averaged to have hill^{-1} basis. The panicles which had at least one grain was considered as effective tillers.

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

The non-effective tillers from ten hills were counted and averaged to have hill^{-1} basis. The panicles which had no grain were considered as ineffective tillers.

Panicle length (cm)

Measurement of panicle length was taken from basal node of the rachis to the apex of each panicle. Each observation was an average of 20 panicles.

Number of filled grains panicle^{-1}

Filled grain was considered to be fertile if any kernel was present there in. The number of filled grains present on each ten panicles were recorded and averaged.

Number of unfilled grains panicle^{-1}

Unfilled spikelets present on each ten panicles were counted and averaged.

Total number of grains panicle^{-1}

The number of filled grains panicle^{-1} plus the number of unfilled grains panicle^{-1} gave the total number of grains panicle^{-1}. The total number of grains panicle^{-1} was calculated with the following formula:

Total Number of grains panicle^{-1} = Number of filled grains panicle^{-1} + number of unfilled grains panicle^{-1}.

Weight of 1000-grain (g)

One thousand cleaned dried grains were counted randomly from each plot and weighed by using a digital electric balance when the grains retained 12% moisture and the mean weight was expressed in gram.

Grain yield (t ha^{-1})

Grain yield was determined from the central 3 m^2 area of each plot and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

Straw yield (t ha^{-1})

Straw yield was determined from the central 3 m^2 area of each plot, after separating the grains. The sub-samples were oven dried to a constant weight and finally converted to t ha^{-1}.

Biological yield (t ha^{-1})

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

Biological yield = Grain yield + Straw yield

Harvest index (%)

It is the ratio of economic yield to biological yield and was calculated with the following formula (Gardner *et al.*, 1985).

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

3.11 Statistical analysis of the data

All the data collected on different parameters were statistically analyzed following the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) using the MSTAT computer package program. The mean differences among the treatments were compared by least significant difference test at 5 % level of significance.

Chapter 4
Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

Results were obtained from the present study regarding the nitrogen sources and spacing on the growth and yield of T-*aman* rice and their interaction effect of the crop characters of that rice variety that have been presented and discussed parameter wise in this chapter. The results of the study have been presented in Table 1 to Table 13, Figure 1 to Figure 14 and Appendix V to Appendix IX.

4.1 Plant height

4.1.1 Effect of nitrogen

Nitrogen sources exerted significant effect on the plant height of BRRI dhan 31 (Fig. 1 and appendix V). Among the three levels of nitrogen USG (U_2) gave the maximum plant height at 20, 40 and 60 DAT and at harvest (39.25, 82.59, 95.01 and 105.7 cm, respectively) which was statistically similar with prilled urea (U_1) treated plot at 60 DAT and at harvest. On the other hand, the lowest plant height 36.01, 80.65, 91.33 and 102.0 cm was found at 20, 40 and 60 DAT, and at harvest, respectively with foliar application of urea (U_3) which was statistically similar with prilled urea (U_1) at 40 DAT. The increase in plant height due to application of nitrogen might be associated with nitrogen application with stimulating effect of nitrogen on various physiological processes including cell division and cell elongation of the plant. The results are in agreement with that of Singh and Singh (1986) who reported that USG produced taller plants than prilled urea when applied @ 27 to 87 kg N ha^{-1}.

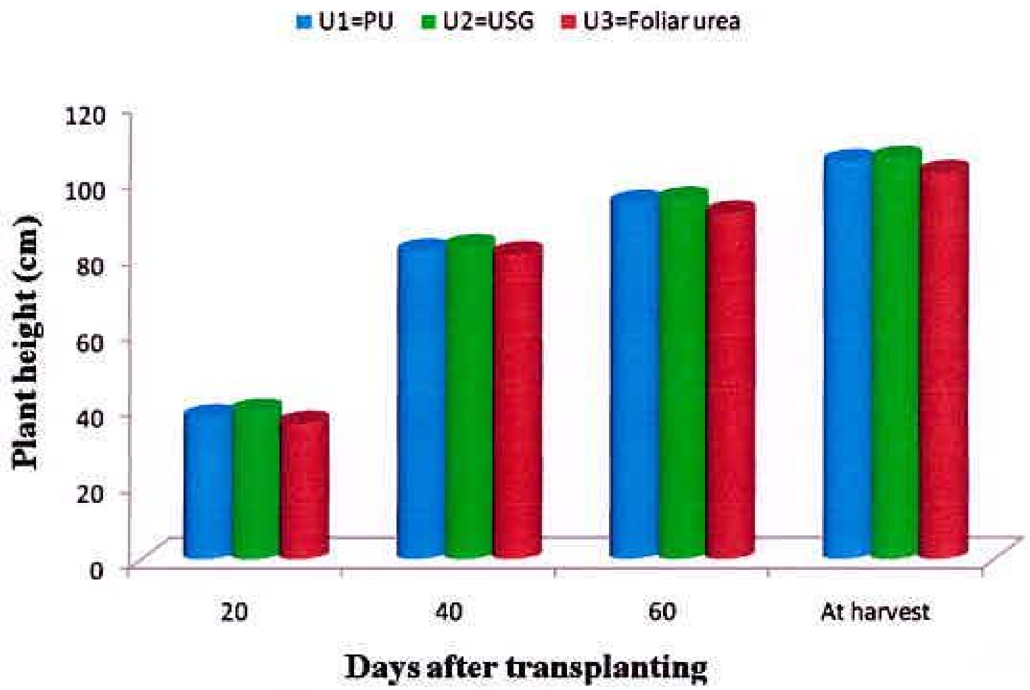


Figure 1. Effect of nitrogen sources on plant height at different days after transplanting of BRRI dhan 31 (LSD $_{.05}$ = 0.55, 1.01, 1.38 and 2.13 at 20, 40 and 60 DAT, and at harvest, respectively)

4.1.2 Effect of spacing

Plant height was significantly affected by plant spacing at 20, 40 and 60 DAT, and at harvest (Fig. 2 and Appendix V). It can be inferred from the result that the tallest plant (39.86, 84.54, 96.34, and 106.6 cm, respectively at 20, 40 and 60 DAT and at harvest) was obtained at the widest spacing S_5 (35 cm × 15 cm) which was statistically similar with spacing S_4 at 60 DAT; spacing S_4 (30 cm × 15 cm) and S_3 (25 cm × 15 cm) at harvest. On the other hand, the shortest plant at 20, 40 and 60 DAT, and at harvest (34.81, 78.48, 90.24 and 101.8 cm, respectively) was produced in closest spacing S_1 (15 cm × 15 cm) due to higher competition of nutrient, pace, light and air occurs in closer spacing. As a result cell division decreased and plant because shorter. Similar result was found by Haque (2002) who reported that wider hill spacing produced the tallest plants than did closer hill spacing.

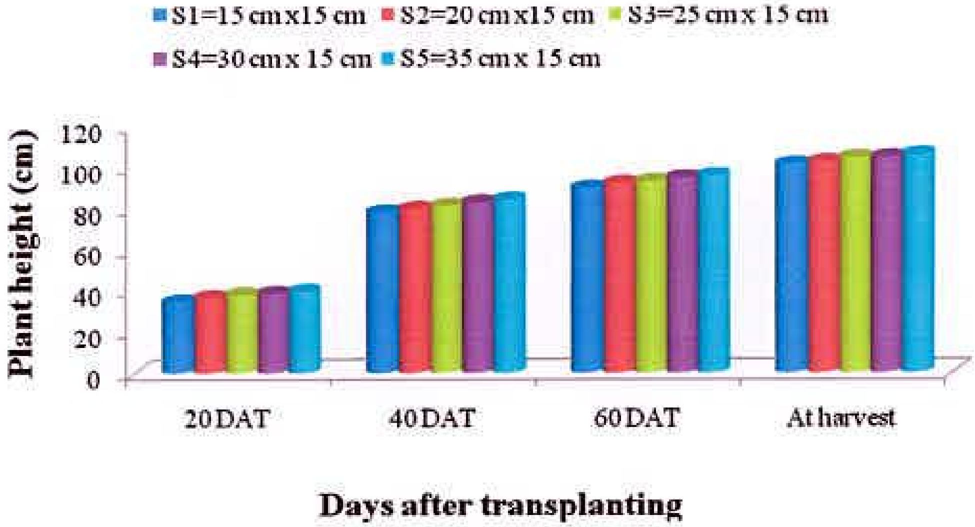


Figure 2. Effect of spacing on plant height at different days after transplanting of BRRI dhan 31 ($LSD_{.05}$ = 0.72, 1.31, 1.78 and 2.75 at 20, 40 and 60 DAT, and at harvest, respectively)

4.1.3 Interaction effect of nitrogen and spacing

There observed a significant difference in plant height due to interaction effect of nitrogen sources and spacing (Table 1 and Appendix V). The result shows that the plant height increased gradually with advances of sampling dates and the highest increased was observed at harvest. The tallest plant (41.38 cm, 85.38 cm, 96.75 cm and 107.8 cm) were found in the interaction of U_2S_5 which was significantly highest than other interactions at all the sampling dates (20, 40 and 60 DAT, and at harvest). At 40 DAT the similar plant height was produced at the interactions of U_2S_5, U_2S_4 and U_3S_5. At 60 DAT, the interactions of U_1S_5, U_2S_4, U_1S_4, U_1S_3, U_2S_2 and U_3S_5 showed similar plant height with U_2S_5 interaction. On the other hand all the interactions except U_1S_1, U_3S_2 and U_3S_1 showed statistically similar plant height at harvest. The interaction effect of different forms of nitrogen application and spacing showed that USG and wider spacing produced the tallest plants. This might be due to advantages of slow released nitrogen in USG for longer time and wider spacing for providing the plants with more space.

Table 1. Interaction effect of nitrogen sources and spacing on plant height of BRRI dhan 31

Forms of nitrogen × spacing	Days after transplanting (DAT)			
	20	40	60	At harvest
Prilled urea ×				
15 cm × 15 cm	35.07 gh	78.77 fg	90.69 ef	101.7 b-d
20 cm × 15 cm	37.41 ef	78.63 fg	92.71 b-e	103.0 a-d
25 cm × 15 cm	38.13 de	81.90 c-e	94.47 a-c	106.0 a-c
30 cm × 15 cm	38.19 de	83.21 a-c	95.62 a-c	106.1 a-c
35 cm × 15 cm	39.73 bc	84.52 ab	97.14 a	107.5 a
Urea super granule ×				
15 cm × 15 cm	35.50 g	79.55 e-g	92.21 c-e	103.6 a-d
20 cm × 15 cm	38.81 cd	81.67 c-e	94.43 a-c	104.8 a-d
25 cm × 15 cm	40.04 bc	82.42 b-d	94.62 a-c	106.0 a-c
30 cm × 15 cm	40.30 b	83.92 a-c	96.13 ab	106.4 ab
35 cm × 15 cm	41.58 a	85.38 a	97.65 a	107.8 a
Foliar urea ×				
15 cm × 15 cm	33.87 h	77.13 g	87.82 f	100.1 d
20 cm × 15 cm	34.09 h	80.03 d-f	90.16 ef	100.6 cd
25 cm × 15 cm	36.22 fg	80.24 d-f	90.92 d-f	102.4 a-d
30 cm × 15 cm	37.62 de	82.14 b-d	93.54 b-e	102.7 a-d
35 cm × 15 cm	38.26 de	83.71 a-c	94.22 a-d	104.4 a-d
LSD (0.05)	1.242	2.268	3.095	4.772
CV (%)	10.96	9.65	9.96	12.72

4.2 Number of tillers hill^{-1}

4.2.1 Effect of nitrogen

Nitrogen sources exerted significant effect on the number of tillers hill^{-1} (Fig. 3 and Appendix VI). The figure shows that number of tillers hill^{-1} increased gradually with advance plant age and the pick was found at 60 DAT for all sampling dates. The highest number of tillers hill^{-1} was obtained from USG (U_2) at 20, 40 and 60 DAT (4.82, 8.61 and 11.03, respectively). The second highest number of tillers hill^{-1} was found U_1 (PU) treatment for all the sampling dates (20, 40 and 60 DAT). However, foliar application of urea (U_3) showed the lowest number of tillers hill^{-1} at 20, 40 and 60 DAT (4.11, 7.71 and 10.04, respectively).

