INFLUENCE OF NITROGEN AND SULPHUR ON THE GROWTH AND YIELD OF BRRI dhan63 IN BORO SEASON

TABASSUM SAMIA

DEPARTMENT OF SOIL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

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INFLUENCE OF NITROGEN AND SULPHUR ON THE GROWTH AND YIELD OF BRRI dhan63 IN BORO SEASON

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TABASSUM SAMIA

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Approved by:

Dr. Alok Kumar Paul	**A.T.M. Shamsuddoha**
Professor	Professor
Supervisor	Co-Supervisor

DEPARTMENT OF SOIL SCIENCE

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **'Influence of Nitrogen and Sulphur on the Growth and Yield of BRRI dhan63 in boro season'** submitted to the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SOIL SCIENCE**, embodies the results of a piece of bonafide research work carried out by **Tabassum Samia**, Registration No. **15-06931** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

.

Dated:
Dhaka, Bangladesh

Dr. Alok Kumar Paul

Professor
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

Supervisor

Dedicated to my

Beloved Parents

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INFLUENCE OF NITROGEN AND SULPHUR ON THE GROWTH AND YIELD OF BRRI dhan63 IN BORO SEASON

ABSTRACT

The experiment was conducted during the period from 13thDecember 2015 to May 2016atboro season in the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh to find out the effect of different levels nitrogen and sulphur on the growth and yield of BRRI dhan63. As planting material BRRI dhan63 also known as 'Soru balam' was used. The experiment was comprised of two factors as Factor A: Levels of N (3 levels)- N_0: 0 kg N ha^{-1}(control), N_1: 100 kg N ha^{-1}, N_2: 140 kg N ha^{-1} and Factor B: Levels of S (3 levels)- S_0: 0 kg S ha^{-1}(control), S_1: 10 kg S ha^{-1}, S_2: 15 kg N ha^{-1}.The experiment was laid out in a randomized complete block design (RCBD) with three replications.Data were recorded on different growth and yield attributes and nutrient status of post-harvest soil and significant variation was observed for different treatment. In case of nitrogen, at 30, 50, 70, 90 DAT and harvest, the tallest plant (39.89, 59.45, 77.45, 85.74 and 89.93 cm, respectively) was recorded from N_1, whereas the shortest plant (34.89, 54.64, 72.30, 80.11 and 80.68 cm, respectively) was found from N_0. The highest grain yield (5.48 t ha^{-1}) was found from N_1, while the lowest grain yield (4.46 t ha^{-1}) was observed from N_0. The highest total nitrogen (0.053%) was found from N_1, while the lowest (0.013%) was observed from N_0.The highest available S (22.05 ppm) was found from N_1, while the lowest (19.57 ppm) was observed from N_0. For sulphur, at 30, 50, 70, 90 DAT and harvest, the tallest plant (39.90, 59.62, 76.88, 85.36 and 91.85 cm, respectively) was observed from S_2, while the shortest plant (34.88, 54.39, 72.40, 75.26 and 77.35 cm, respectively) was observed from S_0. The highest grain yield (5.37 t ha^{-1}) was recorded from S_2, whereas the lowest grain yield (4.35 t ha^{-1}) was observed from S_0.The highest straw yield (6.80 t ha^{-1}) was recorded from S_2, whereas the lowest straw yield (6.01 t ha^{-1}) was observed from S_0.The highest total nitrogen (0.045%) was recorded from S_2, whereas the lowest (0.032%) was found from S_0.The highest available S (22.70 ppm) was recorded from S_2, whereas the lowest (18.76 ppm) was found from S_0. Due to the interaction effect of nitrogen and sulphur, at 30, 50, 70, 90 DAT and harvest, the tallest plant (42.99, 63.52, 80.38, 87.85 and 99.44 cm, respectively) was observed from N_1S_2 and the shortest plant (30.30, 51.70, 69.71, 72.46 and 73.68 cm, respectively) was recorded from N_0S_0.The highest grain yield (5.89 t ha^{-1}) was found from N_1S_2, while the lowest grain yield (4.13 t ha^{-1}) was recorded from N_0S_0.The highest straw yield (7.33 t ha^{-1}) was found from N_1S_2, while the lowest straw yield (5.88 t ha^{-1}) was recorded from N_0S_0.The highest total nitrogen (0.067%) was found from N_1S_1, while the lowest (0.008%) was observed from N_0S_0.The highest available S (24.59 ppm) was found from N_2S_2, while the lowest (16.99 ppm) was observed from N_0S_0.It was revealed that application of 100 kg N ha^{-1} and10 kg S ha^{-1} was more potential in regarding yield contributing characters and yield of BRRI dhan63.

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CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) being the staple food for nearly half of the world's population(FAO, 2004)and placing among the three leading crop produced in world (IRRI, 2009) can easily be called as global staple food. More than 3.5 billion people in the world consume rice which provides 20% of their daily calories (GRiSP, 2013;Fairhurst and Dobermann, 2002).Rice can be grown in a wide range of climate from the wettest areas to driest desert, from low land to dry land, a broad range of solar radiation and temperature (Iizumi and Ramankutty, 2015). As a sub-tropical country, rice is the most extensively cultivated cereal crop in Bangladesh, according to BRRI about 75% of the total cropped area and over 80% of the total irrigated area of Bangladesh is cultivated under rice (Shelley *et al.* 2016;BRKB). Rice is cultivated in 11.527 million hectares of which Boro rice covers about 48.97% of total rice area which is 33.14 % of gross area and contributes to 38.14% of total rice production in the country (BBS, 2012). Again Rice covers 11.527 million hectares of which Boro rice takes 48.97% of total rice area contributing 38.14% of total rice production in the country (BBS, 2012).

This 1000 years old cultivation system provides benefit for millions of people. Butrice production is decreasing due to high population pressure cultivation of improved varieties, narrow genetic background, overuse of pesticide, oversimplified crop management,weak extension system and improper nutrient management are the some of the reasons behind this (GRiSP, 2013).As there are several factors behind the cession of rice growth improper nutrition management plays a key role behind this. It is reported that chemical fertilizers today hold the key to success of production systems of Bangladesh agriculture being responsible for about 50% of the total crop production (BARC, 1997). Judicious use of fertilizers can reduce nutritional imbalance upto a great level. On an average to produce one tone of grain of high-yielding varieties of rice, remove about 22 kg N, 7 kg P_2O_5, 32 kg K_2O, 5 kg MgO,4 kg CaO, 1 kg S and 40 g Zn from the soil (Chaudhary et *al.,* 2007). To adjust nutrition supply for the next crop additional application of chemical fertilizer is essential. Researchers from the International Rice Research Institute (IRRI) have analyzed a numberof long-term experiments on continuous, irrigated rice systems in Asia. They suggest thatunder continuously submerged conditions, the N supplying capacity of the soil is reduced, leading to a decreased yield contribution from nutrient inputs (Dobermann and Cassman, 1996). For these reason judicious nutrient management become an important factor for improved rice production.

Nitrogen is an essential plant nutrient being a component ofamino acids, nucleic acids, nucleotides, chlorophyll, enzymes, and hormones. This macronutrient is needed in greatest quantities in rice. N affects all the plant growth parameter and improves grain yield and grain quality through higher tillering, leaf area development, grain formation, grain filling, and protein synthesis. N is highly mobile within the plant and soil. So absence of N lower than plant requirement shows fastest deficiency symptom in plant(Dobermann and Fairhurst, 2000). Nitrogen deficiency often results in stunted growth, slow growth, and chlorosis. Nitrogen deficient plants also exhibit a purple appearance on the stems, petioles and underside of leaves from an accumulation of anthocyanin pigments (Chaudhuri, 2015). Application of proper doses of N is essential for optimum yield but excess amount of application will enhance vegetative growth (Kumar *et al.,* 1995) thus resulting reduced vegetative growth.The spread of modern rice varieties is associated with an increased use of chemical fertilizer but as N being a volatile fertilizer most of the applied N is easily or washed with water. An increase in the yield of rice by 70 to 80% may be obtained from proper application of N-fertilizer (IFC, 1982).

Sulphur is one of the sixteen essential plant nutrients and ranks fourth major nutrient next to N, P and K. Like other plant nutrients S plays a certain specific functions in the plant growth. Some of them includes Formation of chlorophyll, protein production, primarily because S is a constituent of three S-containing amino acids (cysteine, cystine and methionine), which are the building blocks of protein. About 90% of plant S is present in these amino acids. Activation of enzymes, increases crop yield and improves produce (Rahman *et al*., 2007). Deficiency symptom of S includes: Pale green plants, light green colored young leaves. The tips of young leaves may become chlorotic. paler yellow leaves (Islam *et al.* 1978; Dobermann *et al.* 1998;Blair and Lefroy, 1987). Today, Sulfur is becoming more of a limiting nutrient in crop production than in the past. Reasons behind this includes increasing need of higher crop yields which require more sulfur, reduced amounts of atmospheric sulfur fallout in rainfall and reduced soil sulfur reserves from organic matter losses due to mineralization and erosion(Tandon and Tiwari, 2007). Sulphur requirement of rice varies according to the nitrogen supply.

Keeping in the view of the importance of rice and role of nitrogen and sulphur, therefore, the present research work has been undertaken in Boro season with the following objectives:

- To evaluate the effects of different levels of nitrogen and sulphur fertilizer on the yield of BRRI dhan63; and
- To develop a suitable dose of nitrogen and sulphur fertilizer on the growth and development of BRRI dhan63.

CHAPTER 2

REVIEW OF LITERATURE

This chapter contains a brief and relevant review of many researchers conducted to investigate the effect of N and P on the growth and yield of different rice verities in Bangladesh and other verities of rice. These reviews are cited in this chapter under the following headings and sub headings:

2.1 Effect of Nitrogen fertilizer on yield contributing characters and yield of rice

Dunn *et al.* (2016) conducted an experiment with two semi-dwarf rice varieties which were drill-sown and nitrogen (N) fertilizer (urea) was applied at different rates at the 4-leaf stage before permanent water (pre-PW) and at panicle initiation (PI). They found that the apparent N recoveries were 59% for N applied pre-PW and 25% for N applied at PI, averaged across years, sites, varieties and N rates. Grain yield increased significantly with increased rate of N applied at both stages, but the rate of increase from N applied at PI decreased as the rate of N applied pre-PW increased.

Haque and Haque (2016) treated new rice variety (BUdhan 1) with six levels of nitrogenous fertilizer 0, 20, 40, 60, 80 and 100 kg N ha^{-1} .Resultsrevealedthat the growth of the new rice variety favored at higher levels of applied nitrogen and the highest grain yield (5.36 t·ha−1) was found when the variety was fertilized with 60 kg N ha^{-1}.

Chamely *et al.* (2015) conducted a field experiment with three varieties viz., BRRI dhan28 , BRRI dhan29 and BRRI dhan45 to study the effect of variety rate of nitrogen on the performance of Boro rice. They found that highest grain yield (5.58 t ha^{-1}) was obtained from 200 kg N ha^{-1}.

Dunn *et al.* (2014)conducted an experiment with three varities of rice to evaluate Nitrogen timing and rate effects on growth and grain yield. The results from this research show that applying 100 kg N ha^{-1} before PW for rice grown under DPW was the best N-management option for the experimental fields.

Tabar Y.S. (2012) conducted an investigation to find out the effect of nitrogen and phosphorus fertilizer on growth and yield in rice cultivar Tarom Hashemi. The results showed that tiller number, fertile tiller, total grain, 1000-grain weight and yield increased significantly with nitrogen and phosphorus fertilizer. Application of higher N-fertilizer 150 kg/ha showed a positive respond.

