INFLUENCE OF NITROGEN AND SULPHUR ON THE YIELD OF T. AMAN RICE (BRRI dhan34)

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CERTIFICATE

This is to certify that the thesis entitled **'Influence of Nitrogen and Sulphur on the Yield of T. Aman Rice (BRRI dhan34)'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Soil Science**, embodies the result of a piece of bonafide research work carried out by **Md. Al-Amin Mondal**, Registration number: **07-02219** 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 duly been acknowledged.

Dated:
Dhaka, Bangladesh

Prof. Dr. Alok Kumar Paul
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DEDICATED

TO

MY BELOVED PARENTS

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The Author

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ABSTRACT

The experiment was conducted during the period from July to December, 2013 in T. Aman season in the experimental area Agronomy farm field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka AEZ No. 28 (The Modhupur Tract) to find out the influence of nitrogen and sulphur on yield of T. Aman rice (BRRI dhan34). The experiment comprised of two factors- Factor A: Levels of nitrogen (4 levels)-N_0: 0 kg N ha^{-1} i.e. control, N_1: 80 kg N ha^{-1}, N_2: 100 kg N ha^{-1} and N_3: 120 kg N ha^{-1} and Factors B: Levels of sulphur (3 levels)- S_0: 0 kg S ha^{-1} (control), S_1: 8 kg S ha^{-1} and S_2: 12 kg S ha^{-1}. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In case of nitrogen fertilizer, at 30, 45, 60 and 75 DAT and at harvest, the longest plant (26.09, 53.84, 71.21, 88.38 cm) was observed from N_2, again the shortest plant (20.98, 45.49, 62.23, 76.00 and 102.72 cm) from N_0. The highest grain yield (4.44 t ha^{-1}) was recorded from N_2, whereas the lowest (1.50 t ha^{-1}) from N_0. The highest N, P, K and S concentration in grain (0.507%, 0.230%, 0.327% and 0.239%, respectively) was obtained from N_2, again the lowest (0.189%, 0.221%, 0.268% and 0.1578%, respectively) from N_0. The highest total N (0.063%) was observed from N_2, whereas the lowest (0.023%) from N_0. The highest available S (9.66 ppm) was observed from N_2, whereas the lowest (5.66 ppm) from N_0. For sulphur fertilizer, at 30, 45, 60 and 75 DAT and at harvest, the longest plant (24.59, 51.88, 69.58, 85.75 and 114.30 cm) was recorded from S_1, while the shortest plant (23.42, 49.75, 65.94, 82.35 and 109.48 cm) from S_0. The highest grain yield (3.91 t ha^{-1}) was recorded from S_1, while the lowest (3.12 t ha^{-1}) from S_0. The highest N, P, K and S concentration in grain (0.461%, 0.260%, 0.316% and 0.240%, respectively) was found from S_2, whereas the lowest (0.269%, 0.214%, 0.286% and 0.164%, respectively) from S_0. The highest total N (0.055%) was recorded from S_2, and the lowest (0.042%) from S_0. The highest available S (8.77 ppm) was recorded from S_2, and the lowest (7.53 ppm) from S_0. Due to the interaction effect of different levels of nitrogen and sulphur, at 30, 45, 60 and 75 DAT and at harvest the longest plant (27.17, 55.47, 73.77, 92.33 and 116.53 cm) was found from the treatment combination of N_2S_1, whereas the shortest plant (20.00, 43.80, 59.97, 74.60 and 100.87 cm) from N_0S_0. The highest grain yield (4.83 t ha^{-1}) was found from the treatment combination of N_2S_1, whereas the lowest (1.21 t ha^{-1}) from N_0S_0. The highest N, P, K and S concentration in grain (0.623%, 0.335%, 0.352% and 0.285%, respectively) was observed from N_2S_2 and the lowest (0.164%, 0.205%, 0.261% and 0.121%, respectively) from N_0S_0. The highest total N (0.077%) was observed from N_2S_2, whereas the lowest total N (0.018%) from N_0S_0. The highest available S (11.07 ppm) was observed from N_2S_2, whereas the lowest (5.08 ppm) from N_0S_0. It was observed that, 100.0 kg N ha^{-1} and 8.0 kg S ha^{-1} can be more beneficial for farmers to get better yield.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food in tropical and subtropical regions (Singh *et al*., 2012). It is the staple food of more than three billion people in the world, most of who live in Asia (IRRI, 2009). It is the staple food of not only Bangladesh but also for South Asia (Hien *et al.*, 2006). Rice production and consumption is concentrated in Asia, where more than 90% of all rice is consumed (FAO, 2006). In Bangladesh, the geographical, climatic and edaphic conditions are favorable for year round rice cultivation. The slogan ‘Rice is life’ is most appropriate for Bangladesh as this crop plays a vital role in our food security and is a means of livelihood for millions of rural peoples. About 84.67% of cropped area of Bangladesh is used for rice production, with annual production of 30.42 million tons from 10.4 million hectare of land (BBS, 2013).

Agriculture in Bangladesh is dominated by intensive rice cultivation covering 80% of arable land. The population of Bangladesh is increasing at an alarming rate and the cultivable land is reducing due to urbanization and industrialization resulting in more shortage of food. As it is not possible to have horizontal expansion of rice area so, rice yield unit^{-1} area should be increased to meet this ever-increasing demand of food. Rice and rice based cropping system have important role in the Eastern Indo Gangetic Plain to increase food production for a rapidly growing population. Rice yields are either decelerating/stagnating /declining in post green revolution era mainly due to imbalance in fertilizer use, soil degradation, irrigation and weeding schedule, type of cropping system practiced, lack of suitable rice genotypes/variety for low moisture adaptability and disease resistance (Prakash, 2010). The average yield of rice in Bangladesh is about 2.92 t ha^{-1} (BBS, 2013). However, the national average of rice yield in Bangladesh is very low compared to other rice growing countries, like China (6.30 t ha^{-1}), Japan (6.60 t ha^{-1}) and Korea (6.30 t ha^{-1}) (FAO, 2009).

There are different factors who have dominated role in increasing production of rice and among them essential nutrient is the single most important factor that plays an important role in yield increase if other production factors are not limiting. 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). Nutrient imbalance can be minimized by judicious application of fertilizers. 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). In Bangladesh, there is tendency to use indiscriminate amount of nitrogenous fertilizers and very limited amount of other nutrients' containing high chemical fertilizers (Rahman, 2008). Due to intensification of crop and rapid adoption of improved cultivars has not only increased yield but also have significantly increased the output and, where there has been an imbalance between outputs and inputs, has resulted in declining soil fertility and an increase in the incidence of deficiencies of certain plant nutrients, including sulfur.

Many research works revealed a significant response of rice to N fertilizer in different soils (Hussain *et al*., 1989). Inadequate and improper applications of N are now considered one of the major reasons for low yield of rice in Bangladesh. The utilization efficiency of applied N by the rice plant is very low. 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. The efficient N management can increase crop yield and reduce production cost. An increase in the yield of rice by 70 to 80% may be obtained from proper application of N-fertilizer (IFC, 1982). The optimum dose of N fertilizer plays vital role for the growth and development of rice plant and its growth is seriously hampered when lower dose of N is applied, which drastically reduced yield; further, excessive N fertilization encourages excessive vegetative growth which make the plant susceptible to insect pests and diseases which ultimately reduces yield.

Sulphur (S) is one of the sixteen essential plant nutrients and ranks fourth major nutrient next to N, P and K. Among the essential elements, sulphur is very much beneficial for increasing the production of rice and is one of the major essential nutrient elements involved in the synthesis of chlorophyll, certain amino acids like methionine, cystine, cysteine and some plant hormones such as thiamine and biotin (Rahman *et al*., 2007). Sulphur is required early in the growth of rice plants. If it is limiting during early growth, then tiller number and therefore final yield will be reduced (Blair and Lefroy, 1987). Accumulation of inorganic nitrogen or organic non-protein nitrogen in the tissue, leaf area, seed plant^{-1}, floral initiation and anthesis in plants are affected by the sulphur (Tiwari, 1994). Growing of sulphur responsive crops, high intensive cropping and use of sulphur free fertilizers caused S deficiency in soils (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 transplanted Aman season with the following objectives:

- To develop a suitable dose of nitrogen and sulphur fertilizer on the growth and development of T. Aman rice (BRRI dhan34); and
- To evaluate the effects of different levels of nitrogen and sulphur fertilizer on the yield of T. Aman rice (BRRI dhan34).

CHAPTER II

REVIEW OF LITERATURE

Rice is the main food crop of the people of Bangladesh. Research on this crop is going on various aspects in increase its potential yield including management practices. Nitrogen and sulphur fertilizer is the essential factor for sustainable soil fertility and crop productivity. Sole and combined use of nitrogen and sulphur fertilizer stimulated plant growth, yield contributing characters and that leads to highest yield. Experimental information evidences that the use of nitrogen and sulphur have an intimate effect on the yield and yield attributes of rice. An attempt is made to review the available literature that are related to the effect of nitrogen and sulphur fertilizer on the yield attributes, yield, nutrient concentration in grain & straw of rice and nutrient status of post harvest soil as below under the following headings-

2.1 Effect of nitrogen on rice yield attributes and yield

Of the 16 essential nutrient elements nitrogen is the major and primary elements for the growth and development and better yield of crops. Plants response best to nitrogen compared to other nutrient elements. Urea has been found to be very effective nitrogenous fertilizers. Nitrogen is play pivotal role at yield and yield attributes of rice.

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. Shrirame *et al.* (2000) conducted an experiment during the kharif 1996 in Nagpur, Maharastra, India on rice cv. TNRH-10, TNRH-13 and TNRH-18 were grown at 1, 2, and 3 seedlings $hill^{-1}$ one seedling $hill^{-1}$ showed significantly higher harvest index.

Duhan and Singh (2002) conducted a field experiment and reported that the rice yield and uptake of nutrients increased significantly with increasing N levels. Moreover, the application along with various green manures (GM) showed additive effect on the yield and uptake of micronutrients. Under all GM treatments, the yield and uptake were always higher with 120 kg ha^{-1} than with lower level of nitrogen.

Bayan and Kandasamy (2002) noticed that the application of recommended doses of nitrogen in four splits at 10 days after sowing active tillering, panicle initiation and at heading stages recorded significantly lower dry weight of weeds and increased crop growth viz. effective tillers m^{-2}.

Angayarkanni and Ravichandran (2001) conducted a field experiment in Tamil Nadu, India from July to October to determine the best split application of 150 kg N ha^{-1} for rice cv. IR20. Data from the experiment revealed that that applying 16.66% of the recommended N as basal, followed by 33.33% N at 10 DAT, 25% N at 20 DAT and 25% N at 40 DAT recorded the highest grain (6189.4 kg ha^{-1}) and straw (8649.6 kg ha^{-1}) yields, response ratio (23.40) and agronomic efficiency (41.26).

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

Munnujan *et al*. (2001) treated 4 levels of nitrogen fertilizer (0, 40, 80, and 160 kg ha^{-1}) application at three levels each planting density (20, 40 and 80 hill m^{-1}) and conducted that the highest grain yield (3.8 t ha^{-1}) was obtained with 180 kg N ha^{-1}, which was similar to the yield obtained at 80 kg N ha^{-1} (3.81 t ha^{-1}).

Pully *et al*. (2000) observed that increased yield associated with application of nitrogen stage, although booting stage nitrogen application had no effect or shoot growth or nitrogen uptake. These preliminary results suggested a single application of nitrogen is sufficient to maintain healthy rice growth, alleviating the need for additional N application after flooding. Rice may be responded to N applied as late as booting, but only when the rice is N limited and not severely N stressed. Geethdevi *et al*. (2000) found that 120 kg N ha^{-1} in the form of urea, 50% nitrogen was applied in four splits resulted in higher number of tillers, filled grains $panicle^{-1}$ and higher grain weight $hill^{-1}$.

