EFFECT OF NITROGEN LEVELS AND SPACING ON THE PERFORMANCE OF BRRI dhan 44

BY

KANAK KUMAR BISWAS

Registration No. 00991

A Thesis
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

SEMESTER: JANUARY- JUNE, 2008

Approved by:

(Prof. Md. Sadrul Anam Sardar) Department of Agronomy SAU, Dhaka **Supervisor**	**(Prof. Dr. Md. Fazlul Karim)** Department of Agronomy SAU, Dhaka **Co-Supervisor**

(Prof. Dr. Md. Jafar Ullah)
Chairman
Examination Committee

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
PABX: +88029144270-9
Fax: +88029112649

Ref: *Date: ....*

CERTIFICATE

This is to certify that the thesis entitled, "EFFECT OF NITROGEN LEVELS AND SPACING ON THE PERFORMANCE OF BRRI dhan 44" Submitted to the Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE IN AGRONOMY embodies the result of a piece of bonafide research work carried out by KANAK KUMAR BISWAS, Registration No. 00991 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 26/06/2018
Dhaka, Bangladesh

Prof. Md. Sadrul Anam Sardar
Supervisor
Department of Agronomy
Sher-e-Bangla Agricultural University
Dhaka-1207

Dedicated to

My

Departed Reverend

Elder Brother

ACKNOWLEDGEMENTS

At every moment the author would like to express his profound gratefulness to the Almighty God, the merciful and the beneficent to all creations for blessing to present this thesis.

The author wishes to express his sincere gratitude and indebtedness to his honorable teacher and research Supervisor Prof. Md. Sadrul Anam Sardar, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, outstanding assistance, valuable advice and suggestions for the successful completion of the research work and preparation of this manuscript.

The author sincerely expresses his heartfelt gratitude and deepest sense to his Co-supervisor Prof. Dr. Md. Fazlul Karim, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his kind co-operation and constructive suggestions in all phases of the research work.

The author whishes to pay his gratefulness to all the honorable teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for their kind illuminating suggestions during the research work period.

The author is proud to express his heartiest gratitude to his parents, elder brother Pijush Kanti Biswas, late Kishore Kumar Biswas and grandfather late Shree Hiralal Bagmar for their sacrifice and rendered inspiration for his higher study.

The author thanks to his senior brothers Shariful Islam and Khairul Alam, Scientific Officer, Soil Science Division, and Rashedul Haque, Scientific Officer, Agronomy Division, BARI, Gazipur, for their cordial co-operation and inspiration during the research work.

The author feels much pleasure and also to convey the profound thanks to his friends Md Iqbal Hosen, Samrat, Sumit, Palash, Masum, Tomal, Sumona, Rupok, Baten, Reza Bhai, Badal Bhai and many more for their constant encourage and valuable suggestions.

Thanks are also due to all the staff members of the office, field and laboratory of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for their timely help during the experimental work.

Dated:
Dhaka, Bangladesh

The Author

EFFECT OF NITROGEN LEVELS AND SPACING ON THE PERFORMANCE OF BRRI dhan 44

ABSTRACT

The field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka during the Aman season from 7 July to 3 December 2007 to observe the performance of nitrogen and spacing on the yield and yield contributing characters of BRRI dhan 44. The experiment consist of four levels of nitrogen viz. 0, 40, 80 and 120 kg ha^{-1} and three spacing viz. 25 cm × 25 cm, 25 cm × 20 cm and 25 cm × 15 cm. The experiment was laid out in split plot design with three replications, assigning the N rates in the main plot and spacing in the sub-plots. Gradual Increase of N up to a certain level increased plant height, tillers hill^{-1}, effective tillers hill^{-1}, grains panicle^{-1}, grain and straw yield. The spacing 25 cm × 15 cm showed better performance in all parameters compared to other spacing. Nitrogen @ 80 kg ha^{-1} coupled with hill arrangement at 25cm × 15 cm influenced plant to produce more yield components and yield. The maximum yield 5.69 tha^{-1} was recorded for this combination effect.

CONTENTS

Cont'd........

Cont'd........

LIST OF TABLES

LIST OF FIGURES

APPENDIX

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Rice is one of the oldest cultivated crops and the leading cereals of the world. Rice is cultivated over a wide range of climatic conditions from 45°N to 40°S latitude especially wherever an abundant water supply is available. Rice is the staple food for the largest number of people on earth. Rice means many things to many people. Without rice there is no life. Celebrate rice, celebrate life. Rice gives jobs to farmers, scientists, millers and vendors.

According to one estimate global rice production must reach to 800 million tons from the present 585 million tons in 2003 to meet the demand in 2025 (IRRN, 2004). It is because irrigated rice contributes more than 75% of the total rice production, enhancing its yield potential which would be key to meeting the global rice requirement for an additional 215 million tons. Tropical rice growing countries need an increased supply of rice because of their increasing populations and decreasing land.

In 2001-2002 agriculture contributes her gross domestic products (at current price) about 23.31% (BBS, 2003). Agriculture of Bangladesh is dominated by intensive rice production. In 2000-2001 rice covers about 26.7 million acres with production of 25.09 million tons and the average yield is 2.3 ton ha^{-1}. The total production of rice in Bangladesh is not sufficient to feed her people. Rice yield in unit area is very low as compared to other rice growing countries such as Japan, China, Korea, USA where yield ha^{-1} is 6.70, 6.23, 6.59, 7.04 t ha^{-1}, respectively (FAO, 2001). Moreover, total area under rice would be reduced gradually from 10.4 million hectare to 7.6 million hectare by year 2030 (Karim, 1996). Bangladesh is running with shortage of food. In order to attain self-sufficiency in food, efforts must be made to enhance the yield per unit area and improve the quality of the produce. At the beginning of the Green Revolution, world plant breeders tried to develop modern varieties of rice to satisfy food demands of the growing population of the planet. The hybrid rice technology offers an opportunity to increase rice yields and there by ensure a steady supply of rice grown in about 1 million ha of several hybrids in 2003 from the public and private sector in India, Philippines, Vietnam, Bangladesh, and Indonesia. Farmers are harvesting 1-1.5 t ha^{-1} higher yield from these hybrids.

The modern varieties of rice need more nutrients than the traditional varieties. Nevertheless, the present world requires modern varieties of rice for increasing rice production.

Rice crop yields largely depend upon the soil conditions (it's native nutrient status) and also on the supply of available nutrients (chemical fertilizer) like P, K, S and Zn. Most of the farmers of Bangladesh have a tendency to apply more amount of nitrogen to obtain higher yield. Our farmers mainly use urea as N fertilizer which accounts for about 75% of the total fertilizer used in Bangladesh (Bhuiya, 1991). Most of the rice soils of Bangladesh are deficient in N and consequently the response of modern rice varieties to nitrogen application has always been observed remarkable. But the way of meeting the increased demand for nitrogen would be adoption of N use efficient genotype and improved cultural practice for high yield. Plant breeders have been trying to develop advance lines of high yielding capacity. Each genotype has a maximum yield capacity. According to Broadbent *et al.* (1987) and De Datta and Broadbent (1990) there were significant differences in N utilization efficiencies among rice genotypes. Nitrogen use efficiency for rice crop largely ranges from 25% to 35% and seldom exceeds 50% (Singh and Yadav, 1985).

Along with other management practices for increasing the efficiency of applied N fertilizer, the selection of N efficient rice genotypes may be a good option. Therefore, to increase the efficiency of applied N fertilizer, the selection of N efficient advanced lines can be a good option to minimize losses of N as well as to develop high yielding N utilization efficient varieties.

Spacing is an important factor for the growth and yield of rice. Optimal population density and leaf area influence the availability of sunlight and nutrients for growth and development. Competition between the hills is an integral part of the physical environment and competition by neighbours often accentuate the complexity. Both the factors contribute to the determination of yield. Plasticity of the plant and the influence of competition by neighbouring plants affects on yield (Donald, 1963). As growth proceeds, inter plant competition becomes progressively operative, until when flowering and seed setting occur. The load of panicles is as great as to lead to competition among the panicles themselves and thereby to reduce the efficiency of seed production in the individual inflorescence.

So an experiment was undertaken with the use of nitrogen responsive variety BRRI dhan 44 to find out its nitrogen levels and spacing requirement.

Objectives:

- To find out the optimum plant spacing for getting higher yield in BRRI dhan 44
- To find out the optimum nitrogen dose in BRRI dhan 44
- To study the effect of interaction of nitrogen levels and plant spacing in BRRI dhan 44

Chapter 2

Review of literature

CHAPTER 2

REVIEW OF LITERATURE

Nitrogen fertilizer has a great impact and effect on the growth, yield and yield component of rice. Many experiments were conducted on rice with respect to different rates of N and also the nitrogen use efficiency in Bangladesh and in many other rice growing countries of the world. Spacing is an important factor for the growth and yield of rice. Optimal population density and leaf area influence the availability of sunlight and nutrients for growth and development. The findings of different workers on the use of nitrogen at different rates, various spacing and their ultimate effect on the performance of rice have been summarized below.

2.1 Effect of Nitrogen on rice

2.1.1 Crop characters

2.1.1.1 Plant height

Ravisankar *et al.* (2003) conducted a field experiment during the 2000 and 2001 rainy seasons in Port Blari, Andaman and Nicobar Island, India to study the effect of rice cv. Mansarovar cultivated under lowland conditions. The treatments comprised no nitrogen (T_1), 30 kg N ha^{-1} at basal, 30 and 70 days after planting (DAP) (T_2); 45 kg N ha^{-1} at 30 and 70 DAP (T_3); 32 kg N ha^{-1} at basal, 30 and 70 DAP and 25 kg N ha^{-1} at panicle initiation stage (T_4); 4.5% controlled release N at 60% of the recommended dose; and 6.0% controlled release N at 60% of the recommended dose. The highest plant height at harvest (106.0 cm) was obtained with T_3 treatment.

Lawal and Lawal (2002) disclosed that N (120 kg ha^{-1}) significantly increased plant height. A basal N application increased the plant height significantly (Sharma, 1995; Dahatonde, 1992).

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

Rajendran and Veeraputhiran (1999) conducted an experiment during the kharif season of 1996 and 1997 to study the effect of 4 nitrogen levels (0, 75, 150 and 225 kg ha^{-1}) and 3 sowing rates in the nursery (10, 20 and 3 g m^{-2}) on hybrid rice ADTRH1. Nitrogen was applied at 3 equal split namely, 7 days after transplanting, active tillering and panicle initiation stages. They found that the highest plant height was observed in hybrids supplied with 225 kg N ha^{-1}.

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

Idris and Matin (1990) stated that plant height increased up to 120 kg N ha^{-1} compared to the control and thereafter it decreased at 140 kg N ha^{-1}. The longest plant was recorded from 80 kg N ha^{-1} and the lowest one from 0 kg N ha^{-1}.

2.1.1.2 Number of tillers hill^{-1}

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

Mendhe *et al.* (2002) conducted a filed experiment at the National Agriculture Research Project, Navegaon Bardh, Maharshtra, India during the kharif season of 1998-2000 to evaluate the performance and nitrogen requirement of promising cultivars of transplanted paddy (Sye-92-27-11, Sye-116, 225-3-9-2 and surakshah). They found that nitrogen @ 125 kg ha^{-1} significantly increased the number of effective tiller hill^{-1} (9.29) as compared to those of 75 and 100 kg N ha^{-1}.

Singh and Singh (2002) recorded that increasing levels of nitrogen significantly increased total tiller hill^{-1}.

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

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

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

Sahrawat *et al.* (1999) also observed that nitrogen level significantly affected tillering in rice. The number of tiller $hill^{-1}$ increased significantly with increased nitrogen level (Maske *et al.*, 1997).

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

BINA (1996) reported that the effect of different levels of nitrogen was significant for number of tillers $hill^{-1}$.

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

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

Thakur (1993a) observed that increasing levels of N increased the productive tillers m^{-2}. Ghosh *et al.* (1991) observed that application of N increased the number of productive tiller $hill^{-1}$.

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

Idris and Matin (1990) noticed that the maximum tiller $hill^{-1}$ was produced with 140 kg N ha^{-1} which was statistically similar to those with 60, 80, 100 and 120 kg N ha^{-1}. The minimum tillers $hill^{-1}$ was obtained from the control treatment (0 kg ha^{-1}).

