EFFECT OF NITROGEN AND SULPHUR ON THE GROWTH, YIELD AND QUALITY OF BORO RICE (BRRI dhan 28)

BY

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of Nitrogen and Sulphur on the Growth, Yield and Quality of Boro rice (BRRI dhan-28)"** 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 Soil Science**, embodies the result of a piece of bonafide research work carried out by **Md. Asadul Alom**, Registration number: **07- 02593** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University (SAU) farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period of December 2007 to April 2008 to study the effect of nitrogen and sulphur on the growth, yield and quality of Boro rice. BRRI dhan 28 was used as the test crop in this experiment. The experiment was laid out in randomized complete block design (RCBD). There were twelve treatment combinations comprising of four levels of N (0, 120, 140 and 160 kg ha^{-1}) designated as N_0, N_1, N_2 and N_3 and three levels of S (0, 20 and 30 kg S ha^{-1}) designated as S_0, S_1 and S_2. There was a positive impact of each nutrient and their interactions on yield, yield parameters and nutrient contents of boro rice BRRI dhan 28 with increasing rate of nitrogen and sulphur. In case of individual effect of nitrogen the maximum plant height (87.4 cm) was observed in N_2 (140 kg N ha^{-1}) treatment, and number of filled grains $panicle^{-1}$ (102.8) and grain yield (6.9 t ha^{-1}) were recorded in N_3 (160 kg ha^{-1}) treatment. The straw yields were almost similar in different levels of N except N_0 treatment. Application of 30 kg S ha^{-1} produced the highest number of effective tillers $hill^{-1}$ (11.9), filled grains $panicle^{-1}$ (90.1), straw yield (7.8 t ha^{-1}) and grain yield (6.5 t ha^{-1}). There was no significant single effect of S on plant height and 1000-grain weight of BRRI dhan 28. The treatment combination of N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) performed better than other treatments in present trial considering number of filled grains $panicle^{-1}$, grain and straw yield of Boro rice BRRI dhan 28. The uptake and concentration of N, P, K and S in grain and straw increased with increasing levels of N and S. The post harvest soils of N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) resulted the highest total N and available S content. From the view point of grain yield, nutrient concentration and the quality of post harvest soils, the treatment combination of N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) was considered to be the suitable dose of fertilizer for boro rice in Deep Red Brown Terrace soil.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

TABLE OF CONTENTS (Cont'd.)

TABLE OF CONTENTS (Cont'd.)

TABLE OF CONTENTS (Cont'd.)

TABLE OF CONTENTS (Cont'd.)

TABLE OF CONTENTS (Cont'd.)

LIST OF TABLES

LIST OF TABLES (Cont'd.)

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATED TERMS

FULL WORD	ABBREVIATION
Agro-Ecological Zone	AEZ
And others	*et al.*
Bangladesh Agricultural Research Institute	BARI
Bangladesh Rice Research Institute	BRRI
Bangladesh Bureau of Statistics	BBS
Centimeter	cm
Co-efficient of Variation	CV
Etcetera	etc.
Figure	Fig.
Journal	j.
Kilogram	Kg
Meter	m
Hectare	ha
Kilogram per Hectare	kg ha^{-1}
Ton per hectare	t ha^{-1}
Hydrogen ion concentration	pH
Milliequivalent	meq
Nitrogen, Phosphorus and Potassium	NPK
Triple Super Phosphate	TSP
Muriate of Potash	MP
Nitrogen	N
Sulphur	S
Percent	%
Non Significant	NS
Number	No.
Randomized Complete Block Design	RCBD
Replication	R
Research	Res.
Sher-e-Bangla Agricultural University	SAU
Muriate of Potash	MP
Square meter	m^2
Triple Super Phosphate	TSP

Chapter 1
Introduction

CHAPTER 1
INTRODUCTION

Soil fertility deterioration has become a major constraint to higher crop production in Bangladesh. The increasing land use intensity without adequate and balanced use of inorganic fertilizers have caused severe fertility deterioration of our soils. Rice (*Oryza sativa* L.) is the staple food for nearly half of the world's population (FAO, 2003). Bangladesh is one of the most important rice growing countries of the world. Rice (*Oryza sativa L.*) belongs to the family Gramineae and is dominant over all other crops in respect of economic and social significance in Bangladesh. It is the most extensively cultivated crop and the staple food crop of the country. The acreage and production of rice in Bangladesh are about 10.26 million hectares and 2.50 million metric tons, respectively with an average yield of only 2.86 t ha^{-1} (BBS, 2005). Among the rice producing countries, Bangladesh ranks fourth, both in acreage and production the first, second, and third being China, India and Indonesia respectively (FAO, 2003).

Bangladesh is facing a chronic shortage of food over the years due to high population pressure, and total rice growing area is continuously declining due to urbanization and industrialization. Moreover, some rice growing areas are now being used as ponds for raising fishes to meet increasing protein demand of people. Now it is necessary to ensure food security for increasing population.

The reasons for low yield are manifold: some are varietals; some are climatic and some are soil managements. The domestic production of this crop can not entirely meet the requirement of teeming hungry millions of people of the country. Due to the shortage of land, the scope of its cultivation on extended land area is very limited. Therefore, attempts must be made to increase the yield per unit area by applying improved technology and management practices. The yield of Boro rice can be increased with the improved cultivation practices like proper dose of nitrogen and sulphur.

Nitrogen plays a key role in rice production among the fertilizer elements and it is required in larger amount compared to other fertilizers. It affects the vegetative growth, development and yield of rice. The important role of nitrogenous fertilizer for increasing rice yield has been widely recognized, particularly after the development of modern varieties (BRRI, 1990). Rice yield may be increased even up to 80 % by proper utilization of nitrogen fertilizer (Patil and Mirsha, 1994). The efficient fertilizer management can increase crop yield and reduce production cost. Excess amount of nitrogen fertilizer results in lodging of plant, prolonging growing period, delayed in maturity and reducing yield (Uddin, 2003). Nonjudicious application of nitrogen fertilizer not only increases production cost but also reduces the quality of the product. It is essential to determine the optimum nitrogen dose to maximize rice yield under these circumstances.

Most Asian countries have adopted intensified rice-based cropping systems to increase food production for a rapidly growing population. Crop intensification and increased yield have significantly increased the output of nutrients and, where there has been an imbalance between outputs and inputs, has resulted in declining soil fertility and an increase in the incidence of deficiencies of certain plant nutrients, including sulphur. Sulphur is considered as the fourth major nutrient element for crops (Platou and Jones, 1982).

In rice, there is often general yellowing of the whole plants and it appears similar to N deficiency but the symptoms appear first or more marked on the younger leaves (Rao *et al*., 1980). Symptoms of S deficiency include reduced growth and chlorosis or yellowish of the leaves due to diminished levels of chlorophyll (Tabatai, 1982). Chlorosis extends to the older leaves, redding and purpling develops in the stems and leaves (Yoshida *et al*., 1976). Chlorotic plants become stunted, thin stemmed (Tisdale et al., 1997) and spindly (Brady, 1996).

The farmers of this country use on an average 102 kg nutrients/ha annually (70 kg N + 24 kg P + 6 kg K +2 kg S and Zn), while the crop removal is about 200 kg ha^{-1} (Islam *et al.* 1990). Since fertile soil is the fundamental resource for higher crop production, its maintenance is a prerequisite for long-term sustainable crop production.

The reasons for S deficiencies are: greater use of S free fertilizer, higher crop removal of S because of higher yields and intensive cropping, increasing depletion of soil S due to wide gap between additions and removals of S, losses of S by leaching, decreased use of S as an insecticide and fungicide, and smaller addition of S through rainfall due to lowering of atmospheric levels of SO_2 and H_2S.

On the other hand, the demand for increasing rice production is mounting up to feed the ever increasing population. Because rice is a major source of livelihood in terms of providing food, income and employment in densely populated Bangladesh. The status of organic matter in our soil is low and the land of our country deficient in N and S. The cropping intensity is increasing day by day and the status of N and S are declining for intensive crop cultivation. So, it is necessary to use fertilizer in a way in order to obtain sustainable crop yield without affecting soil fertility. A suitable combination N and S fertilizers is necessary for Boro rice cultivation that can ensure rice yield with quality. The present investigation will be under taken to examine the effect of N and S on Boro rice (BRRI dhan 28).

OBJECTIVES

i) To know the effect of N and S on the growth, yield and quality of Boro rice (BRRI dhan 28),

ii) To select a suitable level of N and S fertilizer combination for better yield and quality of Boro rice (BRRI dhan 28) and

iii) To improve the soil fertility status by adding proper dose of N and S for Boro rice (BRRI dhan 28).

Chapter 2
Review of literature

CHAPTER 2

REVIEW OF LITERATURE

Rice is the main food crop for the people of Bangladesh. Many research works on different aspects of rice cultivation have been done at home and abroad for the improvement of rice yield. Research work related to the effect of nitrogen and sulphur on the growth, yield and quality of boro rice (BRRI dhan 28) have been reviewed in this chapter.

2.1 Effect of level of nitrogen on growth, yield and quality of rice

Nitrogen is the key element in the production of rice and gives by far the largest response. Most of the rice varieties are highly responsive to added nitrogen and they are not expected to produce their full yield potential without adequate fertilizers especially with nitrogen fertilizers. Available literatures, which are related to the level of nitrogen, are briefly reviewed in this section.

Chopra and Chopra (2004) showed that nitrogen had significant effects on yield attributes such as plant height, panicles plant^{-1}, and 1000-grain weight. Cumulative effect of yield attributing characters resulted in significant increase in seed yield at 120 kg N ha^{-1} over 60 kg N ha^{-1} and the control. Different spacings did not affect seed yield. The relationship between seed yield and nitrogen was quadratic. The maximum response was observed at 60 kg N ha^{-1} and thereafter it decreases with increase in N rate. The optimum N rate was 141.9 kg ha^{-1}, recording an additional profit of Rs. 18607 over the control.

Namba (2003) showed in their experiment with rice cv. Giza 172 that grain yield ranged from 1470 to 1570 g m^{-2} when rice was grown at 55 hills m^{-2} and supplied with 15 or 20 g N m^{-2} or at 33 hills m^{-2} and supplied with 20 g N m^{-2}.

Lawal and Lawal (2002) conducted three field experiments during the rainy seasons of 1996, 1997 and 1998 in Nigeria to evaluate the growth and yield responses of lowland rice with 4 levels (0, 40, 60, and 80 kg N ha^{-1}). They concluded that grain yield increased significantly up to 80 kg N ha^{-1} and thousand grain weight (1000-grain) increased significantly up to 120 kg ha^{-1}.

Thakur (1993) showed that there was an increasing trend of 1000-grains weight with an increase level of N up to 80 kg ha^{-1}.

Munnujan *et al.* (2001) reported that the highest grain yield (3.8 t ha^{-1}) was obtained at 180 kg N ha^{-1}, which was similar to the yield obtained at 80 kg N ha^{-1} (3.81 t ha^{-1}).

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

Kim *et al.* (1999) stated that increases in tiller and panicle numbers were greater from increased N rate than higher plant density. Ripened grain ratio was slightly lower from dense planting. In brown rice 1000-grain weight was not significantly affected by treatment. Milled rice yield was highest from 165 kg N with standard planting for heavy panicle type rice, while yield for much panicle type rice was highest with 165 kg N and high density.

Sarker *el al.* (2001) evaluate the N responses of Japonica (Yumelvitachi) and an indica (Takanari) rice variety with different N levels viz. 0, 40, 80 and 120 kg N ha^{-1}. They observed that application of N increased grain and straw yields significantly but harvest index was not significantly increased.

Castro and Sarker (2000) reported that the effect of N application as basal (80, 60 and 45 kg ha^{-1}) and top dressing (10, 30 and 45 kg ha^{-1}) on the yield and yield components of Japonica rice and obtained high effective tillers, percentage of ripened grains and high grain yields from 45 kg N ha^{-1} (basal) and 45 kg N ha^{-1} (top dressing).

Chopra and Chopra (2000) found that row spacing did not influence on yield components but seed and straw yields increased linearly up to 80 kg N ha^{-1} and there after a marginal reduction in seed yield was observed at 120 kg ha^{-1}.

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 ha^{-1} gave the maximum grain yield (2647 kg ha^{-1}).

Chopra and Chopra (2000) reported that the application of N at the rate of 80 or 120 kg N ha^{-1} improved all the yield attributes compared with control treatment.

Neelam and Nisha (2000) stated that significant linear increase in seed yield was recorded up to 80 kg N ha^{-1} and thereafter a marginal reduction in seed yield was observed at 120 kg N ha^{-1}. Straw yield increased up to the highest level of N. They recommended 98.5 kg N ha^{-1}.

Sahrawat e*t al.* (1999) reported that N level significantly affected the straw yield.

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

Singh *et al.* (1997) concluded that grain yield increased with up to 60 kg N ha^{-1} and was the highest at the sowing rate of 80 kg seed ha^{-1}.

Spanu and Pruneddu (1997) reported that rice yield increased with increasing N rates, ranging from 5.4 t ha^{-1} to 10.3 t ha^{-1}.

Singh *et al.* (1998) reported that rice cv. Pusa Basmati 1 and Kasturi grown in 2 seasons and found that Pusa Basmati was significantly superior for panicles $hill^{-1}$, rachille $panicle^{-1}$, weight of panicle, grains $panicle^{-1}$ and gave 0.16 t ha^{-1} grain yield than that of Kasuri (3.31 t ha^{-1}). They found significantly linear increase in grain yield up to 100 kg N ha^{-1} beyond which the yields of both the varieties declined, and applying 100 kg N ha^{-1} gave 1.55, 0.25, 0.65 t ha^{-1} grain yields than those of 0, 50 and 150 kg N ha^{-1} respectively.

Maske *et al.* (1997) stated that plant height increased significantly with increased N level.

Chander and Pandey (1996) cited that application of 120 kg ha^{-1} resulted in significant increase in effective tiller m^{-2} compared to 60 kg N ha^{-1}. BINA (1996) reported that the highest number of total and effective tillers was obtained from 120 kg ha^{-1} of N application. And they also stated that a significant increase in grains $panicle^{-1}$, tillers m^{-2}, and grain yield was obtained from application of 120kg N ha^{-1} compared to 60 kg N ha^{-1}.

Chander and Pandey (1996) noted that application of 120 kg N ha^{-1} gave significantly increased in grain yield compared with 60 kg N ha^{-1}.

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

Dahattonde (1992*)* concluded that N fertilizer significantly enhanced the plant height.

Hussain and Sharma (1991) reported that application of nitrogen up to 140 kg ha^{-1} increased plant height. At 80 kg and 120 kg N ha^{-1} the variation in plant height was non significant. The highest plant height was obtained from 120 kg N ha^{-1} and lowest one from the control.

Ali (1994) observed that weight of 1000-grains was higher when 100 kg N ha^{-1} was applied in three equal installments at basal, 30 days after transplanting.

Singh and Pillai (1994) reported that increased doses of nitrogen increased grain yield significantly upto 90 kg N ha^{-1}, thereafter declined. Srivastava and Solanki (1993) in field trials with rice cultivar Kranti giving 0-150 kg N ha^{-1} found that grain yield and net returns increased with increasing N application.

Dahattonde (1992) reported from a field trial on four rice cultivars with nitrogen applied from 0-120 kg N ha^{-1} and yield increased up to 100 kg N ha^{-1}.

Hussain and Sharma (1991) reported that application of nitrogen increased grain number $panicle^{-1}$ up to 80 kg ha^{-1}. Nitrogen application at the rate of 120 kg ha^{-1} did not significantly affect the grains $panicle^{-1}$. The highest number of grains $panicle^{-1}$ was produced by 80 kg N ha^{-1} and the lowest was produced by the control treatment.

Thakur (1991) observed that there was an increasing trend of 1000-grain weight with an increase in levels of nitrogen upto 80 kg ha^{-1}. Similar result was also reported by Thakur (1993).

Islam *et al.* (1990) noted that there was an increasing trend of 1000-grain weight with an increase in levels of nitrogen up to 80 kg ha^{-1}.

Idris and Matin (1990) observed that the grain yield increased gradually with an increase in N and was the maximum at 120 kg N ha^{-1}.

BRRI (1990) reported that the application of N fertilizer in transplant aman rice at doses of 30, 60, 90 and 120 kg N ha^{-1} gave the grain yield of 3.48, 4.41, 4.82 and 4.63 t ha^{-1}, respectively.

Bhuiyan *et al.* (1990) reported that taller plants were produced by higher amount of nitrogen applications.

Biswas and Bhattacharya (1989) observed that increasing nitrogen rates from 0 to 100 kg ha^{-1} increased the rice yield from 0.5 to 5.0 t ha^{-1} in wet season and from 2.7 to 3.7 t ha^{-1} in dry season. Further increase in N up to 150 kg ha^{-1}

did not produce significant variation in rice yield.

The experimental results indicate that higher N application (150 kg ha^{-1}) is required to achieve higher grain yields in hybrid rice (Singh *et al.,* 1998).