BRRI (2000) reported that the grain yield was linearly increased with increasing nitrogen rates. Chopra and Chopra (2000) cited that seed yield increased linearly up to 80 kg N ha^{-1}. Castro and Sarker (2000) conducted field experiment to see the effects of N applications as basal (80, 60, and 45kg N ha^{-1}) and top dressing (10, 30 and 45 kg ha^{-1}) on the yield and yield components of Japonica rice and obtained high effective tiller, percentage of ripened grains and high grain yields from 45 kg N ha^{-1} (basal) and 45 kg N ha^{-1} (top dressing). Singh and Singh (2000) stated that each increment dose of N significantly increased grain and straw yields of rice over its preceding dose. Consequently the crop fertilized with 100 kg N ha^{-1} gave maximum grain yield (2647 kg ha^{-1}).

Bellido *et al*. (2000) evaluate a field experiment with 4 levels of nitrogen (0, 50, 100 and 150 kg N ha^{-1}) and reported that the amount of total dry matter was significantly greater at the N fertilizer rates of 100 and 150 kg nitrogen ha^{-1}.

Kumar and Sharma (1999) conducted a field experiment with 4 levels of nitrogen (0, 40, 80 and 120 kg N ha^{-1}) and observed that dry matter accumulation in rice increased from 0-40 kg N ha^{-1} at 40 DAS, 0-120 kg N ha^{-1} at 60 DAS, 0-80 kg ha^{-1} at 80 DAS. Nitrogen application also hastened the growth and resulted in higher percentage of total dry matter accumulation in early stage of crop growth.

Singh *et al.* (1998) studied the performance of 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}.

Islam and Bhuiya (1997) studied the effect of nitrogen and phosphorus on the growth, yield and nutrient uptake of deep-water rice and observed that nitrogen and phosphorus fertilization significantly increased the number of fertile tiller m^{-2} and also that of grains $panicle^{-1}$, which in turn resulted in significant increase in grain yield. The application of 60 kg N ha^{-1} alone gave 22% yield benefit over control.

Dwibvedi (1997) noticed that application of nitrogen significantly increased in growth, yield and yield components, grain yield, straw yield as well as harvest index with 60 kg N ha^{-1}. BRRI (1997) reported during *boro* and transplant *aman* to determined rice seed yield. The experiment was laid out with four nitrogen levels 0, 50, 100 and 150 kg ha^{-1} and noted that seed yield increased gradually with the gradual increase of nitrogen.

Verma and Achraya (1996) observed that LAI increased significantly at maximum tillering and flowering stages with increasing levels of nitrogen. BINA (1996) stated that the effect of different levels of nitrogen was significant only for number of tillers $hill^{-1}$, effective tillers $hill^{-1}$, straw yield and crop duration. The highest number of total and productive tillers $hill^{-1}$ was obtained from the highest level (120 kg ha^{-1}) of N application.

Adhikary and Rahman (1996) reported that rice grain yield ha^{-1} in various treatments of N showed significant effect. 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^{-1} were obtained from 90 kg N ha^{-1}, respectively.

Andrade and Amorim (1996) observed that increasing level of applied N increased plant height, panicle m^{-2}, grains $panicle^{-1}$ and grain yield significantly. Palm *et al.* (1996) conducted a field trial at Waraseoni in the 1989-90 rainy season and observed that yield of rice cv. R. 269 was the highest (4.47 t ha^{-1}) when 100 kg N ha^{-1} was applied 30% basally, 40% at tillering and 30% at panicle initiation stage.

Effective tillers m^{-2} responded significantly to the application of N fertilizer (Behera, 1995). Effective tillers increased significantly with increase the level of N fertilizer up to 80 kg N ha^{-1}. Patel and Upadhyay (1993) conducted an experiment with 3 levels of N (90, 120 and 150 kg ha^{-1}) and reported that total and effective tillers m^{-2} increased significantly with increasing rates of N up to 120 kg 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 productive tillers increased significantly with the increase of N doses from 0-120 kg N ha^{-1}, but differences in productive tillers between 120 and 180 kg N ha^{-1} and they were not statistically significant.

Awasthi and Bhan (1993) reported that increasing levels of nitrogen up to 60 kg ha^{-1} influenced LAI and dry matter production of rice. Patel and Upadhaya (1993) found that plant height of rice increased significantly with increasing rate of N up to 150 kg ha^{-1}.

Ahmed and Hossain (1992) observed that plant height of wheat were 7939, 82.3 and 84.4 cm with 45, 90 and 135 kg N ha^{-1}, respectively. Plant height increased with increasing nitrogen doses.

BRRI (1992) reported that both grain and straw yields of rice were increased significantly up to 80 kg N ha^{-1}. Application of nitrogen from 120 to 160 kg nitrogen ha^{-1} significantly reduced the yield which was assumed to be due to excessive vegetative growth follower by lodging after flowering.

2.2 Effect of sulphur on rice yield attributes and yield

The productivity of wheat–rice cropping system is declining over time despite adequate supply of major Nutrients Is reported by Singh and Singh (2014). It may be due to deficiency of nutrients like sulphur. A field experiment was conducted with treatments consisting of three sulphate-sulphur (0, 15, 30 and 45 kg ha^{-1}) levels to study the sulphur balance and productivity in wheat-rice cropping sequence in a sandy clay loam soil. The agronomic efficiency and apparent sulphur recovery decreased with increase in levels of sulphate but the percent response increased with increasing sulphate application. Application of sulphur showed the positive sulphur balance, while, it was negative under control.

A field experiment was conducted by Dixit *et al*. (2012) to study the effect of sulphur and zinc on yield, quality and nutrient uptake by hybrid rice grown in sodic soil and found that application of 40 kg S ha^{-1} recorded significantly high grain and straw yield, protein content and sulphur uptake.

A field experiment was conducted by Jawahar and Vaiyapuri (2011) at Experimental Farm, Annamalai University, Annamalai Nagar, Tamil Nadu, India to study the effect of sulphur and silicon fertilization on yield, nutrient uptake and economics of rice. The treatments comprised four levels of sulphur (0, 15, 30 and 45 kg ha^{-1}) and silicon and were laid out in factorial randomized block design with three replications. Among the different levels of sulphur, sulphur at 45 kg ha^{-1} recorded higher values for yield (grain and straw) and nutrient uptake (NPKS) of rice, respectively.

An experiment was conducted by Rahman *et al*. (2009) to know the effect of different levels of sulphur on growth and yield of BRRI dhan41 at soil science Laboratory of Bangladesh Agricultural University, Mymensingh during T. Aman season. There were eight treatments and they were T_0 (without S), T_1 (50% RFD of S), T_2 (75% RFD of S), T_3 (100% RFD of S), T_4 (125% RFD of S), T_5 (150% RFD of S), T_6 (175% RFD of S) and T_7 (200% RFD of S). All yield contributing characters like effective tillers $hill^{-1}$, filled grain $panicle^{-1}$, grain yield, straw yield, biological yield and 1000-grain weight except plant height and panicle length of BRRI dhan41 significantly responded to different levels of S. Generally treatment T_6 performed the best result and T_0 did the worst.

Mrinal and Sharma (2008) conducted a field trials during 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. The growth and yield attributing characters of rice increased with the sulphur application. The grain and straw yields of rice increased significantly with increasing levels of sulphur up to 30 kg S ha^{-1}. The difference between sulphur sources was generally not significant.

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

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, each applied at 12.5 t ha^{-1}, on yield, S use efficiency and S optimization of rice cv. ADT 43. The results revealed that rice responded significantly to the application of S and organics compared to the control. The highest grain (5065 kg ha^{-1}) and straw yields (7524 kg ha^{-1}) was obtained with 40 kg S ha^{-1}.

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

Basumatary and Talukdar (2007) conducted a field experiment at the University, Jorhat, Assam, India 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.

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

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

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

Chandel *et al*. (2003) conducted a field experiment to investigate the effect of sulphur nutrition on the growth and S content of rice and mustard grown in sequence with 4 S levels (0, 15, 30 and 45 kg ha^{-1}). They stated that increasing S levels in rice significantly improved growth attributes i.e. tiller number, leaf number and dry matter production; yield trait such as harvest index of rice up to 45 kg ha^{-1}.

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

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

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

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

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

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

Vaiyapuri and Sriramachandrasekharan (2001) conducted an experiment on integrated use of green manure with graded levels of sulphur (0, 20, and 40 kg ha^{-1}) applied through three different sources in rice cv. ADT 37. It appeared that the maximum nutrient uptake (115.5, 27.6, 220.2 and 24.8 kg ha^{-1} for N, P, K and S, respectively), rice yield (5.07 t kg ha^{-1}) and soil available nutrients (199.5, 13.4, 299.1 and 22.8 kg ha^{-1} for N, P, K and S, respectively) were noticed with 40 kg sulphur ha^{-1}.

Raju and Reddy (2001) conducted field investigations to study the response of both hybrid and conventional rice to sulphur (20 kg ha^{-1}) and zinc applications and reported significant improvement in grain yield was observed due to sulphur application.

Experimental information evidences from the above cited literature that the uses of nitrogen and sulphur fertilizer have an intimate effect on the yield and yield attributes of rice.

2.3 Soil fertility and properties for application of fertilizers

Hemalatha *et al.* (2000) revealed that green manure significantly increased the soil fertility status, organic carbon, available soil N, P and K at post harvest soil. Zaman *et al.* (2000) reported that chemical properties like organic matter content CEC, total N, exchangeable K, available P and S were favorably influenced by the application of organic sources of nitrogen and potassium while the organic sources mostly did not show positive effect. Soil pH decreased slightly compared to the initial status.

Santhi *et al.* (1999) observed that application of 100% NPK plus FYM decreased the bulk density and increased the water holding capacity of soil. The decreased in bulk density in FYM treated plots might be ascribed to better aggregation. The water holding capacity was increased due to the improvement in structural condition of soil that was brought about mainly by the application of FYM in combination with NPK fertilizers.

Xu *et al.* (1997) observed that application of organic matters affect soil pH value as well as nutrient level. Mathew and Nair (1997) reported that cattle manure when applied alone or in combination with chemical fertilizer (NPK) increased the organic C content, total N, available P and K in rice soils. Sarker and Singh (1997) reported that organic fertilizers when applied alone or in combination with inorganic fertilizers increase the level of organic carbon in soil as well as the total N, P and K contents of soil.

Nambiar (1997) views that integrated use of organic manure and chemical fertilizers would be quite promising not only in providing greater stability in production, but also in maintaining healthy soil fertility status. Intensive crop production systems have witnessed serious problems associated with loss of soil fertility as a result of excessive soil mining of plant nutrients and consequently reduction in productivity. Application of external source of plant nutrients is a key element in optimal management of soil organic matter, crop residues and manure for ensuring the bio-availability, the cycling and the balance of nutrients in the soil - plant systems.

Palm *et al.* (1996) stated that organic materials influence nutrient availability nutrients added through mineralization – immobilization pattern as energy sources for microbial activities and as precursors to soil organic matter and by reducing P sorption of the soil.

Nahar *et al*. (1995) had examined the soil condition after one crop cycle (rice wheat). Addition of organic matter during the rice crop doubled the organic C content compared to its original status. Total and available N contents were also significantly improved by addition of organic matter, but had less impact on soil exchangeable cations.