Mirza and Reddy (1989) concluded that increase in N levels significantly increased the total tiller $hill^{-1}$.

Kamal *et al.* (1988) concluded that the highest rate of nitrogen (120 kg ha^{-1}) fertilizer gave the maximum number of tiller $hill^{-1}$ which was significantly grater than all other treatments. Nitrogen application from 0 to 120 kg ha^{-1} in three split dressings increased number of tillers (Reddy *et al.*, 1988).

Mondal *et al.* (1987) stated that increasing rate of N from 40 to 160 kg ha^{-1} increased the numbers of productive tillers $hill^{-1}$.

Nossai and Vargas (1982) stated that number of tillers $hill^{-1}$ and panicle length was increased linearly with increased N level. Increasing rate of nitrogen application increased number of tillers $plant^{-1}$ (Dixit and Singh, 1980).

2.1.1.3 Panicles m^{-2}

Sharma and Dadhich (2003) conducted an experiment using rice cultivars Mahi Sugandha, Pusa Basmati-1 and Basmati-370 and the N rate was (0, 40, 80 or 120 kg N ha^{-1}) in Rajasthan, India during the rainy season of 1997 to determine the effects of N on the yield of the crops They found that Basmati-1 give highest number of panicles m^{-2} (336) than others. Yield attributes of the crop increased with increasing rates of N.

Tunio *et al.* (2002) conducted a field experiment at Central Luzon State University Munoz, Nueva, Ecija, Philippines, during the wet season (July-October) of 1998-99 with the aim to determine the performance of two scented rice cultivars i.e., Kasturi and Basmati 370 under different nitrogen rates (0, 30, 60, 90, 120 and 150 kg ha^{-1}). They found that among the N rates by receiving 60 and 90 kg ha^{-1} N, Basmati-370 produce maximum panicle m^{-2} among the other rates of nitrogen.

Thomass and Martin (1999) conducted a field experiment to develop a suitable integrated nitrogen management practice for wet seceded rice in Tamil Nadu, India during 1994-95. The different integrated nitrogen management practices used were *Sesbania rostrata* of green manure (GM), Azolla (AZ) as biological fertilizer and prilled urea (PU) at different levels (0, 75, 100, 125 and 150 kg ha^{-1}) as chemical fertilizer. They found that the integrated use of green manures and biological fertilizers along with chemical fertilizers has a positive effect on the number of panicle m^{-2}.

2.1.1.4 Panicle length

Sharma and Dadhich (2003) conducted a field experiment in Rajshthan, India during the rainy season of 1997 using rice cultivars Mahi Sugandha, Pusa

Basmati-1 and Basmati-370 and supplied with 0, 40, 80 and 120 kg N ha^{-1}, to determine the effects of nitrogen on the yield of the crops. The Pusa Basmati-1 produced the maximum panicle length (25.1 cm).

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

Freitas *et al*. (2001) conducted a field experiment in Mococa, Sao, Paulo, Bazil during 1997-98 and 1998-99 to evaluate the response of three new rice cultivars (IAC-101, IAC-102 and IAC 104) grown under irrigated conditions N fertilizer was applied as urea (at the rate of 0, 50, 100 and 150 kg ha^{-1}) 33% at seedling transplantation, and 33% at 20 and 40 days. They found that panicle length of three cultivars was significantly affected by N treatments.

The panicle length increased significantly with the increasing level of nitrogen from 0 to 75 kg ha^{-1} (Azad *et al*., 1995). Panicle m^{-2}, panicle length increased due to application of 60 kg N ha^{-1} (Singh and Singh, 1993).

Idris and Matin (1990) concluded that the rate of nitrogen application influenced panicle length positively. Increasing N levels increased panicle length significantly (Rafey *et al*., 1989).

Sharma and Mishra (1986) found that the maximum length of panicle was recorded with higher nitrogen level. The application of different levels of nitrogen on rice increased panicle length significantly (Awan *et al*., 1984).

2.1.1.5 Number of grains panicle^{-1}

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

Mendhe *et al.* (2002) conducted a field experiment at the National Agriculture Research Project-Navegaon Bandh, Maharashtra, India, during the kharif season of 1998-2000 to study the performance and nitrogen requirement of promising cultivars of transplanted paddy (Sye-92-27-11, SK1-6-9-27, Sye-116, 225-5-9-2 and Suraksha). They found that 125 kg N ha^{-1} significantly increased the number of grains per panicle (130.09) in Suraksha compared to 100 kg N ha^{-1}.

Tunio *et al.* (2002) conducted a field experiment at Central Luzon State University Munoz, Nueva, Ecija, Philippines, during the wet season (June-October) of 1998-99 to evaluate the performance of two scented rice cultivars i.e. Kasturi, and Basmati-370 under different nitrogen rates (0, 30, 60, 90, 120 and 150 kg ha^{-1}). They found that Basmati-370 produce more filled grains per panicle. The nitrogen rates of 60 and 90 kg ha^{-1} proved to be the best among the rates evaluated in terms of filled grain per panicle.

Ehsanulla *et al.* (2001) pointed out that the nitrogen level of 125 kg ha^{-1} produced maximum number of grains $panicle^{-1}$. The number of grains $panicle^{-1}$ increased with increasing rate of nitrogen from 0 to 60 kg ha^{-1} (Rafey *et al.*, 1989). Nitrogen significantly influenced the number of grin $panicle^{-1}$ (Bhuiyan *et al.*, 1989).

Thomas and Martin (1999) conducted a field experiment to evaluate the integrated nitrogen management practice for wet seeded rice in Tamil Nadu, India during 1994-95. The different integrated nitrogen management practices used were *Sesbania rostrata* as green manure (GM), Azolla (AZ) as biological fertilizer and prilled urea (PU) at different levels (0, 75, 100, 125 and 150 kg N ha^{-1}) as chemical fertilizer. They found that integrated use of green manures and biological fertilizer along with chemical fertilizers has a positive effect on the number of filled grains per panicle.

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

Rahman *et al.* (1985) noted no significant influence of nitrogen on grains $panicle^{-1}$ of rice.

2.1.1.6 1000-grain weight

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

Rodriguez *et al.* (2002) carried out an experiment in Araure, Portuguesa state (Venezuela) during the rainy season of 1998 to evaluate the response of rice cultivars Fonaiap1 and Cimarron at two different rates of nitrogen (150 and 200 kg N ha^{-1}). They found that nitrogenous fertilizer supplied @ (150 and 200 kg ha^{-1}) has a positive effect on 1000-grain weight (28.979) of both cultivars.

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

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

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

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

Increasing levels of nitrogen significantly increased 1000-grain weight only up to 80 kg N ha^{-1} (Thakur, 1991).

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

Bhuiya *et al.* (1990) reported that application of N at 0-60 kg ha^{-1} increased the weight of 1000-grain. Increasing N levels from 40 to 160 kg ha^{-1} significantly increased the 1000-grain weight (Mondal *et al.*, 1987).

Rahman *et al.* (1985) concluded that nitrogen rate had significant influence on grains $panicle^{-1}$ and 1000-grain weight of rice. Weight of 1000-grain was increased by the application of higher dose of nitrogen fertilizer (Awan *et al.*, 1984).

2.1.2 Grain and Straw yields

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

Singh *et al.* (2004) conducted a field experiment during the rainy (kharif) season, in New Delhi India, to study the effect of nitrogen levels (0, 60, 120 and 180 kg ha^{-1}) on the yield nitrogen use efficiency (NUE) of the rice cultivars

Pusa Basmati-1 (traditional high avidity aromatic rice) and Pusa rice hybrid-10 (aromatic hybrid rice). They found that Pusa rice hybrid -10 had than the significantly higher value for the yield attributes and nutrient accumulation than the non-hybrid Pusa Basmati-1. The maximum grain yield (5.87 t ha^{-1}) was recorded at the highest level of N nutrient (180 kg N ha^{-1}) and was 4.2, 15.5 and 39.3% higher than in the 120, 60 and 0 kg N ha^{-1} treatments respectively.

Jena *et al*. (2003) conducted field experiment on a Typic Haplaquept Orissa, India to evaluate the use efficiency of nitrogen and volatilization losses of amonia in rice by the following application of prilled urea (PU) and urea super granules (USG) at 76 and 114 kg N ha^{-1}. They found that deep placement of urea super-granules (USG) significantly improved grain and straw yield and nitrogen use efficiency of rice and reduced volatilization loss of amonia relative to the application of prilled urea.

Wopereis *et al*. (2002) stated that rice (cultivar IR 1529 and Jay in 1997 WS and IR 1324-108-2-2-3 in 1998) yields increased significantly as a result of an extra late N application on to of two N dressings (applied of the onset of tillering and at panicle initiation) with a total of approximately 120 kg N ha^{-1} in farmers field.

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

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

Geethadevi *et al.* (2000) conducted an experiment during the summer season in Karnataka, India to determine the effects of split application of nitrogen and the timing of application on the growth and yield of rice cultivars KRH-1 and Rasi. Nitrogen was applied at 120 kg ha^{-1} in the form of urea, 50% was applied as basal rate to all treatments while the remaining 50% was applied in four splits at 21 days after transplanting, panicle initiation, boot leaf and 50% flowering. They found that higher grain yield (5950 kg ha^{-1}) was recorded from KRH-1 than Rasi (5181 kg ha^{-1}) and also found that among the split application treatments nitrogen applied at 60 : 20 : 20 : 20 : 0 recorded significantly higher grain yield (6004 kg ha^{-1}) than the recommended practice of 60 : 30 : 30.

Sudhakar *et al.* (2001) carried out an experiment to evaluate the effects of various rice cultivars and nitrogen levels on yield and economics of direct sown semidry rice during kharif 1996 and 97. They found that cultivar PMK-1 show the maximum grain and straw yield, net return and B:C ratio. There was a significant increase in grain yield, straw yield, net return and B:C ratio with each increment of nitrogen application upto 125 kg ha^{-1}.

Freitas *et al.* (2001) conducted a field experiment in Mococa Sao Paulo, Brazil during 1997-98 and 1998-99 to evaluate the response of three new rice cultivars (IAC-101, IAC-102 and IAC-104) grown under irrigation. The nitrogen fertilizer was applied as urea (at, 0, 50, 100 and 150 kg ha^{-1}) 33% at seedling transplantation and 33% at 20 and 40 days later. They found that cultivars responded significantly to N application and the average yield for three cultivars at higher N rates was more than 8 t ha^{-1}. The cultivars IAC-104 and IA-101 presented higher grain yield than an IAC -102.

Singh *et al.* (2000) stated that each incremental dose of N gave significantly higher grain and straw yields of rice over its preceding dose. Consequently the crop fertilized with 100 kg N ha^{-1} gave maximum grain yield (2647 kg ha^{-1}). Pusa Basmati-1 and Sugandha responded will to 100 kg N ha^{-1} with grain yield of 3180 and 2588 kg ha^{-1}, respectively. However, Basmati 370 and BR 10 responded only up to 80 and 60 kg N ha^{-1}, with grain yield of 2286 and BR 10 responded owing to higher yield.

Rajorathinam and Balasubramaniyan (1999) conducted a field experiment in Tamil Nadu, India during 1996-97 and 1997-98 to study the response of rice (*Oryza sativa*) hybrid CORH2 of different N levels (150, 200 and 250 kg ha^{-1}) under lowland conditions. They found that grain yield of rice were highest (59.55 q ha^{-1}) with the 200 kg N ha^{-1} treatment and straw yield was highest (79.45 q ha^{-1}) upon treatment with 250 kg N ha^{-1}.

Sahrawat *et al.* (1999) found that N levels significantly affected the grain and straw yield.

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

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

The influence of two N levels (90 an 150 kg ha^{-1}) on the productivity of two rice hybrids (TNH 1 and TNH 2) was evaluated in comparison with Rasi and Jaya as standard checks. The yield response to N application was significant up to 150 kg ha^{-1}. The interaction effect among the treatments was not significant. Jaya produced the highest grain yield (5.1 t ha^{-1}). The experimental results indicate that the higher N application (150 kg ha^{-1}) is required to achieve higher grain yields in hybrid rice (Singh *et al*., 1998b).

Devaraju *et al*. (1998) reported that KHR2 out yielded to IR 20 at all levels of N application ranging from 0 to 100 kg ha^{-1}.