Wang and Thorat (1988) reported from an experiment with rice cv.R-24 grown under different hill spacings and N rates that N application significantly increased the tiller number over all hill spacings.

Nitrogen application from 0 to 120 kg ha^{-1} in three split dressings increased number of tillers $hill^{-1}$ (Reddy *et al.,* 1986).

Kamal *et al.* (1988) observed that the highest rate of nitrogen fertilizer have maximum tillers $hill^{-1}$, which was significantly greater than any of other treatments.

Kehinde and Fagande (1987) reported that higher N level did not increase yield significantly compared to lower level. Both the level increased yield compared to the control.

Reddy *et al.* (1986) observed that application of 30, 60 and 90 kg N ha^{-1} to rice produced paddy yields of 2.89, 3.77 and 4.39 t ha^{-1}, respectively.

Maskina and Singh (1987) studied the performances of three rice cultivars giving 90, 120 or 150 kg N ha^{-1} and noted that yield and yield components of all the cultivars increased upto 150 kg N ha^{-1} and noted that yield and yield components of all the cultivars increased up to 150 kg N ha^{-1}.

Mondal *et al.* (1987) stated that increasing rate of N from 40 to 160 kg ha^{-1} increased the number of productive tiller $hill^{-1}$. The plant height, number of productive tillers $hill^{-1}$ and grain yield increased with increasing nitrogen application and were found the highest with 120 kg N ha^{-1}.

Kumar *et al.* (1988) repoted that increasing rates of N from 0 to 80 kg ha^{-1} increased yields to 3.94 and 4.7 t ha^{-1} respectively.Increased dose of N from 0 to 80 kg ha^{-1} incresed the no of tillers $hill^{-1}$,number of grains $panicle^{-1}$ and weight of 1000-grain in rice. Grain and straw yields increased from 6.99 to 8.26 and 8.91 to 11.14 t ha^{-1}, respectively.

2.2 Effect of level of sulphur on growth, yield and quality of rice

Mandal *et al.* (2000) carried out a greenhouse experiment to evaluate the effect of N and S fertilizer on nutrient content of rice grain (BRRI dhan 28) at various growth stages (tillering, flowering and harvesting). Nitrogen was applied as urea and S as gypsum at 0, 5, 10 and 20 kg S ha^{-1}. The combined application of these elements increased the straw and grain yield of rice significantly.

Sakal *et al. (2001)* conducted field experiments to determine the direct effect of soil (Ustifluvents) applied with Sulphur (S) on succeeding wheat and rice crops. Sulphur was applied at 0, 15, 30 and 45 kg S ha^{-1} as single super phosphate containing 12% S. A basal dose of 110 kg N, 60 kg P_2O_5 and 5 kg Zn ha^{-1} was applied as urea, DAP (diammonium phosphate), MOP (muriate of potash) and ZnO, respectively. The remaining amount of P_2O_5 in 15 and 30 kg S ha^{-1} treatments were balanced through DAP. After the first rice crop harvest, 3 more crops (wheat, rice and wheat) were grown in succession without S application to determine the residual effect of S on these 3 crops. Rice leaf sample analysis exhibited higher magnitude of S deficiency than wheat leaf samples. Magnitude of S deficiency based on soil analysis was on an average 25% while the extent of S deficiency based on plant analysis was 58%. Total S in soil was positively and significantly correlated with pH, electrical conductivity, and organic carbon, available P_2O_5 and K_2O, whereas soil available S was positively and significantly correlated with total S. Direct effect of S produced the maximum grain yield of rice (14.3 q ha^{-1} at 45 kg S ha^{-1}). The residual response of 45 kg S ha^{-1} in the second wheat crop, third rice crop, and fourth wheat crop was 14.8, 5.2, and 7.5 q ha^{-1} respectively. Sulphur intake by crops increased progressively with increasing levels of sulphur.

Raju and Reddy (2001) conducted field investigations to study the response of both hybrid and conventional rice to sulphur (at 20 kg ha^{-1}) and zinc (at 10 kg ha^{-1}) applications. Conventional rice, MTU 2067 out yielded the hybrid rice MUT-HR 2003 by 21%. Significant improvement in grain yield was observed due to sulphur application. Zinc application failed to improve the yield markedly.

Vaiyapuri and Sriramachandrasekharan (2001) conducted an experiment on integrated use of green manure (12.5 t ha^{-1}) with graded levels of sulphur (0, 20 and 40 kg ha^{-1}) applied through three different sources in rice cv. ADT 37. It appeared that the maximum nutrient uptake (115.5, 27.6, 220.2 and 24.8 kg ha^{-1} for N, P, K and S, respectively), rice yield (5.07 t kg ha^{-1}) and soil available nutrients (199.5, 13.4, 299.1, 22.8 kg ha^{-1} for N, P, K and S, respectively) were noticed with 40 kg ha^{-1}. Among the sources, iron pyrite recorded the maximum uptake (111.6, 26.2, 215.4, 22.7 kg ha^{-1} for N. P, K and S respectively) and rice yield (4.97 t ha^{-1}). However, the highest nutrient uptake (127.7, 28.5, 234.8, 25.5 kg ha^{-1} for N, P, K and S , respectively and rice yield 5.3 t ha^{-1}) was obtained when green manure was applied along with pyrite at 20 kg S ha^{-1} which was comparable with pyrite applied at 40 kg ha^{-1} in the absence of green manure.

Peng *et al.* (2002) carried out a field experiment where the average content of available S in these soil samples was 21.7 mg kg^{-1}. The soil with available S content was lower than the critical value of 16 mg kg^{-1} accounted for 57.8%. Field experiments showed that there was a different yield-increasing efficiency by applying S at the doses of 20-60 kg ha^{-1} to rice plant.

Babu *et al.* (2001) carried out field studies and stated that the direct effect of sulphur through single super phosphate on hybrid rice resulted in a significant increase of 21% in grain yield with an S use efficiency of 13 kg grain kg^{-1} at 45 kg S ha^{-1}.

Chandel *et al.* (2003) conducted an experiment to study the effect of S applied to rice and mustard grown in sequence on the growth and yield of rice .They stated that increasing S levels in rice significantly improved growth attributes i.e. tiller number, leaf number and dry matter production; yield trait such as harvest index of rice up to 45 kg ha^{-1}.

Sen *et al.* (2002) carried out an extensive study on application of sulphur through single super phosphate in a sulphur deficient area of Murshidabad district, in India, in a rice-mustard cropping sequence. Significant yield increase in rice with application of sulphur at 30 kg ha^{-1} and its residual effect on mustard was observed. Sulphur application not only helped to increase yield in both crops but also helped to control the movement and distribution of different cationic micronutrients in both the crops.

Singh and Singh (2002) carried out a field experiment to see the effect of different nitrogen levels (50, 100 and 150 kg ha^{-1}) and S levels (0, 20 and 40 kg ha^{-1}) on rice cv. Swarna and PR-108 in Varanasi, Uttar Pradesh. India. They reported that plant height, tillers m^{-2} row length, dry matter production, panicle length and grains $panicle^{-1}$ were significant with increasing levels of N and S up to 150 kg N ha^{-1} and 40 kg S ha^{-1} respectively. They also found that total N uptake, grain, straw and grain protein yields significantly improved with the increasing level of N and S application being the maximum at 150 kg N ha^{-1} and 40 kg S ha^{-1} respectively.

Biswas *et al.* (2004) reported the effect of S in different region of India. The optimum S rate varied between 30-45 kg ha^{-1}. Rice yields increased from 5 to 51 %. Across the crops and regions the agronomic efficiency varied from 2 to 27 %.

Huda *et al.* (2004) conducted an experiment at the Soil Science Department of Bangladesh Agricultural University, Mymensingh, Bangladesh to evaluate the suitable extractants for available sulphur and critical limits of sulphur for wetland rice soils of Bangladesh. Twenty-two soils from 0-15 cm depth were collected from different locations of Old Brahmaputra Flood plains of the country. Both Geographical and statistical methods were used to determine the critical levels of S. The critical limit for S was found to be 0.12% at 56 days of crop growth.

Mrinal and Sharma (2008) conducted a field trials during the rainy (kharif) season of 2002 and 2003 to study the relative efficiency of different sources (gypsum, elemental sulfur and cosavet) and varying levels of sulfur (0, 10, 20, 30 and 40 kg S ha^{-1}) in rice. The growth and yield attributing characters of rice increased with the sulfur application. The grain and straw yields of rice increased significantly with increasing levels of sulfur up to 30 kg S ha^{-1}. The difference between sulfur sources was generally not significant.

Oo *et al.* (2007) a field experiment was conducted during the rainy season of 2003 at the research farm of the Indian Agricultural Research Institute, New Delhi to study the effect of N and S levels on the productivity and nutrient uptake of aromatic rice. And concluded that aromatic rice requires 100 kg N ha^{-1} and 20 kg S ha^{-1} for increased productivity and uptake of N, P, K and S under transplanted puddled conditions. Treatments comprised: 4 N levels (0, 50, 100 and 150 kg ha^{-1}) and 4 S levels (0, 20, 40 and 60 kg ha^{-1}).

Basumatary and Talukdar (2007) conducted a field experiment during 2002-04 at the University, Jorhat, Assam, India to find out the direct effect of sulfur alone and in combination with graded doses of farmyard manure on rapeseed (*Brassica napus* var. *oleifera*) and its residual effects on rice with respect to yield, uptake and protein content. The N: S ratio in both crops progressively decreased with increasing sulfur levels up to 45 kg ha^{-1}. The lowest N: S ratio was observed upon treatment with 45 kg S ha^{-1} along with 3.0 tonnes farmyard manure ha^{-1}.

Nad *et al.* (2001) observed that ammonium sulfate and gypsum, as compared to pyrite or elemental sulfur, maintained adequate N to S ratio in rice, resulting in a reduction in the percent of unfilled grain, a major consideration in rice yield.

Sakal *et al.* (2001) carried out field experiments in 4 villages selected in Saharsa district in Bihar, India to determine the direct effect of soil (Ustifluvents) applied with sulfur (S) on succeeding wheat and rice crops. Sulfur was applied at 0, 15, 30 and 45 kg S ha^{-1} single superphosphate containing 12% S, and rice cv. Rajshree was grown as a test crop. The residual response of 45 kg S ha^{-1} in the second wheat crop, third rice crop and fourth wheat crop was 14.8, 5.2 and 7.5 q ha^{-1}, respectively. Sulfur intake by crops progressively increased with increasing levels of sulfur.

Chandel *et al.* (2003) conducted a field experiment to investigate the effect of sulfur nutrition on the growth and S content of rice and mustard grown in sequence with 4 S levels (0, 15, 30 and 45 kg ha^{-1}). Increasing S levels applied to rice significantly improved leaf area index, tiller number, dry matter production, harvest index and S content in rice up to 45 kg S ha^{-1} and its residual effect on leaf area index, dry matter production, harvest index and S content in mustard was also significant up to 45 kg S ha^{-1}.

Hassan *et al.* (2005) conducted a hydroponic experiment to investigate the effect of sulfur (S) on growth inhibition and oxidative stress caused by Cd^{2+} toxicity, using two rice cultivars with different grain Cd^{2+} content. Treatments consisted of factorial arrangement of three S levels (0.2, 0.4, and 0.8 mmol), two cadmium (Cd) levels (0 and 1 micro mol), and two rice cultivars ('Bing 97252,' a cultivar with low grain Cd^{2+} content, and 'Xiushui 63,' a cultivar with high grain Cd^{2+} content). The results showed that Cd^{2+} addition in the medium generally increased Cd^{2+} and malondialdehyde (MDA) content in both roots and shoots; the increases were more pronounced in 'Xuishui 63' than in

'Bing 97252.' Dramatic reductions in growth parameters, including plant height, root and shoot weight, tillers per plant, chlorophyll content, and net photosynthetic rate were found in the plants exposed to Cd stress relative to the plants without Cd^{2+} treatment. High Cd^{2+} and MDA content was consistently accompanied by higher SOD activity and higher S levels caused a marked increase in glutathione content and a reduction in SOD activity, indicating a positive effect of S in alleviating oxidative stress.

Xue *et al.* (2002) showed that rice yield increases due to S application ranged from 0.5 to 22.9% (average of 7.3%) or from 12 to 1135 kg hm^{-2} (average of 386 kg hm^{-2}). S at 15-30 kg hm^{-2} was optimum for rice production.

Bhuvaneswari *et al.* (2007) conducted a field experiments during the 2001 kharif season, to study the effect of sulfur (S) at varying rates, i.e. 0, 20, 40 and 60 kg ha^{-1}, with different organics, i.e. green manure, farmyard manure, sulfitation press mud and lignite fly ash, each applied at 12.5 t ha^{-1}, on yield, S use efficiency and S optimization of rice cv. ADT 43. The results revealed that rice responded significantly to the application of S and organics compared to the control. The highest grain (5065 kg ha^{-1}) and straw yields (7524 kg ha^{-1}) was obtained with 40 kg S ha^{-1}.

Yasmin *et al.* (2007) cited that rice crops throughout the world are becoming increasingly affected by sulfur (S) deficiency as the use of S-free fertilizers increases. Sulfur additions, as coatings, to fertilizers such as urea (U), di-ammonium phosphate (DAP), mono-ammonium phosphate (MAP), and triple superphosphate (TSP) offer a way to introduce S back into these fertilizers. Five S sources (elemental sulfur (ES), sulfur coated urea (SU), sulfur coated DAP (SDAP), sulfur coated TSP (STSP), gypsum, and a-S control), were applied to rice under two water regimes (flooded and non-flooded) and with two placements (surface and deep application). The treatments were combined as surface non-flooded (SNF), surface flooded (SF), and deep flooded (DF). Sulfur was applied at the rate of 10 kg ha^{-1} to 35S labelled soil. At maturity of the grain, straw, and roots were analysed for total S and 35S. Sulfur application increased grain yield and all sources were equally effective under all three conditions (SNF, SF and DF), except gypsum, which was not different from the control under SF and DF conditions. Total S content and fertilizer S content in the grain and straw were not different between S sources.

Alamdari *et al.* (2007) conducted a field experiments to study the effect of sulfur (S) and sulfate fertilizers on zinc (Zn) and copper (Cu) by rice. The maximum Cu content in the leaves was attained when N, P, K, S and Cu sulfate were applied compared to the control. But, both Zn and Cu contents in the grain increased when N, P, K, S and Zn, Cu and Mn sulfate were applied together.

Islam *et al.* (2006) an experiment was conducted in Bangladesh to evaluate the effect of gypsum (100 kg ha^{-1}) applied before planting, and at 30 and 60 days after planting, on the nutrient content of transplanted Aus rice (BR-2) in the presence of basal doses of N, P, K fertilizers from May to September 1996. A control without gypsum application was included. Application of gypsum at different dates increased progressively all the nutrients such as N, P, K, S, Ca and Mg, whereas the Na content was found to decreased due to gypsum application. The highest increase of N, P, K, S, Ca and Mg was obtained when the gypsum was applied at 30 days after planting. Synthesis of protein was accelerated with all the treatments of gypsum, and the content was much higher due to application of gypsum at 30 days after planting.

Chapter 3

Materials and Methods

CHAPTER 3
MATERIALS AND METHODS

This chapter highlights the experimental work. The experiment was conducted at Sher-e-Bangla Agricultural University (SAU) Farm, Sher-e-Bangla Nagar, Dhaka with four doses of nitrogenous fertilizer and three doses of sulphur fertilizer. A brief description about the experimental site and season, 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 are presented in this section.

3.1 Experimental site and soil

The experiment was conducted in typical rice growing silt loam soil at the Sher-e-Bangla Agricultural University Farm, Dhaka during the *Boro* season of 2007-2008. The morphological, physical and chemical characteristics of the soil are shown in the Tables 1 and 2.

3.2 Climate

The climate of the experimental area is characterized by high temperature, high humidity and medium rainfall with occasional gusty winds during the *kharif* season (March-September) and a scanty rainfall associated with moderately low temperature in the *rabi* season (October-February). The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season December 2007 to April 2008 have been presented in Appendix II.

Table 1. Morphological characteristics of the experimental field

Morphology	Characteristics
Location	SAU Farm, Dhaka.
Agro-ecological zone	Madhupur Tract (AEZ 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur clay
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

(FAO and UNDP, 1988)

Table 2. Initial physical and chemical characteristics of the soil

Characteristics	Value
Mechanical fractions:	
% Sand (0.2-0.02 mm)	22.53
% Silt (0.02-0.002 mm)	56.72
% Clay (<0.002 mm)	20.75
Textural class	Silt Loam
Consistency	Granular and friable when dry.
pH (1: 2.5 soil- water)	5.8
CEC (cmol kg^{-1})	17.9
Organic C (%)	0.686
Organic Matter (%)	1.187
Total N (%)	0.08
Exchangeable K (cmol kg^{-1})	0.12
Available P (mg kg^{-1})	19.85
Available S (mg kg^{-1})	14.40

3.3 Planting material

BRRI dhan 28 was used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute from the cross between BG 90-2 and BR51-46-5 in 1994. It is recommended for *Boro* season. Average plant height of the variety is 90-95 cm at the ripening stage. The grains are medium fine and white. It requires about 155-160 days completing its life cycle with an average grain yield of 5.0-5.5 t ha^{-1} (BRRI, 2004).