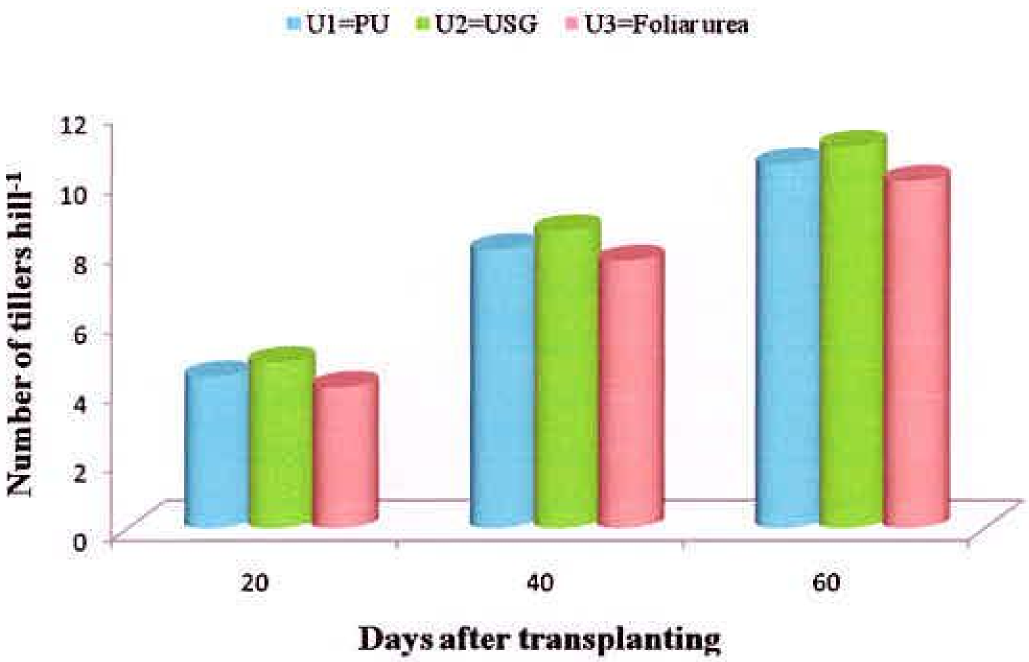


Figure 3. Effect of nitrogen sources on number of tillers hill^{-1} at different days after transplanting of BRRI dhan 31 ($LSD_{.05}$ = 0.15, 0.44 and 0.82 at 20, 40 and 60 DAT, respectively)

4.2.2 Effect of spacing

Production of tillers $hill^{-1}$ was significantly affected by different spacing at 40 and 60 DAT except 20 DAT (Fig. 4 and appendix VI). It was observed from the figure that at 40 and 60 DAT the number of tillers $hill^{-1}$ showed an increasing trend with the increases of spacing and the widest spacing (35 cm × 15 cm) showed the highest number of tillers $hill^{-1}$. In wider spacing plants received more nutrient, moisture and light which resulted in more number of tillers $hill^{-1}$. The result corroborates with the findings of Mustapha (2002) who reported that the widest spacing produces the highest number of tillers $hill^{-1}$ and the lowest number of tillers $hill^{-1}$ was founded in closer spacing.

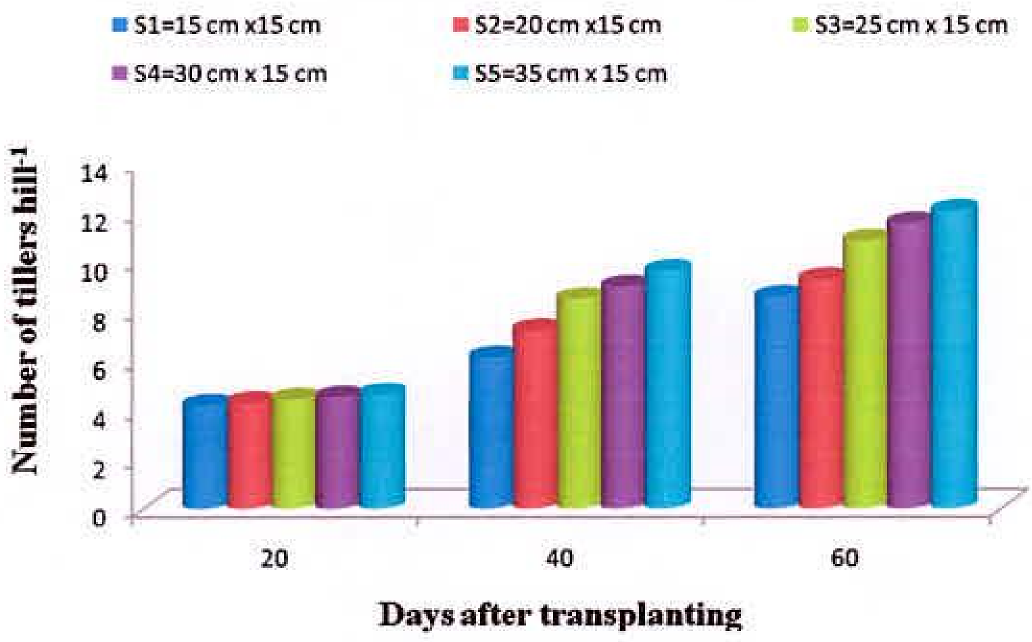


Figure 4. Effect of spacing on number of tillers $hill^{-1}$ at different days after transplanting of BRRI dhan 31 ($LSD_{.05}$ = 0.19, 0.56 and 0.06 at 20, 40 and 60 DAT, respectively)

4.2.3 Interaction effect of nitrogen and spacing

There observed a significant difference in the production of tillers $hill^{-1}$ due to interaction of nitrogen sources and spacing (Table 2 and Appendix VI). Among the sampling dates, the number of tillers $hill^{-1}$ was highest at 60 DAT, for all interactions. Interaction of U_2S_5 showed its superiority in producing highest number of tillers $plant^{-1}$ at 20, 40 and 60 DAT (5.15, 9.99 and 12.51, respectively) than other interactions. At 40 and 60 DAT, the second highest tillers hill^{-1} were observed in the interaction of U_1S_5 (9.65 and 12.21, respectively) which was followed by U_2S_4 interaction. On the other hand the lowest tillers hill^{-1} was obtained from U_3S_1 at 20, 40 and 60 DAT (3.82, 5.81 and 8.01, respectively).

Table 2. Interaction effect of nitrogen sources and spacing on number of tillers hill^{-1} of BRRI dhan 31

Forms of nitrogen ×	Days after transplanting (DAT)		
spacing	20	40	60
Prilled urea ×			
15 cm × 15 cm	4.42 de	5.89 f	8.86 de
20 cm × 15 cm	4.25 ef	7.25 e	9.14 c-e
25 cm × 15 cm	4.37 d-f	8.51 cd	10.65 a-d
30 cm × 15 cm	4.49 de	9.02 a-c	11.75 ab
35 cm × 15 cm	4.52 c-e	9.65 ab	12.21 a
Urea super granule ×			
15 cm × 15 cm	4.45 de	6.83 ef	9.06 de
20 cm × 15 cm	4.73 b-d	7.64 de	9.82 b-e
25 cm × 15 cm	4.85 a-c	9.22 a-c	11.63 ab
30 cm × 15 cm	4.93 ab	9.35 a-c	12.13 a
35 cm × 15 cm	5.15 a	9.99 a	12.51 a
Foliar urea ×			
15 cm × 15 cm	3.82 g	5.81 f	8.01 e
20 cm × 15 cm	4.01 fg	6.93 e	9.01 de
25 cm × 15 cm	4.15 e-g	7.91 de	10.43 a-d
30 cm × 15 cm	4.21 ef	8.64 b-d	11.12 a-c
35 cm × 15 cm	4.35 ef	9.40 a-c	11.62 ab
LSD (0.05)	0.328	0.977	1.834
CV (%)	4.40	7.13	10.33

4.3 Dry matter production plant^{-1} (g)

4.3.1 Effect of nitrogen

Dry matter production exerted significant difference due to nitrogen sources (Fig. 5 and Appendix VII). The figure shows that dry matter production increased with the increases of days after transplanting and the highest production was recorded at harvest. The rate of increase was highest from 60 DAT to at harvest than earlier stage. Among the urea forms of nitrogen application treatments, application of urea super granule showed higher dry matter for all sampling dates than other forms of nitrogen application. Similar result was also reported by Rao *et al.,* (1986) that USG was the most effective in increasing TDM than split application of urea.

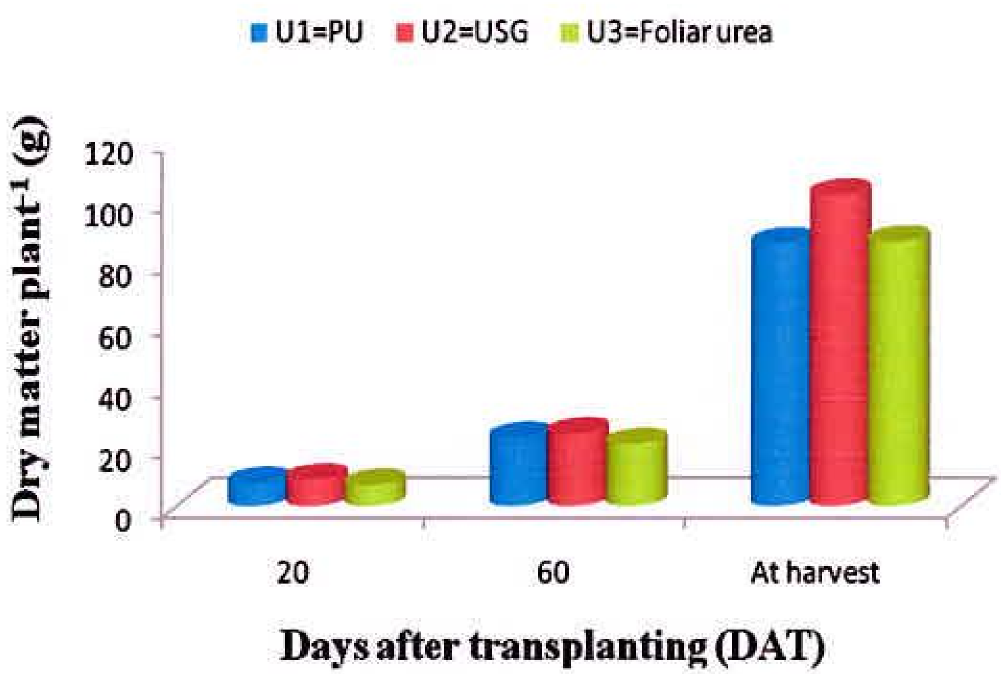


Figure 5. Effect of nitrogen sources on dry matter plant^{-1} at different days after transplanting of BRRI dhan 31 ($LSD_{.05}$ = 0.82, 1.65 and 5.4 at 20, 60 DAT and at harvest, respectively)

4.3.2 Effect of spacing

Dry matter production was significantly influenced by spacing (Fig. 6 and Appendix VII). The trend of dry matter production was that it increased gradually with the increases of spacing from 15 cm × 15 cm to 35 cm × 15 cm. On the other hand, production of dry matter was lower in early stages of growth and it was much higher in the later stage. It was also observed the rate of increase in dry matter production was more rapid in the later stage than earlier stage. The result was in consistent with the findings of Sarker (2003).

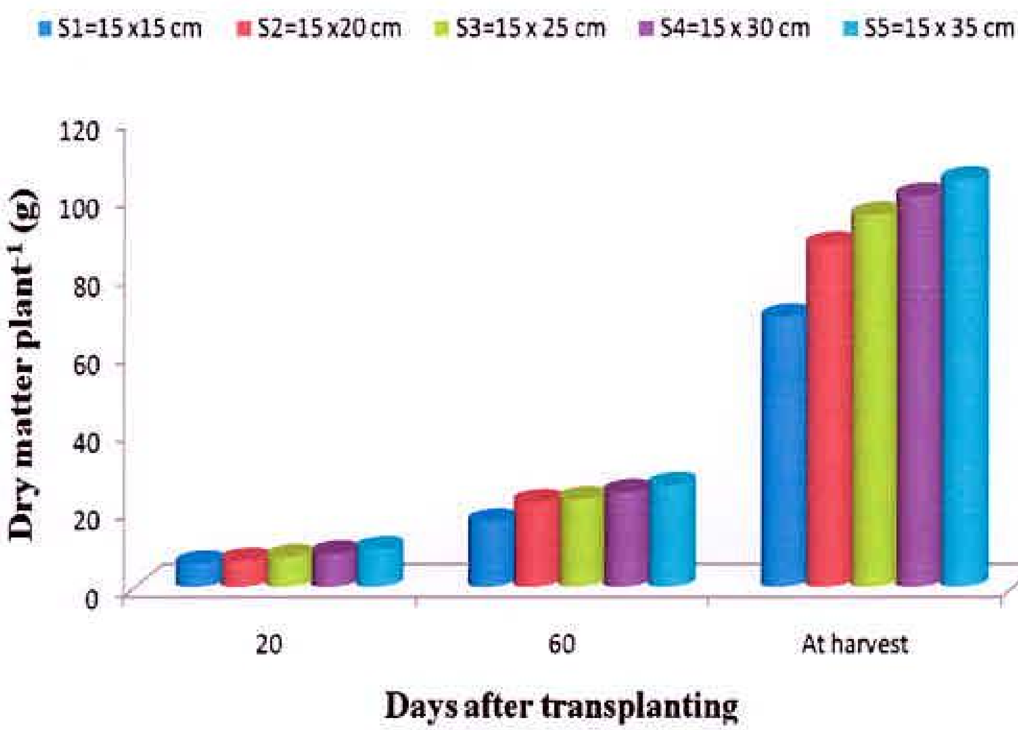


Figure 6. Effect of spacing on dry matter plant^{-1} at different days after transplanting of BRRI dhan 31 ($LSD_{.05}$ = 1.06, 2.12 and 6.9 at 20 and 60 DAT, and at harvest, respectively)

4.3.3 Interaction effect of nitrogen and spacing

Total dry matter production significantly affected due to the interaction of nitrogen sources and spacing (Table 3 and Appendix VII). The highest amount dry matter was obtained from U_2S_5 at 20 and 60 DAT, and at harvest (11.15, 27.77 and 108.6 gm, respectively) which was statistically same with the interaction of U_2S_4 and U_2S_3 at harvest. Statistically similar result was found

20, 60 DAT and at harvest with the interaction of U_2S_4, U_1S_5 and U_2S_2. On the other hand the lowest amount of dry matter was produced the interaction of U_3S_1 at 20 and 60 DAT (5.63 and 125.73 gm respectively) and U_1S_1 at harvest (50.05 gm) which is statistically similar with treatment combination of U_1S_1 and U_3S_2 at 20 DAT.

Table 3. Interaction effect of nitrogen sources and spacing on dry matter plant^{-1} of BRRI dhan 31

Forms of nitrogen × spacing	Dry weight plant $^{-1}$ (g) 20 DAT	60 DAT	At harvest
Prilled Urea ×			
15 cm × 15 cm	5.92 ef	18.60 e	50.05 f
20 cm × 15 cm	6.81 d-f	21.25 c-e	81.20 de
25 cm × 15 cm	7.71 c-f	22.57 b-e	91.55 b-d
30 cm × 15 cm	8.44 b-d	24.58 a-c	102.21 a-c
35 cm × 15 cm	9.63 a-c	26.05 ab	105.51 a
Urea Super Granule ×			
15 cm × 15 cm	6.87 d-f	19.53 de	84.15 de
20 cm × 15 cm	7.76 c-e	23.35 b-d	103.2 ab
25 cm × 15 cm	8.51 b-d	24.12 a-c	105.6 a
30 cm × 15 cm	9.93 ab	25.81 ab	108.1 a
35 cm × 15 cm	11.15 a	27.77 a	108.6 a
Foliar Urea ×			
15 cm × 15 cm	5.63 f	12.73 f	94.51 e
20 cm × 15 cm	6.22 ef	21.01 c-e	79.30 de
25 cm × 15 cm	7.12 d-f	21.27 c-e	89.25 cd
30 cm × 15 cm	7.68 c-f	22.90 b-d	91.1 b-d
35 cm × 15 cm	8.86 b-d	25.22 a-c	99.5 a-c
LSD (0.05)	1.831	3.681	11.96
CV (%)	11.79	9.73	7.77

4.4 Number of effective tillers $hill^{-1}$

4.4.1 Effect of nitrogen

Nitrogen sources had great significant effect on the number of effective tillers $hill^{-1}$. USG (U_2) gave the highest number of effective tillers $hill^{-1}$ (7.55) compare to prilled urea (U_1) (6.95) and foliar application of urea (U_3) (6.26) shown in Fig. 7 and Appendix VIII. The result indicates that's USG showed 8.63 and 20.5 % higher effective tillers $hill^{-1}$ than prilled urea and foliar application of urea, respectively. Adequacy of nitrogen probably favored the cellular activity during development stage which leads to increased number of effective tillers $hill^{-1}$. Rama *et al.,* (1989) reported similar result that USG produced higher number of panicles m^{-2} than split application of urea.

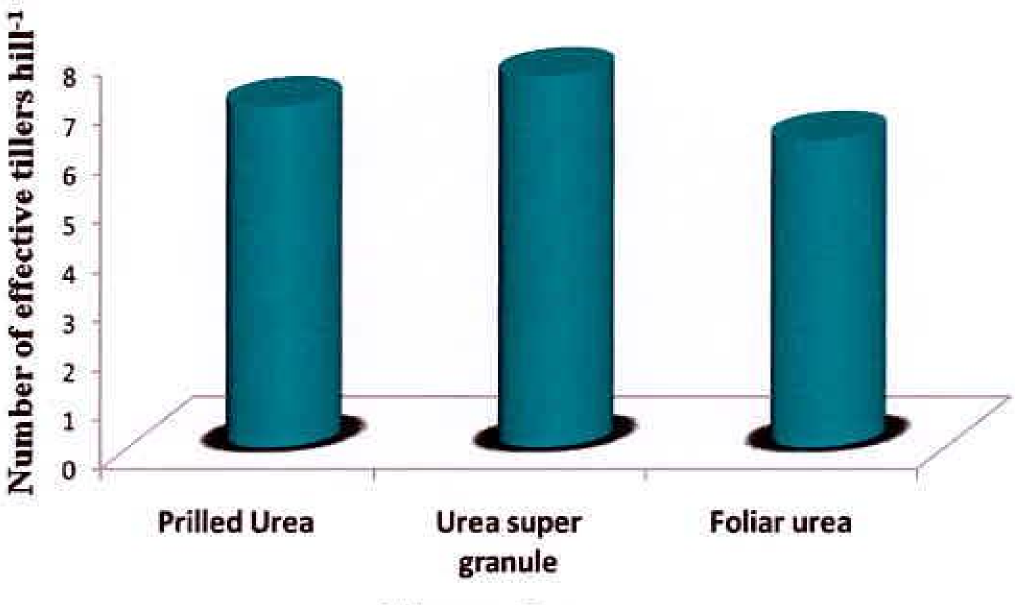


Figure 7. Effect of nitrogen sources on the number of effective tillers $hill^{-1}$ of BRRI dhan 31 ($LSD_{.05}$ = 0.39)

4.4.2 Effect of spacing

Production of effective tillers $hill^{-1}$ was significantly affected by different spacing (Fig. 8 and Appendix VIII). The trend of effective tillers $hill^{-1}$ was that the widest spacing showed the highest number of effective tillers $hill^{-1}$ and then tiller number showed a decreasing trend with reduced spacing. The closest spacing showed the lowest number of effective tillers hill^{-1}. The competition among the plants for nutrient, air, space and light might be the main reasons for decreasing tillers production in closer spacing. This result was in agreement with the findings of Miah *et al.,* (1990), who reported that highest number effective tillers were produced in wider spacing and lowest in closer spacing.

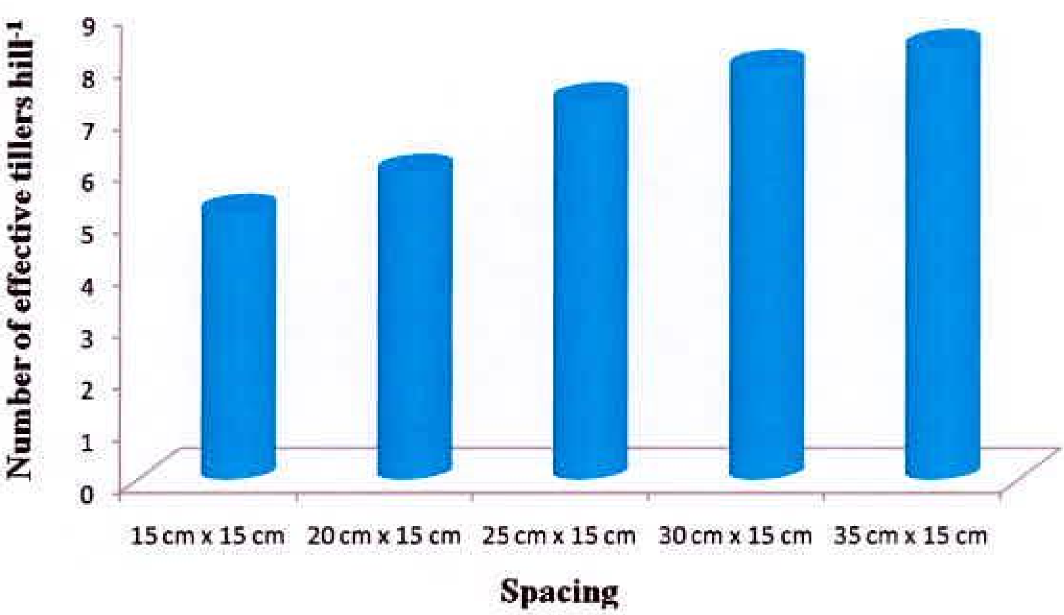


Figure 8. Effect of spacing on number of effective tillers hill^{-1} of BRRI dhan 31 (LSD$_{.05}$ = 0.50)

4.4.3 Interaction effect of nitrogen and spacing

Results of the study showed significant variation on the number of effective tillers hill^{-1} due to the interaction of nitrogen sources and spacing (Table 5 and Appendix VIII). It was observed that the highest number of effective tillers hill^{-1} (9.22) was recorded in U_2S_3, which is statistically similar with U_2S_4 (8.57). On the other hand, the lowest number of effective tillers hill^{-1} (4.80) was produced by the interaction of U_3S_1 and which was statistically similar with U_1S_1, U_2S_1 and U_3S_2.

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

4.5.1 Effect of nitrogen

Non-effective tillers hill^{-1} was found significant due to nitrogen sources (Table 4 and Appendix VIII). The lowest number of non-effective tiller (2.48) was observed with USG (U_2) applied treatment because of long time supply of nitrogen influence plant to produce more effective tillers which is statistically similar with PU (U_1) and the highest numbers of non effective tillers (3.46) were observed with foliar application of urea (U_3).

4.5.2 Effect of spacing

Production of non-effective tillers hill^{-1} was significantly affected by spacing shown in the Table 4 and Appendix VIII. The highest values of non-effective tillers hill^{-1} (3.32) was found in 15 cm ×15 cm spacing. The lowest number of non-effective tillers hill^{-1} (2.63) was produced by S_5 (35 cm × 15 cm) spacing which was statistically similar with the S_4 (30 cm × 15 cm) and S_3 (25 cm × 15 cm) spacing. In wider spacing, plants received more nutrient, moisture and light which resulted on less number of non-effective tiller hill^{-1}. Mustapha (2002) also supported this view.

Table 4. Effect of nitrogen sources and spacing on number of non-effective tillers hill^{-1} of BRRI dhan 31

Forms of nitrogen	Number of non-effective tillers hill^{-1}
Prilled Urea	2.84 b
Urea Super Granule	2.48 b
Foliar Urea	3.46 a
LSD(0.05)	0.399
Spacing	
15 cm × 15 cm	3.32 a
20 cm × 15 cm	3.17 ab
25 cm × 15 cm	2.75 b
30 cm × 15 cm	2.77 b
35 cm × 15 cm	2.63 b
LSD(0.05)	0.515
CV (%)	10.08

4.5.3 Interaction effect of nitrogen and spacing

The highest numbers of non-effective tillers hill^{-1} (4.10) were found from the interaction of U_3S_5 which was statistically similar with the interactions of U_3S_4, U_3S_2 and U_1S_5. On the other hand, the lowest one (2.26) was recorded from the interaction of U_2S_3 which was statistically similar with U_1S_1, U_1S_2, U_1S_3, U_1S_4, U_2S_1, U_2S_2, U_2S_4, U_2S_5 U_3S_1 and U_3S_3 (2.55, 2.64, 2.92, 2.90, 2.56, 2.32, 2.62, 2.65, 3.09 and 2.75, respectively) interactions (Table 5 and Appendix VIII).

Table 5. Interaction effect of nitrogen sources and spacing on number of effective and non-effective tillers $hill^{-1}$ of BRRI dhan 31

Forms of nitrogen × spacing	Number of tillers $hill^{-1}$	
	Effective	Non-effective
Prilled Urea ×		
15 cm × 15 cm	5.17 hi	2.55 cd
20 cm × 15 cm	6.01 gh	2.64 cd
25 cm × 15 cm	7.31 c-f	2.92 cd
30 cm × 15 cm	8.09 b-d	2.90 cd
35 cm × 15 cm	8.24 bc	3.21 a-d
Urea Super Granule ×		
15 cm × 15 cm	5.50 hi	2.56 cd
20 cm × 15 cm	6.50 fg	2.32 cd
25 cm × 15 cm	9.22 a	2.26 d
30 cm × 15 cm	8.57 ab	2.62 cd
35 cm × 15 cm	7.98 b-d	2.65 cd
Foliar Urea ×		
15 cm × 15 cm	4.80 i	3.09 b-d
20 cm × 15 cm	5.25 hi	3.36 a-c
25 cm × 15 cm	6.62 e-g	2.78 cd
30 cm × 15 cm	7.13 d-f	3.99 ab
35 cm × 15 cm	7.52 c-e	4.10 a
LSD (0.05)	0.875	0.892
CV (%)	7.50	10.08

4.6 Panicle length (cm)

4.6.1 Effect of nitrogen

Significant difference on panicle length was observed due to nitrogen sources (Table 6 and Appendix VIII). It was observed that the longest panicle length (26.19) was produced due to use of USG (U_2). The shortest panicle length (24.39) was produced due to foliar application of urea (U_3). It was revealed that USG produced the longest panicle which might be due to the longer period of nitrogen absorption. Sen and Pandey (1990) found similar panicle length by applying 38.32 kg N ha^{-1} either in the form of USG or prilled urea.

4.6.2 Effect of spacing

Panicle length was significantly influenced by spacing (Table 6 and Appendix VIII). The longest panicle (27.17 cm) was produced by S_3 (25 cm × 15 cm) spacing and that shortest (23.85 cm) was produced by S_1 (15 cm × 15 cm) spacing. The plants grown in widest spacing got more light, space, air and nutrient facilities which stimulated positively towards panicle development than in closer spacing. Similar results were observed by Rekhashri *et al.*, (1997) and Liou (1987) who stated that closer spacing decreased panicle length.

Table 6. Effect of nitrogen sources and spacing on panicle length (cm) of BRRI dhan 31

Different forms of nitrogen	Panicle length (cm)
Prilled Urea	25.24 b
Urea Super Granule	26.19 a
Foliar Urea	24.39 c
LSD(0.05)	0.458
Spacing	
15 cm × 15 cm	23.85 d
20 cm × 15 cm	24.60 c
25 cm × 15 cm	27.17 a
30 cm × 15 cm	25.63 b
35 cm × 15 cm	25.12 bc
LSD(0.05)	0.590
CV (%)	7.28

4.6.3 Interaction effect of nitrogen and spacing

Panicle length differs significantly due to interaction of nitrogen sources and spacing (Table 7 and Appendix VIII). The highest panicle length (28.02 cm) shown in U_2S_3. On the other hand the lowest panicle length (22.67 cm) was observed in U_3S_1 which is statistically similar with U_3S_4.

Table 7. Interaction effect of nitrogen sources and spacing on panicle length (cm) of BRRI dhan 31

Forms of nitrogen × spacing	Panicle length (cm)
Prilled Urea ×	
15 cm × 15 cm	26.78 b
20 cm × 15 cm	25.61 cd
25 cm × 15 cm	25.12 c-e
30 cm × 15 cm	24.76 c-f
35 cm × 15 cm	24.92 c-f
Urea Super Granule ×	
15 cm × 15 cm	25.82 bc
20 cm × 15 cm	26.75 b
25 cm × 15 cm	28.02 a
30 cm × 15 cm	25.42 c-e
35 cm × 15 cm	26.71 b
Foliar Urea ×	
15 cm × 15 cm	22.67 h
20 cm × 15 cm	24.52 d-g
25 cm × 15 cm	24.43 e-g
30 cm × 15 cm	23.62 gh
35 cm × 15 cm	23.95 fg
LSD (0.05)	1.024
CV (%)	7.28

4.7 Number of filled grains panicle^{-1}

4.7.1 Effect of nitrogen

Filled grains panicle^{-1} significantly affected by nitrogen sources (Fig. 9 and Appendix VIII). The maximum numbers of filled grains panicle^{-1} (92.60) was observed with USG (U_2) which was statistically similar with PU (U_1). On the other hand, the lowest numbers of filled grains panicle^{-1} (80.38) were produced from the foliar application of urea (U_3) plot. Nitrogen took part both in grain formation and development and for this reason number of grains panicle^{-1} increased with adequate uploaded of nitrogen. The result was supported by Rama *et al.*, (1989) as they found significantly higher filled grains panicle^{-1} with 40, 80 or 120 kg N ha^{-1} applied as USG over split application of urea.

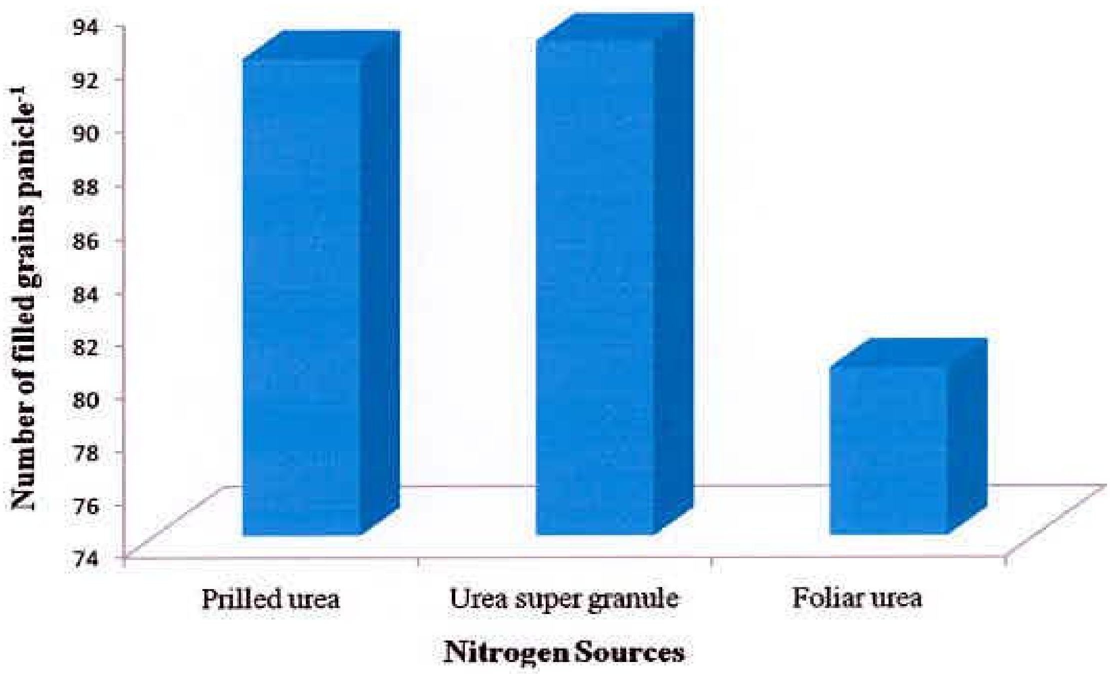


Figure 9. Effect of nitrogen sources on number of filled grains panicle^{-1} of BRRI dhan 31 ($LSD_{.05}$ = 3.11)

4.7.2 Effect of spacing

Filled grains panicle^{-1} was significantly affected by the spacing (Fig. 10 and appendix VIII). The result revealed that optimum spacing S_3 (25 cm x 15 cm) showed the highest (102.2) numbers of grains panicle^{-1}. The spacing higher and lower than the optimum reduced the production of grains panicle^{-1} gradually. However, the lowest productions of grains panicle^{-1} (72.39) was found with the closest spacing S_1 (15 cm x 15 cm). The result was supported by Ghosh *et al.*, (1988) and Uddin (1996) that wider spacing produced higher number of grains panicle^{-1}.

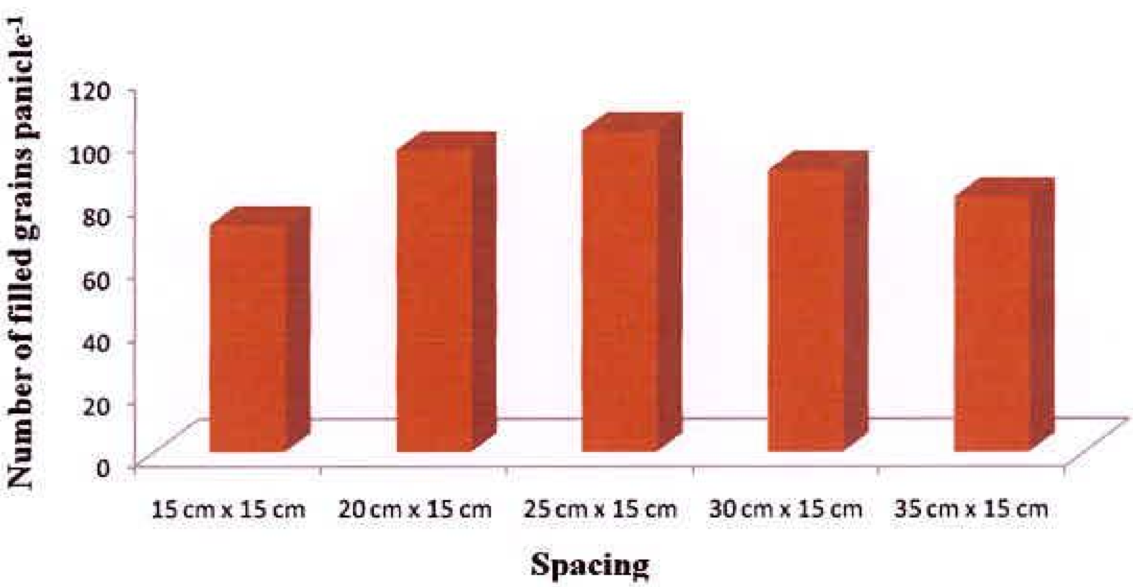


Figure 10. Effect of spacing on number of filled grains panicle^{-1} of BRRI dhan 31 ($LSD_{.05}$ = 3.14)

4.7.3 Interaction effect of nitrogen and spacing

Numbers of filled grains panicle^{-1} were found significant by the interaction of nitrogen sources and different spacing (Table 9 and appendix VIII). The Table shows that the highest numbers of grains panicle^{-1} (107.5) were obtained from the interaction of U_2S_3 which was statistically similar with U_2S_4 and U_1S_3. On the other hand, lowest numbers of filled grains panicle^{-1} (65.37) were obtained from the interaction of U_3S_1 which was statistically similar with U_3S_5.

4.8 Number of unfilled grains panicle^{-1}

4.8.1 Effect of nitrogen

Nitrogen sources showed significant effect on unfilled grains panicle^{-1} (Table 8 and appendix VIII). The table shows that application nitrogen as foliar spray (U_3) produced the highest number of unfilled grains panicle^{-1} (22.08) than other forms of nitrogen application treatments. Significantly lowest and similar number unfilled grains panicle^{-1} (19.61 and 20.70) was found from the nitrogen application treatments as urea super granules (USG) and prilled urea (PU), respectively.

4.8.2 Effect of spacing

Spacing exerted significant effect on number of unfilled grains panicle^{-1} (Table 8 and appendix VIII). The table shows that the closest spacing S_1 (15 cm × 15 cm) showed the highest number of unfilled grains panicle^{-1} (24.46) followed by 22.78 and 20.44 from S_2 (20 cm × 15 cm) and S_3 (25 cm × 15 cm) spacing, respectively. The trend of unfilled grains panicle^{-1} was that the values reduced gradually with the increases of spacing from S_4 (15 cm × 15 cm) to S_4 (35 cm × 15 cm). However, the lowest numbers of unfilled grains panicle^{-1} (17.18) were produced in S_5 (35 cm × 15 cm) spacing and which was statistically similar with S_4 (30 cm × 15 cm) spacing. Competition of the plants for nutrient, air, space and light might be the reasons for increasing unfilled grains production in the closer spacing. The result corroborates with the findings of Verma *et al.*, (2002) that closer spacing produces higher sterility percentage than wider spacing.

Table 8. Effect of nitrogen sources and spacing on number of unfilled grains panicle^{-1} of BRRI dhan 31

Different forms of nitrogen	Number of unfilled grains panicle^{-1}
Prilled Urea	20.70 b
Urea Super Granule	19.61 b
Foliar Urea	22.08 a
LSD(0.05)	3.137
Spacing	
15 cm × 15 cm	24.46 a
20 cm × 15 cm	22.78 ab
25 cm × 15 cm	20.44 a-c
30 cm × 15 cm	19.13 bc
35 cm × 15 cm	17.18 c
LSD(0.05)	4.050
CV (%)	10.01

4.8.3 Interaction effect of nitrogen and spacing

The interaction between nitrogen sources and spacing had significant effect on unfilled grains panicle^{-1} shown in Table 9 and appendix VIII. It was observed that the lowest unfilled grains panicle^{-1} (15.01) found in the interaction of U_2S_3 and which was statistically similar with all the interaction except U_1S_1, U_2S_1, U_3S_1 and U_3S_2. On the other hand, the highest unfilled grains panicle^{-1} (25.76) was observed in the interaction of U_3S_1 which are statistically same with all other interaction except U_2S_3.

Table 9. Interaction effect of nitrogen sources and spacing on number of filled and unfilled grains panicle^{-1} of BRRI dhan 31

Forms of nitrogen × spacing	Number of grains panicle^{-1}	
	Filled	Unfilled
Prilled Urea ×		
15 cm × 15 cm	75.30 fg	24.12 a
20 cm × 15 cm	93.55 cd	22.45 ab
25 cm × 15 cm	101.3 abc	20.35 ab
30 cm × 15 cm	86.23 e	18.84 ab
35 cm × 15 cm	85.18 e	17.76 ab
Urea Super Granule ×		
15 cm × 15 cm	76.50 fg	23.50 a
20 cm × 15 cm	98.79 bc	22.06 ab
25 cm × 15 cm	107.5 a	15.01 b
30 cm × 15 cm	104.6 ab	18.43 ab
35 cm × 15 cm	93.93 cd	19.04 ab
Foliar Urea ×		
15 cm × 15 cm	65.37 h	25.76 a
20 cm × 15 cm	88.07 de	23.83 a
25 cm × 15 cm	94.57 cd	21.93 ab
30 cm × 15 cm	81.62 ef	20.12 ab
35 cm × 15 cm	72.26 gh	18.76 ab
LSD (0.05)	6.960	7.014
CV (%)	6.68	10.01

4.9 Weight of 1000-grains (g)

4.9.1 Effect of nitrogen

The weight of 1000-grain was not influenced by the nitrogen sources (Table 10 and Appendix IX) However, numerically the heaviest weight of 1000-grain (23.57 g) was recorded from USG (U_2) applied plot and the lowest (22.58 g) was recorded with foliar application of urea (U_3) treatment. This not significant variation might be due to fact that 1000-grain weight are generally fixed by each variety. The present result agrees with the findings of Rahman (2003) and Alam (2002) that 1000-grain weight did not affected by different level of USG.

4.9.2 Effect of spacing

Weight of 1000-grain had no significant effect by the spacing (Table 10 and Appendix IX). However, numerically heaviest weight of 1000-grain (23.84 g) was recorded from S_3 (25 cm × 15 cm) spacing and the lowest one (22.94 g) was recorded from the S_1 (15 cm × 15 cm) spacing. These results revealed that the weight of rice grain of the studied variety was partially affected due to plant spacing. The present finding was confirmed by Wang *et al.*, (2002) that thousand grains weight did not affected by spacing.

Table 10. Effect of nitrogen sources and spacing on 1000-grain weight of BRRI dhan 31

Different forms of nitrogen	1000-grains weight (g)
Prilled Urea	23.51
Urea Super Granule	23.57
Foliar Urea	22.58
LSD(0.05)	NS
Spacing	
15 cm × 15 cm	22.94
20 cm × 15 cm	23.28
25 cm × 15 cm	23.84
30 cm × 15 cm	23.57
35 cm × 15 cm	23.24
LSD(0.05)	NS
CV (%)	7.21

NS = Non Significant

4.9.3 Interaction effect of nitrogen sources and spacing

Weight of 1000-grain was found to be non responsive due to interaction of nitrogen sources and spacing (Table 11 and Appendix IX). Numerically the combination of U_2S_3 produced heaviest weight (24.80 g) of 1000-grain and the lightest one (22.51 g) was measured from the combination U_3S_1.

Table 11. Interaction effect of nitrogen sources and spacing on 1000-grain weight (g) of BRRI dhan 31

Forms of nitrogen × spacing	Weight of 1000-grain (g)
Prilled Urea ×	
15 cm × 15 cm	22.67
20 cm × 15 cm	23.85
25 cm × 15 cm	24.25
30 cm × 15 cm	23.52
35 cm × 15 cm	23.28
Urea Super Granule ×	
15 cm × 15 cm	23.63
20 cm × 15 cm	24.01
25 cm × 15 cm	24.80
30 cm × 15 cm	24.19
35 cm × 15 cm	24.32
Foliar Urea ×	
15 cm × 15 cm	22.51
20 cm × 15 cm	22.77
25 cm × 15 cm	23.10
30 cm × 15 cm	22.59
35 cm × 15 cm	22.52
LSD (0.05)	1.671
CV (%)	7.21

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

4.10.1 Effect of nitrogen

Grain yield varied significantly due to the N-fertilizer (Fig.11 and appendix VIII). Highest amount grain yield (4.58 t ha^{-1}) by USG (U_2) indicated its superiority over prilled urea (U_1) (4.02) and foliar application (U_3) of urea (3.53 t ha^{-1}). Highest grain yield in USG (U_2) application may be due to the highest number of effective tillers $hill^{-1}$, highest filled grains panicle^{-1} and heavier seeds which ultimately gave higher grain yield than other application of others forms of urea. This result was in agreement with the findings of Singh and Singh (1992) and Dwivedi and Bajpai (1995) that application of nitrogen as USG gave higher yield than other sources of nitrogen.

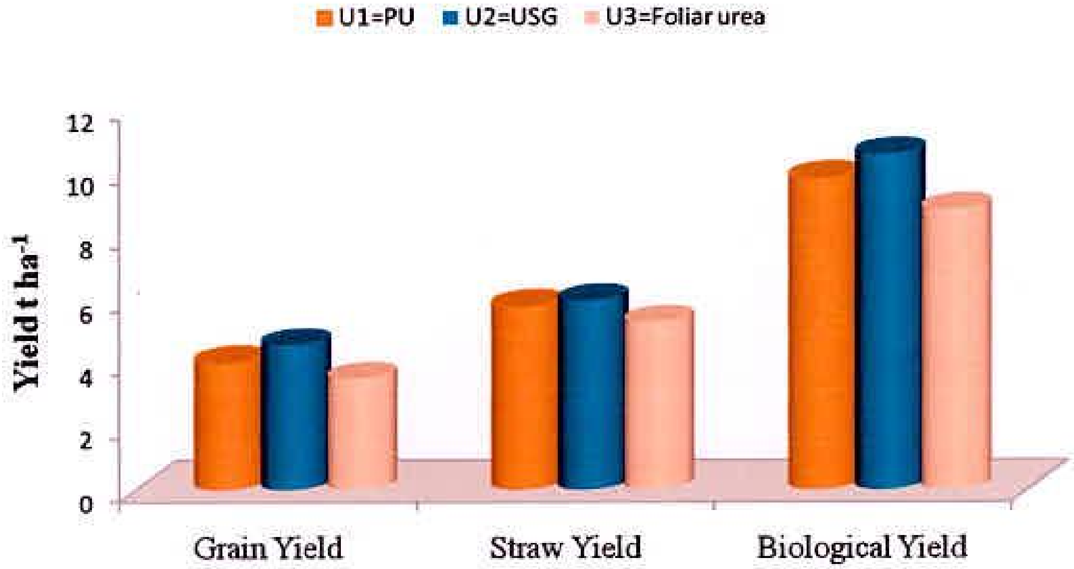
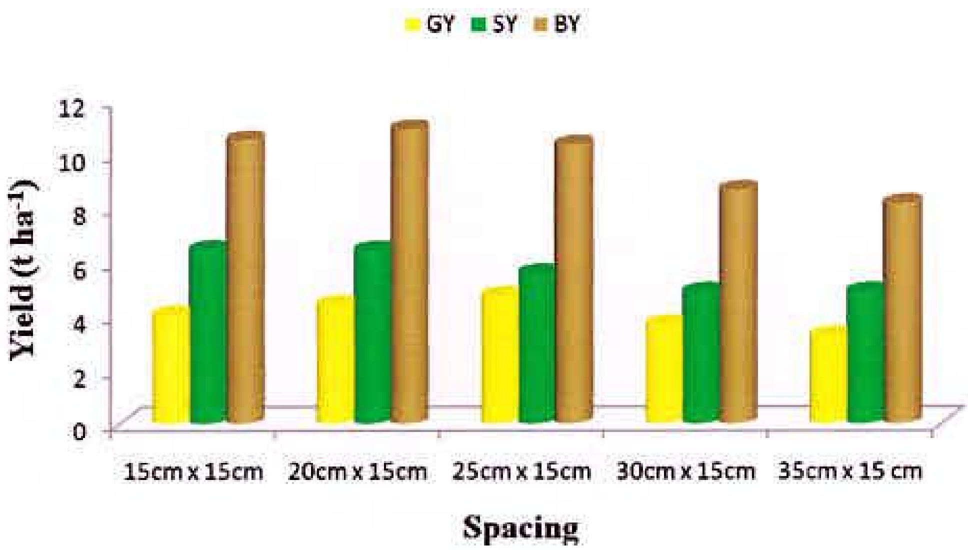


Figure 11. Effect of nitrogen sources on grain, straw and biological yield of BRRI dhan 31 ($LSD_{.05}$ = 0.23, 0.39 and 0.48 for grain yield, straw yield and biological yield, respectively)

4.10.2 Effect of spacing

Grain yield differed significantly due to spacing (Fig. 12 and Appendix IX). Spacing S_3 (25 cm × 15 cm) gave the highest grain yield than the other lower and wider spacing. It was also observed that grain yield reduction was more in wider spacing than closer spacing. Higher grain yield in S_3 (25 cm × 15 cm) may be attributing to higher numbers of grains panicle^{-1} and heavier seeds in the treatment which ultimately helped to produce higher yield. On the other hand, S_3 (25 cm × 15 cm) plant spacing contains standard plants m^{-2} and every plant can get proper nutrition which also helped the plant to produce higher yield. The findings of Azad *et al.,* (1995), Patel (1999) and BRRI (2000) agreed with the present result.



GY=Grain Yield, SY=Straw Yield and BY=Biological Yield

Figure 12. Effect of spacing on grain yield, straw yield and biological yield of BRRI dhan 31 ($LSD_{.05}$ = 0.29, 0.51 and 0.62 for grain, straw and biological yield, respectively)

4.10.3 Interaction effect of nitrogen and spacing

Effect of interaction between nitrogen sources and spacing on grain yield was significant (Table 12 and Appendix IX). Interaction U_2S_3 (5.20 t ha^{-1}) showed its superiority by producing higher seed yield (5.20 t ha^{-1}) which was significantly highest than other interaction except U_1S_3 (4.79 t ha^{-1}) and U_2S_2 (4.73 t ha^{-1}), mainly because of its higher effective tillers $hill^{-1}$ and higher number of grains $panicle^{-1}$. On the other hand, the lowest grain yield (2.86 t ha^{-1}) was obtained in U_3S_5 which was statistically similar with U_3S_4 and U_1S_5.

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

4.11.1 Effect of nitrogen

Straw yield varied significantly due to nitrogen sources (Fig. 11 and Appendix IX). The highest straw yield (5.970 t ha^{-1}) was obtained with USG (U_2), which was statistically similar with PU (U_1) and the lowest straw yield (5.30 t ha^{-1}) was recorded with foliar application of urea (U_3). The highest straw yield with USG application may be due to the capability of this fertilizer to release nitrogen slowly and longer period which helped the plant to grow vigorously, ultimately help to increase straw yield. The result was consistent with the findings of Mishra *et al*., (1999) and Swain *et al*., (1995) that USG gave higher straw yield than PU and other forms of nitrogen application.

4.11.2 Effect of spacing

Straw yield varied significantly due to spacing (Fig. 12 and Appendix IX). The closest spacing S_1 (15 cm × 15 cm) produced maximum straw yield (6.45 t ha^{-1}) which was statistically similar with S_2 (20 cm × 15 cm) spacing and on the other hand, the widest spacing S_5 produced the minimum straw yield (4.91 t ha^{-1}), which was similar to the straw yield (4.90 t ha^{-1}) produced by the S_4 (30 cm × 15 cm) spacing. Highest straw yield in closely spaced treatment might be attributed to higher number of plants in closely spaced plots. The result was supported by Islam *et al*., (1994) and Chavan *et al*., (1989) that straw yield increase with closer spacing.

4.11.3 Interaction effect of nitrogen and spacing

Interaction of nitrogen sources with spacing exerted significant effect on straw yield (Table 12 and Appendix IX). The maximum straw yield (6.83 t ha^{-1}) was achieved with interaction of U_3S_2, which was statistically similar with combination of U_3S_1, U_1S_1 and U_1S_2. On the other hand, the lowest straw yield (4.75 t ha^{-1}) was obtained form the combination of U_2S_5 which is statistically similar with U_1S_3, U_1S_4, U_1S_5, U_2S_1, U_2S_4, U_3S_3, U_3S_4 and U_3S_5.

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

4.12.1 Effect of nitrogen

Biological yield was significantly affected due to nitrogen sources (Fig. 11 and Appendix IX). The maximum biological yield (10.55 t ha^{-1}) was found from application of USG (U_2) and the lowest one (8.83 t ha^{-1}) obtained from foliar application of urea (U_3). It was also observed that biological yield of PU (U_1) was 9.80 t ha^{-1}. Shrirame *et al.*, (2000) reported that biological yield increased with the increasing of nitrogen level.

4.12.2 Effect of spacing

Spacing differed significantly among them regarding biological yield (Fig. 12 and Appendix IX). Maximum biological yield (10.91 t ha^{-1}) was achieved from the S_2 spacing which was statistically similar to the biological yield of 10.51 t ha^{-1} and 10.34 t ha^{-1}, respectively from S_1 (15 cm × 15 cm) and S_3 (25 cm × 15 cm) spacing. The minimum biological yield (8.16 t ha^{-1}) was produced by the wider spacing S_5 (35 cm × 15 cm) which was statistically similar with S_4 (15 cm × 15 cm) spacing (8.65 t ha^{-1}). Haque (2002) and Hossain (2002) found similar results that closer spacing produced the higher biological yield compare than wider spacing.

4.12.3 Interaction effect of nitrogen and spacing

Combinations of different forms of nitrogen and spacing exerted significant effect on biological yield (Table 12 and Appendix VIII). The maximum biological yield (11.01 t ha^{-1}) was achieved from the combination of U_2S_3 which was statistically similar with U_1S_1, U_1S_2, U_1S_3, U_2S_1, U_2S_2, U_3S_1 and U_3S_2. On the other hand, the minimum biological yield (7.81 t ha^{-1}) was achieved from the interaction of U_3S_5, which was statistically same with U_1S_4 U_1S_5, U_3S_5 and U_3S_4.

Table 12. Interaction effect of nitrogen sources and spacing on grain, straw and biological yield of BRRI dhan 31

Forms of nitrogen × spacing	Grain Yield. (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Prilled Urea ×			
15 cm × 15 cm	4.10 c-e	6.75 ab	10.85 ab
20 cm × 15 cm	4.51 bc	6.31 a-c	10.82 ab
25 cm × 15 cm	4.79 ab	5.63 de	10.42 ab
30 cm × 15 cm	3.85 d-f	4.87 de	8.720 cd
35 cm × 15 cm	3.31 f-h	5.01 de	8.260 d
Urea Super Granule ×			
15 cm × 15 cm	4.32 b-d	5.77 b-e	10.10 ab
20 cm × 15 cm	4.73 ab	5.79 cd	10.66 ab
25 cm × 15 cm	5.20 a	5.81 b-d	11.01 a
30 cm × 15 cm	4.02 c-e	4.84 de	8.867 cd
35 cm × 15 cm	3.65 e-g	4.75 e	8.400 d
Foliar Urea ×			
15 cm × 15 cm	3.75 d-g	6.82 a	10.57 ab
20 cm × 15 cm	4.02 c-e	6.83 a	10.85 ab
25 cm × 15 cm	4.32 b-d	5.31 de	9.630 bc
30 cm × 15 cm	3.22 gh	5.13 de	8.390 d
35 cm × 15 cm	2.86 h	4.95 de	7.810 d
LSD (0.05)	0.514	0.890	1.076
CV (%)	7.53	9.33	6.58

4.13 Harvest index (%)

4.13.1 Effect of nitrogen

Harvest index is the ratio of grain yield and biological yield. Harvest index was significantly affected due to nitrogen sources (Appendix IX). Urea super granules (U_2) showed its superiority by producing higher harvest index (43.41 %) than other forms of nitrogen application treatment (Fig.13). Application of nitrogen as foliar spray showed lowest harvest index (39.97 %) which was 3.44 % and 1.05 % lower than urea super granule (U_2) and foliar application of nitrogen, respectively.

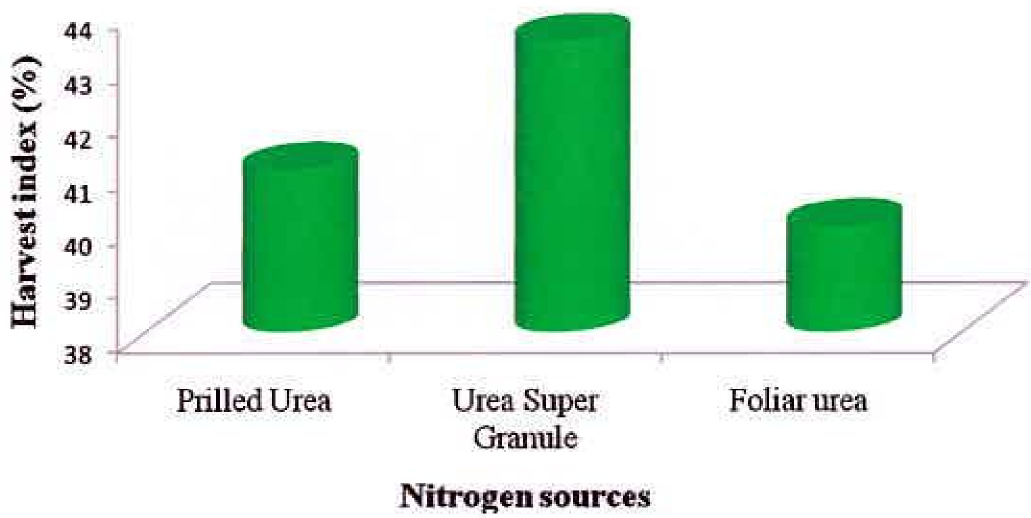


Figure 13. Effect of nitrogen sources on harvest index (%) of BRRI dhan 31 ($LSD_{.05}$ = 2.38)

4.13.2 Effect of spacing

Spacing showed significant influence on harvest index (Fig. 14 and Appendix IX). The highest harvest index (45.97 %) was measured from the S_3 (25 cm × 15 cm) spacing. Harvest index increased sharply from closest spacing (15 cm × 15 cm) to 25 cm × 15 cm (Optimum) spacing after that the values of harvest index reduced gradually. However, the lowest harvest index (38.53 %) was recorded from the closest (15 cm × 15 cm) spacing. Similar trend of harvest index was also reported by Bhab *et al.*, (1987) and Kim *et al.*, (1990).

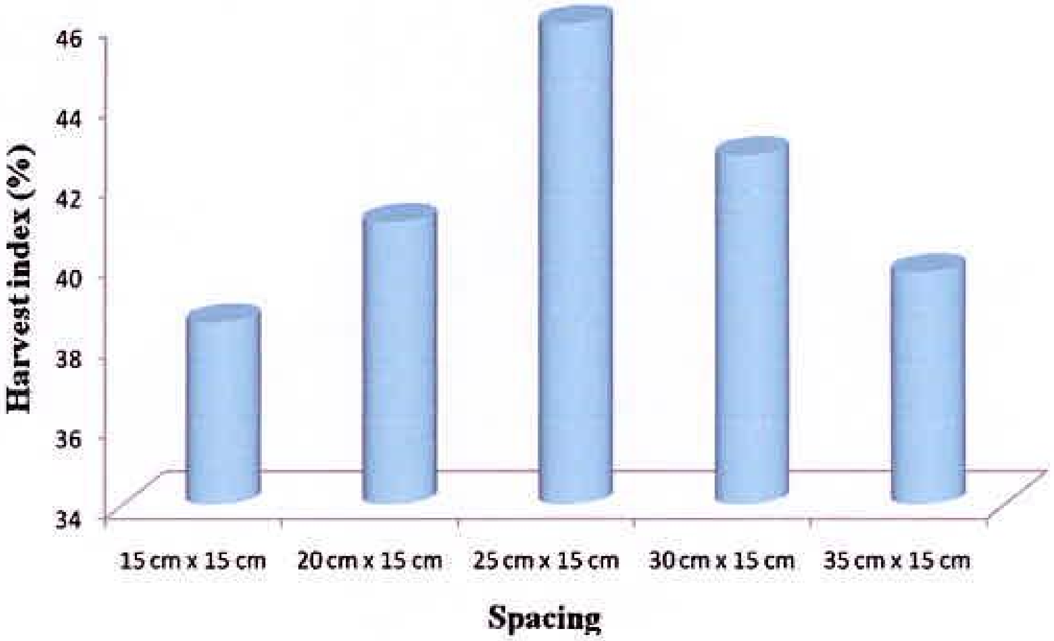


Figure 14. Effect of spacing on harvest index (%) of BRRI dhan 31 ($LSD_{.05}$ = 3.07)

4.13.3 Interaction effect of nitrogen and spacing

Interaction effect of nitrogen sources with spacing was found to be significant in terms of harvest index (Table 13 and Appendix IX). The maximum harvest index (47.23 %) was measured from the interaction of U_2S_3, which was followed by U_1S_3, U_2S_2, U_2S_4, U_1S_4, U_3S_3 and U_2S_5. On the other hand, the minimum harvest index (35.43 %) was measured form the interaction U_3S_1, which was statistically similar with U_1S_1, U_1S_5, U_3S_1, U_3S_2, U_3S_4 and U_3S_5.

Table 13. Interaction effect of nitrogen sources and spacing on harvest index (%) of BRRI dhan 31

Forms of nitrogen × spacing	Harvest index (%)
Prilled Urea ×	
15 cm × 15 cm	37.52 e-g
20 cm × 15 cm	41.68 b-f
25 cm × 15 cm	45.91 ab
30 cm × 15 cm	43.87 a-d
35 cm × 15 cm	39.48 c-g
Urea Super Granule ×	
15 cm × 15 cm	42.66 a-f
20 cm × 15 cm	45.61 ab
25 cm × 15 cm	47.23 a
30 cm × 15 cm	45.21 a-c
35 cm × 15 cm	43.18 a-e
Foliar Urea ×	
15 cm × 15 cm	35.43 g
20 cm × 15 cm	36.97 fg
25 cm × 15 cm	44.83 a-d
30 cm × 15 cm	39.00 d-g
35 cm × 15 cm	36.64 fg
LSD (0.05)	5.319
CV (%)	7.59

Chapter 5
Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The present piece of work was conducted at the Agronomy Field Laboratory of the Sher-e-Bangla Agricultural University, Dhaka during the period from June to November 2007 under the Modhupur Tract (AEZ-28) with a view to evaluate the effect of nitrogen sources and spacing on the performance of T-aman rice *cv.* BRRI dhan 31. The study comprised of (i) three forms of nitrogen sources viz. Prilled urea (PU), Urea super granules (USG) and foliar urea and (ii) five spacing viz. 15 cm × 15 cm, 20 cm × 15 cm, 25 cm × 15 cm, 30 cm × 15 cm and 35 cm × 15 cm spacing. The experiment was laid out in a split plot design with three replications. Each replication was divided three main plots and each main plot was divided into five subplots where urea application was assigned in the main plots and spacing in the subplot at random. There were 15 treatments combinations. Total number of unit plot was 45 and size of unit plot was 4m × 3m = 12 m^2. The distance maintained between two unit plots was 1.0 m and that between replications was 1.5 m. All the unit plots were equally provided with triple super phosphate, muriate of potash, gypsum and zinc sulphate as basal dose. Prilled urea (PU) was applied two equal splits, the first one-half of urea was applied after recovery at 7 days after transplantation; second one-half was applied at maximum tillering stage. On the other hand, USG (1g) was placed in 6-9 cm depth of soil in the middle of four consecutive hills of two adjacent rows. Intercultural operations such as gap filling, weeding, water management and pest management were done as and when necessary. Five hills plot^{-1} excluding the border ones were selected at random and uprooted prior to harvest for recording data on crop parameter under study for each sampling dates. The crop was harvested when 90% of the grains become golden yellow color and was done on 26 November 2007. The threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 12%. Straw was also sun dried properly.

The data on crop growth characters like plant height, number of tillers hill^{-1}, dry mater were recorded in the field and plant height was recorded at 20, 40, 60 DAT and at harvest, number of tillers hill^{-1} was recorded at 20, 40 and 60 DAT and dry matter was recorded at 20, 60 DAT and at harvest. On the other hand yield as well as yield contributing characters like number of effective and non-effective tillers hill^{-1}, panicle length, number of filled and unfilled grains panicle^{-1}, 1000-grains weight, grain yield, straw yield, biological yield and harvest index were recorded after harvest. Finally grain yield and straw yield were recorded and converted to t ha^{-1}. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

Results showed that different forms of nitrogen had significant effect on all the studied parameters except 1000-grain weight. The tallest plant at 20, 40 and 60 DAT, and at harvest were 39.25, 82.59, 95.01, and 107.5 cm, respectively obtained from USG. The maximum numbers of tillers hill^{-1} at 20, 40 and 60 DAT were 4.82, 8.61 and 11.03, respectively, from USG. Maximum dry weight at 20 and 60 DAT, and at harvest were 8.85, 24.12 and 101.95 g, respectively obtained from USG. The maximum number of effective tillers hill^{-1} (7.55), minimum numbers of non-effective tillers hill^{-1} (2.48), maximum panicle length (26.19 cm), maximum number of filled grains panicle^{-1} (92.60) and minimum number of unfilled grains panicle^{-1} (19.61) were obtained from USG. As a result BRRI dhan 31 contribute to higher grain yield (4.58 t ha^{-1}), straw yield (5.97 t ha^{-1}), biological yield (10.55 t ha^{-1}) and harvest index (43.41 %) by using urea super granule. On the other hand, the lowest plant height was observed at foliar urea at 20, 40 and 60 DAT, and at harvest (36.01, 80.65, 91.33 and 102. 0 cm respectively). The minimum numbers of tillers hill^{-1} at 20, 40 and 60 DAT were 4.11, 7.74 and 10.04, respectively obtained from foliar urea. Minimum dry weight observed at foliar urea at 20 and 60 DAT, and at harvest were 7.10, 20.62 and 86.65 g, respectively. The minimum number of effective tillers hill^{-1} (6.26), maximum numbers of non-effective tillers hill^{-1}

(3.46), minimum panicle length (24.39 cm), minimum number of filled grains panicle^{-1} (80.38) and maximum number (22.08) of unfilled grains panicle^{-1} were obtained from foliar application of urea. As a result BRRI dhan 31 contribute to lower grain yield (3.53 t ha^{-1}), straw yield (5.30 t ha^{-1}), biological yield (8.83 t ha^{-1}) and harvest index (39.97 %).

Spacing had a great effect on growth and yield attributes except 1000-grains weight. Plant height, number of tillers hill^{-1}, dry weight, number of effective tillers hill^{-1}, panicle length and number of filled grains panicle^{-1} were higher at wider spacing. The highest plant height (39.86, 84.54, 96.34, 106.6 cm at 20, 40 and 60 DAT, and at harvest, respectively) was observed from the wider spacing 35 cm × 15 cm and the lowest (34.81, 78.48, 90.24 and 101.8 cm at 20, 40 and 60 DAT, and at harvest, respectively) from closer spacing 15 cm × 15 cm. Maximum number of tillers hill^{-1} and dry weight plant^{-1} also observed from wider spacing and minimum from closer spacing. The maximum number of effective tillers hill^{-1} (8.32) was obtained from wider spacing 35 cm × 15 cm and minimum number of effective tillers hill^{-1} (5.15) from closer spacing 15 cm × 15 cm. Panicle length was highest (27.17 cm) in optimum plant spacing (25 cm × 15 cm) and that of lowest (24.62 cm) was in 20 cm × 15 cm spacing. The maximum numbers of filled grains panicle^{-1} (102.2) were achieved from 25 cm × 15 cm spacing which leads to production of maximum grain yield (4.76 t ha^{-1}). The minimum grain yield (3.27 t ha^{-1}) was obtained from 35 cm × 15 cm spacing where as minimum numbers of unfilled grains panicle^{-1} (72.39) were achieved from 15 cm × 15 cm spacing. Straw yields were maximum (6.45 t ha^{-1}) and minimum (4.90 t ha^{-1}) when the crop was planted by maintaining 15 cm × 15 cm spacing and 30 cm × 15 cm spacing, respectively.

Interaction effect of nitrogen sources and spacing was significant to all crop characters except 1000-grain yield. The interaction of widest spacing with prilled and urea super granule showed the higher plant height for all sampling dates (20, 40 and 60 DAT, and at harvest), while the closest spacing the lower plant highest. USG and optimum spacing (25 cm × 15 cm) gave highest effective tillers hill^{-1} and lowest non-effective tillers hill^{-1}. Interaction of widest spacing with all the forms of urea showed higher level of dry matter plant^{-1} than closer spacing.

Interactions of USG and spacing (25 cm × 15 cm) showed highest effective tillers hill^{-1} (9.22), filled grains panicle^{-1} (107.5) weight of 1000-grains (24.8 g), panicle length (28.02 cm), grain yield (5.20 t ha^{-1}), biological yield (11.01 t ha^{-1}) and harvest index (47.23 %). On the other hand, interaction of wider spacing and foliar application of urea showed lower grains panicle^{-1} (72.26), panicle length (23.95), 1000-grain weight (22.52 g), grain yield (2.86 t ha^{-1}), straw yield (4.95 t ha^{-1}), biological yield (7.81 t ha^{-1}) and harvest index (36.64). Non-effective tillers hill^{-1} and unfilled grains panicle^{-1} were lower in USG and optimum plant spacing. Thousand grain weights have no significant effect because of same variety does not show significant effect.

From the above discussion, the following conclusions may be drawn

- Urea super granules (USG) gives higher yield and yield contributing characters than use of other nitrogen sources
- Plant spacing of 25 cm × 15 cm shows higher grain, biological yield and harvest index compare to others spacing and
- The interaction of USG and 25 cm × 15 cm spacing shows better performance than others interactions.

However, to arrive at sound conclusion and recommendation, more research work should be done in different Agro-ecological zones of Bangladesh.

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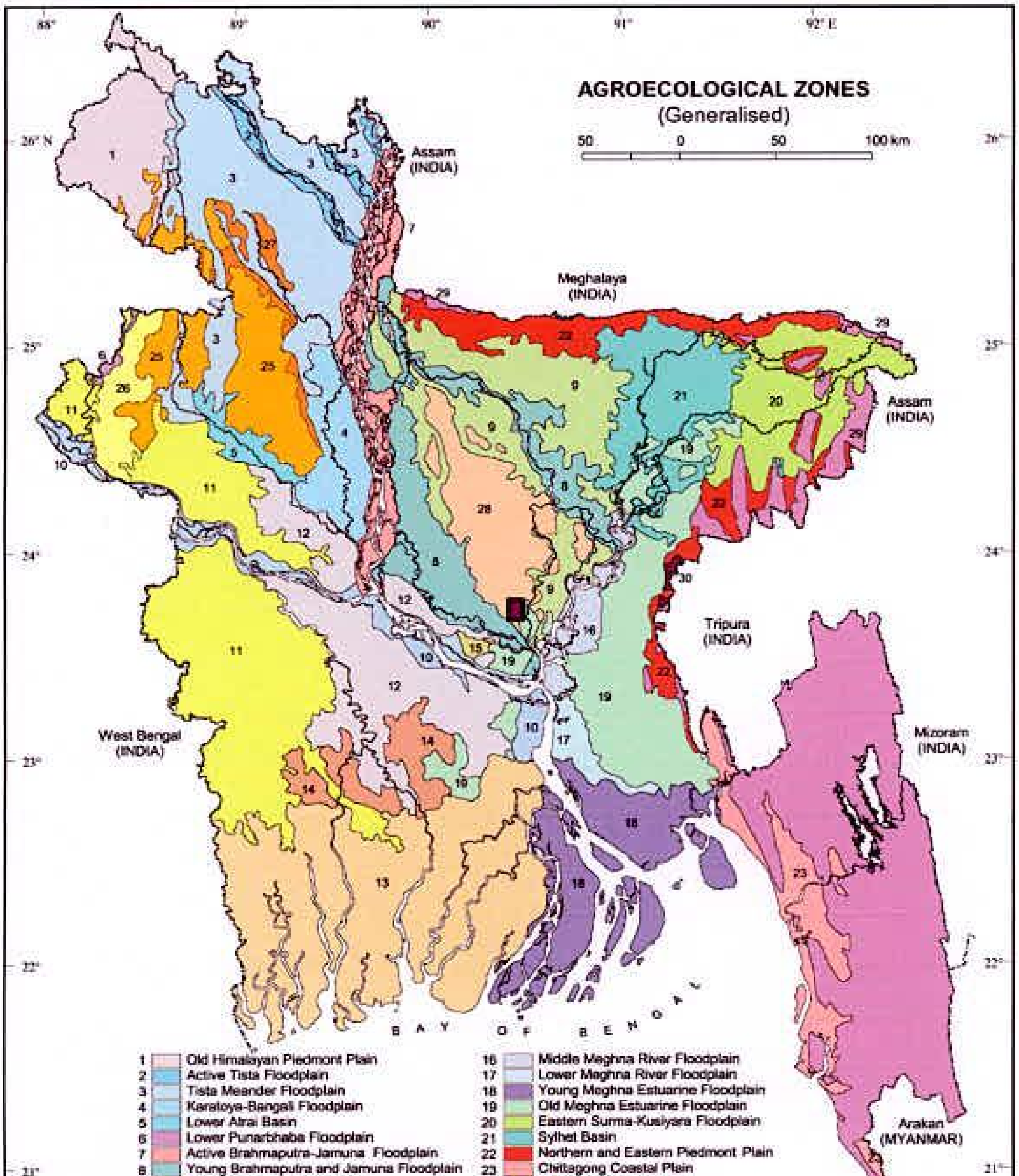
Appendices

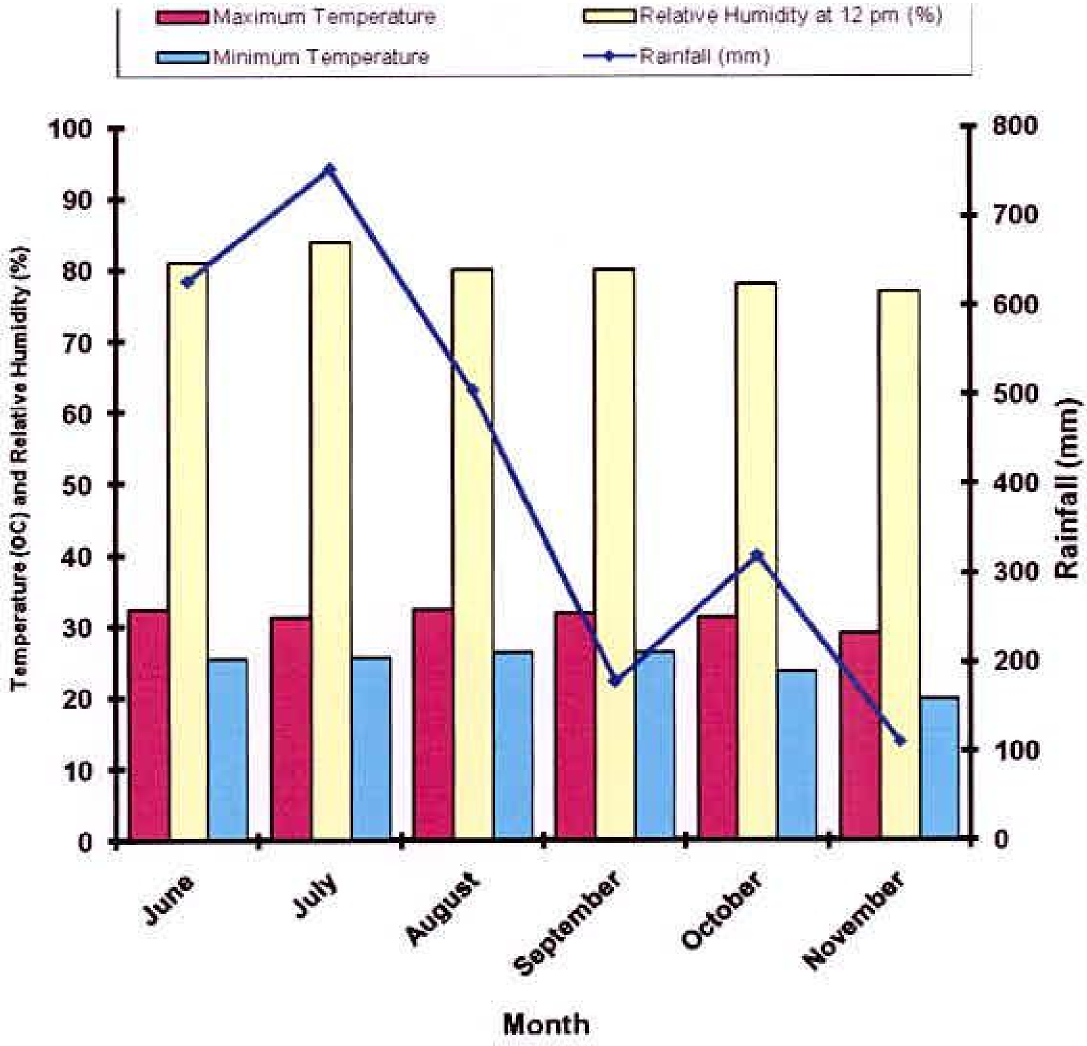
APPENDICES

Appendix I. Map showing the experimental sites under study



■ **The experimental site under study**

Appendix II. Monthly average air temperature, relative humidity and total rainfall of the experimental site during June to November 2007

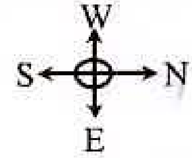


Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212

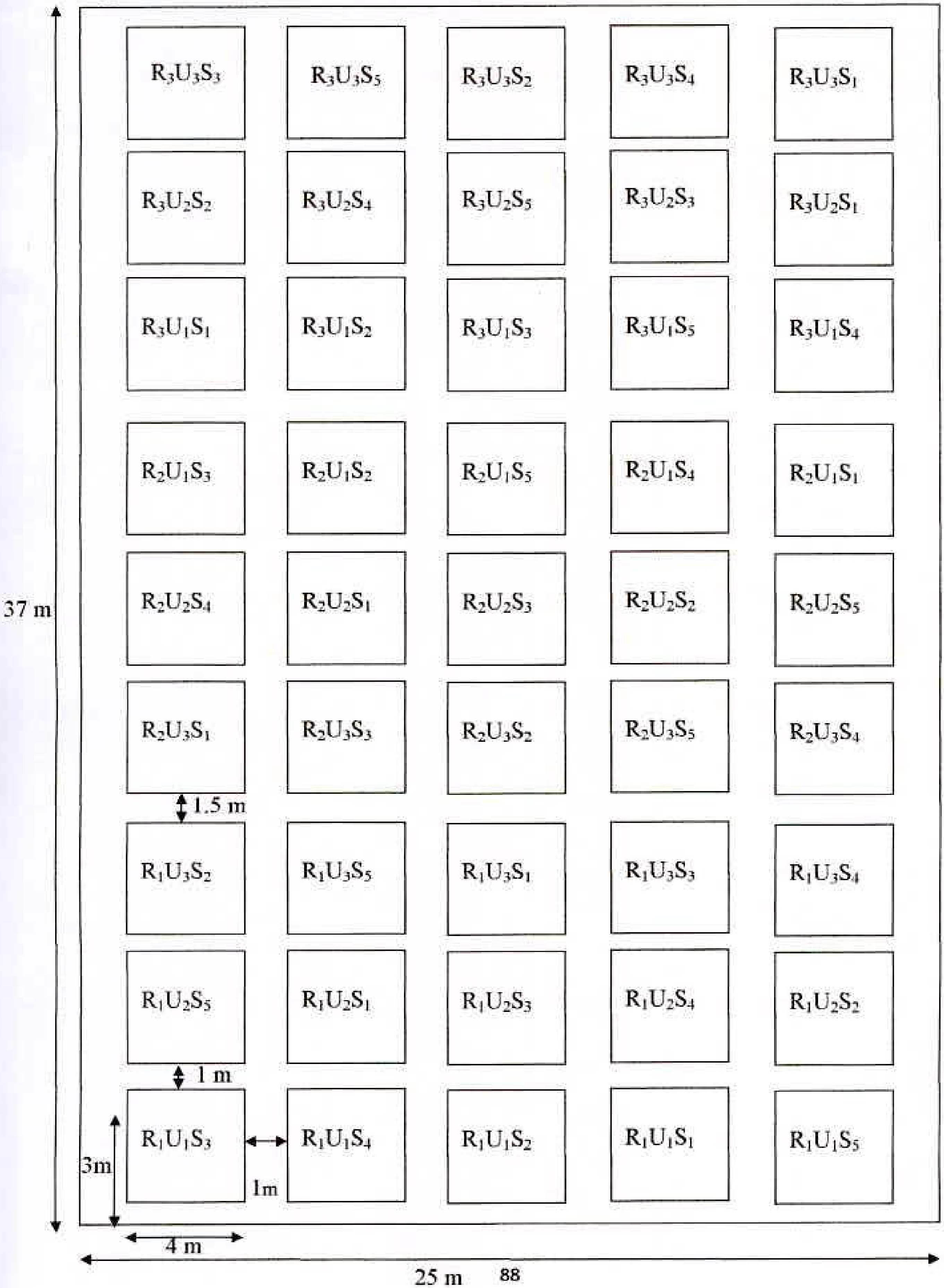
Appendix III. Physiochemical characteristics of the initial soil

Characteristics	Value
Partical size analysis	
% Sand	26
% Silt	45
% Clay	29
Textural class	Silty clay
P^H	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source : Soil Resources Development Institute (SRDI), Dhaka-1207



Appendix IV. Layout of the experimental field



Appendix V. Mean square values for plant height of BRRI dhan 31 at different days after transplantation

Sources of variation	Degree of freedom	Mean square values at different days after transplantation			
		20	40	60	At harvest
Replication	2	1.017	4.519	2.195	1.790
Nitrogen	2	39.266	14.317	55.237	56.643
Error (a)	4	1.638	6.012	3.686	15.884
Spacing	4	33.804	51.234	50.388	33.220
Nitrogen x Spacing	8	1.435	1.404	0.649	0.750
Error (b)	24	0.543	1.812	3.373	8.023

* Significant at 5% level

** Significant at 1% level

Appendix VI. Mean square values for number of tillers $hill^{-1}$ of BRRI dhan 31 at different days after transplantation

Sources of variation	Degree of freedom	Mean square values at different days after transplantation		
		20	40	60
Replication	2	0.473	2.044	9.137
Nitrogen	2	1.927	2.887	3.686
Error (a)	4	0.241	0.328	3.461
Spacing	4	0.274	17.736	20.142
Nitrogen x Spacing	8	0.041	0.097	0.107
Error (b)	24	0.038	0.336	1.184

Appendix VII. Mean square values for total dry matter weight (g) of BRRI dhan 31 at different days after transplantation

Sources of variation	Degree of freedom	Mean square values at different days after transplantation		
		20	60	At harvest
Replication	2	4.141	42.352	2.328
Nitrogen	2	11.747	45.982	48.535
Error (a)	4	0.681	13.685	2.315
Spacing	4	19.331	111.814	68.822
Nitrogen x Spacing	8	0.196	4.349	7.607
Error (b)	24	1.181	4.771	2.022

* Significant at 5% level

** Significant at 1% level

Appendix VIII. Mean square values for yield components of BRRI dhan 31

Sources of variation	Degree of freedom	Mean square values				
		Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Panicle length (cm)
Replication	2	1.612	1.757	151.472	2.130	1.727
Nitrogen	2	6.250	3.688	707.956	23.039	12.106
Error (a)	4	0.409	0.377	150.516	1.383	0.895
Spacing	4	16.332	0.800	1254.744	75.067	14.016
Nitrogen x Spacing	8	0.123	0.242	17.058	0.900	0.254
Error (b)	24	0.270	0.280	3.814	17.324	0.688

Appendix IX. Mean square values for yield components of BRRI dhan 31

Sources of variation	Degree of freedom	Mean square values				
		1000-grains weight (g)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index (%)
Replication	2	1.507	0.500	0.395	4.519	152.869
Nitrogen	2	14.867	2.150	0.817	0.828	143.931
Error (a)	4	1.954	0.216	0.053	0.255	16.920
Spacing	4	2.147	3.114	0.361	13.493	75.063
Nitrogen x Spacing	8	0.227	0.016	5.183	0.425	5.649
Error (b)	24	0.983	0.093	0.279	0.408	9.962

* Significant at 5% level

** Significant at 1% level