EFFECT OF SULPHUR AND ZINC ON THE GROWTH AND YIELD OF ONION

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Certificate

This is to certify that the thesis entitled, **"EFFECT OF SULPHUR AND ZINC ON THE GROWTH AND YIELD OF ONION"** submitted to the Department of Soil Science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207 in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in SOIL SCIENCE embodies the result of a piece of bona fide research work carried out by **MD. SAROAR ZAMAN**, **Registration No. 02579/007** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged by him.

Dated:

Dhaka, Bangladesh

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Supervisor

Dedicated
To My
Beloved Parents

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ABSTRACT

A field experiment was carried out at Sher-e-Bangla Agricultural University Farm during the *Rabi* season of 2008 to investigate the effect of sulphur and zinc on the growth and yield of onion cv. *taharpuri*. The red tarrece soil of Tejgaon was silty loam in texture having pH 5.6. The experiment was conducted in a RCBD with three replications. The experiment comprises 4 levels of sulphur from gypsum (0 kg, 10 kg, 20 kg and 30 kg sulphur ha^{-1}) and 4 levels of zinc from zinc oxide (0 kg, 1 kg, 3 kg and 4 kg zinc ha^{-1}). There was combination of sixteen treatments including control (no fertilizer).It was observed from the experiment that S and Zn alone or in combination significantly increased all the parameters studied. S_{20}, Zn_3 and Zn_4 individually gave the height results over the control in respect of most cases. Maximum results were found with (S_{20} +Zn_3) treatment combination in respect of all the studied parameters and S_0 + Zn_0 produced minimum results. The highest N, P, K, S and Zn content in bulb and in leaf were also obtained with $S_{20}Zn_3$ treatment combination. Thus the findings of the experiment suggested that combined use of 20 kg sulphur with 3 kg zinc produced maximum growth and yield of onion in red terrace soil of the Tejgaon series. This fertilizer combination of sulphur and zinc not only gives maximum growth and yield of onion but also keeps the soil fertile and productive.

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LIST OF ABBRIVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
CBR	=	Cost Benefit Ratio
cm	=	Centimeter
^0C	=	Degree Centigrade
DAS	=	Days after sowing
et al.	=	and others *(at elli)*
Kg	=	Kilogram
Kg/ha	=	Kilogram/hectare
g	=	gram (s)
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
P^H	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t/ha	=	ton/hectare
%	=	Percent

Chapter 1
Introduction

INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important spices as well as vegetable crops grown all over the country mainly during *Rabi* season. It belongs to the genus *Allium* and family *alliaceae*. Iran, Afghanistan and especially their northern regions are thought to be places of origin of onion, the leading onion producing countries of the world are China, India, USA, Russia, Iran, Pakistan, Japan, Brazil, Spain, and Korea (FAO, 2003).

Generally onion is grown in all parts of Bangladesh in order to meet up the family demand but for commercial purposes it is cultivated in the greater districts of Faridpur, Pabna, Comilla, Rajshahi, Rangpur and Jessore (BBS, 2008). In respect of area and production onion ranks second among the spice crops grown in Bangladesh (BBS, 2008). The production of onion in Bangladesh during the year 2007-2008 was 769000 metric tones from 286000 acres of lands with an average yield of 2.09 Mt./ acre (BBS, 2008), which is very low as compared to that of onion growing countries of the world such as Spain, Pakistan, Australia, Korea, Japan, USA and Germany (FAO, 2005).

The total requirement of onion in Bangladesh is about 450 thousand metric tones but total production in the country is 153 thousand metric tones (BBS, 2004). As a result huge amount of onion bulb is imported from neighboring countries like India, Burma, Pakistan and China at the cost of hard earned foreign currency. Due to limitation of land, it is not possible to raise the area of production to increase the yield of the crop horizontally. The production can however be increased by proper management practices and providing inputs especially fertilizer, irrigation etc.

Only three primary nutrients viz. nitrogen, phosphorus and potassium along with one secondary nutrient i.e. sulphur are used by the farmers of Bangladesh for onion cultivation. The importance of the use of micronutrients is mostly ignored although they can be chief limiting factors for crop production. Presently there has been great increase in fertilizer use, yet the amount of different nutrients used in the country is not well balanced. Nitrogen alone constitutes about 78% of the total nutrients used (Amin, 1999) which may not help to improve crop productivity unless other essential nutrients are supplemented. In order to improve crop productivity, the other limiting nutrient(s) must be identified and the soils should be enriched with addition of these nutrients in properly balanced fertilizer programme.

Soil fertility is the main factor for increasing production of any crop. Soil nutrient management is therefore, a very vital area of research. In an integrated nutrient management homestead cropping pattern, sole application of either organic manure or chemical fertilizers gave inferior results to their integrated use (BARI Annual Report, 2006-07). A large variety of organic wastes are available in the country that can be used as potential manure to improve soil organic matter as well as crop productivity. It includes the excreta (cow dung and urine) of the domestic animals. Cow dung is basically the digested residue of herbivorous matter which is acted upon by symbiotic bacteria residing within animal's rumen. The resultant faucal matter is rich in minerals. The urine of cattle is rich in nitrogen and should be preserved with the dung that also improves soil organic matter content.

Soil organic matter improves the physico-chemical properties of soil and ultimately promotes crop production. The application of different fertilizers and manures influences the physical and chemical properties of soil and ultimately promotes crop production. The application of different fertilizers and manures influences of soil microbes. The organic and chemical fertilizers are also positively correlated with soil porosity, enzymatic activity and CO_2 production. These stimulate soil biological activity. Sulphur and zinc fertilizer enhances soil porosity by increasing regular and irregular pores and causes a priming effect on native soil organic matter (Marinari *et al.*, 2006). In Bangladesh, the farmers are using chemical fertilizers continuously without knowing the actual dose and their residual effects on soil properties. Under these imbalanced conditions various beneficial soil microorganisms are being adversely affected. The soil is loosing its fertility as well as productivity day by day. So, judicious application of inorganic fertilizers mainly N, P, K including other like sulphur and zinc containing fertilizers needs to be applied for the improvement of soil physical properties. Information are limited regarding the integrated application of sulphur and zinc fertilizers with respect to the soil and crop of Bangladesh under existing agro-climatic conditions which needs to be studied.