3.4 Land preparation

The land was first opened on 24 November, 2007 by a tractor and prepared thoroughly by ploughing and cross ploughing with a power tiller followed by country plough. Laddering helped breaking the clods and leveling the land followed every ploughing. Before transplanting each unit of plot was cleaned by removing the weeds, stubbles and crop residues. Finally each plot was prepared by puddling.

3.5 Experimental design and layout

The experiment was laid out in a randomized complete block design (RCBD), where the experimental area was divided into four blocks representing the replications to reduce soil heterogenetic effects. Each block was divided into twelve unit plots as treatments with raised bunds around. Thus the total number of unit plot size was 2.2 m × 1.2 m and ailes separated plots from each other. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively.

3.6 Initial soil sampling

Before land preparation, initial soil samples at 0-15 cm depth were collected from different spots of the experimental field. The composite soil sample were air-dried, crushed and passed through a 2 mm (8 meshes) sieve. After sieving, the soil samples were kept in a plastic container for physical and chemical analysis of the soil.

3.7 Treatments: Two factorial RCBD.

Two different types of inorganic fertilizer (Nitrogen and Sulphur) will be used in the study. Viz.

A. Nitrogen level (4)

a) 0 kg N ha^{-1} (N_o)

b) 120 kg N ha^{-1} (N_1)

c) 140 kg N ha^{-1} (N_2)

d) 160 kg N ha^{-1} (N_3)

B. Sulphur level (3)

a. 0 kg S ha^{-1} (S_o)

b. 20 kg S ha^{-1} (S_1)

c. 30 kg S ha^{-1} (S_2)

The experiment consisted of 12 treatments combination. The treatments combinations are as follows:

I. N_oS_o = 0 kg N ha^{-1} + 0 kg S ha^{-1}

II. N_oS_1 = 0 kg N ha^{-1} + 20 kg S ha^{-1}

III. $N_o S_2$ = 0 kg N ha^{-1} + 30 kg S ha^{-1}

IV. N_1S_o = 120 kg N ha^{-1} + 0 kg S ha^{-1}

V. $N_1 S_1$ = 120 kg N ha^{-1} + 20 kg S ha^{-1}

VI. $N_1 S_2$ = 120 kg N ha^{-1} + 30 kg S ha^{-1}

VII. N_2S_o = 140 kg N ha^{-1} + 0 kg S ha^{-1}

VIII. $N_2 S_1$ = 140 kg N ha^{-1} + 20 kg S ha^{-1}

IX. $N_2 S_2$ = 140 kg N ha^{-1} + 30 kg S ha^{-1}

X. N_3S_o = 160 kg N ha^{-1} + 0 kg S ha^{-1}

XI. $N_3 S_1$ = 160 kg N ha^{-1} + 20 kg S ha^{-1}

XII. $N_3 S_2$ = 160 kg N ha^{-1} + 30 kg S ha^{-1}

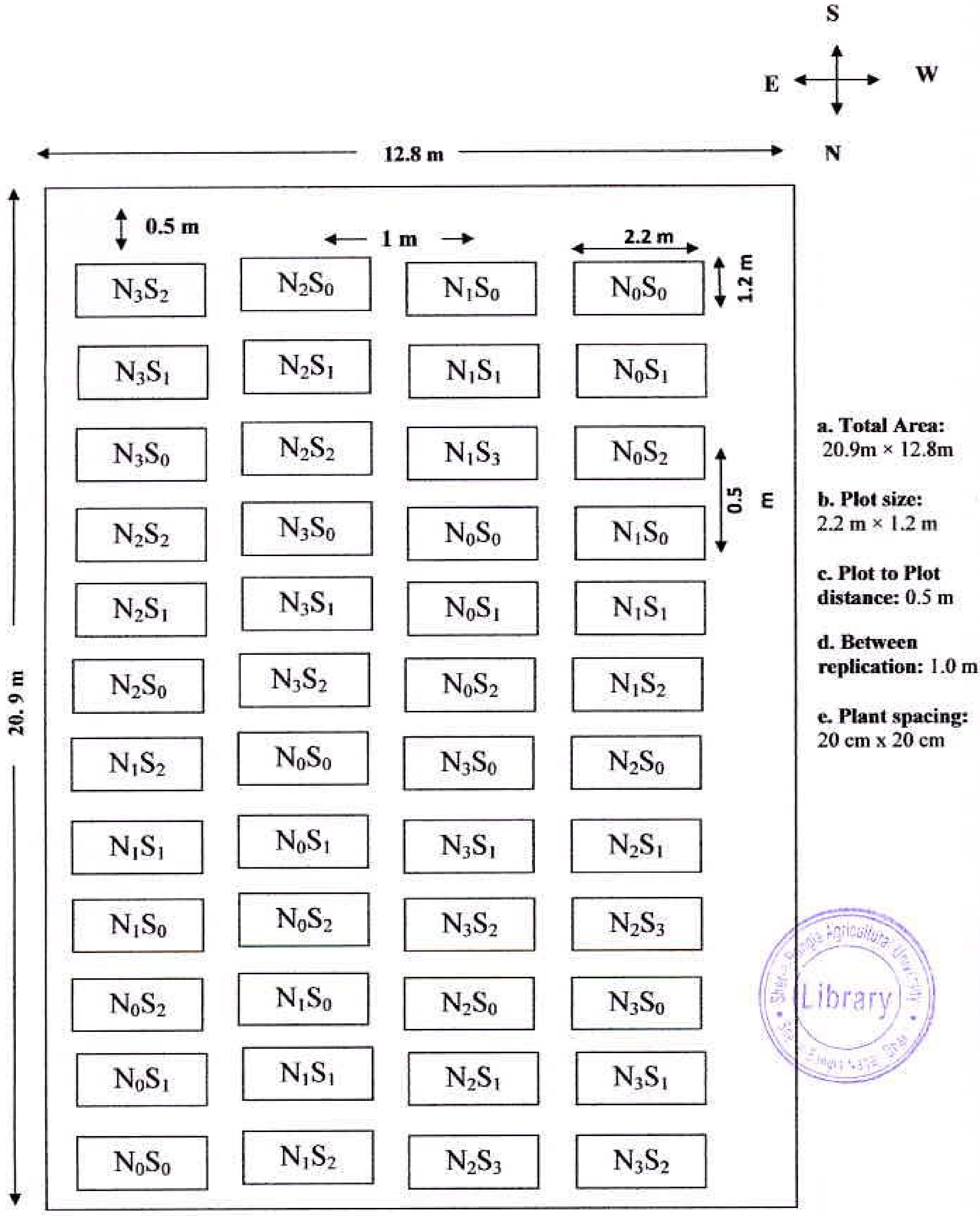

Figure 1. Layout of the experimental field

3.8 Fertilizer application

Full amounts of TSP (125 kg ha^{-1}), MP (120 kg ha^{-1}) and gypsum were applied as basal before transplanting of rice seedlings. Urea was applied in 3 equal splits: one third was applied at 10 days after transplanting, one third at active tillering stage (30-35 DAT) and the remaining one third was applied at 5-7 days before panicle initiation stage (55-60 DAT).

3.9 Raising of seedlings

The seedlings of rice were raised wet-bed methods. Seeds (95% germination) @ 5 kg/ha were soaked and incubated for 48 hour and sown on a well-prepared seedbed. During seedling growing, no fertilizers were used. Proper water and pest management practices were followed.

3.10 Transplanting

Forty days old seedlings of BRRI dhan 28 were carefully uprooted from the seedling nursery and transplanted on 1 January, 2008 in well puddled plot. Two seedlings per hill were used following a spacing of 20 cm × 20 cm. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings.

3.11 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.11.1 Irrigation

Necessary irrigations were provided to the plots as and when required during the growing period of rice crop.

3.11.2 Weeding

The plots were infested with some common weeds, which were removed by uprooting them from the field three times during the period of the cropping season.

3.11.3 Insect and pest control

There was no infestation of diseases in the field but leaf roller (*Chaphalocrosis medinalis*, Pyralidae, Lepidoptera) was observed in the field and used Malathion @ 1.12 L ha^{-1}.

3.12 Crop harvest

The crop was harvested at full maturity when 80-90% of the grains were turned into straw colored on 26 April, 2008. The crop was cut at the ground level and plot wise crop was bundled separately and brought to the threshing floor.

3.13 Yield components

3.13.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of harvesting stage. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle.

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

The number of tillers $hill^{-1}$ was recorded at the time of harvesting stage. Data were recorded as the average of 10 hills selected at random from the inner rows of each plot.

3.13.3 Effective tillers $hill^{-1}$

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

3.13.4 Non-effective tillers $hill^{-1}$

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

3.13.5 Total tiller hill^{-1}

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

3.13.6 Length of panicle

The length of panicle was measured with a meter scale from 10 selected plants and the average value was recorded as per plant.

3.13.7 Filled grains panicle^{-1}

The total numbers of filled grains was collected randomly from selected 10 plants of a plot on the basis of grain in the spikelet and then average numbers of filled grain per panicle was recorded.

3.13.8 Sterile grains per panicle^{-1}

The total numbers of sterile grains was collected randomly from selected 10 plants of a plot on the basis of not grain in the spikelet and then average numbers of sterile grains panicle^{-1} was recorded.

3.13.9 Total grains panicle^{-1}

The total numbers of grain was collected randomly from selected 10 plants of a plot by adding filled and unfilled grains and then average numbers of grain panicle^{-1} was recorded.

3.13.10 Weight of 1000 grain

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

3.13.11 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The grain dry weight of 1 m^2 plot was recorded for the final grain yield plot^{-1} and finally converted to t ha^{-1}.

3.13.12 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The straw dry weight of 1 m^2 plot was recorded for the final straw yield $plot^{-1}$ and finally converted to t ha^{-1}.

3.14 Chemical analysis of plant samples

3.14.1 Preparation of plant samples

The plant samples were dried in an oven at 70 ^{0}C for 72 hours and then ground by a grinding machine to pass through a 20-mesh sieve. The grain and straw samples were analyzed for determination of N, P, K and S concentrations. The methods were as follows:

3.14.2 Digestion of plant samples with sulphuric acid for N

For the determination of nitrogen an amount of 0.2 g oven dry, ground sample was taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 5 ml conc. H_2SO_4 were added. The flasks were heated at 120^0C and added 2.5 ml 30% H_2O_2 then heating was continued at 200^0C until the digests became clear and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

3.14.3 Digestion of plant samples with nitric-perchloric acid for P, K and S

A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten (10) ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^0C. Heating was stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask was boiled until the digest became clean and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. The concentration of P, K and S were determined from this digest.

3.14.4 Determination of P, K and S from plant samples

3.14.4.1 Phosphorus

Plant sample (grain and straw) was digested with nitric percholoric acid solution. Phosphorus in the digest was determined by using 1 ml for grain sample and 2 ml for straw sample from 100 ml extract by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*, 1982).

3.14.4.2 Potassium

Five milli-liter of digest sample for the grain and 10 ml for the straw were taken and diluted 50 ml volume to make desired concentration so that the absorbance of samples were measured within the range of standard solutions. The absorbances were measured by flame photometer.

3.14.4.3 Sulphur

Sulphur content was determined from the digest of the plant samples (grain and straw) with $CaCl_2$ (0.15%) solution as described by Page *et al.* 1982. The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelength (Hunter, 1984).

3.15 Nutrient Uptake

After chemical analysis of straw and grain samples, the nutrient contents were calculated and nutrient uptakes were also calculated by following formula:

Nutrient uptake (Kg ha^{-1}) = Nutrient content (%) × Yield (kg ha^{-1}) / 100

3.16 Post harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil sample of each plot were air-dried, crushed and passed through a two mm (8 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.17 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. organic matter, pH, total N and available P, K, and S contents. These results have been shown in the Tables (15-17). The soil samples were analyzed by the following standard methods as follows:

3.17.1 Textural class

Mechanical analysis of soil were done by hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values of % sand, % silt and % clay to the Marshall's triangular co-ordinate following the USDA system.

3.17.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 (Jackson, 1962).

3.17.3 Organic matter

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1935). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al*, 1982).

3.17.4 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated 200 ^{0}C and added 3 ml H_2O_2 and then heating at 360 ^{0}C was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al*, 1982).

Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water.

Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100 / S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

1 ml N $H_2SO_4 \equiv 0.014$ g N

3.17.5 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated the standard P curve (Page *et al*, 1982).

3.17.6 Exchangeable potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al*, 1982).

3.17.7 Available sulphur

Available S content was determined by extracting the soil with $CaCl_2$ (0.15%) solution as described by (Page *et al*, 1982). The extractable S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wave length.

3.18 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on yield and yield contributing characters of BRRI dhan29. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents the experimental results along with their possible interaction and discussion in relation to determine the effect of different levels of nitrogen and sulphur on the yield, yield contributing characters and nutrient contents of boro rice cv. BRRI dhan 28. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Effects of nitrogen on yield and yield contributing characters

Effects of nitrogen on different crop characters of transplant Boro rice cv BRRI dhan 28 and it have been shown in Table (3 and 4).

4.1.1 Plant height

Plant height was significantly affected by nitrogen levels (Table 3). The plant height was increased with increasing N levels upto N_3 (160 kg N ha^{-1}) level. At maturity, the tallest plant (87.4 cm) was produced in N_2 (140 kg N ha^{-1}) treatment which was identical (87.0 cm and 86.6 cm) with N_3 (160 kg N ha^{-1}) and N_1 (120 kg N ha^{-1}) treatments. The shortest one (82.1cm) was obtained from N_0 (0 kg N ha^{-1}) treatment (Table 3). The results also revealed that taller plants were obtained in all plots fertilized with nitrogen compared to without nitrogen treated plots. Higher levels of nitrogen have positive effect on growth and development in rice. Similar results were also reported by Kumar *et al.* (1995) and Sahrawat *et al.* (1999).

4.1.2 Effective tillers $hill^{-1}$

Level of nitrogen significantly influenced the number of effective tillers $hill^{-1}$ (Table 3). The highest number of effective tillers $hill^{-1}$ (11.7) was recorded in 160 kg N ha^{-1} application followed by 10.7 in 140 kg N ha^{-1}, 9.1 in 120 N ha^{-1}. The lowest number of effective tillers $hill^{-1}$ (6.5) was produced in N_0 (0 kg N ha^{-1}) treatment. Mondal *et al.* (1987) also found similar result.

4.1.3 Non-effective tillers hill^{-1}

Non-effective tillers hill^{-1} was significantly affected by nitrogen treatments. The highest number of non-effective tillers hill^{-1} (3.6) was observed in N_0 (0 kg N ha^{-1}) and the lowest number of non-effective tillers hill^{-1} (2.1) was found in N_3 (160 kg N ha^{-1}) treatments (Table 3).

4.1.4 Length of panicle

The longest panicle length (22.2 cm) was produced with N_1 (120 kg N ha^{-1}) treatment (Table 3), which was statistically identical (22.1 cm) with N_0 (0 kg N ha^{-1}) and N_3 (160 kg N ha^{-1}) treatment and the shortest one was recorded with N_2 (140 kg N ha^{-1}) treatments. Kim *et al.* (1999) reported that application of nitrogen affects the length of panicle.

4.1.5 No. of filled grains panicle^{-1}

Number of filled grains panicle^{-1} varied significantly due to nitrogen levels. Number of grains panicle^{-1} progressively increased with the increasing nitrogen level upto N_3 (160 kg N ha^{-1}) treatment. The highest number (102.8) of filled grains panicle^{-1} was produced in N_3 (160 kg N ha^{-1}) treatment and the lowest number (67.0) was produced from N_0 (0 kg N ha^{-1}) treatment (Table 3). Mondal and Chaterjee, (1998) reported that the number of filled grains of rice increased with the increasing rates of N. Islam and Bhuiya (1997) found that N fertilizer significantly increased the number of filled grains panicle^{-1}.

4.1.6 Sterile grains panicle^{-1}

The effect of different levels of nitrogen on the number of sterile grains panicle^{-1} was statistically significant. Results presented in the Table 4 showed that N_0 (0 kg N ha^{-1}) treatment produced the highest number of sterile grains panicle^{-1} (19.5). The lowest number of sterile grains panicle^{-1} (13.0) was recorded with N_2 (140 kg N ha^{-1}) treatment. The results showed that the number of sterile grains panicle^{-1} gradually decreased with the increasing level of nitrogen upto N_3 (160 kg N ha^{-1}) level.