Meelu *et al.* (1992) reported that organic C and total N increased significantly when *Sesbania* and *Crotolaria* were applied in the preceded rice crop for two wet seasons. Medhi *et al*. (1996) reported that incorporation of organic and inorganic sources of N increased soil solution NH_4-N to a peak and then declined to very low levels.

Bhandari *et al*. (1992) reported that an application of fertilizers or their combined use with organic manure increased the organic C status of soil. The NPK fertilizers at 100% level and their combined use with organic N also increased the available N and P by 5.22 kg and 0.8-3.8 kg ha^{-1} from their initial values.

Prasad and Kerketta (1991) conducted an experiment to assess the soil fertility, crop production and nutrient removal for cropping sequences in the presence of recommended doses of fertilizers and cultural practices along with 5 t ha^{-1} compost applied to the crops. There was an overall increase in organic C, increase in total N (83.9%), available N (69.9%), available P (117.3%) and CEC (37.7%).

Bair (1990) stated that sustainable production of crop can not be maintained by using chemical fertilizers only and similarly it is not possible to obtain higher crop yield by using organic manure alone. Sustainable crop production might be possible through the integrated use of organic manure and chemical fertilizers.

Application of NPK at 100-150% based on the initial soil test showed appreciable improvement in available soil N, P, and K. Organic C content was highest under FYM treatment. Depletion of P was highest under 100% treatment and K under 100% N and P treatment (Singh and Nambiar, 1984).

Organic materials are widely used to maintain soil fertility and improve soil properties in intensive cropping systems especially in traditional agriculture. Total N, exch. K and available P in soil increased by green manuring. The application of FYM increased organic C, total N, available P, Exchangeable K and CEC than GM (IRRI, 1979).

The literature review discussed above indicates that nitrogen and sulphur fertilizer greatly influence the yield contributing characters and yield of rice. The properties of soils are also influenced by the inclusion of nitrogen and sulphur fertilizer.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the influence of nitrogen and sulphur on the yield of T. Aman rice (BRRI dhan34). The details of the materials and methods i.e. location of experimental site, soil and climate condition of the experimental plot, materials used, design of the experiment, data collection and data analysis procedure that used in this experiment has been presented below under the following headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from July to December, 2013 in T. Aman season.

3.1.2 Site description of the experimental plot

The present piece of research work was conducted in the experimental area of Agronomy farm field, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level.

3.1.3 Climatic condition

The geographical location of the experimental site was under the subtropical climate which is characterized by three distinct seasons, namely winter season from the month of November to February, the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al*., 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, Dhaka and details has been presented in Appendix I.

3.1.4 Soil characteristics of the experimental plot

The soil belongs to "The Modhupur Tract", AEZ-28 (FAO, 1988). Top soil was Silty Clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The initial soil samples at a depth of 0-15 cm were collected prior to transplanting. The details of the initial soil have been presented in Appendix II.

3.2 Experimental details

3.2.1 Planting material

BRRI dhan34 was used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute (BRRI) through selection process. It is recommended for Aman season and average plant height of the variety is 117 cm. The aromatic grains are small and white. It requires about 135 days completing its life cycle with an average yield of 3.5 t ha^{-1} (BRRI, 2013).

3.2.2 Treatment of the experiment

The experiment comprised of two factors

Factor A: Levels of nitrogen (4 levels)

- i) N_0: 0 kg N ha^{-1} i.e. control
- ii) N_1: 80 kg N ha^{-1} (173.91 kg urea ha^{-1})
- iii) N_2: 100 kg N ha^{-1} (217.39 kg urea ha^{-1})
- iv) N_3: 120 kg N ha^{-1} (260.87 kg urea ha^{-1})

Factors B: Levels of sulphur (3 levels)

- i) S_0: 0 kg S ha^{-1} i.e. control
- ii) S_1: 8 kg S ha^{-1} (44.44 kg gypsum ha^{-1})
- iii) S_2: 12 kg S ha^{-1} (66.67 kg gypsum ha^{-1})

There were in total 12 (4×3) 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, N_2S_2, N_3S_0, N_3S_1 and N_3S_2.

3.2.3 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications, where the experimental area was divided into three blocks representing the replications to reduce soil heterogenetic effects. Each block was divided into 12 unit plots as treatments with raised bunds around. Thus the total numbers of plots were 36. The unit plot size was 3.0 m × 1.8 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.3 Growing of crops

3.3.1 Seed collection and sprouting

Seeds were collected from BRRI, Gazipur just 20 days ahead of the sowing of seeds in seed bed. Seeds were immersed in water in a bucket for 24 hours. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

3.3.3 Land preparation

The plot selected for conducting the experiment was opened in the 1^{st} week of July 2013 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots in accordance with the experimental design. Organic and inorganic manures as indicated 3.3.4 were mixed with the soil of each unit plot.

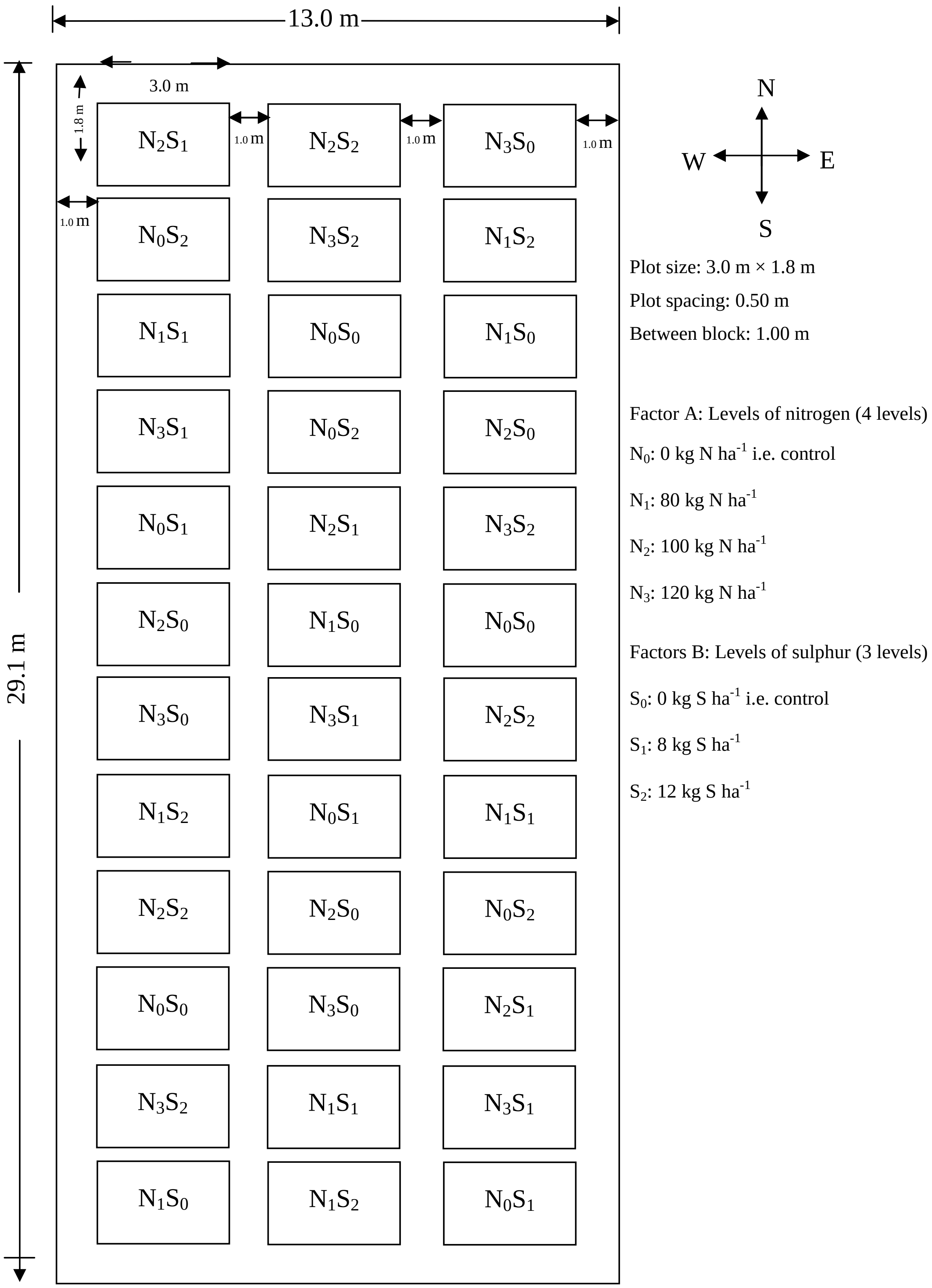

Figure 1. Layout of the experimental plot

3.3.4 Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MoP, Gypsum, zinc sulphate and borax, respectively were applied. The one third amount of urea and entire amount of TSP, MoP, gypsum, zinc sulphate and borax were applied during the final land preparation. 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 1.

Table 1. Dose and method of application of fertilizers in rice field

Fertilizers	Dose (ha^{-1})	Application (%)		
		Basal	1^{st} installment	2^{nd} installment
Urea	As per treatment	33.33	33.33	33.33
TSP	60 kg	100	--	--
MoP	90 kg	100	--	--
Gypsum	As per treatment	100	--	--
Zinc sulphate	3 kg	100		
Borax	10 kg	100	--	--

Source: BRRI, 2013 (Adunik Dhaner Chash)

3.3.5 Transplanting of seedling

Thirty days old seedlings of BRRI dhan34 were carefully uprooted from the seedling nursery and transplanted on 25 July, 2013 in Irrigated Late Seedling (ILS) condition. Three seedlings $hill^{-1}$ were used following a spacing of 25 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.

3.3.6 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.

3.3.6.1 Irrigation

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

3.3.6.2 Weeding

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

3.3.6.3 Insect and pest control

There was no infection of diseases in the field but leaf roller (*Chaphalocrosis medinalis*) was observed in the field and used Diazinon 60 EC @ 1.12 L ha^{-1}.

3.4 Harvesting, threshing and cleaning

The crop was harvested at full maturity at 01 December, 2013 when 80-90% of the grains were turned into straw colored. The harvested crop was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning period of rice grain. Fresh weight of rice grain and straw were recorded plot wise from 1 m^2 area. The grains were dried, cleaned and weighed for individual plot. The weight was adjusted to a moisture content of 14%. Yields of rice grain and straw m^{-2} were recorded and converted to t ha^{-1}.

3.5 Data collection on yield components and yield

3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 30, 45, 60, 75 days after transplanting (DAT) and at harvesting stage. Data were recorded as the average of 5 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/flag leaf.

3.5.2 Effective tillers $hill^{-1}$

The total number of effective tillers $hill^{-1}$ was counted as the number of panicle bearing tiller during harvesting. Data on effective tillers $hill^{-1}$ were counted from 5 selected hills and average value was recorded.

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

The total number of non-effective tillers $hill^{-1}$ was counted as the number of non-panicle bearing tillers during harvesting. Data on non effective tillers $hill^{-1}$ were counted from 5 selected hills and average value was recorded.

3.5.4 Total tillers hill^{-1}

The number of total tillers hill^{-1} was counted as the number of panicle and bearing and non-panicle bearing tillers during harvesting. Data on total tillers hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.5 Length of panicle

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

3.5.6 Filled grains 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 grains panicle^{-1} was recorded.

3.5.7 Unfilled grains 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 grains panicle^{-1} was recorded.

3.5.8 Total grains 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 grains panicle^{-1} was recorded.

3.5.9 Weight of 1000-grain

One thousand grains were counted randomly from the total cleaned harvested grains 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 1 m^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 ton hectare^{-1} (t ha^{-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 1 m^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 ton $hectare^{-1}$ (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.