Singh *et al*. (1998a) studied the performance of three hybrids KHR 1, ProAgro 103 and MGR 1 using Jaya and Rasi as standard checks at four levels of N (0, 60, 120 and 180 kg ha^{-1}). They observed that the varieties responded linearly to the applied N levels up to 120 kg ha^{-1}.

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

The performances of genotypes IET 5760, IET 5914 and IET 8002 were evaluated against national check Pankaj and local checks Radha and Rajshree at five levels of N (0, 40, 80, 120 and 160 kg ha^{-1}). It was observed that the genotype IET 8002 gave significantly higher grain and straw yields that did the other genotypes. Interaction effect of N levels and genotypes was significant for yield. At 0, 40 and 80 N kg ha^{-1}, rice genotypes Rajshree and IET 8002 were at par and significantly superior to other genotypes (Singh and Kumar, 1996).

Grain yield differences among test hybrids and varieties were significant in different seasons. Varieties responded linearly to application of N level up to 120 kg ha^{-1}. The maximum grain yield was recorded in ProAgro-103. Jaya KHR-1, MGR-1 and Rasi produced 5 to 14% less grain yield as compared to ProAgro-103 (Singh *et al*., 1996).

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

Hong *et al*. (1995) found that the yield increased by reducing basal application of N.

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

Thakur (1993a) stated that increasing levels of N increased the growth and yield attributes of rice significantly.

Thakur (1993b) concluded that most of the yield contributing characters particularly panicles m^{-2} and spikelets $panicle^{-1}$ increased with increase in N levels and followed this trend with the grain yield.

Thakur (1991) reported that increasing levels of N increased the yield and yield attributes of rice significantly.

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

Pandey *et al.* (1991) found significant increase in yield with increase in N levels. Dwarf varieties gave significantly more yield than tall ones (except straw yield). The interactions of N with varieties revealed significant improvement in yield up to 90 kg N ha^{-1}, for all the varieties except tall ones.

Kandasamy and Palaniappan (1990) concluded that grain yield and panicle m^{-2} increased with increasing N application.

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

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

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

Mirza and Reddy (1989) concluded that increase in N level from 30 to 90 kg ha^{-1} significantly increased the grain and straw yields of rice. Reddy and Reddy (1989) also reported similar result with up to 120 kg N ha^{-1}.

Thakur (1989) reported that grain and straw yields were significantly increased with increasing levels of nitrogen application.

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

Balasubramaniyan and Palaniappan (1989) observed that the grain yield of rice increased with increasing N levels. In general increasing the N level up to 150 kg ha^{-1} was found to be the optimum.

Subbiah *et al.* (1988) conducted an experiment with two rice cultivars (IR 50 and RI 20) each grown in two seasons and found that increasing N rates increased grain yield from 3.71 to 4.69 t ha^{-1} in IR 20 and from 4.14 to 6.58 t ha^{-1} in IR 50 when both cultivars were grown in the kharif season.

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

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

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

Grain and straw yields increased significantly at each successive level of N application, due to increase in the number of panicles m^{-2}, length of panicle, spikelets $panicle^{-1}$ and 1000-grain weight (Dalai and Dixit, 1987).

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

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

Grain yield of rice significantly increased with increase in the level of N up to 1000 kg ha^{-1}. The yield and yield attributes increased with increasing levels of N up to 100 kg ha^{-1} reflecting their effect on yield (Thakur and Singh, 1987).

Significant increase in grain yield (49%) was observed with increase in N from 0 to 20 kg ha^{-1}. There was no improvement in yield with further increase in up to 40 or 60 kg ha^{-1}. The effect of interaction between cultivars (CR 1016 and CR 1018) and N levels was significant in respect of grain yield (Gosh *et al.*, 1987).
Reddy *et al.* (1986) observed that the grain yield of rice increased significantly with successive increment in the level of nitrogen from 30 to 90 kg ha^{-1}.

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

Reddy and Reddy (1986) in a field experiment showed that grain yield of lowland rice (cv. Tella Hamsa) increased significantly with increasing doses of nitrogen up to 120 kg ha^{-1}. However, the rate of increase in grain yield from 80 to 120 kg N ha^{-1} was marginal. Khole and Mitra (1985) reported from an experiment that higher levels of nitrogen were effective for significantly higher yield of rice.

Singh and Singh (1984) observed that the grain yield of rice increased significantly with each increment in the level of nitrogen producing higher panicles m^{-2}, panicle weight and 1000-grain weight.

Awan *et al.* (1984) studied the effect of different N levels (46.92 and 138 kg ha^{-1}) on rice (IR 6) and obtained the maximum grain yield (8.1 t ha^{-1}) with 138 kg N ha^{-1}. The grain yields from all the fertilizer treatments were significantly higher than that of control.

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

An additive element trial with BR 3 and BR 4 rice was carried out at BAU farm and farmer's fields during 1980-82 by Eaqub and Mian (1984). Their experimental results showed that the application of N alone significantly increased the grain yield.

Thind *et al.* (1983) studied the influence of nitrogen application on grain yield of rice and observed that increasing rates of N application increased the yield significantly up to 180 kg N ha^{-1}.

Subbiah (1983) obtained significantly higher grain yield of rice with 120 kg N ha^{-1} than 40 kg N ha^{-1}.

Singh and Kumar (1983) conducted a field experiment with five levels of nitrogen 0, 29, 58, 87 and 116 kg ha^{-1} on flooded transplant rice found significantly and consistent increase in the grain yield with the increase in the nitrogen level up to 87 kg ha^{-1}.

Sadaphal *et al.* (1981) observed that the yield of grain increased with the increase in the rates of nitrogen.

Mahayan and Nagar (1981) reported from a field experiment that paddy yields of rice increased significantly through increasing of nitrogen rates from 50-150 kg N ha^{-1}.

In an experiment with three rice varieties (Saket 3, Ratna and CR 4.4-1) and five levels of nitrogen (0, 20, 40, 60 and 80 kg ha^{-1}), Kumar and Sharma (1980) observed significant increase in grain yield from each additional dose of nitrogen over control. The yield increased significantly up to 40 kg N ha^{-1}. However, the differences levels of nitrogen over control. The yield increased significantly up to 40 kg N ha^{-1}. However, the differences in the levels of nitrogen 40, 60 and 80 kg ha^{-1} were not significant.

Application of nitrogen significantly influenced the yield components of rice. Significantly increase in number of tillers panicles $hill^{-1}$, panicle length, 1000-grain weight and grain yield of rice (Sharma and Prasad, 1980).

The maximum grain yield of rice was recorded with an application of 180 kg N ha^{-1}, which was followed by 120, 60 and control. The response per kg N application was 24.0, 14.2 and 15.2 kg of rice at 60, 120 and 180 kg N ha^{-1}, respectively (Singh and Paliwal, 1980).

Chapter 3

Materials and methods

CHAPTER 3

MATERIALS AND METHODS

This chapter presents a brief description about the work which is related to the experiment. It represents a brief description about the experimental site, soil, climate, crops, treatments, experimental design followed, land preparation, seedling transplanting, intercultural operations, harvesting, data recording, collection and preparation of soil and plant samples and the methods for the chemical and statistical analysis.

3.1. Experimental site and season

The experiment was laid out in the non calcarious Dark Grey Floodplain soil of Sher-e- Bangla Agricultural University, Sher-e- Bangla Nagar, Dhaka. This soil belongs to the Modhupur tract (AEZ 28). The selected plot was medium high land and the soil series was tejgaon series. The soil characteristics were silty loam in texture with pH value 6.5 and C:N ratio 8:1. The site of the experimental plot is in the 23°74' latitude and 90°35' longitude with an elevation of 8.2 m above sea level (Anon, 1989)

3.2. Climate

The climate of the experimental area is characterized by sub-tropical accompanied by bright sunshine, high rainfall associated with moderately high temperature during Aman (May-November) Season.

3.3. Plant materials

One modern rice variety BRRI dhan 44 was tested. The life cycle of this variety ranges from 150-155 days. Seed of the variety was collected from Breeding Division of Bangladesh Rice Research Institute (BRRI).

3.4. Treatments

There were four levels of nitrogen. Nitrogen was assigned in the main plot while spacing in the sub-plot.

The experimental treatments are as follows:

A. Nitrogen : 4 levels

N_0 : 0 Kg N ha^{-1}

N_{40} : 40 Kg N ha^{-1}

N_{80} : 80 Kg N ha^{-1}

N_{120} : 120 Kg N ha^{-1}

B. Spacing (row to row distance × Plant to plant distance): 3

S_1 : 25 cm × 25 cm

S_2 : 25 cm × 20 cm

S_3 : 25 cm × 15 cm

Every treatment received P, K, S and Zn as basal doses. The rates and sources of nutrients used in the study are given in Table 1.

Table 1. Nutrients, their sources and rates used for the experiment

Name of the fertilizer	Rate (kg ha^{-1})	Chemical formula
Nitrogen	0, 40, 80 and 120	$CO(NH_2)_2$
Triple super phosphate (TSP)	126	$Ca\ (H_2PO_4)_2$
Muriate of potash (MOP)	130	KCl
Gypsum	60	$CaSO_4, 2H_2O$
Zinc oxide	2	ZnO

3.5. Experimental design and layout

The experiment was laid out in a split plot design with three replications whereas nitrogen was in the main plot and spacing in subplot. The size of the unit plot was 4.0 m × 3.0 m. Total plots in the experiment field were 36. There were 1 m drains between the blocks. The treatments were randomly distributed to each block.

3.6. Land preparation

Land preparation was started on 10 July 2007. The land was prepared by repeated ploughing and cross ploughing followed by laddering. After uniformly levelling and puddling, the experimental plots were laid out as per treatments and design of the experiment.

3.7. Seedling raising

A well puddled land was selected for seedling raising. The sprouted seeds were sown uniformly at 6 July, 2007 and covered with a thin layer of fine earth. Proper care of the seedlings was taken in the nursery.

3.8. Fertilizer application

All the fertilizers with 1/3 portion of total N were added to the soil during final land preparation. Urea was applied in three equal splits. The second split on 11 September, 2007, 32 days after transplanting and third split on 2 October, 2007, 52 days after transplanting. The fertilizers were mixed throughly with the soil by hand.

3.9. Transplanting of seedling

Thirty two days old seedlings were uprooted carefully from the seedbed and transplanted in the experimental plots on 09 August 2007 following different spacing. Three seedlings were transplanted in each hill.

3.10. Intercultural operations

Intercultural operations were done for ensuring and maintaining the normal growth of the crop. The detailed intercultural operations were recorded in the Table 2. The following intercultural operations were done as and when required.

3.11. Irrigation

After transplanting 5-6 cm water was maintained in each plot through irrigation during the growth period.

3.12. Weeding

The crop was infested with some common weeds, which were controlled by uprooting and remove them three times from the field during the period of experiment. Weeding was done after 15, 32 and 52 days of transplanting.

3.13. Disease and insect pest control

There were some incidence in insects specially grasshopper, rice stemborer, rice ear cutting caterpillar, thrips and rice bug which were controlled by spraying Curatter 5 G and Sumithion. Narrow brown spot of rice was controlled by spraying Tilt.

3.14. Harvesting and threshing

The crop was harvested plot wise at maturity from 3 December, 2007. The harvested crop of each plot was bundled separately and brought to the threshing floor. The harvested crops were threshed, cleaned and processed. Grain and straw yields were recorded plot-wise and moisture of straw was calculated on oven dry basis. Grain and straw yields were converted into t ha^{-1}.

Table 2. Intercultural operations done during the field study

Intercultural operations	Working date
First ploughing of the field	10-7-07
Second ploughing and laddering	20-7-07
Third ploughing and laddering	30-7-07
Final ploughing, plot preparation and application of fertilizers (TSP, MP, Gypsum, ZnO)	3-8-07
Intercultural operations	**Working date**
Transplanting of seedlings	9-8-07
First split application of urea and first weeding	24-8-07
Second split application of urea and second weeding	11-9-07
Third split application of urea and third weeding	2-10-07
Insecticides spraying – i.Curatter 5 G (granular) ii.Sumithion	 10-9-07 19-9-07
Harvesting and threshing	3-12-07 to 7-12-07

3.15. Data collection and recording

Six hills were selected randomly from each unit plot prior to harvest for recording data on crop parameters and the yield of grain and straw were taken plot wise.