Table 3. Effect of nitrogen on yield parameters of Boro rice cv. BRRI dhan 28

Levels of nitrogen	Plant height (cm)	No. of effective tillers $hill^{-1}$	No. of non effective tillers $hill^{-1}$	Length of panicle (cm)	No. of filled grains $panicle^{-1}$
N_0 (0 kg N ha^{-1})	82.1b	6.5d	3.6a	21.5ab	67.0d
N_1 (120 kg N ha^{-1})	86.6a	9.1c	3.1b	22.2a	83.0c
N_2 (140 kg N ha^{-1})	87.4a	10.7b	2.9b	20.8b	90.9b
N_3 (160 kg N ha^{-1})	87.0a	11.7a	2.1c	22.1a	102.8a
$LSD_{0.05}$	3.266	0.634	0.388	0.752	3.731
Level of Significance	0.01	0.01	0.01	0.01	0.01
CV (%)	4.58	8.03	16.02	4.18	5.22

In a column means followed by same letter are not significantly different at 5% level by DMRT.

4.1.7 Weight of 1000-grain

1000-grain weight was not significantly affected by different doses of nitrogen (Table 4). However, 1000- grain weight from N_0 (0 kg N ha^{-1}) dose was 21.8 g which was numerically close to 21.7 g, 21.6 g and 21.5 g from N_2 (140 kg N ha^{-1}), N_1 (120 kg N ha^{-1}) , N_3(160 kg N ha^{-1}) doses, respectively. The non significant variation might be due to the fact that 1000-grain weight generally fixed by individual variety. But Islam *et al.* (1990) found that increasing level of N increases 1000 grain weight of rice.

4.1.8 Grain yield

Analysis of variance indicates significant differences among the nitrogen levels in respect of grain yield. Grain yield ranged from 5.1 t ha^{-1} in N_0 (0 kg N ha^{-1}) to 6.9 t ha^{-1} in N_3 (160 kg N ha^{-1}) treatment (Table 4). Grain yield increased with the increase in nitrogen level upto N_3 (160 kg N ha^{-1}) level. The highest grain yield (6.9 t ha^{-1}) was obtained from N_3 (160 kg N ha^{-1}) and the lowest one (5.1 t ha^{-1}) from N_0 (0 kg N ha^{-1}) doses (Fig. 2). Better performances of yield components such as number of bearing tillers $hill^{-1}$ and number of grains $panicle^{-1}$ in N_3 (160 kg N ha^{-1}) treatment ultimately contributed to higher grain yield of BRRI dhan 28. Kanda and Dixit (1996) reported that grain yield increased with increasing N application due to improvement in yield components.

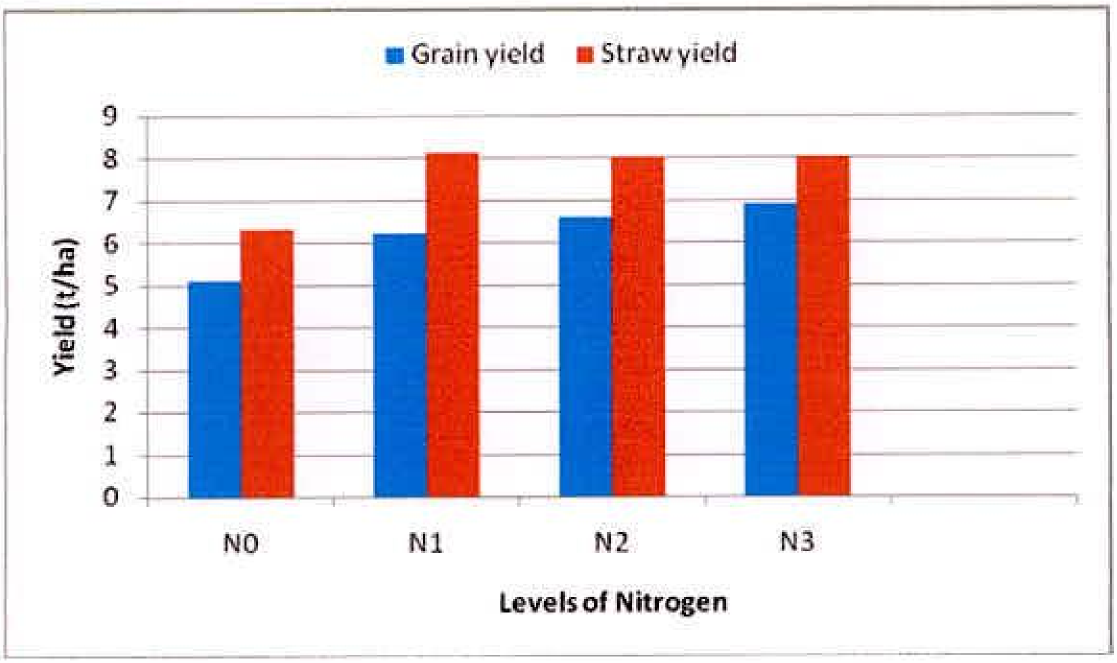

Figure 2. Effect of different levels of nitrogen on grain and straw yields of Boro rice cv. BRRI dhan 28

4.1.9 Straw yield

Straw yield was significantly increased by nitrogen levels. Straw yield was found to increase with increasing nitrogen levels (Fig. 2). The highest straw yield (8.1 t ha^{-1}) (Table 4) was produced at N_1 (120 kg N ha^{-1}) dose which was statistically identical (8.0) with N_3 (160 kg N ha^{-1}) dose (Table 4) while the lowest one (6.3 t ha^{-1}) was produced by the N_0 (0 kg N ha^{-1}) dose. Similar results on the effect of nitrogen level on straw yield were also reported by Singh *et al.* (2000).

Table 4. Effect of nitrogen on yield and yield parameters of Boro rice cv. BRRI dhan 28

Levels of nitrogen	No. of sterile grains panicle^{-1}	1000-grain wt. (g)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
N_0(0 kg N ha^{-1})	19.5a	21.8	5.1d	6.3c
N_1(120 kg N ha^{-1})	16.7b	21.6	6.2c	8.1a
N_2(140 kg N ha^{-1})	13.0c	21.7	6.6b	8.0b
N_3(160 kg N ha^{-1})	13.1c	21.5	6.9a	8.0ab
LSD $_{0.05}$	1.169	–	0.079	0.087
Level of Significance	0.01	NS	0.01	0.01
CV (%)	9.04	3.17	1.57	1.38

In a column means followed by same letter are not significantly different at 5% level by DMRT.
NS =Non significant.

4.2 Effects of sulphur on yield and yield contributing characters

Effects of sulphur on different crop characters of transplant Boro rice cv BRRI dhan 28 have been shown in Table 5 and 6.

4.2.1 Plant height

Different levels of sulphur application had no-significant effect on plant height of BRRI dhan 28 at maturity. Numerically, the tallest plant (86.6 cm) and the shortest plant (84.3 cm) was obtained from S_0 (0 kg S ha^{-1}) and S_2 (30 kg S ha^{-1}) treatments respectively (Table 5). Similar results were reported by Oo *et al.* (2007).

4.2.2 Effective tillers $hill^{-1}$

The highest number of effective tillers $hill^{-1}$ (11.9) was obtained from S_2 (30 kg S ha^{-1}) level that differed significantly from other levels of sulphur and the lowest number of effective tillers $hill^{-1}$ (7. 6) was obtained with S_0 (0 kg S ha^{-1}) level. Chandel *et al.* (2003) found significantly increased tiller number with increasing S level in rice (Table 5).

4.2.3 Non-effective tillers $hill^{-1}$

The highest number of non- effective tillers $hill^{-1}$ (3.6) was obtained from S_0 (0 kg S ha^{-1}) and the lowest number of non-effective tillers $hill^{-1}$ (1.9) was found in S_2 (30 kg S ha^{-1}) level (Table 5). The number of non-effective tillers $hill^{-1}$ was found to increase negatively with the increase of sulphur.

4.2.4 Length of panicle

The results presented in Table 5 showed that levels of sulphur had significant effect on panicle length. However, the highest panicle length (22. 6 cm) was found from the S_0 (0 kg S ha^{-1}) level whereas the lowest (21.2 cm) one was found from the S_2 (30 kg S ha^{-1}) and S_1 (20 kg S ha^{-1}) treatments.

4.2.5 Filled grains $panicle^{-1}$

No. of filled grains $panicle^{-1}$ varied significantly due to sulphur levels. The no. of filled grains $panicle^{-1}$ increased with sulphur levels upto S_2 (30 kg S ha^{-1}) level. The highest number of grains $panicle^{-1}$ (90.1) was obtained from S_2 (30 kg S ha^{-1}) level which was statistically identical (90.0) with S_1 (20 kg S ha^{-1}) level. The lowest number of grains $panicle^{-1}$ (77.8) was obtained at the S_0 (0 kg S ha^{-1}) level (Table 5). The growth and yield attributing characters of rice increased with the sulfur application. (Mrinal and Sharma, 2008).

4.2.6 Sterile grains $panicle^{-1}$

Number of sterile grains $panicle^{-1}$ was significantly decreased with increase the application of sulphur fertilizer. The highest number of sterile grains $panicle^{-1}$ (16.8) was obtained from the S_0 (0 kg S ha^{-1}) levels which differed significantly from other sulphur levels. The lowest number of sterile grains $panicle^{-1}$ (14.1) was obtained at S_1 (20 kg S ha^{-1}) level (Table 6). The highest sterile grains in lower levels of sulphur might be due to lower nutrients supply and absorption by rice plant. Similar results were reported by Oo *et al.* (2007).

4.2.7 Weight of 1000 grains

Data on Table 6 showed that sulphur levels had no significant effect on 1000-grain weight. However, the sulphur levels of 20 kg S ha^{-1} produced (21.7 g) the highest 1000-grain weight.

4.2.8 Grain yield

Sulphur levels had significant effect on the grain yield of BRRI dhan 28. Grain yield increased with the increase of sulphur levels upto S_2 (30 kg S ha^{-1}) level. The highest grain yield (6.5 t ha^{-1}) was obtained from S_2 (30 kg S ha^{-1}) level (Fig. 3). The lowest grain yield (5.8 t ha^{-1}) was obtained from S_0 (0) level. The results indicated that increase of sulphur application increased the grain yield of rice. Grain yield decreased with lower levels sulphur due to higher number of sterile grains $panicle^{-1}$. On the other hand, grain yield decreased in wider levels sulphur due to improper utilization of nutrient. It was observed that S_1 (20 kg S ha^{-1}) level was the most suitable sulphur level for grain production (Table 6). Mrinal and Sharma (2008) stated that grain yields of rice increased significantly with increasing levels of sulfur up to 30 kg S ha^{-1}

Table 5. Effect of sulphur on yield parameters of Boro rice cv. BRRI dhan 28

Levels of sulphur	Plant height (cm)	No. of effective tillers $hill^{-1}$	No. of non-effective tillers $hill^{-1}$	Length of panicle (cm)	No. of filled grains $panicle^{-1}$
S_0(0 kg S ha^{-1})	86.6	7.6c	3.6a	22.6a	77.8b
S_1(20 kg S ha^{-1})	86.4	9.1b	3.2b	21.2b	90.0a
S_2(30 kg S ha^{-1})	84.3	11.9a	1.9c	21.2b	90.1a
$LSD_{0.05}$	-	0.549	0.336	0.651	3.231
Level of Significance	NS	0.01	0.01	0.01	0.01
CV (%)	4.58	8.03	16.02	4.18	5.22

In a column means followed by same letter are not significantly different at 5% level by DMRT.
NS =Non significant.

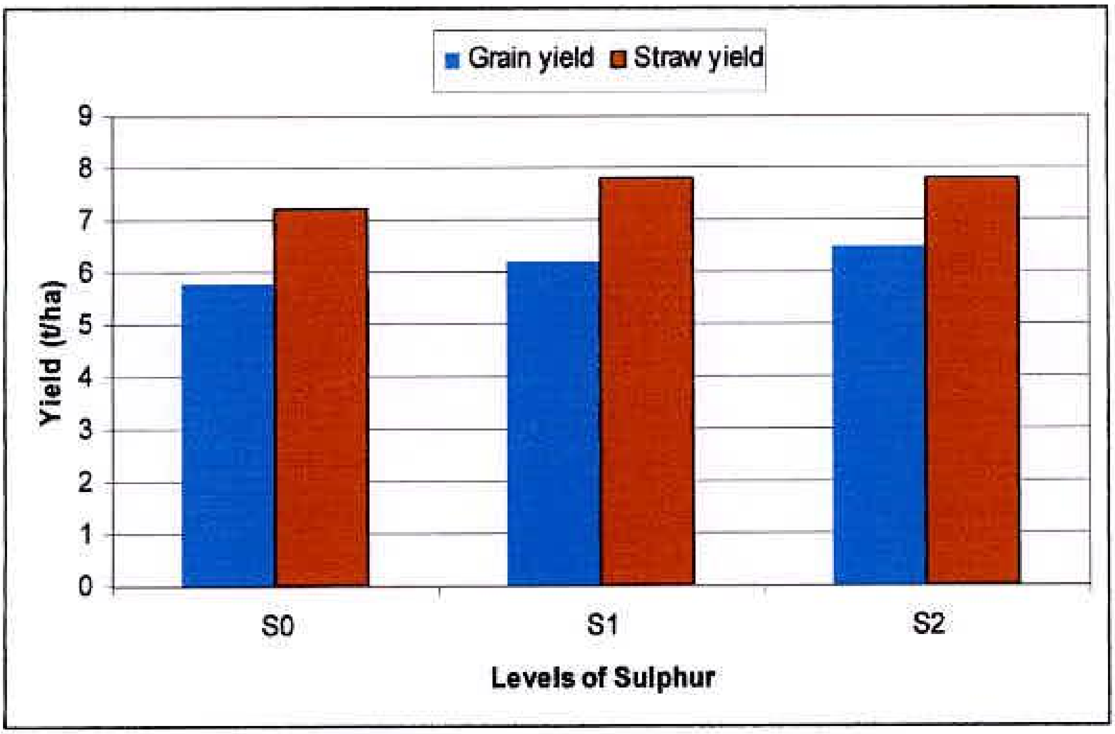

Figure 3. Effect of different levels of sulphur on grain and straw yield of Boro rice cv. BRRI dhan 28.

4.2.9 Straw yield

In the Straw yield of BRRI dhan 28 had statistical significant effect of sulphur levels upto S_2 (30 kg S ha^{-1}) treatment (Table 6).The highest straw yield (7.8 t ha^{-1}) and the lowest straw yield (7.2 t ha^{-1}) obtained from S_2 (30 kg S ha $^{-1}$) and S_0 (0 kg S ha^{-1}) levels respectively (Fig. 3).

Table 6. Effect of sulphur on yield and yield parameters of Boro rice cv. BRRI dhan 28

Levels of sulphur	No. of sterile grains Panicle^{-1}	1000- grain wt (g)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
S_0 (0 kg S ha^{-1})	16.8a	21.6	5.8c	7.2b
S_1 (20 kg S ha^{-1})	14.1c	21.7	6.2b	7.8a
S_2 (30 kg S ha^{-1})	15.8b	21.6	6.5a	7.8a
$LSD_{0.05}$	1.012	–	0.068	0.075
Level of Significance	0.01	NS	0.01	0.01
CV (%)	9.04	3.17	1.57	1.38

In a column means followed by same letter are not significantly different at 5% level by DMRT.
NS =Non significant.

4.3 Interaction effects of nitrogen and sulphur on yield and yield contributing characters

Interaction effect of nitrogen and sulphur levels on yield parameters was shown in Table 7 and 8.

4.3.1 Plant height

Plant height was not significantly differed by the interaction effects of nitrogen and sulphur. Numerically, the tallest plant (89.5 cm) was found in $N_2 S_0$ (120 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Table 7). The shortest plant (81.6 cm) was found in treatment combination of N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}). Results revealed that plant height increased with increasing nitrogen level.

4.3.2 Effective tillers $hill^{-1}$

The interaction effect between different nitrogen levels and sulphur levels was also not significant on the number of effective tillers $hill^{-1}$. Numerically, the highest number of effective tillers $hill^{-1}$ (13.7) was obtained from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment combination and the lowest number of effective tillers $hill^{-1}$ (4.7) was obtained from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination. (Table 7). It was observed that the number of non-effective tillers (4.5) $hill^{-1}$.

4.3.3 Non-effective tillers $hill^{-1}$

The interaction effect of N and S on non-effective tillers $hill^{-1}$ was statistically significant (Table 7). It was observed that the number of non-effective tillers (4.5) $hill^{-1}$ was found in the treatment combination of N_0 (0 kg N ha^{-1}) with S_1 (20 kg S ha^{-1}) which was statistically identical with the treatment combination of $N_2 S_0$ (140 kg N ha^{-1} + 0 kg S ha^{-1}), N_1S_0 (120 kg N ha^{-1} + 0 kg S ha^{-1}) and N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}). The lowest number of non- effective tillers (1.7) $hill^{-1}$ was found in $N_1 S_3$ (120 kg N ha^{-1} + 30 kg S ha^{-1}). This result implies that the influence of suitable N and S levels was effective for increasing the number of effective tillers (Kamal *et al,* 1988).

4.3.4 Length of panicle

The experimental results showed that the interaction effect between the nitrogen and sulphur levels failed to produce significant effect on panicle length. However, numerically the longest panicle (23.9 cm) was obtained from N_1S_0 (120 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination. The shortest panicle (20.2 cm) obtained from the N_2S_2 (140 kg N ha^{-1} + 30 kg S ha^{-1}) treatment (Table 7).

4.3.5 Filled grains panicle^{-1}

The number of filled grains per panicle was significantly affected by the interaction of N and S. The higher number of grains panicle^{-1} (111. 9) was obtained from N_3 S_1 (160 kg N ha^{-1} + 20 kg S ha^{-1}) treatment combination (Table 7), which was statistically identical to N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}). The lowest number of grains panicle^{-1} (63.7) was obtained from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) (Table 7).Such result proves that the increasing level of N and S had an influence on the increasing number of filled grains. Similar results were reported by Nad *et al.* (2001).

4.3.6 Sterile grains panicle^{-1}

The interaction effect of nitrogen and sulphur levels on sterile grains panicle^{-1} was significant (Table 8). The higher number of sterile grains panicle^{-1} (21. 3) was obtained from the N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment which was statistically identical (20.4) with treatment of N_0S_1 (0 kg N ha^{-1} + 20 kg S ha^{-1}). The lowest number of sterile grains panicle^{-1} (10.5) was obtained from N_3S_1 (160 kg N ha^{-1} + 20 kg S ha^{-1}) (Table 8).This result proved that higher level of N and S had an positive influence for decreasing grain sterility of rice.

Table 7. Interaction effect of nitrogen and sulphur on yield parameters of Boro rice cv. BRRI dhan 28

Interaction	Plant height (cm)	No. of effective tillers $hill^{-1}$	No. of non-effective tillers $hill^{-1}$	Length of panicle (cm)	No. of filled grains $panicle^{-1}$
N_0S_0	81.6	4.7	4.1a	21.6	63.7e
N_0S_1	82.8	6.1	4.5a	21.6	68.1de
N_0S_2	81.9	8.8	2.3cd	21.2	69.3de
N_1S_0	86.7	7.1	4.2a	23.9	73.9d
N_1S_1	87.2	8.6	3.4b	21.4	89.0c
N_1S_2	86.0	11.7	1.7d	21.3	86.2c
N_2S_0	89.5	8.1	4.2a	21.8	84.9c
N_2S_1	88.5	10.5	2.6c	20.4	91.0bc
N_2S_2	84.1	13.4	1.9cd	20.2	96.9b
N_3S_0	88.8	10.4	2.1cd	22.9	88.5c
N_3S_1	87.1	11.1	2.3cd	21.4	111.9a
N_3S_2	85.0	13.7	1.9cd	21.9	108.0a
$LSD_{0.05}$	–	–	0.672	–	6.463
Level of Significance	NS	NS	0.01	NS	0.01
CV (%)	4.58	8.03	16.02	4.18	5.22

In a column means followed by same letter are not significantly different at 5% level by DMRT.
NS =Non significant.

A. Nitrogen level (4) : **a)** 0 kg N ha^{-1} (N_o), **b)** 120 kg N ha^{-1} (N_1), **c)** 140 kg N ha^{-1} (N_2), **d)** 160 kg N ha^{-1} (N_3)
B. Sulphur level (3) : **a)** 0 kg S ha^{-1} (S_o), **b)** 20 kg S ha^{-1} (S_1), **c)** 30 kg S ha^{-1} (S_2)

4.3.7 Weight of 1000-grain

The interaction effect between nitrogen and sulphur levels was insignificant (Table 8). However, apparently the highest 1000-grain weight (22.1) was obtained from N_2S_1 (140 kg N ha^{-1} + 20 kg S ha^{-1}) treatment combination and the lowest one (21.0) was obtained from the treatment N_3S_0 (160 kg N ha^{-1} + 0 kg S ha^{-1}) level (Table 8).

4.3.8 Grain yield

The grain yield over the treatment combination of N and S was statistically significant (Table 8). The highest grain yield (7.4 t ha^{-1}) was obtained from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}). The lowest grain yield (4.8 t ha^{-1}) was obtained from the N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Fig. 4). Oo *et al.* (2007) also found the same result that grain yield increased significantly with increasing N and S levels.

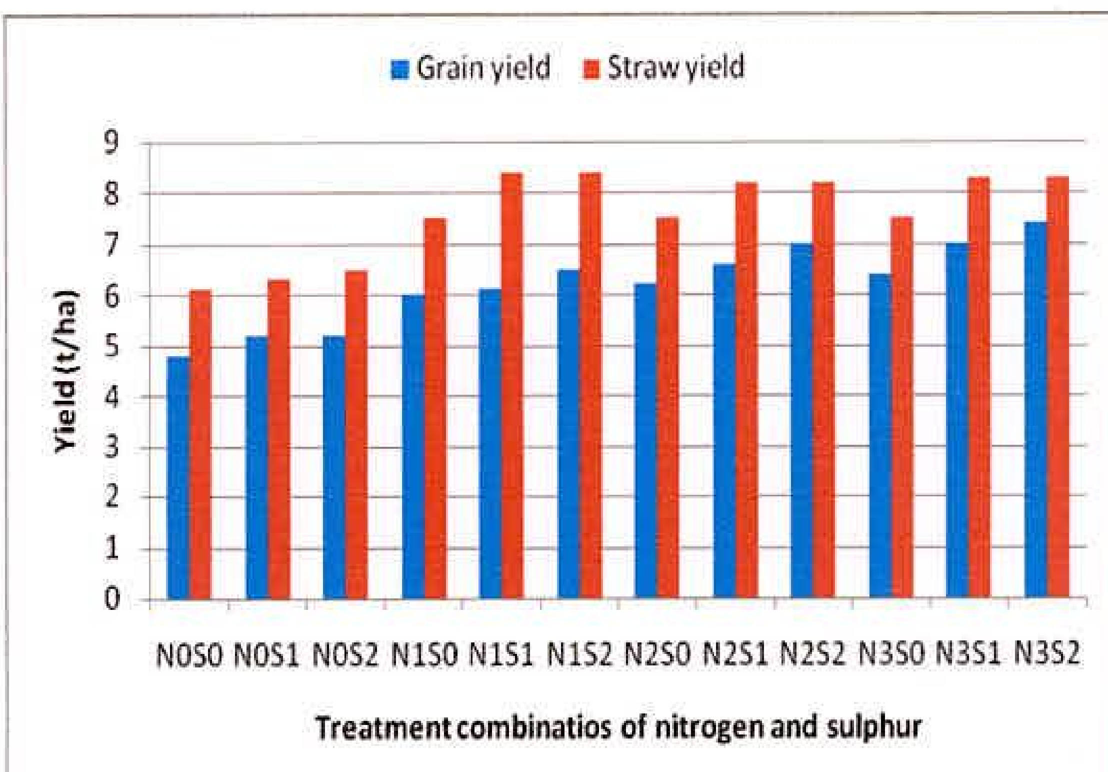

Figure 4. Interaction effect of different levels of nitrogen and sulphur on grain and straw yield of Boro rice cv. BRRI dhan 28.

4.3.9 Straw yield

Straw yield was significantly influenced by treatment combination of nitrogen and sulphur. The highest straw yield (8.4 t ha^{-1}) was produced from N_1(120 kg N ha^{-1})with S_1(20 kg S ha^{-1}) and S_2(30 kg S ha^{-1}) treatments (Table 8), which was statistically identical to (8.3 t ha^{-1}) produced by N_3S_1 (160 kg N ha^{-1} + 20 kg S ha^{-1}) and N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment combinations. The lowest straw yield (6.1 t ha^{-1}) was produced from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Fig. 4). Similar results were reported by Nad *et al.* (2001).

Table 8. Interaction effect of nitrogen and sulphur on yield and yield parameters of Boro rice cv. BRRI dhan 28

Interaction	No. of sterile grains $panicle^{-1}$	1000- grain wt (g)	Grain Yield ($t\ ha^{-1}$)	Straw Yield ($t\ ha^{-1}$)
N_0S_0	21.3a	21.9	4.8h	6.1e
N_0S_1	20.4a	22.0	5.2g	6.3d
N_0S_2	16.9b	21.6	5.2g	6.5c
N_1S_0	17.9b	21.5	6.0f	7.5b
N_1S_1	14.3c	22.1	6.1ef	8.4a
N_1S_2	17.8b	21.3	6.5d	8.4a
N_2S_0	14.0c	21.9	6.2e	7.5b
N_2S_1	11.3d	21.2	6.6c	8.2a
N_2S_2	13.7c	22.1	7.0b	8.2a
N_3S_0	14.2c	21.0	6.4d	7.5b
N_3S_1	10.5d	21.7	7.0b	8.3a
N_3S_2	14.7c	22.0	7.4a	8.3a
$LSD_{0.05}$	2.024	–	0.137	0.151
Level of Significance	0.01	NS	0.01	0.01
CV (%)	9.04	3.17	1.57	1.38

In a column means followed by same letter are not significantly different at 5% level by DMRT.
NS =Non significant.

A. Nitrogen level (4): **a)** 0 kg N ha^{-1} (N_0), **b)** 120 kg N ha^{-1} (N_1) , **c)** 140 kg N ha^{-1} (N_2), **d)** 160 kg N ha^{-1} (N_3)
B. Sulphur level (3): **a)** 0 kg S ha^{-1} (S_0), **b)** 20 kg S ha^{-1} (S_1), **c)** 30 kg S ha^{-1} (S_2)

4.4 Effect of N on N, P, K and S concentrations in grain and straw

4.4.1 N concentration in grain

Application of nitrogen significantly increased the nitrogen concentration in rice grain (Table 9). At N_0 (0 kg N ha^{-1}) treatment nitrogen concentration in rice grain was 0.72% and at N_3 (160 kg N ha^{-1}) treatment it was increased to 0.89% which was statistically identical (0.88% and 0.86%) with N_2 (140 kg N ha^{-1}) and N_1 (120 kg N ha^{-1}) treatments respectively. Nad *et al.* (2001) stated that nitrogen content in rice significantly increased with the increasing rates of urea application.

4.4.2 P concentration in grain

Phosphorous concentration in grain of BRRI dhan 28 showed statistically significant variation due to the application of various levels of nitrogen fertilizer (Table 9). The highest P concentration in grain (0.34%) was recorded from N_3 (160 kg N ha^{-1}) level which was statistically identical (0.33% and 0.32%) with N_2 (140 kg N ha^{-1}) and N_1 (120 kg N ha^{-1}) levels respectively. On the other hand, the lowest P concentration in grain (0.27%) was found from N_0 (0 kg N ha^{-1}) level as control condition (Table 9). An increase in P contents both in rice grain due to the application of nitrogen reported by Sarkunan *et al.* (1998).

Table 9. Effect of nitrogen on nutrient contents in grain and straw of Boro rice cv. BRRI dhan 28

Levels of nitrogen	Grain				Straw			
	N (%)	P (%)	K (%)	S (%)	N (%)	P (%)	K (%)	S (%)
N_0(0 kg N ha^{-1})	0.72b	0.27b	0.27	0.11	0.58b	0.13b	1.13c	0.08d
N_1(120 kg N ha^{-1})	0.86a	0.32a	0.26	0.14	0.64a	0.17a	1.16bc	0.09c
N_2 (140 kg N ha^{-1})	0.88a	0.33a	0.28	0.13	0.65a	0.17a	1.32a	0.10b
N_3(160 kg N ha^{-1})	0.89a	0.34a	0.27	0.14	0.69a	0.18a	1.20b	0.11a
$LSD_{0.05}$	0.053	0.045	–	–	0.045	0.037	0.069	0.008
Level of Significance	0.01	0.01	NS	NS	0.01	0.05	0.01	0.01
CV (%)	7.24	16.18	16.97	26.01	9.17	28.45	7.13	20.90

In a column means followed by same letter are not significantly different at 5% level by DMRT.
NS =Non significant.

4.4.3 K concentration in grain

Potassium concentration in grain of BRRI dhan 28 did not differ significantly due to the application of nitrogen (Table 9). However, the highest K concentration in grain (0.28%) was obtained from N_2 (140 kg N ha^{-1}) treatment. On the other hand, the lowest K concentration in grain (0.26%) was observed from N_1 (120 kg N ha^{-1}) treatment. The application of nitrogen had not any role in potassium contents in grain in this study.

4.4.4 S concentration in grain

The application of nitrogen had no significant effect in S concentration in grain of BRRI dhan 28 (Table 9). The highest S concentration in grain (0.14%) was recorded from N_3 (160 kg N ha^{-1}) and N_1 (120 kg N ha^{-1}) treatments. On the other hand, the lowest S concentration in grain (0.11%) was recorded from N_0 (0 kg N ha^{-1}) as control condition (Table 9).

4.4.5 N concentration in straw

Statistically significant variation was recorded for N concentration in straw of BRRI dhan 28 due to the application of various levels of nitrogen fertilizer (Table 9). The highest N concentration in straw (0.69%) was found from N_3 (160 kg N ha^{-1}) level which was statistically identical (0.65% and 0.64%) with N_2 (140 kg N ha^{-1}) and N_1 (120 kg N ha^{-1}) levels respectively. On the other hand, the lowest N concentration in straw (0.58%) was obtained from N_0 (0 kg N ha^{-1}) as control condition (Table 9).

4.4.6 P concentration in straw

Phosphorous concentration in straw of BRRI dhan 28 showed statistically significant variation due to the application of various levels of nitrogen fertilizer (Table 9). The highest P concentration in straw (0.18%) was found from N_3 (160 kg N ha^{-1}) which was statistically identical (0.17% and 0.17%) with N_2 (140 kg N ha^{-1}) and N_1 (120 kg N ha^{-1}) respectively. On the other hand, the lowest P concentration in straw (0.13%) was recorded from N_0 (0 kg N ha^{-1}) treatment.

4.4.7 K concentration in straw

The K concentration in straw of BRRI dhan 28 varied significantly due to the application of different levels of nitrogen (Table 9). The highest K concentration in straw (1.32%) was recorded from N_2 (140 kg N ha^{-1}) level. On the other hand, the lowest K concentration in straw (1.13%) was found from N_0 (0 kg N ha^{-1}) as control condition which was closely followed (1.16%) by N_1 (120 kg N ha^{-1}) level (Table 9).

4.4.8 S concentration in straw

Sulphur concentration in straw of BRRI dhan 28 showed statistically significant variation due to the application of various levels of nitrogen fertilizer (Table 9). The highest S concentration in straw (0.11%) was obtained from N_3 (160 kg N ha^{-1}) level. On the other hand, the lowest S concentration in straw (0.08%) was found from N_0 (0 kg N ha^{-1}) level as control condition (Table 9).

4.5 Effect of S on N, P, K and S concentrations in grain and straw

4.5.1 N concentration in grain

Nitrogen concentration in grain of BRRI dhan 28 showed statistically significant variation due to the application of different levels sulphur (Table 10).The level of grain-N increased with increasing the levels of S fertilizer in soil. The highest N concentration in grain (0.87%) was recorded from S_3 (30 kg S ha^{-1}), which was statistically similar (0.84) with S_1 (20 kg S ha^{-1}). On the other hand, the lowest N concentration in grain (0.81%) was found from S_0 (0 kg S ha^{-1}) as control condition (Table 10). An increase in N contents both in grain and straw of rice due to the application of sulphur. (Sharma and Bali, 2000)

Table 10. Effect of sulphur on nutrient contents in grain and straw of Boro rice cv. BRRI dhan 28

Levels of sulphur	Grain				Straw			
	N (%)	P (%)	K (%)	S (%)	N (%)	P (%)	K (%)	S (%)
S_0(0 kg S ha^{-1})	0.81b	0.30	0.28	0.12	0.62b	0.15	1.20	0.08c
S_1(20 kg S ha^{-1})	0.84ab	0.31	0.27	0.13	0.62b	0.16	1.21	0.09b
S_2(30 kg S ha^{-1})	0.87a	0.33	0.26	0.14	0.68a	0.17	1.20	0.10a
$LSD_{0.05}$	0.045	–	–	–	0.039	–	–	0.007
Level of Significance	0.01	NS	NS	NS	0.01	NS	NS	0.05
CV (%)	7.24	16.18	16.97	26.01	9.17	28.45	7.13	20.90

In a column means followed by same letter are not significantly different at 5% level by DMRT.
NS =Non significant.

4.5.2 P concentration in grain

Phosphorous concentration in grain of BRRI dhan 28 was not significantly affected by the application of various levels sulphur (Table 10). However, numerically the highest P concentration in grain (0.33%) was recorded from S_2 (30 kg S ha^{-1}). On the other hand, the lowest P concentration in grain (0.30%) was found from S_0 (0 kg S ha^{-1}) (Table 10). An increase in P concentration in rice grain due to the application of sulphur.

4.5.3 K concentration in grain

Potassium concentration in grain of BRRI dhan 28 did not differ significantly due to the application of S (Table 10). However, numerically the highest K concentration in grain (0.28%) was obtained from S_0 (0 kg S ha^{-1}) and on the other hand the lowest K concentration in grain (0.26%) was observed from S_2 (30 kg S ha^{-1}) level (Table 10). Increase in S application slightly decreased the K concentration in rice grain.