Hirze *et al.* (2011) conducted a study on nutritional management in rice in two locations of Chile. By applying N rates of 80, 100, 120, 140, and 160 kg ha^{-1} in different development stages, yield was increased with N rates higher than 120 and 140 kg ha^{-1}. Moreover, higher productivity with split N fertilization was 33% of N at sowing, 33% at tillering, and 34% at panicle initiation or 50% of N at sowing and 50% at panicle initiation.

Sathiya and Ramesh(2009) observed application of 150 kg N ha^{-1} in four gave higher tillers (361 m^{-2}), plant height (77.0 cm), dry matter at flowering (5.20 t ha^{-1}) and grain yield (2827 kg ha^{-1}) and concluded four splits are suitable nitrogen management technique in aerobic rice cultivation at Coimbatore.

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

Ahmed *et al.* (1998) found that by increasing N level increased grain and straw yield of selected rice varieties (BR22,BR23 and Nizersail). Where grain yield was highest in BR23 (5.08 tha) followed by BR22 (4.59 t/ ha).

Singh *et al.* (1998) conducted an experiment with three hybrids KHR 1, Pro Agro 103 and MGR 1 using Jaya and Rasi as standard checks at four levels of N (0, 60, 120, and 180 kg ha-1). They observed that the varieties responded linearly to the applied N level up to 120 kg ha-1.

Perez *et al.* (1996) said that Rice yields of 10 and 6 t/ha can be achieved in the humid tropics during the dry and wet seasons, respectively. Late nitrogen (N) fertilizer application at flowering at the International Rice Research Institute (IRRI) farm often results in increased rough rice yield. Again the combined effects of N application at flowering resulted in a 30-60% increase in head-rice protein.

Adhikary and Rhaman (1996) reported that rice grain yield ha^{-1} showed significant effect with various treatments of N. The highest yield was obtained from 100 kg N ha^{-1} (4.52 t ha^{-1}) followed by 120 kg N ha^{-1}(4.46 t ha^{-1}) and 80 kg N ha-1 (4.40 t ha^{-1}).

Khanda and Dixit (1996) reported that the increased levels of applied nitrogen significantly influenced the grain yields. They found that maximum grain and straw yields of 4.58 and 6.21 t ha-with the application of 90 kg N ha^{-1}.

Kumar *et al.* (1995) conducted a field experiment with four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and reported that with the increase of N doses from 0-120 kg N ha^{-1} productive tillers increased significantly, but above this dose productive tillers were not statistically significant.

Awasthi and Bhan (1993) reported that by increasing levels of nitrogen up to 60 kg ha^{-1} influenced LAI and dry matter production of rice.

Patel and Upadhaya (1993) observed significant increase of rice plant with increasing rate of N up to 150 kg ha^{-1}.

Kropff *et al.* (1993) conducted a field study to find out the yield potential of rice varieties and implication for N management which were evaluated in a series of field studies. Results revealed that yield levels of 6 t ha^{-1} in the wet season and 10 t ha^{-1} in the dry season can be obtained in thetropics only when the N supply from soil and fertilizer isadequately maintained at key growth stages.

2.2 Effect of Sulphur fertilizer on yield contributing characters and yield of rice

Singh and Singh (2014) conducted a field experiment on wheat-rice cropping system to find out the reasons behind declining productivity. Field experiment was with three sulphur levels (15, 30 and 45 kg ha^{-1}) along with control. With increased levels of sulphate agronomic efficiency and apparent sulphur recovery decreased but percent response increased. Sulphurof application showed the positive sulphur balance while it was negative under control.

Shivay *et al.* (2014) conducted a field experiment to study the effect of levels and sources of sulfur (S) on cultivar 'Improved Basmati Rice' (Pusa 1460). Response to S application was obtained up to 45 kg S ha^{-1} and Bentonite-S out-performed other than three sources, namely, gypsum, ordinary super phosphate (OSP) and elemental S in several growth characters, yield attributes, S concentration, and uptake but not in grain yield.

Singh *et al.* (2012) conducted a field experiment to ascertain the role of sulphur and zinc on rice. Results showed that highest uptake of P (91.1 kg/ha) and K (150.4 kg/ha) was recorded in the plot supplemented with no Zn and sulphur at 40 kg ha^{-1}

Dixit *et al.* (2012) conducted a field experiment with different S and Zn doses on Narendra Sankar Dhan-2. They found that yield increased upto 40 kg S application (59.69 kg ha^{-1} grain yield 74.45 kg ha^{1} straw yield) and with higher application yield became almost constant.

Crusciol *et al.* (2012) the effect of S on mineral nutrition on upland rice growth and found that intermediate and modern cultivars are more responsive to S fertilization.

Moreover, S fertilization allows significant increases in upland rice growth and increased yield.

Jawahar and Vaiyapuri (2011) conducted a field experiment to study the effect of sulphur and silicon fertilization on yield, nutrient uptake and economics of rice. They designed the treatments in randomized complete block design with four levels of sulphur (0, 15, 30 and 45 kg ha^{-1}) and silicon. Among different levels of sulphur 45 kg ha^{-1} gave highest yield (grain and straw) and nutrient uptake (NPKS) of rice.

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

Bhuvaneswari et al. (2007) conducted a field experiment during kharif season, to study the effect of sulphur (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. 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}.

Oo et al. (2007) conducted a field experiment to study the effect of N and S levels on the productivity and nutrient uptake of aromatic rice and concluded that aromatic rice requires 20 kg S $ha^{-1}$for increased productivity and uptake of N, P, K and S under transplanted puddled conditions.

Lunde *et al.* (2008) conducted an experiment on the effect of sulphur starvation on rice plants' growth parameters such as photosynthesis, carbohydrate metabolism, and oxidative stress protective pathways which are directly related to yield. Results revealed that, photosynthetic apparatus was severely affected under sulfur deficiency. The Chlorophyll content was reduced by 49% resulting a decreased yield from S received plants.

Rahman *et al.* (2008) conducted a field experiment at Bangladesh Agricultural University, Mymensingh in Boro season to evaluate the effect of S and Zn on rice on BRRI dhan29. With single supply of S highest grain yield was 5.57 tha^{-1} and 7.25 tha^{-1} straw yield.

Rahman *et al.* (2007) conducted a field experiment on a Non-Calcareous Dark Gray Floodplain Soil (Sonatola series) at BAU, farm, Mymensingh during Boro season of. The soil was silt loam having pH 6.8 to evaluate the effect of S applied at different level. Yield was increased level of S, highest grain yield 5.54 tha^{-1} and straw yield 6.95 kgha^{-1}when S was applied 40 kgha^{-1}. A decrease in yield was observed at higher dose of S.

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

Sarkunan *et al.* (1998) conducted a pot experiment to find out the effect of P and S on yield of rice under flooded condition, on a P and S deficient sandy loam soil. They found Sulphur addition at 25 mg/kg resulted in 9% increase in grain yield.

Williams & Wilkins (1974) observed the effect of sulfur supply on the optimum concentration of nitrogen in leaves of the rice plant and came to the conclusion that adequate amount of S supply is essential for optimum N use in rice plant.

2.3 Combined Effect of Nitrogen and S fertilizer on yield contributing characters and yield of rice

Chaturvedi (2005) conducted a experiment with hybrid rice variety ‘Proagro 6207 during 2002 and 2003 and found that all the growth characters, yield parameters and grain nitrogen (N) increased significantly with an application of sulphur-containing nitrogen fertilizer- Super Net. These results were statistically at par with where ammonium sulphate nitrate was applied. In this series of experiment, non-sulphur-containing nitrogen fertilizer, urea gave lowest yield and grain.

Shivay *et al.* (2007) found that grain, straw and biological yields increased significantly with N and S levels in Pusa Sugandh 5 rice. From their experiment they concluded that based on the total N uptake (grain + straw) there was 49.9, 63.9 and 70.4% increase in the N uptake over the control with 50, 100 and 150 kg N, respectively. From this field study it can be concluded that aromatic rice requires 100 kg N and 20 kg S ha^{-1} for increased productivity and uptake of N,P, K and S, under transplanted puddled condition.

Basumatary and Talukdar (2007) conducted a field experiment to find out the direct effect of sulphur alone and in combination with graded doses of farmyard manure on rapeseed 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 sulphur levels up to 45 kg ha-1. The lowest N: S ratio was observed upon treatment with 45 kg S ha-1 alone with 3.0 tonnes farmyard manure per hectare.

Habtegebrial *et al.* (2013) conducted a study in 2009/10 to investigate the effect of N and S fertilization on yield, N uptake, N use efficiency, and grain protein content of the upland NERICA-4 rice variety. They concluded that the leaf and grain N concentration, total DM and grain N-yield, and the grain protein content increased with N applications, but they were significantly enhanced when N was fertilized with S.

Dash *et al.* (2015)conducted field experiment for two years in Inceptisol of coastal Odisha to investigate the integrated effect of major (N, P, K), secondary (S) and micronutrient (B and Zn) on yield, nutrient accumulation and uptake by rice. Results revealed that omission of S reduced grain yield by 25.1%.

CHAPTER 3

MATERIALS AND METHODS

This materials and methodschapter comprisea short description of the location of experimental site, soil and climatic condition of the experimental area, crops,treatments, materials used for the experiment, design of the experiment, data collection and data analysis procedure. The details are presented below under the following headings –

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment started in 13th December 2015 which lasted upto May 2016 inthe boro season.

3.1.2 Experimental site

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude and at an elevation of 8.2 m from sea level (Anon., 1989).

3.1.3 Agro-Ecological Region

The experimental field belongs to the Agro-ecological zone of “The Modhupur Tract” AEZ-28(UNDP, 1998).This region is a complex of relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain.

3.1.4 Soil characteristics of the experimental site

The soil of the experimental site is Silty Clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH is 6.2 and have organic carbon 0.45%. The experimental area is flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details have been presented in Table I.

Table I. Characteristics of experimental field soil as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Research Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	6.2
Organic matter (%)	1.13
Total N (%)	0.03
Available S (ppm)	23

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

3.1.5 Climate and Weather

The area of the experimental region is situated in the sub tropical climatic zone and is characterized by low temperature and ample sunshine from November to February during Rabi season covering October to March. The Kharif Season covers April to September is characterized by heavy rainfall during the month of April to September and scanty of rain during the rest of the year (SRDI,1991). Details have been presented in table II

Table II. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2015 to March 2016

Month	*Air temperature (ºc)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2015	25.8	16.0	78	00	6.8
December, 2015	22.4	13.5	74	00	6.3
January, 2016	24.5	12.4	68	00	5.7
February, 2016	27.1	16.7	67	30	6.7
March, 2016	31.4	19.6	54	11	8.2

* Monthly average,
* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1207

3.2 Experiment details

3.2.1 Planting material

As planting material BRRI dhan63 also known as 'Soru balam' was used.The variety was developed from the cross between BRRI dhan28 and Iranian rice Amul-3 at Bangladesh Rice Research Institute. Following pedigree selection this BRRI dhan63 was invented and released in 2013 which got approval from National Seed Certification Agencyto be cultivated in boro season at the year 2014(BRRI, 2016).

3.2.2 Land preparation

In 'saturate' condition the land was ploughed with the tractor drawn disc plough. Ploughed soil was brought into desirable fine tilth by 4 ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds were removed.

3.2.3 Treatment of the experiment

The experiment was comprised of two factors.

