

**EFFECT OF NITROGEN AND SULPHUR ON GROWTH AND
YIELD OF BRRI DHAN41**

**A THESIS
BY**

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Approved as to style and content
by

.....
Prof. Dr. Md. Yasin Ali
(Supervisor)

.....
Prof. Khan Golam Quddus
(Cosupervisor)

.....
Prof. Dr. Md. Yasin Ali
Chairman
Examination Committee

DEDICATED TO

MY BELOVED PARENTS

AND

ELDEST BROTHER

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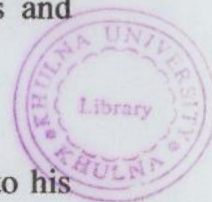
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ABSTRACT

A field experiment was conducted at the Agrotechnology Field Laboratory of Khulna University, Khulna, during the *aman* season from June to December, 2007 to evaluate the effect of nitrogen and sulphur on growth and yield of BRRI dhan41. The study consisted of four levels of nitrogen viz. 0, 66, 132 and 198 kg N ha⁻¹ and three levels of sulphur viz. 17, 34 and 51 kg S ha⁻¹. The experiment was laid out in a Randomized Complete Block Design (RCBD) with two factors. The results showed that application of 198 kg N ha⁻¹ produced tallest plant (115.72 cm), highest number of tiller hill⁻¹ (12.38), highest panicle number hill⁻¹ (10.96), maximum weight of dry matter (452.88 g m⁻²), highest panicle length (21.81 cm), maximum number of grain panicle⁻¹ (105.95), highest grain yield (4.46 t ha⁻¹) and highest harvest index (45.82%) but highest straw yield (5.42 t ha⁻¹) was produced by application of 132 kg N ha⁻¹ which was statistically differed from other treatments. In case of sulphur, application of 34 kg S ha⁻¹ produced tallest plant (111.57 cm), highest tiller number hill⁻¹ (11.70), highest panicle number hill⁻¹ (10.16), maximum dry matter (437.52 g m⁻²), highest panicle length (21.16 cm), maximum number of grain panicle⁻¹ (104.66), highest grain yield (4.03 t ha⁻¹) and highest straw yield (5.29 t ha⁻¹) but highest harvest index (43.46%) was produced by application of 17 kg S ha⁻¹ which was statistically similar to 34 kg S ha⁻¹ (42.93%) and 51 kg S ha⁻¹ (41.88%). The interaction effect of nitrogen and sulphur varied significantly at all parameters of growth, yield and yield attributes of BRRI dhan41 except number of unfilled spikelets panicle⁻¹. Tallest plant (118.15 cm), maximum number of tiller hill⁻¹ (13.58), maximum panicle number hill⁻¹ (11.83), highest panicle length (23.03 cm), maximum number of grain panicle⁻¹ (109.32), highest grain yield (5.15 t ha⁻¹), biological yield (10.79 t ha⁻¹) and highest harvest index (47.73) was observed from treatment combinations of 198 kg N ha⁻¹ with 34 kg S ha⁻¹ but highest straw yield (6.09 t ha⁻¹) obtained by treatment combinations of 132 kg N ha⁻¹ with 34 kg S ha⁻¹.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important cereal crop in the world in terms of area under cultivation and the number of people depending on the crop. It is the most important food grain in the diet of more than half of the world's population in tropical and subtropical Asia, Africa and Latin America (Yoshida, 1981). It is the staple food crop in Bangladesh.

In Bangladesh, rice covers 76% of total cropped area with an average yield of 2.39 t ha⁻¹ (BBS, 2004). Total cultivated land of T. aman rice is 49.24 lac hectares and total production is 102.19 lac metric ton and yield is 4.5-6 ton ha⁻¹ (BBS, 2006). Bangladesh ranks third position in rice area and fourth in production among the rice growing countries of the world (BRRI, 1988). But the average yield in our country is very low as compared to other rice growing countries of the world (FAO, 2000).

The population of Bangladesh is increasing very rapidly where as the total rice area is continuously declining due to urbanization and industrialization. Therefore, it is an urgent need to increase rice production through increasing yield. As per report of IRRI (1999), rice production must be increased by 70% over the next three decades to meet up the demand of the increasing population and to sustain global food security.

The soil and climate of Bangladesh are favorable for rice cultivation throughout the year but the yield per unit area of this crop is much below the potential level. The reasons for low yield of rice are manifold, such as varietal, technological and climatic, etc. The newly developed modern varieties have higher yield potential as compared to existing other modern varieties. High yield produced by the supply of growth factors such as seed, fertilizers, irrigation, pesticides, etc.

Nitrogen and sulphur are two important crop nutrients occurring in soil both in organic and inorganic forms. Proper tiller and ear production for higher yield in rice may be greatly influenced by nitrogen and sulphur fertilizers. These are essential elements for growth and development of rice. Fertilizer is now one of the expensive inputs for crop production in Bangladesh. Among the nutrients, nitrogen stands prominent in raising rice yields. Almost all the soils of Bangladesh are low in organic matter and hence of nitrogen (Huo, 1988; Bacon *et al.*, 1990). Among many factors, deficiency of nitrogen is now considered as major reason for low yield production of rice in soils of Bangladesh. Although the response of rice to added nitrogen is almost universal, the extent of response for maximum grain yield depends primarily on the variety, soil and environmental conditions. Besides, sulphur is an essential element for growth and development of rice since it is a constituent of S-containing amino acids and enzymes required for the synthesis of proteins, chlorophyll, oil and vitamins. Application of sulphur significantly increased the grain and straw yield of transplant aman rice (Islam *et al.*, 1999). Sulphur fertilizer improves nutritive value of several crops. Sulphur deficiency affects both the yield and quality of food for human and animal consumption. Both nitrogen and sulphur deficiency reduces grain yield in rice by reducing tillers, number of panicles, grain number panicle⁻¹ and grain weight and in severe cases by increasing empty grains (Ismunadjii *et al.*, 1982). Majid (1986) reported that the deficiency of sulphur in soils of Bangladesh is much more widespread than was reported earlier. It is now apprehended that the present S deficient soils comprise a total of as much as 3.95 million ha (BARC, 1988). So application of sulphur fertilizers to the crop field is essential to fulfill the sulphur deficiency of soils and it is important to maintain appropriate dose for better growth and higher yield of rice crops.

Attempts have been made in home and abroad to determine the effect of nitrogen applied as in the form of urea in two equal installments and sulphur applied as different basal doses on growth and yield of crops, specifically rice. For these reasons as discussed above an attempt has been made to observe the effect of

nitrogen and sulphur on growth and yield of BRRI dhan41. Therefore, the research work was undertaken with the following objectives:

1. To find out the effect of nitrogen and sulphur on growth and yield of BRRI dhan41.
2. To find out the interaction effect of nitrogen and sulphur on growth and yield of BRRI dhan41.

CHAPTER II

REVIEW OF LITERATURE

Crop plants are usually grown in community. Crop yield is determined by the effectiveness with which the community of crop plants exploits its environmental resources. Growth and development of rice plants are greatly influenced by the environmental factors (i.e. water, light, temperature etc.), variety used and agronomic practices (i.e. planting density, fertilizer, irrigation etc.). An attempt has been made in this chapter to present a brief review of the pertinent works on the effect of nitrogen and sulphur on rice done by different researchers in home and abroad.

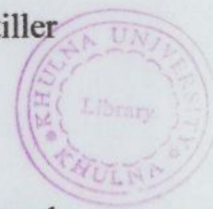
Rice plant requires nitrogen throughout the growing period. Matsushima (1965) pointed out that when rice plant is supplied with much nitrogen during its vegetative period, the plant requires little nitrogen during its generative period; but in general, the rice plant has two peak stages for nitrogen requirement, one at the vegetative period and the other at the reproductive period.

Plant characters may be influenced by different levels and time of N fertilization. In a low-response cultivar the related uptake of nutrients at later growth stages may be related to serious mutual shading of the lower leaves

Plant height increased with increasing rates of nitrogen application (Talukder, 1973). The higher levels of nitrogen (120 kg N ha^{-1}) significantly increased the plant height (Lenka and Behera, 1967).

Tillering is one of the most important developmental stages of rice, since it has a decisive bearing on grain yield. Tiller number, particularly effective tiller is strongly correlated with grain yield, depending on the cultivars and crop environment. Tillering of rice plant is strongly influenced by nitrogen supply (Chandler, 1969; BRRI, 1989 and 1990a) and adequate nitrogen is necessary

during tillering stage to ensure sufficient number of panicle bearing tillers. Higher N-content in leaf blade ($>3.0\%$) promotes tillering and nitrogen content lower than 1.5% causes death of weak tillers (Kumara, 1956). However, there remain differences in terms of nitrogen content. Tanaka (1983) observed in a typical tropical rice cultivar that nitrogen content higher than 2.0% in the culm promoted tillering and lower than 0.8% favored the death of tillers. The rice plant requires nitrogen throughout the growing period. Kumara (1956) observed that the number of tillers was correlated with the nitrogen during the tillering period. Final tiller number per hill was a linear function of the maximum tiller at booting stage (Khanam, 1994). Lin and Lin (1983) raised two rice cultivars treated with 80, 120, and 160 kg N ha^{-1} . They found that high nitrogen levels resulted in the higher tiller number per unit area.



Hossain and coworkers (1995) observed that application of nitrogen in general increased LAI of rice after panicle initiation. A maximum LAI (upto 4.56) was noticed for all the nitrogen levels during the flowering stage and it declined at harvesting possibly due to leaf senescence. Leaf area is an important index used to study plant growth, assimilation and transpiration as related to utilization of solar radiation. At the optimum LAI the photosynthesis of the lowest leaves is equal only to their respiration. With increase in LAI the light intensity becomes lower and even below the light compensation point at the basal part of the canopy and results in a negative contribution by lower leaves to total dry matter production (Gupta *et al.*, 1990). In agronomic practices nitrogen application is one of the major factors influencing leaf area growth under most conditions. Nitrogen application affects average leaf size, number of leaves per shoots and number of shoots per hill, tillering capacity of a variety modifies the influences of nitrogen application. When the leaf area exceeds a certain point, only the amount of respiration increases with leaf area and the grain carbon assimilation never increases due to mutual and self-shading of leaves. The LAI reduces its highest value a little before heading. The increase in LAI is caused by increased in number of tillers and in size of successive leaves. Nitrogen increases LAI or weight of leaf

blades and this effect is greatest before panicle initiation (Murayama, 1979). LAI increases as growth advances and reaches a maximum at around heading when the rice plant has its 5 largest leaves. Yoshida (1981) showed a close correlation between grain yield and leaf area index at heading.

The outer diameter of internodes (about 2-6 mm) varies with internode position, kind of shoot (main culm or tiller) and environmental conditions. In cross section, the internode has large hollow space called medullary cavity, whose diameter is the inner diameter of the internode (Yoshida, 1981). Amin (1999) found an increasing tendency of internode diameter and internode length with the higher nitrogen levels.

Dry weight of rice plant is an important character for the vegetative dragness and growth forecast of this plant (Kusuda, 1993). There are many reports on the increase in total dry matter due to increased fertilizer application, particularly nitrogen (Park, 1987). Dry matter production depends upon the balance between photosynthesis and respiration (Tanaka *et al.*, 1964). Fertilization of crop with the higher rate of nitrogen (120 Kg N ha^{-1}) was found superior to the lower rate (80 Kg N ha^{-1}) in dry matter production (Mehrotra and Singh, 1982). Takana (1968) found close correlation between yield and the amount of dry matter produced between headings to maturity. Excess nitrogen gives higher dry weight around heading simultaneously becomes low, causing a yield decline due to reduced ripening percentage. This situation is often referred to as overgrowth. The varieties which had high dry matter weight also had high leaf area. Leaf area is positively correlated with total dry matter (Anonymous, 1988).