Micro nutrient deficiencies in general, are reported from different part of globe in world literature. Zinc deficiencies are widespread throughout the world. Especially in the rice land of Asia and deficiencies occur in neutral and calcareous soils (Rodriguez *et al.* 1997). It was reported that about 2.0 million hectares of agricultural land are zinc deficient under different agro ecological zones in Bangladesh. Zinc is essential for numerous enzyme systems and is capable of forming many stable bonds with nitrogen and sulphur legends. Zinc plays an important role in many physiological functions in plant. It acts as the constituent of plant metabolic enzyme system as alcohol dehydrogenase, carbonic anhydrase. Zinc is involved in biosynthesis of tryptophan, a precursor of auxin which is essential for elongation. It has also been found to be essential for normal chlorophyll formation in plants. Zinc is required in small amount but critical concentrations to allow several key plant physiological pathways to function normally. These pathways have important roles in photosynthesis and sugar formation, protein synthesis, fertility and seed production, growth regulation and defense against disease (Bray and Kurtz, 1999).

The necessitates an improvement of per hectare yield, which is possible through adoption of high yielding varieties and judicious application of fertilizer. Concerning fertilizer application sulphur and zinc are important since these two elements are highly deficient in our country's soils. Onion responded to N and S positively in term of yield and quality of bulbs (Patel and Patel, 1990). Sulphur is essential for building up sulphur containing amino acids and also for good vegetative growth and bulb development in onion (Anwar *et al.*2001). Research information regarding the sulphur and zinc requirement for onion production in Bangladesh is insufficient. In a view of this, the present experiment was undertaken to assess the different rates of nitrogen and sulphur fertilizers both the S and Zn uptake and yield performance of onion.

With a view to generate information on the aspect, a field experiment was carried out at Shere-e-Bangla Agricultural University farm. Considering the above conditions the present experiment was carried out with the following objectives;

1. To study the growth and yield of winter onion under different level of Zn and S application.
2. To find out the best combination of S and Zn for maximizing the production of winter onion.

Chapter 2
Review of literature

REVIEW OF LITERATURE

Onion is an important crop of the world. Different types of chemical fertilizers play an important role on its growth, yield and quality. Many works have been done in the world on the effect of fertilizer on onion. In this chapter an attempt has been made to review the research works related to present investigation.

2.1 Effect of Sulphur on the Growth and Yield of Onion

Yasin and Bufler (2007) conducted an experiment to relate features of S metabolism to the dormant and/or sprouting states of onion bulbs (*Allium cepa* L.) during storage at 18^0 C. For this purpose, onion bulbs were dissected at 2-week or 4-week intervals into sprout leaves, stem plate, inner scale, and fleshy leaf to measure total sulphur content, sulphate content, gamma-glutamyl transpeptidase (GGT) activity and enzymatically-formed pyruvate (EPY).Subsequently increased during initial sprout growth. GGT activity started to increase in the fleshy leaf and in the inner scale at the start of sprouting in both cultivars. In general, changes in S metabolism at the transition from the dormant to the sprouting state suggest sprouting-enhanced sulphur metabolism, depending on the cultivar. In addition, the results indicated remobilization and reallocation of sulphur compounds within the onion bulb during dormancy and initial sprouting.

Channagoudar and Janawade (2006) a field experiment was carried out during rabi 2002-03, in Dharwad, Karnataka, India, to study the effect of different levels of irrigation (0.9, 1.1, 1.3 and 1.5 iW/CPE ratios) and sulfur (0, 20, 40 and 60 kg/ha) on the growth, yield and quality of onion cv. Bellary red. Significantly higher bulb yield (189.29 q ha^{-1}) and yield components, like bulb length, bulb diameter and weight of 20 bulbs, were obtained. The growth components, i.e. plant height, number of leaves, leaf area, leaf area index, leaf area duration and total dry matter production per plant, were also higher in 1.5 IW/CPE ratios. Application of 40 kg S ha^{-1} recorded significantly higher bulb yield (170.60 q ha

^{1}) over 20 kg S ha^{-1} and no sulfur application but was on per with application of 60 kg S ha^{-1}. Similar trend was observed in yield components and sulfur uptake. Significantly higher TSS (12.26 per cent) and pyruvic acid (3.1 micro mole/g) content in onion bulb were recorded in 60 kg S ha^{-1} over 20 kg S ha^{-1} and no sulfur application, but was on par with 40 kg S ha^{-1}.

Josephine *et al.* (2006) conducted a field experiment during 2001 and 2002 in Annamalai, Tamil Nadu, India, to optimize the source (0, 30, 60 and 90 kg/ha) and dose (superphosphate, gypsum and ammonium sulfate) of S for maximum yield of onion in Typic Ustifluvent soil. Superphosphate at 60 kg/ha gave maximum plant height, number of leaves per plant, number of tillers per plant, bulb length, bulb diameter, number of bulbs per plant, individual bulb weight and bulb yield.

Jaggi *et al.* (2006) conducted an experiment during the winter (rabi) seasons of 2000-01 and 2001-02, at Palampur, Himachal Pradesh, India, to compare the effects of 2 sources of sulfur on onion (*Allium cepa)* under acidic soil and to work out their optimum doses. The results showed the superiority of gypsum both at linear and curvature level by 0.0721 and 0.00066 tone/ha. The optimum level of S< sub>95</ sub> was determined to be 42.14 kg/ha while that of gypsum was determined to be 55.17 kg/ha.The returns over fertilizer cost for S< sub>95</ sub> and gypsum. The study clearly indicates that gypsum is a superior sulfur source for onion crop.

Qureshi and Lawande (2006) the effects of sulfur on the yield, quality and storability of onion cv. B 780 were determined in a field experiment conducted in Maharashtra, India during the kharif season of 2001-03. Elemental sulfur (15, 30, 45, 60 and 75 kg/ha) was applied along with 100 kg N/ha, 50 kg P/ha and 50 kg K/ha. Onion responded significantly to 30-75 kg S/ha. The highest bulb yield of 39.1 t/ha was recorded with the application of 75 kg S/ha. Sulfur content in bulbs increased by 48.0% due to the application of 75 kg S/ha over the NPK treatment.

Jaggi (2005) conducted an experiment in Palampur, Himachal, Pradesh, India during 2000-01 and 2001-02 to investigate the effect of S rates (0, 15, 30 and 60 kg/ha) and sources (S95 and Gypsum) on the yield performance of onion cv. Patna Red. The fresh and dry weights of onion yield, plant height, leaf number/plant and weight per 10 bulbs increased with increasing S rates up to 30 kg/ha.

Losak (2005) conducted an experiment and showed that the effects of N (g per pot, as ammonium nitrate) and S (mg/kg, as sulfate) fertilizers (0.0 + 25.0, 0.9 + 25.0, 0.9 + 40.0, or 0.9 + 60.0) on the performance of onion (cv. Stutgartska) were studied in a pot experiment. The application of 0.9 g N per pot and 25.0-40.0 mg S/kg increased the weight and diameter of bulbs by 50.3-62.3 and 20.9-23.1%, respectively, and reduced the nitrate content of bulbs by 10.8-25.2% over the control (0.0 g N per pot + 25.0 mg S/kg, which is the amount of S in the soil). The increase in the level of sulfate to 40 and 60 mg/kg increased the bulb yield.