3.6 Chemical analysis of grain and straw samples

3.6.1 Collection of grain and straw samples

Grain and straw samples were collected after threshing. The samples were finely ground by using a Wiley-Mill with stainless contact points to pass through a 60-mesh sieve. The samples were stored in plastic vial for analyses of N, P, K and S.

3.6.2 Preparation of samples

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

3.6.3 Digestion of plant samples with sulphuric acid for N

For the determination of nitrogen an amount of 0.2 g oven dry, ground sample were taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 5 ml conc. H_2SO_4 were added. The flasks were heated at 120^{0}C and added 2.5 ml 30% H_2O_2 then heated at 180^{0}C until the digests became clear and colorless. After cooling, the content was transferred into a 100 ml volumetric flask and volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

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

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

3.6.5 Determination of P, K and S from grain and straw samples

3.6.5.1 Phosphorus

Phosphorus was digested from the plant sample (grain and straw) with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 1 ml for grain sample and 2 ml for straw sample from 100 ml 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).

3.6.5.2 Potassium

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

3.6.5.3 Sulphur

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

3.7 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.

3.8 Post harvest soil analysis

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

3.8.1 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.

3.8.2 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_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.8.3 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_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

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

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.8.4 Available phosphorus

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

3.8.5 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).

3.8.6 Available sulphur

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

3.9 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference due to the application of nitrogen and sulphur fertilizer on yield contributing characters& yield of BRRI dhan34, nutrient content in grain & straw and soil properties of post harvest soil. 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 IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the influence of nitrogen and sulphur on the yield of T. Aman rice (BRRI dhan34). Data on different growth parameter & yield of rice, nutrient concentration in grain & straw and characteristics of post harvest soil was recorded. The analyses of variance (ANOVA) of the data on different recorded parameters are presented in Appendix III-VIII. The results have been presented and discusses with the help of table and graphs and possible interpretations were given under the following headings:

4.1 Yield contributing characters and yield of rice

4.1.1 Plant height

Different levels of nitrogen showed significant differences on plant height of BRRI dhan34 at 30, 45, 60 and 75 days after transplanting (DAT) and at harvest (Appendix III). At 30, 45, 60 and 75 DAT and at harvest, the longest plant (26.09, 53.84, 71.21, 88.38 cm) was observed from N_2 (100 kg N ha^{-1}) which was statistically similar (25.73, 53.63, 70.94, 87.67 and 115.36 cm) with N_3 (120 kg N ha^{-1}) and closely followed (23.27, 50.80, 67.90, 84.48 and 113.46 cm) by N_1 (80 kg N ha^{-1}), again the shortest plant (20.98, 45.49, 62.23, 76.00 and 102.72 cm) was recorded from N_0 (0 kg N ha^{-1}) at same DAT (Figure 2). Data revealed that with the increase of nitrogen fertilizer, plant height increased upto a certain level then decreases. Optimum level of 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. BRRI (1992) reported that application of nitrogen from 120 to 160 kg ha^{-1} was assumed to be due to excessive vegetative growth follower by lodging after flowering. Patel and Upadhaya (1993) found that plant height of rice increased significantly with increasing rate of N up to 150 kg ha^{-1}. Andrade and Amorim (1996) also observed that increasing level of N increased plant height.

Plant height of BRRI dhan34 varied significant at 30, 45, 60 and 75 DAT and at harvest due to the different levels of sulphur (Appendix III). At 30, 45, 60 and 75 DAT and at harvest, the longest plant (24.59, 51.88, 69.58, 85.75 and 114.30 cm) was recorded from S_1 (8 kg S ha^{-1}) which was statistically similar (24.04, 51.20, 68.69, 84.29 and 110.44 cm) with S_2 (12 kg S ha^{-1}), while the shortest plant (23.42, 49.75, 65.94, 82.35 and 109.48 cm) was observed from S_0 (0 kg S ha^{-1}) at same DAT (Figure 3). Data revealed that with the increase of application of sulphur nutrients plant height showed increasing trend and after a certain level it was also decreased. Tandon and Tiwari (2007) reported that growing of sulphur responsive crops, high intensive cropping and use of sulphur free fertilizers caused S deficiency. Rahman *et al*. (2007) stated that among the essential elements, sulphur is very much beneficial for the growth and development of rice plant and is one of the major essential nutrient elements involved in the synthesis of chlorophyll, certain amino acids like methionine, cystine, cysteine and some plant hormones such as thiamine and biotin which influences vegetative growth of rice. Singh and Singh (2002) reported that plant height of rice were significant with increasing levels of S up to 40 kg S ha^{-1} but Chandel *et al*. (2003) reported that plant height increases increasing S levels up to 45 kg ha^{-1}, whereas Rahman *et al*. (2009) reported that plant height BRRI dhan41 was not to be significantly responded to different levels of S fertilizer.

Interaction effect of different levels of nitrogen and sulphur showed significant differences for plant height of BRRI dhan34 at 30, 45, 60 and 75 DAT and at harvest under the present trial (Appendix III). At 30, 45, 60 and 75 DAT and at harvest, the longest plant (27.17, 55.47, 73.77, 92.33 and 116.53 cm) was found from the treatment combination of N_2S_1 (100 kg N ha^{-1} and 8 kg S ha^{-1}), whereas the shortest plant (20.00, 43.80, 59.97, 74.60 and 100.87 cm) was observed from the treatment combination of N_0S_0 (0 kg N ha^{-1} and 0 kg S ha^{-1}) at same DAT (Table 2).

Table 2. Interaction effect of different levels of nitrogen and sulphur on plant height of BRRI dhan34

Treatment	Plant height (cm) at				
	30 DAT	45 DAT	60 DAT	75 DAT	Harvest
N_0S_0	20.00 e	43.80 g	59.97 f	74.60 f	100.87 g
N_0S_1	20.80 de	45.73 f	62.20 f	77.27 f	105.80 f
N_0S_2	22.13 cd	46.93 f	64.53 e	76.13 f	101.50 g
N_1S_0	22.73 c	49.70 e	65.53 e	82.83 e	111.13 e
N_1S_1	24.53 b	52.07 cd	69.80 cd	86.50 bcd	116.00 b
N_1S_2	22.53 c	50.63 de	68.37 d	84.10 de	113.23 cd
N_2S_0	25.07 b	52.37 bcd	69.23 cd	84.53 cde	113.07 cd
N_2S_1	27.17 a	55.47 a	73.77 a	92.33 a	116.53 b
N_2S_2	26.03 ab	53.70 abc	70.63 bcd	88.27 b	112.70 d
N_3S_0	25.87 ab	53.13 bc	69.03 cd	87.43 bc	112.87 d
N_3S_1	25.87 ab	54.23 ab	72.57 ab	86.90 bcd	118.87 a
N_3S_2	25.47 b	53.53 abc	71.23 bc	88.67 b	114.33 c
$LSD_{(0.05)}$	1.511	1.794	2.252	3.013	1.312
Level of significance	*	*	*	*	*
CV(%)	6.00	5.73	7.41	9.54	7.86

*: Significant at 0.05 level of probability

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

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

N_1: 80 kg N ha^{-1}

N_2: 100 kg N ha^{-1}

N_3: 120 kg N ha^{-1}

S_0: 0 kg S ha^{-1}

S_1: 8 kg S ha^{-1}

S_2: 12 kg S ha^{-1}

4.1.2 Number of effective tillers hill^{-1}

Number of effective tillers hill^{-1} of BRRI dhan34 showed statistically significant differences due to different levels of nitrogen (Appendix IV). The maximum number of effective tillers hill^{-1} (13.27) was recorded from N_2 which was closely followed (12.76) by N_3, whereas the minimum number (9.07) was found from N_0 treatment which was followed (11.03) by N_1 (Table 3). BINA (1996) stated that the effect of different levels of nitrogen was significant for number of effective tillers hill^{-1}.

Different levels of sulphur varied significantly in terms of number of effective tillers hill^{-1} of BRRI dhan34 (Appendix IV). The maximum number of effective tillers hill^{-1} (12.13) was recorded from S_1 which was closely followed (11.40) by S_2, while the minimum number (11.07) was observed from S_0 (Table 3). Rahman *et al*. (2009) reported that effective tillers hill^{-1} significantly responded to different levels of S.

Statistically significant variation was recorded due to the interaction effect of different levels of nitrogen and sulphur in terms of number of effective tillers hill^{-1} of BRRI dhan34 (Appendix IV). The maximum number of effective tillers hill^{-1} (13.93) was found from the treatment combination of N_2S_1, whereas the minimum number (8.40) was observed from the treatment combination of N_0S_0 (Table 4).

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

Different levels of nitrogen showed significant differences on number of non-effective tillers hill^{-1} of BRRI dhan34 (Appendix IV). The maximum number of non-effective tillers hill^{-1} (3.63) was found from N_2 which was closely followed (2.88 and 2.58) by N_3 and N_1 and they were statistically similar, while the minimum number (1.59) was observed from N_0 (Table 3). Singh and Singh (2014) reported from earlier experiment that the highest non-effective tillers hill^{-1} with the application of sulphur at 45 kg ha^{-1}.

Table 3. Effect of different levels of nitrogen and sulphur on yield contributing characters of BRRI dhan34

Treatments	Number of effective tillers $hill^{-1}$	Number of non effective tillers $hill^{-1}$	Number of filled grains $panicle^{-1}$	Number of unfilled grains $panicle^{-1}$
Levels of nitrogen				
N_0	9.07 d	1.59 c	62.89 d	9.32 a
N_1	11.03 c	2.58 b	82.61 c	6.02 b
N_2	13.27 a	3.63 a	90.43 a	4.59 d
N_3	12.76 b	2.88 b	87.41 b	5.26 c
$LSD_{(0.05)}$	0.337	0.334	1.630	0.544
Significance level	**	**	**	**
Levels of sulphur				
S_0	11.07 c	3.05 a	78.61 c	7.34 a
S_1	12.13 a	2.78 a	83.66 a	5.32 c
S_2	11.40 b	2.18 b	80.24 b	6.23 b
$LSD_{(0.05)}$	0.292	0.290	1.412	0.471
Significance level	**	**	**	**
CV(%)	12.96	10.39	5.95	7.50

**: Significant at 0.01 level of probability

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

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

N_1: 80 kg N ha^{-1}

N_2: 100 kg N ha^{-1}

N_3: 120 kg N ha^{-1}

S_0: 0 kg S ha^{-1}

S_1: 8 kg S ha^{-1}

S_2: 12 kg S ha^{-1}

Table 4. Interaction effect of different levels of nitrogen and sulphur on yield contributing characters of BRRI dhan34

Treatments	Number of effective tillers $hill^{-1}$	Number of non effective tillers $hill^{-1}$	Number of filled grains $panicle^{-1}$	Number of unfilled grains $panicle^{-1}$
N_0S_0	8.40 h	2.20 f	59.00 h	11.80 a
N_0S_1	9.23 g	1.20 g	68.70 g	7.43 c
N_0S_2	9.57 g	1.37 g	60.97 h	8.73 b
N_1S_0	10.53 f	2.87 cde	79.77 f	6.53 cd
N_1S_1	11.90 e	2.70 def	85.17 de	5.33 ef
N_1S_2	10.67 f	2.17 f	82.90 e	6.20 de
N_2S_0	12.87 bcd	3.73 ab	89.33 bc	5.20 ef
N_2S_1	13.93 a	4.23 a	92.40 a	4.10 g
N_2S_2	13.00 bc	2.93 cd	89.57 b	4.47 fg
N_3S_0	12.47 cde	3.40 bc	86.33 cd	5.83 de
N_3S_1	13.43 ab	2.97 cd	88.37 bc	4.40 fg
N_3S_2	12.37 de	2.27 ef	87.53 bcd	5.53 de
$LSD_{(0.05)}$	0.584	0.579	2.823	0.943
Significance level	**	*	**	**
CV(%)	12.96	10.39	5.95	7.50

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

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

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

N_1: 80 kg N ha^{-1}

N_2: 100 kg N ha^{-1}

N_3: 120 kg N ha^{-1}

S_0: 0 kg S ha^{-1}

S_1: 8 kg S ha^{-1}

S_2: 12 kg S ha^{-1}

Number of non-effective tillers hill^{-1} of BRRI dhan34 varied significantly due to the different levels of sulphur (Appendix IV). The maximum number of non-effective tillers hill^{-1} (3.05) was attained from S_0 which was statistically similar (2.78) with S_1, while the minimum number (2.18) was found from S_0 (Table 3).