Factor A: Levels of N (3 levels)

i. N_0: 0 kg N ha^{-1}(control)

ii. N_1: 100 kg N ha^{-1}

iii. N_2: 140 kg N ha^{-1}

Factor B: Levels of S (3 levels)

i. S_0: 0 kg N ha^{-1}(control)

ii. S_1: 10 kg N ha^{-1}

iii. S_2: 15 kg N ha^{-1}

There were in total 9 (3×3) treatment combinations such as N_0S_0, N_0S_1, N_0S_2, N_1S_0, N_1S_1, N_1S_2, N_2S_0, N_2S_1 and $N_2S_2$with 3 replications R_1, R_2, R_3.

3.2.4 Experimental design and layout

The experiment was laid out in a randomized complete block design (RCBD), where the experimental area was divided into three blocks representing the replications to reduce soilheterogeneity. Each block was divided into nine unit plots as treatments combinations.Total treatment combination: 3 x 3 = 9with raised bunds around. Thus the total numbers of plots were 27. Unit plot size was 3×2= 6m^2 with 1m border distance.

3.3 Growing of crops

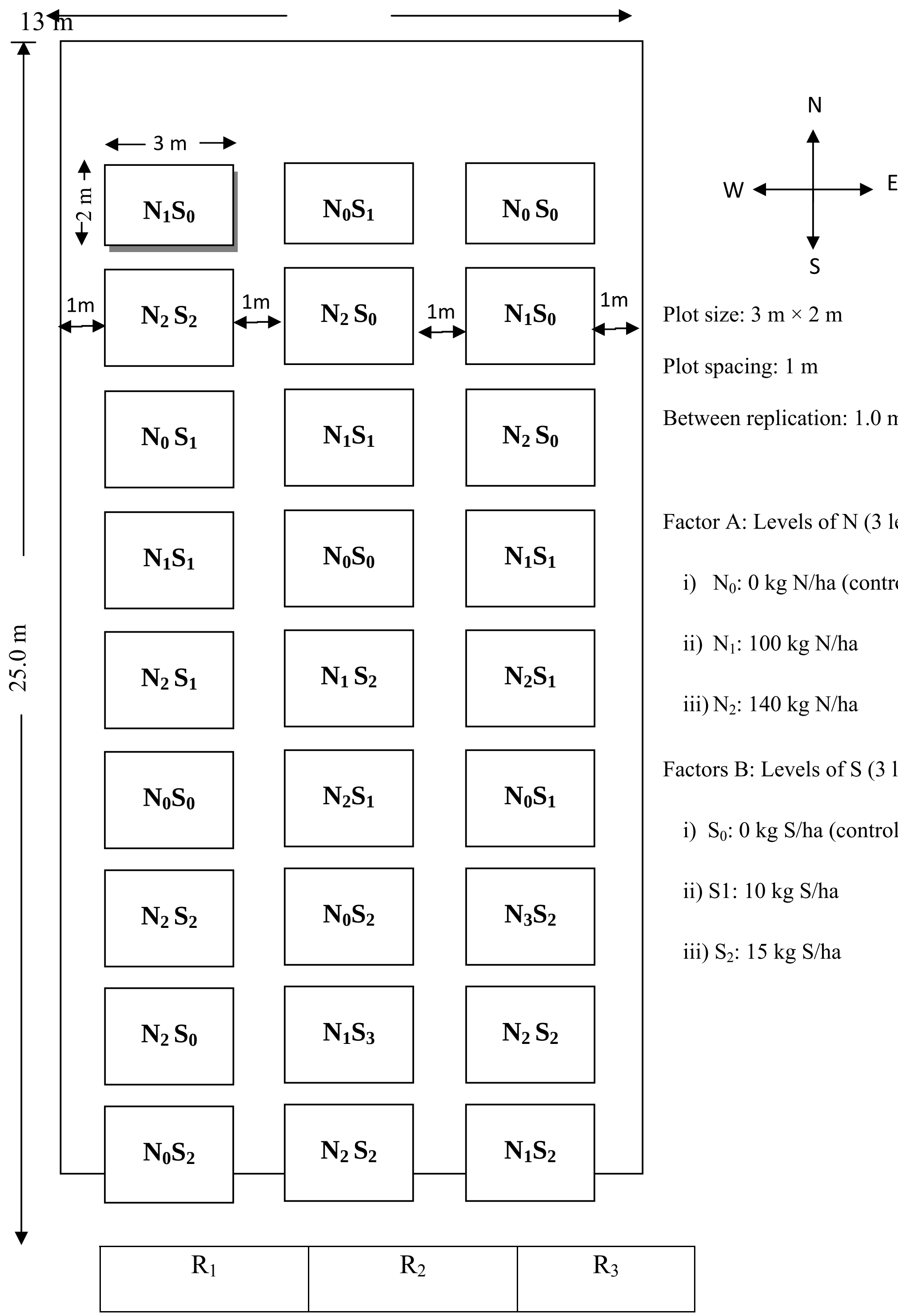
3.3.1 Fertilizer application

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MoP, Gypsum, zinc oxide and borax respectively were applied. Gypsum acted as a single source of S.The one third amount of urea and entire amount of TSP, MoP, gypsum, zinc oxide were applied during the final preparation of land. Rest urea was applied in two equal installments at tillering and panicle initiation stages.The dose and method of application of fertilizers are presented in Table III.

Table III. Dose and method of application of fertilizers in rice field

Fertilizers	Dose ha^{-1}	Application (%)		
		Basal	1st Installment	2nd Installment
Urea	150 kg	33.33	33.33	33.33
TSP	60 kg	100	-	-
MoP	90 kg	100	-	-
Gypsum	As per treatment	100	-	-
Zinc oxide	As per treatment	100	-	-
Borax	10 kg	100	-	-

Source: BRRI, 2013 (Adunik Dhaner Chash)



Plot size: 3 m × 2 m

Plot spacing: 1 m

Between replication: 1.0 m

Factor A: Levels of N (3 levels)

i) N_0: 0 kg N/ha (control)

ii) N_1: 100 kg N/ha

iii) N_2: 140 kg N/ha

Factors B: Levels of S (3 levels)

i) S_0: 0 kg S/ha (control)

ii) S1: 10 kg S/ha

iii) S_2: 15 kg S/ha

Figure 1. Layout of the experimental plot

3.3.2 Raising of seedlings

The seedlings of rice were raised wet-bed methods. Seeds were soaked for 95 % germination during 13th December 2015 and incubated for 48 hour and then were sown on a well-prepared seedbed.

3.3.3 Transplanting

Forty days old seedlings of BRRI dhan63 were carefully uprooted from the seedling nursery and transplanted on 25th January, 2016 in well puddle plot. Two or three seedlings per hill were used following a spacing of 20 cm × 15 cm. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings whenever required.

3.3.4 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.

3.3.5 Irrigation

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

3.3.6 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.

3.3.7 Insect and pest control

Rice plant was infested with cut worms (*Spodoptera litura*) and rice stem borer (*Scirpophaga incertulas*). For this Insecticide was applied 2nd March 2016 to control this.

3.4 Crop harvest

The crop was harvested at full maturity when 80-90% of the grains were turned into straw colored on 9th May 2016. The crop was cut at the ground level and plot wise crop was bundled separately and brought to the threshing floor.

3.5 Collected data on yield components

3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 30, 50, 70, 90 days and at 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.

3.5.2 Effective tiller hill^{-1}

The total number of effective tiller 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.

3.5.3 Non-effective tiller hill^{-1}

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

3.5.4 Total tiller hill^{-1}

The total number of tiller 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.

3.5.5 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.

3.5.6 Filled grain panicle^{-1}

The total numbers of filled grain 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 panicle^{-1}was recorded.

3.5.7 Unfilled grain panicle^{-1}

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

3.5.8 Total grain panicle^{-1}

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

3.5.9 Weight of 1000 seeds

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

3.5.10 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1m^{-2}area and five sample plants were added to the respective unit plot yield to record the final grain yield plot^{-1}and finally converted to tha^{-1}.

3.5.11 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of central 1m^{2}area and five sample plants were added to the respective unit plot yield to record the final straw yield plot^{-1} and finally converted to t ha^{-1}.

3.5.12 Biological yield

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

Biological yield = Grain yield + Straw yield.

3.5.13 Harvest index

The harvest index was calculated with the following formula:

Harvest index = (Grain yield ×100) ÷ Biological yield

Biological yield = Grain yield + Biological yield

3.6 Post-harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil samples of each plot was air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.7 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. organic matter, pH, total N and available P and exchangeableP contents. The soil samples were analyzed by the following standard methods as follows:

3.7.1 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 as described by (Page *et al.,* 1982).

3.7.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method. 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_3PO4 and to titrate the excess $K_2Cr_2O_7$ 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).

3.7.3 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 200^0C and added 3 ml $H_2O_2$and then heating at 360^0C 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_3indicator 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:

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

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

3.7.4Available 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 solution (20 ppm S as K_2SO_4in 6N HCl) and $BaCl_2$crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths

3.7.5 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH8.5 (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 with the standard P curve (Page *et al*., 1982). **3.7.6**

3.7.6 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).

3.8Statistical analysis

The data obtained for different parameters were statistically analyzed using MSTAT-C computer program to find out the significant difference of different treatments on yield contributing characters, yield and soil properties of BRRI dhan63. 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

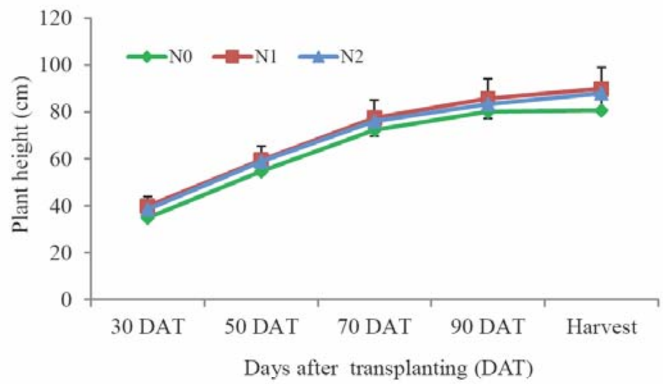
The experiment was conducted to study the effect of different levels nitrogen and sulphur on the growth and yield of BRRI dhan63. The analyses of variance (ANOVA) of the data on different yield and yield attributes and nutrient status of post harvest soil are presented in Appendix II-V. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Yield contributing characters and yield of rice

4.1.1Plant height

Statistically significant variation was recorded for plant height of BRRI dhan63 due to different levels of nitrogen at 30, 50, 70, 90 DAT (days after transplanting) and at harvest (Appendix II). Data revealed that at 30, 50, 70, 90 DAT and harvest, the tallest plant (39.89, 59.45, 77.45, 85.74 and 89.93 cm, respectively) was recorded from N_1 (100 kg N ha^{-1}) which was statistically similar (38.56, 58.84, 76.06, 83.25 and 87.96 cm, respectively) to N_2 (140 kg N ha^{-1}), whereas the shortest plant (34.89, 54.64, 72.30, 80.11 and 80.68 cm, respectively) was found from N_0 i.e. control condition (Figure 2). It was revealed that with the increase of nitrogen fertilizer, plant height was increased upto a certain level then decreased. Optimum nitrogen (N) is essential for vegetative growth but excess N may cause excessive vegetative growth, prolong the growth duration and delay crop maturity with reduction in grain yield. Dunn *et al.* (2016) reported that plant height increased significantly with increased rate of N as a certain level.