In the improved varieties grown yield and total dry matter production came with a significant increase in dry matter production dose not necessarily increase the grain yield, thus extra dry matter produced by application of fertilizer is not usually compensated for higher grain yields. Traditional varieties have low grain

yields, despite high dry matter production because they have low harvest index (Anonymous, 1977).

The factors influencing efficient use of solar radiation by crop stands are the amount of light interception, the uniformity of light distribution over the total leaf area and photosynthesis light response function characteristics to a given variety. Monteith's (1972) analysis of crop productivity showed the importance of solar radiation interception as a major determinant of dry matter production.

Yosida (1983) determined the influence of light intensity and N fertility on yield and the components contributing to yield. As light intensity was reduced, grain yield was lowered at all N levels. At first the plant receives light and produces chemical energy is used for dry matter production. Biomass is the function of photosynthetic carbon metabolism, which in turn is dependent on leaf area development and light interception. Nitrogen application influences light transmission ratio (LTR) significantly (Khanam, 1994).

Nitrogen absorbed by the rice plant during panicle development increases the number of filled grain per panicle (Tanaka, 1980). Panicle number per plant is determined by effective tillers produced and those which survive for grain production. Mondal and colleagues (1987) reported that increasing rates of nitrogen, from 40 to 160 kg N ha⁻¹ increased the number of panicles per unit area. Dixit and Singh (1979) found that the increased nitrogen application increased the productive tillers per plant and panicle length. When the number of productive tillers per square meter was increased with increasing the number of fully formed spikelets per panicle was decreased. Further, panicles per hill, seed size, spikelets per panicle, sink size and grain yield increased with increasing nitrogen fertilizer rates (Pandey and Rao, 1991).

Thakur (1991) reported that total grains per panicle was the highest when 40%, 30% and 30% N was applied as basal, at maximum tillering and panicle initiation

stages, respectively. Penar and Avila (1983) reported that the increasing rates of N fertilizers generally increased the number of panicles m^{-2} and number of grains panicle $^{-1}$. Kuo (1971) reported that increasing N up to 35 kg ha $^{-1}$ increased grain yield mainly through increasing panicle length and number of filled grains per panicle. Huo (1988) found that high nitrogen application reduced grain number per panicle due to lodging. Yoshida and Parao (1976) reported that the decrease in the number of filled grains at higher N levels was due to lodging or culm bending. In regard to the rice plant type which is considered to be closely related to the percentage of ripened grains under overluxuriant growth conditions is proved to be important factors. In most cases as the amount of nitrogen which can be absorbed during the ripening period is very small compared to the nitrogen required in grains. A large amount of nitrogen is translocated from leaves to grains with the advance of ripening. The percentage of ripened grains generally tends to decrease with the increase in the number of grains.

Variation in 1000-grain weight was reported by several reporters. Islam and coworkers (1990) reported that there was an increasing trend of thousand grain weight with an increase in levels of nitrogen up to 80 kg ha $^{-1}$. Tanaka (1968) reported a decrease in the 1000 grain weight with increasing nitrogen supply particularly in the traditional varieties. Tanaka (1968) stated that the depression of grain yield of *Indica* at higher nitrogen levels is seen to be due to decrease both the number of filled grains per panicle and weights of 1000 grains, factors which are mainly decided at the reproductive stage.

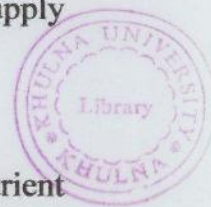
Nitrogen response is more conspicuous than other nutrients. Grain yield increases with increasing nitrogen fertilizer upto a certain level and then decreases (Singh and Pillai, 1991). Sing and associates (1995) reported that the paddy yield continuously increased by added nitrogen from 0-150 kg N ha $^{-1}$. Many investigations at BRRI revealed that grain and straw yields were strongly influenced by nitrogen fertilizer (Anonymous, 1989). The yield of rice generally increases with the increasing nitrogen fertilizer rates (Lin *et al.*, 1981). Higher

levels of nitrogen produced higher amount of straw and grain of rice (Awan *et al.*, 1984). Idris and Matin (1990) observed that grain yield increased gradually with an increase in nitrogen levels and was maximum at 120 kg N ha⁻¹. Hamissa and coworkers (1980) reported that grain yield increased with increasing nitrogen application up to 190 kg N ha⁻¹. These results indicated that increasing rates of nitrogen increased grain yield.

Harvest index (HI), the ratio of the yield of grain to the biological yield is positively correlated with yield. The increase in the plant height as a resultant of wet season planting or high N level resulted in a decrease in HI (Amin, 1999). The decrease in HI was greater in the tall than the short lines. Increase in growth duration increases the amount of dry matter produced, but does not necessarily increase grain yield.

Excess nitrogen application causes lodging which reduces the yield. The height of plant increases, the thickness of the culm decreases and leaves become heavier with increases in applied nitrogen. Consequently a higher nitrogen supply aggravates lodging (Bhuiyan *et al.*, 1987).

Lodging is known to reduce grain yield by interrupting water and nutrient translocation in the shoot (Hitaka and Kobayashi 1962, 1964). The effects of translocation impedance are high spikelet sterility (Jennings and Sornchai 1964) lowered grain weight (Hitaka and Kobayashi 1964). More precisely in rice plants subject to lodging in the early stage of ripening both abortive rice kernels and rice screening increase. The percentage of empty grains in non-stacking rice may reach from 25% to as high as 49% if plants lodge two weeks before heading. If they lodge two weeks after heading the percentage of empty grains is reduced to 19% (Jennings and Sornchai, 1964). Lodging tends to occur in vigorously growing rice plants after heading when ripening progresses and panicles develop. Once lodging occurs, the ripening process is hindered by the deterioration of the light intercepting structure of leaves and the damage in conducting tissues. The extent



of damage depends upon when and how lodging has occurred. In particular certain lodging conditions prohibit the use of harvesting machines. Thus lodging causes a significant decrease in harvesting efficiency. Ookawa T. and Kuni Ishihara (1993) showed that density of lignin of the culm was significantly correlated with the bending stress. Higher quantities of nitrogen usually result in lodging and consequent loss of crop.

Increased nitrogen application, which is essential for high yields cause elongation of the lower internode, making the crop more susceptible to lodging. Early lodging of long, thin culms disturbs leaf arrangement, increases mutual shading interrupts transport of nutrients and photosynthates causes sterility and reduces yield. Short and thick culm resists lodging and reduces respiration loss from the culm (Jennings *et al.*, 1979).

Islam (1976) reported that sulphur application increased effective tillers hill⁻¹ in BR4 rice. Hoque and Hobbs (1978) found that sulphur increased rice yield in *aus* season and little increase of grain yield of local varieties of transplanted *aman* rice were also noticed with the application of sulphur.

Hussain (1978) reported that grain yield of BR3 increased from 5.33 to 6.65 t ha⁻¹ due to application of 30 kg S ha⁻¹ from gypsum. Islam (1978) reported that sulphur application increased panicle numbers hill⁻¹, plant height, fertile grains panicle⁻¹, weight of 1000 grain of BR4 rice when sulphur was applied along with urea (N).

Ismunadji and Miyake (1982) reported that the application of sulphur increased grain yield more than the treatments without sulphur. Blair and coworkers (1979) conducted experiments in 18 sites and reported that the response of sulphur on rice grain yield was as high as 27.8% and the average grain yield was 18.6% more than those in zero sulphur plots. He also observed that panicle number increased from 4.1 hill⁻¹ in control treatment to 14.9 hill⁻¹ due to

80 kg S ha⁻¹ application. Wang (1979) observed that 12 and 24 kg S ha⁻¹ increased tiller number by 42 and 80% and also increased the grain yield from 3.79 t ha⁻¹ with nitrogen alone to 5.22 and 6.10 t ha⁻¹, respectively.

Nair and Gupta (1981) reported that sulphur fertilizer in the form of FeSO₄, MnSO₄ and ZnSO₄ increased the straw yield in rice cv. Ratna. Haque and Khan (1981) observed that plant height of BR4 rice was increased by the application of sulphur and nitrogen. They also noted that rice yield increased from 3.80 to 4.92 t ha⁻¹ by applying 80 kg N and 11.3 kg S ha⁻¹. The straw yield was also increased by nitrogen and sulphur application.

IRRI (1981) reported that gypsum had positive effect on the production of higher number of tillers. Momuat and associates (1981) reported that the lowest increment of sulphur increased rice yield significantly. The highest yield was obtained with 80 kg S ha⁻¹ but was not significantly different from the yields obtained with 40 kg S ha⁻¹.

Idris and Jahiruddin (1983) carried out a field trial on non-calcareous dark grey flood plain soil at Bangladesh Agricultural University Farm using BR3 rice as the test crop. Sulphur fertilizer significantly increased number of tiller hill⁻¹, grain and straw yield of BR3 rice significantly.

Mian and Eaquab (1983) carried out an experiment at the Bangladesh Agricultural University Farm with three levels of sulphur (0, 10 and 20 kg S ha⁻¹) from gypsum and commercially available powdered sulphur. The addition of sulphur significantly increased the yield of rice.

Sachdev and coworkers (1983) reported that application of sulphur as gypsum in sulphur deficient soil increased the straw yield. Samosir and Blair (1983) conducted a field trial to study the effect of sulphur nutrition in rice and found that S increased the number of tillers and yield of rice in sulphur

deficit soils. Haque and Eaquab (1984) studied the effects of sulphur and zinc deficiency in Bangladesh soils and found that sulphur in straw of BR3 rice was increased due to application of 25 and 50 kg S ha⁻¹ compared to S control plots.

Jacob (1985) conducted an experiment of split application of phosphorus fertilizer on the performance of BR11 rice and observed that application of phosphorus fertilizer resulted increased number of panicle bearing tillers.

Ahmed and colleagues (1986) conducted a research on the residual effect of sulphur on rice. Application of 30 kg S ha⁻¹ showed the best response in the initial trials, while 100 kg S ha⁻¹ ranked the second position. However, application of 60 kg S ha⁻¹ performed the best under residual conditions. Bhuiyan and Islam (1986) also conducted several field trials with rice in BRRI farm, Joydebpur and observed that the grain yield increased from 0.5 to 1.0 t ha⁻¹ due to the application of sulphur.

Hoque (1986) showed in 3 out of 4 field trials with 25 kg and 50 kg S ha⁻¹ application, respectively. The highest grain yield was recorded with 50 kg S ha⁻¹. Sulphur content in leaf and straw showed some increase with the increase in rate but increase in sulphur content in grain remained consistent. Moris and associates (1986) reported that application of sulphur in most of the crops increased straw yield.

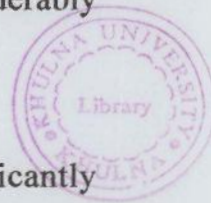
Islam (1978) reported that BR3 variety of rice responded significantly to applications of sulphur either in the form of gypsum or as elemental sulphur. The changes in yield parameters as well as nutrients were significantly affected by sulphur application and yield of BR3 rice increased by about 8% due to application of 30 kg S ha⁻¹ as gypsum. They also found that the plant contained higher sulphur, when 30-40 kg ha⁻¹ was added to the soil.

In order to determine the optimum rate and frequency of application of S for rice production, a field trial was conducted in *boro* season of 1988 in Comilla. Two sulphur doses 10 and 20 kg ha⁻¹ along with NPK were tried. The test variety was BR3. The application of NPK alone significantly improved the yield attributes and increased grain yield from 1.7 t ha⁻¹ (control) to 3.8 t ha⁻¹. Inclusion of S₁₀ in the fertilizer treatment (NPK + S₁₀) further increased grain yield significantly to 4.30 t ha⁻¹ while increasing the dose to 20 kg ha⁻¹ brought about a little increase, and the yield advantage of S₂₀ over S₁₀ was not statistically significant (BRRI, 1988).