Interaction effect of different levels of nitrogen and sulphur showed significant differences for number of non-effective tillers hill^{-1} of BRRI dhan34 (Appendix IV). The maximum number of non-effective tillers hill^{-1} (4.23) was recorded from the treatment combination of N_2S_1, whereas the minimum number (1.20) was found from the treatment combination of N_0S_1 (Table 4).

4.1.4 Number of total tillers hill^{-1}

Different levels of nitrogen showed significant differences on number of total tillers hill^{-1} of BRRI dhan34 (Appendix IV). The maximum number of total tillers hill^{-1} (16.90) was recorded from N_2 which was closely followed (15.63) by N_3, whereas the minimum number (10.66) was found from N_0 which was followed (13.61) by N_1 (Figure 4). BINA (1996) stated that the effect of different levels of nitrogen was significant for number of tillers hill^{-1}.

Number of total tillers hill^{-1} of BRRI dhan34 varied significantly due to the different levels of sulphur (Appendix IV). The maximum number of total tillers hill^{-1} (14.90) was recorded from S_1 which was closely followed (14.12) by S_0, while the minimum number (13.58) from S_2 (Figure 5). Sulphur is required early in the growth of rice plants. If it is limiting during early growth, then tiller number reduced (Blair and Lefroy, 1987). Singh and Singh (2002) reported that tillers m^{-2} row length were significant with increasing levels of S up to 40 kg S ha^{-1}.

Interaction effect of different levels of nitrogen and sulphur showed significant differences for number of total tillers hill^{-1} of BRRI dhan34 (Appendix IV). The maximum number of total tillers hill^{-1} (18.17) was found from the treatment combination of N_2S_1, whereas the minimum number (10.43) was observed from the treatment combination of N_0S_1 (Figure 6).

4.1.5 Panicle length

Different levels of nitrogen showed significant differences on panicle length of BRRI dhan34 (Appendix IV). The longest panicle (23.73) was observed from N_2 which was closely followed (23.26) by N_3, whereas the shortest panicle (20.47) was recorded from N_0 which was followed (22.36) by N_1 (Figure 7). 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 length of panicle.

Panicle length of BRRI dhan34 varied significantly due to the different levels of sulphur (Appendix IV). The longest panicle (23.73) was found from S_1 which was closely followed (22.47) by S_2, while the shortest panicle (21.17) was recorded from S_0 (Figure 8). Singh and Singh (2002) reported that panicle length were significant with increasing levels of S up to 40 kg S ha^{-1}. Rahman *et al*. (2009) reported that panicle length of BRRI dhan41 were not significantly responded to different levels of S.

Interaction effect of different levels of nitrogen and sulphur showed significant differences for panicle length of BRRI dhan34 (Appendix IV). The longest panicle (25.50) was observed from the treatment combination of N_2S_1, whereas the shortest panicle (20.05) was found from the treatment combination of N_0S_0 (Figure 9).

4.1.6 Number of filled grains panicle^{-1}

Different levels of nitrogen showed significant differences on number of filled grains panicle^{-1} of BRRI dhan34 (Appendix IV). The maximum number of filled grains panicle^{-1} (90.43) was recorded from N_2 which was closely followed (87.41) by N_3, whereas the minimum number (62.89) was found from N_0 which was followed (82.61) by N_1 (Table 3). Rahman *et al*. (2009) reported that filled grain panicle^{-1} significantly responded to different levels of S.

Number of filled grains panicle^{-1} of BRRI dhan34 varied significantly due to the different levels of sulphur (Appendix IV). The maximum number of filled grains panicle^{-1} (83.66) was recorded from S_1 which was closely followed (80.24) by S_2, while the minimum number (78.61) was observed from S_0 (Table 3).

Interaction effect of different levels of nitrogen and sulphur showed significant differences for number of filled grains panicle^{-1} of BRRI dhan34 (Appendix IV). The maximum number of filled grains panicle^{-1} (92.40) was found from the treatment combination of N_2S_1, whereas the minimum number (59.00) was observed from the treatment combination of N_0S_0 (Table 4).

4.1.7 Number of unfilled grains panicle^{-1}

Different levels of nitrogen showed significant differences on number of unfilled grains panicle^{-1} of BRRI dhan34 (Appendix IV). The maximum number of unfilled grains panicle^{-1} (9.32) was recorded from N_0 which was closely followed (6.02) by N_1, whereas the minimum number (4.59) was found from N_2 which was followed (5.26) by N_3 (Table 3).

Number of unfilled grains panicle^{-1} of BRRI dhan34 varied significantly due to the different levels of sulphur (Appendix IV). The maximum number of unfilled grains panicle^{-1} (7.34) was recorded from S_0 which was closely followed (6.23) by S_2, while the minimum number (5.32) was observed from S_1 (Table 3).

Interaction effect of different levels of nitrogen and sulphur showed significant differences for number of unfilled grains panicle^{-1} of BRRI dhan34 (Appendix IV). The maximum number of unfilled grains panicle^{-1} (11.80) was found from the treatment combination of N_0S_0, whereas the minimum number (4.10) was observed from the treatment combination of N_2S_1 (Table 4).

4.1.8 Number of total grains panicle^{-1}

Different levels of nitrogen showed significant differences on number of total grains panicle^{-1} of BRRI dhan34 (Appendix IV). The maximum number of total grains panicle^{-1} (95.02) was recorded from N_2 which was closely followed (94.67) by N_3, whereas the minimum number (71.21) was found from N_0 which was followed (87.63) by N_1 (Figure 10). 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 grains panicle^{-1}.

Number of total grains panicle^{-1} of BRRI dhan34 varied significantly due to the different levels of sulphur (Appendix IV). The maximum number of total grains panicle^{-1} (90.97) was recorded from S_1, while the minimum number (86.47) was observed from S_2 which was statistically similar (87.95) with S_0 (Figure 11). Singh and Singh (2002) reported that grains panicle $^{-1}$ were significant with increasing levels of S up to 40 kg S ha^{-1}.

Interaction effect of different levels of nitrogen and sulphur showed significant differences for number of total grains panicle^{-1} of BRRI dhan34 (Appendix IV). The maximum number of total grains panicle^{-1} (96.50) was found from the treatment combination of N_2S_1, whereas the minimum number (70.80) was observed from the treatment combination of N_0S_0 (Figure 12).

4.1.9 Weight of 1000 grains

Different levels of nitrogen showed significant differences on weight of 1000 grains of BRRI dhan34 (Appendix V). The highest weight of 1000 grains (23.01 g) was recorded from N_3 which was statistically identical (22.44 g) with N_2, whereas the lowest weight (16.12 g) was found from N_0 which was followed (19.35 g) by N_1 (Table 5). 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 1000-grain weight.

Table 5. Effect of different levels of nitrogen and sulphur on weight of 1000 seeds, grain, straw and biological yield of BRRI dhan34

Treatments	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Levels of nitrogen				
N_0	16.12 c	1.50 c	3.26 c	4.76 d
N_1	19.35 b	3.97 b	4.99 b	8.96 c
N_2	22.44 a	4.44 a	5.27 a	9.70 a
N_3	23.01 a	3.89 b	5.40 a	9.29 b
$LSD_{(0.05)}$	10.22	0.200	0.155	0.266
Significance level	**	**	**	**
Levels of sulphur				
S_0	18.63 b	3.12 c	4.45 b	7.57 c
S_1	20.80 a	3.91 a	5.19 a	9.10 a
S_2	21.27 a	3.32 b	4.52 b	7.84 b
$LSD_{(0.05)}$	0.885	0.174	0.134	0.230
Significance level	**	**	**	**
CV(%)	5.17	6.72	8.44	7.12

**: Significant at 0.01 level of probability

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

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

N_1: 80 kg N ha^{-1}

N_2: 100 kg N ha^{-1}

N_3: 120 kg N ha^{-1}

S_0: 0 kg S ha^{-1}

S_1: 8 kg S ha^{-1}

S_2: 12 kg S ha^{-1}

Weight of 1000 grains of BRRI dhan34 varied significantly due to the different levels of sulphur (Appendix V). The highest weight of 1000 grains (21.27 g) was recorded from S_1 which was statistically similar (20.80 g) with S_2, while the lowest weight (18.63 g) was observed from S_0 (Table 5). Rahman *et al*. (2009) reported that 1000-grain weight of BRRI dhan41 significantly responded to different levels of S.

Interaction effect of different levels of nitrogen and sulphur showed significant differences for weight of 1000 grains of BRRI dhan34 (Appendix V). The highest weight of 1000 grains (24.11 g) was found from the treatment combination of N_2S_1, whereas the lowest weight (15.69 g) was observed from the treatment combination of N_0S_2 (Table 6).

4.1.10 Grain yield

Different levels of nitrogen showed significant differences on grain yield of BRRI dhan34 (Appendix V). The highest grain yield (4.44 t ha^{-1}) was recorded from N_2 which was closely followed (3.97 t ha^{-1} and 3.89 t ha^{-1}) by N_1 and N_3 and they were statistically similar, whereas the lowest grain yield (1.50 t ha^{-1}) was found from N_0 (Table 5). Dwibvedi (1997) noticed that application of nitrogen significantly increased in grain yield, straw yield as well as harvest index with 60 kg N ha^{-1}. Adhikary and Rahman (1996) reported that the highest yield 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}).

Grain yield of BRRI dhan34 varied significantly due to the different levels of sulphur (Appendix V). The highest grain yield (3.91 t ha^{-1}) was recorded from S_1 which was closely followed (3.32 t ha^{-1}) by S_2, while the lowest grain yield (3.12 t ha^{-1}) was observed from S_0 (Table 5). Mrinal and Sharma (2008) reported that grain yield of rice increased significantly with increasing levels of sulphur up to 30 kg S ha^{-1}. Rahman *et al*. (2009) reported that grain yield of BRRI dhan41 significantly responded to different levels of S. Jawahar and Vaiyapuri (2011) reported that sulphur at 45 kg ha^{-1} recorded higher values for yield (grain) of rice.