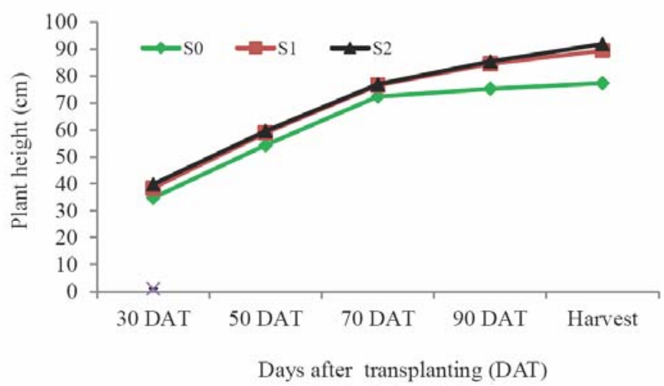
Plant height of BRRI dhan63 varied significantly for different levels of sulphur at 30, 50, 70, 90 DAT and harvest (Appendix II). At 30, 50, 70, 90 DAT and harvest, the tallest plant (39.90, 59.62, 76.88, 85.36 and 91.85 cm, respectively) was observed from S_2 (15 kg S ha^{-1}), which was statistically similar (38.56, 58.92, 76.54, 84.47 and 89.36 cm, respectively) to S_1 (10 kg S ha^{-1}), while the shortest plant (34.88, 54.39, 72.40, 75.26 and 77.35 cm, respectively) was observed from S_0 (0 kg S ha^{-1}) (Figure 3). It revealed that with the increase of application of sulphur plant height showed increasing trend but after a certain level plant height was increased very slowly. Data revealed that with the increase of application of sulphur nutrient plant height showed increasing trend. Crusciol *et al.* (2012) reported that S fertilization allows significant increases in plant height of rice.



N_0: 0 kg N ha^{-1} (control) N_1: 100 kg N ha^{-1}

N_2: 140 kg N ha^{-1}

Figure 2. Effect of different levels of nitrogen on plant height of BRRI dhan63. Vertical bars represent LSD value.



S_0: 0 kg S ha^{-1} (control) S_1: 10 kg S ha^{-1}

S_2: 15 kg S ha^{-1}

Figure 3. Effect of different levels of sulphur on plant height of BRRI dhan63. Vertical bars represent LSD value.

Combined effect of different levels of nitrogen and sulphur showed significant variation on plant height of BRRI dhan63 at 30, 50, 70, 90 DAT and harvest (Appendix II). At 30, 50, 70, 90 DAT and harvest, the tallest plant (42.99, 63.52, 80.38, 87.85 and 99.44 cm, respectively) was observed from N_1S_2 (100 kg N ha^{-1} and 15 kg S ha^{-1}) and the shortest plant (30.30, 51.70, 69.71, 72.46 and 73.68 cm, respectively) was recorded from N_0S_0 (0 kg N ha^{-1} and 0 kg S ha^{-1}) (Table 1).

4.1.2 Number of effective tillers hill^{-1}

Number of effective tillers hill^{-1} of BRRI dhan63 showed statistically significant differences for different levels of nitrogen (Appendix III). The maximum number of effective tillers hill^{-1} (14.60) was found from N_1 which was followed (13.76) by N_2, while the minimum number (10.98) was observed from N_0 (Table 2). Tabar (2012) reported that fertile tiller increased significantly with nitrogen application and upto 150 kg/ha showed a positive respond.

Different levels of sulphur showed statistically significant variation in terms of number of effective tillers hill^{-1} of BRRI dhan63 (Appendix III). The maximum number of effective tillers hill^{-1} (14.37) was recorded from S_2, which was statistically similar (14.13) to S_1, whereas the minimum number (11.85) was found from S_0 (Table 2).

Statistically significant variation was recorded in terms of number of effective tillers hill^{-1} of BRRI dhan63 due to the combined effect of different levels of nitrogen and sulphur (Appendix III). The maximum number of effective tillers hill^{-1} (15.87) was found from N_1S_2, while the minimum number (10.27) was observed from N_0S_0 (Table 3).

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

Different levels of nitrogen showed statistically significant differences in terms of number of non-effective tillers hill^{-1} of BRRI dhan63 (Appendix III). The minimum number of non-effective tillers hill^{-1} (2.27) was found from N_1, while the maximum number (3.07) was found from N_1 which was statistically similar (3.09) to N_0 (Table 2).

Statistically significant variation was recorded in terms of number of non-effective tillers hill^{-1} of BRRI dhan63 (Appendix III). The minimum number of non-effective tillers hill^{-1} (2.67) was recorded from S_0, whereas the maximum number (3.12) was found from S_2 which was statistically similar (2.90) to S_1 (Table 2).

Table 1. Combined effect of different levels of nitrogen and sulphur on plant height of BRRI dhan63

Treatment	Plant height (cm) at				
	30 DAT	50 DAT	70 DAT	90 DAT	Harvest
N_0S_0	30.30 d	51.70 d	69.71 d	72.46 e	73.68 c
N_0S_1	38.35 a-c	57.81 bc	75.20 bc	81.41 d	77.45 c
N_0S_2	36.02 bc	54.42 cd	72.00 cd	81.44 d	90.89 b
N_1S_0	39.66 ab	57.81 bc	76.74 ab	82.23 cd	77.76 c
N_1S_1	39.33 a-c	59.61 ab	77.35 ab	87.14 ab	92.60 ab
N_1S_2	42.99 a	63.52 a	80.38 a	87.85 a	99.44 a
N_2S_0	34.68 c	53.66 cd	70.74 cd	78.09 e	80.60 c
N_2S_1	38.00 bc	59.35 ab	77.07 ab	84.86 bc	91.20 b
N_2S_2	40.68 ab	60.93 ab	78.28 ab	86.80 ab	92.07 ab
$LSD_{(0.05)}$	4.309	3.909	4.270	2.651	7.372
Significance level	0.05	0.05	0.05	0.05	0.01
CV(%)	6.59	4.74	5.46	5.64	5.25

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

N_0: 0 kg N ha^{-1} (control) — S_0: 0 kg S ha^{-1} (control)

N_1: 100 kg N ha^{-1} — S_1: 10 kg S ha^{-1}

N_2: 140 kg N ha^{-1} — S_2: 15 kg S ha^{-1}

Table 2. Effect of different levels of nitrogen and sulphur on yield contributing characters of BRRI dhan63

Treatments	Number of effective tiller hill^{-1}	Number of non effective tiller hill^{-1}	Number of total tiller hill^{-1}	Number of filled grain panicle^{-1}	Number of unfilled grain panicle^{-1}	Number of total grain panicle^{-1}	Length of panicle (cm)
Levels of nitrogen							
N_0	10.98 c	3.09 a	14.07 b	70.09 b	8.74 a	78.83 b	22.27 b
N_1	14.60 a	2.27 b	16.87 a	83.66 a	4.91 c	88.57 a	24.91 a
N_2	13.76 b	3.07 a	16.82 a	82.31 a	5.99 b	88.30 a	25.72 a
$LSD_{(0.05)}$	0.688	0.285	0.804	5.416	0.376	5.450	1.275
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Levels of sulphur							
S_0	11.85 b	2.67 b	14.52 b	68.97 b	8.15 a	77.13 b	21.57 b
S_1	14.13 a	2.90 ab	17.03 a	83.51 a	5.44 c	88.95 a	25.44 a
S_2	14.37 a	3.12 a	17.48 a	85.64 a	5.78 b	91.43 a	25.90 a
$LSD_{(0.05)}$	0.596	0.247	0.697	4.690	0.326	4.720	1.275
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.15	10.06	5.74	6.81	5.96	6.35	5.25

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

N_0: 0 kg N ha^{-1} (control)
N_1: 100 kg N ha^{-1}
N_2: 140 kg N ha^{-1}

S_0: 0 kg S ha^{-1} (control)
S_1: 10 kg S ha^{-1}
S_2: 15 kg S ha^{-1}

Table 3. Combined effect of different levels of nitrogen and sulphur on yield contributing characters of BRRI dhan63

Treatments	Number of effective tiller hill^{-1}	Number of non effective tiller hill^{-1}	Number of total tiller hill^{-1}	Number of filled grain panicle^{-1}	Number of unfilled grain panicle^{-1}	Number of total grain panicle^{-1}	Length of panicle (cm)
N_0S_0	10.27 e	2.60 c-e	12.87 d	60.83 e	9.77 a	70.60 d	18.78 d
N_0S_1	11.07 de	2.93 bc	14.00 cd	69.03 de	7.90 b	76.93 cd	23.47 c
N_0S_2	11.60 cd	3.73 a	15.33 c	80.40 bc	8.57 b	88.97 ab	24.56 c
N_1S_0	12.33 cd	2.33 de	14.67 c	68.00 de	6.10 c	74.10 cd	20.89 d
N_1S_1	15.60 ab	2.33 de	17.93 ab	90.23 ab	4.23 f	94.47 a	25.66 bc
N_1S_2	15.87 a	2.13 e	18.00 a	92.73 a	4.40 ef	97.13 a	28.18 a
N_2S_0	12.47 c	2.93 bc	15.40 c	73.63 cd	8.17 b	81.80 bc	25.02 bc
N_2S_1	14.40 b	3.27 ab	17.67 ab	86.13 ab	4.70 def	90.83 ab	27.20 ab
N_2S_2	14.40 b	3.00 bc	17.40 b	87.17 ab	5.10 de	92.27 ab	24.95 bc
$LSD_{(0.05)}$	1.191	0.494	1.393	9.381	0.651	9.440	2.209
Significance level	0.05	0.01	0.05	0.05	0.05	0.05	0.01
CV(%)	6.15	10.06	5.74	6.81	5.96	6.35	5.25

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

N_0: 0 kg N ha^{-1} (control) S_0: 0 kg S ha^{-1} (control)

N_1: 100 kg N ha^{-1} S_1: 10 kg S ha^{-1}

N_2: 140 kg N ha^{-1} S_2: 15 kg S ha^{-1}

Number of non-effective tillers hill^{-1} of BRRI dhan63 showed statistically significant differences due to the combined effect of different levels of nitrogen and sulphur (Appendix III). The minimum number of non-effective tillers hill^{-1} (2.13) was found from N_1S_2, while the maximum number (3.73) was observed from N_0S_2 (Table 3).

4.1.4 Number of total tillers hill^{-1}

Number of total tillers hill^{-1} of BRRI dhan63 showed statistically significant differences for different levels of nitrogen (Appendix III). The maximum number of total tillers hill^{-1} (16.87) was found from N_1 which was statistically similar (16.82) to N_2, while the minimum number (14.07) was observed from N_0 (Figure 4).

Different levels of sulphur showed statistically significant variation in terms of number of total tillers hill^{-1} of BRRI dhan63 (Appendix III). The maximum number of total tillers hill^{-1} (17.48) was recorded from S_2, which was statistically similar (17.03) to S_1, whereas the minimum number (14.52) was found from S_0 (Figure 5).

Statistically significant variation was recorded in terms of number of total tillers hill^{-1} of BRRI dhan63 due to the combined effect of different levels of nitrogen and sulphur (Appendix III). The maximum number of total tillers hill^{-1} (18.00) was found from N_1S_2, while the minimum number (12.87) was observed from N_0S_0 (Figure 6).