Singh and coworkers (1988) conducted a long time experiment with two doses of gypsum (10 and 14.5 kg ha⁻¹) on crop growth and observed a continued higher plant height. Singh and Abrol (1988) carried out an experiment with two rates of gypsum (10 and 14.5 kg ha⁻¹) on crop growth, yield and changes in soil properties and observed a very poor yield in first year but a continued higher plant height and yield of rice and wheat up to the subsequent 4 years.

Deng and Xu (1989) showed that application of sulphur increased the yield of rice. They reported that plant growth and tillering was affected by the deficiency of sulphur. Hussain (1978) stated that sulphur application significantly increased the straw yields but were not statistically significant over NPK treatment. Sulphur and zinc content in straw increased considerably due to addition of sulphur and zinc respectively.

Haque and Biswas (1990) reported that the grain yield of rice significantly increased due to application of sulphur and the yield increase was greatly boosted up and the increase was 56% and 82% over control treatment. Islam and coworkers (1990) reported that sulphur application significantly increased the grain and straw yield of BR2 rice. They also reported that application of sulphur increased the concentration of sulphur both in grain and straw.



Caenio and Mamaril (1991) reported that application of sulphur significantly enhanced plant height and tiller number. Khan and colleagues (1991) carried out an experiment with rice cv. BR10 on a saline silty clay loam soil in Bangladesh. They recorded grain yields of 3.76-4.68, 1.76-2.7 and 0.94-1.40 t ha⁻¹ using irrigation water having salinity level of 1.9, 8 and 6 ds m⁻¹ respectively. At each salinity level, application of gypsum (160 kg gypsum ha⁻¹) + zinc (5 kg Zn ha⁻¹) produced the highest yield.

The mortality rate of secondary and tertiary tillers is much during the late phase of growth (Gomez *et al.*, 1984; Roy and Satter, 1992). Miller and associates (1991) also reported that the number of actively growing tillers declined until reaching a constant tiller density by heading. Shamim and associates (1991) carried out an experiment with BR11 rice variety to study the effect of sulphur and zinc application and observed that application of sulphur fertilizer increased panicle length.

Tandon (1991) reported the response of about 40 crops to sulphur under field conditions in India. Among the crops, the application of S to rice increased the grain yield by 752 kg ha⁻¹ and on an average paddy yield was found to be increased by 17% in 27 studies. Chowdhury and Badiuzzaman (1992) carried out a field trial on silty clay loam soil at Mymensingh and reported that application of 0, 56, 100 and 150 kg K₂O and 30 and 60 Kg S ha⁻¹ to rice cultivar Pajam gave grain yields of 4.45, 4.40, 4.75 and 4.85 t ha⁻¹, respectively. A combination of 150 kg K₂O + 30 kg S gave the highest grain yield of 5.0 t ha⁻¹ and 1000 grain weight of 17.10 g.

Paliwat and coworkers (1992) carried out a pot experiment and reported that the grain yield and the content of nitrogen and sulphur in grains increased significantly with increased levels of nitrogen and sulphur applied singly and in combination.

Rashid and associates (1992) carried out a trial in Pakistan during 1988-91 on rice *cv* Basmati-385 by applying different sulphur sources and found that elemental sulphur increases yield by 18, 9.2 and 5.8% when applied at transplanting or 15 or 30 days after transplanting. Islam and Hossain (1993) reported that application of 20 kg S ha⁻¹ with NPK significantly increased the grain yield of BR11 rice.

Patnaik and Sathe (1993) reported that increase of grain yield with the application of sulphur (as gypsum) and potassium (as muriate of potash) were relatively less than that with nitrogen. The highest grain yield was obtained with the application of 150 kg N+60 kg K₂O + 60 kg S. Akhter and colleagues (1994) carried out field experiments in silt loam and sandy loam soils. They noted that the S application increased grain yield.

Chowdhury and Majumder (1994) conducted field trial in a loam flood plain soil of Bangladesh to assess the effect of 0-30 kg S ha⁻¹ applied as elemental S, gypsum, potassium sulphate or magnesium sulphate to rice cultivar BR11. They reported that grain yield and yield components were significantly increased due to application of sulphur. Hoque and Jahiruddin (1994) studied the effect of single and multiple applications of sulphur and zinc in a continuous rice cropping system and noted that crop yield was increased by sulphur (20 kg S ha⁻¹ as gypsum) but not by zinc.

Jahiruddin and coworkers (1994) conducted a field experiment on Sonatala silt loam soil at Bangladesh Agricultural University farm during the *boro* season of 1992 to investigate the effects of sulphur, zinc and boron on BR2 rice. They reported that 25 kg S ha⁻¹ application increased grain yield of rice. Raju and associates (1994) showed that the rainy season of 1991, application of 25 or 50 kg S ha⁻¹ significantly increased grain yield rice *cv*. Chaitanya. Jahiruddin and colleagues (1994) reported that application of 25 kg S ha⁻¹ increased the number of tillers hill⁻¹.

Islam and associates (1995) carried out a field experiment during the *aman* season of 1992 to investigate the response of BR11 rice to different nutrients. They reported that application of 30 kg S ha⁻¹ increased the grain yield. Mukhopadhyay and Mukhopadhyay (1995) found that gypsum and pyrite were equally effective in increasing rice yield when applied at the rate of 20 kg S ha⁻¹.

Gupta and coworkers (1996) reported that application of gypsum at the rate of 18.75 kg ha⁻¹ produced highest grain yield of rice in Gobwaia watershed in Punjab. Shahu and colleagues (1996) conducted field experiment on a lateritic soil using different amounts of sulphur. From the study they found that rice produced maximum grain yield with 30 kg S ha⁻¹. Islam and associates (1996) conducted two field experiments during transplanted *aman* season of 1992 to examine the response of BR11 rice to added sulphur. Application of 20 kg S ha⁻¹ at both locations significantly increased the grain yield of rice. Choudhury and colleagues (1996) reported that the grain yield of rice cv.BR11 increased 390 kg ha⁻¹ due to application of 30 kg S ha⁻¹.

Gupta and coworkers (1997) conducted a field experiment to study the effect of sulphur dose (0, 10, 20, 30, or 40 Kg S ha⁻¹) on yield and sulphur uptake of rice cultivar PC-19 compared with control. They reported that rice grain yield increased by 14.2, 24.2, 25.6 and 20.1% with the four doses of sulphur, respectively. Shahu and Nandu (1997) conducted two field experiments one in black soil and another in laterite soil to determine the response of rice cultivar Jajati and Lalat to sulphur (0-60 kg ha⁻¹). They observed that mean grain yield increased with sulphur application on black soil and was highest with 60 kg sulphur on the laterite soil.

Suwanarit and associates (1997) found that moderate application of sulphur fertilizers to a soil deficient in sulphur increased the aroma, softness, stickiness and glassiness of boiled milled grains, but higher rates than the

optimum decreased these quality parameters. To obtain grains with highest aroma and stickiness, doses of sulphur fertilizer well above those giving maximum yield were required. Thakur and coworkers (1997) conducted that a field experiment on a silty clay soil in 1993-94 in Bihar on rice. They showed that S application did not significantly increase grain yield. Uddin and associates (1997) conducted a field experiment at Patuakhali during *aman* season of 1990 to see the effect of nitrogen, phosphorus and sulphur on the yield of rice *cv.* Haloi. They reported that application of 20 kg S ha⁻¹ increased tillering and grain yield of rice.

Mondal and Halder (1998) reported that rice *cv.* BR11 was given all combination of 0, 4, 8, or 12 kg Zn and 0, 5, 10 or 20 kg S ha⁻¹. Application of 8 kg Zn + 20 kg S ha⁻¹ gave the best performance in growth and yield of the crop. Patra and coworkers (1998) carried out a greenhouse experiment to study the effect of sulphur application on yield of rice under continuously flooded condition. They stated that application of S fertilizer during active tillering or panicle initiation stage can increase the yield of rice grains.

Sarkunan and colleagues (1998) carried out a pot experiment to find out the effect of P and S on the yields of rice under flooded condition on a P and S deficient sandy loam soil. The treatments were the combination of 4 levels of P (0, 25, 50 and 100 mg kg⁻¹ soil) as ammonium phosphate and 4 levels of S (0, 10, 25 and 50 mg kg⁻¹ soil) as ammonium sulphate. Sulphur application at 25 mg kg⁻¹ soil resulted in 9% increase in grain yield. The treatment combination of 100 mg P kg⁻¹ and 10 mg S kg⁻¹ soil gave significantly higher grain yield than the other treatments.

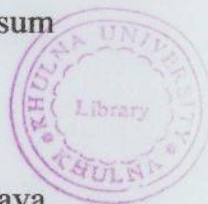
Mandal and coworkers (1999) conducted a pot experiment in a green house where rice *cv.* BR3 was given 0, 50, 75 or 100 kg N ha⁻¹ and 0, 5, 10 or 20 kg S ha⁻¹. There was no significant effect of N or S or their interaction on plant height. Tillering and grain yield were higher with nitrogen. Tillering was the

greatest with 5 kg S, while grain yield was not affected (Yang *et al.*, 2001). Li-Yu Ying and Li-Y (1999) conducted a field experiment on rice. Application of sulphur increased the number of tillers. Poongothi and colleagues (1999) reported that application of 60 kg S ha⁻¹ as gypsum in combination with green leaf manure at the rate 6.25 t ha⁻¹ produced highest grain yield and straw yield resulted in maximum total sulphur uptake. This contribution was found to be optimum for rice growth.

Ram and associates (1999) studied the effect of two sources (pyrites and gypsum) and four levels of S application (0, 30, 60 and 90 kg ha⁻¹) on growth, yield, sulphur use efficiency and uptake in rice (cv. Saket-4) were studied in a reclaimed salt affected soil in Uttar Pradesh, India. Application of S at 90 kg ha⁻¹ gave the highest yield, which was almost similar to that obtained from 60 kg S ha⁻¹. These doses of sulphur, however, produced significantly higher yield than an application of 30 kg S ha⁻¹. Sulphur use efficiency was greater with gypsum than with pyrites, irrespective of their level of application.

Wihardjaka and colleagues (1999) conducted a field experiment in Java, Indonesia during the 1995-96 cropping seasons to determine the effect of sulphur rates (0, 20 and 40 kg S ha⁻¹) on transplanted and direct sown rice cv. IR64. For transplanted rice the highest yield (4.62 t ha⁻¹) was obtained with 20 kg S ha⁻¹.

Mandal and coworkers (2000) carried out a greenhouse experiment to evaluate the effect of nitrogen and sulphur fertilizers on nutrient content of rice grain (cv. BR3) at various growth stages (tillering, flowering and harvesting). Nitrogen was applied as urea and sulphur as gypsum at 0, 5, 10 and 20 kg S ha⁻¹. The combined application of these two elements increased the straw S content only at tillering stage. The uptake of nutrient in the straw and grain improved significantly which was reflected in the straw and grain yields. Wani and Refique (2000) conducted a field experiment during *kharif* 1995 in Shalimar, Jammu and Kashmir, India where



rice cv. K-39 was given 0, 10, 20, 30, 40 or 50 kg S ha⁻¹. Yield and N P K and S uptake increased with increasing sulphur doses up to 40 kg ha⁻¹, then decreased or remained the same.