Sankaran *et al.* (2005) conducted an experiment in Coimbatore, Tamil Nadu, India to determine the effects of sulfur treatments (0, 15, 30 and 45 kg single superphosphate (SSP)/ha) on the yield and nutrient uptake of onions cv. CO3. SSP at 45 kg/ha resulted in a significant increase of 9.6% onion yield over the control and it was at par with SSP treatment at 30 kg/ha. Sulfur application significantly increased the uptake of N, P. K and S by onion crop. Sulfur application had considerable influence on availability of sulfur, whereas the availability of N, P and K was not significantly influenced. Based on agronomical use efficiency and value cost ratio, the application of SSP at 30 kg/ha is the optimum concentration to increase the onion yield.

Shamima and Huq (2005) conducted a field experiment at Gazipur, Bangladesh during the 1995-96, 1996-97 and 1997-98 rabi seasons to determinate the yield, content and uptake of onion cv. Faridpuri, when applied with S at 0, 15, 30, 45, 60, 75 and 90 kg/ha. The S content, uptake and yield of onion significantly responded to different S fertilizers application. Increasing S levels up to 45 kg/ha increased the S content, uptake throughout the seasons and also produced the highest bulb yield. Zero kg S/ha produced the lowest bulb yield.

Jaggi (2004) conducted an experiment and reported that the effects of S (0, 15, 30 or 60 kg/ha) applied through gypsum or the slow released fertilizer S 95 on the composition and yield of onion (cv. Patna Red) were studied in Palanpor, Himachar Pradash, India during the winter of 2000-01 and 2001-02. Application significantly increased bulb and foliage yields and S content and uptake by foliage and bulb + foliage. The dry weight of bulb and foliage, and N and S uptake by bulbs and bulb + foliage increased with increasing S rate up to 30 kg/ha. At 30 kg/ha, the bulb yield increased by 105% over no S.

Poonam *et al.* (2004) conducted an experiment on onion cv. Pusa Red plants were treated with gibberellic acid (GA; 100, 150 and 250 ppm) and sulphur (15 and 30 kg/ha) in Uttar Pradesh, India during the winter season of 1998-99. Onion bulbs were biggest (20.20 cm) with the application of 250 ppm GA + 30 kg S/ ha. Application of 15 kg S/ha, 150 ppm GA + 15 kg S/ha and 150 ppm GA + 30 kg S/ha resulted in the highest moisture (89%), carbohydrate (27.62%) and protein content (1.40%) of onion respectively.

Shakirullah *et al.* (2002) conducted an experiment on the effect of different levels of sulphur on yield and pungency of onion was carried out at the agricultural research station (North), Mingora Swat during the year 1999-2000. The result revealed that most of the parameters were significantly affected by different levels of Sulphur. The mean data indicated that the maximum fresh yield (60.66 t/ha) was obtained with 160kgS/ha while minimum fresh yield (66.50 t/ha) was obtained at 20 kg S/ha. Maximum plant height (66.44 cm) observed in plot with 100 kg S/ha and minimum Plant height (56.66 cm) was observed in control. Maximum bulb weight (156.66) was examined in treatment where S was applied@ 160 kg/ha while minimum bulb weight (120.77g) was observed in treatment with 80 kg S/ha. Minimum number of bulbs/kg (8.633) was obtained 160 kg S/ha while maximum number of bulbs (11.433per kg) obtained with no sulphur.

Suman *et al.* (2002) conducted a field experiment in Bihar, India during 1998-99 and 1999-2000 to study the effect of S and B on the growth, yield and quality of onion cv. Nasik Red. The treatments comprised S at 0, 20, 40 and 60 kg/ha; and B at 0, 1 and 2 kg/ha. Plant height, the number of leaves, leaves length, leaves width, bulb size, bulb weight and bulb yield significantly increased up to 40 S kg/ha and 1 kg B/ha. The neck thickness and storability decreased with increasing levels of S but increased with increasing levels of B. The treatment combination of 40 kg S + 1 kg B/ha gave the highest net return and benefit cost ratio.

El-Desuki and Sawan (2001) conducted an experiment in Shalakan, Kalubia Governorate, Egypt to evaluate the effect of NPK (low, 66:48; 48 kg/feddan) on the yield and quality of onion. Growth, NPK uptake yield and bulb quality increased with increasing level of NPK fertilizer up to 132:96:96 kg/feddan and with increasing level of S fertilizer up to 450 kg/feddan. NO_3N accumulation in the onion bulb gradually and significantly increased with increasing level of NPK fertilizer up to the highest level and with increasing level of S fertilizer up to 450 kg/feddan.

Ajay and Onkar (1999) conducted an experiment and reported that onion (cv. Afrifound Light Red) plants were grown in pots under conditions of S sufficiency or S deficiency. Plants received S were healthy, had dark green leaves, developed a good root system and produced large bulbs which developed a good red color. Plants grown under S-deficient conditions had fewer leaves which were shorter and paler in color, produced fewer rootlets and produced smaller bulbs which were light red in colopur, compared with S-treated plants.

Nagaich *et al.* (1999) conducted an experiment on the effects of 4 rates each of sulphur (0, 20, 40, and 60 kg/ha) and potassium (0, 40, 80 and 120 kg/ha) were studied during 1995-96 and 1996-97 on growth characters, yield attributes, yield and quality of onion on a sandy loam soil in Madhya Pradesh, India.Application of 60 kg S/ha significantly increased plant height, number of leaves, bulb weight per plant and horizontal and vertical diameters of bulb over the control. Onion seed increased significantly up to 60 kg S/ha. Uptake of P, K and S also significantly increased at rates up to 60 kg S/ha. Application of 80 kg K_2O/ha significantly increased bulb weight per plant and horizontal diameter of the bulb. Seed yield also increased significantly with 80 kg K_2O/ha, but a further increase decreased yield. Uptake of P, K and S was highest at 80 kg K_2O/ha.

Anwer *et al.* (1998) observed that the application of nitrogen, phosphorus, potassium, sulphur and zinc increased the number of leaves plant^{-1} along with higher bulb yield of onion with the increasing rates up to 150 kg N, 120 kg P_2O_5, 120 kg K_2O, 20 kg S and 5 kg Zn ha^{-1} at Jessore area.

Nagaich *et al.* (1998) conducted a field experiment at Gwalior and reported that S was applied at O, 20, 40 or 60 kg / ha and K and 0, 40, 80 or 120 kg/ha to Nasik Red onions. Bulb yields increased with S rate and were highest at and intermediate K rate (80 kg/ha).

Nasiruddin *et al.* (1993) conducted experiment on the effect of potassium and sulphur on grown and yield of onion at Mymenshing, Bangladesh. They reported that application of both potassium and sulphur either individually or combinedly increased the plant height, leaf production ability of the plants, bulb diameter, bulb weight as well as the bulb yield. They recommended 100 kg potash and 30-kg sulphur per hector for cultivation of onion for Bangladesh Agricultural University farm soil.

Ahmed *et al.* (1988) studied different levels of nitrogen (0, 60 and 120 kg ha^{-1}) and sulphur (0, 12, 24 and 36 kg ha^{-1}) on local cv. Faridpur Bhati. Both nitrogen and sulphur significantly increased the yield. However, a combined application of nitrogen and sulphur produced higher yield than nitrogen or sulphur alone.

Nitrogen at 60 kg ha^{-1} together with sulphur at 36 kg ha^{-1} produced maximum yield (10.44 t ha^{-1}).

Field studies with the cv. Monaich were conducted by Brown et al. (1988). They compared per plant-bended sulphur coated urea (SCU) with per plant – banded and spilt applications of urea and found total and large bulb (<76 mm in diameter) yields, and N uptake in bulbs and leaves from SCU were significantly higher under N condition than with per plant Urea, but did not differ significantly from those in the split urea treatment.

Singh and Dhankhar (1988) stated that higher level of N reduced bolting and increased plant growth, ascorbic acid content and yield. Potassium also reduced bolting and neck thickness and increased plant growth, yield, ascorbic acid content, dry matter, sugar and S content of the bulbs.

A field trial was conducted by Soto (1988) with critical level for P, K and S and response to N. The rate was 100 kg ha^{-1} for each of P_2O_5 and K_2O and 50 kg S ha^{-1}. The applied nitrogen @ 0, 55, 100 and 150 kg ha^{-1} and observed that 50 kg N ha^{-1} was the best for yield response.

Sulphur is found to be an important fertilizer having significant contribution to the yield of onion cv. Yellow Granex. Peterson (1979) found that the yield was increase by 22.48 percent with the application of sulphur at 17 kg/ha.

2.2 Effect of Zinc on the Growth and Yield of Onion

Zinc is a micronutrient which is reputed for plant growth and development relatively in small amount. Zinc is involved in a diverse range of enzyme of system. The function of Zn includes; auxin metabolism, influence on the activists of dehydrogenises and carbonic abhydrase enzymes, synthesis of cytochrome and stabilization or ribosomal fraction (Tisdale, 1984).

Rafique *et al.* (2008) reported that zinc deficiency is a global nutritional problem in crops grown in calcareous soils. In a greenhouse experiment, Zn requirement, critical concentrations in diagnostic parts and genotypic variation were assessed using four onion cultivars grown in a Zn-deficient calcareous soil. Five rates of Zn, ranging from 0 to 16 mg Zn kg^{-1} soil, were applied as zinc sulphate ($ZnSO_4 \cdot 7H_2O$) along with adequate basal fertilization of nitrogen, phosphorus, potassium, and boron. Zinc application significantly increased dry bulb yield and maximum yield was produced with 8 mg Zn kg^{-1} soil. Application of higher rates did not improve yield further. The cultivars differed significantly in Zn efficiency. Zinc content in mature bulb also appeared to be a good indicator of soil Zn availability status.

Khan *et al.* (2007) conducted an experiment and showed that the response of onion (*Allium cepa*) growth and yield to different levels of nitrogen and zinc in Swat valley was studied at Agricultural Research Station (North) Mingora Swat, during 2003-04. Nitrogen levels under trial were 0, 100 and 200 kg per hectare, while zinc levels were 0, 5, 10 and 15 kg per hectare. The statistical analysis revealed that both nitrogen and zinc significantly affected all the growth parameters studied. Maximum leaf length (41.81 cm), was recorded in plots fertilized with 100 kg nitrogen and 10 kg zinc per hectare, whereas maximum plant height (56.33 cm), bulb weight (136.5 g), yield (22280 kg) per hectare were recorded in plots fertilized with 100 kg nitrogen per hectare and zinc 10 kg per hectare.

Shrivastava *et al.* (2005) conducted a study in Pantnagar, Uttaranchal, India to investigate the effect of Zn and B on the yield, quality and storability of garlic cv. Pant Lohit. Zn was supplied as zinc sulphate at 0, 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2% while B was applied as boric acid at 0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0%. Yield, growth and quality parameters such as plant height, leaves per plant, leaf length, neck diameter, bulb yield per plot, bulb weight, cloves/bulb, total soluble solids content and total yield assessed at 60 and 90 DAP. Boric acid at 0.2% resulted in the maximum bulb total soluble solids content. Zinc sulphate at 0.4% resulted in bulb yield and weight, while a rate of 1.2% resulted in maximum total soluble solids content.

Bybordi and Malakouti (2003) conducted a completely randomized factorial block experiment with 27 treatments and 3 replications was carried out during 2000-01 growing seasons in Bonab and Khosroshahr regions of East Azarbayjan to determine the effect of rates of potassium, zinc and copper on the yield and quality of Azarshahr red onions (*Allium cepa*) under saline soil conditions. Each nutrient was applied at three rates, namely, 1 - based on soil tests (200 kg potassium sulfate, 40 kg zinc sulfate, and 20 kg copper sulfate); 2 - one and a half times the soil test levels (300 kg potassium sulfate, 60 kg zinc sulfate, and 30 kg copper sulfate); and 3 - twice the recommended soil test levels (400 kg potassium sulfate, 80 kg zinc sulfate and 40 kg copper levels) at both locations of medium salinity conditions. The results showed that potassium and zinc significantly affected the onion yields (alpha =0.01), TSS contents, as well as the nitrate concentrations of the onion bulbs at Bonab region. The effect of potassium, zinc and copper treatments on the onions protein contents were statistically significant at 1% level. The highest protein content was obtained with the application of K1, Zn and Cu at rates twice the soil test requirements. The highest level of vitamin C [ascorbic acid] was measured with combined rates of 400 kg potassium sulfate, 80 kg zinc sulfate and 40 kg/ha of copper sulfate.

Selveraj *et al.* (2002) conducted field trials on garlic var. local during the rain (April-July) and autumn cropping (October-January, 1996) seasons in Nilgris, Tamil Nadu, India to study the effect of zinc, boron and molybdenum foliar sprays on yield and rubberization. Boron at 0.1% (w/v) plus sodium molybdate at 0.05% (w/v) recorded the highest healthy bulb yield of 24.9 t/ha, the increase being 23.5% over unsprayed control and reduced premature field sprouting of cloves in the field itself instead of bulking and reduced production of spongy bulbs locally known as rubberization.

Attia (2001) conducted field experiment in Assiut, Egypt during 1998/1999 and 1999/2000 to study the effects of sugarcane filter mud cake (SFMC; 0.0, 2.5 and

5.0 t/feddan), elemental S (800 kg/feddan) under 4 regimes (control, 100% pre-transplanting, 100% post-transplanting or 30 days after transplanting, and 50% pre-transplanting + 50% post-transplanting) and methods of Fe, Mn and Zn application (soil dressing and foliar spray) on the yield and nutrient content of onion. The application of SFMC, elemental S and micronutrients (Fe, Mn and Zn) significantly enhanced the yield, dry matter percentage, and total N, P, K, Fe, Mn and Zn contents of onion bulbs.

Kumar and Das (2000) conducted a field experiment on silty clay loam soil (Aeric Haplustalf pH 6.7) to study the effect of Zn (0, 10 and 20 kg/ha) and S (0, 30 and 60 kg/ha) application on their availability in soil in relation to yield and nutrition of onion cv. N-53. The results showed that the amount of DTPA-extractable Zn and 0.15% $CaCl_2$ extractable SO_4-S in soil increased due to application of Zn as Zn-EDTA and S as the element, respectively. The yield of onions was highest (18.04 t/ha) in the Zn at 10 kg/ha treatment.

Gamili *et al.* (2000) conducted two field trials on clay soil in El Menofiya Governorate, Egypt for two growing seasons (1997/98 and 1998/99) to study the effect of zinc, iron, manganese and some different foliar fertilizers (Byfolan, Foliatren, Wuxal Zn, Wuxal Mn and Wuxal suspensions) on the vegetative growth parameters, bulb fresh and dry weight, marketable bulb yield and storability of onion (cv. Giza 20). The micronutrients and the tested foliar fertilizers were sprayed in two equal doses, while the recommended NPK fertilizers were added as soil application. The growth parameters (plant height, bulb diameter, number of leaves per plant, fresh bulb weight, and total fresh and dry weight per plant) were positively affected by application of micronutrients and the tested foliar fertilizers. Byfolan and Foliatren foliar fertilizers especially significantly increased most of the growth parameters, fresh and dry bulb weight, marketable yield and storability. Bulb diameter and quality, number of leaves, and fresh and dry yield were significantly affected by the different Wuxal suspensions as well as by Byfolan and Foliatren foliar fertilizers. Wuxal Zn significantly increased fresh and dry bulb weight.

A field experiment was conducted at the Agricultural Research Station, Sids, Beni Sweif Governorate, Egypt, during 2 successive seasons (1995-96 and 1996-97) by Sliman *et al.* (1999) to study the effects of Fe, Mn, Zn or Cu applied as sulfates (CuSO4 at 1 g/litre and the others at 3 g/litre) and B applied as borax (0.7 g/litre) on onion cv. Compest 16 yield and nutrient content. Two spray applications were made, at 2 and 4 weeks after transplanting. The highest dry yield was obtained by foliar application of $ZnSO_4$; this treatment increased yield over the control by 23.6 and 27.8% over the 2 seasons, respectively.

Das and Kumar (1999) conducted field trials at Nadia, West Bengal, India, during 1994-96; onion cv. N-53 was grown as a Rabi crop on a sandy loam soil. Three rates of Zn (0, 10 or 20 kg/ha, as Zn-EDTA) and S (0, 30 or 60 kg/ha, as elemental sulfur) were applied. The application of Zn alone at 10 kg/ha resulted in the highest yield (18.40 t/ha).

Pena *et al.* (1999) carried out a study during 1997 in Venezuela with onions cv. Texas early granex 502, sown in black polyethylene bags. Fertilizer treatments were different combinations of S (16 kg/ha), Mg (8 kg/ha), Zn (2.52 kg/ha) and B (5.25 kg/ha), with and without NPK (120 kg N/ha, 60 kg P_2O_5/ha and 120 kg K_2O/ha). One plot received 1000 kg S/ha, 30 days before transplanting. The application of 2.52 kg Zn/ha (as ZnS) significantly increased crop yield, and bulb weights. S, Mg and B fertilizers had no significant effects. The best treatments were NPK + Zn, NPK + ZnMg, NPK + B, NPK + ZnB and NPK + SZnB.

Meena and Singh (1998) conducted a pot experiment on a sandy Aridisol, a sandy clay loam Inceptisol and a clayey Vertisol during the rabi season of 1995-96 raising onion as the test crop. The crop was grown to maturity. Dry weights were recorded for tops and bulbs separately. The results showed that S and Zn treatments significantly enhanced the dry weight of onion tops and bulbs.

According to the experiments undertaken by Munsi *et al.* (1998) in West Bengal using onion cv. N-53 during the rabi [winter] seasons of 1994-96, 0, 10 or 20 kg Zn/ha as Zn-EDTA and 0, 30 or 60 kg S/ha as elemental sulfur were applied before planting and studied the effect on yield and storage quality. The results showed that application of Zn alone at 10 kg/ha gave the highest bulb yield (18.4 t/ha).

Singh and Tiwari (1996) reported the results of an experimental trial with onion cv. Pusa Red plants in a silty loam soil sprayed at 60 and 70 days after transplanting with 1, 2 or 3 ppm. Zn + 50,100 or 150 ppm Fe + 0.25, 0.50 or 0.75 ppm B. The highest bulb yield was 121.40g/pot (5 plants were obtained with 3 ppm Zn + 100 ppm , Fe + 0.75 ppm B).

Singh and Tiwari (1995) also conducted an experiment with Pusa Red onion seedling, transplanted in mid January, and were given foliar sprays of 1-3 ppm Zn, 50-150 ppm Fe and 0.25-0.75 ppm B at 60 and 70 days after transplanting (DAT). Sprays of 3 ppm Zn singly or combined with Fe and B were the most effective for increasing all the growth parameters studied at 90 and 120 days after transplanting (DAT) except leaf FW at 120 DAT. Plant height and bulb fresh weight (FW), equatorial and polar diameters, volume and yield at 120 days after transplanting (DAT) were highest with sprays of 3 ppm Zn + 100 ppm Fe + 0.75 ppm B.

Chowdhury *et al.* (1995) examined the distribution of zinc fraction in the soil of Bangladesh Agricultural University Farm, Mymensingh. It was noticed that phosphorus reduced soil Zn concentration showing an interaction between two elements.

El hawary *et al.* (1991) stated that the croup receving foliar spray with 500g vitaforte (integrated foliar fertilizer)/0.42 ha or with 250, 500 or 750 g foliar (9.3% Mn,2.8%Zn)/0.4 ha. Onion yield was 4.50t/0.42ha without foliar fertilizer and the highest (4.93t/0.42 ha) with vita forte or the 2lowerrate of fulaz.

In another experiment Jitendra *et al.* (1991) conducted an experiment with onion cultivars Pusa Red and Hisar $^{-2}$ growing in the field received different rates of N, K and Zn. After harvest, bulbs were store in cloth bags under ambient conditions. Observation on storage quality was made at intervals up to 120 days. Bulbs weight loss and the incidence of rooting ad sprouting were increased by increasing application of N (80-160 kg/ ha) and reduced by application of K_2O (100 kg/ha). Application of K_2O + 25 $ZnSO_4$/ha and result in poorer storage quality than K_2O alone. Bulbs grown with 80 kg N/ha +100 kg had the best storage quality.

Jitendra *et al.* (1989) their trial of onion cvs applied N at 80, 120, or 160kg/ha K_2O at 100+$ZnSo_4$ at 25kg/ha. High N levels increased plant growth and yield. K alone and with Zn also increased plant growth. Yield and DM contents, the highest yields (27.48-32.68 t/ha) were obtained with the higher rate of N.

Jawaharlal *et al.* (1986) in their trails with onion, applied $ZnSO_4$ $FeSO_4$ each at 25 or 50 kg/ha to the soil or at 0.5 or 1% to the foliage. Bulb yield were the highest (17.1 t/ha) with the soil application of Zn or Fe at the highest rate. With foliar applications, the yields were just were over 13 t/ha.

Lal and Maurya (1981 a) reported that plant height, number of roots and leaves / plants, fresh and dry weight of plants and number of leaves/plant, bulb size, and bulb fresh and dry weight were determined in 2-year trials with the onion cv. Poona Red grown in sand and receiving Zn at 1,2 or 3 ppm. Bulb fresh and dry weights were greatest in plants receiving Zn at 3 ppm.

Maurya and Lal (1975a) observed that sand culture onions responded well to Zn nutrition (1.0-3.0 ppm) as regards yield and bulb quality.

2.3 Combined effect of S and Zn on the yield of onion

Mukesh and Das (2000) conducted an experiment on silty clay loam soil to study the effect of Zn (0, 10 and 20 kg/ha) and S (0, 30 and 60 kg/ ha) application on their availability in soil in relation to yield and nutrition of onion. The result showed that the amount of DTPA-extractable Zn and 0.15% $CaCl_2$ extractable SO_4 –S in soil increased due to the application of Zn as Zn-EDTA and S as the element respectively. However, the magnitude of increase for both Zn and S was the highest in combined applications (Zn_{20}, S_{60}), exhibiting as synergistic relationship. The yield of onion was highest (18.04 t/ha) in the Zn at 10kg/ha treatment. In combined treatments, the best yield (16.44 t/ha) was seen in the Zn_{20} S_{30} treatment.

Mukesh *et al.* (2000) conducted an experiment and showed that in a field experiment at Kalyani on a silty clay loam (Haplustalf) of p^H 6.7, onion cv. N-53 was given 0, 10 or 20 kg Zn/ha and 0, 30 or 60 kg S/ha. Bulb yield was highest (18.4 t/ha) when 10 kg/ha Zn alone was applied. Data are also tabulated on TSS, ascorbic acid, reducing sugar, moisture, pyruvic acid and anthocyanin contents.

Mukesh (2000) conducted a field experiment at Kalyani on a silty clay loam (Haplustalf) of pH 6.7, onion cv. N-53 was given 0, 10 or 20 kg Zn/ha and 0, 30 or 60 kg S/ha. Bulb yield was highest (18.4 t/ha) when 10 kg/ha Zn alone was applied. Data are also tabulated on TSS, ascorbic acid, reducing sugar, moisture, pyruvic acid and anthocyanin contents.

Mukesh *et al.* (2000) conducted an experiment and reported that the application of Zn alone (10 kg/ha as Zn-EDTA) recorded highest yield of onion (18.4 t/ha). This treatment exhibited lower percentage of rooting (13.7 %), sprouting (2.1 %) and physiological weight loss (7.71 %) for up to 120 days storage in perforated paper compared with other treatments. Application of Zn alone or in combination with S (30kg/ha) reduce rotting, sprouting and physiological weight loss during storage.

Mukesh *et al.* (1999) conducted an experiment on the yield and storage life of onion (*Allium cepa* L.) as affected by zinc and sulphur application in field trials at Nadia, West Bengal, India, during 1994-1996 and showed that application of Zn alone or with low rate of S (30 kg/ha) resulted in low rate of rotting, sprouting and physiological weight loss. All these storage parameters gradually increased with an increase in storage duration irrespective of storage method, but they significantly lower for onions kept in 30% perforated brown paper packets; the application of Zn alone at 10 kg/ha resulted in the highest yield (18.40 t/ha) with a low percentage of rotting (11.1%). sprouting (1.8%) and physiological weight loss (3.1%) during 60 days^{-1} storage.

Meena and Singh (1998) conducted an experiment on sandy aridisol, a sandy clay loam inceptisol and clay vertisol during the rabi season of 1995-96 raising onion. The result showed that S and Zn treatments significantly enhanced the dry weight of onion tops and bulbs. Higher level of 30 mg S kg^{-1} caused an antagonistic effect. An S dose of 20 mg S kg^{-1} on S-deficient soils and 10 mg S with 5 mg Zn^{-1} kg for low S soils was appropriate for better onion yields. A total S uptake by onion crops on all three soils was enhanced significantly. The aridisol was the most responsive to sulphur followed by the inceptisol.

Mukesh *et al.* (1998) conducted an experiment in West Bengle using onion during rabi seasons of 1994-96, and reported that 0, 10 or 20kg Zn/ha as Zn-EDTA and 0,30 or 60 kg S/ha as elemental S were applied before planting and the effects on storage quality. Applying Zn alone at 10kg/ha. Gave the highest bulb yield (18.4 t/ha) and the lowest incidence of sprouting (1.9%) rooting (12.2%) and physiological weight loss (5.6%) when bulb weight perforated paper for up to 90 days. Zn application decreased bulb neck thickness and moisture content while S applications increase them.

Chapter 3
Materials and Methods

MATERIALS AND METHODS

This chapter arranges the materials and methods including a brief description of the experimental site, onion variety, soil, climate, land preparation, experimental design, treatments, and cultural operations, collection of soil and plant samples etc. and analytical methods used for the experiment. The details of research procedure are described here.