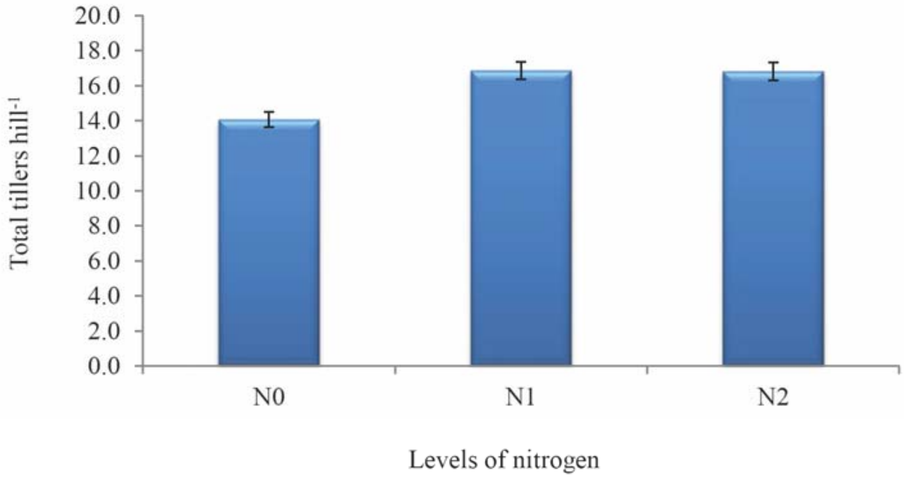
4.1.5 Number of filled grains panicle^{-1}

Number of filled grains panicle^{-1} of BRRI dhan63 showed statistically significant differences for different levels of nitrogen (Appendix III). The maximum number of filled grains panicle^{-1} (83.66) was found from N_1 which was statistically similar (82.31) to N_2, while the minimum number (70.09) was observed from N_0 (Table 2).

Different levels of sulphur showed statistically significant variation in terms of number of filled grains panicle^{-1} of BRRI dhan63 (Appendix III). The maximum number of filled grains panicle^{-1}

(85.64) was recorded from S_2, which was statistically similar (83.51) to S_1, whereas the minimum number (68.97) was found from S_0 (Table 2).

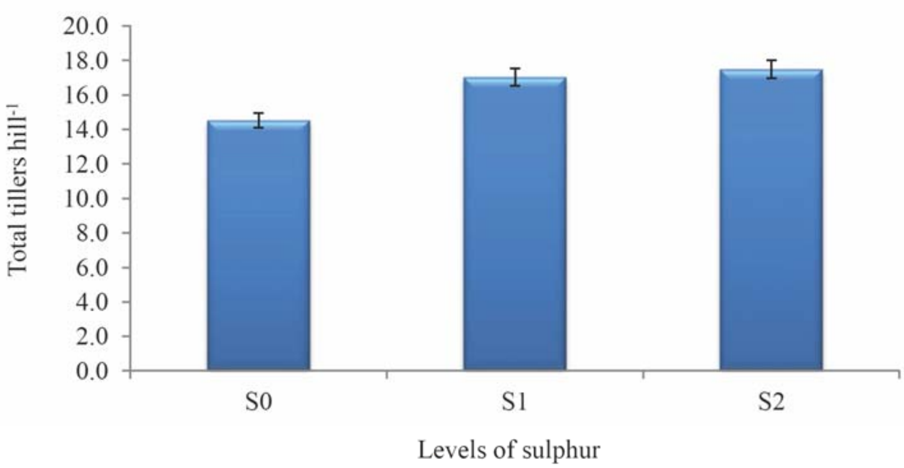
Statistically significant variation was recorded in terms of number of filled grains panicle^{-1} of BRRI dhan63 due to the combined effect of different levels of nitrogen and sulphur (Appendix III). The maximum number of filled grains panicle^{-1} (92.73) was found from N_1S_2, while the minimum number (60.83) was observed from N_0S_0 (Table 3).



N_0: 0 kg N ha^{-1} (control) N_1: 100 kg N ha^{-1}

N_2: 140 kg N ha^{-1}

Figure 4. Effect of different levels of nitrogen on number of total tillers hill^{-1} of BRRI dhan63. Vertical bars represent LSD value.



S_0: 0 kg S ha^{-1} (control) S_1: 10 kg S ha^{-1}

S_2: 15 kg S ha^{-1}

Figure 5. Effect of different levels of sulphur on number of total tillers hill^{-1} of BRRI dhan63. Vertical bars represent LSD value.

4.1.6 Number of unfilled grains panicle^{-1}

Number of unfilled grains panicle^{-1} of BRRI dhan63 showed statistically significant differences for different levels of nitrogen (Appendix III). The minimum number of unfilled grains panicle^{-1} (4.91) was found from N_1 which was closely followed (5.99) by N_2, while the maximum number (8.74) was observed from N_0 (Table 2).

Different levels of sulphur showed statistically significant variation in terms of number of unfilled grains panicle^{-1} of BRRI dhan63 (Appendix III). The minimum number of filled grains panicle^{-1} (5.44) was recorded from S_1, which was closely followed (5.78) by S_2, whereas the maximum number (8.15) was found from S_0 (Table 2).

Statistically significant variation was recorded in terms of number of unfilled grains panicle^{-1} of BRRI dhan63 due to the combined effect of different levels of nitrogen and sulphur (Appendix III). The minimum number of unfilled grains panicle^{-1} (4.23) was found from N_1S_1, while the maximum number (9.77) was observed from N_0S_0 (Table 3).

4.1.7 Number of total grains panicle^{-1}

Number of total grains panicle^{-1} of BRRI dhan63 showed statistically significant differences for different levels of nitrogen (Appendix III). The maximum number of total grains panicle^{-1} (88.57) was found from N_1 which was statistically similar (88.30) to N_2, while the minimum number (78.83) was observed from N_0 (Table 2). Tabar (2012) reported that total grains increased significantly with nitrogen application and upto 150 kg/ha showed a positive respond.

Different levels of sulphur showed statistically significant variation in terms of number of total grains panicle^{-1} of BRRI dhan63 (Appendix III). The maximum number of total grains panicle^{-1} (91.43) was recorded from S_2, which was statistically similar (88.95) to S_1, whereas the minimum number (77.13) was found from S_0 (Table 2).

Statistically significant variation was recorded in terms of number of total grains panicle^{-1} of BRRI dhan63 due to the combined effect of different levels of nitrogen and sulphur (Appendix III). The maximum number of total grains panicle^{-1} (97.13) was found from N_1S_2, while the minimum number (70.60) was observed from N_0S_0 (Table 3).

4.1.8 Length of panicle

Different levels of nitrogen showed statistically significant differences in terms of length of panicle of BRRI dhan63 (Appendix III). The longest panicle (25.72 cm) was found from N_2 which was statistically similar (24.91 cm) to N_1, whereas the shortest panicle (22.27 cm) was observed from N_0 (Table 2).

Statistically significant variation was recorded in terms of length of panicle of BRRI dhan63 (Appendix III). The longest panicle (25.90 cm) was recorded from S_2 which was statistically similar (25.44 cm) to S_1, while the shortest panicle (21.57 cm) was found from S_0 (Table 2).

Length of panicle of BRRI dhan63 showed statistically significant differences due to the combined effect of different levels of nitrogen and sulphur (Appendix III). The longest panicle (28.18 cm) was found from N_1S_2, while the shortest panicle (18.78 cm) was observed from N_0S_0 (Table 3).

4.1.9 Weight of 1000-grains

Weight of 1000-grains of BRRI dhan63 showed statistically significant differences for different levels of nitrogen (Appendix IV). The highest weight of 1000 grains (22.78 g) was found from N_1 which was statistically similar (22.61 g) to N_2, while the lowest weight (20.57 g) was observed from N_0 (Table 4). Tabar (2012) reported that 1000-grain weight and yield increased significantly with nitrogen application and upto 150 kg/ha showed a positive respond.

Different levels of sulphur showed statistically significant variation in terms of weight of 1000 grains of BRRI dhan63 (Appendix IV). The highest weight of 1000-grains (22.47 g) was recorded from S_2, which was statistically similar (22.43 g) to S_1, whereas the lowest weight (21.07 g) was found from S_0 (Table 4).

Statistically significant variation was recorded in terms of weight of 1000-grains of BRRI dhan63 due to the combined effect of different levels of nitrogen and sulphur (Appendix IV). The highest weight of 1000-grains (23.39 g) was found from N_1S_2, while the lowest weight (19.09 g) was observed from N_0S_0 (Table 5).

Table 4. Effect of different levels of nitrogen and sulphur on yield contributing characters and yield of BRRI dhan63

Treatments	Weight of 1000 grains (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
Levels of nitrogen					
N_0	20.57 b	4.46 b	6.06 b	10.52 b	37.73 b
N_1	22.78 a	5.48 a	6.83 a	12.30 a	41.88 a
N_2	22.61a	5.34 a	6.75 a	12.09 a	41.29 a
$LSD_{(0.05)}$	0.314	0.184	0.292	0.384	1.447
Significance level	0.01	0.01	0.01	0.01	0.01
Levels of sulphur					
S_0	21.07 b	4.35 c	6.01 c	10.37 c	36.95 b
S_1	22.43 a	5.08 b	6.47 b	11.54 b	40.79 a
S_2	22.47 a	5.37 a	6.80 a	12.17 a	41.25 a
$LSD_{(0.05)}$	0.314	0.212	0.337	0.444	1.670
Significance level	0.01	0.01	0.01	0.01	0.01
CV(%)	4.57	5.31	6.21	4.71	4.04

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

N_0: 0 kg N ha^{-1} (control) S_0: 0 kg S ha^{-1} (control)

N_1: 100 kg N ha^{-1} S_1: 10 kg S ha^{-1}

N_2: 140 kg N ha^{-1} S_2: 15 kg S ha^{-1}

Table 5. Combined effect of different levels of nitrogen and sulphur on yield contributing characters and yield of BRRI dhan63

Treatments	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0S_0	19.09 e	4.13 f	5.88 d	10.01 e	35.44 d
N_0S_1	21.70 c	4.30 ef	5.98 d	10.28 de	36.62 cd
N_0S_2	20.93 d	4.55 de	5.97 d	10.52 de	39.11 a-c
N_1S_0	21.73 c	4.50 d-f	5.93 d	10.42 de	38.88 a-d
N_1S_1	23.21 a	5.42 bc	6.69 bc	12.11 bc	42.17 a
N_1S_2	23.39 a	5.89 a	7.33 a	13.22 a	41.19 a
N_2S_0	22.38 b	4.43 ef	6.04 d	10.47 de	37.56 b-d
N_2S_1	22.38 b	5.41 c	6.72 a-c	12.14 c	41.94 ab
N_2S_2	23.09 a	5.68 a-c	7.10 ab	12.78 a-c	41.91 ab
$LSD_{(0.05)}$	0.545	0.367	0.584	0.769	2.893
Significance level	0.01	0.01	0.05	0.01	0.05
CV(%)	4.57	5.31	6.21	4.71	4.04

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

N_0: 0 kg N ha^{-1} (control) S_0: 0 kg S ha^{-1} (control)

N_1: 100 kg N ha^{-1} S_1: 10 kg S ha^{-1}

N_2: 140 kg N ha^{-1} S_2: 15 kg S ha^{-1}

4.1.10 Grain yield ha^{-1}

Statistically significant variation was recorded in terms of grain yield of BRRI dhan63 due to different levels of nitrogen (Appendix IV). The highest grain yield (5.48 t ha^{-1}) was found from N_1 which was statistically similar (5.34 t ha^{-1}) to N_2, while the lowest grain yield (4.46 t ha^{-1}) was observed from N_0 (Table 4). Tabar (2012) reported that yield increased significantly with nitrogen application and upto 150 kg/ha showed a positive respond.