The following parameters were recorded at harvest.

i. Plant height (cm)

ii. Number of tillers hill^{-1}

iii. Number of effective tillers hill^{-1}

iv. Panicle per m^{-2}

v. Panicle length (cm)

vi. Number of grains panicle^{-1}

vii. Weight of 1000 grain (g)

viii. Grain yield (t ha^{-1})

ix. Straw yield (t ha^{-1})

3.15.1 Data collection

3.15.1.1 Plant height

Plant height was measured from the base of the plant to the tip of the tallest panicle.

3.15.1.2 Number of tillers hill^{-1}

Tillers which had at least one leaf visible were counted. It includes both productive and unproductive tillers.

3.15.1.3 Number of effective tillers hill^{-1}

The panicles that had at least one grain were considered as bearing tillers.

3.15.1.4 Number of panicles per m^{-2}

Panicles m^{-2} was also counted.

3.15.1.5 Panicle length

Panicle length was measured from the basal node of rachis to the tip of the panicle.

3.15.1.6 Number of grains panicle^{-1}

Number of grains panicle^{-1} was counted.

3.15.1.7 Weight of 1000-grain

One thousand grain was counted from the seeds obtained from the samples plants and weighed by using an electric balance.

3.15.1.8 Grain and straw yields ha^{-1}

After harvesting of the crop, grain yield of each unit plot was dried and weight. The result was expressed as kg ha^{-1} on 14% moisture basis. After harvesting of the crop, straw yields obtained from each unit plot were dried and weighed carefully. The results were expressed as kg ha^{-1} and expressed on oven dry basis.

3.16 Statistical analysis

The data were analyzed statistically by F-test to examine whether treatment effects were significant (Gomez and Gomez, 1984). The mean comparisons for the treatments were evaluated by DMRT (Duncan's Multiple Range Test). The software package, MSTATC was followed for statistical analysis.

Chapter 4

Result and discussion

CHAPTER 4

RESULTS AND DISCUSSION

A field experiment was carried out with four levels of applied N and three spacing to study the response of BRRI dhan 44. The experiment was laid out in a split plot design where nitrogen levels were assigned to main plot and spacing to sub-plots. The N levels were 0, 40, 80 and 120 kg ha^{-1} (for high yield goal on the basis of soil test value) and the spacing was (25 cm × 25 cm, 25 cm × 20 cm and 25 cm × 15 cm). Experimental results have been presented and discussed in this chapter.

4.1. Effect of nitrogen

4.1.1 Plant height

The application of nitrogen significantly increased plant height of rice. The highest plant height (119.8 cm) and the lowest (100 cm) were found in N_{120} and N_0 treatments, respectively (Table 3). Similar finding was reported by Lawal and Lawal (2002), who disclosed that plant height increased significantly due to nitrogen application. The increase in plant height due to application of nitrogen might be associated with stimulating effect of nitrogen on various physiological processes including cell division and cell elongation of the plant.

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

The application of N significantly increased the tiller number of rice (Fig. 1). The highest tiller number $hill^{-1}$ in N_{120} plots were 16.20 and the lowest (9.65) tiller number was found in N_0 treated plot. The improvement in the formation of tillers with N application in the present experiment might be due to increase of nitrogen availability which enhanced tillering. Singh and Singh (2002) found similar result.

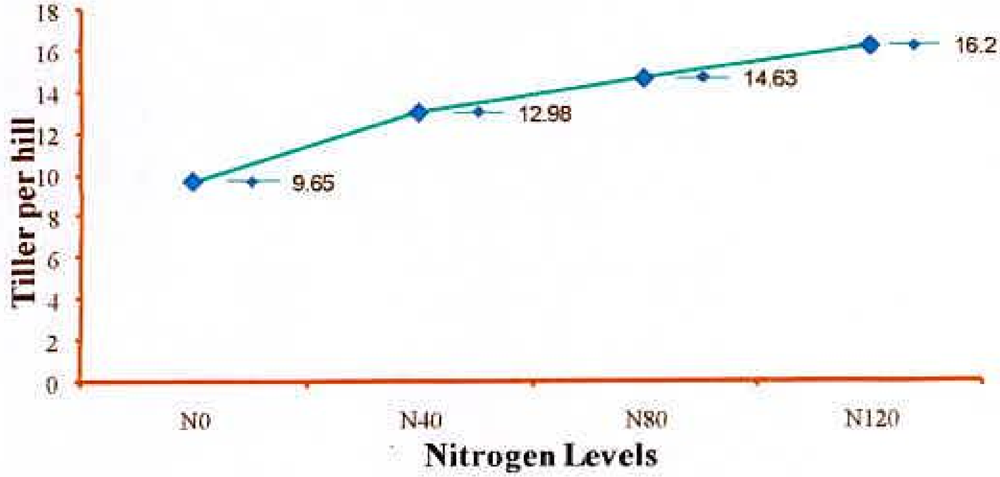

Fig. 1. Effect of different N levels on number of tillers hill^{-1} of BRRI dhan 44 (LSD$_{0.5}$: 1.214)

4.1.3 Number of effective tillers hill^{-1}

The number of effective tillers hill^{-1} was significantly influenced by nitrogen application (Fig. 2). The highest number of effective tillers hill^{-1} (13.17) was in N_{80} treated plots, and the lowest (5.41) in N_0 plots. Adequacy of nitrogen probably favored the cellular activities during formation and development which lead to increased number of effective tillers hill^{-1}.

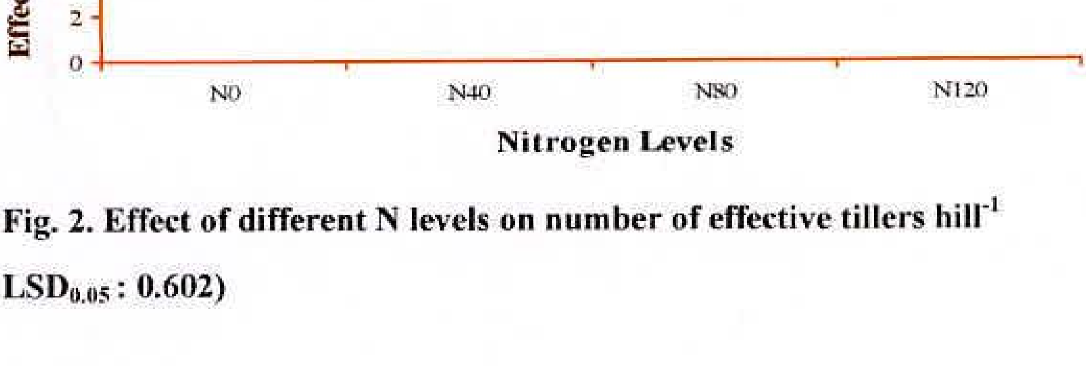

Fig. 2. Effect of different N levels on number of effective tillers hill^{-1} LSD$_{0.05}$: 0.602)

4.1.4 Panicle m^{-2}

The number of panicle m^{-2} was significantly influenced by nitrogen application (Table 3). The highest number of panicle m^{-2} (274.7) was found from N_{80} treated plots, and the lowest (113.4) in N_0 plots. Adequacy of nitrogen probably favored the cellular activities during formation and development which led to increased number of panicles m^{-2}.

4.1.5 Panicles length

Panicle length was influenced significantly by nitrogen application (Table 3). The highest panicle length (27.44 cm) was observed in N_{80} and the lowest (19.46 cm) in N_0.Treatments N_{40} and N_{120} were found statistically similar in obtaining panicle length. It reveals that panicle length increased with the increased of N level upto 80 kg ha^{-1} after which there was retardation effect. Azed *et al.* (1995) observed that panicle length increased significantly with nitrogen application. Nitrogen takes part both in panicle formation and elongation. For this reason panicle length increased with increasing of nitrogen level.

4.1.6 Grains panicle^{-1}

The application of nitrogen significantly increased the number of grains panicle^{-1}. The number of grains panicle^{-1} were 107.0, 152.8, 186.4 and 166.2 in N_0, N_{40}, N_{80} and N_{120} plots, respectively (Table 3). Adequate supply of nitrogen contributed to grain formation that probably increased the number of grains panicle^{-1}. There was progressive increase of grains panicle^{-1} with the increase of N level upto 80 kg N ha^{-1} after which there was negative effect of N in rice. It might be due to higher accumulation of N in vegetative parts with lower partitioning of dry matter to the grains. The present results explicitly confirm similar results obtained by Bhuiya *et al.* (1989) who reported that grains panicle^{-1} were increased significantly due to nitrogen application.

4.1.7. 1000 grain weight

The application of nitrogen had a significant effect on 1000 grain weight. The average 1000 grain weight in N_0 plots was 23.60 g, in N_{40} plots 25.28 g, in N_{80} 26.72 g and in N_{120} 26.04 g (Table 3). The weight of 1000 grain increased with the increased of N level upto N_{80} after which there observed a slight declination weight of 1000 grain.

4.1.8. Grain yield

The different levels of N application significantly increased the grain yield of rice. Result revealed that there was sharp increase of yield t ha^{-1} with increased of N level upto N_{80} after which there observed declination of yield t ha^{-1} due to higher vegetative growth with low partitioning of dry matter in the grain. The yield was found 2.51 t ha^{-1}, 4.10 t ha^{-1}, 5.26 t ha^{-1}, 4.58 t ha^{-1} in N_0, N_{40}, N_{80} and N_{120} plots, respectively (Table 3).

4.1.9. Straw yield

The application of N significantly increased the straw yield of rice (Table 3). The average values of straw yield was 3.15 t ha^{-1}, 3.84 t ha^{-1}, 5.81 t ha^{-1} and 4.58 t ha^{-1} in N_0, N_{40}, N_{80} and N_{120} plots, respectively. There was a successive increase of straw yield with the increase of N upto 80 kg ha^{-1} after which straw yield reduced. Nitrogen influenced vegetative growth in terms of number of tillers hill^{-1} which resulted in increased straw yield.

Table 3. Response of yield and yield contributing characters of BRRI dhan 44 to different levels of nitrogen

N levels	Plant height (cm)	Panicles m^{-2} (No.)	Panicle length (cm)	Grain $panicle^{-1}$ (No.)	1000 grain weight (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
N_0	100 d	113.4c	19.46c	107.0d	23.60b	2.51d	3.15d
N_{40}	107.7c	232.1b	25.35b	152.8c	25.28a	4.10c	3.84c
N_{80}	115.7b	274.7a	27.44a	186.4a	26.72a	5.26a	5.81a
N_{120}	119.8a	246.7b	25.05b	166.2b	26.04a	4.58b	4.58b
$LSD_{5\%}$	3.039	16.37	0.963	8.119	2.014	0.238	0.346
CV (%)	3.58	4.86	2.29	3.05	4.58	3.55	4.60

Treatments:

N_0	: 0 Kg N ha^{-1}
N_{40}	: 40 Kg N ha^{-1}
N_{80}	: 80 Kg N ha^{-1}
N_{120}	: 120 Kg N ha^{-1}

4.2. Effect of spacing

4.2.1 Plant height

There was non significant variation observed among different spacing with respect to plant height. However, the tallest plant height was found in S_3 (112.8 cm) and the shortest plant height (109.8 cm) was found in S_1 (Table 4) Non significant effect of spacing on number of plant height was also reported by Hossain *et al.* (1989) who noticed that number of plant height did not differed among the spacing.

4.2.2 Number of tillers hill^{-1}

There was non significant variation among different spacing with respect to tiller number hill^{-1}. However, the highest number of tillers hill^{-1} was found in S_3 (13.74) and the lowest tiller number hill^{-1} (13.20) was found in S_1 (Fig. 3). Non significant effect of spacing on number of total tillers hill^{-1} was also reported by Hossain *et al.* (1989) who noticed that number of total tillers hill^{-1} did not differ among the spacing.