4.5.4 S concentration in grain

Due to the application of different levels of sulphur grain- S concentration of BRRI dhan 28 did not differed significantly (Table 10). However, numerically the highest S concentration in grain (0.14%) was recorded from S_2 (30 kg S ha^{-1}). On the other hand, the lowest S concentration in grain (0.12%) was recorded from S_0 (0 kg S ha^{-1}) level (Table 10).

4.5.5 N concentration in straw

A significant variation was recorded for N concentration in straw of BRRI dhan 28 due to the application of different levels of S (Table 10). Table 10 showed that the highest N concentration in straw (0.68%) was found from S_2 (30 kg S ha^{-1}). On the other hand, the lowest N concentration in straw (0.62%) was obtained from S_0 (0 kg S ha^{-1}) and S_1 (20 kg S ha^{-1}) level (Table 10).

4.5.6 P concentration in straw

Phosphorous concentration in straw of BRRI dhan 28 did not show significant variation by the levels of sulphur (Table 10). However, numerically the highest

P concentration in straw (0.17%) was found from S_2 (30 kg S ha^{-1}) level. On the other hand, the lowest P concentration in straw (0.15%) was recorded from S_0 (0 kg S ha^{-1}) level (Table 10).

4.5.7 K concentration in straw

The straw-K concentration was not significantly influenced by the application of different levels of sulphur in BRRI dhan 28 (Table 10). However, numerically the highest K concentration in straw (1.21%) was recorded from S_1 (20 kg S ha^{-1}). On the other hand, the lowest K concentration in straw (1.20%) was found from S_0 (0 kg S ha^{-1}) and S_2 (30 kg S ha^{-1}) treatment (Table 10).

4.5.8 S concentration in straw

Sulphur concentration in straw of BRRI dhan 28 showed statistically significant variation due to the application of various levels of sulphur (Table 10). The highest S concentration in straw (0.10%) was obtained from S_2 (30 kg S ha^{-1}). On the other hand, the lowest S concentration in straw (0.08%) was found from S_0 (0 kg S ha^{-1}) treatment (Table 10).This result indicates that the accumulation of S in straw increased with the increasing application of S.

4.6 Interaction effect of N and S on N, P, K and S concentrations in grain and straw

4.6.1 N concentration in grain

The interaction effect of nitrogen and sulphur had no significant effect on grain-N concentration (Table 11). However, numerically the highest N concentration (0.93%) was obtained from the treatment of N_3 (160 kg N ha^{-1}) with S_2 (30 kg S ha^{-1}) and the lowest number of N concentration (0.69%) was obtained from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment (Table 11).

4.6.2 P concentration in grain

Phosphorous concentration in grain of BRRI dhan 28 did not differ significantly by the interaction of different levels of nitrogen and sulphur (Table 11). However, numerically the highest P concentration in grain (0.36%) was recorded from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}). On the other hand, the lowest P concentration in grain (0.24%) was found from $N_0 S_1$ (0 kg N ha^{-1} + 20 kg S ha^{-1}) treatment (Table 11).

4.6.3 K concentration in grain

The interaction of nitrogen and sulphur on potassium concentration in grain of BRRI dhan 28 was showed significant (Table 11). The highest K concentration in grain (0.31%) was obtained from N_2S_0 (140 kg N ha^{-1} + 0 kg S ha^{-1}) which was identical(0.03%) with N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}), N_2S_1 (140 kg N ha^{-1} + 20 kg S ha^{-1}) and N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatments respectively and the lowest K concentration in grain (0.22%) was observed fromN_3S_0 (160 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Table 11).

4.6.4 S concentration in grain

Grain-S concentration was not affected significantly due to interaction of N and S (Table 11). However, numerically the highest S concentration in grain (0.148%) was recorded from N_3S_0 (160 kg N ha^{-1} + 0 kg S ha^{-1}) and N_1S_2 (120 kg N ha^{-1} + 30 kg S ha^{-1}). On the other hand, the lowest S concentration in grain (0.09 %) was recorded from N_0 (0 kg N ha^{-1}) control condition with S_0 (0 kg S ha^{-1}) treatment combination (Table 11).

4.6.5 N concentration in straw

N concentration in straw of BRRI dhan 28 was not affected significantly due to the interaction of nitrogen and sulphur (Table 11). However, numerically highest N concentration in straw (0.74%) was found from N_3 (160 kg N ha^{-1}) with S_2 (30 kg S ha^{-1}) level. On the other hand, the lowest N concentration in straw (0.56%) was obtained from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Table 11).

Table 11. Interaction effect of nitrogen and sulphur on nutrient contents in grain and straw of Boro rice cv. BRRI dhan 28

Interaction	Grain				Straw			
	N (%)	P (%)	K (%)	S (%)	N (%)	P (%)	K (%)	S (%)
N_0S_0	0.69	0.27	0.30a	0.098	0.56	0.12	1.12cd	0.07
N_0S_1	0.74	0.24	0.24ab	0.112	0.59	0.12	1.17bcd	0.08
N_0S_2	0.72	0.29	0.27ab	0.127	0.60	0.13	1.10d	0.08
N_1S_0	0.84	0.32	0.29ab	0.127	0.63	0.15	1.29ab	0.07
N_1S_1	0.81	0.28	0.26ab	0.130	0.60	0.15	1.14cd	0.08
N_1S_2	0.92	0.35	0.24ab	0.148	0.70	0.20	1.04d	0.10
N_2S_0	0.84	0.32	0.31a	0.117	0.62	0.16	1.34a	0.09
N_2S_1	0.90	0.35	0.30a	0.127	0.65	0.18	1.29ab	0.10
N_2S_2	0.91	0.31	0.25ab	0.145	0.69	0.18	1.33a	0.10
N_3S_0	0.86	0.32	0.22b	0.148	0.69	0.18	1.05d	0.11
N_3S_1	0.89	0.35	0.29b	0.145	0.63	0.19	1.25abc	0.11
N_3S_2	0.93	0.36	0.30a	0.140	0.74	0.16	1.31a	0.12
$LSD_{0.05}$	–	–	0.064	–	–	–	0.120	–
Level of Significance	NS	NS	0.05	NS	NS	NS	0.01	NS
CV (%)	7.24	16.18	16.97	26.01	9.17	28.45	7.13	20.90

In a column means followed by same letter are not significantly different at 5% level by DMRT.
NS =Non significant

A. Nitrogen level (4): **a)** 0 kg N ha^{-1} (N_o), **b)** 120 kg N ha^{-1} (N_1), **c)** 140 kg N ha^{-1} (N_2), **d)** 160 kg N ha^{-1} (N_3)
B. Sulphur level (3): **a)** 0 kg S ha^{-1} (S_o), **b)** 20 kg S ha^{-1} (S_1), **c)** 30 kg S ha^{-1} (S_2)

4.6.6 P concentration in straw

Straw-P concentration of BRRI dhan 28 did not differ significantly by the interaction of nitrogen and sulphur levels (Table 11). However, numerically the highest P concentration in straw (0.20%) was found from N_1S_2 (120 kg N ha^{-1} + 30 kg S ha^{-1}). On the other hand, the lowest P concentration in straw (0.12%) was recorded from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Table 11).

4.6.7 K concentration in straw

The Straw-K concentration of BRRI dhan 28 was significantly influenced by the interaction of different levels of nitrogen and sulphur (Table 11). Table 11 revealed that the highest K concentration in straw (1.34%) was recorded from N_2S_0 (140 kg N ha^{-1} + 0 kg S ha^{-1}) which was statistically identical (1.33% and 1.31%) with the N_2S_2 (140 kg N ha^{-1} + 30 kg S ha^{-1}) and N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment combinations, respectively. On the other hand, the lowest K concentration in straw (1.10%) was found from N_0S_2 (0 kg N ha^{-1} + 30 kg S ha^{-1}) treatment combination (Table11).

4.6.8 S concentration in straw

Sulphur concentration in straw of BRRI dhan 28 showed non-significant difference by the application of levels of nitrogen and sulphur (Table 11). However, numerically the highest S concentration in straw (0.12%) was obtained from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment. On the other hand, the lowest S concentration in straw (0.07%) was found from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Table 11).

4.7 Effect of N on N, P, K and S uptake by grain and straw

4.7.1 N uptake by grain

The N uptake by grain increased with increasing level of N fertilizer in soil. Statistically significant variation was recorded for N uptake by grain of BRRI dhan 28 due to the application of different levels of nitrogen (Table 12). The highest N uptake by grain (61.81 kg ha^{-1}) was recorded from N_3 (160 kg N ha^{-1})

level. On the other hand, the lowest N uptake by grain (36.21 kg ha^{-1}) was recorded from N_0 (0 kg N ha^{-1}) as control condition (Table 12). Sengar *et al.* (2000) reported that the N uptake by rice grain and straw increased significantly with the combined application of organic manure and chemical fertilizers. Rahman (2001), Duhan and Singh (2002), Azim (1999) and Hoque (1999) also reported similar results.

4.7.2 P uptake by grain

Potassium uptake by grain of BRRI dhan 28 showed statistically significant variation due to the application of different levels of nitrogen (Table 12). The highest P uptake by grain (23.60 kg ha^{-1}) was observed from N_3 (160 kg N ha^{-1}) which was statistically similar (21.35 kg ha^{-1}) with N_2 (140 kg N ha^{-1}) level. On the other hand, the lowest P uptake by grain (13.44 kg ha^{-1}) was observed from N_0 (0 kg N ha^{-1}) level as control condition (Table 12).

4.7.3 K uptake by grain

The grain-K uptake of BRRI dhan 28 showed statistically significant variation due to the application of different levels of nitrogen (Table 12). The highest K uptake by grain (18.74 kg ha^{-1}) was found from N_3 (160 kg N ha^{-1}) which was statistically identical (18.51 kg ha^{-1}) with N_2 (140 kg N ha^{-1}). On the other hand, the lowest K uptake by grain (13.66 kg ha^{-1}) was observed from N_0 (0 kg N ha^{-1}) as control level (Table 12). Sengar *et al.* (2000) reported that application of chemical fertilizer significantly increased the K uptake by rice. Similar results were also found by Cassman (1995), Azim (1999) and Hoque (1999).

Table 12. Effect of nitrogen on nutrient uptake by grain and straw of Boro rice cv. BRRI dhan 28

Levels of nitrogen	Uptake by grain (kg ha^{-1})				Uptake by straw (kg ha^{-1})			
	N	P	K	S	N	P	K	S
N_0(0 kg N ha^{-1})	36.21d	13.44c	13.66c	5.72b	36.76b	7.90b	70.56c	4.74c
N_1(120 kg N ha^{-1})	52.97c	19.63b	16.14b	8.35a	51.88a	13.57a	92.78b	6.89b
N_2(140 kg N ha^{-1})	58.12b	21.35ab	18.51ab	8.58a	52.04a	13.77a	105.08a	7.59b
N_3(160 kg N ha^{-1})	61.81a	23.60a	18.74a	9.94a	55.01a	14.19a	96.98b	8.92a
$LSD_{0.05}$	3.168	2.674	2.383	1.772	3.703	2.961	5.826	1.196
Level of Significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	7.30	16.51	17.12	26.19	9.11	28.85	7.68	20.47

In a column means followed by same letter are not significantly different at 5% level by DMRT.
NS = Non significant

4.7.4 S uptake by grain

Sulphur uptake by grain of BRRI dhan 28 showed statistically significant variation due to the application of different levels of nitrogen (Table 12). The highest S uptake by grain (9.94 kg ha^{-1}) was obtained from N_3 (160 kg N ha^{-1}) which was statistically identical (8.58 and 8.35 kg ha^{-1}) with N_2 (140 kg N ha^{-1}) and N_1 (120 kg N ha^{-1}), respectively. On the other hand, the lowest S uptake by grain (5.72 kg ha^{-1}) was observed from N_0 (0 kg N ha^{-1}) as control condition (Table 12). Azim (1999) and Hoque (1999) recorded the higher uptake of S with the application of fertilizers either alone or in combinations. Similar results were also reported by Sengar *et al.*, (2000) and Rahman (2001).

4.7.5 N uptake by straw

Nitrogen uptake by straw of BRRI dhan 28 showed statistically significant variation due to the application of different levels of nitrogen (Table 12). The highest N uptake by straw (55.01 kg ha^{-1}) was recorded from N_3 (160 kg N ha^{-1}) which was statistically identical (52.04 and 51.88 kg ha^{-1}) with N_2 (140 kg N ha^{-1}) and N_1 (120 kg N ha^{-1}), respectively. On the other hand, the lowest N uptake by straw (36.76 kg ha^{-1}) was observed from N_0 (0 kg N ha^{-1}) as control level (Table 12).

4.7.6 P uptake by straw

Statistically significant variation was recorded for P uptake by straw of BRRI dhan 28 due to the application of various levels of nitrogen (Table 12). The highest P uptake by straw (14.19 kg ha^{-1}) was found from N_3 (160 kg N ha^{-1}) which was statistically identical (13.77 and 13.57 kg ha^{-1}) with N_2 (140 kg N ha^{-1}) and N_1 (120 kg N ha^{-1}) treatment respectively. On the other hand, the lowest P uptake by straw (7.90 kg ha^{-1}) was observed from N_0 (0 kg N ha^{-1}) treatment (Table 12).

4.7.7 K uptake by straw

Potassium uptake by straw of BRRI dhan 28 showed statistically significant variation due to the application of various levels of nitrogen (Table 12). The highest K uptake by straw (105.08 kg ha^{-1}) was recorded from N_2 (140 kg N ha^{-1}). On the other hand, the lowest K uptake by straw (71.56 kg ha^{-1}) was found from N_0 (0 kg N ha^{-1}) treatment (Table 12).

4.7.8 S uptake by straw

Sulphur (S) uptake by straw of BRRI dhan 28 showed statistically significant variation due to the application of levels of nitrogen (Table 12). The highest S uptake by straw (8.92 kg ha^{-1}) was observed from N_3 (160 kg N ha^{-1}). On the other hand, the lowest S uptake by straw (4.74 kg ha^{-1}) was observed from N_0 (0 kg N ha^{-1}) level (Table 12).

4.8 Effect of S on N, P, K and S uptake by grain and straw

4.8.1 N uptake by grain

Nitrogen uptake by grain of BRRI dhan 28 showed statistically significant variation due to the different levels sulphur (Table 13). The highest N uptake in grain (57.15 kg ha^{-1}) was recorded from S_2 (30 kg S ha^{-1}). On the other hand, the lowest N uptake in grain (47.50 kg ha^{-1}) was found from S_0 (0 kg S ha^{-1}) treatment (Table 13). An increase in N contents in rice grain due to the application of sulphur.

4.8.2 P uptake by grain

Grain-P uptake of BRRI dhan 28 showed significant difference by the application of various levels sulphur (Table 13). The highest P uptake by grain (21.41 kg ha^{-1}) was recorded from S_2 (30 kg S ha^{-1}) which was statistically identical (19.21 kg ha^{-1}) with S_1 (20 kg S ha^{-1}). On the other hand, the lowest P uptake in grain (17.90 kg ha^{-1}) was found from S_0 (0 kg S ha^{-1}) treatment (Table 13). An increase in P contents in rice grain due to the application of sulphur.

4.8.3 K uptake by grain

Potassium uptake by grain of BRRI dhan 28 did not differ significantly due to the application of various levels of S (Table 13). However, numerically the highest K uptake in grain (17.13 kg ha^{-1}) was obtained from S_2 (30 kg S ha^{-1}) and on the other hand the lowest K uptake in grain (16.27 kg ha^{-1}) was observed from S_0 (0 kg S ha^{-1}) level (Table 13).

4.8.4 S uptake by grain

S uptake by grain of BRRI dhan 28 did not show significant difference by the application of different levels of sulphur (Table 13). However, numerically the highest S uptake in grain (9.14 kg ha^{-1}) was recorded from S_2 (30 kg S ha^{-1}). On the other hand, the lowest S uptake in grain (7.26 kg ha^{-1}) was recorded from S_0 (0 kg S ha^{-1}) treatment (Table 13).

4.8.5 N uptake by straw

A significant variation was recorded for N uptake by straw of BRRI dhan 28 due to the application of different levels of S (Table 13). Table 13 showed that the highest N uptake in straw (53.81 kg ha^{-1}) was found from S_2 (30 kg S ha^{-1}). On the other hand, the lowest N uptake in straw (44.85 kg ha^{-1}) was obtained from S_0 (0 kg S ha^{-1}) level (Table 13).This result implies that the accumulation of N increased with increasing levels of S application.

4.8.6 P uptake by straw

The straw-P uptake of BRRI dhan 28 did not show significant differ by the different levels of sulphur application (Table 13). However, numerically the highest P uptake in straw (13.38 kg ha^{-1}) was found from S_2 (30 kg S ha^{-1}). On the other hand, the lowest P uptake in straw (10.90 kg ha^{-1}) was recorded from S_0 (0 kg S ha^{-1}) treatment (Table 13).