Different levels of sulphur showed statistically significant variation in terms of grain yield of BRRI dhan63 (Appendix IV). The highest grain yield (5.37 t ha^{-1}) was recorded from S_2, which was closely followed (5.08 t ha^{-1}) by S_1, whereas the lowest grain yield (4.35 t ha^{-1}) was observed from S_0 (Table 4). Dixit *et al.* (2012) found that yield increased upto 40 kg S application and with higher application yield became almost constant.

Combined effect of different levels of nitrogen and sulphur showed statistically significant variation in terms of grain yield of BRRI dhan63 (Appendix IV). The highest grain yield (5.89 t ha^{-1}) was found from N_1S_2, while the lowest grain yield (4.13 t ha^{-1}) was recorded from N_0S_0 (Table 5).

4.1.11 Straw yield ha^{-1}

Statistically significant variation was recorded in terms of straw yield of BRRI dhan63 due to different levels of nitrogen (Appendix IV). The highest straw yield (6.83 t ha^{-1}) was found from N_1 which was statistically similar (6.75 t ha^{-1}) to N_2, while the lowest straw yield (6.06 t ha^{-1}) was observed from N_0 (Table 4). Mondal and Swamy (2003) found that application of N (120 kg ha^{-1}) resulted in the highest straw yield.

Different levels of sulphur showed statistically significant variation in terms of straw yield of BRRI dhan63 (Appendix IV). The highest straw yield (6.80 t ha^{-1}) was recorded from S_2, which was closely followed (6.47 t ha^{-1}) by S_1, whereas the lowest straw yield (6.01 t ha^{-1}) was observed from S_0 (Table 4). Mrinal and Sharma (2008) reported that straw yields of rice increased significantly with increasing levels of sulphur fertilizer up to 30 kg ha^{-1}.

Combined effect of different levels of nitrogen and sulphur varied significantly in terms of straw yield of BRRI dhan63 (Appendix IV). The highest straw yield (7.33 t ha^{-1}) was found from N_1S_2, while the lowest (5.88 t ha^{-1}) from N_0S_0 (Table 5).

4.1.12 Biological yield ha^{-1}

Statistically significant variation was recorded in terms of biological yield of BRRI dhan63 due to different levels of nitrogen (Appendix IV). The highest biological yield (12.30 t ha^{-1}) was found from N_1 which was statistically similar (12.09 t ha^{-1}) to N_2, while the lowest biological yield (10.52 t ha^{-1}) was observed from N_0 (Table 4).

Different levels of sulphur showed statistically significant variation in terms of biological yield of BRRI dhan63 (Appendix IV). The highest biological yield (12.17 t ha^{-1}) was recorded from S_2, which was closely followed (11.54 t ha^{-1}) by S_1, whereas the lowest biological yield (10.37 t ha^{-1}) was found from S_0 (Table 4).

Combined effect of different levels of nitrogen and sulphur showed statistically significant variation in terms of biological yield of BRRI dhan63 (Appendix IV). The highest biological yield (13.22 t ha^{-1}) was found from N_1S_2, while the lowest biological yield (10.01 t ha^{-1}) was recorded from N_0S_0 (Table 5).

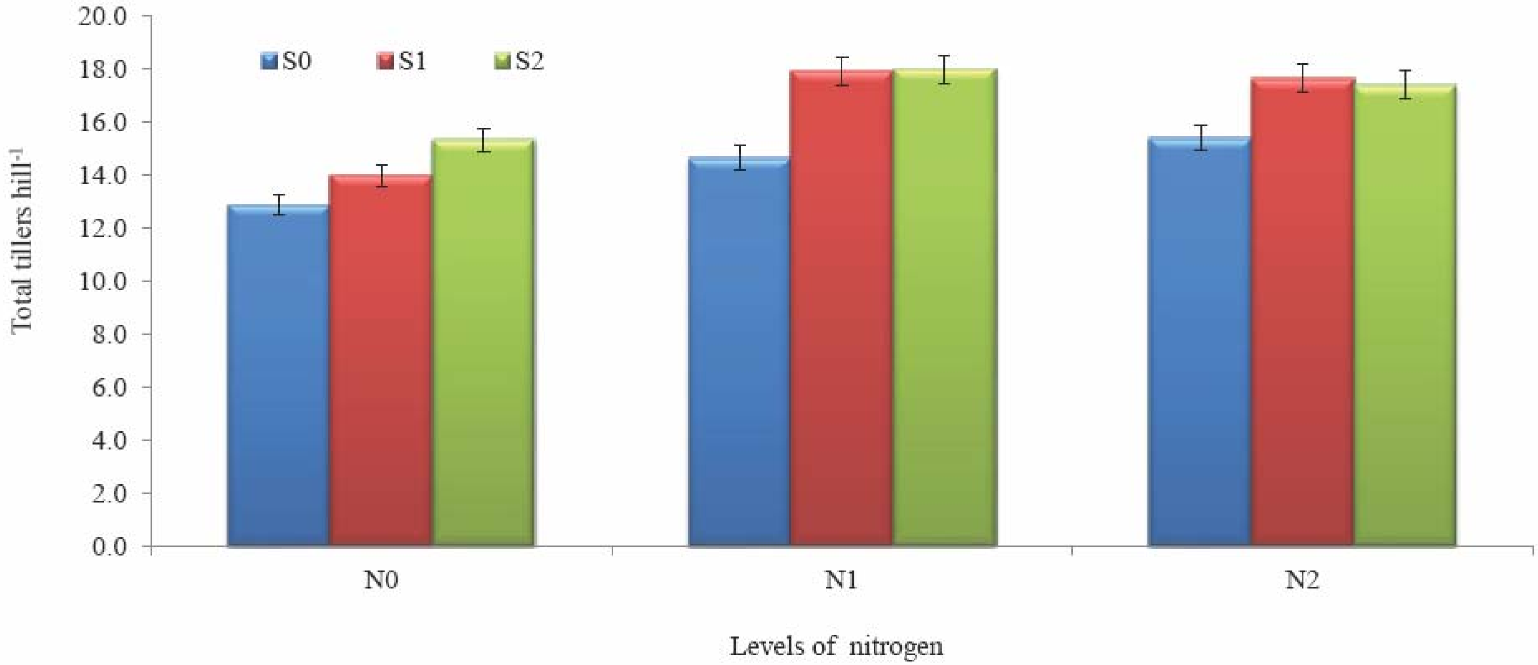
4.1.13 Harvest index

Statistically significant variation was recorded in terms of harvest index of BRRI dhan63 due to different levels of nitrogen (Appendix IV). The highest harvest index (41.88%) was found from N_1 which was statistically similar (41.29%) to N_2, whereas the lowest harvest index (37.73%)

was observed from N_0 (Figure 7). Mondal and Swamy (2003) found that application of N (120 kg ha^{-1}) resulted in the highest harvest index.

Different levels of sulphur showed statistically significant variation in terms of harvest index of BRRI dhan63 (Appendix IV). The highest harvest index (41.25%) was recorded from S_2, which was statistically similar (40.79%) to S_1, while the lowest harvest index (36.95%) was observed from S_0 (Figure 8).

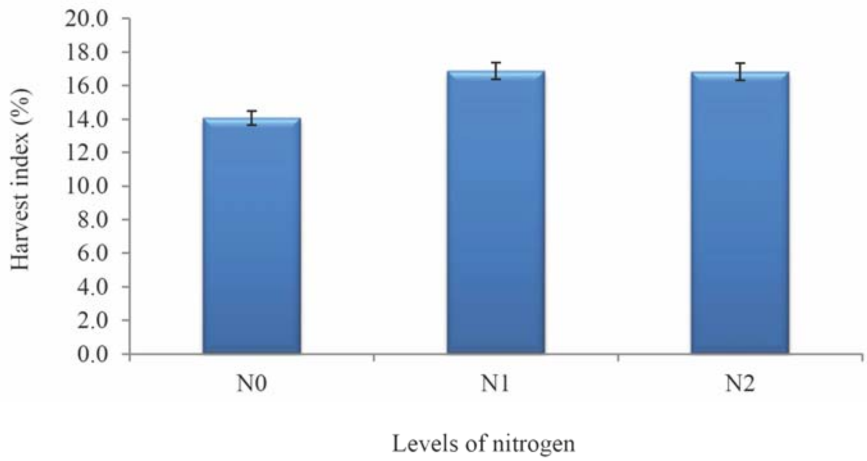
Combined effect of different levels of nitrogen and sulphur showed statistically significant variation in terms of harvest index of BRRI dhan63 (Appendix IV). The highest harvest index (42.17%) was found from N_1S_1, whereas the lowest harvest index (35.44%) was recorded from N_0S_0 (Figure 9).



N_0: 0 kg N ha^{-1} (control) N_1: 100 kg N ha^{-1} S_0: 0 kg S ha^{-1} (control) S_1: 10 kg S ha^{-1}

N_2: 140 kg N ha^{-1} S_2: 15 kg S ha^{-1}

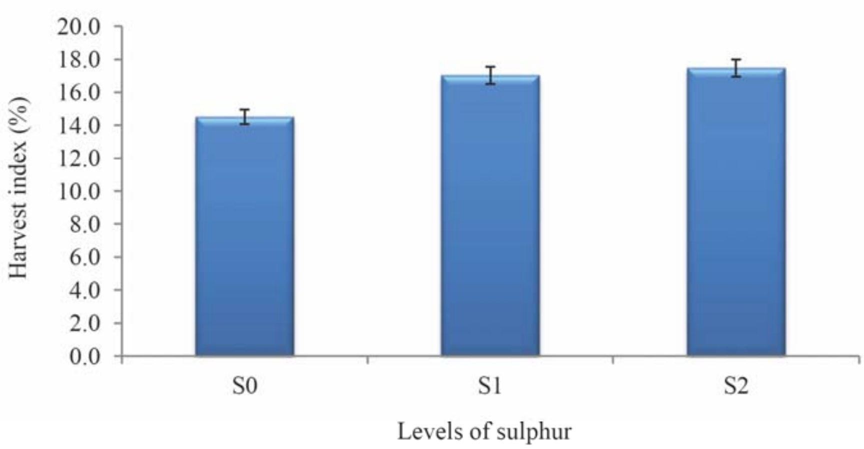
Figure 6. Combined effect of different levels of nitrogen and sulphur on number of total tillers hill^{-1} of BRRI dhan63. Vertical bars represent LSD value.