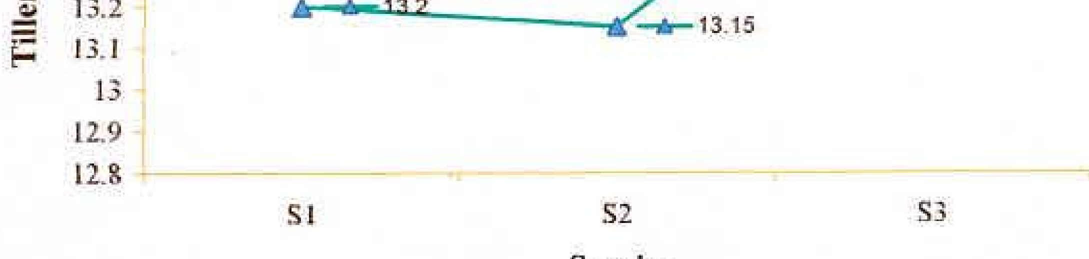

Fig. 3. Effect of different spacing on number of tillers hill^{-1} of BRRI dhan44 (LSD $_{0.05}$: 1.214)

4.2.3 Number of effective tiller hill^{-1}

Spacing had non significant effect on effective tillers hill^{-1}. The results indicated that numerically maximum number of effective tillers hill^{-1} (10.80) was produced from N_{80} and the lowest number (10.32) was found in N_0 treatment (Fig. 4). The reason for having no difference in producing effective tillers hill^{-1} might be due to the same variety. This was confirmed by Chowdhury *et al*. (1993) and BRRI (1991) who stated that effective tillers hill^{-1} varied with variety.

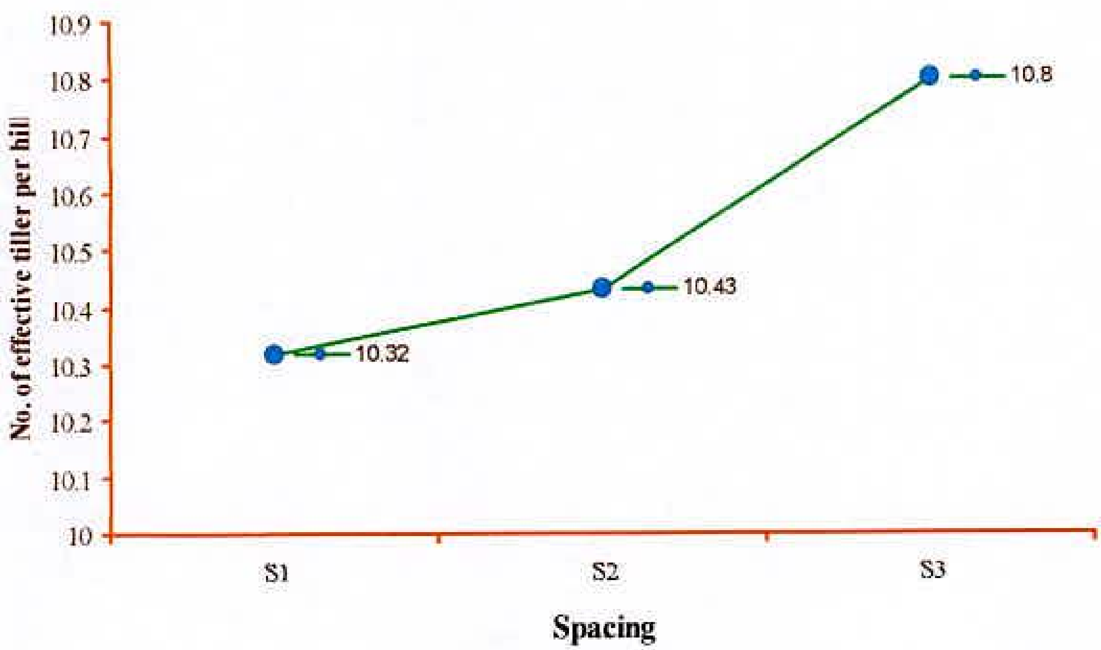

Fig. 4. Effect of different spacing on number of effective tillers hill^{-1} of BRRI dhan 44 (LSD $_{0.05}$: 0.602)

4.2.4 Panicle m^{-2}

Spacing had significant effect on panicles m^{-2} (Table 4). The results indicated that highest number. of panicle m^{-2} (237.1) was produced from N_{80} and the lowest number (196.7) was found in N_0 treatment. The reason for significant difference in producing panicle m^{-2} might be due to the same variety. This was confirmed by Chowdhury *et al.* (1993) and BRRI (1991) who stated that panicle m^{-2} varied with spacing variation.

4.2.5 Panicle length

There was significant effect of spacing on panicle length (Table 4). The highest and lowest value were 24.88 cm and 23.74cm for S_3 and S_1 respectively

4.2.6 Grains panicle^{-1}

The results revealed that the number of grains panicle^{-1} was non significantly influenced by spacing. Table 4 showed that S_1 (25cm x 25 cm) produced numerically maximum number of grains panicle^{-1} (154.6). The minimum number of grains panicle^{-1} was found in S_2 (25 cm x 20 cm) (152.10).

4.2.7. 1000 seed weight

Results revealed that 1000 grain weight was not significantly differing among the spacing treatments. The average weight in S_1 plots was 25.44 g, in S_2 plots 25.27 g and in S_3 25.52 g (Table 4).

4.2.8. Grain yield

The grain yield of rice varied significantly among differed spacing. The highest grain yield was found in S_3 (4.66 t ha^{-1}). The lowest grain yield was found in S_1 (4.11 t ha^{-1}) which was statistically similar to that of S_2 (4.26 t ha^{-1}) (Table 4).

4.2.9. Straw yield

The different rice spacing varied significantly in straw yield. The highest value was observed in S_3 (4.18 t ha^{-1}). The lowest value was observed S_1 (3.66 t ha^{-1}) which was statistically similar to 3.80 t ha^{-1} observed in S_2 (Table 4).

Table 4. Response of yield and yield contributing characters of BRRI dhan 44 to different levels of spacing

Spacing	Plant height (cm)	Panicle m^{-2} (No.)	Panicle length (cm)	Grain $panicle^{-1}$ (No.)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
S_1	109.8	196.7 c	23.74 b	154.6	25.44	4.11 b	3.66 b
S_2	109.9	216.4 b	24.35 a	152.1	25.27	4.26 b	3.80 b
S_3	112.8	237.1 a	24.88 a	152.6	25.52	4.66 a	4.18 a
$LSD_{5\%}$	NS	16.37	0.963	NS	NS	0.346	0.238
CV (%)	3.58	4.86	2.29	3.05	4.58	4.60	3.55

Treatments:

S_1 : 25 cm × 25 cm

S_2 : 25 cm × 20 cm

S_3 : 25 cm × 15 cm

4.3. Interaction effect of nitrogen and spacing

4.3.1 Plant height

The interaction effect of nitrogen and spacing was also statistically significant in respect of plant height (Table 5). The application of nitrogen increased plant height in all spacing treatments. The highest plant height of 121.7 cm was found in $N_{120}S_3$ treatment combination and the lowest was found in N_0S_1 treatment combination (97.88 cm).

4.3.2 Number of tillers hill^{-1}

The interaction effect of nitrogen and spacing was also statistically significant in terms of tiller production (Fig. 5). The maximum number of tiller (16.36) was found in $N_{120}S_2$ treatment which was statistically similar followed by $N_{80}S_1$, N_{120} S_1 and $N_{120}S_2$, respectively. The minimum number of tillers (9.27) was found in N_0S_1 treatments that was statistically similar to N_0S_2 and N_0S_3. All the interaction effect of nitrogen and spacing produced higher number of tiller hill^{-1} in N_{40}, N_{80} and N_{120} plots than those in corresponding N_0 plots.

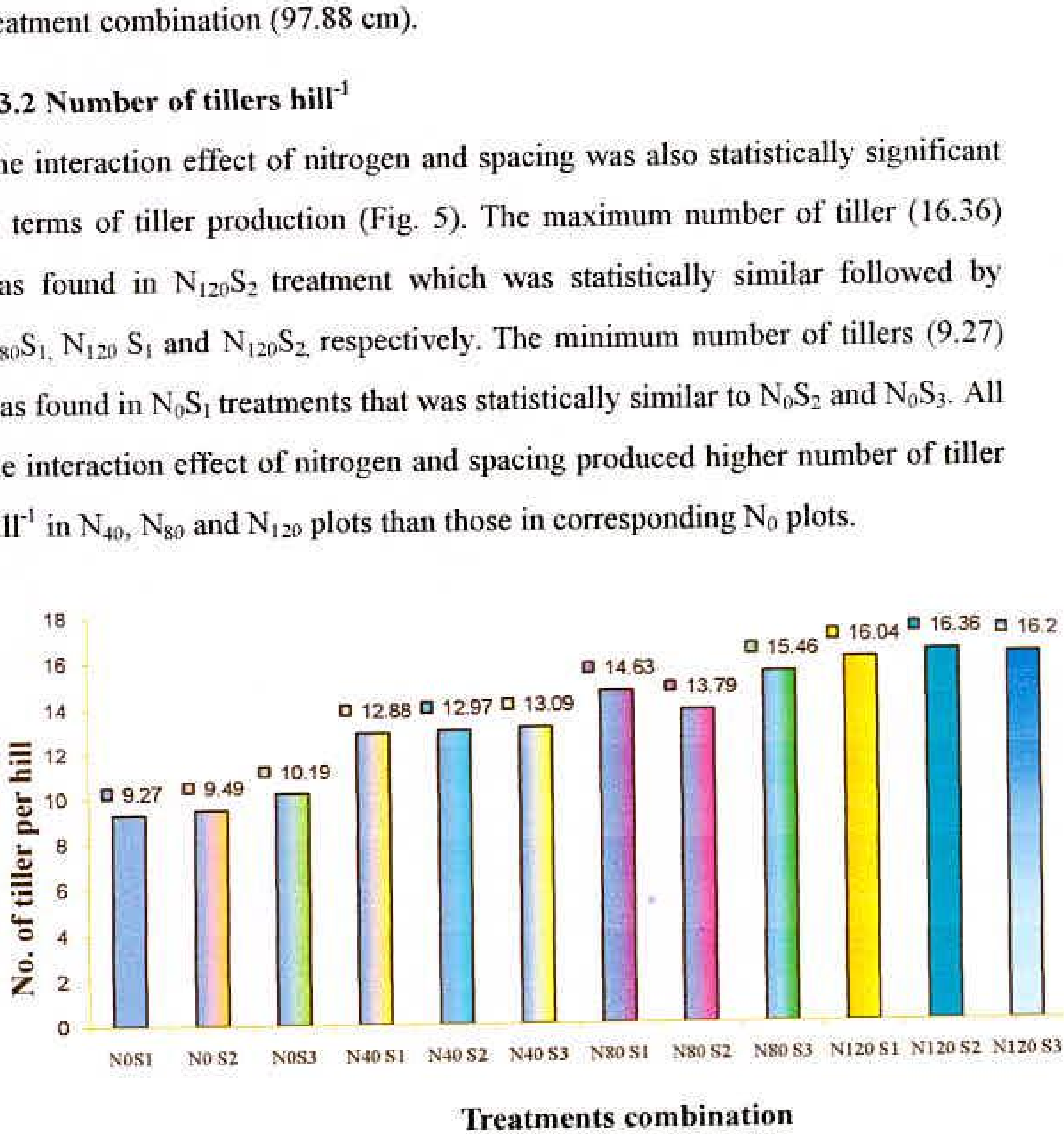

Fig. 5. Interaction effect of nitrogen and spacing on the number of tiller hill^{-1} of BRRI dhan 44 (LSD $_{0.05}$: 1.214)

4.3.3 Number of effective tillers hill^{-1}

The interaction effect of nitrogen and spacing was statistically significant in terms of number of effective tillers hill^{-1} (Fig. 6). All the spacing produced higher number of effective tillers hill^{-1} in N_{40}, N_{80} and N_{120} plots than those in corresponding N_0 plots. In N_{80} plots the highest number of effective tillers hill^{-1} was found in all spacing treatments. On the other hand in N_0 plots the lowest number of effective tillers hill^{-1} was found in all spacing treatments.