Table 6. Interaction effect of different levels of nitrogen and sulphur on weight of 1000 seeds, grain, straw and biological yield of BRRI dhan34

Treatments	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
N_0S_0	15.86 c	1.21 g	2.93 h	4.14 h
N_0S_1	16.80 c	2.03 f	3.84 g	5.87 g
N_0S_2	15.69 c	1.26 g	2.90 h	4.16 h
N_1S_0	17.50 c	3.76 de	4.80 ef	8.56 ef
N_1S_1	20.05b	4.56 ab	5.55 ab	10.11 ab
N_1S_2	20.51 b	3.60 de	4.61 f	8.21 f
N_2S_0	20.37 b	3.96 cd	5.01 de	8.96 de
N_2S_1	22.85 a	4.83 a	5.76 a	10.59 a
N_2S_2	24.11 a	4.53 ab	5.19 cd	9.72 bc
N_3S_0	20.77 b	3.57 e	5.07 de	8.64 ef
N_3S_1	23.49 a	4.21 bc	5.60 ab	9.81 ab
N_3S_2	24.76 a	3.90 cde	5.37 bc	9.27 cd
$LSD_{(0.05)}$	17.69	0.347	0.268	0.461
Significance level	*	*	*	**
CV(%)	5.17	6.72	8.44	7.12

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

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

N_0: 0 kg N ha^{-1} i.e. control
S_0: 0 kg S ha^{-1}
N_1: 80 kg N ha^{-1}
S_1: 8 kg S ha^{-1}
N_2: 100 kg N ha^{-1}
S_2: 12 kg S ha^{-1}
N_3: 120 kg N ha^{-1}

Interaction effect of different levels of nitrogen and sulphur showed significant differences for grain yield of BRRI dhan34 (Appendix V). The highest grain yield (4.83 t ha^{-1}) was found from the treatment combination of N_2S_1, whereas the lowest grain yield (1.21 t ha^{-1}) was observed from the treatment combination of N_0S_0 (Table 6).

4.1.11 Straw yield

Different levels of nitrogen showed significant differences on straw yield of BRRI dhan34 (Appendix V). The highest straw yield (5.40 t ha^{-1}) was recorded from N_3 which was statistically similar (5.27 t ha^{-1}) with N_2, whereas the lowest straw yield (3.26 t ha^{-1}) was found from N_0 which was followed (4.99 t ha^{-1}) by N_1 (Table 5). 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 straw yield.

Straw yield of BRRI dhan34 varied significantly due to the different levels of sulphur (Appendix V). The highest straw yield (5.19 t ha^{-1}) was recorded from S_1 which was closely followed (4.52 t ha^{-1}) by S_2, while the lowest straw yield (4.45 t ha^{-1}) was observed from S_0 (Table 5). Mrinal and Sharma (2008) reported that straw yield of rice increased significantly with increasing levels of sulphur up to 30 kg S ha^{-1}. Rahman *et al*. (2009) reported that straw yield of BRRI dhan41 significantly responded to different levels of S. Dixit *et al*. (2012) reported that application of 40 kg S ha^{-1} gave significantly higher straw yield.

Interaction effect of different levels of nitrogen and sulphur showed significant differences for straw yield of BRRI dhan34 (Appendix V). The highest straw yield (5.76 t ha^{-1}) was found from the treatment combination of N_2S_1, whereas the lowest straw yield (2.90 t ha^{-1}) was observed from the treatment combination of N_0S_2 (Table 6).

4.1.12 Biological yield

Different levels of nitrogen showed significant differences on biological yield of BRRI dhan34 (Appendix V). The highest biological yield (9.70 t ha^{-1}) was recorded from N_2 which was closely followed (9.29 t ha^{-1}) by N_3, whereas the lowest biological yield (4.76 t ha^{-1}) was found from N_0 which was followed (8.96 t ha^{-1}) by N_1 (Table 5). Rahman *et al*. (2009) reported that biological yield of BRRI dhan41 significantly responded to different levels of S.

Biological yield of BRRI dhan34 varied significantly due to the different levels of sulphur (Appendix V). The highest biological yield (9.10 t ha^{-1}) was recorded from S_1 which was closely followed (7.84 t ha^{-1}) by S_2, while the lowest biological yield (7.57 t ha^{-1}) was observed from S_0 (Table 5).

Interaction effect of different levels of nitrogen and sulphur showed significant differences for biological yield of BRRI dhan34 (Appendix V). The highest biological yield (10.59 t ha^{-1}) was found from the treatment combination of N_2S_1, whereas the lowest biological yield (4.14 t ha^{-1}) was observed from the treatment combination of N_0S_0 (Table 6).

4.2 N, P, K and S concentration in grain and straw

4.2.1 N, P, K and S concentration in grain

Statistically significant variation was recorded for N, P, K and S concentration in grain due to different levels of nitrogen (Appendix VI). The highest N, P, K and S concentration in grain (0.507%, 0.230%, 0.327% and 0.239%, respectively) was obtained from N_2, again the lowest N, P, K and S concentration in grain (0.189%, 0.221%, 0.268% and 0.1578%, respectively) was observed from N_0 i.e. control condition (Table 7).

N, P, K and S concentration in grain varied significantly for different levels of sulphur (Appendix VI). The highest N, P, K and S concentration in grain (0.461%, 0.260%, 0.316% and 0.240%, respectively) was found from S_2, whereas the lowest N, P, K and S concentration in grain (0.269%, 0.214%, 0.286% and 0.164%, respectively) from S_0 (Table 7).

Table 7. Effect of different levels of nitrogen and sulphur on N, P, K and S and Zn concentrations in grain of BRRI dhan34

Treatments	Concentration (%) in grain			
	N	P	K	S
Levels of nitrogen				
N_0	0.189 c	0.221 b	0.268 c	0.157 c
N_1	0.492 a	0.228 b	0.299 b	0.229 a
N_2	0.507 a	0.271 a	0.327 a	0.239 a
N_3	0.329 b	0.230 b	0.320 a	0.207 b
$LSD_{(0.05)}$	0.077	0.031	0.010	0.157
Significance level	**	**	**	**
Levels of sulphur				
S_0	0.269 c	0.214 b	0.286 b	0.164 c
S_1	0.408 b	0.238 ab	0.309 a	0.219 b
S_2	0.461 a	0.260 a	0.316 a	0.240 a
$LSD_{(0.05)}$	0.066	0.027	0.008	0.136
Significance level	**	**	**	**
CV(%)	4.47	7.54	4.95	5.13

**: Significant at 0.01 level of probability

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

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

N_1: 80 kg N ha^{-1}

N_2: 100 kg N ha^{-1}

N_3: 120 kg N ha^{-1}

S_0: 0 kg S ha^{-1}

S_1: 8 kg S ha^{-1}

S_2: 12 kg S ha^{-1}

Interaction effect of different levels of nitrogen and sulphur showed significant variation on N, P, K and S concentration in grain (Appendix VI). The highest N, P, K and S concentration in grain (0.623%, 0.335%, 0.352% and 0.285%, respectively) was observed from N_2S_2 and the lowest N, P, K and S concentration in grain (0.164%, 0.205%, 0.261% and 0.121%, respectively) was recorded from N_0S_0 i.e. control condition (Table 8).

4.2.2 N, P, K and S concentration in straw

Statistically significant variation was recorded for N, P, K and S concentration in straw due to different levels of nitrogen (Appendix VII). The highest N, P, K and S concentration in straw (0.570%, 0.046%, 1.419% and 0.063%, respectively) was obtained from N_3, again the lowest N, P, K and S concentration in straw (0.368%, 0.041%, 1.084% and 0.047%, respectively) was observed from N_0 i.e. control condition (Table 9).

N, P, K and S concentration in straw varied significantly for different levels of sulphur (Appendix VII). The highest N, P, K and S concentration in straw (0.578%, 0.046%, 1.327% and 0.062%, respectively) was found from S_2, whereas the lowest N, P, K and S concentration in straw (0.431%, 0.041%, 1.192% and 0.047%, respectively) from S_0 (Table 9).

Interaction effect of different levels of nitrogen and sulphur showed significant variation on N, P, K and S concentration in straw (Appendix VII). The highest N, P, K and S concentration in straw (0.675%, 0.048%, 1.465% and 0.071%, respectively) was observed from N_3S_2 and the lowest N, P, K and S concentration in straw (0.348%, 0.036%, 1.025% and 0.041%, respectively) was recorded from N_0S_0 i.e. control condition (Table 10).

Table 8. Interaction effect of different levels of nitrogen and sulphur on N, P, K and S and Zn concentrations in grain of BRRI dhan34

Treatments	Concentration (%) in grain			
	N	P	K	S
N_0S_0	0.164 e	0.205 b	0.261 f	0.121 g
N_0S_1	0.215 e	0.234 b	0.267 ef	0.165 f
N_0S_2	0.187 e	0.246 b	0.275 ef	0.184 def
N_1S_0	0.329 d	0.216 b	0.285 de	0.164 f
N_1S_1	0.537 b	0.225 b	0.302 cd	0.252 b
N_1S_2	0.610 a	0.221 b	0.310 bc	0.271 ab
N_2S_0	0.358 d	0.222 b	0.283 e	0.169 ef
N_2S_1	0.541 b	0.256 b	0.345 a	0.264 ab
N_2S_2	0.623 a	0.335 a	0.352 a	0.285 a
N_3S_0	0.223 e	0.213 b	0.312 bc	0.201 cd
N_3S_1	0.340 d	0.238 b	0.322 b	0.197 cde
N_3S_2	0.425 c	0.238 b	0.326 b	0.221 c
$LSD_{(0.05)}$	0.133	0.054	0.017	0.027
Significance level	*	**	*	**
CV(%)	4.47	7.54	4.95	5.13

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

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

N_0: 0 kg N ha^{-1} i.e. control
N_1: 80 kg N ha^{-1}
N_2: 100 kg N ha^{-1}
N_3: 120 kg N ha^{-1}

S_0: 0 kg S ha^{-1}
S_1: 8 kg S ha^{-1}
S_2: 12 kg S ha^{-1}

Table 9. Effect of different levels of nitrogen and sulphur on N, P, K and S concentrations in straw of BRRI dhan34

Treatments	Concentration (%) in straw			
	N	P	K	S
Levels of nitrogen				
N_0	0.368 c	0.041 c	1.084 d	0.047 b
N_1	0.522 b	0.042 bc	1.249 c	0.055 ab
N_2	0.557 ab	0.045 ab	1.348 b	0.060 a
N_3	0.570 a	0.046 a	1.419 a	0.063 a
$LSD_{(0.05)}$	0.044	0.0031	0.044	0.010
Significance level	**	**	**	**
Levels of sulphur				
S_0	0.431 c	0.041 b	1.192 b	0.047 b
S_1	0.504 b	0.044 a	1.306 a	0.059 a
S_2	0.578 a	0.046 a	1.327 a	0.062 a
$LSD_{(0.05)}$	0.038	0.0027	0.038	0.008
Significance level	**	**	**	**
CV(%)	8.72	4.84	6.27	8.35

**: Significant at 0.01 level of probability

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

N_0: 0 kg N ha^{-1} i.e. control
N_1: 80 kg N ha^{-1}
N_2: 100 kg N ha^{-1}
N_3: 120 kg N ha^{-1}

S_0: 0 kg S ha^{-1}
S_1: 8 kg S ha^{-1}
S_2: 12 kg S ha^{-1}

Table 10. Interaction effect of different levels of nitrogen and sulphur on N, P, K and S concentrations in straw of BRRI dhan34

Treatments	Concentration (%) in straw			
	N	P	K	S
N_0S_0	0.348 e	0.036 c	1.025 f	0.041 e
N_0S_1	0.372 e	0.043 ab	1.131 de	0.050 b-e
N_0S_2	0.383 e	0.043 ab	1.097 ef	0.049 c-e
N_1S_0	0.437 d	0.041 bc	1.177 d	0.046 de
N_1S_1	0.533 bc	0.042 bc	1.273 c	0.059 a-e
N_1S_2	0.598 ab	0.043 ab	1.296 c	0.060 a-e
N_2S_0	0.471 cd	0.042 ab	1.186 d	0.044 de
N_2S_1	0.545 bc	0.045 ab	1.410 ab	0.067 a-c
N_2S_2	0.655 a	0.048 a	1.449 ab	0.069 ab
N_3S_0	0.469 cd	0.043 ab	1.380 b	0.057 a-e
N_3S_1	0.566 b	0.046 ab	1.411 ab	0.061 a-d
N_3S_2	0.675 a	0.048 a	1.465 a	0.071 a
$LSD_{(0.05)}$	0.076	0.0054	0.076	0.017
Significance level	*	*	**	*
CV(%)	8.72	4.84	6.27	8.35

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

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

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

N_1: 80 kg N ha^{-1}

N_2: 100 kg N ha^{-1}

N_3: 120 kg N ha^{-1}

S_0: 0 kg S ha^{-1}

S_1: 8 kg S ha^{-1}

S_2: 12 kg S ha^{-1}

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

4.3.1 pH

Statistically non significant variation was recorded for pH in post harvest soil due to different levels of nitrogen (Appendix VIII). The highest pH (6.00) was observed from N_1, whereas the lowest pH (5.6) was found from N_2 (Table 11).

Different levels of sulphur showed non significant differences in terms of pH in post harvest soil under the present trial (Appendix VIII). The highest pH (6.0) was recorded from S_0 and the lowest pH (5.8) from S_1 and S_2 (Table 11).

Interaction effect of different levels of nitrogen and sulphur showed non significant variation in terms of pH in post harvest soil (Appendix VIII). The highest pH (6.1) was found from N_0S_1, whereas the lowest pH (5.5) from N_1S_0 (Table 12).

4.3.2 Organic matter

Statistically non significant variation was recorded for organic matter in post harvest soil due to different levels of nitrogen (Appendix VIII). The highest organic matter (1.68%) was observed from N_2, whereas the lowest organic matter (1.43%) was found from N_0 i.e. control condition (Table 11).

Different levels of sulphur showed non significant differences in terms of organic matter in post harvest soil under the present trial (Appendix VIII). The highest organic matter (1.59%) was recorded from S_2 and the lowest organic matter (1.48%) from S_0 (Table 11).

Interaction effect of different levels of nitrogen and sulphur showed non significant variation in terms of organic matter in post harvest soil (Appendix VIII). The highest organic matter (1.64%) was observed from N_3S_2, whereas the lowest organic matter (1.40%) was observed from N_0S_0 (Table 12).

Table 11. Effect of different levels of nitrogen and sulphur on pH, organic matter, total N, exchangeable K and available S in post harvest soil

Treatments	pH	Organic matter (%)	Total N (%)	Exchangeable K (me %)	Available S (ppm)
Levels of nitrogen					
N_0	5.8	1.43	0.023 c	0.150 c	5.66 c
N_1	6.0	1.50	0.052 b	0.173 b	8.57 b
N_2	5.6	1.68	0.063 a	0.185 a	9.66 a
N_3	5.8	1.59	0.060 ab	0.183 ab	9.28 a
$LSD_{(0.05)}$	--	--	0.010	0.010	0.604
Significance level	NS	NS	**	**	**
Levels of sulphur					
S_0	6.0	1.48	0.042 b	0.158 b	7.53 b
S_1	5.8	1.58	0.053 a	0.176 a	8.58 a
S_2	5.8	1.59	0.055 a	0.184 a	8.77 a
$LSD_{(0.05)}$	--	--	0.008	0.008	0.523
Significance level	NS	NS	**	**	**
CV(%)	4.24	4.55	15.56	6.45	9.82

**: Significant at 0.05 level of probability

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

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

N_1: 80 kg N ha^{-1}

N_2: 100 kg N ha^{-1}

N_3: 120 kg N ha^{-1}

S_0: 0 kg S ha^{-1}

S_1: 8 kg S ha^{-1}

S_2: 12 kg S ha^{-1}

Table 12. Interaction effect of different levels of nitrogen and sulphur on pH, organic matter, total N, exchangeable K and available S in post harvest soil

Treatments	pH	Organic matter (%)	Total N (%)	Exchangeable K (me %)	Available S (ppm)
N_0S_0	5.8	1.40	0.018 e	0.143 f	5.08 f
N_0S_1	6.1	1.48	0.027 de	0.148 ef	5.98 f
N_0S_2	5.6	1.41	0.026 de	0.158 def	5.93 f
N_1S_0	5.5	1.46	0.049 c	0.164 de	8.23de
N_1S_1	5.9	1.49	0.053 bc	0.171 bcd	8.58 cde
N_1S_2	5.6	1.56	0.056 bc	0.184 abc	8.90 cd
N_2S_0	5.7	1.59	0.043 cd	0.155 def	7.67 e
N_2S_1	5.8	1.64	0.069 ab	0.197 a	10.25 ab
N_2S_2	6.0	1.64	0.077 a	0.203 a	11.07 a
N_3S_0	5.6	1.47	0.058 bc	0.170 cd	9.15 bcd
N_3S_1	5.6	1.63	0.062 abc	0.189 ab	9.51 bc
N_3S_2	5.8	1.67	0.059 bc	0.190 ab	9.19 bcd
$LSD_{(0.05)}$	--	--	0.017	0.017	1.047
Significance level	NS	NS	**	*	**
CV(%)	4.24	4.55	15.56	6.45	9.82

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

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

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

N_1: 80 kg N ha^{-1}

N_2: 100 kg N ha^{-1}

N_3: 120 kg N ha^{-1}

S_0: 0 kg S ha^{-1}

S_1: 8 kg S ha^{-1}

S_2: 12 kg S ha^{-1}

4.3.3 Total N

Statistically significant variation was recorded for total N in post harvest soil due to different levels of nitrogen (Appendix VIII). The highest total N (0.063%) was observed from N_2 which were statistically similar (0.060%) with N_3, whereas the lowest total N (0.023%) was found from N_0 i.e. control condition which was followed (0.052%) by N_1 (Table 11).

Different levels of sulphur showed significant differences in terms of total N in post harvest soil under the present trial (Appendix VIII). The highest total N (0.055%) was recorded from S_2, which were statistically identical (0.053%) with S_1 and the lowest total N (0.042%) from S_0 i.e. control condition (Table 11).

Interaction effect of different levels of nitrogen and sulphur showed significant variation in terms of total N in post harvest soil (Appendix VIII). The highest total N (0.077%) was observed from N_2S_2, whereas the lowest total N (0.018%) was observed from N_0S_0 (Table 12).

4.3.4 Available P

Different levels of nitrogen showed statistically significant variation was recorded for available P in post harvest soil (Appendix VIII). The highest available P (30.50 ppm) was observed from N_2 which was closely followed (27.11 ppm and 25.32 ppm) with N_3 and N_1, whereas the lowest available P (22.17 ppm) was found from N_0 i.e. control condition (Figure 13).

Significant variation was recorded due to different levels of sulphur in terms of available P in post harvest soil (Appendix VIII). The highest available P (32.48 ppm) was recorded from S_2, which were statistically identical (31.70 ppm) with S_1 and the lowest available P (14.65 ppm) from S_0 (Figure 14).

Available P in post harvest soil showed significant variation due to interaction effect of different levels of nitrogen and sulphur (Appendix VIII). The highest available P (39.78 ppm) was observed from N_2S_2, whereas the lowest available P (14.03 ppm) was observed from N_0S_0 (Figure 15).

4.3.5 Exhalable K

Statistically significant variation was recorded for exchangeable K in post harvest soil due to different levels of nitrogen (Appendix VIII). The highest exchangeable K (0.185 me%) was observed from N_2 which were statistically similar (0.183 me%) with N_3 and closely followed (0.173 me%) by N_1, whereas the lowest exchangeable K (0.150 me%) was found from N_0 i.e. control condition (Table 11).

Different levels of sulphur showed significant differences in terms of exchangeable K in post harvest soil (Appendix VIII). The highest exchangeable K (0.184 me%) was recorded from S_2, which were statistically identical (0.176 me%) with S_1 and the lowest exchangeable K (0.158 me%) from S_0 (Table 11).

Interaction effect of different levels of nitrogen and sulphur showed significant variation in terms of exchangeable K in post harvest soil (Appendix VIII). The highest exchangeable K (0.203 me%) was observed from N_2S_2, whereas the lowest exchangeable K (0.143 me%) was observed from N_0S_0 (Table 12).

4.3.6 Available S

Statistically significant variation was recorded for available S in post harvest soil due to different levels of nitrogen (Appendix VIII). The highest available S (9.66 ppm) was observed from N_2 which were statistically similar (9.28 ppm) with N_3 and closely followed (8.57 ppm) by N_1, whereas the lowest available S (5.66 ppm) was found from N_0 i.e. control condition (Table 11).

Different levels of sulphur showed significant differences in terms of available S in post harvest soil under the present trial (Appendix VIII). The highest available S (8.77 ppm) was recorded from S_2, which were statistically identical (8.58 ppm) with S_1 and the lowest available S (7.53 ppm) from S_0 (Table 11).

Interaction effect of different levels of nitrogen and sulphur showed significant variation in terms of available S in post harvest soil (Appendix VIII). The highest available S (11.07 ppm) was observed from N_2S_2, whereas the lowest available S (5.08 ppm) was observed from N_0S_0 (Table 12).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from July to December, 2013 in T. Aman season in the experimental area at Agronomy farm field, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the influence of nitrogen and sulphur on the yield of T. Aman rice (BRRI dhan34). The experiment comprised of two factors- Factor A: Levels of nitrogen (4 levels)-N_0: 0 kg N ha^{-1} i.e. control, N_1: 80 kg N ha^{-1}, N_2: 100 kg N ha^{-1} and N_3: 120 kg N ha^{-1} and Factors B: Levels of sulphur (3 levels)- S_0: 0 kg S ha^{-1} (control), S_1: 8 kg S ha^{-1} and S_2: 12 kg S ha^{-1}. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

In case of nitrogen fertilizer, at 30, 45, 60 and 75 DAT and at harvest, the longest plant (26.09, 53.84, 71.21, 88.38 cm) was observed from N_2, again the shortest plant (20.98, 45.49, 62.23, 76.00 and 102.72 cm) from N_0. The maximum number of effective tillers $hill^{-1}$ (13.27) was recorded from N_2, whereas the minimum number (9.07) from N_0. The maximum number of non-effective tillers $hill^{-1}$ (3.63) was found from N_2, while the minimum number (1.59) from N_0. The maximum number of total tillers $hill^{-1}$ (16.90) was recorded from N_2, whereas the minimum number (10.66) from N_0. The longest panicle (23.73) was observed from N_2, whereas the shortest panicle (20.47) from N_0. The maximum number of filled grains $panicle^{-1}$ (90.43) was recorded from N_2, whereas the minimum number (62.89) from N_0. The maximum number of unfilled grains $panicle^{-1}$ (9.32) was recorded from N_0, whereas the minimum number (4.59) from N_2. The maximum number of total grains $panicle^{-1}$ (95.02) was recorded from N_2, whereas the minimum number (71.21) from N_0. The highest weight of 1000 grains (23.01 g) was recorded from N_3, whereas the lowest weight (16.12 g) from N_0. The highest grain yield (4.44 t ha^{-1}) was recorded from N_2, whereas the lowest (1.50 t ha^{-1}) from N_0. The highest straw yield (5.40 t ha^{-1}) was recorded from N_3, whereas the lowest

(3.26 t ha^{-1}) from N_0. The highest biological yield (9.70 t ha^{-1}) was recorded from N_2, whereas the lowest (4.76 t ha^{-1}) from N_0.

The highest N, P, K and S concentration in grain (0.507%, 0.230%, 0.327% and 0.239%, respectively) was obtained from N_2, again the lowest (0.189%, 0.221%, 0.268% and 0.1578%, respectively) from N_0. The highest N, P, K and S concentration in straw (0.570%, 0.046%, 1.419% and 0.063%, respectively) was obtained from N_3, again the lowest (0.368%, 0.041%, 1.084% and 0.047%, respectively) from N_0. The highest pH (6.00) was observed from N_1, whereas the lowest (5.6) from N_2. The highest organic matter (1.68%) was observed from N_2, whereas the lowest (1.43%) from N_0. The highest total N (0.063%) was observed from N_2, whereas the lowest (0.023%) from N_0. The highest available P (30.50 ppm) was observed from N_2, whereas the lowest (22.17 ppm) from N_0. The highest exchangeable K (0.185 me%) was observed from N_2, whereas the lowest (0.150 me%) from N_0. The highest available S (9.66 ppm) was observed from N_2, whereas the lowest (5.66 ppm) from N_0.

For sulphur fertilizer, at 30, 45, 60 and 75 DAT and at harvest, the longest plant (24.59, 51.88, 69.58, 85.75 and 114.30 cm) was recorded from S_1, while the shortest plant (23.42, 49.75, 65.94, 82.35 and 109.48 cm) from S_0. The maximum number of effective tillers $hill^{-1}$ (12.13) was recorded from S_1 while the minimum number (11.07) from S_0. The maximum number of non-effective tillers $hill^{-1}$ (3.05) was attained from S_0, while the minimum number (2.18) from S_0. The maximum number of total tillers $hill^{-1}$ (14.90) was recorded from S_1, while the minimum number (13.58) from S_2. The longest panicle (23.73) was found from S_1, while the shortest panicle (21.17) from S_0. The maximum number of filled grains $panicle^{-1}$ (83.66) was recorded from S_1, while the minimum number (78.61) from S_0. The maximum number of unfilled grains $panicle^{-1}$ (7.34) was recorded from S_0, while the minimum number (5.32) from S_1. The maximum number of total grains $panicle^{-1}$ (90.97) was recorded from S_1, while the minimum number (86.47) from S_2. The highest weight of 1000 grains (21.27 g) was recorded from S_1, while the lowest weight (18.63 g) from S_0. The highest grain yield (3.91 t ha^{-1}) was recorded from

S_1, while the lowest (3.12 t ha^{-1}) from S_0. The highest straw yield (5.19 t ha^{-1}) was recorded from S_1, while the lowest (4.45 t ha^{-1}) from S_0. The highest biological yield (9.10 t ha^{-1}) was recorded from S_1, while the lowest (7.57 t ha^{-1}) from S_0.

The highest N, P, K and S concentration in grain (0.461%, 0.260%, 0.316% and 0.240%, respectively) was found from S_2, whereas the lowest (0.269%, 0.214%, 0.286% and 0.164%, respectively) from S_0. The highest N, P, K and S concentration in straw (0.578%, 0.046%, 1.327% and 0.062%, respectively) was found from S_2, whereas the lowest (0.431%, 0.041%, 1.192% and 0.047%, respectively) from S_0. The highest pH (6.0) was recorded from S_0 and the lowest (5.8) from S_1 and S_2. The highest organic matter (1.59%) was recorded from S_2 and the lowest (1.48%) from S_0. The highest total N (0.055%) was recorded from S_2 and the lowest (0.042%) from S_0. The highest available P (32.48 ppm) was recorded from S_2 and the lowest (14.65 ppm) from S_0. The highest exchangeable K (0.184 me%) was recorded from S_2, and the lowest (0.158 me%) from S_0. The highest available S (8.77 ppm) was recorded from S_2, and the lowest available S (7.53 ppm) from S_0.

Due to the interaction effect of different levels of nitrogen and sulphur, at 30, 45, 60 and 75 DAT and at harvest the longest plant (27.17, 55.47, 73.77, 92.33 and 116.53 cm) was found from the treatment combination of N_2S_1, whereas the shortest plant (20.00, 43.80, 59.97, 74.60 and 100.87 cm) from N_0S_0. The maximum number of effective tillers $hill^{-1}$ (13.93) was found from the treatment combination of N_2S_1, whereas the minimum number (8.40) from N_0S_0. The maximum number of non-effective tillers $hill^{-1}$ (4.23) was recorded from the treatment combination of N_2S_1, whereas the minimum number (1.20) from N_0S_1. The maximum number of total tillers $hill^{-1}$ (18.17) was found from the treatment combination of N_2S_1, whereas the minimum number (10.43) from N_0S_1. The longest panicle (25.50) was observed from the treatment combination of N_2S_1, whereas the shortest panicle (20.05) from N_0S_0. The maximum number of filled grains $panicle^{-1}$ (92.40) was found from the treatment combination of N_2S_1, whereas the minimum number (59.00) from N_0S_0. The maximum number of unfilled grains panicle^{-1} (11.80) was found from the treatment combination of N_0S_0, whereas the minimum number (4.10) from N_2S_1. The maximum number of total grains panicle^{-1} (96.50) was found from the treatment combination of N_2S_1, whereas the minimum number (70.80) from N_0S_0. The highest weight of 1000 grains (24.11 g) was found from the treatment combination of N_2S_1, whereas the lowest weight (15.69 g) from N_0S_2. The highest grain yield (4.83 t ha^{-1}) was found from the treatment combination of N_2S_1, whereas the lowest grain yield (1.21 t ha^{-1}) from N_0S_0. The highest straw yield (5.76 t ha^{-1}) was found from the treatment combination of N_2S_1, whereas the lowest straw yield (2.90 t ha^{-1}) from N_0S_2. The highest biological yield (10.59 t ha^{-1}) was found from the treatment combination of N_2S_1, whereas the lowest (4.14 t ha^{-1}) from N_0S_0.

The highest N, P, K and S concentration in grain (0.623%, 0.335%, 0.352% and 0.285%, respectively) was observed from N_2S_2 and the lowest (0.164%, 0.205%, 0.261% and 0.121%, respectively) from N_0S_0. The highest N, P, K and S concentration in straw (0.675%, 0.048%, 1.465% and 0.071%, respectively) was observed from N_3S_2 and the lowest (0.348%, 0.036%, 1.025% and 0.041%, respectively) from N_0S_0. The highest pH (6.1) was observed from N_0S_1, whereas the lowest (5.5) from N_1S_0. The highest organic matter (1.64%) was observed from N_3S_2, whereas the lowest (1.40%) from N_0S_0. The highest total N (0.077%) was observed from N_2S_2, whereas the lowest (0.018%) from N_0S_0. The highest available P (39.78 ppm) was observed from N_2S_2, whereas the lowest (14.03 ppm) from N_0S_0. The highest exchangeable K (0.203 me%) was observed from N_2S_2, whereas the lowest (0.143 me%) from N_0S_0. The highest available S (11.07 ppm) was observed from N_2S_2, whereas the lowest (5.08 ppm) from N_0S_0.

Conclusion

It was observed that, nitrogen and sulphur application have significant positive effect on growth and yield of BRRI dhan34. From the above results, it can be concluded that combination of 100.0 kg N ha^{-1} and 8.0 kg S ha^{-1} can be more beneficial for farmers to get better yield and economic return.

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 level of phosphorous, potassium, zinc and other fertilizers.

3. More experiments may be carried out with the inclusion of different organic manure.

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from July to December 2013

Month (2013)	Air temperature (^{0}c)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
July	36.0	24.6	83	563	3.1
August	36.0	23.6	81	319	4.0
September	34.8	24.4	81	279	4.4
October	26.5	19.4	81	22	6.9
November	25.8	16.0	78	00	6.8
December	22.4	13.5	74	00	6.8

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

Appendix II. 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	Exprimental field, SAU, Dhaka
AEZ	28, Madhupur Tract
General Soil Type	Grey terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil (0-15 cm depth)

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	5.5

Source: SRDI

Appendix III. Analysis of variance of the data on plant height of BRRI dhan34 as influenced by different levels of nitrogen and sulphur

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		30 DAT	45 DAT	60 DAT	75 DAT	Harvest
Replication	2	0.234	0.435	0.213	1.879	0.398
Levels of nitrogen (A)	3	4.034**	14.122**	46.108**	39.347*	83.543**
Levels of sulphur (B)	2	50.234**	139.45**	161.97**	298.65**	309.22**
Interaction (A×B)	6	2.150*	4.933*	4.088*	9.662*	1.417*
Error	22	0.796	1.123	1.768	3.167	0.600

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

Appendix IV. Analysis of variance of the data on effective, non-effective & total tillers plant^{-1}, length of panicle, filled, unfilled and total grains of BRRI dhan34 as influenced by different levels of nitrogen and sulphur

Source of variation	Degrees of freedom	Mean square						
		Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Total tillers hill^{-1}	Panicle length (cm)	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Number of total grains panicle^{-1}
Replication	2	0.112	0.020	0.101	0.155	1.252	0.577	1.231
Levels of nitrogen (A)	3	3.291**	2.145**	5.177**	19.567**	79.688**	12.339**	31.352**
Levels of sulphur (B)	2	31.123**	6.892**	67.345**	18.891**	789.123**	39.538**	951.287**
Interaction (A×B)	6	0.456**	0.399*	1.298**	0.979**	11.187**	2.190**	7.986*
Error	22	0.119	0.117	0.298	0.280	2.780	0.310	2.894

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

Appendix V. Analysis of variance of the data on weight of 1000 grains, grain, straw and biological yield of BRRI dhan34 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)	Straw yield (t/ha)	Biological yield (t/ha)
Replication	2	0.010	0.025	0.011	0.056
Levels of nitrogen (A)	3	5.346**	2.167**	1.874**	7.945**
Levels of sulphur (B)	2	15.567**	15.347**	8.984**	47.457**
Interaction (A×B)	6	1.368*	0.148*	0.096*	0.234**
Error	22	0.178	0.042	0.025	0.074

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

Appendix VI. Analysis of variance of the data on N, P, K and S concentration in grain of BRRI dhan34 as influenced by different levels of nitrogen and sulphur

Source of variation	Degrees of freedom	Mean square			
		Nutrient concentration in grain (%)			
		N	P	K	S
Replication	2	0.001	0.0001	0.001	0.0001
Levels of nitrogen (A)	3	0.014**	0.015**	0.195**	0.019**
Levels of sulphur (B)	2	0.025**	0.018**	0.088**	0.038**
Interaction (A×B)	6	0.003*	0.003**	0.004*	0.006**
Error	22	0.001	0.000	0.002	0.001

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

Appendix VII. Analysis of variance of the data on N, P, K and S concentration in straw of BRRI dhan34 as influenced by different levels of nitrogen and sulphur

Source of variation	Degrees of freedom	Mean square			
		Nutrient concentration in straw (%)			
		N	P	K	S
Replication	2	0.000	0.0001	0.000	0.0001

Levels of nitrogen (A)	3	0.005**	0.332**	0.008**	0.025**
Levels of sulphur (B)	2	0.009**	0.064**	0.007**	0.098**
Interaction (A×B)	6	0.002*	0.005*	0.001**	0.002*
Error	22	0.001	0.002	0.000	0.001

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

Appendix VIII. Analysis of variance of the data on pH, organic matter, N, P, K and S and in post harvest soil 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	0.0001	0.000	0.0001	0.948	0.0001	0.0001
Levels of nitrogen (A)	3	0.009	0.014	0.006**	10.778**	0.098**	0.009**
Levels of sulphur (B)	2	0.056	0.013	0.011**	51.984**	0.057**	0.002**
Interaction (A×B)	6	0.007	0.001	0.002**	4.673*	0.004*	0.0001**
Error	22	0.062	0.023	0.001	1.343	0.001	0.000

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