N_0: 0 kg N ha^{-1} (control) N_1: 100 kg N ha^{-1}

N_2: 140 kg N ha^{-1}

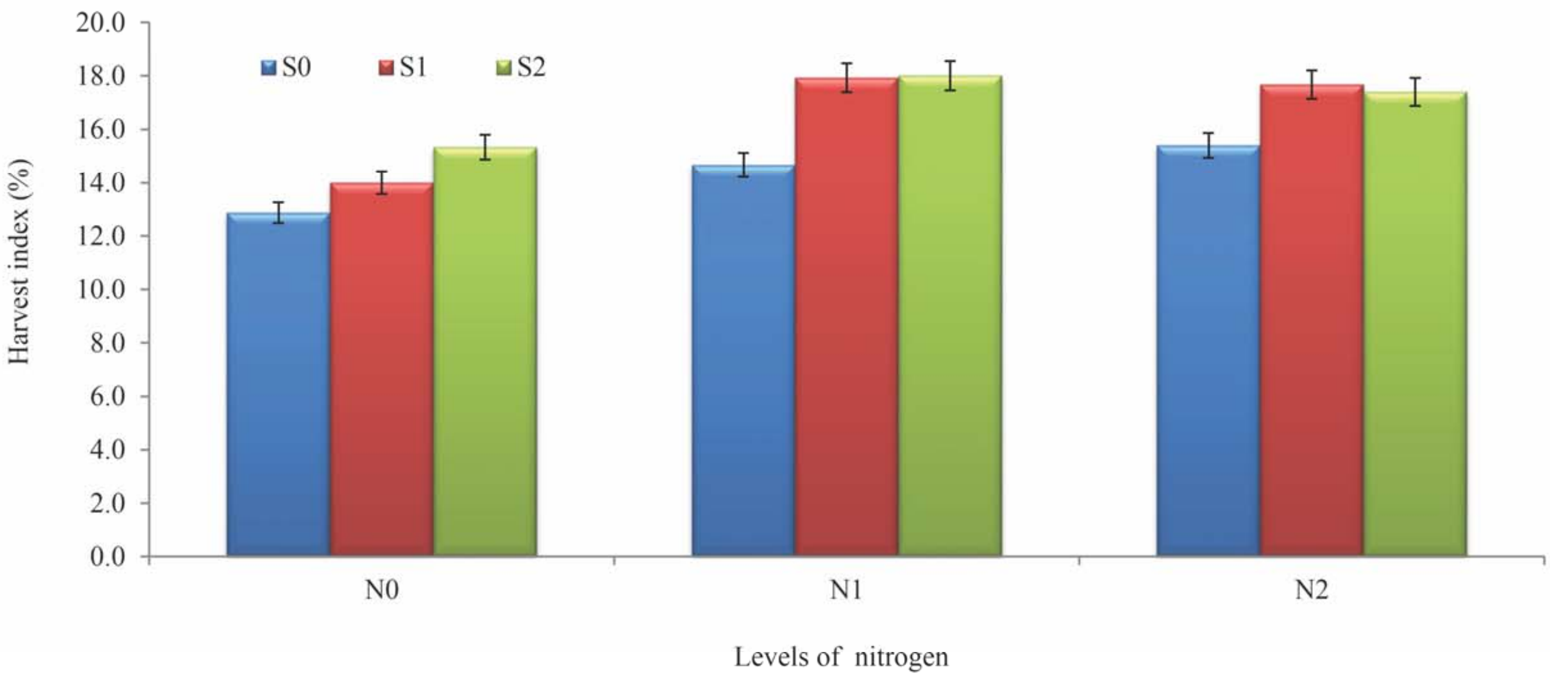
Figure 7. Effect of different levels of nitrogen on harvest index of BRRI dhan63. Vertical bars represent LSD value.



S_0: 0 kg S ha^{-1} (control) S_1: 10 kg S ha^{-1}

S_2: 15 kg S ha^{-1}

Figure 8. Effect of different levels of sulphur on harvest index of BRRI dhan63. Vertical bars represent LSD value.



N_0: 0 kg N ha^{-1} (control) N_1: 100 kg N ha^{-1} S_0: 0 kg S ha^{-1} (control) S_1: 10 kg S ha^{-1}

N_2: 140 kg N ha^{-1} S_2: 15 kg S ha^{-1}

Figure 9. Combined effect of different levels of nitrogen and sulphur on harvest indexof BRRI dhan63. Vertical bars represent LSD value.

4.2 Soil pH, organic matter, total N, available P, exchangeable K and available S in post harvest soil

4.2.1 Soil pH

Soil pH in post harvest soil showed statistically non significant differences for different levels of nitrogen (Appendix V). The highest soil pH (6.46) was found from N_2, whereas the lowest (6.36) was observed from N_0 (Table 6).

Different levels of sulphur showed statistically non significant variation in terms of soil pH in post harvest soil (Appendix V). The highest soil pH (6.49) was recorded from S_2 whereas the lowest (6.34) was found from S_0 (Table 6).

Statistically non significant variation was recorded in terms of soil pH in post harvest soil due to the combined effect of different levels of nitrogen and sulphur (Appendix V). The highest soil pH (6.54) was found from N_2S_2, while the lowest (6.31) was observed from N_0S_0 (Table 7).

4.2.2 Organic matter

Organic matter in post harvest soil showed statistically non significant differences for different levels of nitrogen (Appendix V). The highest organic matter (1.37%) was found from N_2, whereas the lowest (1.30%) was observed from N_0 (Table 6).

Different levels of sulphur showed statistically non significant variation in terms of organic matter in post harvest soil (Appendix V). The highest organic matter (1.39%) was recorded from S_2 whereas the lowest (1.28%) was found from S_0 (Table 6).

Statistically non significant variation was recorded in terms of organic matter in post harvest soil due to the combined effect of different levels of nitrogen and sulphur (Appendix V). The highest organic matter (1.44%) was found from N_2S_2, while the lowest (1.25%) was observed from N_0S_0 (Table 7).

4.2.3 Total nitrogen

Statistically significant variation was recorded for total nitrogen in post harvest soil for different levels of nitrogen (Appendix V). The highest total nitrogen (0.053%) was found from N_1 which was followed (0.042%) by N_2, while the lowest (0.013%) was observed from N_0 (Table 6).

Total nitrogen in post-harvest soil showed statistically significant variation for different levels of sulphur (Appendix V). The highest total nitrogen (0.045%) was recorded from S_2 which was statistically similar (0.043%) to S_1, whereas the lowest (0.032%) was found from S_0 (Table 6).

Combined effect of different levels of nitrogen and sulphur showed statistically significant variation in terms of total nitrogen in post harvest soil (Appendix V). The highest total nitrogen (0.067%) was found from N_1S_1, while the lowest (0.008%) was observed from N_0S_0 (Table 7).

Table 6. Effect of different levels of nitrogen and sulphur on pH, organic matter, total N, available P, exchangeable K and available S of post harvest soil

Treatments	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (me %)	Available S (ppm)
Levels of nitrogen						
N_0	6.36	1.30	0.013 c	22.17 c	0.140 c	19.57 b
N_1	6.43	1.35	0.053 a	30.50 a	0.175 a	22.05 a
N_2	6.46	1.37	0.042 b	25.32 b	0.163 b	21.11 a
$LSD_{(0.05)}$	--	--	0.010	2.978	0.010	1.133
Significance level	NS	NS	0.01	0.01	0.01	0.01
Levels of sulphur						
S_0	6.34	1.28	0.032 b	14.65 b	0.148 b	18.76 b
S_1	6.42	1.37	0.043 a	31.70 a	0.166 a	21.84 a
S_2	6.49	1.39	0.045 a	32.48 a	0.174 a	22.70 a
$LSD_{(0.05)}$	--	--	0.008	2.579	0.008	0.981
Significance level	NS	NS	0.01	0.01	0.01	0.01
CV(%)	4.73	8.53	15.56	11.17	6.45	5.49

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

N_0: 0 kg N ha^{-1} (control) S_0: 0 kg S ha^{-1} (control)

N_1: 100 kg N ha^{-1} S_1: 10 kg S ha^{-1}

N_2: 140 kg N ha^{-1} S_2: 15 kg S ha^{-1}

Table 7. Combined effect of different levels of nitrogen and sulphur on pH, organic matter, total N, available P, exchangeable K and available S of post harvest soil

Treatments	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (me %)	Available S (ppm)
N_0S_0	6.31	1.25	0.008 e	14.03 d	0.133 f	16.99 e
N_0S_1	6.36	1.31	0.017 de	25.60 c	0.138 ef	20.49 cd
N_0S_2	6.41	1.32	0.016 de	26.87 bc	0.148 d-f	21.22 cd
N_1S_0	6.35	1.29	0.033 cd	13.40 d	0.145 d-f	20.06 d
N_1S_1	6.41	1.36	0.067 a	39.78 a	0.193 a	20.79 cd
N_1S_2	6.53	1.39	0.059 ab	38.32 a	0.187 a	22.48 bc
N_2S_0	6.32	1.27	0.039 c	14.00 d	0.154 de	17.91 e
N_2S_1	6.52	1.41	0.043 bc	30.73 bc	0.161 b-d	23.64 ab
N_2S_2	6.54	1.44	0.046 bc	31.23 b	0.174 a-c	24.59 a
$LSD_{(0.05)}$	--	--	0.017	5.159	0.017	1.962
Significance level	NS	NS	0.01	0.01	0.05	0.05
CV(%)	4.73	8.53	15.56	11.17	6.45	5.49

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

N_0: 0 kg N ha^{-1} (control) S_0: 0 kg S ha^{-1} (control)

N_1: 100 kg N ha^{-1} S_1: 10 kg S ha^{-1}

N_2: 140 kg N ha^{-1} S_2: 15 kg S ha^{-1}

4.2.4 Available P

Statistically significant variation was recorded for available P in post harvest soil for different levels of nitrogen (Appendix V). The highest available P (30.50 ppm) was found from N_1 which was followed (25.32 ppm) by N_2, while the lowest (22.17 ppm) was observed from N_0 (Table 6).

Available P in post harvest soil showed statistically significant variation for different levels of sulphur (Appendix V). The highest available P (32.48 ppm) was recorded from S_2 which was statistically similar (31.70 ppm) to S_1, whereas the lowest (14.65 ppm) was found from S_0 (Table 6).

Combined effect of different levels of nitrogen and sulphur showed statistically significant variation in terms of available P in post harvest soil (Appendix V). The highest available P (39.78 ppm) was found from N_1S_1, while the lowest (14.03 ppm) was observed from N_0S_0 (Table 7).

4.2.5 Exchangeable K

Statistically significant variation was recorded for exchangeable K in post harvest soil for different levels of nitrogen (Appendix V). The highest exchangeable K (0.175 me%) was found from N_1 which was followed (0.163 me%) by N_2, while the lowest (0.140 me%) was observed from N_0 (Table 6).

Exchangeable K in post harvest soil showed statistically significant variation for different levels of sulphur (Appendix V). The highest exchangeable K (0.174 me%) was recorded from S_2 which was statistically similar (0.166 me%) to S_1, whereas the lowest (0.148 me%) was found from S_0 (Table 6).

Combined effect of different levels of nitrogen and sulphur showed statistically significant variation in terms of exchangeable K in post harvest soil (Appendix V). The highest exchangeable K (0.193 me%) was found from N_1S_1, while the lowest (0.133 me%) was recorded from N_0S_0 (Table 7).

4.2.6 Available S

Statistically significant variation was recorded for available S in post harvest soil for different levels of nitrogen (Appendix V). The highest available S (22.05 ppm) was found from N_1 which was statistically similar (21.11 ppm) to N_2, while the lowest (19.57 ppm) was observed from N_0 (Table 6).

Available S in post harvest soil showed statistically significant variation for different levels of sulphur (Appendix V). The highest available S (22.70 ppm) was recorded from S_2 which was statistically similar (21.84 ppm) to S_1, whereas the lowest (18.76 ppm) was found from S_0 (Table 6).

Combined effect of different levels of nitrogen and sulphur showed statistically significant variation in terms of available S in post harvest soil (Appendix V). The highest available S (24.59 ppm) was found from N_2S_2, while the lowest (16.99 ppm) was observed from N_0S_0 (Table 7).