Raju and Reddy (2001) conducted field investigations at Agricultural Research Station, Maruteru, Andhra Pradesh, India to study the response of both hybrid and conventional rice of sulphur (at 20 kg S ha⁻¹). Conventional rice, MTU 2067 out yielded the hybrid rice MTU-HR 2003 by 21%. Significant improvement in grain yield was observed due to sulphur application. Sakal and coworkers (2001) conducted field experiment in Bihar, India to determine the direct effect of soil applied with sulphur on rice crops. Sulphur was applied at 0, 15, 30 and 45 kg ha⁻¹ as single super phosphate containing 12% S, and rice cv. Rajshree was grown as a test crop. Direct effect of S produced the maximum grain yield of rice (14.3 q ha⁻¹ at 45 kg S ha⁻¹).

Peng and colleagues (2002) carried out a field experiment with one hundred and sixteen soil samples were collected from cultivated soils in Southeast Fujian, China. The average content of available S in these soil samples was 21.7 mg kg⁻¹. The soil with available sulphur 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 sulphur at the dose of 20-60 kg ha⁻¹ to the rice plant. The increasing rate of rice was 2.9-15.5%. Sen and associates (2002) carried out an experiment on application of sulphur through single super phosphate in a sulphur deficient area of Murshidabad district in a rice-mustard cropping system. They recorded significant yield increase in rice with application of sulphur at 30 kg ha⁻¹. Babu *et al.*, (2002) observed that gypsum applied with presumed gave the highest grain yield of 3.92 t ha⁻¹ in 1991 and 4.53 t ha⁻¹ in 1992, which produced 0.68 and 0.73 t ha⁻¹ higher yield, respectively over control treatment. Rashid (2003) reported that application of sulphur fertilizer at the rate of 30 kg ha⁻¹ performed better result of harvest index (%).

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted at the Agrotechnology Field Laboratory of Khulna University, Khulna during the *aman* season from June to December, 2007 to observe the effect of different doses of nitrogen and sulphur on growth, yield and yield attributes of BRRI dhan41. The materials used and the methodologies followed for this study are described below:

Location

The experimental site was located at the latitude of 22°47' N and longitude of 89°34' E. It belongs to the Agroecological Zone of Ganges Tidal Flood Plain (AEZ-13). The experimental field was typical rice growing medium high land under physiographic unit of Ganges Tidal Flood Plain soil.

Soil

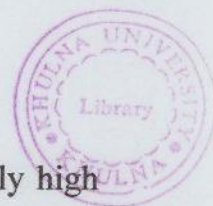
The soil of the experimental field was medium high with sandy loam textured soils with having pH value of 7.6 and some pit soils were found downward having high organic matter content (Appendix 1).

Climate

The experimental field was characterized by subtropical climate moderately high temperature and heavy rainfall during the *kharif* season (April-September) and scanty rainfall with low temperature during the *rabi* season (October- March). Meteorological information during the study period was presented in Appendix 2.

Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with two factors. The unit plot was (4.0 m × 2.5 m). Rice variety BRRI dhan41 was used as plant material. It can tolerate 8 ds m⁻¹ salinity. The plant is very hardy and can protect lodging (BRRI, 2004).



Experimental treatment

There are two factors included in the experiment which were as follows:

Factor A. Nitrogen dose

Four levels of nitrogen fertilizer were used in the experiment, i.e.

$$N_0 = 0 \text{ kg N ha}^{-1} \text{ (as control)}$$

$$N_1 = 66 \text{ kg N ha}^{-1}$$

$$N_2 = 132 \text{ kg N ha}^{-1}$$

$$N_3 = 198 \text{ kg N ha}^{-1}$$

Factor B. Sulphur dose

Three levels of sulphur fertilizer were used in the experiment, i.e.

$$S_1 = 17 \text{ kg S ha}^{-1}$$

$$S_2 = 34 \text{ kg S ha}^{-1}$$

$$S_3 = 51 \text{ kg S ha}^{-1}$$

Land preparation and transplanting

The experimental land was ploughed with the help of a power tiller and was leveled by a ladder carefully to get a well puddled soil. The seedlings of rice variety BRRI dhan41 were transplanted at the age of 31 days, giving three seedlings in each hill. Row to row and hill to hill distance were same as 25 cm.

Fertilizer application

The experimental plots were fertilized with triple super phosphate (TSP) and muriate of potash (MP) as the sources of P_2O_5 and K_2O , respectively. TSP and MP were applied at the rate of 51 and 60 kg ha^{-1} , respectively as recommended by Bangladesh Rice Research Institute (BRRI, 2003). Sulphur fertilizers were applied to the plots as per treatment in the form of gypsum (18% S). All fertilizers except urea was applied and thoroughly mixed with the soil at the time of final land preparation. Urea as a source of nitrogen (N) was applied in two equal installments, first at tillering stage (21 days after transplanting) and 2nd before panicle initiation stage (46 days after transplanting).

Weeding

Weeding was done three times at 16, 30 and 45 days after transplanting (DAT) as well as the field was kept weed free all the time during the experimentation.

Irrigation

First irrigation was provided at 12 DAT due to lack of proper moisture in the field. Next irrigation was also provided two times at 32 and 55 DAT in order to maintain enough moisture in the field during experimentation.

Harvesting

The crop was harvested at full maturity when 90% of the seeds turned golden yellow in color. The harvested crop of each plot was bundled separately, tagged properly and brought to a clean threshing floor. The bundles were dried in the open sunlight, threshed and the seeds were cleaned. The grain and straw weight for each plot were recorded after proper drying in sun and microwave oven then converted into $t\ ha^{-1}$. The grain and straw yield were adjusted to 14% moisture content. During harvesting randomly selected five plant samples from each plot were cut from the basal portion carefully for collecting data on yield contributing characters. To avoid border effect plants were sampled from any of the inner rows.

SAMPLING AND DATA COLLECTION

Data on growth and yield components were recorded from five selected hills in each plot. The grain and straw yields were recorded from the central two square meter area from each plot. The data on yield contributing characters from the collected hills were recorded as follows:

Plant height

The plant height was measured from the base of the plant upto the tip of the tallest leaf or panicle.

Total number of tillers and panicles per hill

The total number of tillers and panicles in five hills were counted and the means were recorded.

Length of panicle

Panicle length was measured from the base of the panicle to the tip of each panicle and mean values were collected.

Number of grain and unfilled spikelets per panicle

Spikelets were separated from panicles and the number of grain and unfilled spikelets per panicle were counted manually.

Thousand grain weight

Thousand clean dried grains from the seed stock of each central two square meter plot were counted separately and weighted by an electric balance and adjusted at 14% moisture content (MC) by using the following formula.

Thousand grain weight at 14% MC =

$$\frac{(100 - \text{SampleMC}) \times \text{Thousand grain weight at sample MC}}{(100 - 14)}$$

Grain yield

Grain yield was measured by using a electric balance and converted the yield into 14% moisture by using above mentioned formula and express in t ha⁻¹.

Straw yield

Total straw yield of the harvested area of each plot was determined. Sample straw of each plot was dried in an oven at 80°C for 48 hours and converted the sample into total straw yield and express in tha⁻¹.

Biological yield

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

Biological yield = Grain yield + Straw yield.

Harvest index (%)

It is the ratio of economic yield to biological yield and was calculated with the following formula:

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

Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984) using a computer operated program named MSTAT-C. Regression analysis was done between growth factors and yield attributes of BRRI dhan41. Functional relationships were also developed between nitrogen and sulphur doses with yield as well as yield attributes.

CHAPTER IV

RESULTS AND DISCUSSION

Results of the present study regarding the influence of nitrogen and sulphur fertilizers on growth, yield and yield attributes of transplanted *aman* rice cv. BRRI dhan41 have been presented and discussed in this chapter.

EFFECT OF NITROGEN ON THE GROWTH, YIELD AND YIELD ATTRIBUTES OF BRRI DHAN41

Plant height (cm)

The effect of nitrogen fertilizer on plant height differed significantly. Variation in plant height was observed among the treatments (Table 1). Plant height increased progressively over time upto harvest due to application of different levels of nitrogen fertilizer. The tallest plant (115.72 cm) at harvest was found from application of 198 kg N ha⁻¹ which differed significantly from other treatments and control treatment (0 kg N ha⁻¹) produced the shortest plant (97.54 cm). Similar result was found by Talukder (1973) who observed a continued higher plant height with the application of nitrogen fertilizer.

Tiller number hill⁻¹

The dynamics of tiller production in time has been shown in Table 2. The effect of nitrogen on tiller number hill⁻¹ was found statistically significant. Tiller number in all the treatments increased almost exponentially upto 45 DAT. A sharp decline in tiller number from 45 DAT and onwards was noticed (Table 2). This might be due the fact that the mortality rate of secondary and tertiary tillers is much during the later phase of growth (Roy and Satter, 1992). Miller and associates (1991) also reported that the number of actively growing tillers declined until reaching a constant tiller density by heading. The highest tiller number hill⁻¹ (13.54) was recorded from application of 198 kg N ha⁻¹ and the lowest was found in the control at 45 DAT. At harvest or maturity period application of 198 kg N ha⁻¹ produced higher tiller number hill⁻¹ (12.38) which was statistically similar to 132 kg N ha⁻¹ and 0 kg N ha⁻¹ produced the lowest tiller number hill⁻¹ (8.68). Singh and Arya

(1992) reported that increasing rate of nitrogen upto 30 kg N ha⁻¹ increased number of tillers hill⁻¹.

Dry matter accumulations (g m⁻²)

The effect of nitrogen on dry matter production at different days after transplanting was found to be statistically significant. Dry matter accumulation increased progressively in time due to application of different levels of nitrogen fertilizer (Table 3). Higher amount of dry matter (204.08 g m⁻², 353.12 g m⁻² and 452.88 g m⁻²) was found at 30 DAT, 45 DAT and 60 DAT, respectively from the application of 198 kg N ha⁻¹ and control treatment produced minimum amount of dry matter. However, appreciable difference was not found between N₂ and N₃ treatments regarding dry matter production. Similar results were found by Singh and Arya (1992).

Panicle number hill⁻¹

Number of panicle hill⁻¹ ranged from 7.48 to 10.96 (Table 4). The maximum number of panicle hill⁻¹ (10.96) was found from the application of 198 kg N ha⁻¹ and the minimum was found in control (Table 4). The results were in agreement with Singh and Arya (1992).

Panicle length (cm)

Length of panicle of BRRI dhan41 was significant and varied from 18.57 to 21.81 cm (Table 4). The longest panicle (21.81 cm) was found from the application of 198 kg N ha⁻¹ which differed significantly from other treatments. Shortest panicle (18.57 cm) was observed in control. Similar result was found by Talukder (1973).

Grain number panicle⁻¹

The effect of nitrogen on number of grain panicle⁻¹ varied significantly. The maximum number of grain panicle⁻¹ (105.95) was found from the application of 198 kg N ha⁻¹ which differed significantly than other treatments and the minimum was recorded in control treatment (Table 4). Mandal and colleagues (2000) also reported that application of nitrogen fertilizer increased number of grains panicle⁻¹.



Table 1. Effect of nitrogen levels on plant height (cm) of BRRI dhan41 at different days after transplanting (DAT)

Nitrogen levels	Plant height (cm) at				Harvest
	30 DAT	45 DAT	60 DAT		
N ₀ (0 kg N ha ⁻¹)	59.92c	78.54c	88.10c		97.54d
N ₁ (66 kg N ha ⁻¹)	63.86b	83.61b	93.95b		110.03c
N ₂ (132 kg N ha ⁻¹)	65.96a	86.23a	97.32a		114.91b
N ₃ (198 kg N ha ⁻¹)	66.57a	86.72a	97.74a		115.72a
Level of significance	0.01	0.01	0.01		0.01
CV (%)	0.83	0.66	0.55		0.35

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly

Table 2. Effect of nitrogen levels on tiller number hill^{-1} of BRRI dhan41 at different days after transplanting (DAT)

Nitrogen levels	Tiller number hill^{-1} at				Harvest
	30 DAT	45 DAT	60 DAT		
N_0 (0 kg N ha^{-1})	7.00c	9.73d	9.06d		8.68c
N_1 (66 kg N ha^{-1})	8.57b	11.68c	10.86c		10.51b
N_2 (132 kg N ha^{-1})	9.72a	12.94b	12.27b		12.01a
N_3 (198 kg N ha^{-1})	9.94a	13.54a	12.74a		12.38a
Level of significance	0.01	0.01	0.01		0.01
CV (%)	2.67	2.02	1.99		2.41

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly

Table 3. Effect of nitrogen levels on dry matter (g m^{-2}) accumulation by BRRI dhan41 at different days after transplanting (DAT)

Nitrogen levels	Dry matter (g m^{-2}) accumulation at		
	30 DAT	45 DAT	60 DAT
N ₀ (0 kg N ha ⁻¹)	129.44c	257.68c	364.64c
N ₁ (66 kg N ha ⁻¹)	168.64b	305.76b	424.64b
N ₂ (132 kg N ha ⁻¹)	201.68a	349.04a	447.68a
N ₃ (198 kg N ha ⁻¹)	204.08a	353.12a	452.88a
Level of significance	0.01	0.01	0.01
CV (%)	4.24	2.57	1.57

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly

Unfilled spikelets panicle⁻¹

Number of unfilled spikelet panicle⁻¹ of the tested cv. BRRI dhan41 differed significantly and ranged from 12.67 to 15.53 (Table 4). The maximum number of unfilled spikelet panicle⁻¹ (15.53) was observed in control treatment which was statistically similar to the unfilled spikelets produced from 66 kg N ha⁻¹ and the minimum was found from application of 198 kg N ha⁻¹ which was statistically similar to unfilled spikelets obtained from 132 kg N ha⁻¹.

Weight of thousand grains (g)

Nitrogen application had a significant effect on weight of thousand grains of BRRI dhan41 which ranged from 22.65 to 24.58 g. The highest weight of thousand grains (24.58 g) came from application of 198 kg N ha⁻¹ and lowest was found in control treatment (Table 4). The results showed that increasing rate of nitrogen increased weight of thousand grains. The result was supported by Islam and colleagues (1990).

Grain yield (t ha⁻¹)

The effect of nitrogen on grain yield of BRRI dhan41 was significant and varied from 2.64 to 4.46 t ha⁻¹ (Table 4). The highest grain yield (4.46 t ha⁻¹) was obtained from the plot receiving the highest dose of nitrogen (198 kg N ha⁻¹) and the lowest (2.64 t ha⁻¹) was found in control treatment. The results showed that grain yield decreased with the decreasing rate of nitrogen fertilizer. The highest grain yield in N₃ treatment might be due to maximum number of panicle hill⁻¹, greater panicle length, more number of grain panicle⁻¹, highest weight of thousand grains and higher harvest index (Table 4). Similar result was found by Awan and coworkers (1984).

Straw yield (t ha⁻¹)

Straw yield varied due to application of nitrogen fertilizer and ranged from 4.05 to 5.42 t ha⁻¹ (Table 4). The highest straw yield (5.42 t ha⁻¹) was found from application of 132 kg N ha⁻¹ which varied significantly from other treatments and

Table 4. Effect of nitrogen levels on yield and yield attributes of BRRI dhan41

Nitrogen levels	Panicle number hill ⁻¹	Panicle length (cm)	Grain number panicle ⁻¹	Unfilled spikelets panicle ⁻¹	1000 grain weight (g)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index (%)
N ₀ (0 kg N ha ⁻¹)	7.48c	18.57d	100.33d	15.53a	22.65d	2.64d	4.05d	6.69c	39.49c
N ₁ (66 kg N ha ⁻¹)	9.16b	20.34c	102.73c	14.74a	23.15c	3.45c	4.72c	8.17b	42.22b
N ₂ (132 kg N ha ⁻¹)	10.39ab	21.46b	104.24b	13.60b	24.29b	4.15b	5.42a	9.57a	43.49b
N ₃ (198 kg N ha ⁻¹)	10.96a	21.81a	105.95a	12.67b	24.58a	4.46a	5.26b	9.72a	45.82a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	2.17	1.00	0.38	4.64	0.60	3.67	1.60	1.87	2.49

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly



the lowest (4.05 t ha^{-1}) was obtained from control treatment. Similar results were observed by Paliwat and associates (1992); they reported that application of nitrogen fertilizer increased the straw yield of BRRI dhan41.

Biological yield (t ha^{-1})

The effect of nitrogen on biological yield was significant. Biological yield ranged from 6.69 to 9.72 t ha^{-1} (Table 4). The highest biological yield (9.72 t ha^{-1}) was found from application of 198 kg N ha^{-1} which was identical to 132 kg N ha^{-1} and the lowest (6.69 t ha^{-1}) was obtained from control treatment.

Harvest index (%)

Harvest index varied significantly due to application by nitrogen and ranged from 39.49 to 45.82% (Table 4). The experimental results showed that the highest harvest index (45.82%) was obtained from application of 198 kg N ha^{-1} and the lowest was recorded from control treatment.

EFFECT OF SULPHUR ON THE GROWTH, YIELD AND YIELD ATTRIBUTES OF BRRI DHAN41

Plant height (cm)

The effect of sulphur on plant height differed significantly. Variation in plant height was found among the treatments (Table 5). The tallest plant was produced from application of 34 kg S ha^{-1} which differed significantly from plant height obtained in other treatments and 51 kg S ha^{-1} produced the shortest plant at all growth stages. Similar results were reported by Singh and associates (1988).

Tiller number hill^{-1}

Number of tillers hill^{-1} differed significantly due to sulphur application. Tiller number in all the treatments increased almost exponentially upto 45 DAT (Table 6). A sharp decline in tiller number from 45 DAT and onwards was noticed. The highest tiller number hill^{-1} (12.77) was recorded from application of 34 kg S ha^{-1} and the lowest (11.32) was found from application of 51 kg S ha^{-1} at 45 DAT. At

harvest or maturity period application of 34 kg S ha⁻¹ produced the highest tiller number hill⁻¹ (11.70) which differed significantly from other treatments. The results were in agreement with Uddin and coworkers (1997).

Dry matter accumulations (g m⁻²)

The effect of sulphur on dry matter production at different DAT was found to be statistically significant. It was observed that dry matter increased progressively over time upto harvest due to application of different levels of sulphur fertilizer (Table 7). The maximum weight of dry matter (186.32 g m⁻², 328.24 g m⁻² and 437.52 g m⁻²) was found at 30 DAT, 45 DAT and 60 DAT, respectively from application of 34 kg S ha⁻¹ which was differed significantly from dry matter obtained in other treatments. Application of 51 kg S ha⁻¹ produced minimum amount of dry matter at different DAT which was identical to 17 kg S ha⁻¹. The result was supported by Singh and Arya (1992).

Panicle number hill⁻¹

The response of sulphur on the number of panicle hill⁻¹ differed significantly and ranged from 8.86 to 10.16 (Table 8). The maximum number of panicle hill⁻¹ (10.16) was found from the application of 34 kg S ha⁻¹ which differed significantly from panicle length obtained in other treatments and the minimum was found in 51 kg S ha⁻¹ treatment. Similar results were observed by Jacob (1985).

Panicle length (cm)

Panicle length of BRRI dhan41 found to be influenced significantly by application of sulphur. It was observed that panicle length ranged from 19.93 to 21.16 cm (Table 8). The longest panicle (21.16 cm) was produced by application of 34 kg S ha⁻¹ which was differed significantly from panicle length of other treatments and the lowest (19.93 cm) was found from application of 51 kg S ha⁻¹. Similar result was found by Shamim and coworkers (1991).

Table 5. Effect of sulphur levels on plant height (cm) of BRRI dhan41 at different days after transplanting (DAT)

Sulphur levels	Plant height (cm) at			
	30 DAT	45 DAT	60 DAT	Harvest
S ₁ (17 kg S ha ⁻¹)	63.94b	83.69b	94.09b	109.42b
S ₂ (34 kg S ha ⁻¹)	65.35a	85.15a	96.10a	111.57a
S ₃ (51 kg S ha ⁻¹)	62.95c	82.48c	92.64c	107.65c
Level of significance	0.01	0.01	0.01	0.01
CV (%)	0.83	0.66	0.55	0.35

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly

Table 6. Effect of sulphur levels on tiller number hill⁻¹ of BRRI dhan41 at different days after transplanting (DAT)

Sulphur levels	Tiller number hill ⁻¹ at				Harvest
	30 DAT	45 DAT	60 DAT		
S ₁ (17 kg S ha ⁻¹)	8.45b	11.84b	11.11b		10.74b
S ₂ (34 kg S ha ⁻¹)	9.37a	12.77a	12.00a		11.70a
S ₃ (51 kg S ha ⁻¹)	8.60b	11.32c	10.59c		10.25c
Level of significance	0.01	0.01	0.01		0.01
CV (%)	2.67	2.02	1.99		2.41

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly



Table 7. Effect of sulphur levels on dry matter (g m^{-2}) accumulation by BRRI dhan41 at different days after transplanting (DAT)

Sulphur levels	Dry matter (g m^{-2}) accumulation at		
	30 DAT	45 DAT	60 DAT
S ₁ (17 kg S ha ⁻¹)	172.88b	305.52b	413.68b
S ₂ (34 kg S ha ⁻¹)	186.32a	328.24a	437.52a
S ₃ (51 kg S ha ⁻¹)	168.72b	315.44ab	416.24b
Level of significance	0.01	0.01	0.01
CV (%)	4.24	2.57	1.57

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly

Grain number panicle⁻¹

Number of grains panicle⁻¹ was significantly influenced by sulphur application (Table 8). The maximum number of grain panicle⁻¹ (104.66) was found from the application of 34 kg S ha⁻¹. The minimum number of grain panicle⁻¹ (102.38) was recorded from application of 51 kg S ha⁻¹ which was statistically similar to grains obtained in 17 kg S ha⁻¹. The finding was supported by Nair and Gupta (1981) and Mandal and colleagues (2000).

Unfilled spikelets panicle⁻¹

Number of unfilled spikelet panicle⁻¹ of the tested variety was not influenced by application of sulphur. The maximum number of unfilled spikelet panicle⁻¹ (14.43) was observed in 17 kg S ha⁻¹ which was statistically similar to other treatments (Table 8).

Weight of thousand grains (g)

The effect of sulphur fertilizer on weight of thousand grains of BRRI dhan41 was significant which ranged from 23.30 to 23.97 g (Table 8). The highest weight of thousand grains (23.97 g) came from application of 34 kg S ha⁻¹ and the lowest (23.30 g) was found in 51 kg S ha⁻¹ treatment. The result was supported by Islam and associates (1996).

Grain yield (t ha⁻¹)

It was observed that grain yield of BRRI dhan41 ranged from 3.35 to 4.03 t ha⁻¹ (Table 8). The highest grain yield (4.03 t ha⁻¹) was obtained from application of 34 kg S ha⁻¹ and the lowest (3.35 t ha⁻¹) was found in 51 kg S ha⁻¹. Similar results were recorded by Haque and Biswas (1990).

Table 8. Effect of sulphur levels on yield and yield attributes of BRR1 dhan41

Sulphur levels	Panicle number hill ⁻¹	Panicle length (cm)	Grain number panicle ⁻¹	Unfilled spikelets panicle ⁻¹	1000 grain weight (g)	Grain yield ha ⁻¹	Straw yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index (%)
S ₁ (17 kg S ha ⁻¹)	9.47b	20.55b	102.89b	14.43	23.73b	3.65b	4.68b	8.33b	43.46
S ₂ (34 kg S ha ⁻¹)	10.16a	21.16a	104.66a	13.87	23.97a	4.03a	5.29a	9.32a	42.93
S ₃ (51 kg S ha ⁻¹)	8.86c	19.93c	102.38b	14.11	23.30c	3.35c	4.62b	7.97c	41.88
Level of significance	0.01	0.01	0.01	NS	0.01	0.01	0.01	0.01	NS
CV (%)	2.17	1.00	0.38	4.64	0.60	3.67	1.60	1.87	2.49

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly

Straw yield (t ha^{-1})

Sulphur application had a significant effect on straw yield which ranged from 4.62 to 5.29 t ha^{-1} (Table 8). The highest straw yield (5.29 t ha^{-1}) was observed in 34 kg S ha^{-1} and the lowest (4.62 t ha^{-1}) was found in 51 kg S ha^{-1} . Similar results were observed by Sachdev and colleagues (1983).

Biological yield (t ha^{-1})

The effect of sulphur on biological yield was significant which ranged from 7.97 to 9.32 t ha^{-1} (Table 8). The highest biological yield (9.32 t ha^{-1}) was produced by application of 34 kg S ha^{-1} and the lowest (7.97 t ha^{-1}) was found where sulphur was applied at 51 kg S ha^{-1} . The better result of biological yield in 34 kg S ha^{-1} might be due to the significant increase in grain and straw yield, as had also been reported by Hoque and Hobbs (1978).

Harvest index (%)

The variation among harvest index due to different level of sulphur application was not influenced significantly. Results presented in Table 8 showed that 17 kg S ha^{-1} produced the highest harvest index (43.46%) which was statistically identical to 34 kg S ha^{-1} (42.93%) and 51 kg S ha^{-1} (41.88%).

INTERACTION EFFECT OF NITROGEN AND SULPHUR ON THE GROWTH, YIELD AND YIELD ATTRIBUTES OF BRRI DHAN41**Plant height (cm)**

Interaction effect of nitrogen and sulphur on plant height was significant (Table 9). It was observed that the tallest plant (118.15 cm) was found at harvest from treatment combinations of 198 kg N ha^{-1} with 34 kg S ha^{-1} which differed significantly than plant heights of other treatments which was 68.75 cm at 30 DAT and treatment combinations of 0 kg N ha^{-1} with 51 kg S ha^{-1} produced the shortest plant (94.62 cm) at harvest that differed significantly from other treatments which was 58.27 cm at 30 DAT. Almost similar results were reported by Mandal and associates (1999).

Tiller number hill⁻¹

Number of tillers hill⁻¹ differed significantly due to interaction effect of nitrogen and sulphur. Tiller number in all the treatment combinations increased almost exponentially upto 45 DAT (Table 10). A sharp decline in tiller number from 45 DAT onwards was found. The highest tiller number hill⁻¹ (14.63) was recorded from treatment combinations of 198 kg N ha⁻¹ with 34 kg S ha⁻¹ and the lowest (8.81) was found from treatment combinations of 0 kg N ha⁻¹ with 17 kg S ha⁻¹ at 45 DAT. At harvest or maturity period at the rate of 198 kg N ha⁻¹ with 34 kg S ha⁻¹ treatment combinations produced higher tiller number hill⁻¹ (13.58) which was differed significantly from other treatments. The result was in agreement with Mandal and coworkers (2000).

Dry matter accumulations (g m⁻²)

The interaction effect of nitrogen and sulphur on dry matter of BRRI dhan41 at different DAT was found statistically significant. It was observed that dry matter increased progressively over time due to application of different levels of nitrogen and sulphur fertilizers (Table 11). The maximum weight of dry matter (470.40 g m⁻²) was found at 60 DAT from treatment combinations of 198 kg N ha⁻¹ with 34 kg S ha⁻¹ which was statistically similar (468.48 g m⁻²) to dry matter obtained in treatment combinations of 132 kg N ha⁻¹ with 34 kg S ha⁻¹ and at the rate of 0 kg N ha⁻¹ with 51 kg S ha⁻¹ treatment combinations produced minimum amount (122.64 g m⁻²) of dry matter at 30 DAT. The result was supported by Islam and colleagues (1990).

Panicle number hill⁻¹

The number of panicle hill⁻¹ differed significantly by interaction between nitrogen and sulphur which ranged from 6.83 to 11.83 (Table 12). The maximum number of panicle hill⁻¹ (11.83) was found from 198 kg N ha⁻¹ with 34 kg S ha⁻¹ treatment combinations which differed significantly than other treatments and the minimum was found in treatment combinations of 0 kg N ha⁻¹ with 17 kg S ha⁻¹. Similar results were observed by Jacob (1985).

Table 9. Interaction effect of nitrogen and sulphur on plant height (cm) of BRRI dhan41 at different days after transplanting (DAT)

Treatment combinations	Plant height (cm) at			Harvest
	30 DAT	45 DAT	60 DAT	
N ₀ S ₁	60.29i	79.12i	88.44g	98.15j
N ₀ S ₂	61.20h	80.13h	90.86f	99.86i
N ₀ S ₃	58.27j	76.37j	85.01h	94.62k
N ₁ S ₁	63.69fg	83.46fg	93.65e	109.83g
N ₁ S ₂	64.56ef	84.26ef	94.84d	111.81f
N ₁ S ₃	63.34g	83.12g	93.35e	108.47h
N ₂ S ₁	65.64cd	85.88c	96.91c	114.15d
N ₂ S ₂	66.90b	87.16b	98.45b	116.49b
N ₂ S ₃	65.35cde	85.64cd	96.59c	114.08de
N ₃ S ₁	66.13bc	86.31bc	97.35c	115.57c
N ₃ S ₂	68.75a	89.06a	100.25a	118.15a
N ₃ S ₃	64.83de	84.80de	95.60d	113.44e
Level of significance	0.05	0.05	0.01	0.01
CV (%)	0.83	0.66	0.55	0.35

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly

Note: N₀ = 0 kg N ha⁻¹, N₁ = 66 kg N ha⁻¹, N₂ = 132 kg N ha⁻¹, N₃ = 198 kg N ha⁻¹

S₁ = 17 kg S ha⁻¹, S₂ = 34 kg S ha⁻¹, S₃ = 51 kg S ha⁻¹

Table 10. Interaction effect of nitrogen and sulphur on tiller number hill⁻¹ of BRRI dhan41 at different days after transplanting (DAT)

Treatment combinations	Tiller number hill ⁻¹ at				Harvest
	30 DAT	45 DAT	60 DAT		
N ₀ S ₁	5.41g	8.81i	8.21j		7.83i
N ₀ S ₂	7.56f	10.57g	9.78h		9.41g
N ₀ S ₃	8.01e	9.83h	9.18i		8.81h
N ₁ S ₁	8.38e	11.38f	10.58g		10.18f
N ₁ S ₂	9.15cd	12.45d	11.62e		11.38d
N ₁ S ₃	8.20e	11.22f	10.38g		9.96f
N ₂ S ₁	9.81b	13.18c	12.42d		12.18c
N ₂ S ₂	9.96b	13.42c	12.82c		12.43bc
N ₂ S ₃	9.38c	12.22de	11.57ef		11.42d
N ₃ S ₁	10.20b	13.97b	13.22b		12.77b
N ₃ S ₂	10.81a	14.63a	13.78a		13.58a
N ₃ S ₃	8.83d	12.02e	11.22f		10.78e
Level of significance	0.01	0.01	0.01		0.01
CV (%)	2.67	2.02	1.99		2.41

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly

Note: N₀ = 0 kg N ha⁻¹, N₁ = 66 kg N ha⁻¹, N₂ = 132 kg N ha⁻¹, N₃ = 198 kg N ha⁻¹

S₁ = 17 kg S ha⁻¹, S₂ = 34 kg S ha⁻¹, S₃ = 51 kg S ha⁻¹



Table 11. Interaction effect of nitrogen and sulphur on dry matter (g m^{-2}) accumulation of BRRI dhan41 at different days after transplanting (DAT)

Treatment combinations	Dry matter (g m^{-2}) accumulation at		
	30 DAT	45 DAT	60 DAT
N ₀ S ₁	126.64ef	250.64h	363.44f
N ₀ S ₂	139.20e	268.80g	375.44e
N ₀ S ₃	122.64f	253.60h	355.20f
N ₁ S ₁	172.00d	306.64f	418.40d
N ₁ S ₂	171.68d	299.20f	435.68c
N ₁ S ₃	162.40d	311.44ef	420.00d
N ₂ S ₁	188.48c	322.40de	422.64d
N ₂ S ₂	212.24ab	359.68b	468.48a
N ₂ S ₃	204.24b	365.04b	452.00b
N ₃ S ₁	204.48b	342.40c	450.40b
N ₃ S ₂	222.08a	385.28a	470.40a
N ₃ S ₃	185.60c	331.68cd	437.84c
Level of significance	0.05	0.01	0.05
CV (%)	4.24	2.57	1.57

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly

Note: N₀ = 0 kg N ha⁻¹, N₁ = 66 kg N ha⁻¹, N₂ = 132 kg N ha⁻¹, N₃ = 198 kg N ha⁻¹

S₁ = 17 kg S ha⁻¹, S₂ = 34 kg S ha⁻¹, S₃ = 51 kg S ha⁻¹

Regression analysis between panicle number and grain yield expressed that grain yield is dependent on panicle number hill⁻¹ and 98% of the variation in yield could be defined by the variation in panicle number hill⁻¹ (Fig. 1).

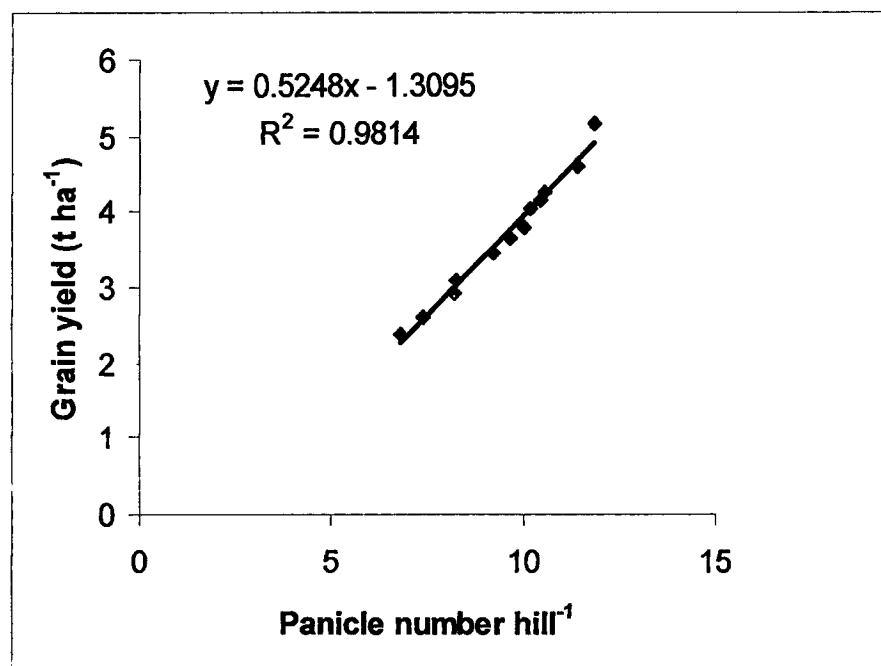


Fig. 1. Functional relationship between panicle number hill⁻¹ and grain yield of BRR dhan41

Panicle length (cm)

Length of panicle was significantly influenced by interaction effect of nitrogen and sulphur. Length of panicle ranged from 17.95 to 23.03 cm (Table 12). However, numerically the longest (23.03 cm) and shortest (17.95 cm) panicle length recorded from treatment combinations of 198 kg N ha⁻¹ with 34 kg S ha⁻¹ and 0 kg N ha⁻¹ with 51 kg S ha⁻¹, respectively. Similar result was found by Paliwat and colleagues (1992).

Grain number panicle⁻¹

Interaction effect of nitrogen and sulphur on number of grain panicle⁻¹ was significant. The maximum number of grain panicle⁻¹ (109.32) was found from treatment combinations of 198 kg N ha⁻¹ with 34 kg S ha⁻¹ and the minimum

(99.53) was recorded from 0 kg N ha⁻¹ with 17 kg S ha⁻¹ treatment combinations (Table 12). This finding is supported by Mandal and coworkers (2000).

Regression analysis taking grain yield as dependent variable and grain number panicle⁻¹ as independent variable expressed a linear and positive relationship. This result suggested that grain yield is dependent on grain number panicle⁻¹ and over 92% of the variation in grain yield could be defined by the variation in number of grain panicle⁻¹ (Fig. 2).

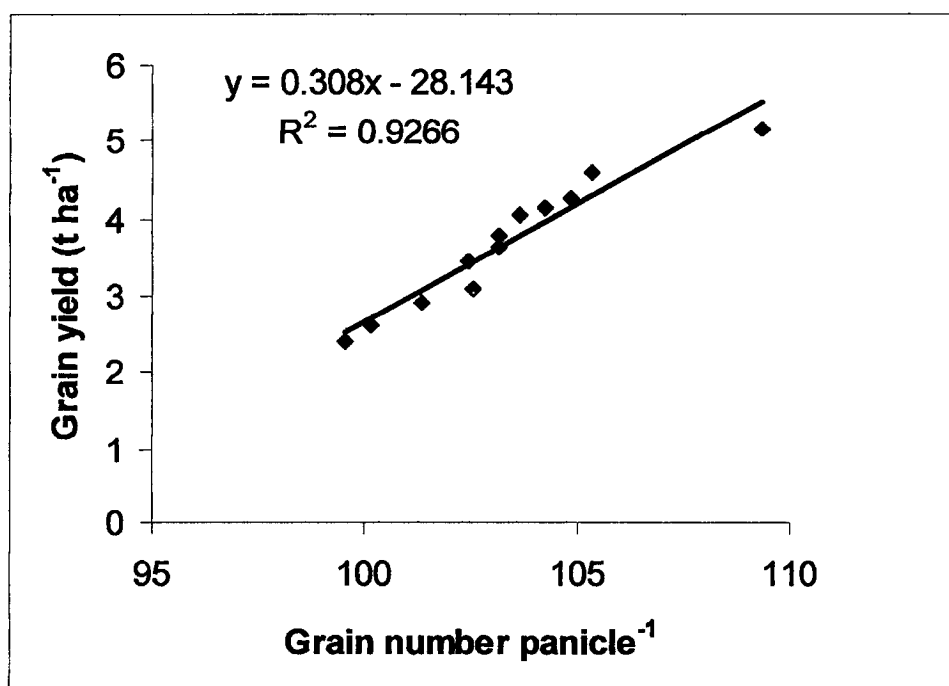


Fig. 2. Functional relationship between grain number panicle⁻¹ and grain yield of BRRI dhan41

Unfilled spikelets panicle⁻¹

Interaction effect of nitrogen and sulphur on number of unfilled spikelet panicle⁻¹ of the tested BRRI dhan41 was found significant. The maximum (15.80) and minimum (12.52) number of unfilled spikelets panicle⁻¹ observed in 0 kg N ha⁻¹ with 17 kg S ha⁻¹ and 198 kg N ha⁻¹ with 34 kg S ha⁻¹ treatment combinations respectively (Table 12).

Table 12. Interaction effect of nitrogen and sulphur on yield and yield attributes of BRRI dhan41

Treatment combinations	Panicle number hill ⁻¹	Panicle length (cm)	Grain number panicle ⁻¹	Unfilled spikelets panicle ⁻¹	1000 grain weight (g)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index (%)
N ₀ S ₁	6.83j	18.80g	99.53i	15.80a	22.49h	2.39g	3.73h	6.12i	39.08d
N ₀ S ₂	8.21h	18.97g	101.33h	15.24abc	22.81g	2.92f	4.54e	7.46g	39.17d
N ₀ S ₃	7.41i	17.95h	100.15i	15.56ab	22.65gh	2.61g	3.88g	6.49h	40.21cd
N ₁ S ₁	9.23g	20.60e	102.42g	15.49ab	23.08f	3.46e	4.28f	7.74f	44.72b
N ₁ S ₂	10.02e	20.75e	103.18ef	14.22cd	23.26ef	3.79d	4.89d	8.68d	43.67b
N ₁ S ₃	8.23h	19.68f	102.58fg	14.53bcd	23.10f	3.09f	4.99d	8.08e	38.28d
N ₂ S ₁	10.42cd	21.32c	104.26cd	13.68de	24.41c	4.15c	4.98d	9.13c	45.47b
N ₂ S ₂	10.57c	21.89b	104.83bc	13.51de	24.41c	4.26c	6.09a	10.35b	41.16c
N ₂ S ₃	10.19de	21.17cd	103.63de	13.61de	24.05d	4.05c	5.19c	9.24c	43.84b
N ₃ S ₁	11.42b	21.47c	105.37b	12.74e	24.92b	4.60b	5.73b	10.33b	44.56b
N ₃ S ₂	11.83a	23.03a	109.32a	12.52e	25.42a	5.15a	5.64b	10.79a	47.73a
N ₃ S ₃	9.63f	20.93de	103.15ef	12.76e	23.40e	3.64de	4.41e	8.05e	45.19b
Level of significance	0.01	0.01	0.01	0.05	0.01	0.01	0.01	0.01	0.01
CV (%)	2.17	1.00	0.38	4.64	0.60	3.67	1.60	1.87	2.49

In a column, figures bearing letter(s) in common do not differ significantly, whereas figures with dissimilar letter(s) differ significantly

Note: N₀ = 0 kg N ha⁻¹, N₁ = 66 kg N ha⁻¹, N₂ = 132 kg N ha⁻¹, N₃ = 198 kg N ha⁻¹

S₁ = 17 kg S ha⁻¹, S₂ = 34 kg S ha⁻¹, S₃ = 51 kg S ha⁻¹

Weight of thousand grains (g)

Weight of thousand grains of BRRI dhan41 varied significantly by interaction effect of nitrogen and sulphur fertilizer on which ranged from 22.49 to 25.42 g (Table 12). The highest weight of thousand grains (25.42 g) came from treatment combinations of 198 kg N ha⁻¹ with 34 kg S ha⁻¹ and the lowest (22.49 g) was found in 0 kg N ha⁻¹ with 17 kg S ha⁻¹ treatment combinations. This result was supported by Paliwat and colleagues (1992).

Grain yield (t ha⁻¹)

Grain yield of BRRI dhan41 was highly significant due to interaction effect of nitrogen and sulphur. It was observed that grain yield ranged from 2.39 to 5.15 t ha⁻¹ (Table 12). The highest grain yield (5.15 t ha⁻¹) was obtained from treatment combinations of 198 kg N ha⁻¹ with 34 kg S ha⁻¹ and the lowest (2.39 t ha⁻¹) was found in 0 kg N ha⁻¹ with 17 kg S ha⁻¹ treatment combinations. The highest grain yield of 198 kg N ha⁻¹ with 34 kg S ha⁻¹ might be due to maximum number of panicle, greater panicle length, maximum number of grain panicle⁻¹, maximum weight of thousand grains and highest harvest index. Almost similar results were recorded by Islam and associates (1990).

Simple linear regressions showed that grain yield of BRRI dhan41 were highly dependent on nitrogen dose. Results indicated that yield of BRRI dhan41 increased with increment of nitrogen doses (Fig. 3). The regression equations obtained are -

$$\text{Grain yield (S}_1\text{)} = 2.552 + 0.732 \times \text{nitrogen dose (R}^2 = 0.965\text{)}$$

$$\text{Grain yield (S}_2\text{)} = 2.956 + 0.716 \times \text{nitrogen dose (R}^2 = 0.987\text{)}$$

$$\text{Grain yield (S}_3\text{)} = 2.74 + 0.405 \times \text{nitrogen dose (R}^2 = 0.6896\text{)}$$

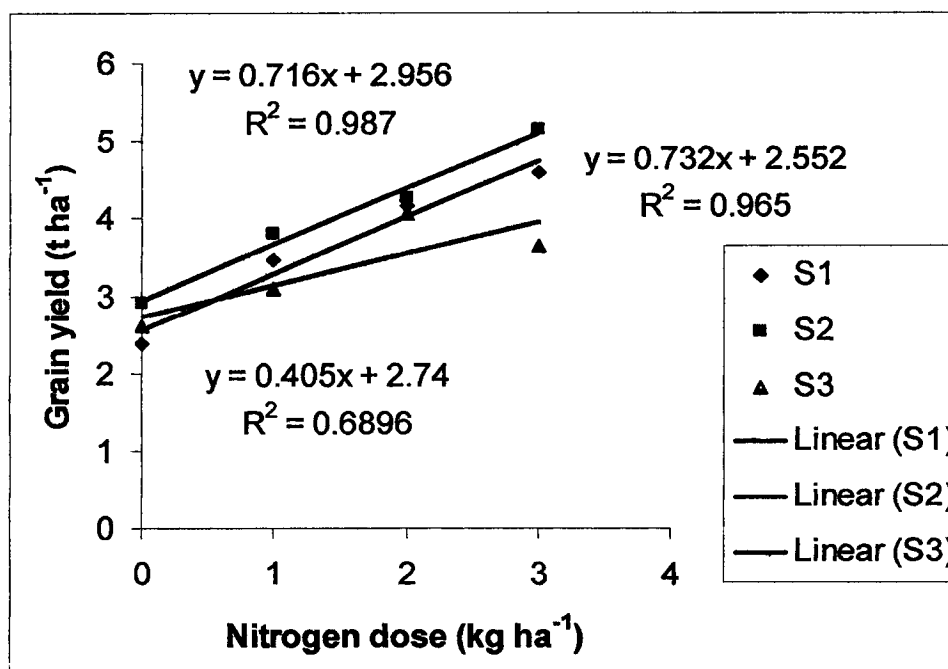


Fig. 3. Functional relationship between nitrogen dose and grain yield of BRRI dhan41

S ₁ : 17 kg S ha ⁻¹	0 : 0 kg N ha ⁻¹
S ₂ : 34 kg S ha ⁻¹	1 : 66 kg N ha ⁻¹
S ₃ : 51 kg S ha ⁻¹	2 : 132 kg N ha ⁻¹
	3 : 198 kg N ha ⁻¹

Straw yield (t ha⁻¹)

Interaction effect of nitrogen and sulphur had a significant effect on straw yield which ranged from 3.73 to 6.09 t ha⁻¹ (Table 12). The highest straw yield (6.09 t ha⁻¹) observed in treatment combinations of 132 kg N ha⁻¹ with 34 kg S ha⁻¹ and the lowest (3.73 t ha⁻¹) was found in 0 kg N ha⁻¹ with 17 kg S ha⁻¹ treatment combinations. Similar results were observed by Uddin and coworkers (1997).

Biological yield (t ha⁻¹)

Biological yield of BRRI dhan41 was significantly affected by interaction between nitrogen and sulphur. Biological yield ranged from 6.12 to 10.79 g (Table 12). The highest (10.79 g) and lowest (6.12 g) biological yield was obtained from 198 kg

N ha⁻¹ with 34 kg S ha⁻¹ and 0 kg N ha⁻¹ with 17 kg S ha⁻¹ treatment combinations respectively.

Regression analysis taking biological yield as independent variable and grain yield as dependent variable showed a linear and positive relationship. This result indicates that over 93% of the variation in grain yield could be explained by the variation in biological yield (Fig. 4).

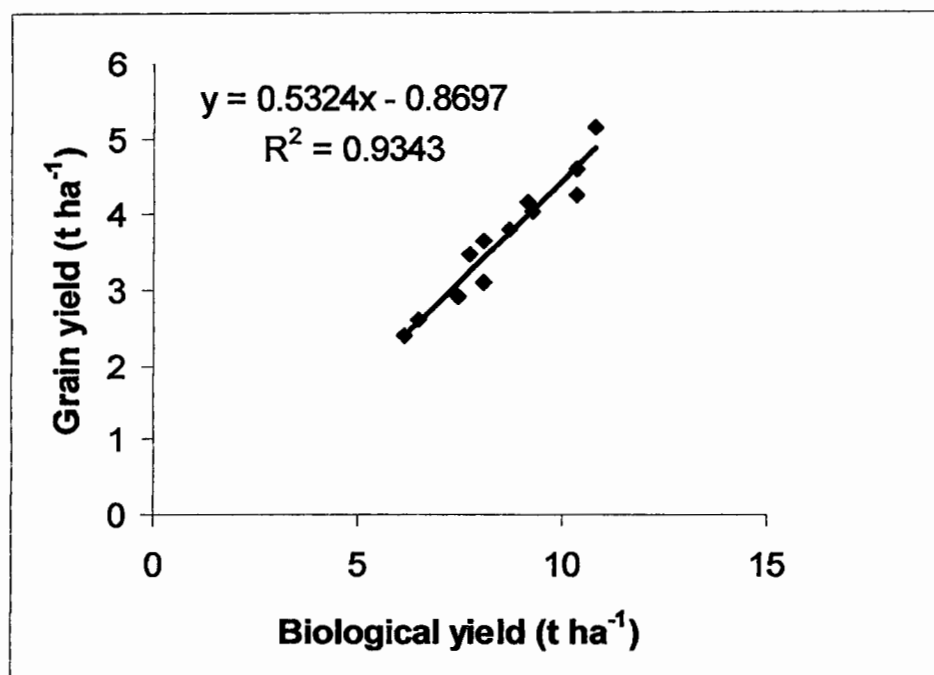


Fig. 4. Functional relationship between biological yield and grain yield of BRRI dhan41

Harvest index (%)

Harvest index differed significantly by interaction between nitrogen and sulphur which ranged from 38.28 to 47.73% (Table 12). The highest harvest index (47.73%) obtained from treatment combinations of 198 kg N ha⁻¹ with 34 kg S ha⁻¹ and the lowest (38.28%) was found in 66 kg N ha⁻¹ with 51 kg S ha⁻¹ treatment combinations which statistically identical to 0 kg N ha⁻¹ with 17 kg S ha⁻¹ treatment combinations (39.08%) and 0 kg N ha⁻¹ with 34 kg S ha⁻¹ treatment combinations (39.17%). The result was in partial agreement with Uddin and coworkers (1997).

Regression analysis between harvest index and grain yield showed that grain yield had a positive relation with harvest index. Over 63% of the variation in grain yield could be explained by the variation in harvest index (Fig. 5).

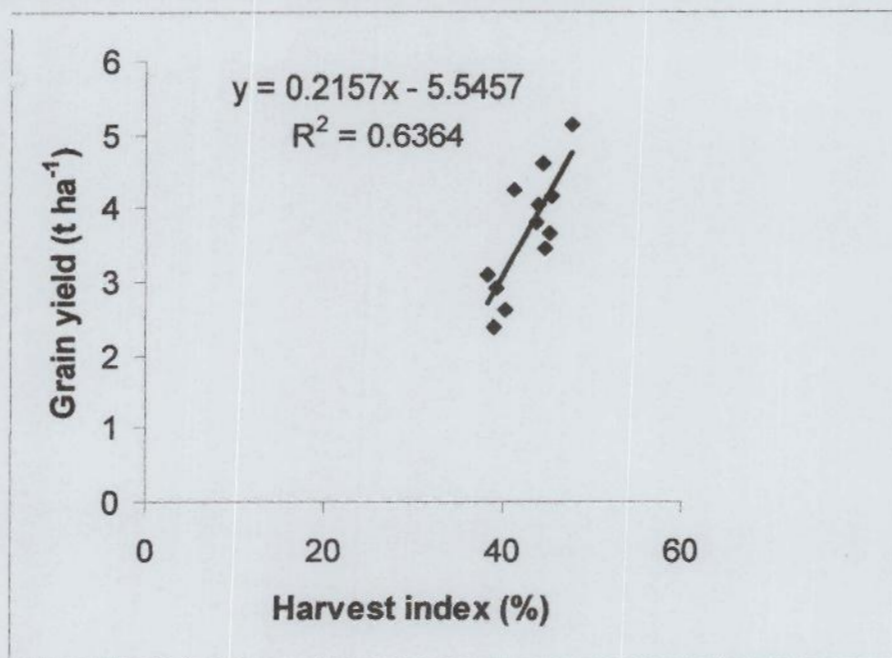


Fig. 5. Functional relationship between harvest index and grain yield of BRRI dhan41



CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted during the *aman* season from June to December, 2007 at the Agrotechnology Field Laboratory of Khulna University, Khulna to evaluate the effect of nitrogen and sulphur on growth, yield and yield attributes of BRRI dhan41. The experiment was laid out in a factorial Randomized Complete Block Design (RCBD) with three replications. Four levels of nitrogen viz., 0 kg N ha⁻¹, 66 kg N ha⁻¹, 132 kg N ha⁻¹ and 198 kg N ha⁻¹ as well as three levels of sulphur viz., 17 kg S ha⁻¹, 34 kg S ha⁻¹ and 51 kg S ha⁻¹ were used in this experiment. The total numbers of experimental units were 4 x 3 x 3 = 36. The unit plot size was 4 m x 2.5 m. Block to block and plot to plot distance was maintained by 0.5 m. The experimental land was fertilized with triple super phosphate (TSP) and muriate of potash (MP) applied at the rate of 51 and 60 kg ha⁻¹ respectively as recommended by BRRI. Nitrogen and sulphur fertilizers were applied to the plots as per treatment in the form of urea and gypsum. All fertilizers except urea were applied and thoroughly mixed with the soil at the time of final land preparation. Urea was applied in two equal installments, first at tillering stage (21 DAT) and second before panicle initiation stage (46 DAT). The seedlings of rice variety BRRI dhan41 were transplanted on 25th August, 2007 at the age of 31 days, giving three seedlings hill⁻¹. Row to row and hill to hill distance were same as 25 cm. Intercultural operations were given as and when necessary. The crop was harvested on 1st December, 2007 at 97 DAT. Crop growth data such as plant height, tiller number hill⁻¹ and dry matter and at harvest yield data such as plant height, number of tiller hill⁻¹, number of panicle hill⁻¹, panicle length, number of grain panicle⁻¹, number of unfilled spikelet panicle⁻¹, thousand grain weight, grain yield, straw yield, biological yield and harvest index were collected.

The results revealed that the effect of nitrogen had significant effect on all parameters. Among the four treatments, application of 198 kg N ha⁻¹ produced tallest plant (115.72 cm), highest number of tiller hill⁻¹ (12.38), highest panicle

number hill⁻¹ (10.96), maximum weight of dry matter (452.88 g m⁻²), highest panicle length (21.81 cm), maximum number of grains panicle⁻¹ (105.95), highest grain yield (4.46 t ha⁻¹) and highest harvest index (45.82%) but highest straw yield (5.42 t ha⁻¹) was produced by application of 132 kg N ha⁻¹.

Fertilization of sulphur had also significant effect on all parameters where application of 34 kg S ha⁻¹ produced tallest plant (111.57 cm), highest tiller number hill⁻¹ (11.70), highest panicle number hill⁻¹ (10.16), maximum dry matter (437.52 g m⁻²), highest panicle length (21.16 cm), maximum number of grain panicle⁻¹ (104.66), highest grain yield (4.03 t ha⁻¹) and highest straw yield (5.29 t ha⁻¹) but highest harvest index (43.46%) obtained by application of 17 kg S ha⁻¹ which was statistically similar to 34 kg S ha⁻¹ (42.93%) and 51 kg S ha⁻¹ (41.88%).

The interaction effect of nitrogen and sulphur showed significant influenced in parameters of growth, yield and yield attributes of BRRI dhan41. Tallest plant (118.15 cm), maximum number of tiller hill⁻¹ (13.58), maximum panicle number hill⁻¹ (11.83), highest panicle length (23.03 cm), maximum weight of dry matter (470.40 g m⁻²), maximum number of grain panicle⁻¹ (109.32), highest grain yield (5.15 t ha⁻¹), biological yield (10.79 t ha⁻¹) and highest harvest index (47.73%) observed by treatment combinations of 198 kg N ha⁻¹ and 34 kg S ha⁻¹ but highest straw yield (6.09 t ha⁻¹) obtained by application of 132 kg N ha⁻¹ with 34 kg S ha⁻¹.

It can be concluded that from the experiment, application of nitrogen fertilizer had a significant effect on growth, yield and yield attributes of BRRI dhan41. Application of 198 kg N ha⁻¹ in two equal installments showed better performance of tallest plant (115.72 cm), highest number of tiller hill⁻¹ (12.38), highest panicle number hill⁻¹ (10.96), number of grain panicle⁻¹ (105.95), maximum thousand grain weight (24.58 g), highest grain yield (4.46 t ha⁻¹) and highest harvest index (45.82%). 34 kg S ha⁻¹ applied as basal dose performed well than other treatments in such cases of tallest plant (111.57 cm), highest tiller number hill⁻¹ (11.70), highest panicle number hill⁻¹ (10.16), number of grain panicle⁻¹ (104.66), highest

grain yield (4.03 t ha^{-1}) and biological yield (9.32 t ha^{-1}). Tallest plant (118.15 cm), maximum number of tiller hill⁻¹ (13.58), maximum panicle number hill⁻¹ (11.83), highest panicle length (23.03 cm), number of grain panicle⁻¹ (109.32), highest grain yield (5.15 t ha^{-1}) and highest harvest index (47.73%) was observed from those treatments where 198 kg N ha^{-1} with 34 kg S ha^{-1} were applied. Further research is needed to determine the optimum dose of nitrogen and sulphur for getting higher yield in BRRI dhan41 and to find out the physicochemical reasons of yield increase due to application of different levels of nitrogen and sulphur fertilizers.



CHAPTER VI

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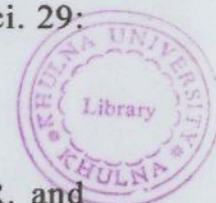
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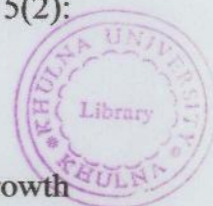
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APPENDICES

Appendix 1. Physical and chemical characteristics of soil (0-15 cm soil layer) of the experimental location

Sl. No.	Name of the elements	Average amount of nutrients
1	p ^H	7.6
2	Calcium (m.e./100g.soil)	22.75
3	Magnesium (m.e./100g.soil)	7.00
4	Potassium (m.e./100g.soil)	0.42
5	Total Nitrogen (%)	0.208
6	Phosphorus (µg/g soil)	4.01
7	Sulphur (µg/g soil)	458.55
8	Boron (µg/g soil)	0.77
9	Copper (µg/g soil)	10.32
10	Iron (µg/g soil)	48.20
11	Manganese (µg/g soil)	19.66
12	Zinc (µg/g soil)	1.42
13	Organic matter (%)	2.23
14	Textural class	Clay

Source: Data collected from Soil Resource Development Institute, Regional Research Centre, Doulatpur, Khulna