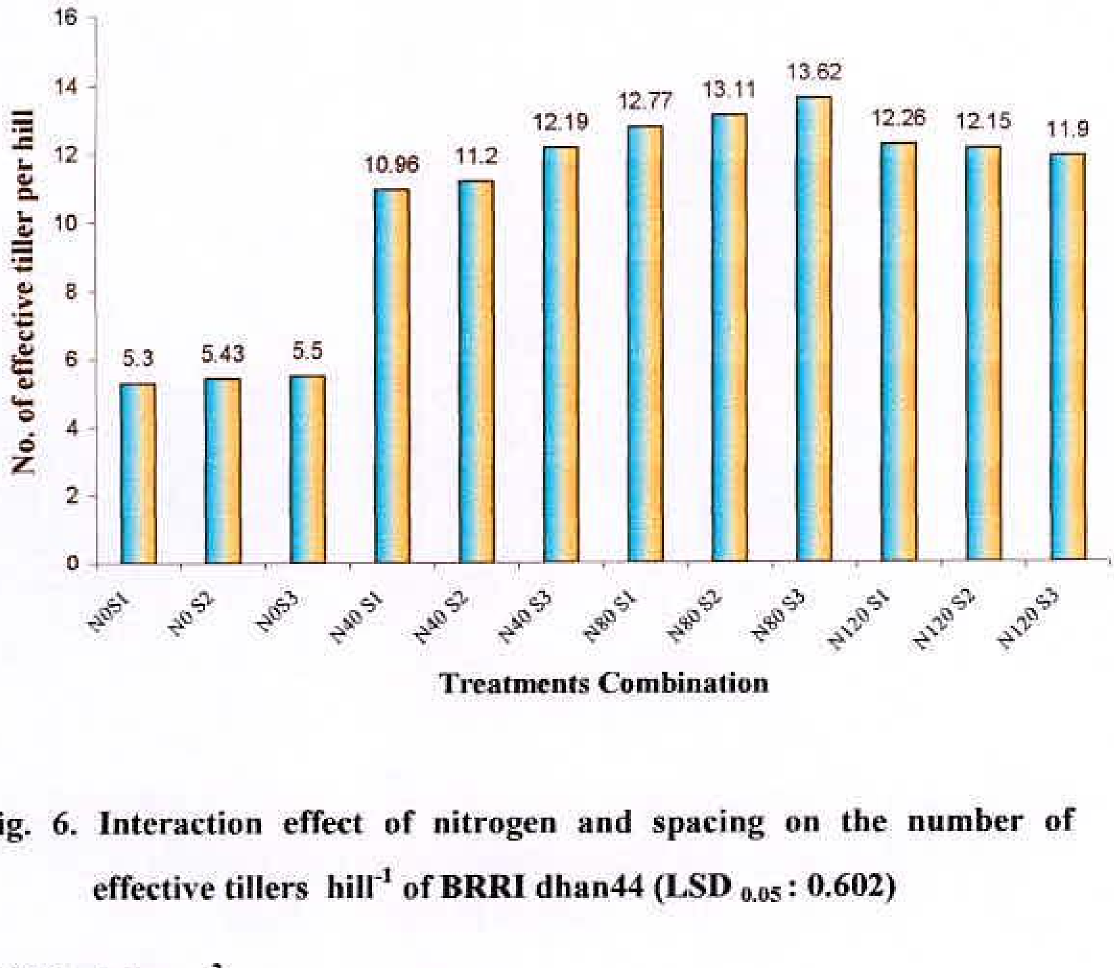

Fig. 6. Interaction effect of nitrogen and spacing on the number of effective tillers hill^{-1} of BRRI dhan44 (LSD $_{0.05}$: 0.602)

4.3.4 Panicles m^{-2}

The interaction effect of nitrogen and spacing was statistically significant in terms of number of panicles m^{-2} (Table 5). All the spacing produced significantly higher number of panicle m^{-2} in N_{40}, N_{80} and N_{120} plots compared to those in corresponding N_0 plots. In N_{80} plots the highest number of panicles

m^{-2} was found in all spacing treatments. On the other hand in N_0 plots the lowest number of panicle m^{-2} was found in all spacing treatments.

4.3.5 Panicle length

The interaction effect of nitrogen and spacing was statistically significant in terms of panicle length (Table 5). All the spacing produced higher number of panicle length in N_{80} plots than those in corresponding N_0, N_{40}, and N_{120} plots. In N_{80} plots the highest number of panicle length (28.70 cm) was found in S_3 spacing treatment. On the other hand in N_0 plots the lower number of panicle length (18.60 cm) was found in all spacing treatments and the lowest one was with the treatment N_0S_1.

4.3.6 Grains panicle^{-1}

The interaction effect of nitrogen and spacing was statistically significant in terms of grains panicle^{-1}. Treatment N_{80} with all spacing produced always higher number of grains panicle^{-1} compared to treatment combination of other spacing with N levels. Significantly the highest number of grains panicle^{-1} (189.0) was observed in the treatment combination of $N_{80}S_3$ which was statistically similar to 188.7 and 181.5 resulted from $N_{80}S_1$ and $N_{80}S_2$ treatment combination, respectively. Of course N_{120} level with S_1 and S_2 produced significantly higher grains panicle^{-1} compared to N_{40} level with S_1 and S_2 while $N_{40}S_3$ showed better performances than $N_{120}S_3$. With all spacing N_0 showed lower number of grains panicle^{-1} and the lowest number of grains panicle (100.0) was recorded from N_0S_3.

4.3.7. 1000 grain weight

The interaction effect of nitrogen and spacing was statistically significant in terms of 1000 grain weight (Table 5). N_{80} plots gave the highest 1000 grain weight against all spacing treatments followed by N_{120} and N_{40}. N_0 plots gave the lowest values of 1000 grain weight ranging from 23.25 to 24.11 g against all spacing treatments. The highest 1000 grain weight (26.61) was found in $N_{80}S_3$ treatment combination and the lowest value (23.25 g) was found in N_0S_2 treatment combination.

4.3.8. Grain yield

Interaction effect of N application and spacing was found significant in grain yield of the crop (Table 5). The highest grain yield was found 5.69 t ha^{-1} followed by 4.27 t ha^{-1}, 4.20 t ha^{-1}, 4.07 t ha^{-1} in combination treatments of $N_{80}S_3$, $N_{120}S_1$, $N_{120}S_2$ and $N_{120}S_3$ treatments, respectively. The above values showed that the application of 80 kg N ha^{-1} gave the highest amount of yield than other doses of nitrogen. N_0 gave the lowest amount of yield than others. Wittwer (1986) showed that some farmers of USA and Philippines produced very high rice yield 14.4 and 28.0 t ha^{-1}, respectively.

4.3.9. Straw yield

The combination effect of nitrogen application and different spacing was significant in producing straw yield (Table 5). In N_{80}, the highest straw yield (6.25 t ha^{-1}) was found with S_3 and the lowest (5.58 t ha^{-1}) value was found with S_1, in N_{120}, the highest straw yield (4.69 t ha^{-1}) was found with S_1 and the lowest (4.43 t ha^{-1}) value was found with S_3 and in N_{40}, the highest straw yield (4.52 t ha^{-1}) was found with S_3 and the lowest (3.49 t ha^{-1}) value was observed with S_1. All the above straw yield values showed that the highest straw yield 6.25 t ha^{-1} was obtained with the treatment combinations of $N_{80} \times S_3$ (25 cm × 15 cm) and the lowest (2.67 t ha^{-1}) straw yield from $N0S_1$. In N_0 the values of straw yield with all spacing lower yield compared to those of the other N levels with all the spacing. Singh *et al.* (2000) stated that each incremental dose of N gave significantly higher grain and straw yields of rice over it are the preceding dose.

Table 5. Yield and other crop characters of BRRI dhan 44 as affected by the interaction effect of nitrogen and spacing

Treatment combination	Plant height (cm)	Panicle m^{-2} (No.)	Panicle length (cm)	Grain $panicle^{-1}$ (No.)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
N_0S_1	97.88 f	84.53h	18.60d	112.0g	23.45e	2.22e	2.67g
$N_0 S_2$	99.09 f	109.2g	19.63d	109.0g	23.25e	2.43d	3.31f
N_0S_3	103.0 e	146.4f	20.15d	100.0h	24.11e	2.89de	3.47ef
$N_{40} S_1$	106.8 d	218.1e	25.21c	145.0f	25.18d	3.17d	3.49e
$N_{40} S_2$	107.2 d	232.0d	25.33c	151.0ef	25.22d	3.51cd	3.51e
$N_{40} S_3$	109.2 d	246.1e	25.51c	162.3cd	25.45cd	4.10c	4.52cd
$N_{80} S_1$	115.7 bc	259.5cd	26.00bc	188.7a	26.61ab	5.00ab	5.58b
$N_{80} S_2$	114.3 c	268.3bc	27.63ab	181.5ab	26.36ab	5.09a	5.60b
$N_{80} S_3$	117.2 bc	296.5b	28.70a	189.0a	27.2a	5.69a	6.25a
$N_{120} S_1$	118.8 ab	224.7a	25.16c	172.7bc	26.53bcd	4.27c	4.69c
$N_{120} S_2$	118.9 ab	256.1e	24.82c	166.8cd	26.25bc	4.20bc	4.62c
$N_{120} S_3$	121.7 a	259.4bc	25.16c	159.1de	25.34cd	4.07c	4.43d
$LSD_{5\%}$	3.039	16.37	0.963	8.119	2.014	0.238	0.346
CV (%)	3.58	4.86	2.29	3.05	4.58	3.55	4.60

Chapter 5

Summery and conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

An experiment was conducted at the Agronomy Field of Sher-e-Bangla Agricultural University Farm, Dhaka during the aman season from July 17 to December 3, 2007, to study the effect of nitrogen levels and spacing on the yield and yield contributing characters of BRRI dhan 44. The soil of the experimental filed belongs to Madhupur tract representing Tejgaon series. The experiment was laid out in a split plot design with three replications assigning N in the main plot and spacing in the subplots. The N levels were N_0 (Control) and soil test based N rate for high yield goal (40, 80 and 120 kg N ha^{-1}). The tested rice variety was BRRI dhan 44. There were 36 plots (4 × 3), each plot measuring 4 m × 3 m, the spacing were, S_1 (25 cm × 25 cm), S_2 (25 cm × 20 cm) and S_3 (25 cm × 15 cm). All nutrients except N were added to soil at a time during final land preparation. Nitrogen was applied in three equal splits, the first application was made 15 days after transplanting (DAT), the second application was made 32 days after transplanting (DAT) and the third application was made 52 days after transplanting (DAT).

All management practices and intercultural operations such as weeding, irrigation and pest management were done as and when necessary. Six hills from each plot were selected randomly at harvest and tagged for taking data of plant height, number of tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, panicle length, number of grains $panicle^{-1}$, panicle m^{-2}, grain yield and straw yield.

Grain yield t ha^{-1} and straw yield t ha^{-1} were recorded from and grain moisture was recorded and grain yield was expressed at 14% moisture. Straw yield was expressed on oven dry basis.

The N fertilizer treatments differed significantly on plant height, number of tillers hill^{-1}, number of effective tillers hill^{-1} except panicle length. The highest number of effective tillers (13.17), panicle meter^{-2}(274.7), panicle length (27.44 cm), grains panicle^{-}1(186.4), 1000 grains weight (26.72g), grain yield (5.26 t ha^{-1}) and also straw yield (5.81 t ha^{-}1) were found in N_{80} level except plant height and number of tillers.

Among the spacing, the highest plant height of 112.8 cm was found in S_3 and lowest of that 109.8cm in S_1. The highest number of number of tillers hill^{-1} (13.74), number of effective tillers hill^{-1} (10.80), panicle meter^{-2}(237.1), 1000 grains weight (25.52 g), grain yield t ha^{-1} (4.66) and straw yield (4.18 t ha^{-}1) was found in S_3.

The interaction between nitrogen and spacing had significant effect on panicle length, on 1000 grain weight, number of grains panicle^{-1} and number of filled grains panicle^{-1}. The highest number of grains panicle^{-1} (189.0) and filled grains m^{-2} (65920) was found in $N_{80}S_3$ plots and the lowest was found in N_0S_2 (109.0) for grains panicle^{-1}.

The interaction effect of nitrogen application and spacing was significant for grain yield and straw yield. The maximum grain yield (5.69 t ha^{-1}) and straw yield of rice (6.25 t ha^{-1}) was found in $N_{80}S_3$ plots and the lowest grain yield (2.22 t ha^{-1}) and straw yield (2.67 t ha^{-1}) were found in N_0S_1.

Therefore, considering all these factors studied it is concluded that BRRI dhan 44 could be cultivated with nitrogen @ 80 kg ha^{-1} along with hill arrangement at 25 cm × 15 cm for optimum yield in present situation. The result could further be verified doing research in different locations of the country.

References

REFERENCES

Awan, I.U., Ahmed, H.K. and Gandapur, S.U.D. (1984). Effect of different Nitrogen application on rice grain yield. *Intl. Rice Res. Newsl.* **9**(6): 26.

Azad, A.K, Gaffer, M.A., Samanta, S.C., Kashem, M.A. and Islam, M.T. (1995). Response of BR10 rice to different levels of Nitrogen and spacings. *Bangladesh J. Sci. Ind. Res.* **30**(1): 31-38.

Balasubramaniyan, P. and Palaniappan, S.P. (1989). Influence of organic and inorganic Nitrogen fertilization on growth and yield of lowland rice. *Indian J. Agron.* **34**(1): 64-66.

BBS (Bangladesh Bureau of Statistics). (2003). Statistical yearbook of Bangladesh. Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh. pp.101-134.

Bhuiya, M.S.U., Hossain, S.M.A. and Kabir, S.K.G. (1989). Nitrogen fertilization in rice cv. BR10 after green manuring. *Bangladesh J. Agril. Sci.* **16**(1): 89-92.

Bhuiya, N.I. (1991). Integrated nutrient management for sustainable rice based cropping system. In Proc. the Workshop on experiences with modern rice cultivation, BARC, Dhaka. pp 94-109.

Bhuiyan, N.I. and Saleque, M.A. (1990). Response of some modern rice genotypes and a promising line to applied urea in irrigated culture. Proc. 14 Ann. Bangladesh Sci. Conf. BAAS. 7-9 July 1989, Dhaka. p 15.

BINA (Bangladesh Institute of Nuclear Agriculture). (1996). Annual Report for 1993-94. Bangladesh Institute of Nuclear Agriculture Mymensingh. p 173.

Bindra, A.D. Kalia, B.D. and Kumar, S. (2000). Effect of graded levels of Nitrogen and dates of transplanting on growth, yield and yield attributes of scented rice. *Advances Agril. Res. India.* **13**: 209-213.

Brodadbent, F.E., S.K. De Datta and E.V. Laureles. (1987). Measurements of Nitrogen utilization efficiency in rice genotypes. *Agron. J.* **79**: 786-791.

BRRI (Bangladesh Rice Research Institute). (1991). Annual Report for 1988. Bangladesh Rice Res. Inst. Joydebpur, Gazipur. Bangladesh. Pub. No. 98. pp 82-300.

Budhar, M.N., Elangovan, K., Rangasamy, A., Palanippan, S.P. and Velusamy, R. (1987). Effect of different levels of Nitrogen and forms of urea on rice yield. *Indian J. Agron.* **32**(4): 463-464.

Chander, S. and Pandey, J. (1996). Effect of herbicide and Nitrogen in yield of scented rice (*Oryza sativa*) under different rice cultures. *Indian J. Agron.* **4**(2): 114-209.

Choudhury, A.T. and Khanif, Y.M. (2002). Effect of Nitrogen, Copper and Magnesium fertilization on yield and nutrition of rice. *Pakistan J. Sci. Indus. Res.* **45**(2): 102-107.

Chowdhury, M.J.U, Sarker, A.U., Sarker, M.A.R. and Kashem, M.A. (1993). Effect of variety and number of seedlings $hill^{-1}$ on the yield and its components on late transplanted aman rice. *Bangladesh J. Agril. Sci.* **20**(2): 311-316.

Dahatonde, B.N. (1992). Response of promising prereleased rice (*Oryza sativa* L.) varieties to graded levels of Nitrogen. *Indian J. Agron.* **37**(4): 802-803.

Dalai, P.K. and Dixit, L. (1987). Response of medium rice varieties (dwarf indica) to levels of N. *Indian J. Agron.* **32**(3): 286-287.

De Datta, S.K. and Broadbent, F.E. (1990). Nitrogen use efficiency of 24 rice genotypes on an N-deficient soil. *Field Crop Res.* **23**: 81-92.

Devaraju, K.M., Gowada, H. and Raju, B.M. (1998). Nitrogen response of Karnataka Rice Hybrid 2. *Intl. Rice Res. Notes.* **23**(2): 43.

Devasenamma, V., Reddy, M.R. and Soundararajan, M.S. (2001). Effect of varying levels of Nitrogen on yield and yield components of hybrid rice. *J. Res. ANGRAU.* **29**(1): 1-3.

Dixit, R.S. and Singh, M.M. (1980). Response of rice varieties to N levels under rainfed seeded conditions. *Intl. Rice Res. Newsl.* **28**(2): 26-28.

Dubey, O.P., Upadhyaya, S.P., Dixit, J.P. and Grag, D.C. (1991). Response of short duration paddy varieties to Nitrogen under rainfed condition. *Indian J. Agron.* **36**(2): 255-256.

Eaqub, M. and Abedin Mian, M.J. (1984). In Proc: Soil Test Crop Response Correlation Studies, M.A. Mannan *et al*. ed; BARC, Dhaka. pp 322-337.

Ebaid, R.A. and Ghanem, S.A. (2000). Productivity of Giza 177 rice variety grown after different winter crops and fertilized with different Nitrogen levels. *Egyptian J. Agril. Res*. **87**(2): 717-731.

Ehsanullah, K., Nawaz, H.M.A., Muhammad, U. and Cheema, M.S. (2001). Effect of various levels and methods of Nitrogen application on Nitrogen use efficiency in rice Super Basmati. *Int. J. Agric. Biol*. **3**(1): 41-51.

Ehsanullah, Nawaz, H.M.A., Muhammad-Usman and Cheema, M.S. (2001). Effect of various levels and methods of Nitrogen application on Nitrogen use efficiency in rice Supper Basmati. *Intl. J. Agril. Bio*. **3**(1): 61-63.

Fageria, N.K. and Baligar, V.C. (2001). Lowland rice response to Nitrogen fertilization. Commun. *Soil Sci. Plant Annal*. **32**: 9-10.

FAO, (2001). Production Year Boo. Food and Agricultural Organization of the United Nations, Rome: pp 76-77.

Freitas, J.G., Azzini, L.E., Cantarrella, H., Bastos, C.R., Castro-LHSM-de, Gallo, P.B., Felicio, J.C., de-Freitas, J.G. and de-Castro, L.H.S.M. (2001). Response of irrigated rice cultivars to Nitrogen. *Scientia Agricola*. **58**(3): 573-579.

Geethadevi, T., Andani, G., Vidyachandra, B., Babu, B.T.R. and Gpwda, A. (2000). Studies on split application of Nitrogen and their timings on growth and yield of rice genotypes. *Current Res. Univ. Agril. Sci. Bangalore.* **29**(3-4): 42-44.

Ghosh, B.C., Raghavaian, C.V. and Jana, M.K. (1991). Effect of seed rate and Nitrogen on growth and yield of direct sown rice (*Oryza sativa* L.) under intermediate deep water conditions. *Indian J. Agron.* **36**: 227-228.

Ghosh, B.C., Reddy, B.B., Panda, M.M. and Reddy, M.D. (1987). Response of direct seeded rice to Nitrogen under intermediate deep water conditions. *Indian J. Agron.* **23**(1): 44-48.

Gill, P.S. and Shahi, H.N. (1987). Effect of Nitrogen levels in relation of age of seedlings and time of transplanting on growth yield and milling characteristics of rice. *Indian J. Agric. Sci.* **57**(9): 630-634.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedures for Agricultural Research. 2nd edn. John Wiley and Sons. New York. p. 680.

Hari, O.K., Katyal, S.K. and Dhiman, S.D. (1997). Effect of Nitrogen and seed rate in nursery on growth and yield of hybrid rice (*Oryza sativa* L.). *Indian J. Agron.* **42**(2): 275-277.

Hong, X.F., Jong, P.Y., Xu, Z.F., Fen, L.D., Zheng, Z.S., Lu, C.Y. and Haung, C.M. (1995). Studies on the Nitrogen fertilizer application technique for paddy fields in the Hilly red region. *Acta Agriculture Zhejion Gensis.* **7**: 5, 347-351, 4184.

Hossain, A., Islam, R. and Miah, N.A. (1989). Response of rice of Sulphur and zinc fertilization. *Bangladesh J. Agril. Sci.* **16**(1): 131-134.

Hossain, M.A., Salahuddin, A.B.M., Roy, S.K. Nasreen, S. and Ali, M.A. (1995). Effect of green manuring on the growth an yield of transplant aman rice. *Bangladesh J. Agril. Sci.* **22**(2): 21-29.

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

IRRN (International Rice Research Notes). (2004). Half Yearly Report for. (2004). International Rice Research Institute, Philippines. p. 46.

Islam, M.R., Haque, M.S. and Bhuiya, Z.H. (1990). Effect of Nitrogen and Sulphur fertilization on on the growth, yield and nutrient uptake of deep water rice. *Bangladesh J. Agril. Sci.* **24**(2): 93-96.

Jena, D., Misra, C. and Bandyopadhyay, K.K. (2003). Effect of prilled urea and urea super granules on dynamics of ammonia volatilization and Nitrogen use efficiency of rice. *J. Indian Soc. Soil Sci.* **51**(3): 257-261.

Jha, K.P., Gangadharan, C. and Manna, G.B. (1991). Onfarm evaluation of promising lowland rice (*Oryza sativa*) genotypes and their response to date of seedling and Nitrogen level under flood-pron rainfed lowlands of Orissa. *Indian J. Agric. Sci.* **61**(4): 232-242.

Kamal, A.M.A., Azam, M.A. and Islam, M.A. (1988). Effect of cultivars and NPK combination on the yield contributing characters of rice. *Bangladesh J. Agril. Sci.* **15**(1): 105-110.

Kandasamy, O.S. and Palaniappan, S.P. (1990). Rate and time of N application for direct seeded irrigated rice. *Intl. Rice Res. Newsl.* **15**(3): 24.

Karim, Z. (1996). Seminar on Importance of Land Budgeting for sustainable Agricultural development in Bangladesh. August 27, 1996. Organized by Bangladesh Association of Scientists and Scientific Professions (BASSP); Venue: BARC Auditorium Dhaka-1215, Bangladesh.

Katayama, K., Song, X., Hiroto, O., Agata, W. and Takeda, T. (1990). Comparison of Fertilizer responsiveness between rice cultivars in warmer area and Japonica-Indica hybrid rice. *Sci. Bull. Facul. Agri., Kyushu Univ.* **45**(1-2): 91-98.

Katoch, K.K., Sharma, B.R. and Bhatnagar, V.K. (1987). Response of rainfed rice to Nitrogen level and post planting soil management practices. *Intl. Rice Res. Newsl.* **12**(1): 32.

Khole, C.A. and Mitra, R.A. (1985). Response of Joya variety of paddy to N, P, K and S on farmer's field in Mysore district. *Mysore J. Agric. Sci.* **24**(1): 29-34.

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

Kumar, S.D. and Sharma, H.C. (1980). Response of direct sown rice of levels of Nitrogen under rainfed condition. *Indian J. Agron.* **25**(4): 717-718.

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

Lawal, M.I. and Lawai, A.B. (2002). Influence of Nitrogen rate and placement method on growth and yield of rice (*Oryza sativa* L.) at Kadawa, Nigeria. *Crop Res. Hisar.* **29**(3): 403-411.

Lawal, M.I. and Lawal, A.B. (2002). Influence of Nitrogen rate and placement method on growth and yield of rice (*Oryza sativa* L.) at Kadawa, Nigeria. *Crop Res. Hisar.* **23**(3): 403-411.

Mahayan, A.G. and Nager, K.T. (1981). The Nitrogen sources, levels and time of application on the grain and straw yield of aman rice. Dept. *Soil Sci., Panjab Rao Krisividyapeeth, Akol, Madras.* **7**(4): 29.

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

Mendhe, S.N., Chaudhari, C.S., Sawaji, B.V., Farkade, B.K. and Khadse, V.A. (2002). Nitrogen requirement and yield performance of promising cultures of transplanted paddy. *J. Soils Crop.* **22**(2): 284-288.

Milam, M.R., Mobley, O.G. and Sheppard, R. (1988). Influence of Relationship. 1988. Influence of per-plant Nitrogen cultivar, Nitrogen rate and date of flood on yield and agronomic traits of rice. In: *Annual. Prog. Rept. Lousiana Agric. Res. Station.* 50-56.

Mirza, W.A. and Reddy, S.N. (1989). Performance of modified urea materials at graded levels of Nitrogen under experimental and farmers management condition in low land rice (*Oryza sativa*). *Indian J. Agron.* **33**(2): 218-220.