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted during the period from December 2015 to May 2016 at boro season in the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh to find out the effect of different levels nitrogen and sulphur on the growth and yield of BRRI dhan63. As planting material BRRI dhan 63 also known as ‘Soru balam’ was used. The experiment was comprised of two factors as Factor A: Levels of N (3 levels)- N_0: 0 kg N ha^{-1} (control), N_1: 100 kg N ha^{-1}, N_2: 140 kg N ha^{-1} and Factor B: Levels of S (3 levels)- S_0: 0 kg S ha^{-1} (control), S_1: 10 kg S ha^{-1}, S_2: 15 kg N ha^{-1}. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Data were recorded on different yield and yield attributes and nutrient status of post harvest soil and significant variation was observed for different treatment.

In case of nitrogen, at 30, 50, 70, 90 DAT and harvest, the tallest plant (39.89, 59.45, 77.45, 85.74 and 89.93 cm, respectively) was recorded from N_1, whereas the shortest plant (34.89, 54.64, 72.30, 80.11 and 80.68 cm, respectively) was found from N_0. The maximum number of effective tillers hill^{-1} (14.60) was found from N_1, while the minimum number (10.98) was observed from N_0. The minimum number of non-effective tillers hill^{-1} (2.27) was found from N_1, while the maximum number (3.07) was observed from N_1. The maximum number of total tillers hill^{-1} (16.87) was found from N_1, while the minimum number (14.07) was observed from N_0. The maximum number of filled grains panicle^{-1} (83.66) was found from N_1, while the minimum number (70.09) was observed from N_0. The minimum number of unfilled grains panicle^{-1} (4.91) was found from N_1, while the maximum number (8.74) was observed from N_0. The maximum number of total grains panicle^{-1} (88.57) was found from N_1, while the minimum number (78.83) was observed from N_0. The longest panicle (25.72 cm) was found from N_2, whereas the shortest panicle (22.27 cm) was observed from N_0. The highest weight of 1000 grains (22.78 g) was found from N_1, while the lowest weight (20.57 g) was observed from N_0. The highest grain yield (5.48 t ha^{-1}) was found from N_1, while the lowest grain yield (4.46 t ha^{-1}) was observed from N_0. The highest straw yield (6.83 t ha^{-1}) was found from N_1, while the lowest straw yield (6.06 t ha^{-1}) was observed from N_0. The highest biological yield (12.30 t ha^{-1}) was found from N_1, while the lowest biological yield (10.52 t ha^{-1}) was observed from N_0. The highest harvest index (41.88%) was found from N_1, whereas the lowest harvest index (37.73%) was observed from N_0.

The highest soil pH (6.46) was found from N_2, whereas the lowest (6.36) was observed from N_0. The highest organic matter (1.37%) was found from N_2, whereas the lowest (1.30%) was observed from N_0. The highest total nitrogen (0.053%) was found from N_1, while the lowest (0.013%) was observed from N_0. The highest available P (30.50 ppm) was found from N_1, while the lowest (22.17 ppm) was observed from N_0. The highest exchangeable K (0.175 me %) was found from N_1, while the lowest (0.140 me%) was observed from N_0. The highest available S (22.05 ppm) was found from N_1, while the lowest (19.57 ppm) was observed from N_0.

For sulphur, at 30, 50, 70, 90 DAT and harvest, the tallest plant (39.90, 59.62, 76.88, 85.36 and 91.85 cm, respectively) was observed from S_2, while the shortest plant (34.88, 54.39, 72.40, 75.26 and 77.35 cm, respectively) was observed from S_0. The maximum number of effective tillers $hill^{-1}$ (14.37) was recorded from S_2, whereas the minimum number (11.85) was found from S_0. The minimum number of non-effective tillers $hill^{-1}$ (2.67) was recorded from S_0, whereas the maximum number (3.12) was found from S_2 which was statistically similar (2.90) to S_1. The maximum number of total tillers $hill^{-1}$ (17.48) was recorded from S_2, whereas the minimum number (14.52) was found from S_0. The maximum number of filled grains $panicle^{-1}$ (85.64) was recorded from S_2, whereas the minimum number (68.97) was found from S_0. The minimum number of filled grains $panicle^{-1}$ (5.44) was recorded from S_1, whereas the maximum number (8.15) was found from S_0. The maximum number of total grains $panicle^{-1}$ (91.43) was recorded from S_2, whereas the minimum number (77.13) was found from S_0. The longest panicle (25.90 cm) was recorded from S_2, while the shortest panicle (21.57 cm) was found from S_0. The highest weight of 1000-grains (22.47 g) was recorded from S_2, whereas the lowest weight (21.07 g) was found from S_0. The highest grain yield (5.37 t ha$^-$

^{1}) was recorded from S_2, whereas the lowest grain yield (4.35 t ha^{-1}) was observed from S_0. The highest straw yield (6.80 t ha^{-1}) was recorded from S_2, whereas the lowest straw yield (6.01 t ha^{-1}) was observed from S_0. The highest biological yield (12.17 t ha^{-1}) was recorded from S_2, whereas the lowest biological yield (10.37 t ha^{-1}) was found from S_0. The highest harvest index (41.25%) was recorded from S_2, while the lowest harvest index (36.95%) was observed from S_0.

The highest soil pH (6.49) was recorded from S_2 whereas the lowest (6.34) was found from S_0. The highest organic matter (1.39%) was recorded from S_2 whereas the lowest (1.28%) was found from S_0. The highest total nitrogen (0.045%) was recorded from S_2, whereas the lowest (0.032%) was found from S_0. The highest available P (32.48 ppm) was recorded from S_2, whereas the lowest (14.65 ppm) was found from S_0. The highest exchangeable K (0.174 me %) was recorded from S_2, whereas the lowest (0.148 me%) was found from S_0. The highest available S (22.70 ppm) was recorded from S_2, whereas the lowest (18.76 ppm) was found from S_0.

Due to the interaction effect of nitrogen and sulphur, at 30, 50, 70, 90 DAT and harvest, the tallest plant (42.99, 63.52, 80.38, 87.85 and 99.44 cm, respectively) was observed from N_1S_2 and the shortest plant (30.30, 51.70, 69.71, 72.46 and 73.68 cm, respectively) was recorded from N_0S_0. The maximum number of effective tillers $hill^{-1}$ (15.87) was found from N_1S_2, while the minimum number (10.27) was observed from N_0S_0. The minimum number of non-effective tillers $hill^{-1}$ (2.13) was found from N_1S_2, while the maximum number (3.73) was observed from N_0S_2. The maximum number of total tillers $hill^{-1}$ (18.00) was found from N_1S_2, while the minimum number (12.87) was observed from N_0S_0. The maximum number of filled grains $panicle^{-1}$ (92.73) was found from N_1S_2, while the minimum number (60.83) was observed from N_0S_0. The minimum number of unfilled grains $panicle^{-1}$ (4.23) was found from N_1S_1, while the maximum number (9.77) was observed from N_0S_0. The maximum number of total grains $panicle^{-1}$ (97.13) was found from N_1S_2, while the minimum number (70.60) was observed from N_0S_0. The longest panicle (28.18 cm) was found from N_1S_2, while the shortest panicle (18.78 cm) was observed from N_0S_0. The highest weight of 1000-grains (23.39 g) was found from N_1S_2, while the lowest weight (19.09 g) was observed from N_0S_0.

The highest grain yield (5.89 t ha^{-1}) was found from N_1S_2, while the lowest grain yield (4.13 t ha^{-1}) was recorded from N_0S_0. The highest straw yield (7.33 t ha^{-1}) was found from N_1S_2, while the lowest straw yield (5.88 t ha^{-1}) was recorded from N_0S_0. The highest biological yield (13.22 t ha^{-1}) was found from N_1S_2, while the lowest biological yield (10.01 t ha^{-1}) was recorded from N_0S_0. The highest harvest index (42.17%) was found from N_1S_1, whereas the lowest harvest index (35.44%) was recorded from N_0S_0.

The highest soil pH (6.54) was found from N_2S_2, while the lowest (6.31) was observed from N_0S_0. The highest organic matter (1.44%) was found from N_2S_2, while the lowest (1.25%) was observed from N_0S_0. The highest total nitrogen (0.067%) was found from N_1S_1, while the lowest (0.008%) was observed from N_0S_0. The highest available P (39.78 ppm) was found from N_1S_1, while the lowest (14.03 ppm) was observed from N_0S_0. The highest exchangeable K (0.193 me%) was found from N_1S_1, while the lowest (0.133 me%) was recorded from N_0S_0. The highest available S (24.59 ppm) was found from N_2S_2, while the lowest (16.99 ppm) was observed from N_0S_0.

Conclusion

It was revealed that application of 100 kg N ha^{-1} and 10 kg S ha^{-1} was more potential in regarding yield contributing characters and yield of BRRI dhan63.

Considering the above results of this experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performances.

2. More experiments may be carried out with other organic, inorganic and also macro nutrients.

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Appendix II. Analysis of variance of the data on plant height of BRRI dhan63 as influenced by different levels of nitrogen and sulphur

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		30 DAT	50 DAT	70 DAT	90 DAT	Harvest
Replication	2	0.423	0.280	0.111	0.897	1.461
Levels of nitrogen (A)	2	74.067**	60.312**	61.620**	63.880**	71.748**
Levels of sulphur (B)	2	68.375**	60.686**	72.591**	56.155**	97.771**
Interaction (A×B)	4	19.761**	17.358*	18.168*	8.194*	124.385**
Error	16	6.198	5.099	6.086	2.345	18.135

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix III. Analysis of variance of the data on yield contributing characters of BRRI dhan63 as influenced by different levels of nitrogen and sulphur

Source of variation	Degrees of freedom	Mean square						
		Number of effective tiller $hill^{-1}$	Number of non effective tiller $hill^{-1}$	Number of total tiller $hill^{-1}$	Number of filled grain $panicle^{-1}$	Number of unfilled grain $panicle^{-1}$	Number of total grain $panicle^{-1}$	Length of panicle (cm)
Replication	2	0.005	0.429	0.080	0.539	1.011	2.388	0.437
Levels of nitrogen (A)	2	35.733**	49.934**	32.120**	133.110**	33.220*	141.927**	29.304**
Levels of sulphur (B)	2	20.640**	44.428**	32.194**	143.360**	25.584*	154.275**	50.977**
Interaction (A×B)	4	9.037*	16.128**	9.586*	95.234*	5.652*	97.662*	17.596**
Error	16	2.157	1.238	3.427	24.340	1.849	25.648	4.629

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the dataon yield contributing characters and yield of BRRI dhan63 as influenced by different levels of nitrogen and sulphur

Source of variation	Degrees of freedom	Mean square				
		Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.078	0.061	0.662	0.055	0.115
Levels of nitrogen (A)	2	18.387**	10.436**	24.506**	29.033**	24.691**
Levels of sulphur (B)	2	12.573**	12.570**	22.751**	31.941**	26.508**
Interaction (A×B)	4	10.219**	9.748**	12.937*	16.937**	12.898*
Error	16	1.083	0.793	1.263	2.230	4.460

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the dataon plant height of BRRI dhan63 as influenced by different levels of nitrogen and sulphur

Source of variation	Degrees of freedom	Mean square					
		pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (me %)	Available S (ppm)
Replication	2	0.147	0.010	0.130	0.603	0.083	0.037
Levels of nitrogen (A)	2	0.877	0.512	13.915**	13.106**	9.500**	13.622**
Levels of sulphur (B)	2	1.658	0.863	28.164**	16.081**	6.548**	5.742**
Interaction (A×B)	4	0.342	0.970	1.020**	1.021**	0.505*	1.320**
Error	16	0.893	0.354	0.046	12.406	0.046	0.156

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability