EFFECT OF SULPHUR AND ZINC ON THE YIELD AND NUTRIENT CONTENT OF T.AMAN RICE (*Oryza sativa*)

BY

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CERTIFICATE

This is to certify that the thesis entitled **"Effects of sulphur and zinc on the yield and nutrient content of T.aman rice"** submitted to the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL CHEMISTRY**, embodies the result of a piece of bona fide research work carried out by **MST. SARABON TAHURA**, Registration Number: **05-1645** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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TO

MY BELOVED PARENTS

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ABSTRACT

A field experiment was conducted at Sher-e-bangla Agricultural University research farm,Sher-e-bangla nagar, Dhaka from July - November, 2011 with the objective of evaluating the effect of S and Zn on the yield and nutrient content of T-Aman Rice. The experiment compared with four different individual and combined treatment (sixteen) of sulphur *viz.* S_0 (control), S_8 (8 kg ha^{-1}), S_{12} (12 kg ha^{-1}) and S_{16} (16 kg ha^{-1}) and zinc *viz.* Zn_0 (0 kg ha^{-1}), $Zn_{1.0}$ (1.0 kg ha^{-1}), $Zn_{1.5}$ (1.5 kg ha^{-1}) and $Zn_{2.0}$ (2.0 kg ha^{-1}) on yield performance and nutrient content of rice . The experiment was laid out in a randomized complete block design(RCBD). All plots received recommended doses of N, P, and K to support normal plant growth and yield. N, P, K, S, and Zn were applied in the form of Urea, TSP, MOP, Gypsum, and $ZnSO_4$, respectively. The application of sulphur and zinc had a positive significant effect on all yield contributing characters *viz.* plant height, tillers hill^{-1}, panicle length, grains panicle^{-1}, 1000-grains weight, grain and straw yield. The longest plant (124.0 cm), highest grain yield (5.663 t ha^{-1}) and straw yield (8.163 t ha^{-1}) of T-Aman Rice was recorded in $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}). The application of sulphur and zinc fertilizer significantly increased the S and Zn contents in soil. Overall results indicate that the treatment combination of $S_{12}Zn_{1.5}$(12 kg S ha^{-1} and 1.5 kg Zn ha$^{-1)}$ alone or combinedly was more effective to produce higher yield and more nutrient of T-Aman rice supported with recommended doses of N, P, and K under the agroclimatic condition of SAU.

ABBREVIATIONS AND ACRONYMS

Full word	**Abbreviation**
And others (at elli)	*et al.*
Centimeter	cm
Concentrate	Conc.
Cultivar	cv.
Cowdung	CD
Degree Celsius	°C
Degree of freedom	df
Emulsifiable Concentrate	EC
Gram	g
Granular	G
Hectare	ha
Hydrogen ion conc.	pH
Kilogram	kg
Least significant difference	LSD
Liter	L
Meter	m
Microgram	µg
Milliequivalent	meq
Milligram	mg
Milliliter	mL
Millimeter	mm
Nanometer	nm
Parts per million	ppm
Pound	lb
Poultry Manure	PM
Square centimeter	cm^2
Square meter	m^2
Ton	t

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Chapter I

Introduction

CHAPTER I
INTRODUCTION

Rice belongs to the Gramminae family with the scientific name *Oryza sativa*. Rice is the staple food for more than three billion people that is over half of the world's total population (FAO, 2004). Rice is the most important source of the food energy for more than half of the human population. Rice is grown in 114 countries across the world on an area about 150 million hectares with annual production of over 525 million tonnes, constituting nearly 11 per cent of the world's cultivated land (Rai, 2006). More than 90 per cent of the world's rice is produced and consumed in Asia where it is an integral part of culture and tradition. In Asia, it is the main item of the diet of 3.5 billion people. Therefore, increase in population will require 70 percent more rice in 2025 than is consumed today (Kim and Krishnan, 2002). According to the Food and Agriculture Organization (FAO) of the U.N., 80% of the world rice production comes from 7 countries (UAE/FAO, 2012). However, if we talk about world rice production 2009-2010, the worldwide rice production by countries- in fact, the top ten countries of world counted for their rice production raining is China: Mt: 166,417,000 (32.7%), India: Mt: 132,013,000 (26.0%), Indonesia: Mt: 52,078,832 (10.2%), Bangladesh: Mt: 38,060,000 (7.5%), Vietnam: Mt: 34,518,600 (6.8%), Thailand: Mt: 27,000,000 (5.3%), Myanmar: Mt: 24,640,000 (4.8%), Philippines: Mt: 14,031,000 (2.8%), Brazil: Mt: 10,198,900 (2.0%) and Japan: Mt: 9,740,000 (1.9%) (UAE/FAO, 2012).

In Bangladesh, about 80% of the total lands are used for rice cultivation. Rice contributes 91.1% of the total grain production and covers 74% of the total calorie intake for the people of Bangladesh. (MOA, 2001). Area under Bangladesh is the 4th largest country of the world with respect to rice cultivation. Rice is cultivated in about 28056 thousand acres land and total annual production is 31975 thousand M. tons, with an average of 1168 kg acre^{-1} (BBS, 2011) where at T aman season rice cultivated at 13993 thousand acre and annual production of 9403 thousand M. tons with an average yield of 872 kg acre^{-1} (BBS, 2011). Bangladesh is predominantly an agrarian economy. It is one of the most densely populated countries of the world with almost 1000 person in each of the 147570 square kilometer area. Agriculture is the single largest producing sector of

Bangladesh economy since it comprises about 20% of the country's Gross Domestic Product (GDP) and employs around 45% of the total labor force. Agricultural growth has accelerated from less than 2.0% per year during the first two decades after independence in 1971 to around 3.0% during the last decade. Despite such a steady growth in agriculture as well as in food production, Bangladesh has been facing persistent challenges in achieving food security. This is mainly due to natural disasters and fluctuations in food prices from the influence of volatile international market for basic food items (Rahman, 2011). Hossain (2002) also reported that the rice sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh. Thus, rice plays a vital role in the livelihood of the people. The country is now producing about 42.3 million tons of clean rice @ 3.78 t ha^{-1} in 11.2 million ha of land. A conservative statistics given by Bhuiyan *et al.* (2002) indicates that about 21% higher amount of rice than the production of 2000 have to be produced to feed the population by the year 2025.

T aman is one of the most important rice crops period which might suffer from high temperature at the different growth stages from germination to maturity (BRRI, 2007). A study showed that most Asian countries will not be able to feed their projected populations without irreversibly degrading their land resources, even with high levels of management inputs (Beinroth *et al.*, 2001). So, we need to fertile the soil by using different organic and inorganic fertilizers while the crop productivity will be significant increase. Unfortunately fertility of the soil this country has been deteriorating over the years which are responsible for stagnating or declining crop yields. Plant nutrients in soil, whether naturally endowed or artificially maintained, is a major determinant of the success or failure of a crop production system. The crop production system with high yield targets can not be sustainable unless nutrient inputs to soil are at least balanced against nutrient removal by crops (Bhuiyan *et al.,* 1991). In Bangladesh the use of chemical fertilizers as a supplemental source of nutrients has been increasing steadily, however they are not usually applied in balanced proportions (BARC, 1997). Hence, a pragmatic step needs to be taken for balanced application of fertilizer with the limiting nutrient elements wherever necessary.

The farmers of Bangladesh use only about 172 kg nutrients ha^{-1} annually (132 kg N, 17 kg P, 4 kg S and 2 kg Zn + B + others), while the crop removal is about 250 kg ha^{-1} (Islam et al., 2009a/b). Consequently, in addition to N, P and K deficiencies, some other nutrients such as B, Zn and S deficiencies are being observed in many parts of the country. Sulphur (S) is an essential macronutrient and it plays a vital role in the plant system. The deficiency of S in Bangladesh was first detected in rice at BRRI farm at Joydebpur in 1976. In recent years, S deficiency has been receiving much attention as a major limiting factor for wetland rice. For rice cultivation, next to N, S application is very important. So, in fertilizer schedule, it is commonly included (Islam *et al.*, 2009). Sulphur deficiency affects not only the growth and yield of rice but also the protein quality through its effect on the synthesis of certain amino acids such as systein and methionine. Zinc also plays a vital role in the physiological process of rice plant such as cell elongation, protein synthesis, meristematic tissues development and ribosome formation (Gupta *et al.,* 1996). The use of almost sulphur free fertilizer such as urea and triple super phosphate (TSP) may be an important reason for widespread occurrence of S deficiency problem. About 1.2 million hectors of land are suspected to be potentially Zn deficient in Bangladesh. The deficiencies of these elements are due to intensive cropping with modern crop varieties with high yield potential.

Declining land productivity with negative nutrient balance is the main concerns against the food security problems in the country. Fertilization is one of the most important notable measures that help to increase agricultural production. So, application of adequate amount of mineral nutrients to crop is one of the important factors in achieving higher productivity. Modern rice varieties obviously require higher amount of nutrients to give higher crop yields. The intensive cropping with modern varieties, nutrient leaching with monsoon rains and light textured soils are also favoring the emergence of micronutrient deficiency in the soil, consequently Zn and B deficiencies are frequently reported on some soils and crop (Jahiruddin *et al.*, 1995).

Nutrient stresses in Bangladesh soils are increasing day by day. Before 1980's, deficiency of NPK was a major problem in Bangladesh soils, and thereafter along with NPK, deficiency of S and Zn are frequently reported (Hoque & Jahiruddin, 1994). Sulphur deficiency has been recognized in many areas of Bangladesh which roughly covers 44% of the total cropped area (Hussain, 1990). The use of almost S free fertilizers such as urea and TSP may be an important reason for widespread occurrence of S deficiency problem. Hoque and Jahiruddin (1994) suggested this element would be applied in every rice crop.

However, depletion of soil fertility is a major constraint for sustainable crop production in Bangladesh. As our soils are deficit in NPK with S and Zn, necessary study should be done to grow rice successfully and profitably (Rahman *et al.*, 2008). On the other hand, continuous application of large amounts of micronutrients can be toxic to the plants. If plant nutrients are not supplied in an adequate amount with an appropriate proportion, high yielding crop varieties under intensive cropping may fail to express their full potential. Considering above points, the present study was undertaken with the following objective

i. to determine the effects of S and Zn on the yield and yield attributes of rice.
ii. to examine the effects of S and Zn on the nutrient contents of rice cv. BRRI- dhan 40.

Chapter II

Review of Literature

CHAPTER II
REVIEW OF LITERATURE

An attempt has been made in this chapter to present a brief and relevant review of many researchers in relation to the effects of S and Zn on the growth, yields, and nutrient uptake by rice in Bangladesh perspective and also in the other parts of the world. The related review of literature was present under the following heading and sub headings:

2.1 Main effects of sulphur on growth and yield of rice

Jena and Kabi (2012) reported that the effect of gromor bentonite S pastilles and gypsum on yield and nutrient uptake by hybrid rice-potato-green gram cropping system. Application of S significantly increased the grain and straw yield, nutrient uptake by hybrid rice-potato-green gram cropping system. A dose of 60 kg S ha^{-1} through S-bentonite pastilles increased the yield of hybrid rice, potato and green gram over control by 34, 21 and 18 per cent, respectively.

Bhuiyan *et al.* (2011c) investigated to the kharif-II season of 2002 at the Bangladesh Agricultural University Farm, Mymensingh, to find out the integrated use of organic and inorganic fertilizers on the yield of T. Aus and mungbean in a Wheat-T. Aus/mungbean-T. Aman cropping sequence. The rates of N, P, K and S for T. Aus rice were 60, 12, 32 and 5 kg ha^{-1} for MYG, and 90, 18, 48 and 7.5 kg ha^{-1} for HYG, respectively. The variety BR 26 for T. Aus rice was planted in all three years. The results showed that grain yields (3.46 t ha^{-1}) and straw yields (5.19 t ha^{-1}) of T. Aus rice (mean of three years) was increased significantly by the application of fertilizers. The application of chemical fertilizers, NPKS (HYG) remarkably increased the crop yields while the lowest mean grain yields of 1.48 t ha^{-1} for T. Aus and 0.42 t ha^{-1} for mungbean were recorded in the unfertilized control plots.

Rahman *et al.* (2009) studied to know the effect of different levels of sulphur on growth and yield of BRRI dhan 41 at Soil Science Field Laboratory of

Bangladesh Agricultural University (BAU), Mymensingh during T. aman season of 2007. There were eight treatments with three replications. Recommended dose were of fertilizer N 90 kg ha^{-1}, P 15 kg ha^{-1}, K 40 kg ha^{-1} and Zn 2 kg ha^{-1} were applied as basal does from urea, TSP, Muriate of Potash and Zinc Oxide, respectively and S at 90 kg ha^{-1} from gypsum was applied as per treatments by BARC, 2005. The treatments used in the experiment were T_0 (without S), T_1 (50% RFD of S), T_2 (75% RED 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 dhan 41 significantly responded to different levels of applied S.

Islam *et al*. (2009a) conducted an experiment at the Department of Soil Science of Bangladesh Agricultural University (BAU), Mymensingh during T. aman season of 2006 to evaluate the effects of different rates and sources of sulphur on the yield, yield components, nutrient content and nutrient uptake of hybrid and inbred rice. There were seven treatments consisting of four levels of sulphur (0, 8, 12 and 16 kg S ha^{-1}) applied. The grain and straw yields as well as the other yield contributing characters like effective tillers $hill^{-1}$, panicle length, filled grains $panicle^{-1}$ and 1000 grain weight were significantly influenced due to application of sulphur. The highest grain yield of 5293 kg ha^{-1} and straw yield of 6380 kg ha^{-1} were obtained from 16 kg S ha^{-1} applied as gypsum. The lowest grain yield (4200 kg ha^{-1}) and straw yield (4963 kg ha^{-1}) were recorded with S control treatment. The overall results suggest that application of sulphur @ 16 kg S ha^{-1} as gypsum was the best treatment for obtaining higher grain yield as well as straw yield of T. aman rice.

Rahman *et al*. (2007b) conducted a field experiment on a non-calcareous dark gray floodplain soil (Sonatola series) of BAU farm, Mymensingh during Boro season of 2004 using rice (cv. BRRI dhan29) as a test crop. The soil was silt loam having pH 6.8, organic matter 1.62%, available Sulphur (S) 9 ppm and available Phosphorus (P) 7.62 ppm. All plots received an equal dose of N, P, K and Zn. The application of S had a significant positive effect on tillers $hill^{-1}$, plant height, panicle length and grains $panicle^{-1}$. The highest grain (5.81 t ha^{-1}), and straw (7.38 t ha^{-1}) yields were recorded in 20 kg S ha^{-1}. The control had the lowest grain yield of 4.38 t ha^{-1} as well as the lowest straw yield of 5.43 t ha^{-1}. Regression analysis showed that the optimum dose of S was 32.89 kg ha^{-1} and the economic dose of S was 31.59 $kgha^{-1}$ for maximizing the yield.

Lar Oo *et al.* (2007) studied on the effect of N and S levels on productivity and nutrient uptake in aromatic rice. The experiment was carried out with 16 treatments combinations of 4 N levels (0, 50, 100 and 150 kg ha^{-1}) and 4 S levels (0, 20, 40 and 60 kg ha^{-1}) in factorial randomized block design replicated thrice. Growth and yield attributes, grain, straw and biological yields increased significantly with N and S levels. The increase in grain yield due to application of 100 and 150 kg N ha^{-1} over control was 1.99 tonnes ha^{-1} and 1.95 tonnes and in terms of percentage increase was 49.5 and 48.5% respectively. The percentages increase in the grain yield of rice at application of 20, 40 and 60 kg S ha^{-1} over the control were in the order of 6.5, 7.3 and 8.8% respectively.

Biswas *et al.* (2004) reported the effect of S in various region of India. The optimum Srate 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%.

Sarfaraz *et al.* (2002) conducted a field experiment to determine the effect of different S fertilizers at 20 kg ha^{-1} on crop yield and composition of rice cv. Shaheen Basmati in Pakistan. They found that the number of tillers $m\text{-}^{2}$, 1000-grain weight, grain, and straw yield were significantly increased with the application of NPK and S fertilizer compared to the control.

Babu and Hegde (2002) carried out field studies in Andhra Pradesh, India to evaluate the direct and residual effects of Sulphur on rice-sunflower cropping system. The direct effect of Sulphur through single super phosphate on hybrid rice resulted in a significant increase of 21 % in grain yield with S use efficiency of 13 kg grain kg^{-1} at 45 kg S ha^{-1}. The residual effect of this on succeeding sunflower crop resulted in 37% increase in seed yield and 45% increase in oil content.

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

Poongothai *et al.* (1999) showed that application of 60 kg S ha^{-1} as gypsum along with green leaf manure at the rate of 6.25 t ha^{-1} increased the Sulphur use efficiency, straw and grain yields of rice

Li and Li (1999) conducted pot experiments with rice grown on black soils given NPK (control), NPK+Ca, NPK+gypsum, NPK+S or NPK +Ammonium Sulphate. Application of ammonium sulphate or elemental S increased yield by 28.8% and 19.7% respectively. In the field experiment S increased yield by 9.71%. The added element increased plant growth, the number of tillers, grains/ panicle and yield.

Sarkunan *et al.* (1998) carried out a pot experiment to find out the effect of P and S on the yield of rice under flooded condition on a P and S deficient sandy loam soil. The treatments were the combination of 4 levels of P (0, 25, 50 and 100 mg kg^{-1} soil) as ammonium phosphate and 4 levels of S (0, 10, 25 and 50 mg kg^{-1} soil) as ammonium sulphate. Increasing levels of P from 0-100mg kg^{-1} progressively increased the grain yield from 16.9 to 42.5 g pot^{-1}. Sulphur addition at 25 mg kg^{-1} resulted in 9% increase in grain yield. The treatment combination of 100 mg P and 10 mg S kg^{-1} soil gave significantly higher grain yield than the other treatments.

Uddin *et al.* (1997) conducted a field experiment in Patuakali during aman season of 1990 to see the effect of N, P, and S on the yield of rice cv. Haloi. They reported that application of 20 kg S ha^{-1} increased tillering, grains $panicle^{-1}$ and grain yield of rice.

Sahu and Nandu (1997) carried out two field experiments, one in black soil and other in laterite soil to determine the response of rice cv. Jajati and Lalat to sulphur (0-60 kg ha^{-1}) in Orissa. They observed that mean grain yield increased with up to 40 kg S ha^{-1} on black soil and the yield was the highest with 60 kg S ha^{-1} on the laterite soil.

Gupta *et al.* (1997) conducted field experiments in the karif seasons of 1996 and 1997 at one Regional Agricultural Research Station, India to study the effects of sulphur sources sulphur powder, gypsum, iron pyrites and sulphur dose (0, 10, 20, 30 or 40 kg S ha) on rice. They showed that compared with controls, rice grain yield increased by 14.2, 24.2, 25.6 and 20.1% with the four rates of sulphur respectively. The optimum dose was 20 kg S ha^{-1}.

Islam *et al.* (1996) conducted field experiments during T. aman season of 1992 to examine the response of BR 11 rice to S, Zn and B. They found that application of 20 kg S ha^{-1} at both locations significantly increased the grain yield of rice.

Tandon *et al.* (1995) observed that S application of 20 to 60 kg ha^{-1} significantly increased grain yield of rice and the average yield response due to S application was 17.1%. He also noted different sources of S were equally effective.

Islam *et al.* (1995) carried out a field experiment during aman season of 1992 to investigate the response of BR 31 rice to different nutrients including S. They reported that application of 20 kg S ha^{-1} with 100 kg N

ha^{-1} increased the grain yield by 1300 kg N ha^{-1} application. Mukhopadhyay *et al.* (1995) found that gypsum and pyrite were equally effective in increasing rice yield when applied at the rate of 20 kg S ha^{-1}.

2.2 Main effects of zinc on growth and yield of rice

This experiment was carried out in 2012 by Yadi and Dastan (2012) at Sari, Mazandaran, Iran. Zinc fertilizer application was chosen as main plots (0, 20 and 40 $kgha^{-1}$) and genotypes as sub plots. The results showed that the most panicle number m^{-2} and harvest index had observed in 40 kg Zn ha^{-1} and the least of those was obtained in control treatment. Mahalli Tarom cultivar had the maximum panicle length and plant height, but the maximum panicle number m^{-2}, grain yield and harvest index were produced for var. Neda and Shiroodi.

Khan *et al.* (2012) carried out to study the effect of different levels of zinc (Zn) i.e. 0, 3, 6, 9, 12 and 15 kg Zn ha^{-1} on the rice genotype Sarshar evolved at NIA, Tandojam. The results revealed that the plant height, productive tillers per hill, number of grains per panicle, 1000-grain weight, straw and paddy yield showed increasing trend up to 9 kg Zn ha^{-1}. The highest average paddy yield (8.63 tons ha^{-1}), Plant height (108 cm), number of grains per panicle (194.5), 1000-grain weight (30.35 g) and productive tillers per plant (16) were recorded at 120 kg N and 90 kg P2O5 along with 9 kg Zn ha^{-1}. It is recommended that 120 kg N and 90 kg P2O5 along with 9 kg Zn ha^{-1} may be adopted as the most economical dose for obtaining the maximum yield from this rice genotype under the agro-climatic conditions of Sindh.

Arif *et al.* (2012) studied to diminished growth and yield of rice. The effect of soil application of Zinc (Zn), Boron (B) and Microtone (MT) on growth, chlorophyll contents, mineral profile and yield components were investigated in rice at Pakistan in the year 2011. Seven treatments which includes Zn 33% at 3 kg $acre^{-1}$, Zn 33% at 6 kg $acre^{-1}$, B 11.3% at 1.5 kg $acre^{-1}$, B 11.3% at 3 kg $acre^{-1}$, Zn + B at 3 + 1.5 kg $acre^{-1}$, Zn + B at 6 + 3 kg $acre^{-1}$ and MT + Zn 6% + B + Fe + Mn + Cu 1% each at 500 ml $acre^{-1}$, and F0 considered as the control were used. The results reveal that foliar application of Zn and B (Zn + B at 6 + 3 kg/acre) were proved as the best balanced fertilizer dose for higher growth and yield response. The plant height, tiller plant^{-1}, panicle length, kernels plant^{-1}, filled kernel plant^{-1}, productive kernel, straw, paddy and biological yield increased up to 29.75, 38.40, 28.19, 25.81, 36.52, 38.52, 32.47, 38.27 and 31.79%, respectively. The chlorophyll contents, B and Zn contents in rice plant also increased significantly as compared to the control. However, the B, Zn and MT application reduced the amylase and protein contents of rice plant at all treatment levels.

Abid *et al.* (2012) were investigated the effect of Zn, Fe and Mn on yield and yield contributing parameters and mineral contents of rice variety KS-282. Two rates of Zn (0, 5 and 10 mg kg^{-1} soil) and one rate of each Fe and Mn (5 mg kg^{-1} soil) along with a basal dose of NPK (100-50-50 mg kg^{-1}) were added in various combinations before the transplanting of rice seedlings. Number of tillers, number of grains panicle^{-1}, 1000-grain weight and grain yield increased significantly with the application of Zn, Fe and Mn alone or in various combinations. However, more increase in paddy yield and yield contributing growth parameters was noted in treatment comprising 10 mg kg^{-1} Zn along with 5 mg kg^{-1} Mn and a basal dose of N. P and K fertilizers. The Zn and Mn concentration in the grain were 46.53 and 99.40 mg kg^{-1}, respectively in the treatment, where 10 mg kg^{-1} Zn was applied along with NPK+Mn. The maximum Fe was 166.1 mg kg^{-1} in grain, where 5 mg kg^{-1} Zn was applied along with the NPK +Fe.

Two pot experiments were conducted by Malik *et al.* (2011) at the Dept. of Soil, Water and Environment, University of Dhaka to examine the effects of Zn on red amaranth (Amaranthus sp.) and rice (Oryza sativa). Four Zn levels were maintained by treating the experimental soils with 0, 200, 300 and 400 mg Zn kg^{-1} soil. A significant impact of zinc was observed on growth and yield of red amaranth and rice. The concentration of zinc increased with increasing zinc treatment in red amaranth and rice roots, shoots and grain. In case of rice the length of roots, shoots and spikelets increased with increasing zinc levels and the highest was observed at 200 ppm Zn. The fresh and dry matter production decreased at 200 ppm Zn but increased at 300 and 400 ppm Zn for rice.

Qaisrani (2011) was studied to evaluate the effect of different methods and timing of zinc application on growth and yield of rice. Experiment was comprised of eight treatments viz., control, rice nursery root dipping in 0.5 % Zn solution, $ZnSO_4$ application at the rate of 25 kg ha^{-1} as basal dose, foliar application of 0.5 % Zn solution at 15, 30, 45, 60 and 75 days after transplanting. Super Basmati, a promising variety of rice was used as a test crop. Maximum productive tillers m^{-2} (249.80) were noted with basal application at the rate 25 kg ha^{-1} 21 % $ZnSO_4$ and minimum (220.28) were recorded with foliar application at 60 DAT @ 0.5 % Zn solution. Zinc application methods and timing had significantly pronounced effect on paddy yield. Maximum paddy yield (5.21 t ha^{-1}) was achieved in treatment Zn2 (Basal application at the rate of 25 kg ha^{-1} 21 % ZnSO4) and minimum paddy yield (4.17 t ha^{-1}) was noted in Zn7 (foliar application at 75 DAT @ 0.5% Zn solution). Zinc application increases the crop growth rate of rice.

Sridevi *et al.* (2010a) conducted a field experiment on non-calcareous, zinc deficient clay loam soil (Typic Ustopept). Rice (variety ADT-45) was the test crop to study the effect of zinc-enriched organic manures. The treatments were NPK alone, NPK+200 kg FYM without enrichment, NPK+200 kg FYM enriched with different levels of Zn (1.25, 2.50 and 5.0 kg $Znha^{-1}$), NPK+cow dung without enrichment and NPK+200 kg cow dung enriched with different levels of Zn. The results of the field experiment revealed that recommended dose of NPK+200 kg FYM enriched with 5.0 kg zinc increased the grain (5430 $kgha^{-1}$) and straw (7075 $kgha^{-1}$) yields which was due to increased availability of zinc.

Nemeno *et al.* (2010) studied to evaluate the effect of water management on grain Zn concentration and uptake. Results revealed that continuous flooding

(W1) increased grain yields of MS13 and IR72 in Buguey possibly due. Zinc concentration in grains was significantly higher in Alimodian with higher level of HCl-extractable Zn. In both soils, grain Zn concentration of MS13 was higher compared to IR72. This indicates that water management had no effect on grain Zn concentration in MS13.

Khan *et al.* (2010) studies were conducted for two consecutive years to assess the nutritional requirements of newly evolved rice genotype IR-6-25A. The experiment comprising of seven fertilizer treatments with N applied at 90, 120 and 150 kg ha^{-1} and P_2O_5 at 60, 90 and 120 kg ha^{-1} with or without 25 kg ha^{-1} $ZnSO_4$ (36.4% Zn), was laid out according to RCB design with four replications. Paddy yield increased linearly with the increasing levels of N and P application. Zinc sulfate applied at 25 kg ha^{-1} provided an additional harvest of 14-35% over their respective N and P applications. A significant antagonism between P and Zn absorption in plant was observed.

A field investigation was undertaken by Veeranagappa *et al.* (2010) during *Kharif* 2008 at College of Agriculture, Navile, Shivamogga to study the effect of zinc enriched compost on soil properties, yield and uptake of nutrients by rice (*Oryza sativa* L.). There were eleven treatment combinations comprising of recommended dose of compost, NPK fertilizers, $ZnSO_4$ and zinc enriched compost. Significantly higher growth and yield attributes were recorded in package of practice followed by NPK + Zn-E compost at 15 and 10 kg ha^{-1}. Grain yield and straw yield were also superior in the same treatments.

A field experiment was conducted by Islam *et al.* (2010) with an objective of evaluating the direct renewed and residual effects of secondary nutrients (S & Mg), micro nutrients and organic amendments (PM and CD) on the growth, yields and nutrients uptake of T-aman crops. The eight treatments were viz. T_1: NPK (control), T_2: NPK + S, T_3: NPK + S + Mg, T_4: NPK + S + Mg + Zn, T_5: NPK + S + Mg + Zn + B, T_6: NPK + S + Mg + Zn + B + Mo, T_7: NPK + Poultry manure (PM) and T_8: NPK + Cowdung (CD). The doses of secondary, micro nutrients, PM and CD were 30 kg S ha^{-1}, 15 kg Mg ha^{-1}, 5 kg Zn ha^{-1}, 2 kg B ha^{-1}, 1.5 kg Mo ha^{-1}, 5 ton PM ha^{-1} and 5 ton CD ha^{-1}. The grain and straw yields of T. aman rice significantly influenced due to application of secondary nutrients. Grain yields of T. aman rice varied from 3410 kg to 3937 kg ha^{-1}, with the highest yield recorded in the treatment T_7: N P K + (PM) & lowest in T_1: NPK (control).

Yakan *et al.* (2006) studied to examine the effect of zinc application on rice grain yield and some agronomic characters and to find out a suitable Zn application rate. Four zinc treatments, 0, 15, 30, and 45 kg ha^{-1} were utilized and $ZnSO_4.7\ H_2O$ was used as zinc source. The concentration of DTPA-extractable Zn in the soils was 0.22 and 0.43 mg kg^{-1} in 1998 and 1999, respectively. Although Zn application was not significantly effective on rice grain yield. A considerable increase observed in grain yield with Zn application. It was 12.3% and 8.4% in 1998 and 1999, respectively. On average, grain yield increase was 8.9% and also, Zn concentration of the plant and the rice grain increased with Zn application. In addition to these, the day to maturity and spikelet sterility decreased, and the number of panicle per square meter and head rice yield increased with Zn application.

Rahman *et al.* (2006) studied to evaluate the necessity of Zn for the growth and yield of rice (IRRI-11) grown on a loamy soil. Zn was applied at the rate of 0, 2, 4, 8 and 16 kg Zn ha^{-1}. Two kg Zn ha^{-1} treated soil significantly ($p=0.05$) showed the highest straw and grain yields (10.28 and 9.80 g $plant^{-1}$, respectively). A gradual decrease in growth and yield parameters of rice were observed in doses of 4, 8 and 16 kg Zn ha^{-1} compared to 2 kg Zn ha^{-1}. The results suggest that 2 kg Zn ha^{-1} was sufficient and more effective to promote the growth and yield of rice (IRRI-11)

Kulandaivel *et al.* (2003) conducted a field experiments to determine the optimum dose and suitable mode of Zn and Fe application on the productivity of rice hybrid rice. The treatments comprised $ZnSO_4$ 10, 20, 30 and 40 kg ha^{-1} and $FeSO_4$ at 5 and 10 kg ha^{1}. $ZnSO_4$ had a positive response on the number of tillers m^{-2}, dry matter production, and leaf area index and crop growth rate. The maximum dry matter (162.80 g ha^{1}) at harvest was recorded with the application of 40kg $ZnSO_4$ ha^{1}. The successive increase in the rate of $ZnSO_4$ and $FeSO_4$ had a positive effect on the grain and straw yields of rice. However, it was significant only up to 30 kg $ZnSO_4$ ha^{1}. On an average, a 15% increase in grain yield, due to 30 kg $ZnSO_4$ $ha^{1,}$ was recorded compared to the control.

Khan *et al.* (2003) conducted a field experiment to Investigate the comparative effect of three different methods of Zn application in transplanted flooded rice (cv. IRRI.6) grown in alkaline calcareous soil and also to evaluate the comparative effect of Zn levels applied by different methods. Among the three methods i.e. nursery root dipping in 1.0% $ZnSO_4$ 0.20% $ZnSO_4$ solution spray after transplanting and 10 kg Zn ha^{-1} day field broadcast method; the last one is more superior, because it produced significantly higher paddy yield.

Prasad *et al.* (2002) conducted a field experiment in Bihar, India, for five years to study the optimal frequency of Zn fertilizer application on Zn deficient soil in the rice-wheat cropping system. The treatments were soil and foliar application of $ZnSO_4$ at different doses. The results indicate that the pooled yield of rice (32.5 q ha^{-1}) was higher than that of wheat grain (15.8 q ha^{-1}). The rates of increase in yields of rice and wheat were 52.4 and 21.0 kg of $ZnSO_4$, respectively and the percent increase in yield of rice was 46.6 and 38.1. The rice and wheat yields in the cropping system were significantly correlated with Zn removal.

Kumar *et al.* (2002) studied the effects of Zn source ($ZnSO_4$. ZnO or chelated Zn) and Zn and P rates (0, 10, 20 or 30 ppm) on the performance of rice cv. Saket 4 in Lalthaoit, Butandshahr, Uttar Pradesh, India. Among the various Sources of Zn, they found that chelated Zn resulted in the maximum grain (2 923 t ha^{-1}) and straw (4. 861 t ha^{-1}) yields nitrogen (1.16%), phosphorus (0.28%), potassium (0.54%) and Zn (5.19%) contents of straw. Among Zn rates, 10 ppm gave the maximum grain (3.0 t $ha^{1)}$ and straw (4.83 t ha^{1}) yield. They also found that Zn content of grain (2.30 ppm) and straw (5.32 ppm) was highest at 30 ppm.

Vasudeva and Ananthanarayana (2001) conducted a field experiment in India to investigate the effect of added Zn based on Zn absorption maximum on rice yield and nutrient dynamics in acid soils (Ulti Paleusalf). The treatments comprised different levels 0, 2.2, 10, 20 and 40 kg ha^{-1}, which correspond to 0, 0.22, 0.55, 1.10, 1.65 and 2.20% of zinc absorption maxima) and sources of Zn ($ZnSO_4$ and ZnO) along with recommended dose of farmyard manure (5 t ha^{-1}) and fertilizers N, P and K ha^{-1} (75 :75: 90). Results showed that the paddy rice responded well to Zn application at 20 kg $ZnSO_4$ ha^{-1} in acidic soils, which gave a maximum grain yield of 7002 kg ha^{-1}. With regards to Zn source, the plants, which received Zn as ZnO, showed lower yield compared ton Zn as $ZnSO_4$ this could be attributed to the lower solubility of ZnO.

Ullah *et al.* (2001) conducted an experiment to study the effect of $ZnSO_4$ (0, 10 20 kg ha- ^{1}) on rice cv. BRRI dhan 30 in Mymensingh, Bangladesh. $ZnSO_4$ along with 60 kg P_20_5 ha^{1}, 40 kg K_20 ha^{-1} and 80 kg N ha^{-1} were applied to the plot. They found that plant height, tiller number, 1000-grain weight, grain and aw yields; and grain, straw and soil Zn contents increased with $ZnSO_4$ application. They also found the tallest plants (75.67 cm) and the highest number of tillers (10.6 per hill), 1000-grain weight (28.7g) and straw (101.93) ppm and grain (73.33 ppm) Zn contents were obtained with 20 kg $ZnS0_4$ ha1.

Hossain *et al.* (2001) studied to investigate the requirement of secondary (Ca, Mg and S) and micronutrients (Zn, Cu, B and Mo) for the cultivation of BRRI Dhan 32. There were 12 treatments, grain and straw yields were significantly reduced by the omission of secondary (Ca, Mg and S) and micronutrients (Zn, Cu, B and Mo) from the complete treatment in bth the locations. The treatment comprising secondary and micronutrients gave the highest yield of 4913 and 4732 kg ha^{-1} at Dinajpur and Ranpur, respectively while the absolute control produce the minimum yield (2743 and 2627 kg ha^{-1}). Amongst secondary nutrients, omission of S (T_5) from the complete treatment showed lower yield compared to Ca and Mg missing treatments. Boron and Zn missing plots showed lower yield compared to those of Cu and Mo missing plots. Application of secondary and micronutrients revealed a beneficial effect on yield contributing characters, which in turns resulted in higher grain yield of BRRI Dhan 32.

Sharma *et al.* (1999) conducted field experiments in 1995-96 at Hanumangarh, Rajasthan India, with rice cv. Java and PR 106 given 0, 12, 24 or 36 kg $ZnSO_4$ ha^{-1} at 30 or 30 + 45 days after transplanting. Yields increased with increasing rate of Zn application, with 36 kg Zn ha^{-1} giving the maximum yield, followed by two spraying.

Islam *et al.* (1997) reported that autumn rice responded significantly to S, Zn and B applications. The highest grain yield (4.5 t ha^{-1}) was obtained in S +Zn+ B treatment with 41.8% grain yield increased over control, while the application of S, Zn or B alone gave yield increased of 23.3, 21.7 and 14.6%, respectively.

Ingle *et al.* (1997) conducted a field trail at Sindewahi, Maharashtra, India, using rice cv. Sye-75 given 0, 5, 10 or 15 kg Zn ha^{-1} as $ZnSO_4$ or ZnO. They observed that grain yield was increased with increasing Zn rates but was not affected by sources of Zn. Singh *et al.* (1996) observed that grain yield of rice increased significantly with up to 100 kg N ha^{-1} alone or with Zn. Net returns were highest with applying 150 kg N + 25 kg Zn ha^{-1}.

Kumar and Singh (1996) reported that dipping the seedling roots in 2% $ZnSO_4$ solution gave higher yield (5.15 t ha^{-1}) almost similar to the application of 25 kg $ZnSO_4$ ha^{-1} compared to control.

Khanda and Dixit (1996) stated that application of Zn significantly increased the grain and straw yields over no Zn application. They stated that the appl ication of N and Zn increased the grain yield by 7. 2% and straw yield by 12. 9% over soil N.

Ramadass *et al.* (1995) in a few field trials in the Aman season of 1990-91 at Bhavanisagar, Tamil Nadu, and India with 10 rice cultivars using 0, 25 or 50 kg $ZnSO_4$ ha^1. They reported that grain yield increased with up to 25 kg $ZnSO_4$ ha^{-1}

Ram *et al.* (1995) reported that grain yield was obtained as 2.7 t ha^{-1} without applied Zn and 3.3-4.0 t ha^{-1} in the fertilizer treatments, with the highest yield given by 20 kg $ZnSO_4$ ha^{-1} application.

2.3 Combined effects of sulphur and zinc on growth and yield of rice

Quddus *et al.* (2012) conducted a field experiment on Chickpea-Mungbean-T. Aman cropping pattern at Pulses Research Sub-Station, Madaripur under Low Ganges River Floodplain Soils ($AEZ^{-1}2$) during 2007-08 and 2008-09 to find out the suitable fertilizer doses for this pattern. Four treatments were set up for each crop. For T. Aman, the treatments were T_1= Recommended fertilizer dose as per FRG, BARC (N66P7K12S6Zn1); T_2=Soil test based fertilizer dose (N130P14K76S6Zn1.5B1.0); T_3=Farmer practice (N90P10K15); and T_4=control. Experimental results revealed that among the treatments the highest seed and stover / straw yields of T. Aman (5414 $kgha^{-1}$ and 5615 $kgha^{-1}$) were recorded in treatment T_2. This treatment was significant at 5% level except seed yield of chickpea in 2008-09. T_3 treatment showed significant difference with T_4 treatment. The lowest seed and stover / straw yields of all the crops were recorded in control treatment (T_4). After completion of two years' pattern cycle, the organic matter, total nitrogen, phosphorus, sulphur, zinc, and boron were higher in treatment T_2.

Devi *et al.* (2012) studied the effect of sulphur and boron fertilization on yield, quality and nutrient uptake by soybean under upland condition. The experiment comprises five levels of sulphur (0, 10, 20, 30 and 40 kg sulphur per hectare) and five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg boron per hectare). The study revealed that yield attributing characters like number of branches per plant, pods per plant and 100 seed weight and yield were increased with the application of sulphur and boron as compare to control. The overall result revealed that application of 30 kg sulphur per hectare and 1.5 kg boron per hectare were found to be the optimum levels of sulphur and boron for obtaining maximum yield attributes, yield, oil and protein content, total uptake of sulphur and boron, net return, cost and benefit ratio of soybean under upland condition as compare to other levels of sulphur and boron respectively.

Bhuiyan *et al.* (2011b) conducted an experiment at BAU Farm, Mymensingh to investigate the effect of integrated use of organic and inorganic fertilizers on yield and nutrient uptake of T. Aus rice and mungbean in the Wheat-T. Aus/Mungbean-T.Aman cropping pattern. There were four treatments for wheat- T_1: Control, T_2: NPKSZnB (MYG), T_3: NPKSZnB (HYG) and T_4: NPKSZnB (MYG) + CD. The nutrient rates for four treatments of wheat were $N_0P_0K_0S_0Zn_0B_0$ kgha^{-1} for T_1, $N_{80}P_{20}K_{50}S_{10}Zn_1B_1$ kgha^{-1} for T_2, $N_{120}P_{30}K_{75}S_{15}Zn_2B_2$ kgha^{-1} for T_3 and $N_{80}P_{20}K_{50}S_{10}Zn_1B_1$ kgha^{-1} + CD (5 tha^{-1}) for T_4. In T. Aus/Mungbean one-third plot of each treatment was cultivated by T. Aus rice and the rest two-thirds plot by mungbean. The rates of N, P, K, and S for T. Aus rice were, respectively, 60, 12, 32 and 5 kgha^{-1} for MYG, and 90, 18, 48 and 7.5 kgha^{-1} for HYG. The results showed that grain (3.46 tha^{-1}) and straw yields (5.19 tha^{-1}) of T. Aus rice increased significantly due to application of fertilizers. The application of NPKS (HYG) fertilizers remarkably increased the crop yield.

Bhuiyan *et al.* (2011a) reported that the highest straw yields recorded in the 1st and 3rd year trials for NPKSZnB (HYG) were comparable with the straw yields for NPKSZnB (MYG) with and without cowdung, but in the second year trial, the straw yield was significantly higher for NPKSZnB (HYG) than for

NPKSZnB (MYG) with or without cowdung. The straw yield recorded with NPKSZnB (MYG) with cowdung was statistically identical to NPKSZnB (MYG) without cowdung. The grain and straw yield data revealed that significant yield improvement was achieved due to NPKSZnB fertilizers for HYG. The highest grain and straw yields of 3.13 and 6.66 tha^{-1} (mean of 3 years) showing 266 and 145% yield increase, respectively, over control were obtained with the application of NPKSZnB (HYG) fertilizers (T3). On the other hand, the lowest grain yield of 0.87 tha^{-1} and straw yield of 2.73 tha^{-1} were recorded in unfertilized control (T1) plots. Inclusion of cowdung with NPKSZnB for MYG contributed a little to the grain and straw yield increase (8.7% high grain and 2.8% high straw over NPKSZnB for MYG fertilizers).

Uddin *et al.* (2011) conducted a field experiment with BRRI dhan 29 at the Soil Science field laboratory, BAU, Mymensingh during the period from February to June 2007 to evaluate the effects of split application on the yield, nutrient content, and nutrient uptake of BRRI dhan 29. There were 9 treatments, such as control (NPSZn + K50), (NPSZn + K25 (FLP)) + K25 (SA), (NPSZn + K75 (FLP)), (NPSZn + K37.5 (FLP)) + K37.5 (SA), (NPSZn + K100 (FLP)), (NPSZn + K50 (FLP) + K50(SA)), (NPSZn + K125(FLP)), and (NPSZn + K62.5 (FLP) + K62.5 (SA)). The grain and straw yield was highly favoured by split application of potassium. The highest grain yield was 6.72 tha^{-1} and straw yield was 6.83 tha^{-1} in treatment (NPSZn + K37.5 (FLP) + K37.5 (SA)).

Kabir *et al.* (2011) conducted an experiment at BINA substation to investigate the effects of different combinations of inorganic fertilizers in order to achieve sustainable high yield goal in the STL-655 rice mutant cultivar. The six treatment combinations were: T_1 (absolute control), T_2 (N60 P20 K40 S10 Zn1), T_3 (N80 P25 K50 S15 Zn1.5), T_4 (N100 P30 K60 S20 Zn2), T_5 (N120 P35 K70 S25 Zn3) and T_6 (N140 P40 K80 S30 Zn4) that was laid out in RCBD with three replications having per plot size was 5m x 4m. The results revealed that grain and straw yields of STL-655 rice mutant responded significantly with the different treatment combinations. The highest grain (3.95 tha^{-1}) and straw yield (7.38 tha^{-1}) was obtained in T_6, which was significantly higher than all other treatments. The treatment T_6 caused an increase of 60% grain yield and 27% higher straw yield over the control.

Hasan *et al.* (2009) carried out a field experiment during the aman season of 2006 in silt loam soil of sonatala series at BAU firm, Mymensingh in order to see the effect of 29 years of fertilization and manuring on soil chemical properties and yields of 65^{th} crops (T-aman: BR 11) and nutrient uptake by rice. The result indicated that the continuous application of N, P, K, S and Zn fertilizers in different combinations for 29 years remarkably increased the grain and straw yield of T-aman, 2006.

The experiment was conducted at Bangladesh Agricultural Univ., Mymensingh farm during 2004 Boro season to evaluate the effect of S and Zn on rice (cv. BRRI dhan29) Rahman *et al.* (2008). There were seven treatments viz. S_0Zn_0, $S_{10}Zn_0$, $S_{20}Zn_0$, $S_0Zn_{1.5}$, S_0Zn_3, $S_{10}Zn_{1.5}$ and $S_{20}Zn_3$. The subscripts of S and Zn represent the dose in kg ha^{-1}. The highest grain (5.76 t ha^{-1}) and straw (7.32 t ha^{-1}) yields were recorded in the $S_{20}Zn_3$ treatment (100% recommended dose). The S_0Zn_0 (control) had the lowest grain yield with 4.35 t ha^{-1} as well as the lowest straw yield with 5.47 t ha^{-1}.

Bala and Hossain (2008) conducted an experiment at the field laboratory of the Dept. of Agronomy, Bangladesh Agril. Univ., Mymensingh to evaluate the effect of molybdenum (Mo) with recommenced chemical fertilizer and organic matter on yield and quality of rice cv. BRRI dhan 30. Three levels of Mo viz. 0, 100 and 200 ppm were applied with recommended dose of chemical fertilizers (80, 15, 40, 10, 1.5 kg ha^{-1} NPKSZn) and organic matter as both cow dung and compost. Number of total spikelets $panicle^{-1}$, grains $panicle^{-1}$, nitrogen content, nitrogen uptake in grain and straw, and protein content in grain were recorded better when 100 ppm Mo was applied with cowdung. Those parameters were minimum when 0 ppm Mo was applied with either cowdung or compost or NPK. The best performance was obtained when 100 ppm Mo was applied either with recommended fertilizers or with cow dung/compost. The performance of rice with 200 ppm of Mo was better than no addition of Mo in respect of yield and yield contributing characters.

Mythili *et al.* (2003b) conducted a greenhouse experiment to study the effect of green manuring with *Sesbania aculeata* and two Sources of Zn ($ZnSO_4$ and ZnEDTA at 5 kg Zn ha^{-1}) and S (gypsum at 50 kg ha^{-1}) on the yield and Zn and S uptake of rice grown on clay loam and sandy loam soils. NPK at 100: 50: 50 kg ha^{-1} respectively manuring resulted in the highest grain yield for both clay and sandy loam soils (46.8 and 39.4 g pot-$^{-1}$ respectively). The uptake of Zn and S significantly increased with green manure application in addition to improved soil fertility.

Mythili *et al.* (2003a) conducted a field experiment at Tamil Nadu Agricultural University, India. They stated that the effects of green manure (GM) and inorganic Zn and S fertilizer combinations on the yield of a short duration rice cultivar (ADT 36). NPK (100: 50: 50 N: P_20_5: K_20 kg ha^{-1}) respectively Zn as $ZnSO_4$ (5 kg Zn ha^{-1}) and S as gypsum (50 kg ha^{-1}) coupled with green manure produced the highest grain (5627 kg ha^{-1}) and straw (5723 kg ha^{-1}) yields.

Uddin *et al* (2002) conducted a field experiment to study the effects of S, Zn and B supplied from chemical fertilizers and poultry manure on yield and nutrient uptake by rice (cv. BRRI Dhan-30). There were ten treatments. The rate of different nutrients were 100 kg N ha^{-1} from urea, 30 kg P ha^{-1} from TSP, 60 kg K ha^{-1} from MP, 20 kg S ha^{-1} from gypsum, 2 kg Zn ha^{-1} from zinc oxide, 1 kg B ha^{-1} from borax and 4 t poultry manure ha^{-1}. Different nutrients significantly increased plant height, effective tillers hill-$^{-1}$, filled grains panicle"$^{-1}$, 1000 grain weight, grain and straw yields of rice. The highest grain yield of 4850 kg ha^{-1} was obtained when S, Zn and B were applied together with NPK fertilizers which was comparable to the yields obtained when S, Zn or B were applied singly or in combination of two with NPK fertilizers and also with the application of poultry manure with reduced NPK application.

Shukla and Lal (2002) reported that the present status of Indian soils indicates that the sulphur and zinc deficiency is increasing. Approximately 25 and 50% of the total cultivated area of the country are estimated to be affected by deficiency of sulphur and zinc, respectively.

Mandal and Halder (1998) conducted a pot experiment using rice cv. BR 11 with all combinations of 0, 4, 8 or 12 kg Zn $ha^{-1}$and 0, 5, or 20 kg S ha^{-1}. Addition of 8 kg Zn+ 20 kg S ha^{-1} gave the best performance in growth and yield of rice.

Islam *el al.* (1997) conducted field experiments on a slit loam soil (Aeric Haplaquept) to study the effect of S, Zn and B applications on autumn rice and their residual effects on the following mustard crop. They obtained the highest grain yield of 4.5 t ha^{-1} in S+ Zn+ B treatment with a record of 41.8% yield increase over control while the application of S alone brought 23.3 percent yield increase.

Hoque and Jahiruddin (1994) reported the effects of single and multiple applications of Zn and S in a continuous rice cropping system on loam soil were investigated at Mymensingh, Bangladesh. The treatments were S alone, Zn alone and S + Zn, each added to the first crop, 1^{st} and 2^{nd} crops or all 3 crops. The rate of S was 20 kg ha^{-1} (gypsum) and that of Zn was 10 kg ha^{-1}. Rice cv. BR3 was grown as the first and second crops (grown in boro season) and cv. BR 11 as the crop (grown in aman season). Crop yields were increased by S but not generally by Zn.

Khan *et al.* (1991) carried out an experiment with rice cv. BRIO on a saline, silty clay loam soil in Bangladesh. They found that grain yields 3.76-6.8, 1.76-2.27, and $0.94^{-1}.40$ t ha^{-1} using irrigation water of 1.9, 8, and 6 ds m-$^{-1}$, respectively. At each salinity level, application of gypsum (160 kg gypsum ha^{-1}) + Zn (5 kg Zn ha^{-1}) produced the highest yield.

2.4 Effects of S and Zn and their combination on nutrient content

This experiment was carried out in 2012 by Yadi and Dastan (2012) at Sari, Mazandaran, Iran. The highest Zinc content in grain, zinc uptake in grain and straw, and nitrogen uptake in grain were observed in 40 kg Zn ha, as the most zinc content in straw, nitrogen content in grain and straw, and nitrogen uptake in straw were observed with application of 40 and 20 kg Zn ha. The maximum zinc content in grain and straw and zinc uptake in straw was obtained for var. Sang Tarom, but the most zinc uptake in grain and nitrogen uptake in straw had produced for var. Neda and Shiroodi. The highest nitrogen content in grain and straw and nitrogen uptake in grain was obtained for var. Shiroodi. The most zinc content in grain and straw were produced at interaction of 40 kg Zn haand var. Sang Tarom and the highest nitrogen content in straw and nitrogen uptake in straw had produced under interaction of 20 kg Zn ha^{-1} and var. Shiroodi. So according to the results 20 and 40 kg Zn ha^{-1} was the best treatment.

Khan *et al.* (2012) carried out to study the effect of different levels of zinc (Zn) i.e. 0, 3, 6, 9, 12 and 15 kg Zn ha^{-1} on the rice genotype Sarshar evolved at NIA, Tandojam. The Zn concentration in soil, rice grain and straw increased significantly with an increase in Zn level, upto15 kg ha^{-1}. The highest N uptake in rice grain and straw were found where zinc was applied at rate of 9 kg Zn ha^{-1}. However, a decrease in P concentration was found with the application of zinc.

Jena and Kabi (2012) reported that the effect of gromor bentonite S pastilles and gypsum on yield and nutrient uptake by hybrid rice-potato-green gram cropping system. A dose of 60 kg S ha^{-1} were uptake of N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu by hybrid rice-potato-green gram system were increased significantly in S-treated soil. Among the three sources, gromor bentonite S pastille was found to be best source of S because of high concentration, slow release and minimum leaching loss.

Devi *et al.* (2012) studied the effect of sulphur and boron fertilization on yield, quality and nutrient uptake by soybean under upland condition. The experiment comprises five levels of sulphur (0, 10, 20, 30 and 40 kg sulphur per hectare) and five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg boron per hectare). The overall result revealed that application of 30 kg sulphur per hectare and 1.5 kg boron per hectare were found to be the optimum levels of sulphur and boron for obtaining maximum oil and protein content, total uptake of sulphur and boron, net return, cost and benefit ratio of soybean under upland condition as compare to other levels of sulphur and boron respectively.

Bhuiyan *et al.* (2011b) conducted an experiment to investigate the effect of integrated use of organic and inorganic fertilizers on yield and nutrient uptake of T. Aus rice and mungbean in the Wheat-T. Aus/Mungbean-T.Aman cropping pattern. The N, P, K, S, Zn, and B uptake by T.Aus/Mungbean remarkably increased with increasing supply of nutrients. The highest uptake of N, P, K, S, Zn, and B by the crops was noted in the treatment T_3 that received HYG fertilizers in T. Aus rice. The removal of N ranged from 27.3 to 63.2 kgha^{-1} and 29.8 to 48.1 kgha^{-1}, P from 5.62 to 15.80 kgha^{-1} and 2.60 to 4.69 kgha^{-1}, K from 35.8 to 71.8 kgha^{-1} and 21.9 to 37.4 kgha^{-1}, S from 4.08 to 10.26 kgha^{-1} and 2.12 to 4.11 kgha^{-1}, Zn from 44 to 132 gha^{-1} and 56 to 101 gha^{-1}, B from 17 to 70 gha^{-1} and 7 to 16 gha^{-1} by T. Aus rice and mungbean, respectively. Application of cowdung along with chemical fertilizers resulted in markedly higher uptake of nutrients. The lowest grain yield and the lowest nutrient uptake were noted in control plots receiving no fertilizer or manure.

Uddin *et al.* (2011) conducted a field experiment with BRRI dhan 29 at the Soil Science field laboratory, BAU, Mymensingh to evaluate the effects of split application on the yield, nutrient content, and nutrient uptake of BRRI dhan 29. Among the nine treatments, NPSZn + K37.5 (FLP) + K37.5 (SA) obtained the higher nutrient uptake (N, P, K, S, Zn) in grain and straw.

Kabir *et al.* (2011) conducted an experiment to investigate the effects of different combinations of inorganic fertilizers in order to achieve sustainable high yield goal in the STL-655 rice mutant cultivar. Nutrient uptake of N, P, K and S by grain of boro rice (STL-655 rice mutant) varied from 25.14 to 48.02, 5.40 to 8.14, 11.76 to 23.02 and 4.15 to 7.09 kgha^{-1}, respectively. The N, P, K and S uptake by straw of boro rice (STL-655 rice mutant) varied from 20.36 to 35.85, 5.47 to 11.05, 59.01 to 159.6 and 9.54 to 12.97 kgha^{-1}, respectively.

Veeranagappa *et al.* (2010) studied on the effect of zinc enriched compost on soil properties, yield and uptake of nutrients by rice (*Oryza sativa* L.). Among the treatment, NPK + Zn-E compost at 15 and 10 kg ha^{-1} noticed higher uptake of primary, secondary and micronutrients.

Sridevi *et al.* (2010a) investigated to study the effect of zinc-enriched organic manures. Uptake of nitrogen, phosphorus, potassium and zinc were found uniform trend with the highest uptake in the plots receiving recommended fertilizers along with 200 kg of FYM or cow dung enriched with 2.5 kg or 5.0 kg Zn as compared to control.

Sridevi *et al.* (2010b) conducted a field experiment on non-calcareous, zinc deficient clay loam soil (Typic Ustopept). Rice (variety ADT-45) was the test crop to study the effect of zinc-enriched organic manures. Uptake of nitrogen, phosphorus and potassium, and zinc uniform trend with the highest uptake in the plots receiving recommended fertilizers along with 200 kg of FYM or cow dung enriched with 2.5 or 5.0 kg Zn when compared to control.

Nemeno *et al.* (2010) studied to evaluate the effect of water management on grain Zn concentration and uptake. Results revealed that continuous flooding (W1) increased availability of nutrients brought about by shallow submergence of the soil as reflected on grain NPK uptake. In Alimodian, where inherent fertility status is lower, alternately wetting and drying (W2) resulted in increased NPK uptake and grain yield. IR72 was more sensitive to changes in water management and soil fertility status. Grain Zn concentration and uptake were also influenced by the ability of the soil to supply Zn, rice variety and water management.

Khan *et al.* (2010) studies were conducted for two consecutive years to assess the nutritional requirements of newly evolved rice genotype IR-6-25A. The experiment comprising of seven fertilizer treatments with N applied at 90, 120 and 150 kg ha^{-1} and P_2O_5 at 60, 90 and 120 kg ha^{-1} with or without 25 kg ha^{-1} $ZnSO_4$ (36.4% Zn), was laid out according to RCB design with four replications. Zinc concentration and uptake were significantly reduced due to increased P application; the reverse was true for P concentration and uptake. Dilution of Zn within plants occurred by increasing levels of N application.

Islam *et al.* (2010) investigated on the growth, yields and nutrients uptake of T-aman crops. There were also significant effect of the treatments on N, P, K, S, Mg, Zn, B, and Mo contents and their uptake by the crop. In rice crop, the highest nutrients uptake by both grain and straw was obtained from T_7 treatment and lowest from control. Secondary nutrients and micronutrients along with NPK fertilizer showed less response than those of organic amendments plus NPK fertilizers. The overall results express that organic amendments with NPK is essential to obtain satisfactory yield of T. aman in the experiment soil.

Swami and Shekhawat (2009) conducted an experiment in rice consisting of three moisture regimes (25, 50 and 75 mm irrigation) and four levels of zinc sulphate (0, 15, 30 and 45 kg ha^{-1}) replicated thrice under factorial randomized block design. The grain, straw yield and the uptake of N, P and K by rice increased significantly with increasing levels of zinc up to 30 kg $ZnSO_4$ ha^{-1}. The relative uptake of zinc was higher at the first level of 15 kg $ZnSO_4$ ha^{-1} rather than respective higher doses. A slight increase in the grain and straw yield of rice was observed with higher moisture regimes. The productivity and uptake of various nutrients by rice were highest at 30 kg $ZnSO_4$ ha^{-1} and 75 mm of irrigation.

Rahman *et al.* (2009) studied to know the effect of different levels of Sulphur on growth and yield of BRRI dhan 41. The treatments used in the experiment were

T_0 (without S), T_1 (50% RFD of S), T_2 (75% RED 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). The N, P, K, and S content and uptake by grain and straw were significantly influenced by the application of different levels of S. Generally, treatment T_6 performed the best result and T_0 did the worst. From the above study it can be summarized that BRRI dhan 41 responded to the application of higher levels up to 175% of the recommended dose of sulphur. This might be due to luxuriant uptake of S by rice.

Islam *et al.* (2009b) conducted an experiment to evaluate the effects of different rates and sources of sulphur on the yield, yield components, nutrient content and nutrient uptake of rice (cv. BRRI dhan30). The application of sulphur significantly increased N, P, K and S uptake.

Hasan *et al.* (2009) carried out a field experiment during the aman season of 2006 in silt loam soil of sonatala series at BAU firm, Mymensingh in order to see the effect of 29 years of fertilization and manuring on soil chemical properties and yields of 65^{th} crops (T-aman: BR 11) and nutrient uptake by rice. The soil pH was decreased from the initial status. The increase of N was almost 2.1 to 2.5 times higher than initial content in general the P content of soil decreased over the initial status. The concentration of P treated soil was also equal or below the initial content. A very strong decrease in exchangeable K+ amounting to almost 50% of initial level was found after 29 years. The status of S increased in soil when it was added but slightly decreased when it was not added. The N and P content in grain and straw were increased with the combined application of N, P, K, S and Zn. The content of S in grain and straw increased in case of S treated plot. The total uptake of N, P, K and S increased with the application of N, P, K, S and Zn in different combinations.

The experiment was conducted by Rahman *et al.*, 2007a on a Non-Calcareous Dark Gray Floodplain Soil (Sonatola series) of BAU farm, Mymensingh during Boro season of 2004. The soil was silt loam having pH 6.8, organic matter

1.62%, available S 9 ppm and available P 7.62 ppm. There were five treatments viz. T_0 (control), T_1 (10 kg Sha^{-1}), T_2 (20 kg Sha^{-1}), T_3 (40 kg Sha^{-1}) and T_4 (60 kg Sha^{-1}). The highest N, P, K and protein content was recorded from treatment T_2 (20 kg S ha^{-1}). On the other hand, the highest S, Ca and Mg content was recorded from treatment T4 (60 kg Sha^{-1}). However, the application of S fertilizer significantly increased protein, N, P, K, S, Ca and Mg content as well as their uptake over control. The S balance was positive where S was added as treatment combination. Negative S balance was recorded where no S was added (control).

Lar Oo *et al.* (2007) studied on the effect of N and S levels on productivity and nutrient uptake in aromatic rice. Various N and S levels had a significant effect on N, P, K and S uptake by grain, straw and their total. Based on the total N uptake (grain + straw) there was 49.9, 63.9 and 70.4% increase in the N uptake over the control with 50, 100 and 150 kg Nka, respectively. From this field study it can be concluded that aromatic rice requires 100 kg N and 20 kg Slhafor increased productivity and uptake of N, P, K and S, under transplanted puddled condition.

Rahman *et al.* (2006) studied to evaluate the necessity of Zinc for the growth and yield of rice (IRRI-11) grown on a loamy soil. Zinc was applied at the rate of 0, 2, 4, 8 and 16 kg Zn ha^{-1}. Zn at 2.0 kg ha^{-1} uptake the N, P and K nutrients (198, 33, 238 mg, respectively) and increased the straw and grain productions over control were recorded as 144 and 149 per cent, respectively by the rice plants.

A field experiment was observed by Virendra Dixit *et al.* (2006) to study the individual and interactive effect of S and Zn on yield and uptake of nutrients by hybrid rice. Application of 60 kg S ha^{-1} recorded significantly higher grain and straw yield and sulphur uptake. Similarly significant response of rice to Zn addition was recorded upto 15 kg^{-1}. Increase in S and Zn levels increased significantly their uptake by rice crop. The interaction of S and Zn was non significant and the highest grain and straw yield were recorded with the combined application of 60 kg S and 15 kg Zno ha^{-1}. Nitrogen and phosphorus uptake in crop increased significantly with S and Zn additions in all treatments.

Fluda *et al.* (2004) conducted an experiment at the Soil Science Department of Bangladesh Agricultural University, Mymensingh, to evaluate the suitable extractants for available sulphur and critical limits of sulphur for wetland rice soils of Bangladesh.

Jadhav *et al.* (2003) studied the effect of Zn fertilizer with or without farmyard manure (FYM) on the performance of rice cv. Ratnagiri grown on lateritie soil in Konkan, Maharashtra, India. They considered the treatment consisted of NPK (recommended rate of 100: 50: 50 kg ha^{-1}), NPK + Zn at 15, 30 or 45 kg ha^{-1}, NPK+FYM (10 t ha^{-1}) and NPK+ FYM+ Zn at 15, 30 or 45 kg ha^{-1}. They also found that, the application of NPK+ FYM+ Zn at 30 kg ha^{-1} resulted in the highest total N (97.10 kg ha) and P uptake (12.0 kg ha^{-1}), whereas NPK+ Zn at 15 kg ha^{-1} gave the highest total K uptake (128.2 kg ha^{-1}.

Uddin *et al* (2002) conducted a field experiment to study the effects of S, Zn and B supplied from chemical fertilizers and poultry manure on yield and nutrient uptake by rice (cv. BRRI Dhan-30). The concentrations and uptake of N, P, K and S by grain and straw were higher when poultry manure was used as a source of 5, Zn and B with reduced amount of NPK. It appeared that application of S, Zn and B along with NPK was essential in this soil to get the maximum yield of BRRI dhan 30. If poultry manure can be applied at 4 tha^{-1} the use of NPK can be reduced and S, Zn and B fertilizers may not be needed.

Singh and Singh (2002) carried out a field experiment to see the effect of different nitrogen levels (50, 100 and 150 kg ha^{1}) and S levels (0, 20 and 40 kg ha^{1}) on rice cv. Swarna and $PR^{-1}08$ in Varanasi, Uttar Pradesh. India. They reported that total N uptake, grain, straw and grain protein yields significantly improved with the increasing level of N and S application being the maximum at 150 kg N ha^{-1} and 40 kg S, respectively.

Peng *et al.* (2002) carried out a field experiment where 116 soil samples were collected from cultivated soils in Southeast Fujian, China. The average content of available S in these soil samples was 21.7 mg kg^{-1}. The soil with available 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 of rice plant.

Mythili *et al.* (2002) conducted a greenhouse experiment to investigate the effect of green manure on the relatively efficiency of applied Zn. Radio-tracer viz., ^{65}Zn was tagged to two sources of Zn ($ZnSO_4$ and EDTA-Zn at 5 kg Zn ha) to determine the contribution of fertilizer sources. The beneficial effect of integrated use of green- manure (GM) with inorganic fertilizer nutrients particularly, ZnSO4 in clay loam and EDTA-Zn in sandy loam soil was evident due to higher uptake and increased dry matter yield obtained at harvest NPK + gypsum+ GM+ ZnSO4 application recorded the highest grain, straw and root yields in both the soils. The highest total Zn uptake of 3.87 mg pot ha-1 with NPK+ gypsuni+ GM +ZnSO4 application and greater percentage of fertilizer Zn derivation was observed with NPK+$ZnSO_4$ (86.20%) followed by NPK+EDTA-Zn alone.

Dunn *et al.* (2002) conducted an experiment on the effect of soil pH and Zn on rice cv. Cypress, Kaybonnel and Drew on a Crowley slit loam soil (fine, montmorillonite, thermie Typic Albaqualf) at Qulin, Missouri, USA. Their experiment was split-plot; main plots continued rice cultivars, subplots had annual applications of lime and Zn treatments were untreated, soil applied Zn as $ZnSO_4$, and foliar applied Zn as Zn-EDTA chelate. After two years, they found that, lime application increase soil pH from 6.01 to 7.2. They stated that soil pH had a significant effect on the extractable Zn following two years of applying $ZnSO_4$ fertilizer but soil pH did not significantly affect plant Zn concentrations. They concluded that soil applied Zn fertilizer increased Zn concentrations in plant tissue more than foliar Zn.

Vaiyapuri and Sriramachandrasekharan (2001) conducted an experiment on integrated use of green manure (12.5 t ha) with graded levels of sulphur (0, 20 and 40 kg ha) 9 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) and soil available nutrients (199.5, 13.4, 299.1, 22.8 kg ha^{-1} for N, P, K and S, respectively) were noticed with 40 $kgha^{-1}$ in Tamil Nadu, India. Among the sources, iron pyrite recorded the maximum uptake (111.6, 26.2, 215.4, 22.7 kg ha^{-1} for N, P, K and S respectively) and rice yield (4.97 t ha^{-1}).

Sakal *et al.* (2001) conducted field experiments in Bihar, India to determine the direct effect of soil (Ustifluvents) applied with Sulphur (S) on succeeding wheat and rice crops. Sulphur was applied at 0, 15, 30 and 45 kg S h''^{-1} a as single super phosphate containing 12% S, and rice cv. Rajshree was grown as a test crop. A basal dose of 110 kg N, 60 kg P_20_5 and 5 kg Zn ha^{-1} was applied as urea, DAP (diammonium phosphate), MOP (muriate of potash) and ZnO respectively. Rice leaf sample analysis exhibited higher magnitude of S deficiency than wheat leaf samples. Magnitude of S deficiency based on soil analysis was on an average 25% while the extent of S deficiency based on plant analysis was 58%. Direct effect of S produced the maximum grain yield of rice (14.3 q ha^{-1} at 45 kg S ha^{-1}). Sulphur intake by crops increased progressively with increasing levels of sulphur

Mythili *et al.* (2001) conducted a greenhouse experiment at the Tamil Nadu Agricultural University, India on soils, which are both deficient in S and Zn using rice as the test crop to investigate the effect of green manure *(Sesbania aculeata)* on soil S and Zn availability. The 11 treatments were used as control (T1), NPK (T2), NPK+GM (T3), NPK+ $ZnSO_4$ (T_5), NPK+

EDTA-Zn (T6), NPK + gypsum (TA NPK+ GM+ $ZnSO_4$ (T8), NPK + EDTA-Zn + GM (T_9), NPK + gypsum + GM (T_{10}) and NPK + gypsum + GM + $ZnSO_4$ (T11) GM application in sandy loam soil showed higher availability of DPTA-Zn, particularly with EDTA-Zn than in clay loam soil. T_9 enhanced the availability of Zn at active tillering stage (AT) (2.91 mg kg^{-1}), panicle initiation (PI) stage (3.60 mg kg^{-1}) and harvest stages (2.80 mg kg^{-1}) followed by T_{11}. The highest Sulphur availability was obtained with T_{11} at (21.38 mg kg ^{1}) and PI (20.13 mg .kg ^{1}) and with T_{11} at harvest stages (26.38m g kg ^{1}).

Wani *et al.* (2000) carried out a field experiment during Aman season 1995 in India with rice given 0, 10, 20, 30, 40, or 50 kg S ha^{-1}. Grain contents of crude protein, methionine and cystine increased with increasing S rates up to 40 kg ha^{-1} and then decreased slightly.

Mandal *et al.* (2000) carried out a greenhouse experiment to evaluate the effect of N and S fertilizers on nutrient content of rice grain (cv. BR 3) at various growth stages (tillering, flowering and harvesting). Nitrogen was applied as urea and S as gypsum at 0, 5, 10, and 20 kg S ha^{-1}. The combined application of these elements increased the straw and grain yield of rice significantly.

Singh *et al.* (1999) carried out a long term experiment to study the effect of decade long fertilizer and manurial treatments on soil pH, fertility and productivity of a rice cropping system in a Mollisol. The treatment included various combinations of N, P. K, Zn and FYM. After 10 years of continuous intensive cropping under various fertilizer and manurial treatments, the differences in the values of soil pH, organic matter, available P. K, S, B, M_O and DTPA extractable micronutrient contents in soil at 20 cm depth and crop productivity were found to be statistically significant.

Ram *et al.* (1999) studied the effect of 2 sources (pyrite and gypsum) and 4 levels of S application (0, 30, 60, and 90 kg ha^{-1}) on growth, yield, S use efficiency and S uptake in rice in a reclaimed salt affected soil in Uttar

Pradesh, India. Application of S at 90 kg ha^{-1} gave the highest yield, which was significantly the highest than obtained with application of 30 kg S ha^{-1}.

Zinc content of the lithosphere is about 80 mg kg^{-1}. The total Zn content in soils ranges from 10 to 300 mg kg^{-1}, the average being 50 mg kg^{-1} (Tisdale *et al.,* 1997). Not all Zn are available to plants, less than 10% is plant available Zn. In Bangladesh, the Zn deficiency is widespread and it is particularly evident in calcareous and wetland rice soils.

Trivedi and Verma (1997) carried out field trials in the 1992 and 1993 seasons; rice cv. Java and BR11 were given 0, 5, 11.2, or 16.8 kg Zn ha^{1}. The experimental soil was low in DTPA extractable Zn (0.06 mg kg^{-1}) with pH of 7.9. Applied Zn increased crop yield and Zn uptake, with quadratic relationships with application rate.

Plants absorb zinc in the form of Zn^{2+}. The normal concentration of Zn in dry matter of plant ranges from 25 to 150 ppm. Deficiencies are usually associated with leaf concentrations less than 20 ppm and toxicities will occur when Zn leaf concentration exceeds 400 ppm. Zinc deficiencies are widespread through out the world; especially in the rice land of Asia deficiencies occur in neutral and calcareous soils (Tisdale *et al.* 1997).

Khan *et al.* (1996) observed that the combined application of gypsum and Zn at the rates of 16 and 5 kg ha^{-1} respectively produced 49, 45 and 41% more grain yields above control at 0.6, 8 and 16 m mhos cm^{-1} levels of salinity, respectively. They further noted that combined application of gypsum and Zn was effective in increasing protein concentrations in rice grains and total concentrations of Ca, Mg and K in plant tissue.

Zia *et al.* (1995) concluded form the studies on the S status of soils under rice based cropping sequences that out of 39 soil samples from rice growing areas in the district of Sheikhupura, Pakistan, none were deficient in S. At a constant level of N application, S concentration and its uptake were higher with ammonium sulphate than with urea. The study showed possible response of rice to S application even the native S status of the soil was well above the critical level.

Total S status of soils varied between 23.1 and 369.3 mg kg^{-1} soils (Singh *et al.* 1995). Total S in mineral soils may range from <20 mg kg^{-1} in sandy soils to >600 mg kg^{-1} in heavy textured soils. Organic soils may contain as much as 0.5% S.

Chapter III
Materials and Methods

CHAPTER III
MATERIALS AND METHODOLOGY

This chapter describes the experimental aspects of the study. The experiment was conducted at Sher-e-Bangla Agricultural University farm with (BRRIdhan 40) under some selected treatments. Chemical analysis of soil and plant (grain, straw and soil) was carried out in the Agricultural Chemistry Laboratory, Sher-e-Bangla Agricultural University, Dhaka. This section for convenience of presentation has been divided into various sub-sections such as site and soil, climate, crop and variety, land preparation, experimental design, treatments, fertilizer application, sowing and transplanting, intercultural operations, harvesting and threshing, data collection, soil analysis, plant analysis and statistical analysis.

3.1 Experimental site

The present research work was conducted at the south west corner of the main farm of Sher-e-Bangla Agricultural University, Dhaka during the period from July-May, 2012. The experimental area is located at 23.41^0 N and 90.22^0 E latitude and at an altitude of 8.6 m from the sea level.

3.2 Soil

The soil of the experimental field was silt loam in texture belonging to the agro-ecological zone of the Madhupur Tract (AEZ-28). The selected plot was medium high land that remained fallow during the previous summer. The physical and chemical characteristics of the soil were determined at the Agricultural Chemistry Laboratory. Sher-e-Bangla Agricultural University, Dhaka. The characteristics of the soil are shown in Table 3.1.

Table 3.1 Morphological, physical and mechanical characteristics of the soil of the experimental area.

a) Morphological characteristics

Locality	South-west corner of the Farm Building, Sher-e-Bangla Agricultural University
Soil series	Tejgaon Series
General Soil type	Calcarious Dark Grey Flood Plain
Physiographic unit	Madhupur Tract
Topography	Medium High Land
Drainage	Adequate
Flood level	Above flood level
Climate	Humid, Sub-tropical
Vegetation	Cropped with rice, pulse, mustard and other vegetation

b) Physical characteristics

Depth in cm	Description
0-15 cm	The soil is soft and feels floury. It appears cloddy but readily broken. The soil is light brownish in color when pulverized. The soil is light brownish in color when wet, it shows finger print when pressed with thumb.

c) Mechanical composition of soil

Constitutents	**Percent**
Sand	30.56
Silt	37.26
Clay	32.15
Textural class	Silt loam

d) pH and chemical composition of the soil

Parameters	Content
pH	5.65
Organic carbon (%)	0.75
Organic matter (%)	1.18
Total N (%)	0.032
Available P (μg g^{-1})	19.85
Exchangeable K (me $100g^{-1}$ soil)	0.12
Exchangeable Ca (me $100g^{-1}$ soil)	5.03
Excangeable Mg (me $100g^{-1}$ soil)	2.32
Available S (μg g^{-1})	16
Available B (μg g^{-1})	0.013
Available Zn (μg g^{-1})	0.8

3.3 Climate and weather

The experimental area is situated in the sub-tropical climate zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year (Biswas, 1987). The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The detailed meteorological data in respect of air temperature, relative humidity, total rainfall and soil temperature recorded by the National Meteorological Research Centre, Dhaka during the period of study have been presented in Appendix III.

3.4 Planting materials

One cultivars of T-aman rice cv. BRRI Dhan 40 were selected as plant materials for this study which was collected and released from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur- 1701.

3.5 Experimental materials

The experimental materials consisted with two factors i.e. sulphur and zinc which is presented as follows

i. **Factor A: Sulphur (S)**

S_0 : 0 kg S ha^{-1}
S8 : 8 kg S ha^{-1}
S_{12} : 12 kg S ha^{-1}
S_{16} : 16 kg S ha^{-1}

ii. **Factor B: Zinc (Zn)**

Zn_0 : 0 kg Zn ha^{-1}
$Zn_{1.0}$: 1 kg Zn ha^{-1}
$Zn_{1.5}$: 1.5 kg Zn ha^{-1}
$Zn_{2.0}$: 2.0 kg Zn ha^{-1}

So, the treatments combinations are as follows

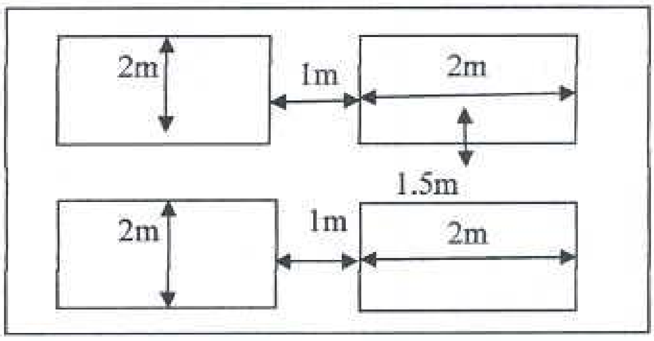
$S_0\times Zn_0$: 0 kg ha^{-1} × 0 kg ha^{-1}
$S_0\times Zn_1$: 0 kg ha^{-1} × 1.0 kg ha^{-1}
$S_0\times Zn_{1.5}$: 0 kg ha^{-1} × 1.5 kg ha^{-1}
$S_0\times Zn_2$: 0 kg ha^{-1} × 2.0 kg ha^{-1}
$S_8\times Zn_0$: 8 kg ha^{-1} × 0 kg ha^{-1}
$S_8\times Zn_{1.0}$: 8 kg ha^{-1} × 1.0 kg ha^{-1}
$S_8\times Zn_{1.5}$: 8 kg ha^{-1} × 1.5 kg ha^{-1}
$S_8\times Zn_{2.0}$: 8 kg ha^{-1} × 2.0 kg ha^{-1}
$S_{12}\times Zn_0$: 12 kg ha^{-1} × 0 kg ha^{-1}
$S_{12}\times Zn_{1.0}$: 12 kg ha^{-1} × 1.0 kg ha^{-1}
$S_{12}\times Zn_{1.5}$: 12 kg ha^{-1} × 1.5 kg ha^{-1}
$S_{12}\times Zn_{2.0}$: 12 kg ha^{-1} × 2.0 kg ha^{-1}
$S_{16}\times Zn_0$: 16 kg ha^{-1} × 0 kg ha^{-1}
$S_{16}\times Zn_{1.0}$: 16 kg ha^{-1} × 1.0 kg ha^{-1}
$S_{16}\times Zn_{1.5}$: 16 kg ha^{-1} × 1.5 kg ha^{-1}
$S_{16}\times Zn_{2.0}$: 16 kg ha^{-1} × 2.0 kg ha^{-1}

3.6 Experimental design and layout

The experimental was laid out in a Randomized Completely Block Design (RCBD) with three replications having 16 treatment combinations. Thus the total number of unit plots was 48. The size of unit plot was 4 m^2 (2 m × 2 m). The plot to plot distance was 1 m and between block was 1 m. The treatments were randomly distributed to the plots within block with proper fertilization. The bunds around individual plots were sufficiently strong to control water movement between plots. A drain of 1 m wide was provided around the whole experimental plot and between the blocks.

The complete lay-out of the experiment has been presented in Figure 3.1

Total length = 17 m
Total width = 21 m
Total area = 360 m^2
Distance between two blocks = 1 m
Distance between two plots = 1.5 m
Plot size = 2m × 2m



R_1	S_0Zn_1	S_0 Zn_0	S_{16} Zn_0	S_{16} $Zn_{1.5}$	S_8 $Zn_{1.5}$	S_8 Zn_0	S_0 $Zn_{1.5}$	S_{16} Zn_1
	S_{16} Zn_3	S_8 Zn_1	S_{12} $Zn_{1.5}$	S_{12} Zn_1	S_{12} Zn_3	S_8 Zn_3	S_0 Zn_3	S_{12} Zn_0
R_2	S_8 Zn_0	S_0 Zn_1	S_0 Zn_0	S_{12} Zn_3	S_{16} Zn_1	S_0 $Zn_{1.5}$	S_8 Zn_3	$S_{12}Zn_1$
	S_{12} Zn_0	S_{16} $Zn_{1.5}$	S_8 Zn_1	S_{16} Zn_0	S_{12} $Zn_{1.5}$	S_8 $Zn_{1.5}$	S_{16} Zn_3	S_0 Zn_3
R_3	$S_{16}Zn_0$	S_0 Zn_3	S_8 Zn_3	S_0 Zn_1	S_{12} Zn_1	S_{16} $Zn_{1.5}$	S_8 Zn_0	S_8 $Zn_{1.5}$
	S_0 $Zn_{1.5}$	S_{16} Zn_3	S_{16} Zn_1	S_{12} Zn_0	S_0 Zn_0	$S_{12}Zn_{1.5}$	S_8 Zn_1	S_{12} Zn_3

Figure 3.1 Layout of the experiment

3.7 Land preparation

Power tiller was used for the preparation of the experimental field. Then it was exposed to the sunshine for 5/6 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed and deep ploughing was obtained good tilth, which was necessary to get better yield of this crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field. The plots were spaded one day before planting and the whole amount of fertilizers were incorporated thoroughly befor planting according to fertilizer recommendation guide (BARC, 1997). The soil was treated with insecticides at the time of final ploughing. Insecticides Furadan 5G was used @ 8 kg ha^{-1} to protect young plants from the attack of mole cricket, ants, and cutworms.

3.8 Fertilizers

Sulphur and zinc fertilizers were applied to each plot as per treatments. Fertilizer such as urea, TSP, MoP, Gypsum and $ZnSO_4$ were used as source for N, P, K, S, and Zn, respectively. Sulphur and zinc required for each unit plot were calculated from the rate of application as per treatments. Among the other fertilizer, one-third of urea, MoP and the entire required amounts of other fertilizers were applied as basal to the individual plots during final land preparation. The fertilizers were incorporated into soil by spading. The second split of urea and MoP was applied at maximum tillering stage and the remaining split at panicle initiations stage.

All treatments had received N, P, and K at recommended rate in order to support normal plant growth. The rates and sources of different nutrients used in this experiment are given in below

Nutrient elements, their sources, and doses used in the experiment

Nutrient element	Source	Rate(Kg/ha)
Sulphur	Gypsum	0,12,16, 20
Zinc	$ZnSO_4$	0,1, 2
Nitrogen	Urea	120
Phosphorus	TSP	20
Potassium	MoP	50

Source: BARC 1997 (Fertilizer Recommended Guide)

3.9 Sowing and transplanting

A well-puddled land was selected for the raising of seedlings. The sprouted seeds of rice were sown in the seedbed on July 2011. Adequate care of the seedlings was taken. The 30 days old seedlings were uprooted carefully from the seedbed in the morning and transplanted on the same day. After satisfactory land preparation followed by layout of the experimental field, the rice seedling were transplanted in the plots on July15, 2007. Three seedlings were placed in each hill with a spacing of 15 cm × 20cm.

3.10 Intercultural operations

During growing period of the crop, all necessary cares were done for ensuring and maintaining the normal growth and development of the crop. The following intercultural operations were done.

3.10.1 Weeding

The experimental plots were infested with some common weeds, which were removed twice by uprooting.

3.10.2 Irrigation

The experiment was conducted during wet season and so, irrigation was not needed frequently. The plots were irrigated (3-4) times so as to maintain the requisite soil moisture for optimum growth of the plants. About 5-6 cm water height was maintained in the plots up to the milk stage of rice plant. Excess water was drained out when the grains reached hard drough stage.

3.10.3 Disease and pest management

The research field looked nice with normal green plants. Field was observed time to time to detect visual difference among the treatments and any kind of infestation. The field was infested by rice stem borer, which was controlled by spraying Furadan 3G on 15 August 2011.

3.11 Harvesting and threshing

The crop was harvested at maturity on 24 November, 2011 for data collection when about 80% of the grains attained maturity. The morphological, growth and yield attributes crop sampling was done after harvest. Data were recorded on ten hills were randomly selected from each plot of the middle portion of each plot for average results. The harvested plants of each treatment were brought to the cleaned threshing floor and separated grains from plants by hand and allowed them for drying well under bright sunlight. Grain and straw yield were recorded separately plot wise and expressed at t ha^{-1} on sun-dry basis. Dry weight for both grain and straw were also recorded.

3.12 Data collection

The data on the following yields contributing characters of the crop were recorded as follows:

3.12.1 Plant height (cm)

The height of the plant in cm was measured from the ground level to the top of the panicle. From each plot, plants of ten hills were measured and averaged.

3.12.2 Number of tillers/hill

Ten tillers were taken at random from each plot. The number of tillers $hill^{-1}$ was counted. The numbers of effective and non effective tillers $hill^{-1}$ were also determined.

3.12.3 Panicle length (cm)

Panicle length in cm was measured from basal node of the rachis to apex of each panicle. Each observation was an average of 10 hills.

3.12.4 Number of grains per panicle

Ten panicles were taken at random and the unfilled and filled grain panicle^{-1} was counted and their total was also counted.

3.12.5 1000-grain weight

The weight of 1000 grains from each plot was taken after sun drying by an electrical balance and expressed in g.

3.12.6 Grain yield

After harvesting of the crop, grain yield from each unit plot was dried and weighed. The result was expressed as t ha^{-1} on 12%moisture basis.

3.12.7 Straw yield

After harvesting the crop, straw yield from each unit plot was dried and weighted. The result was expressed as t ha^{-1}.

3.13 Chemical analysis of soil sample

3.13.1 Collection and preparation of soil samples

Soil samples from the experimental field before the start of the experiment were collected from 10 different random spots from a depth of 0-15 cm. the soil samples were mixed thoroughly to make a composite sample and the unwanted materials such as stubbles, stones, weeds, etc. were removed from soil. The soil samples were air-dried, ground, and sieved through a 2-mm (10 mesh) sieve. The composite sample was stored in a clean container for physical and chemical analysis.

3.13.2 Analysis of the soil sample

Soil samples were analyzed were both physical and chemical properties in the laboratory of the dept. of soil Science. SAU Dhaka The properties studied included soil texture, pH, organic matter, total N, available S and Zn content The physical and chemical properties of initial soil have been presented in table 3.1 The soil was analyzed following standard nethod.

3.13.3 Mechanical analysis

Mechanical analysis was done by hydrometer method (Bouyoucos, 1951). The textural class was determined by plotting the values for % Sand, % silt and % clay to the "Marshall's Textural Triangular coordinate" following the SDA system.

3.13.4 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the -water ratio being 1:2.5. as described by Jackson (1962).

3.13.5 Organic matter content

Organic carbon in soil was determined by wet oxidation method of Walkley and Black (1934). The amount of organic matter was calculated by reptiplying the percent organic carbon with the van Bemmelen factor, 1.73 .The result was expressed in percentage.

3.13.6 Total nitrogen

Total N content of soil was determined by Kjeldahi method where the soil sample was digested with 30%H_2O_2,conc. H_2SO_4 and catalyst mixture (K_2SO_4 : $CuSO_4.5H_2O$: Se powder in the ratio of 10:1:0.1). Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.01 N H_2SO_4 (Page *et al.,* 1982).

3.13.7 Available phosphorous

Available P content was extracted from soil with 0.5 M $NaHCO_3$ solution at a pH 8.5 (Olsen *et al.,* 1954). The P in the extract was then determined by developing blue color with $SnCl_2$ reduction of phosphomolybdate complex and measuring the colour by spectrometer at 660 nm wavelengths (Page *et al.,* 1982)

3.13.8 Exchangeable potassium

Exchangeable K was determined by extraction with I M NH_4OAc, pH 7.0 solution followed by measurement of extractable K by flam photometer and Ca and Mg by atomic absorption spectrophotometer (Black, 1965).

3.13.9 Available sulphur

Available S content in soil was determined by extracting soil sample with $CaCl_2$ (0.15%) solution as described by Page *et al.* (1982). The S content in the extract was determined turbidimeterically and the turbid was measured by spectrometer at 420 nm wavelength.

3.13.10 Available zinc

Available Zn content in soil was extracted by DTPA extraction method as described by Hunter (1984). The concentration of the element in the extract was determined by atomic absorption spectrophotometer.

3.14 Chemical analysis of plant samples

3.14.1 Preparation of plant sample

The plant samples were dried in an oven at 60°C for about 48 hours and then ground by a grinding machine. The ground plant materials were stored in paper bags in desiccators. The grain and straw samples were analyzed for determination of N, S and Zn concentration. The methods were as follows:

3.14.2 Digestion of plant samples with nitric-perchloric acid

A sub-sample weighing 0.5 g was transferred into a dry, clean 100 mL kjeldahl flask. A 10 mL of diacid mixture ($HN0_3$:$HClO_4$ in the ratio 2:1) was added. After leaving for while, the flask was heated at a temperature slowly raised to 200°C. Heating was momentarily stopped when the dense white fumes of $HClO_4$ occurred. The contents of the flask were boiled until they became clean and colorless. Elements like P, K, S and Zn were determined from the digest.

3.14.3 Digestion of plant samples with sulphuric acid

An amount of 100 mg oven dry, ground samples was taken in a 100 mL Kjeldhal flask. Into the flask, 1.0 g catalyst mixture (K_2SO_4:$CuSO_4.5H_20$: Se =10:1:0.1), 2 ml 30% H_20_2 and 3mL conc. H_2SO_4 were added. The flask was swirled and allowed to stand for about 10 minutes, followed by heating at 200°C. Heating was continued until the digest was clear and colorless. After cooling, the contents were taken into a 100 mL volumetric flask and the volume was made with distilled water. This digestion was used for N determination exclusively.

3.15 Determination of elements

Nitrogen content: The N concentration in the digest was determined by distillation with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.01N H_2SO_4 (Page *et al.,* 1982).

3.15.1 Sulphur content

The concentration in the digest was determined by developing turbidity with a spectrophotometer using 420 nm wavelength.

3.15.2 Zinc content

The Zn concentration in the digest was measured directly by an atomic absorption spectrophotometer.

3.16 Statistical analysis

The data obtained from experiment on various parameters were statistically analyzed in MSTAT-C computer program by Completely Randomized Block Design (RCBD) (Russel, 1986). The analysis of variance for various crop characters and also for nutrient concentration and uptake were done following the principle of F-statistics. The mean values for all the parameters were calculated and the analysis of variance for the characters was accomplished by Duncan's Multiple Range Test (DMRT) and the significance of difference between pair of means was tested by the Least Significant Differences (LSD) test at 5 % levels of probability (Gomez and Gomez, 1984).

Chapter IV
Results and Discussion

CHAPTER IV
RESULTS AND DISCUSSION

The present experiment was conducted to determine the effect of different levels of Sulphur (S) and Zinc (Zn) on the yield and yields contributing characters of T. aman rice cv. BRRI Dhan 40 as well as the nutrient content by grain and straw. Data on different characters were also recorded and analyzed due to the effects of Sulphur and Zinc on T. aman rice. The results have been presented and discussed, and possible interpretations are given under the following headings.

4.1 Yield and yield contributing character of rice

Yield and yield contributing characters such as plant height (cm), number of effective/ non effective and total tillers hill^{-1}, panicle length (cm), filled, and total grains panicle^{-1}, 1000-grains weight (g), grain yield (t ha^{-1}) and straw yield (t ha^{-1}) were recorded at the time of harvest and their detailed results were described under the following sub-headings.

4.1.1 Plant height (cm)

Plant height differed significantly due to the application of different level of S in T. aman rice (Appendix II and Fig. 1). The tallest plant (119.10 cm) was recorded in S_{12} (12 kg S ha^{-1}) which was differed significantly among the other treatments of S. The shortest plant (95.78 cm) was recorded in S_0 treatment .

Statistically significant difference was also recorded due to the application of different levels of Zn in respect of plant height (Appendix II and Fig. 2). The maximum plant height (114.10 cm) was found in $Zn_{1.5}$. On the other hand, the plant of untreated plots gave the shortest plant (103.60 cm) at harvest (Table 4.1). With increasing level of zinc plant height also increased. Khan *et al.* (2012) reported similar result where plant height showed increasing trend up to 3 kg Zn ha^{-1}.

Combined effect between S and Zn found to be the significant in consideration of plant height (Appendix II and Table 4.1). The tallest plant (124.0 cm) was recorded in the treatment combination of $S_{12}Zn_{1.5}$ which was significantly different from other treatments combinations. Treatment $S_{12}Zn_2$ produced the second tallest plant (120.30 cm) which was followed by the treatment combinations of $S_{16}Zn_{1.5}$ (119.70 cm) and it was statistically identical (118.0 cm) with the treatment combinations of $S_{12}Zn_{1.0}$. In contrast, the shortest plant (92.38 cm) was recorded in control(Table 4.1).

4.1.2 Number of effective tillers hill^{-1}

Number of effective tillers hill^{-1} was significantly influenced by the application of different levels of S in T-aman rice in relation of number of effective tillers hill^{-1} (Appendix II and Table 4.1). Among the treatments, S_{12} noticed the maximum number of effective tillers hill^{-1} (19.00) comparison with S_8 16.83 number of effective tillers hill^{-1} and S_{16} (15.83 number of effective tillers hill^{-1}) . However, control treatment recorded the minimum number of effective tillers hill^{-1}(14.00). Islam *et al.* (2009) also reported the similar results. They observed that the effective tillers hill^{-1} was significantly influenced due to application of S where S_{16} recorded the maximum effective tillers hill^{-1}.

Different levels of Zinc also showed significant variation in respect of number of effective tillers hill^{-1} (Appendix II and Table4.1). Among the Zn treatments, the maximum number of effective tillers hill^{-1} (18.75) was recorded in $Zn_{1.5}$ treatment (17.25 number of effective tillers hill^{-1}), $Zn_{1.0}$ treatment (15.67 number of effective tillers hill^{-1}) and control treatment (14.00 number of effective tillers hill^{-1}) where control treatment produce the lower number of effective tillers hill^{-1} . Similar trend was also observed by Khan *et al.* (2012) who reported that productive tillers per hill showed increasing trend up to 9 kg Zn ha^{-1}. The highest average productive tillers per plant (16) was recorded at 120 kg N and 90 kg P_2O_5 along with 9 kg Zn ha^{-1}.

Interaction effect between S and Zn was significantly influenced on the production of number of effective tillers $hill^{-1}$ (Appendix II and Table4.1). Among the treatments, the maximum number of effective tiller $hill^{-1}$ (22.67) was recorded in the treatment combination of $S_{12}Zn_{1.5}$ followed by $S_{12}Zn_{2.0}$ (20.00 number of effective tillers $hill^{-1}$) while the minimum number of effective tillers $hill^{-1}$ (12.33) was recorded in the control treatment (S_0Zn_0).

4.1.3 Number of total tillers $hill^{-1}$

Different levels of sulphur in T. aman rice varied significantly in respect of number of total tiller $hill^{-1}$ (Appendix II and Table 4.1). Among the treatment, the total tillers $hill^{-1}$ had higher (21.00) in S_{12} (12 kg S ha^{-1}) followed by S_8 or 8.0 kg S ha^{-1} (19.42) and S_{16} or 16.0 kg S ha^{-1} (18.50). In contrast, control treatment produces the lower total tillers $hill^{-1}$ (18.08). These result revealed that number of total tillers $hill^{-1}$ increased with the increasing levels of S up to 21 kg ha^{-1} after that it was decreased.

A significant variation was also recorded on number of total tiller $hill^{-1}$ due to the application of different levels of zinc (Appendix II and Table 4.1). Number of total tillers $hill^{-1}$ was the maximum (20.83) in $Zn_{1.5}$ (1.5 kg Zn ha^{-1}) which was statistically similar (20.08) to Zn_2 (2.0 kg Zn ha^{-1}). On the other hand, the minimum number of total tillers $hill^{-1}$ (17.58) was recorded in Zn_0 treatment which was also statistically similar (18.50) with Zn_1 (1.0 kg Zn ha^{-1}) (Table 4.1).

A significant variation was observed due to the interaction effect between Sulphur and Zinc in consideration of number of total tillers $hill^{-1}$ (Appendix II and Table 4.1). From the Table 4.1, it was showed that the maximum number of total tillers $hill^{-1}$ (24.00) was recorded in the treatment combination of $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) which was followed by (22.67) the treatment $S_{12}Zn_2$ (12 kg S ha^{-1} + 2.0 kg Zn ha^{-1}). The minimum number of total tillers $hill^{-1}$ (17.33) was recorded in the treatment combination of S_0Zn_0 (0 kg S + Zn ha^{-1}) which was followed by 8, 12 and 16 kg S ha^{-1} with 0 kg Zn ha^{-1} (S_8Zn_0, $S_{12}Zn_0$ and $S_{16}Zn_0$) of 17.67 tillers $hill^{-1}$

where they were statistically similar with S_0Zn_2 (0 kg S ha^{-1} + 2.0 kg Zn ha^{-1}) S_8Zn_1 (8 kg S ha^{-1} + 1.0 kg Zn ha^{-1}) and $S_{16}Zn_1$ (16 kg S ha^{-1} + 1.0 kg Zn ha^{-1}) of 18.0 tillers $hill^{-1}$, S_0Zn_1 (0 kg S ha^{-1} + 1.0 kg Zn ha^{-1}) of 18.33 tillers $hill^{-1}$, $S_0Zn_{1.5}$ (0 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) of 18.67 tillers $hill^{-1}$ (Table 4.1).

4.1.4 Panicle length (cm)

Panicle length varied significantly among the application of different level of Sulphur in T-aman rice (Appendix II and Table 4.1). Among the treatments, the panicle length had higher (28.76 cm) in 12 kg S ha^{-1} (S_2) which was statistically similar (28.03 cm) to S_{16} (16 kg S ha^{-1}). On the other hand, the lower panicle length (24.50 cm) was recorded in S_0 i.e. control condition (Table 4.1). Similar results were also obtained by Islam *et al.* (2009) who reported that 16 kg S ha^{-1} was more effective on panicle length of T. aman rice cv. BRRI Dhan 30.

Interaction effect between Sulphur (S) and Zinc (Zn) on panicle length was found to be significant difference (Appendix II and Table 1). From the table 4.2, it was found that the longest panicle length (29.86 cm) was recorded in the treatment combination of $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) which was followed by $S_{12}Zn_2$ (29.19 cm), $S_{12}Zn_1$ (29.00 cm), $S_{16}Zn_{1.5}$ (28.84 cm), $S_{16}Zn_2$ (28.01 cm), $S_{16}Zn_1$ (28.00 cm) and $S_8Zn_{1.5}$ (27.85 cm). The minimum panicle length (23.67 cm) was recorded in the treatment combination of S_0Zn_0 i.e. without Sulphur and Zinc and it was also statistically identical (23.99 cm) with S_0Zn_1 (Table 4.1).

Table 4.1 Individual and combined effect of S and Zn on yield and yield contributing characters of rice cv. BRRI dhan 40

Treatments	Plant height (cm)	Effective tillers hill^{-1} (No)	Total tillers hill^{-1} (No)	Panicle length (cm)
S concentration				
S_0	95.78 d	14.00 d	18.08 c	24.50 c
S_8	105.1 c	16.83 b	19.42 b	26.58 b
S_{12}	119.1 a	19.00 a	21.00 a	28.76 a
S_{16}	115.5 b	15.83 c	18.50 bc	28.03 a
S/X	0.4376	0.2553	0.3199	0.3307
Zn concentration				
Zn_0	103.6 d	14.00 d	17.58 b	25.76 c
$Zn_{1.0}$	107.2 c	15.67 c	18.50 b	26.78 b
$Zn_{1.5}$	114.1 a	18.75 a	20.83 a	28.01 a
$Zn_{2.0}$	110.5 b	17.25 b	20.08 a	27.31 ab
S/X	0.4376	0.2553	0.3199	0.3307
S × Zn combinations				
$S_0 \times Zn_0$	92.38 i	12.33 h	17.33 f	23.67 f
$S_0 \times Zn_1$	94.36 i	14.00 g	18.33 ef	23.99 f
$S_0 \times Zn_{1.5}$	99.46 h	15.33 fg	18.67 def	25.47 def
$S_0 \times Zn_2$	96.92 h	14.33 g	18.00 ef	24.85 ef
$S_8 \times Zn_0$	97.41 h	14.33 g	17.67 ef	25.14 def
$S_8 \times Zn_1$	102.5 g	15.33 fg	18.00 ef	26.13 cde
$S_8 \times Zn_{1.5}$	113.1 de	19.33 bc	21.33 bc	27.85 abc
$S_8 \times Zn_{2.0}$	107.2 f	18.33 cd	20.67 cd	27.19 bcd
$S_{12} \times Zn_0$	114.0 d	15.33 fg	17.67 ef	26.99 bcd
$S_{12} \times Zn_1$	118.0 bc	18.00 cd	19.67 cde	29.00 ab
$S_{12} \times Zn_{1.5}$	124.0 a	22.67 a	24.00 a	29.86 a
$S_{12} \times Zn_2$	120.3 b	20.00 b	22.67 ab	29.19 ab
$S_{16} \times Zn_0$	110.6 e	14.00 g	17.67 ef	27.26 bcd
$S_{16} \times Zn_1$	114.1 d	15.33 fg	18.00 ef	28.00 abc
$S_{16} \times Zn_{1.5}$	119.7 bc	17.67 de	19.33 cdef	28.84 ab
$S_{16} \times Zn_2$	117.4 c	16.33 ef	19.00 def	28.01 abc
S/X	0.8752	0.5106	0.6398	0.6613
Level of significance				
CV (%)	1.39	5.39	5.76	4.25

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

4.1.5 Number of filled grains per panicle

Number of filled grains panicle^{-1} differed significantly due to the application of different levels of Sulphur in T-aman rice cv. BRRI Dhan 40 in this experiment (Appendix II and Table 4.2). The maximum number of filled grains panicle^{-1} (67.33) were recorded in S_2 treatment (12 kg S ha^{-1}) where S_3 (16 kg S ha^{-1}) gave the second maximum (65.92), S_1 (8 kg S ha^{-1}) produces the third maximum (62.33) and the control treatment (S_0) recorded the lowest number of filled grains panicle^{-1} (60.42). Similar observations were also studied by Islam *et al.* (2009).

A significant difference was also recorded due to the application of different levels on the Zinc for number of filled grains panicle^{-1} (Appendix II and Table 4.2) where significantly the maximum number of filled grains panicle^{-1} (68.83) was recorded in Zn_2 treatment (1.5 kg Zn ha^{-1}) followed by S_3 (66.67) and S_1 (62.33). On the other hand, the minimum number of filled grains panicle^{-1} (58.17) was recorded in Zn_0 (Control) treatment (Table 4.2).

Combined effect between Sulphur and Zinc on the number of filled grains per panicle was found statistically significant (Appendix IIand Table 4.2). The maximum number of filled grains panicle^{-1} (72.67) was recorded from the treatment combination of S_2Zn_2 (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) which was statistically similar (71.67) with S_3Zn_2 and it was followed (70.67) by S_2Zn_3 (12 kg S ha^{-1} + 2.0 kg Zn ha^{-1}). The minimum number of filled grains panicle^{-1} (55.67) was obtained from the treatment combination of S_0Zn_0 i.e. without any Sulphur and Zinc and it was also statistically same (57.33) with S_1Zn_0 (8 kg S ha^{-1} + 0 kg Zn ha^{-1}) (Table 4.2).

4.1.6 Number of total grains panicle^{-1}

Number of total grains panicle^{-1} differed significantly due to the application of different levels of Sulphur in T-aman rice (Appendix II and Table 4.2). The maximum number of totals grain panicle^{-1} (75.25) was recorded in S_{12} (12 kg S ha^{-1}) which was statistically similar (74.75) with S_{16} (16 kg S ha^{-1}). The minimum number of total grains panicle^{-1} (71.17) was recorded in S_0 treatment and it was also statistically same (71.92) with S_8 (8 kg S ha^{-1}).

Statistically significant variation was recorded on the number of total grains panicle^{-1} due to the application of different levels of Zinc in this experiment (Appendix IV and Table 4.2). The maximum number of total grains panicle^{-1} (76.17) was recorded in $Zn_{1.5}$ treatment (1.5 kg Zn ha^{-1}) which was statistically identical (75.17) with Zn_2 treatment (2.0 kg Zn ha^{-1}). On the other hand, the minimum number of total grains panicle^{-1} (69.25) was recorded in Zn_0 treatment. Statistically significant difference was also recorded for panicle length due to the application of different levels of zinc (Appendix IIand Table 1). The maximum panicle length (28.01 cm) was recorded in $Zn_{1.5}$ treatment (1.5 kg Zn ha^{-1}) which was followed (27.31 cm) by Zn_2 (2.0 kg Zn ha^{-1}) and the shortest panicle length (25.76 cm) was recorded in Zn_0 treatment. Increasing levels of zinc showed increasing panicle length up to 1.5 kg Zn ha^{-1}. Khan *et al.* (2012) reported the similar observation with my study where they reported that grains per panicle showed increasing trend up to 9 kg Zn ha^{-1}. The highest average number of grains per panicle (194.5) was recorded at 120 kg N and 90 kg P2O5 along with 9 kg Zn ha^{-1}.

Interaction effect was significantly influenced between Sulphur and Zinc in consideration of number of total grains panicle^{-1} (Appendix II and Table 4.2). The maximum number of total grains panicle^{-1} (79.00) was recorded in the treatment combination of $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) which was statistically similar (78.67, 78.00 and 77.33) at per treatment $S_{16}Zn_{1.5}$ (16 kg S ha^{-1} + 1.5 kg Zn ha^{-1}), $S_{16}Zn_2$ (16 kg S ha^{-1} + 2.0 kg Zn ha^{-1}) and $S_{12}Zn_2$ (12 kg S ha^{-1} + 2.0 kg Zn ha^{-1}), respectively. On the other hand, the minimum number of total grains panicle^{-1} (68.00) was recorded in the treatment combination of S_0Zn_0 i.e. without Sulphur and Zinc followed (70.00, 69.67 and 69.33) by 0 kg Zn ha^{-1} combination with 12, 16 and 8 kg S ha^{-1} ($S_{12}Zn_0$, $S_{16}Zn_0$ and S_8Zn_0), respectively where they were also statistically identical (Table 4.2).

4.1.7 Weight of 1000 grains (g)

Thousand grains weight showed significant variation due to the application of different levels of Sulphur in this experiment (Appendix II and Table 4.2). The highest weight of 1000 grains (25.44 g) was recorded in S_{12} treatment (12 kg S ha^{-1}) while the lowest weight of 1000 grains (23.33 g) was recorded in control treatment (Table 4.2). These results observed that the 1000 grains weight increase with the increasing level of Sulphur up to 12 kg ha^{-1}.

A statistically non significant variation was recorded for weight of 1000 grains due to the application of different levels of Zinc (Appendix II and Table 4.2). The highest weight of 1000 grains (25.41 g) was recorded in $Zn_{1.5}$ treatment (1.5 kg Zn ha^{-1}) which was statistically similar (24.72 g) with Zn_2 (2.0 kg Zn ha^{-1}). In contrast, the lowest weight of 1000 grains (23.34 g) was recorded in Zn_0. These results observed that the 1000 grains weight increase with the increasing level of Zinc up to 1.5 kg ha^{-1}.

Interaction effect also showed significant differences between Sulphur and Zinc application in consideration of weight of 1000 grains (Appendix II and Table 4.2). The highest weight of 1000 grains (26.52 g) was recorded in the treatment combination of $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) followed (25.52, 25.51, 25.27, 25.17 and 25.12 g) by $S_{12}Zn_1$ (12 kg S ha^{-1} + 1.0 kg Zn ha^{-1}), $S_8Zn_{1.5}$ (8 kg S ha^{-1} + 1.5 kg Zn ha^{-1}), $S_{12}Zn_2$ (12 kg S ha^{-1} + 2.0 kg Zn ha^{-1}), S_8Zn_2 (8 kg S ha^{-1} + 2.0 kg Zn ha^{-1}) and $S_{16}Zn_{1.5}$ (16 kg S ha^{-1} + 1.5 kg Zn ha^{-1}), respectively. In contrast, the lowest weight of 1000 grains (22.48 g) was recorded in the treatment combination of S_0Zn_0 i.e. without Sulphur and Zinc which was also statistically similar (22.50 g) with S_0Zn_1 and followed by S_8Zn_0 (23.43 g), S_8Zn_1 (23.63 g), S_0Zn_2 (23.85 g) and S_8Zn_1 (24.13) (Table4. 2).

4.1.8 Grain yield (t ha^{-1})

Grain yield varied significantly for different levels of Sulphur in T-aman rice (Appendix II and Table 4.2). The highest grain yield (5.277 t ha^{-1}) was recorded in S_{12} treatment consisting of 12 kg S ha^{-1} which was followed (4.797 t ha^{-1}) by

S_8 (8 kg S ha^{-1}). The lowest grain yield (4.193 t ha^{-1}) was recorded in S_0 treatment i.e. control condition and it was statistically identical (4.293 t ha^{-1}) with S_{16} (16 kg S ha^{-1}). On the basis of this results investigation it was observed that the increasing levels of Sulphur increased the grain yield. Similar trend was also observed by Islam *et al.* (2009) who reported that the highest grain yield of 5293 kg ha^{-1} was obtained from 16 kg S ha^{-1} applied as gypsum. The lowest grain yield (4200 kg ha^{-1}) was recorded with S control treatment.

A statistically significant variation was recorded for grain yield due to the application of different levels of Zinc (Appendix II and Table 4.2). The highest grain yield (5.021 t ha^{-1}) was recorded from $Zn_{1.5}$ treatment comprising of 1.5 kg Zn ha^{-1} followed (4.736 t ha^{-1}) by Zn_1 treatment (1 kg Zn/ha) which was statistically similar (4.606 t ha^{-1}) with Zn_1 (1.0 kg Zn ha^{-1}). On the other hand, the lowest grain yield (4.196 t ha^{-1}) was recorded in Zn_0 treatment From this results investigation it was found that the increasing levels of Zinc increased the grain yield. Similar trend were also obtained by Rahman *et al.* (2006). Who reported that the two kg Zn ha^{-1} treated soil significantly ($p=0.05$) showed the highest grain yields (9.80 g $plant^{-1}$).

Interaction effect between Sulphur and Zinc was significantly influenced on grain yield of T-Aman in this study (Appendix II and Table 4.2). The highest grain yield (5.663 t ha^{-1}) was found from the treatment combination of $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) which was closely followed (5.417, 5.337 and 5.250 t ha^{-1}) by $S_{12}Zn_2$ (12 kg S ha^{-1} + 2.0 kg Zn ha^{-1}), $S_{12}Zn_1$ (12 kg S ha^{-1} + 1.0 kg Zn ha^{-1}) and $S_8Zn_{1.5}$ (8 kg S ha^{-1} + 1.5 kg Zn ha^{-1}), respectively. In contrast, the lowest grain yield (3.937 t ha^{-1}) was recorded in the treatment combination of S_0Zn_0 i.e. without Sulphur and Zinc which was also statistically same (3.990 t ha^{-1}) with $S_{16}Zn_0$ (16 kg S ha^{-1} + 0 kg Zn ha^{-1}) and followed by S_0Zn_1 (4.087 t ha^{-1}), S_8Zn_0 (4.167 t ha^{-1}), $S_{16}Zn_1$ (4.223 t ha^{-1}), $S_{16}Zn_2$ (4.263 t ha^{-1}) and S_0Zn_2 (4.270 t ha^{-1}). Similarly, Rahman *et al.* (2008) also found the highest grain (5.76 t ha^{-1}) in S_0Zn_3 treatment (100% recommended dose). The S_0Zn_0 (control) had the lowest grain yield with 4.35 t ha^{-1}.

4.1.9 Straw yield (t ha^{-1})

Different levels of Sulphur differed significantly on straw yield of T-aman rice (Appendix II and Table 2). The highest straw yield (7.777 t ha^{-1}) was recorded in S_{12} treatment consisting of 12 kg S ha^{-1} which was varied significantly with the other treatments where the lowest straw yield (6.652 t ha^{-1}) was recorded in S_0 or control treatment.Similarly Islam *et al.* (2009) reported that the highest straw yield of 6380 kg ha^{-1} was obtained from 16 kg S ha^{-1} applied as gypsum and the lowest straw yield (4963 kg ha^{-1}) was recorded with S control treatment.

Statistically significant difference was also observed due to the application of different levels of Zinc on straw yield of T-Aman (Appendix IV and Table 4.2). The highest straw yield (7.50 t ha^{-1}) was recorded in Zn_2 treatment (1.5 kg Zn ha^{-1}) followed (7.234 and 7.089 t ha^{-1}) by Zn_3 (2.0 kg Zn ha^{-1}) and Zn_1 (1.0 kg Zn ha^{-1}), respectively where the lowest straw yield (6.698 t ha^{-1}) was recorded in Zn_0 treatment i.e. control condition under the present study (Table 4.2). Similar results were also observed by Rahman *et al.* (2006) who found that the two kg Zn ha^{-1} treated soil significantly ($p=0.05$) showed the highest straw yields (10.28 g $plant^{-1}$).

Interaction effect also showed statistically significant differences between Sulphur and Zinc in consideration of straw yield (Appendix II and Table 4.2) where significantly the highest straw yield (8.163 t ha^{-1}) was recorded from the treatment combination of S_2Zn_2 (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) while the lowest straw yield (6.417 t ha^{-1}) was recorded from the treatment combination of S_0Zn_0 i.e. without Sulphur and Zinc (Table 4.2). Table 2 also showed that all the treatment combinations of Sulphur and Zinc were significantly difference with each others. Similar results were also trend by Rahman *et al.* (2008) who found that the highest straw (7.32 t ha^{-1}) yields was recorded in the treatment combinations of S20Zn3 (100% recommended dose) when the S0Zn0 (control) had the lowest straw yield with 5.47 t ha^{-1}.

Table 4.2 Individual and combined effect of S and Zn on yield and yield attributing of rice cv. BRRI dhan 40

Treatments	Filled grain panicle^{-1}	Un filled grain panicle^{-1}	Total grains panicle^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
S concentration						
S_0	60.42 d	10.75 a	71.17 b	23.33 c	4.193 c	6.652 d
S_8	62.33 c	9.583 b	71.92 b	24.56 b	4.797 b	7.301 b
S_{12}	67.33 a	7.917 d	75.25 a	25.44 a	5.277 a	7.777 a
S_{16}	65.92 b	8.833 c	74.75 a	24.08 bc	4.293 c	6.793 c
S/X	0.3354	0.2563	0.3582	0.2682	0.06831	0.04082
Zn concentration						
Zn_0	58.17 d	11.08 a	69.25 c	23.34 b	4.196 c	6.698 d
Zn_1	62.33 c	10.17 b	72.50 b	23.94 b	4.606 b	7.089 c
$Zn_{1.5}$	68.83 a	7.333 d	76.17 a	25.41 a	5.021 a	7.500 a
Zn_2	66.67 b	8.500 c	75.17 a	24.72 a	4.736 b	7.234 b
S/X	0.3354	0.2563	0.3582	0.2682	0.06831	0.04082
S × Zn combinations						
$S_0 \times Zn_0$	55.67 i	12.33 a	68.00 f	22.48 f	3.937 g	6.417 h
$S_0 \times Zn_1$	59.67 h	11.67 abc	71.33 de	22.50 f	4.087 fg	6.533 fgh
$S_0 \times Zn_{1.5}$	64.33 de	8.667 fg	73.00 bcd	24.47 bcde	4.477 def	6.893 e
$S_0 \times Zn_2$	62.00 fg	10.33 cde	72.33 cd	23.85 bcdef	4.270 efg	6.763 ef
$S_8 \times Zn_0$	57.33 i	12.00 ab	69.33 ef	23.43 def	4.167 fg	6.697 efg
$S_8 \times Zn_1$	60.67 gh	10.67 bcd	71.33 de	24.13 bcdef	4.777 cd	7.263 cd
$S_8 \times Zn_{1.5}$	66.67 c	7.333 ghi	74.00 bc	25.51 ab	5.250 ab	7.750 b
$S_8 \times Zn_2$	64.67 cde	8.333 fgh	73.00 bcd	25.17 abcd	4.993 bc	7.493 c
$S_{12} \times Zn_0$	60.33 gh	9.667 def	70.00 ef	24.44 bcde	4.690 cde	7.190 d
$S_{12} \times Zn_1$	65.67 cd	9.000 ef	74.67 b	25.52 ab	5.337 ab	7.837 b
$S_{12} \times Zn_{1.5}$	72.67 a	6.333 i	79.00 a	26.52 a	5.663 a	8.163 a
$S_{12} \times Zn_2$	70.67 ab	6.667 i	77.33 a	25.27 abc	5.417 ab	7.917 b
$S_{16} \times Zn_0$	59.33 h	10.33 cde	69.67 ef	22.99 ef	3.990 g	6.490 gh
$S_{16} \times Zn_1$	63.33 ef	9.333 def	72.67 bcd	23.63 cdef	4.223 fg	6.723 efg
$S_{16} \times Zn_{1.5}$	71.67 a	7.000 hi	78.67 a	25.12 abcd	4.693 cde	7.193 d
$S_{16} \times Zn_2$	69.33 b	8.667 fg	78.00 a	24.57 bcde	4.263 efg	6.763 ef
S/X	0.6708	0.5125	0.7165	0.5263	0.1366	0.08165
Level of significance						
CV (%)	1.82	9.57	1.69	3.74	2.13	1.96

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

4.2 Effects of S and Zn on grain N, P, K, S and Zn contents of rice

4.2.1 Main effect of S on grain N, P, K, S and Zn contents of rice

Nutrient content of Nitrogen (N), Phosphorus (P), Potassium (K), Sulphur (S) and Zinc (Zn) in grain showed significant difference due to the application of different levels of sulphur in T-aman rice cv. BRRI dhan 40 in this study (Appendix III and Table 4.3). Among the different levels of Sulphur, 12 kg S ha^{-1} (S_2) recorded the higher nutrient content of N, P, K, S and Zn (1.702, 0.2204, 0.5378, 0.1907 and 35.37%, respectively) in grain where S_{16} (16 kg S ha^{-1}) recorded the statistically similar nutrient content of P and S (0.2134 and 0.1902%, respectively) in grain. On the other hand, control or without S levels produce the lower (1.432, 0.2000, 0.35820.1718 and 23.71%) content of N, P, K, S and Zn, respectively in grain and it was also statistically identical (0.2035 and 0.1777%) with S_8 (8 kg S ha^{-1}) on P and S content in grain, respectively (Table 4.3).

4.2.2 Main effect of Zn on grain N, P, K, S and Zn contents of rice

A significant difference was found to be the effect of different levels of Zn on nutrient content of N, P, K, S and Zn in grain of T-aman rice cv. BRRI Dhan 40 in this study (Appendix III and Table 4.3). The higher nutrient content of N, P, K, S and Zn (1.714, 0.2213, 4967, 0.1937 and 33.81%, respectively) in grain where S_{16} (16 kg S ha^{-1}) recorded the statistically similar nutrient content of K and S (0.4706 and 0.1877%, respectively) in grain. On the other hand, control or without Zn levels produce the lower (1.355, 0.1988, 0.4017, 0.1698 and 24.91%) content of N, P, K, S and Zn, respectively in grain (Table 4.3).

4.2.3 Combined effect of S and Zn on nutrient content of N, P, K, S and Zn

Combined effect between S and Zn showed significant variation on the nutrient content of Potassium (K) and Zinc (Zn) in grain of T-aman rice cv. BRRI Dhan 40 in this study (Appendix III and Table 4.3). Among the combined effect of S and Zn, the higher nutrient content of Potassium (0.5927%) was found in the treatment combinations of $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) which was statistically identical (0.5750%) with $S_{12}Zn_2$ (12 kg S ha^{-1} + 2.0 kg Zn ha^{-1}). On the other hand, the lowest nutrient content of

Potassium (0.3353%) was taken from without Sulphur and Zinc concentration (S_0Zn_0) which was also statistically similar (0.3520%) with S_0Zn_1 (0 kg S ha^{-1} + 1.0 kg Zn ha^{-1}) followed (0.3650, 0.3803 and 0.3917%) by S_0Zn_2 (0 kg S ha^{-1} + 2.0 kg Zn $ha-^{1}$), $S_0Zn_{1.5}$ (0 kg S ha^{-1} + 1.5 kg Zn $ha-^{1}$) and S_8Zn_0 (8 kg S ha^{-1} + 0 kg Zn $ha-^{1}$), respectively. Similarly, 12 kg S ha^{-1} + 1.5 kg Zn ha-1 ($S_{12}Zn_{1.5}$) recorded the higher nutrient content of Zinc (39.93%) in grain when without Sulphur and Zinc (0 kg S ha^{-1} + 0 kg Zn $ha-^{1}$) produce the lower content of Zinc (20.27%) in grain of BRRI Dhan 40 in this study (Table 4.3). Nutrient content of N, P and S were statistically similar in all the treatment combinations of Sulphur and Zinc in case of their combined effect did not differ significantly among the nutrient content of N, P and S (Table 4.3).

Table 4.3. Individual and combined effect of S and Zn on grain N,P,K,S and Zn contents of rice

Treatments	Nutrient content of grains (%)				
	N	P	K	S	Zn
S concentration					
S_0	1.432 d	0.2000 b	0.3582 c	0.1718 b	23.71 d
S_8	1.480 c	0.2035 b	0.4462 b	0.1777 b	27.12 c
S_{12}	1.702 a	0.2204 a	0.5378 a	0.1907 a	35.37 a
S_{16}	1.597 b	0.2134 a	0.4652 b	0.1902 a	32.43 b
S/X	0.01581	0.002887	0.009129	0.002887	0.1817
Zn concentration					
Zn_0	1.355 d	0.1988 c	0.4017 c	0.1698 c	24.91 d
Zn_1	1.535 c	0.2069 bc	0.4383 b	0.1792 b	28.37 c
$Zn_{1.5}$	1.714 a	0.2213 a	0.4967 a	0.1937 a	33.81 a
Zn_2	1.606 b	0.2103 b	0.4706 a	0.1877 a	31.55 b
S/X	0.01581	0.002887	0.009129	0.002887	0.1817
S × Zn combinations					
$S_0 \times Zn_0$	1.263	0.195	0.3353 e	0.159	20.27 j
$S_0 \times Zn_1$	1.410	0.194	0.3520 e	0.165	22.93 i
$S_0 \times Zn_{1.5}$	1.573	0.211	0.3803 de	0.186	26.98 g
$S_0 \times Zn_2$	1.480	0.200	0.3650 de	0.177	24.67 h
$S_8 \times Zn_0$	1.327	0.194	0.3917 de	0.162	23.06 i
$S_8 \times Zn_1$	1.470	0.198	0.4193 cd	0.173	25.45 h
$S_8 \times Zn_{1.5}$	1.637	0.218	0.4930 b	0.189	31.16 e
$S_8 \times Zn_2$	1.487	0.205	0.4810 b	0.186	28.79 f
$S_{12} \times Zn_0$	1.465	0.206	0.4677 bc	0.181	29.12 f
$S_{12} \times Zn_1$	1.690	0.228	0.5157 b	0.188	33.95 d
$S_{12} \times Zn_{1.5}$	1.877	0.228	0.5927 a	0.199	39.93 a
$S_{12} \times Zn_2$	1.777	0.220	0.5750 a	0.195	38.49 b
$S_{16} \times Zn_0$	1.367	0.200	0.4123 cd	0.177	27.18 g
$S_{16} \times Zn_1$	1.570	0.208	0.4660 bc	0.191	31.15 e
$S_{16} \times Zn_{1.5}$	1.770	0.229	0.5210 b	0.200	37.15 c
$S_{16} \times Zn_2$	1.680	0.217	0.4613 bc	0.193	34.24 d
S/X			0.01826		0.3633
			Level of significance		
CV (%)	2.33	3.38	2.01	3.42	2.12

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

4.3 Effects of S and Zn on straw N, P, K, S and Zn contents of rice

4.3.1 Main effect of S on straw N, P, K, S and Zn contents of rice

Nitrogen (N), Phosphorus (P), Potassium (K), Sulphur (S) and Zinc (Zn) content of straw of T-aman rice cv. BRRI Dhan 40 were showed significant difference in this study (Appendix III and Table4. 4). Nutrient content of N had higher (1.252%) in 12 kg S ha^{-1} (S_{12}) which was closely followed (1.187%) by 16 kg S ha^{-1} (S_{16}) while control or without Sulphur recorded the lower N content (0.959%). Similarly, 12 kg S ha^{-1} (S_{12}) recorded the higher nutrient content of P, K, S and Zn (0.1476, 2.224, 0.1699 and 26.92%, respectively) of straw of BRRI Dhan 40 where S_{16} (16 kg S ha^{-1}) recorded the statistically similar nutrient content of S (0.1693%). However, control or without S levels produce the lower (0.1168, 1.160, 0.1514 and 17.42%) content of P, K, S and Zn, respectively in straw and it was also statistically identical (0.1245 and 0.1572%) with S_8 (8 kg S ha^{-1}) on both P and S content in straw, respectively (Table 4.4).

4.3.2 Main effect of Zn on nutrient content of N, P, K, S and Zn

A significant difference was also found on nutrient content of N, P, K, S and Zn in straw due to the effect of different concentration of Zinc (Appendix V and Table 4.4). The higher nutrient content of N in straw (1.295%) was observed in $Zn_{1.5}$ (1.5 kg Zn ha^{-1}) while the lowest nutrient content of N in straw (0.945%) was taken from without Zn application (Table 4.4.). Similarly, nutrient content of K and Zn in straw (1.949 and 25.2%, respectively) were recorded in 1.5 kg Zn ha^{-1} ($Zn_{1.5}$) and lower nutrient content of K and Zn in straw (1.551 and 19.77%, respectively) were found from the without Zn application (control treatment). Treatment $Zn_{1.5}$(1.5 kg Zn ha^{-1}) also showed significantly the higher (0.1414 and 0.1729%) nutrient content of P and S in straw, respectively where statistically similar (0.1343 and 0.1675%) nutrient content of both P and S in straw, respectively were found with Zn_2 (2.0 kg Zn ha^{-1}). In contrast, control or without Zn (Zn_0) recorded the lower (0.1186 and 0.1487%) nutrient content of P and S, respectively (Table 4.4).

4.3.3 Combined effect of S and Zn on nutrient content of N, P, K, S and Zn

Combined effect between S and Zn showed significant variation on the all nutrient content except S in straw of T-aman rice cv. BRRI Dhan 40 in this study (Appendix III and Table 4.4). Nutrient content of S in straw were statistically more or less similar result in all the treatment combinations of Sulphur and Zinc application in case of they did not different significantly on S nutrient content. However, the treatment combinations of 12 kg S ha^{-1} + 1.5 kg Zn ha^{-1} ($S_{12}Zn_{1.5}$) recorded the higher nutrient content of N in straw (1.377%) which was statistically same (1.345 and 1.332%) with both the treatment combinations of $S_{16}Zn_{1.5}$ (16 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) and $S_8Zn_{1.5}$ (8 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) and it was also closely followed (1.266, 1.249, 1.232, 1.227 and 1.226%) by $S_{12}Zn_2$ (12 kg S ha^{-1} + 2.0 kg Zn ha^{-1}), $S_{12}Zn_1$ (12 kg S ha^{-1} + 1.0 kg Zn ha^{-1}), $S_{16}Zn_2$ (16 kg S ha^{-1} + 2.0 kg Zn ha^{-1}), $S_{16}Zn_1$ (16 kg S ha^{-1} + 1.0 kg Zn ha^{-1}) and S_8Zn_2 (8 kg S ha^{-1} + 2.0 kg Zn ha^{-1}), respectively where they were statistically similar. Similarly, P content had higher (0.1613%) in $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) followed (0.1543%) by S_2Zn_3 (12 kg S ha^{-1} + 2.0 kg Zn ha^{-1}). Another two treatment combinations *viz.* $S_{12}Zn_1$ (12 kg S ha^{-1} + 1.0 kg Zn ha^{-1}) and $S_{16}Zn_{1.5}$ (16 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) were statistically identical and obtained the same (0.1463%) nutrient content of P. On the other hand, the lowest nutrient content of P (0.1097%) was taken from without Sulphur and Zinc concentration (S_0Zn_0) followed by S_0Zn_1 (0.1150%), S_8Zn_0 (0.1170%), S_0Zn_3 (0.1173%), $S_{16}Zn_0$ (0.1193%), S_8Zn_1 (0.1227%), $S_0Zn_{1.5}$ (0.1250%), S_1Zn_2 (0.1253%) and $S_{12}Zn_0$ (0.1283%). In another observation of nutrient content, the higher nutrient content of K in straw (2.400%) was found in the treatment combinations of $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) followed (2.369%) by $S_{12}Zn_2$ (12 kg S ha^{-1} + 2.0 kg Zn ha^{-1}). However, the lowest nutrient content of K (1.139%) was noticed from the treatment combinations of S_0Zn_0 or without Sulphur and Zinc and it was also statistically identical (1.153, 1.169 and 1.178%) by the treatment combinations of S_0Zn_1 (0 kg S ha^{-1} + 1.0 kg Zn ha^{-1}), S_0Zn_2 (0 kg S ha^{-1} + 2.0 kg Zn ha^{-1}) and $S_0Zn_{1.5}$ (0 kg S ha^{-1} + 1.5 kg Zn ha^{-1}), respectively (Table 4). Nutrient content of Zn in straw was also higher (29.79%) in $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) while the lowest nutrient of Zinc in straw (16.07%) was obtained with the treatment combinations of S_0Zn_0 (0 kg S ha^{-1} + 0 kg Zn ha^{-1}) where all the treatment combinations were statistically differed on nutrient content of Zn in straw.

Table 4.4 Individual and combined effect of S and Zn on straw N,P,K,S and Zn contents of rice

Treatments	Straw nutrient content of rice (%)				
	N	P	K	S	Zn µg g^{-1}
S concentration					
S_0	0.959 c	0.1168 c	1.160 d	0.1514 b	17.42 d
S_8	1.152 b	0.1245 c	1.719 c	0.1572 b	22.22 c
S_{12}	1.252 a	0.1476 a	2.224 a	0.1699 a	26.92 a
S_{16}	1.187 ab	0.1343 b	2.068 b	0.1693 a	23.93 b
S/X	0.02887	0.002887	0.01291	0.002887	0.3291
Zn concentration					
Zn_o	0.945 d	0.1186 c	1.551 d	0.1487 c	19.77 d
Zn_1	1.110 c	0.1289 b	1.767 c	0.1587 b	21.84 c
$Zn_{1.5}$	1.295 a	0.1414 a	1.949 a	0.1729 a	25.28 a
Zn_2	1.201 b	0.1343 ab	1.903 b	0.1675 a	23.60 b
S/X	0.02887	0.002887	0.01291	0.002887	0.3291
S × Zn combinations					
$S_0 \times Zn_0$	0.790 e	0.1097 f	1.139 g	0.137	16.07 n
$S_0 \times Zn_1$	0.841 e	0.1150 ef	1.153 g	0.145	16.83 m
$S_0 \times Zn_{1.5}$	1.127 bc	0.1250 def	1.178 g	0.166	19.00 k
$S_0 \times Zn_2$	1.077 bcd	0.1173 ef	1.169 g	0.158	17.78 l
$S_8 \times Zn_0$	0.929 de	0.1170 ef	1.418 f	0.142	18.89 k
$S_8 \times Zn_1$	1.121 bc	0.1227 def	1.627 e	0.153	21.09 i
$S_8 \times Zn_{1.5}$	1.332 a	0.1330 cde	1.911 d	0.168	25.54 e
$S_8 \times Zn_2$	1.226 ab	0.1253 def	1.921 d	0.165	23.36 h
$S_{12} \times Zn_0$	1.115 bc	0.1283 cdef	1.949 d	0.160	23.66 g
$S_{12} \times Zn_1$	1.249 ab	0.1463 abc	2.177 c	0.167	25.99 d
$S_{12} \times Zn_{1.5}$	1.377 a	0.1613 a	2.400 a	0.178	29.79 a
$S_{12} \times Zn_2$	1.266 ab	0.1543 ab	2.369 ab	0.174	28.25 b
$S_{16} \times Zn_0$	0.945 cde	0.1193 ef	1.699 e	0.155	20.46 j
$S_{16} \times Zn_1$	1.227 ab	0.1317 cde	2.112 c	0.170	23.45 h
$S_{16} \times Zn_{1.5}$	1.345 a	0.1463 abc	2.308 b	0.179	26.79 c
$S_{16} \times Zn_2$	1.232 ab	0.1400 bcd	2.153 c	0.173	25.02 f
S/X	0.05774	0.005774	0.02582		0.06583
Level of significance					
CV (%)	2.08	3.32	2.22	5.54	0.51

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

Chapter V
Summary and Conclusion

CHAPTER V
SUMMARY AND CONCLUSION

The present experimental research work was conducted at the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from July- November, 2011 to study on the effect of Sulphur (S) and Zinc (Zn) on yield performance and nutrient content of rice cv. BRRI Dhan 40. The experiment compared with four different individual and combined treatment of Sulphur *viz.* S_0 (control), S_8 (8 kg ha^{-1}), S_{12} (12 kg ha^{-1}) and S_{16} (16 kg ha^{-1}) and Zinc *viz.* Zn_{0with} three r (0 kg ha^{-1}), Zn_1 (1.0 kg ha^{-1}), $Zn_{1.5}$ (1.5 kg ha^{-1}) and Zn_2 (2.0 kg ha^{-1}) on yield performance and nutrient content of rice cv. BRRI Dhan 40. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

The yield and yield contributing characters of rice cv. BRRI Dhan 40 were showed significant difference at all the characters due to the effect of different levels of eplicationSulphur where 12 kg S ha^{-1} produced the higher performance on all the characters of growth and yield. Among the treatments, 12 kg S ha^{-1} (S_2) recorded the tallest plant (119.10 cm); maximum number of effective tillers $hill^{-1}$ (19.00), minimum number of non effective tillers $hill^{-1}$ (2.00) and maximum number of total tillers $hill^{-1}$ (21.00). The longest panicle (28.76 cm); maximum filled grain per penicle (67.33), minimum unfilled grain per penicle (7.917) and the total grains $panicle^{-1}$ (75.25) were also observed in 12 kg S ha^{-1} (S_2). Similar treatment, also recorded the highest 1000-grains weight (25.44 g), highest grain (5.277 t ha^{-1}) and straw yield (7.777 t ha^{-1}). In contrast, control or without Sulphur recorded the lower performance on plant height (95.78 cm), effective tillers $hill^{-1}$ (14.00), non effective tillers $hill^{-1}$ (4.083), total tillers $hill^{-1}$ (18.08), panicle length (24.50 cm), filled grains $panicle^{-1}$ (60.42), unfilled grains $panicle^{-1}$ (10.75), total grains $panicle^{-1}$ (71.17), 1000-grains weight (23.33 g), grain yield (4.193 t ha^{-1}) and straw yield (6.652 t ha^{-1}). Zinc application also showed significant difference for the whole characters of growth and yield characters of rice cv. BRRI Dhan 40 where 1.5 kg Zn ha^{-1} showed greater results. The tallest plant (114.10 cm), maximum effective tillers $hill^{-1}$ (18.75), minimum non effective tillers $hill^{-1}$ (2.083) and maximum total tillers $hill^{-1}$ (20.83), longest panicle (28.01 cm); maximum filled grain $panicle^{-1}$ (68.83), minimum unfilled grain $panicle^{-1}$

(7.333) and maximum total grains panicle^{-1} (76.17) were taken from 1.5 kg Zn ha^{-1} (Zn_2). Similar treatment, also recorded the highest 1000-grains weight (25.41 g), highest grain yield (5.021 t ha^{-1}) and straw yield (7.500 t ha^{-1}). In contrast, control or without Zinc noticed the lower performance on plant height (103.60 cm), effective tillers hill^{-1} (14.00), non effective tillers hill^{-1} (3.583), total tillers hill^{-1} (17.58), panicle length (25.76 cm), filled grains panicle^{-1} (58.17), unfilled grains panicle^{-1} (11.08), total grains panicle^{-1} (69.25), 1000-grains weight (23.34 g), grain yield (4.196 t ha^{-1}) and straw yield (6.698 t ha^{-1}). Combined effect between Sulphur and Zinc was significantly influenced on all yield contributing characters where the treatment combinations of 12 kg S ha^{-1} and 1.5 kg Zn ha^{-1} ($S_{12}Zn_{1.5}$) produced the greater results. Among the treatment combinations, 12 kg S ha^{-1} and 1.5 kg Zn ha^{-1} ($S_{12}Zn_{1.5}$) showed the greater performance on plant height (124.0 cm); effective tillers hill^{-1} (22.67), non effective tillers hill^{-1} (1.33) and total tillers hill^{-1} (24.00); panicle length (29.86 cm); filled grain panicle^{-1} (72.67), unfilled grain (6.33) and total grains N, P, K, S and Zn (79.00), 1000-grains weight (26.52 g), grain yield (5.663 t ha^{-1}) and straw yield (8.163 t ha^{-1}).

Sulphur application on the nutrient content of N, P, K, S and Zn in grain and straw and total were showed statistically significant where 12 kg S ha^{-1} recorded the higher nutrient content of N, P, K, S and Zn in grain (1.702%, 0.2204%, 0.5378%, 0.1907% and 35.37%, respectively), N, P, K, S and Zn in straw (1.252%, 0.1476%, 2.224%, 0.1699% and 26.92%, respectively) and in total of grain and straw N, P, K, S and Zn (2.956%, 0.3652%, 2.761%, 0.3607 and 62.29%, respectively). On the other hand, control or without Sulphur application noticed the lower nutrient content in grain (1.432%, 0.2000%, 0.3582%, 0.1718% and 23.71%, respectively), in straw 0.959%, 0.1168%, 1.160%, 0.1514% and 17.42%, respectively) and in total of grain and straw nutrient content of (2.389%, 0.3142%, 1.518%, 0.3239% and 41.13%, respectively). Similarly, Zn application of 1.5 kg ha^{-1} also gave significantly the higher nutrient content of N, P, K, S and Zn in grain (1.714%, 0.2213%, 0.4967%, 0.1937% and 33.81%, respectively), in straw (1.295%, 0.1414%, 1.949%, 0.1729 and 25.28%, respectively) and in total of grain and straw (3.008%, 0.3627%, 2.446%, 0.3666% and 59.09%, respectively) while control treatment observed the lower N, P, K, S and Zn content in grain (1.355%, 0.1988%, 0.4017%, 0.1698% and 24.91%, respectively), in straw (0.945%, 0.1186%, 1.551%, 0.1487% and 19.77%, respectively) and in total of grain and straw (2.302%, 0.3149%, 1.953%, 0.3185 % and 44.68%, respectively). A significant variation was found on K and Zn content in grain where N, P and S nutrient content did not vary significant due to the combined effect between S and Zn. The highest nutrient content of K and Zn in grain (0.5927% and 39.93%, respectively) was taken from the treatment combinations of $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) while control treatment observed the lowest nutrient content (0.3353% and 20.27%, respectively). A significant variation was also recorded for all nutrient content except S where the treatment combinations of $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) recorded the maximum nutrient content of N, P, K and Zn in straw (1.377%, 0.1613%, 2.400% and 29.79%, respectively) when the lowest (0.790%, 0.1097%, 1.139% and 16.07%, respectively) was found in control combinations (S_0Zn_0). Total (grain and straw) nutrient content of K and Zn showed significant variation due to the combined effect between S and Zn where N, P and S were not significant. Among the treatment combinations, $S_{12}Zn_{1.5}$ (12 kg S ha^{-1} + 1.5 kg Zn ha^{-1}) recorded the higher total of grain and straw nutrient content of K and Zn (2.944% and 69.72%, respectively) when control treatment gave the lower content of K and Zn (1.475% and 36.34%, respectively).

CONCLUSION

From the above results investigate, it could be concluded that alone or combined levels of 12 kg S ha^{-1} and 1.5 kg Zn ha^{-1} produced the greater performance on growth, yield and nutrient content of rice cv. BRRI Dhan 40 comparison with other single or combined application of Sulphur and Zinc. If so, somehow 16 kg S ha^{-1} or 2.0 kg Zn ha^{-1} recorded the statistically more or less similar results on yield contributing character and nutrient content of rice. So, on the basis of this results investigation it is clear that 12 kg S ha^{-1} and 1.5 kg Zn ha^{-1} alone or combinedly suitable or optimum levels for higher production and better nutrient content of rice cv. BRRI Dhan 40.

Recommendation

Considering the above observation of the present experiment, further studies in the following areas may be suggested.

1. Further study may be needed to ensuring the performance of yield and yield contributing characters in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.
2. More Sulphur or Zinc levels may be needed to include for future study as sole or different combination to make sure these yield and nutrient performance.

Chapter VI

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Chapter VII
Appendices

APPENDICES

Appendix I. Monthly records of Air temperature, Relative humidity and Rainfall of the experiment site during the period from July to November, 2011.

Month	* Air temperature (° C)		*Relative humidity (%)	*Rainfall (mm)
	Maximum	Minimum		
July	31.4	19.6	54	11
August	33.2	21.1	61	88
September	34.1	20.2	78	102
October	35.3	24.6	79	134
November	36.4	25.2	82	165

*Monthly Average

Source : Bangladesh Metrological Department (climate and weather division) Agargaon, Dhaka- 1212.

Appendix II. Mean square of yield and yield contributing characters of rice cv. BRRI dhan 40 at harvest

Source of variation	Degrees of freedom	Mean square of										
		Plant height (cm)	Effective tillers hill^{-1}	Non effective tillers hill^{-1}	Total tillers hill^{-1}	Panicle length (cm)	Filled grain panicle^{-1}	Un filled grain panicle^{-1}	Total grains panicle^{-1}	1 000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Replication	2	55.504	20.271	0.161	30.250	9.579	76.750	21.521	118.896	8.363	0.583	0.675
S doses (A)	3	1333.818**	52.111**	9.389**	20.056**	42.370**	121.611**	17.243**	49.465**	9.383**	3.004**	3.160**
Zn doses (B)	3	239.538**	50.167**	4.500**	26.167**	10.732**	269.111**	33.743**	114.965**	9.779**	1.411**	1.343**
A × B	9	7.551**	2.537**	0.407**	3.889**	0.467ns	3.315*	0.650ns	4.910**	0.289ns	0.056**	0.059**
Error	30	2.298	0.782	0.134	1.228	1.312	1.350	0.788	1.540	0.831	0.010	0.020

Appendix III. Mean square of nutrient content (N, P, K, S and Zn) in grain and straw of rice cv. BRRI dhan 40

Source of variation	Degrees of freedom	Mean square of									
		Grain					Straw				
		Nitrogen	Phosphorus	Potassium	Sulphur	Zinc	Nitrogen	Phosphorus	Potassium	Sulphur	Zinc
S doses (A)	3	0.177**	0.005**	0.065***	0.003**	328.493**	0.191**	0.002**	2.670**	0.006**	189.838**
Zn doses (B)	3	0.273**	0.002**	0.020**	0.002**	179.926**	0.267**	0.001**	0.382**	0.003**	67.057**
A × B	9	0.003ns	0.001ns	0.001**	0.01ns	2.938**	0.009**	0.001**	0.043**	0.001ns	1.839**
Error	32	0.003	0.000	0.000	0.000	0.396	0.001	0.000	0.002	0.000	0.013

Appendix IV (Contd.). Mean square of nutrient content (N, P, K, S and Zn) in total of grain and straw of rice cv. BRRI dhan 40

Source of variation	Degrees of freedom	Mean square of				
		Total of grain and straw				
		Nitrogen	Phosphorus	Potassium	Sulphur	Zinc
S doses (A)	3	0.693**	0.006**	3.539**	0.004**	999.621**
Zn doses (B)	3	1.070**	0.005**	0.575**	0.005**	466.359**
A × B	9	0.010ns	0.01ns	0.056**	0.001ns	8.005**
Error	32	0.006	0.001	0.002	0.000	0.543