Mondal, S.S., Dasmahapatra, A.N. and Chetterjee, B.N. (1987). Effect of high rates of potassium and Nitrogen on rice yield components. *Env. Ecol.* **5**(2): 300-303.

Munnujan, K., Hamid, A., Hashem, A., Hirota, O. and Khanam, M. (2001). Effects of Nitrogen fertilizer levels and planting density on growth and yield of long grain rice. *Bangladesh Agric. Sci.* **9**(2): 19-20.

Nossai, E. and Vargas, Z.P. (1982). Response of IR8 rice variety to Nitrogen fertilizers under irrigated field condition. *Agric. Res. J. Kerala.* **36**(4): 294.

Pandey, P.C., P.S and Lal, P. (1989). Effect of rice yield of N applied during reproductive phase. *Int. Rice Res. Newlett.* **14**(4): 32-33.

Pandey, S.K., Rajkumar, R.S. and Singh, B.B. (1991). Effect of different doses of Nitrogen on dwarf and tall genotypes of rice (*Oryza sativa* L.). *Indian J. Agril. Sci.* **61**(2): 135-138.

Rafey, A., Khan, P.A. and Srivastava, V.C. (1989). Effect of N on growth, yield and nutrient uptake of upland rice. *Indian J. Agron.* **34**(1): 133-135.

Rahman, M.S., Miah, A.J. and Mansur, M.A. (1985). Agronomic performance of rice mutants with varying N fertilizer dose and plant spacing. *Bangladesh J. Nuclear Agric.* **1**(1): 59-64.

Rajarathinam, P. and Balasubramaniyan, P. (1999a). Effect of plant population and Nitrogen on yield attributes and yield of hybrid rice (*Oryza sativa*). *Indian J. Agron.* **44**(4): 717-721.

Rajarathina, P. and Balasubramaniyan, P. (1999b). Optimum plant population, seedling density and N levels for medium duration hybrid rice (*Oryza sativa* L.). *Indian J. Agron.* **44**(4): 583-585.

Rajendran, K. and Veeraputhiran, R. (1999). Effect of seed rate and Nitrogen levels on hybrid rice (*Oryza sativa*). *Madras Agril. J.* **86**(7-9): 459-460.

Rao, C.P. and Raju, M.S. (1987). Effect of age of seedling, Nitrogen and spacing on rice. *Indian J. Agron.* **32**(1): 100-102.

Ravisankar, N., Nair, A.K., Pramanik, S.C., Dinesh, R. and Choudhuri, S.G. (2003). Effect of controlled release Nitrogen on growth, yield, economic and energetics of medium duration 'Mansarovar' rice (*Oryza sativa*) under lowland condition. *Indian J. Agril. Sci.* **73**(5): 289-290.

Reddy, G.R., Reddy, G.B., Ramaiah, N.V. and Reddy, G.B. (1990). Effect of different levels of Nitrogen and forms of urea on growth and yield of wetland rice. *Indian J. Agron.* **31**(4): 118-416.

Reddy, G.R.S. and Reddy, K.A. (1986). Effect of different forms of urea at various levels of Nitrogen for lowland rice. *Indian J. Agron.* **56**(11): 775-778.

Reddy, G.R.S. and Reddy, K.A. (1989). Effect of different forms of urea at various levels of Nitrogen for lowland rice. *Indian J. Agron.* **57**(11): 785-786.

Reddy, G.R.S., Reddy, G.B., Ramajah, N.V. and Reddy, G.B. (1986). Effect rates and sources of Nitrogen on transplanted lowland rice. *Indian J. Agril. Sci.* **31**(4): 416-418.

Reddy, J.V., Singh, J.N. and Verma, A.K. (1988). Effect of time of Nitrogen application on growth and yield of rice (*Oryza sativa* L.). *Agric. Sci. Degest. Indian.* **5**: 83-85.

Rodriguez, H.A., Arteaga-de, R.L., Cardona, R., Romon, M., Aleman, L. and Arteaga-de, R.L. (2002). Response of rice varieties Fonaiap 1 and Cimarron at two plant densities and two Nitrogen doses. *Bioagro.* **14**(2): 105-112.

Sadaphal, M.N., Dayanand and Singh, T. (1981). Relative efficiency of different grades of urea and Nitrogen rates of rice. *Indian J. Agron.* **26**(4): 428-431.

Sadeque, M.A., Zaman, S.M., Karim, M.A. and Miah, M.A.J. (1990). Studies on Nitrogen economy of rice plants. *Progress. Agric.* **1**(2): 19-23.

Sahrawat, K.L., Diatta, S. and Singh, B.N. (1999). Nitrogen responsiveness of lowland rice varieties under irrigated conditions in West Africa. *Intl. Rice Res. Notes.* **24**(2): 30.

Sarkar, S., Pal, S., Mandla, N.N. and Maiti, S. (2001). Response of rice cultivars to different levels of Nitrogen. *Environ. Ecol.* **19**(1): 118-120.

Sharma, A.R. (1995). Effect of basal and post-flood Nitrogen fertilization on performance of rice (*Oryza sativa*) under conditions of intermediate deep water and simulated flash flooding. *Indian. Agric. Sci.* **65**(6): 399-404.

Sharma, M.L. and Mishra, V.R. (1986). Effect of fertilizer Nitrogen and algal inoculation on rice crop. *Madras Agric. J.* **71**(2): 155-159.

Sharma, S.K. and Dadhich, L.K. (2003). Response of scanted rice (*Oryza sativa*) varieties to applied Nitrogen under Ghaggar flood plains of Nroth-West Rajasthan. *Annals Agri. Bio. Res.* **8**(1): 49-50.

Sharma, S.N. and Prasad, R. (1980). Relative efficiency of urea nitrification inhibition treated urea and Sulphur coated urea of rice. *Indian. J. Agron.* **25**(3): 403-409.

Sidhu, M.S., Sikka, R. and Singh, T. (2004). Performance of transplanted Basmati rice in different cropping systems as affected by N application. *Intl. Rice Res. Notes.* **29**(1): 63-65.

Singandhupe, R.B. and Rajput, R.K. (1989). Effect of moisture regimes and sources and levels of Nitrogen on yield of rice (*Oryza sativa* L.) in alkali soil. *Indian J. Agric. Sci.* **59**(8): 532-533.

Singh, A.K. and Kumar, A. (1996). Responses of promising rice genotypes to Nitrogen levels in irrigated lowlands. *Intl. Rice Res. Notes.* **21**(1): 46-47.

Singh, B.K. and Singh, P.R. (1984). Responses of promising rice genotypes of urea and rates of Nitrogen in rained lowland rice on Calcareous soil. *Indian J. Agron.* **29**(4): 566-568.

Singh, C.M. and Kumar, N. (1983). Nitrogen fertilization in transplant rice. *Intl. Rice Res. Newsl.* **8**(5): 27.

Singh, C.S. and Singh, U.N. (2002). Effect of Nitrogen and Sulphur nutrition on growth and yield of rice (*Oryza sativa* L.) cultivars. *Res. Crops.* **3**(3): 643-646.

Singh, G. and Singh, O.P. (1993). Effect of method of seedling and levels of Nitrogen on yield and yield attributes of rice (*Oryza sativa* L.) under flood affected condition. *Indian J. Agron.* **38**(4): 551-554.

Singh, M. and Yadav, D.S. (1985). Nitrogen use efficiency in rice. *Fert. Newsl.* **30**: 17-23.

Singh, M.K., Thakur, R., Verma, U.N., Upasani, R.R. and Pal. S.K. (2000). Effect of planting time and Nitrogen on production potential of Basmati rice (*Oryza sativa*) cultivars in Bihar Pateau. *Indian J. Agron.* **45**(2): 300-203.

Singh, S.K. (1997). Response of promising rice genotypes of N levels in rainfed lowlands. *Intl. Rice Res. Notes.* **22**(3): 27-28.

Singh, S.P., Devi, B.S. and Subbiah, S.V. (1998a). Effect of N levels and time of application on grain yield and hybrid rice. *Intl. Rice Res. Notes.* **23**(1): 25.

Singh, S.P., Rao, K.V., Subbiah, S.V. and Pillai, K.G. (1998b). Effect of planting geometry and N levels on grain yield of hybrid cultivars. *Intl. Rice Res. Notes.* **23**(1): 38.

Singh, T., Shivay, T.S. and Singh, S. (2004). Effect of date of transplanting and Nitrogen on productivity and Nitrogen use indices in hybrid and non-hybrid aromatic rice. *Acta Agronomica Hungarica.* **52**(3): 245-252.

Singh, U.B. and Paliwal, S.K. (1980). Effect of different dates of sowing in nursery and Nitrogen levels on rice yield in Rajasthan. *Indian J. Agron.* **25**(3): 378-381.

Subbiah, P. (1983). Relative efficiency of different grade of urea and Nitrogen rates for rice. *Indian J. Agron.* **26**: 428-431.

Subhendu, M., Swamy, S.N. and Mandal, S. (2003). Effect of time of Nitrogen application on yield and yield attributes of rice (*Oryza sativa* L.) cultivars. *Environ. Ecol.* **21**(2): 411-413.

Sudhakar, G., Solaimalai, A. and Ravisankar, N. (2001). Yield and economic of semidry rice as influenced by cultivars and levels of Nitrogen. *Indian J. Dryland Agril. Res. Devlop.* **16**(1): 42-44.

Thakur, K.S. and Singh, C.M. (1987). Effect of organic wastes and N-levels on transplanted rice. *Indian J. Agron.* **32**(2): 161-164.

Thakur, R.B. (1989). Response of medium duration rice genotypes to Nitrogen. *Indian J. Agron.* **34**(4): 491-492.

Thakur, R.B. (1991). Response of rice (*Oryza sativa*) to Nitrogen. *Indian J. Agron.* **36**: 229-230.

Thakur, R.B. (1993a). Perforamnce of summer rice (*Oryza sativa*) to varying levels of Nitrogen. *Indian J. Agron.* **38**(2): 187-190.

Thakur, R.B. (1993b.) Effect of split application of Nitrogen on growth, yield and N-uptake in wetland rice (*Oryza sativa*). *Indian J. Agron.* **38**(2): 191-194.

Thind, H.S., Singh, B. and Deol, P.S. (1983). Effect of different levels and methods of Nitrogenous fertilizers on the rice grain yield and quality. *Intl. Rice Res. Newsl.* **8**(4): 23.

Thomas, D. and Martain, G.J. (1999). Integrated Nitrogen management for wet seeded rice. *Madras Agril. J.* **86**(10-12): 529-532.

Tunio, G.S., Agustin, M.B. Nihal-ud-din, M. and Babar, M.A. (2002). Growth and yield of scanted rice verities under different Nitrogen levels. *Sarhad J. Agril.* **18**(3): pp 303-305.

Wittawr, S.H. (1986). In Research and Technology Needs for the Twenty First Century in a Global Aspects of Food Production. M.S.S. Swaminathan and S.K. Sinha (Ed.) *Intl. Rice Res. Inst., Manila, Philippines.*

Wopereis, P.M.M., Watanabe, H., Moreira, J. Wopereis, M.C.S. (2002). Effect of late Nitrogen application on rice yield, grain quality and profitability in the Senegal River Valley. *European J. Agron.* **17**(3): 191-198.

Appendix

APPENDIX

Appendix 1. Morphological, physiological and chemical characteristics of soil

A. Morphological characteristics

Characteristics	Experimental field
Location	Agronomy Field Laboratory, SAU, Dhaka
AEZ	Madhupur tract
General soil type	Non calcareous Dark Grey Floodplain soils
Drainage	Moderate
Topography	Medium highland
Flood level	Above flood level (8.2 m)
Cropping pattern	Rice crop grown year round (rice-rice)

B. Physical characteristics

Characteristics	Experimental field
% Sand	36.90
% Silt	26.40
% Clay	36.66
Textural class	Clay loam

C. Chemical characteristics

Characteristics	Experimental field
pH (Soil: water = 1:2.5)	5.68
Organic matter (%)	0.82
Total N (%)	0.03
Available P ($\mu g\ g^{-1}$)	11.02
Available S ($\mu g\ g^{-1}$)	13.10
Exchangeable K (C mol kg^{-1} soil)	0.10
Cation Exchange Capacity (C mol kg^{-1} soil)	11.30