Table 13. Effect of sulphur on nutrient uptake by grain and straw of Boro rice cv. BRRI dhan 28

Levels of sulphur	Uptake by grain (kg ha^{-1})				Uptake by straw (kg ha^{-1})			
	N	P	K	S	N	P	K	S
S_0(0 kg S ha^{-1})	47.50c	17.90b	16.27	7.26	44.85c	10.90	85.91b	5.98b
S_1(20 kg S ha^{-1})	52.17b	19.21ab	16.89	8.04	48.11b	12.79	94.55a	7.20a
S_2(30kg S ha^{-1})	57.15a	21.41a	17.13	9.14	53.81a	13.38	93.59a	7.94a
$LSD_{0.05}$	2.743	2.316	–	–	3.207	–	5.046	1.036
Level of Significance	0.01	0.05	NS	NS	0.01	NS	0.01	0.01
CV (%)	7.30	16.51	17.12	26.19	9.11	28.85	7.68	20.47

In a column means followed by same letter are not significantly different at 5% level by DMRT.
NS =Non significant.

4.8.7 K uptake by straw

The straw-K uptake of BRRI dhan 28 was significantly influenced by the different levels of sulphur application (Table 13)The highest K uptake in straw (93.59 kg ha^{-1}) was recorded from S_2 (30 kg S ha^{-1}) which was statistically identical (94.55 kg ha^{-1}) with S_1 (20 kg S ha^{-1}). On the other hand, the lowest K uptake in straw (85.91 kg ha^{-1}) was found from S_0 (0 kg S ha^{-1}) level (Table 13).

4.8.8 S uptake by straw

Sulphur uptake by straw of BRRI dhan 28 showed statistically significant variation due to the application of various levels of sulphur (Table 13). The highest S uptake in straw (7.94kg ha^{-1}) was obtained from S_2 (30 kg S ha^{-1}) which was statistically identical (7.20 kg ha^{-1}) with S_1 (20 kg S ha^{-1}). On the other hand, the lowest S uptake in straw (5.98kg ha^{-1}) was found from S_0 (0 kg S ha^{-1}) level (Table 13).

4.9 Interaction effect of N and S on N, P, K and S uptake by grain and straw

4.9.1 N uptake by grain

The interaction effect of levels of nitrogen and sulphur on N uptake by grain was significant (Table 14). The highest N uptake (68.27 kg ha^{-1}) was obtained from the treatment of N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) and the lowest N uptake (33.02kg ha^{-1}) was obtained from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Table 14).

4.9.2 P uptake by grain

Phosphorous uptake by grain of BRRI dhan 28 did not differ significantly by the interaction effect of nitrogen and sulphur (Table 14). However, numerically the highest P uptake in grain (26.32 kg ha^{-1}) was recorded from N_3 (160 kg N ha^{-1}) with S_2 (30 kg S ha^{-1}). On the other hand, the lowest P uptake in grain (12.35 kg ha^{-1}) was found from N_0S_1 (0 kg N ha^{-1} + 20 kg S ha^{-1}) treatment combination (Table 14).

4.9.3 K uptake by grain

The grain-K uptake of BRRI dhan 28 differed significantly by the interaction of nitrogen and sulphur (Table 14). The highest K uptake in grain (21.13 kg ha^{-1}) was obtained from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) and on the other hand the lowest K uptake in grain (12.39 kg ha^{-1}) was observed from N_0S_1 (0 kg N ha^{-1} + 20 kg S ha^{-1}) treatment (Table 14).

4.9.4 S uptake by grain

Due to the interaction of nitrogen and sulphur, S uptake in grain of BRRI dhan 28 showed non-significant effect (Table 14). However, numerically the highest S uptake in grain (10.30kg ha^{-1}) was recorded from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}). On the other hand, the lowest S uptake by grain (4.70 kg ha^{-1}) was recorded from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Table 14).

4.9.5 N uptake by straw

There was no significant variation was recorded in N uptake by straw of BRRI dhan 28 due to the interaction of different levels of nitrogen and sulphur (Table 14). However, numerically highest N uptake in straw (61.34 kg ha^{-1}) was found from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}). On the other hand, the lowest N uptake in straw (33.82 kg ha^{-1}) was obtained from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Table 14).

4.9.6 P uptake by straw

Phosphorous uptake by straw of BRRI dhan 28 showed not significant by the interaction of levels of nitrogen and sulphur (Table 14). However, numerically the highest P uptake by straw (16.49 kg ha^{-1}) was found from N_1S_2 (120 kg N ha^{-1} + 30 kg S ha^{-1}) treatment combination. On the other hand, the lowest P uptake by straw (7.33kg ha^{-1}) was recorded from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment (Table14).

Table 14. Interaction effect of nitrogen and sulphur on nutrient uptake by grain and straw of Boro rice cv. BRRI dhan 28

Interaction	Uptake by grain (kg ha^{-1})				Uptake by straw (kg ha^{-1})			
	N	P	K	S	N	P	K	S
N_0S_0	33.02e	12.83	14.64cde	4.70	33.82	7.33	67.98f	3.97
N_0S_1	37.93e	12.35	12.39e	5.80	37.33	7.75	74.16ef	5.21
N_0S_2	37.67e	15.13	13.95de	6.65	39.14	8.61	69.54ef	5.05
N_1S_0	50.08d	19.02	17.50bcd	7.63	47.22	11.49	96.53bc	5.46
N_1S_1	49.33d	17.10	15.56bcde	7.88	49.84	12.73	95.03bc	6.68
N_1S_2	59.50bc	22.79	15.35bcde	9.54	58.58	16.49	86.77cd	8.54
N_2S_0	51.74d	19.53	18.81abc	7.24	46.42	11.62	100.13ab	6.56
N_2S_1	59.45bc	23.12	19.65ab	8.42	53.54	14.75	105.78ab	8.01
N_2S_2	63.18ab	21.42	17.07bcde	10.07	56.16	14.93	109.31a	8.21
N_3S_0	55.17cd	20.21	14.12cde	9.46	51.94	13.16	78.98de	7.92
N_3S_1	61.98b	24.28	19.97ab	10.07	51.75	15.92	103.20ab	8.91
N_3S_2	68.27a	26.32	21.13a	10.30	61.34	13.50	108.75a	9.95
$LSD_{0.05}$	5.487	–	4.127	–	–	–	10.09	–
Level of Significance	0.01	NS	0.05	NS	NS	NS	0.01	NS
CV (%)	7.30	16.51	17.12	26.19	9.11	28.85	7.68	20.47

In a column means followed by same letter are not significantly different at 5% level by DMRT.

NS =Non significant.

A. Nitrogen level (4): **a)** 0 kg N ha^{-1} (N_0), **b)** 120 kg N ha^{-1} (N_1), **c)** 140 kg N ha^{-1} (N_2), **d)** 160 kg N ha^{-1} (N_3)

B. Sulphur level (3): **a)** 0 kg S ha^{-1} (S_0), **b)** 20 kg S ha^{-1} (S_1), **c)** 30 kg S ha^{-1} (S_2)

4.9.7 K uptake by straw

The straw-K uptake of BRRI dhan 28 was significantly influenced by the interaction effect of different levels of nitrogen and sulphur application (Table 14). Table 12 revealed that the highest K uptake by straw (109.31 kg ha^{-1}) was recorded from N_2S_2 (140 kg N ha^{-1} + 30 kg S ha^{-1}) treatment which was statistically identical (108.75 kg ha^{-1}) with N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment. On the other hand, the lowest K uptake by straw (67.98 kg ha^{-1}) was found with N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment (Table 14).

4.9.8 S uptake by straw

Sulphur uptake by straw of BRRI dhan 28 was not affected significantly by the interaction effect of nitrogen and sulphur application (Table 14). However, numerically the highest S uptake in straw (9.95 kg ha^{-1}) was obtained from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}). On the other hand, the lowest S uptake in straw (3.97kg ha^{-1}) was found from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment (Table 14).

4.10 Effect of N on pH, organic matter and N, P, K and S content in post harvest soil

4.10.1 pH

A significant variation was recorded in post harvest soil pH due to the application of different levels of nitrogen for BRRI dhan 28 cultivation (Table 15). The highest pH of post harvest soil (5.8) was found from N_1 (120 kg N ha^{-1}) which was statistically identical with N_2 (140 kg N ha^{-1}) and N_3 (160 kg N ha^{-1}) treatments respectively and the lowest pH in post harvest soil (5.28) was recorded from N_0 (0 kg N ha^{-1}) treatment (Table 15).

Table 15. Effect of nitrogen on the post harvest soil of Boro rice cv. BRRI dhan 28

Levels of nitrogen	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (meq /100 g soil)	Available S (ppm)
N_0(0 kg N ha^{-1})	5.3b	1.08d	0.60	19.40c	0.13	14.14c
N_1(120 kg N ha^{-1})	5.8a	1.12c	0.64	20.77bc	0.15	18.06b
N_2(140 kg N ha^{-1})	5.8a	1.15a	0.62	22.36ab	0.14	19.74b
N_3(160 kg N ha^{-})	5.8a	1.13b	0.65	23.75a	0.15	21.75a
LSD $_{0.05}$	0.311	0.037	–	1.656	–	1.925
Level of Significance	0.01	0.05	NS	0.01	NS	0.01
CV(%)	6.61	4.28	7.75	9.24	21.46	12.58

In a column means followed by same letter are not significantly different at 5% level by DMRT.

NS=Non-significant

4.10.2 Organic matter

Organic manure in post harvest soil showed statistically differences due to the application of different levels of nitrogen in BRRI dhan 28 cultivation (Table 15). The highest organic matter in post harvest soil (1.15%) was recorded from N_2 (140 kg N ha^{-1}) and the lowest organic matter in post harvest soil (1.08%) was observed from N_0 (0 kg N ha^{-1}) treatment (Table 15).

4.10.3 Total Nitrogen

Total nitrogen in post harvest soil showed statistically non-significant differences due to the application of different levels of nitrogen fertilizer for BRRI dhan 28 cultivation (Table 15). The highest total nitrogen in post harvest soil (0.65%) was recorded from N_3 (160 kg N ha^{-1}). On the other hand, the lowest total nitrogen in post harvest soil (0.60%) was obtained from N_0 (0 kg N ha^{-1}) treatment (Table 15).

4.10.4 Available P

Available P in post harvest soil showed statistically significant differences due to the application of different levels of nitrogen in BRRI dhan 28 (Table 15). The highest available P in post harvest soil (23.75 ppm) was recorded from N_3 (160 kg N ha^{-1}) and the lowest available P in post harvest soil (19.40 ppm) was observed from N_0 (0 kg N ha^{-1}) level (Table 15).

4.10.5 Exchangeable K

The application of different levels of N fertilizer for rice cultivation had no significant effect on exchangeable K in soil (Table 15). The highest exchangeable K in post harvest soil (0.15 meq /100 g soil)) was recorded from N_3 (160 kg N ha^{-1}). On the other hand, the lowest exchangeable K in post harvest soil (0.13 meq /100 g soil) was obtained from N_0 (0 kg N ha^{-1}) treatment (Table 15).

4.10.6 Available S

Available S in post harvest soil showed statistically significant differences due to the application of different levels of nitrogen in BRRI dhan 28 (Table 15). The highest available S in post harvest soil (21.75 ppm) was recorded from N_3 (160 kg N ha^{-1}) and the lowest available S in post harvest soil (14.14ppm) was observed from N_0 (0 kg N ha^{-1}) levels (Table 15).

4.11 Effect of S on pH, organic matter and N, P, K and S in the post harvest soil

4.11.1 pH

A significant variation was recorded for pH in post harvest soil due to the application ofdifferent levels of sulphur in BRRI dhan 28 (Table 16). The highest pH of post harvest soil (5.8) was found from S_0 (0 kg S ha^{-1}) which was statistically identical with S_2 (30 kg S ha^{-1}) level and the lowest pH in post harvest soil (5.4) was recorded from S_1 (20 kg S ha^{-1}) level (Table 16).

4.11.2 Organic matter

Organic manure in post harvest soil showed statistically non-significant differences due to the application of different levels of sulphur in BRRI dhan 28 (Table 16). The highest organic matter in post harvest soil (1.14%) was recorded from S_1 (20 kg S ha^{-1}) and the lowest organic matter in post harvest soil (1.11%) was observed from S_2 (30 kg S ha^{-1}) level (Table 16).

4.11.3 Total Nitrogen

Total nitrogen in post harvest soil showed statistically non-significant differences due to the application of different levels of sulphur fertilizer in BRRI dhan 28 (Table 16). The highest total nitrogen in post harvest soil (0.64%) was recorded from S_1 (20 kg S ha^{-1}). On the other hand, the lowest total nitrogen in post harvest soil (0.61%) was obtained from S_0 (0 kg S ha^{-1}) level (Table 16).

Table 16. Effect of sulphur on the post harvest soil of Boro rice cv. BRRI dhan 28

Levels of sulphur	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (meq /100 g soil)	Available S (ppm)
S_0(0 kg S ha^{-1})	5.8a	1.12	0.61	21.22	0.13b	17.90
S_1(20 kg S ha^{-1})	5.4b	1.14	0.64	21.54	0.15a	18.34
S_2(30 kg S ha^{-1})	5.8a	1.11	0.63	21.95	0.15a	19.03
$LSD_{0.05}$	0.269	–	–	–	0.023	–
Level of Significance	0.05	NS	NS	NS	0.05	NS
CV (%)	6.61	4.28	7.75	9.24	21.46	12.58

In a column means followed by same letter are not significantly different at 5% level by DMRT.
NS =Non significant.

4.11.4 Available P

Available P in post harvest soil showed statistically non-significant differences due to the application of different levels of sulphur in BRRI dhan 28 (Table 16). The highest available P in post harvest soil (21.95 ppm) was recorded from S_2 (30 kg S ha^{-1}) and the lowest available P in post harvest soil (21.22 ppm) was observed from S_0 (0 kg S ha^{-1}) level (Table 16).

4.11.5 Exchangeable K

Exchangeable K in post harvest soil showed statistically significant differences due to the application of different levels of sulphur fertilizer in BRRI dhan 28 (Table 16). The highest exchangeable K in post harvest soil (0.15 meq /100 g soil) was recorded from S_2 (30 kg S ha^{-1}). On the other hand, the lowest exchangeable K in post harvest soil (0.13 meq /100 g soil) was obtained from S_0 (0 kg S ha^{-1}) (Table 16).

4.11.6 Available S

Available S in post harvest soil showed statistically non-significant differences due to the application of different levels of sulphur in BRRI dhan 28 (Table 16). The highest available S in post harvest soil (19.03 ppm) was recorded from S_2 (30 kg S ha^{-1}) and the lowest available S in post harvest soil (17.90 ppm) was observed from S_0 (0 kg S ha^{-1}) level (Table 16).

4.12 Interaction effect of N and S on pH, organic matter and N, P, K and S in the post harvest soil

4.12.1 pH

Statistically non-significant variation was recorded for pH in post harvest soil due to the interaction of nitrogen and sulphur in BRRI dhan 28 (Table 17). The highest pH of post harvest soil (6.0) was found from N_3 (160 kg N ha^{-1}) and S_2 (30 kg S ha^{-1}) and the lowest pH in post harvest soil (5.2) was recorded from N_0S_1 (0 kg N ha^{-1} + 20 kg S ha^{-1}) treatment combination (Table 17).

Table 17. Interaction effect of nitrogen and sulphur on the post harvest soil of Boro rice cv. BRRI dhan 28

Interaction	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (meq /100 g soil)	Available S (ppm)
N_0S_0	5.4	1.06	0.56c	19.11	0.10	13.53
N_0S_1	5.2	1.14	0.60bc	20.22	0.12	13.05
N_0S_2	5.3	1.04	0.66ab	18.89	0.16	15.83
N_1S_0	5.9	1.13	0.68a	20.99	0.13	17.92
N_1S_1	5.7	1.14	0.64ab	20.10	0.16	17.80
N_1S_2	5.9	1.09	0.60bc	21.23	0.15	18.46
N_2S_0	6.1	1.16	0.60bc	21.58	0.14	19.23
N_2S_1	5.5	1.14	0.64ab	23.58	0.15	21.20
N_2S_2	5.8	1.14	0.63ab	21.92	0.14	18.78
N_3S_0	5.9	1.11	0.61bc	23.21	0.13	20.91
N_3S_1	5.4	1.13	0.69a	22.27	0.17	21.31
N_3S_2	6.0	1.16	0.66ab	25.76	0.16	23.04
$LSD_{0.05}$	–	–	0.064	–	–	–
Level of Significance	NS	NS	0.05	NS	NS	NS
CV (%)	6.61	4.28	7.75	9.24	21.46	12.58

In a column means followed by same letter are not significantly different at 5% level by DMRT.

NS =Non significant.

A. Nitrogen level (4): **a)** 0 kg N ha^{-1} (N_o), **b)** 120 kg N ha^{-1} (N_1) , **c)** 140 kg N ha^{-1} (N_2), **d)** 160 kg N ha^{-1} (N_3)

B. Sulphur level (3): **a)** 0 kg S ha^{-1} (S_o), **b)** 20 kg S ha^{-1} (S_1), **c)** 30 kg S ha^{-1} (S_2)

4.12.2 Organic matter

Organic manure in post harvest soil showed statistically non-significant differences due to the interaction of nitrogen and sulphur levels in BRRI dhan 28 (Table 17). The highest organic matter in post harvest soil (1.16%) was recorded from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}). On the other hand the lowest organic matter in post harvest soil (1.06%) was observed from N_0 S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Table 17).

4.12.3 Total Nitrogen

Total nitrogen in post harvest soil showed statistically significant differences due to the interaction of nitrogen and sulphur levels in BRRI dhan 28 (Table 17). The highest total nitrogen in post harvest soil (0.69%) was recorded from N_3S_1 (160 kg N ha^{-1} + 20 kg S ha^{-1}) which was statistically identical (0.68) with N_1S_0 (120 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combinations. On the other hand, the lowest total nitrogen in post harvest soil (0.56%) was obtained from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination (Table 17).

4.12.4 Available P

Available P in post harvest soil showed statistically non-significant differences due to the interaction of nitrogen and sulphur levels in BRRI dhan 28 (Table 17). The highest available P in post harvest soil (25.76 ppm) was recorded from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) and the lowest available P in post harvest soil (18.89 ppm) was observed from N_0S_2 (0 kg N ha^{-1} + 30 kg S ha^{-1}) (Table 17).

4.12.5 Exchangeable K

Exchangeable K in post harvest soil showed statistically insignificant due to the interaction of nitrogen and sulphur levels in BRRI dhan 28 (Table 17). The highest exchangeable K in post harvest soil (0.17 meq /100 g soil) was recorded from N_3S_1 (160 kg N ha^{-1} + 20 kg S ha^{-1}). On the other hand, the lowest exchangeable K in post harvest soil (0.10%) was obtained from N_0S_0 treatment combination (Table 17).

4.12.6 Available S

Available S in post harvest soil showed statistically non-significant differences due to the interaction of nitrogen and sulphur levels in BRRI dhan 28 (Table 17). The highest available S in post harvest soil (23.04 ppm) was recorded from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) and the lowest available S in post harvest soil (13.05ppm) was observed from N_0S_0 (0 kg N ha^{-1} + 20 kg S ha^{-1}) treatment combination (Table 17).

Chapter 5
Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was carried out at Sher-e-Bangla Agricultural University (SAU) Farm (Tejgaon series under AEZ No. 28), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh during the period of December 2007 to April 2008 to study the effect of nitrogen and sulphur on the growth, yield and quality of boro rice cv. BRRI dhan 28. The experiment was laid out in a randomized complete block design (RCBD), where the experimental area was divided into four blocks representing the replications to reduce soil heterogenetic effects. The treatments consisted of 4(four) levels of Nitrogen (0, 120, 140 and 160 kg ha^{-1}) designated as N_0, N_1, N_2 and N_3 respectively and 3 (three) levels of Sulphur (0, 20 and 30 kg ha^{-1}) designated as S_0, S_1 and S_2 respectively. The soil of the experimental field was silt loam having 6.8 pH, 1.19% organic matter, 0.08 % total N, 0.12 meq /100 g soil exchangeable K, 19.85 mg kg^{-1} available P and 14.40 mg kg^{-1} available S.

The seedlings of 40 days old were transplanted in the experimental plot on January 22, 2008. The crop was harvested on April 26, 2008 at full maturity. Ten hills were selected randomly from each plot to record the yield contributing characters. The grain and straw yields were recorded plot wise and expressed on 14% moisture basis. Grain and straw samples were analyzed for N, P, K and S content. The post harvest soil samples were also analyzed for pH, organic matter, total N, available P, exchangeable K and available S contents. The collected data on different parameters were statistically analyzed by F-test and the mean comparison was made by DMRT at 5% level. The salient result of the experiment is stated below.

The individual and combined effect of nitrogen and sulphur on growth, yield and nutrient status were studied. The result of the experiment revealed that the individual effect of different nitrogen levels were significant on plant height, number of effective tillers $hill^{-1}$, number of non effective tillers $hill^{-1}$, length of panicle, number of filled grains panicle^{-1}, number of sterile grains panicle^{-1}, grain yield and straw yield. With increasing levels of nitrogen the plant height, number of effective tillers hill^{-1}, length of panicle, number of filled grains panicle^{-1} and grain yield were increased.

Plant characters like plant height (87.4 cm) and number of effective tillers hill^{-1} (11.7) were found highest with N_2 (140 kg N ha^{-1}) and N_3 (160 kg N ha^{-1}) treatments, respectively and length of panicle was highest (22.2 cm) at N_1 (120 kg N ha^{-1}) treatment. The total number of filled grains panicle^{-1} (102.8) and grain yield (6.9 t ha^{-1}) were found to be the highest with N_3 (160 kg N ha^{-1}) treatment and straw yield (8.1 t ha^{-1}) with N_1 (120 kg N ha^{-1}) treatment. The yield retarding characters like number of non-effective tillers hill^{-1} and number of sterile grains panicle^{-1} were found to be the highest (3.6 and 19.5, respectively) with N_0 (0 kg N ha^{-1}) treatment. The lowest grain and straw yields (5.1 and 6.3 t ha^{-1}, respectively) were recorded in N_0 (0 kg N ha^{-1}) treatment.

The individual effect of different levels of sulphur was significant on most of the studied parameters except plant height and 1000-grain weight. The highest number of effective tillers hill^{-1} (11.9) and filled grains panicle^{-1} (90.1) were obtained from S_2 (30 kg S ha^{-1}) treatment. The highest grain yield (6.5 t ha^{-1}) and straw yield (7.8 t ha^{-1}) were recorded at S_2 (30 kg S ha^{-1}) treatment and the lowest grain yield (5.8 t ha^{-1}) and straw yield (7.2 t ha^{-1}) were recorded at S_0 (0 kg S ha^{-1}) treatment. The result revealed that the 30 kg S ha^{-1} was favourable for higher grain yield of this crop.

The plant characters viz. plant height, number of effective tillers hill^{-1}, panicle length and 1000-grain weight were not significantly affected by interaction of different levels of N and S. However, the tallest plant (89.5 cm) was observed from the treatment combination of N_2S_0 (140 kg N ha^{-1} + 0 kg S ha^{-1}) and the shortest plant (81.6 cm) was found from NoS_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) control treatment. The highest number of effective tillers hill^{-1} (13.7) was obtained from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment combination and that was followed by (13.42) with the N_2S_2 (140 kg N ha^{-1} + 30 kg S ha^{-1}) treatment combination. The lowest number of effective tillers $hill^{-1}$ (4. 7) was obtained from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination. The higher number of filled grains $panicle^{-1}$ (111. 9) was obtained from N_3S_1 (160 kg N ha^{-1} + 20 kg S ha^{-1}) treatment combination, which was statistically identical to N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}). The lowest number of filled grains $panicle^{-1}$ (63.7) was obtained from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination, which was statistically similar with N_0S_1 and N_0S_2 treatment combinations. The highest grain yield (7.4 t ha^{-1}) was obtained from N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment combination. The lowest grain yield (4.8 t ha^{-1}) was obtained from the control N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination. The highest straw yield (8.4 t ha^{-1}) was produced same by N_1 S_1 (120 kg N ha^{-1} + 20 kg S ha^{-1}) and N_1S_2 (120 kg N ha^{-1} + 30 kg S ha^{-1}) treatment combinations, which was statistically identical (8.3t ha^{-1}) to N_3 S_1 (160 kg N ha^{-1} + 20 kg S ha^{-1}) and N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment combinations and also simultaneously identical (8.2 t ha^{-1}) to N_2S_1 (140 kg N ha^{-1} + 20 kg S ha^{-1}) and N_2S_2 (140 kg N ha^{-1} + 30 kg S ha^{-1}) treatment combinations . The lowest straw yield (6.1 t ha^{-1}) was produced from N_0S_0 (0 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination.

The effect of different levels of N had significant effect on grain N and P and straw N, P, K and S concentrations. The K and S concentrations in grain were not significantly affected by different levels of N. At N_3 (160 kg N ha^{-1}) treatment the highest N and P concentrations in rice grain were recorded 0.89% and 0.34 %, respectively. The highest N, P and S concentrations in straw of 0.69%, 0.18% and 0.11%, were recorded at N_3 (160 kg N ha^{-1}) treatment. The highest K concentrations in grain (0.28%) and straw (1.32%) were obtained from N_2 (140 kg N ha^{-1}) treatment. The highest S concentration in grain (0.14%) was recorded from each of N_3 (160 kg N ha^{-1}) and N_1 (120 kg N ha^{-1}) treatments.

The application of different levels of S showed significant increases in grain and straw N contents. Similarly the concentration of P and S in grain and straw increased with increasing levels of S. The highest levels of N, P and S concentrations in grain were recorded in S_2 (30 kg S ha^{-1}) treatment and the highest grain-K concentration was observed in S_0 (0 kg S ha^{-1}) treatment. The highest straw-N, P and S concentrations were recorded in S_2 (30 kg S ha^{-1}) and highest straw-K concentration was observed in S_1 (20 kg S ha^{-1}) treatment. The combined effect of nitrogen and sulphur levels showed significant effect on grain and straw-K concentration while N, P and S contents remained unaffected. The N_2S_0 (140 kg N ha^{-1} + 0 kg S ha^{-1}) treatment combination resulted the highest grain and straw-K (0.30% and 1.31%, respectively) concentrations, which was statistically identical to N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment.

In case of nutrient uptakes in grain and straw, the effect of N treatment showed significant difference. With the increase of nitrogen levels, different levels of the nutrient (N, K and S) uptakes increased in both grain and straw of rice. The highest grain-N, P, K and S uptake (61.81, 23.60, 18.74 and 9.94 kg ha^{-1}, respectively) were recorded in N_3 (160 kg N ha^{-1}) treatment. The highest straw uptakes of N, P and S (55.01, 14.19 and 8.92 kg ha^{-1}, respectively) were recorded in N_3 (160 kg N ha^{-1}) treatment and highest straw-K uptake 105.08 kg ha^{-1} was found in N_2 (140 kg N ha^{-1}) treatment. The application of different levels of S significantly affected the uptakes of grain-N, P and straw-N, K, S while the uptakes of grain-K, S and straw P were not differed significantly. The N, P, K and S uptakes in grain and straw increased with increase of the levels of N and S. The highest N, P, K and S uptake in grain were 57.15, 21.41, 17.13 and 9.14 kg ha^{-1}, respectively in S_2 (30 kg S ha^{-1}) treatment. The highest amount of N (53.81 kg ha^{-1}), P (13.38 kg ha^{-1}), K (93.59 kg ha^{-1}) and S (7.94 kg ha^{-1}) uptakes in straw were recorded respectively in S_2 (30 kg S ha^{-1}) treatment. The highest N (68.27 kg ha^{-1}), P (26.32 kg ha^{-1}), K (21.13 kg ha^{-1}) and S (10.30 kg ha^{-1}) uptakes in grain were recorded from the combined effect of nitrogen and sulphur at N_3 S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment. The increasing level of N and S in treatment combination increased the uptake of N, P, K and S by straw. The highest amount of N (61.34 kg ha^{-1}) and S (9.95 kg ha^{-1}) uptake in straw were recorded from the combined effect of nitrogen and sulphur at N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment.

The chemical properties of post harvest soil were affected by N application. The highest pH of post harvest soil (5.8) was found from N_3 (160 kg N ha^{-1}) and the lowest pH in post harvest soil (5.3) was recorded from N_0 (0 kg N ha^{-1}). The highest organic matter in post harvest soil (1.15%) was recorded from N_2 (140 kg N ha^{-1}) and the lowest organic matter (1.08%) was observed from N_0 (0 kg N ha^{-1}) treatment. The highest level of total nitrogen (0.65%) , available P (23.75 ppm), exchangeable K (0.15 meq /100 g soil) and available S (21.75 ppm) in post harvest soil were recorded in N_3 (160 kg N ha^{-1}) treatment. On the other hand, the lowest exchangeable K in post harvest soil (0.131 meq /100 g soil) was obtained from N_0 treatment. By considering the effects of sulphur levels the highest pH of post harvest soil (5.8) was found from S_0 (0 kg S ha^{-1}) and the lowest pH in post harvest soil (5.4) was recorded from S_1 (20 kg S ha^{-1}) treatment. The highest level of organic matter (1.14%) and total nitrogen (0.64%) in post harvest soils were recorded in S_1 (20 kg S ha^{-1}) treatment. The highest concentrations of available P (21.95 ppm), exchangeable K (0.15 meq /100 g soil) and available S (19.03 ppm) in post harvest soils were recorded in S_2 (30 kg S ha^{-1}) treatment. The concentrations of total N, available P, K and S in post harvest soils were increased with increase in levels of N and S. The post harvest soils with N_3S_2 (160 kg N ha^{-1} + 30 kg S ha^{-1}) treatment resulted the statistically highest or identical concentrations of total N and available P, K and S.

From above discussion it can be concluded that application of 160 kg N ha^{-1} with 30 kg S ha^{-1} was the best treatment for improving yield, yield contributing characters and quality of boro rice cv. BRRI dhan 28. Further field studies with different AEZs are needed for confirm this findings.

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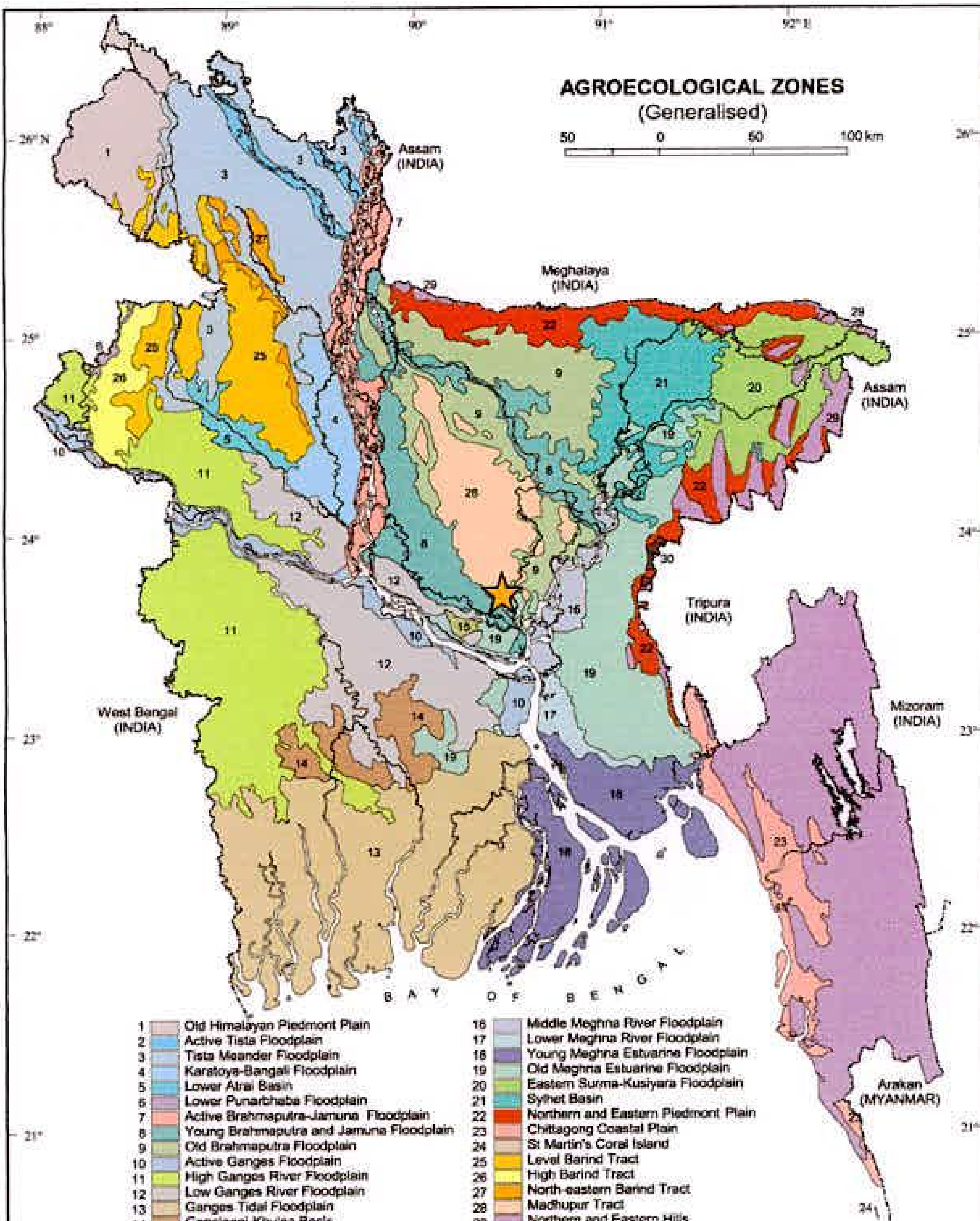
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



★ The experimental site under study

APPENDICES

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

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

* Monthly average,

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