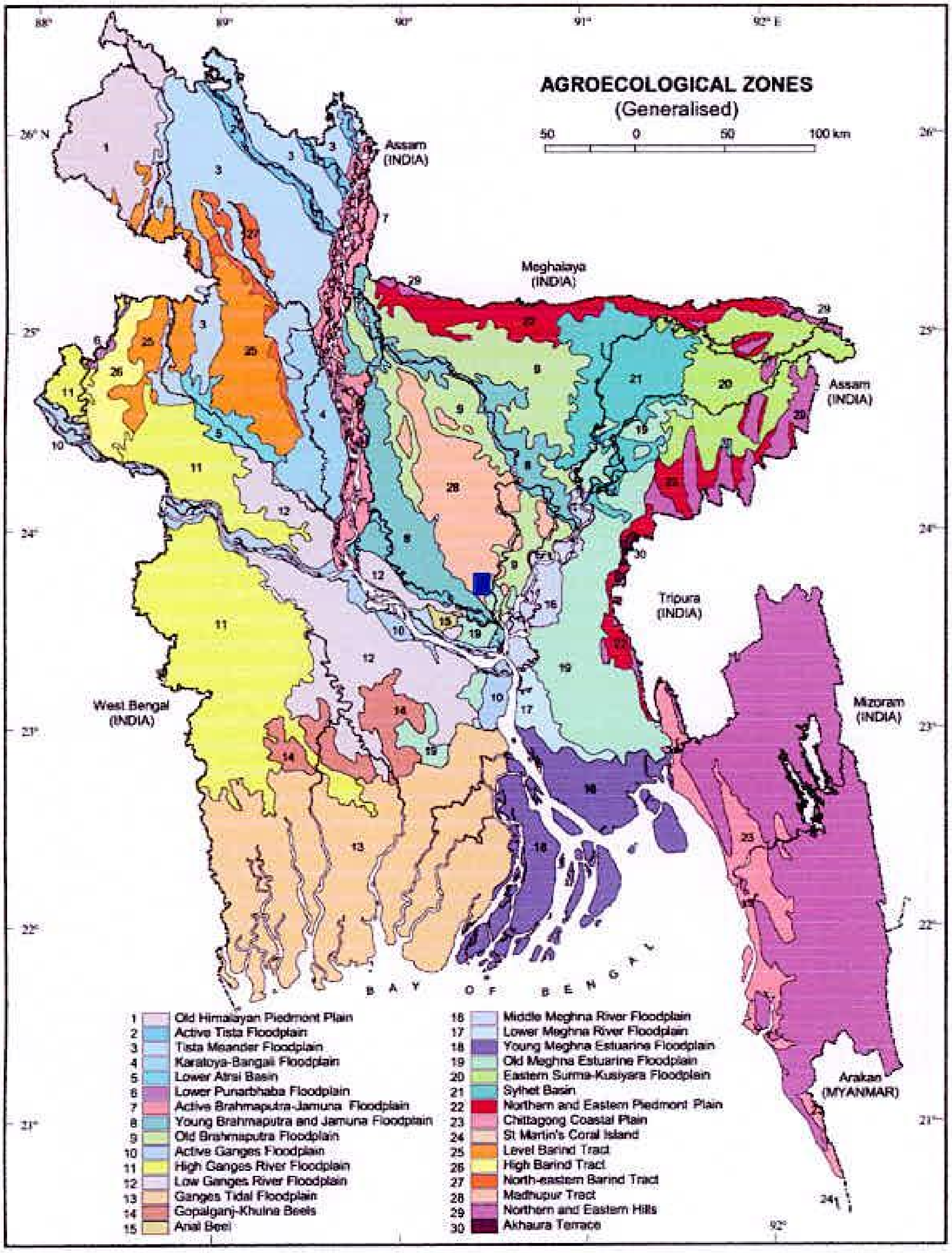
3.1 Description of the experimental site

3.1.1 Location

The research work was conducted in *rabi* season at Sher-e-Bangla Agricultural university Farm, Sher-e-Bangla Nagar, Dhaka-1207 during the *rabi* season of December, 2007. It is located at 90.335^0E longitude and 23.774^0 latitude. The specific location of experimental site is presented in Figure 1.

3.1.2 Soil

The soil of the experimental field belongs to the Tejgaon series of AEZ No. 28, Madhupur Tract and has been classified as Shallow Red Brown Terrace Soils in Bangladesh soil classification system. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, ground and passed through 2 mm sieve and analyzed for some important physical and chemical parameters. Some initial physical and chemical characteristics of the soil are presented in Table 1.



■ **Location of the experimental site**

Figure 1. Map showing the experimental site under study

Table 1. Physical and chemical properties of the initial soil

Soil properties	Value
A. Physical properties	
1. Particle size analysis of soil.	
% Sand	28.2
% Silt	41.20
% Clay	30.6
2. Soil texture	Silty Clay
B. Chemical properties	
1. Soil pH	5.6
2. Organic carbon (%)	0.68
3. Organic matter (%)	1.17
4. Total N (%)	0.08
5. C : N ratio	9.75 : 1
6. Available P (ppm)	13.42
7. Available K (ppm)	0.10
8. Available S (meq/100g soil)	23.74
9. Available Zn (ppm)	3.10

3.1.3 Climate

The experimental area has sub tropical climate characterized by heavy rainfall during May to September and scanty rainfall during rest of the year. The annual precipitation of the site is 2152 mm and potential evapotranspiration is 1297 mm. The experiment was carried out during *rabi* season of 2007-08. Air temperature during the cropping period ranged from 13.32^{0}C to 34.12^{0}C. The relative humidity varied from 62.55% to 96.70% and monthly rainfall varied from 0.64 mm to12.12 mm from the beginning of the experiment to harvest. The monthly maximum and minimum temperature, humidity and rainfall of the site during the experimental period are given in appendix Table 1.

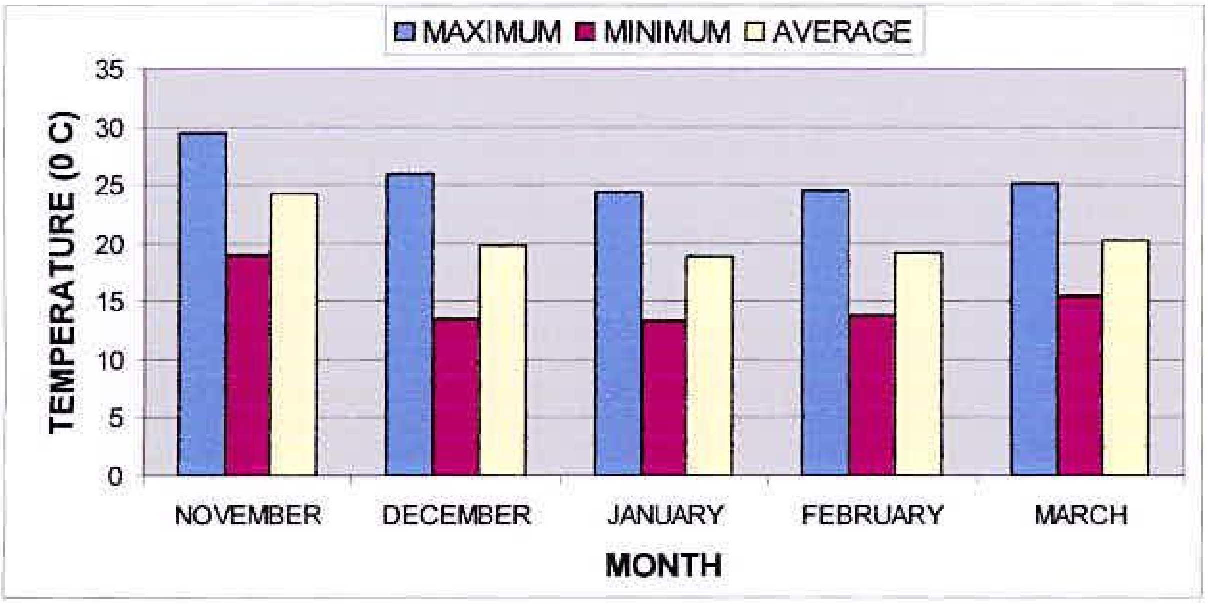


Figure 2. Monthly average, maximum and minimum air temperature (°C) of the experimental site, Dhaka during the growing time (November, 2007 to March 2008)

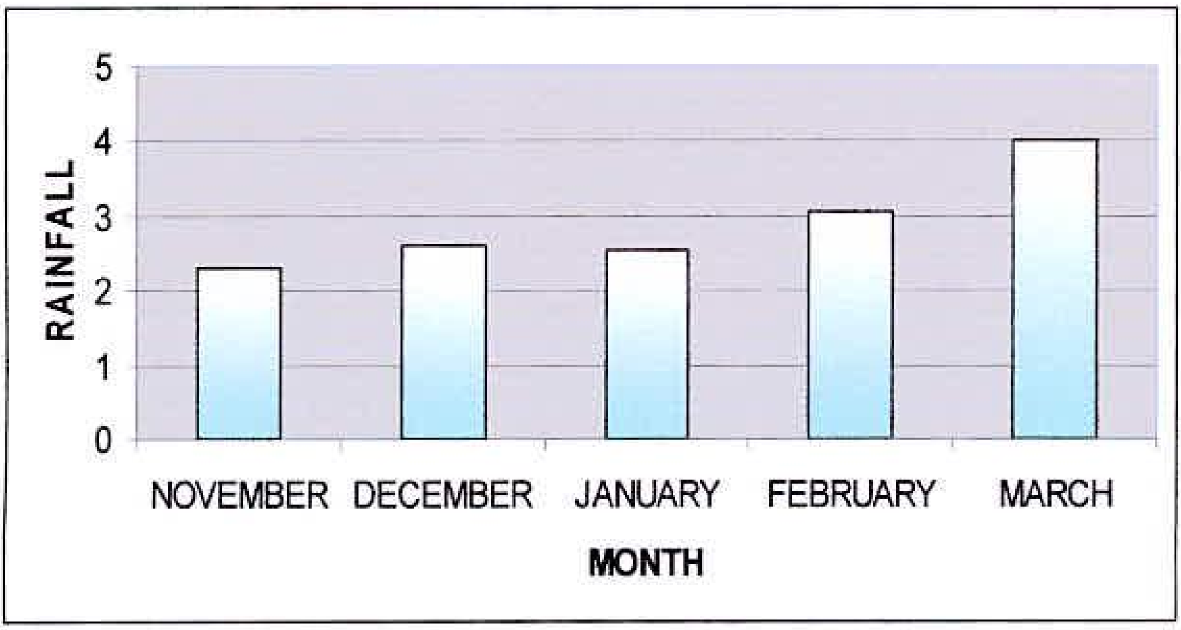


Figure 3. Monthly total rainfall (mm) of the experimental site, Dhaka during the growing period (November, 2007 to March 2008)

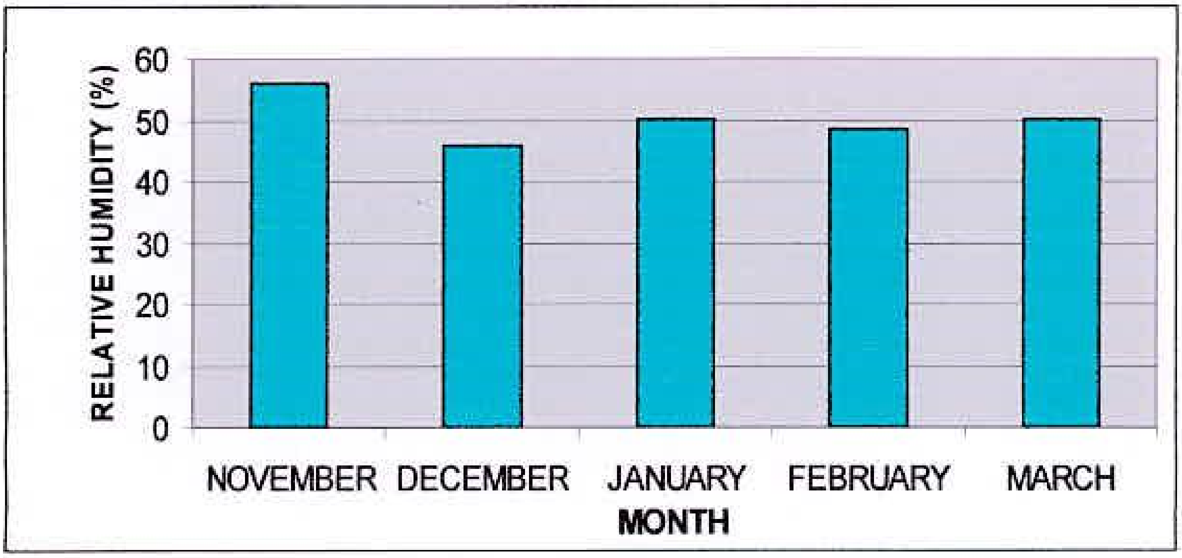


Figure 4. Monthly average relative humidity (%) of the experimental site, Dhaka during the growing period (November, 2007 to March 2008)

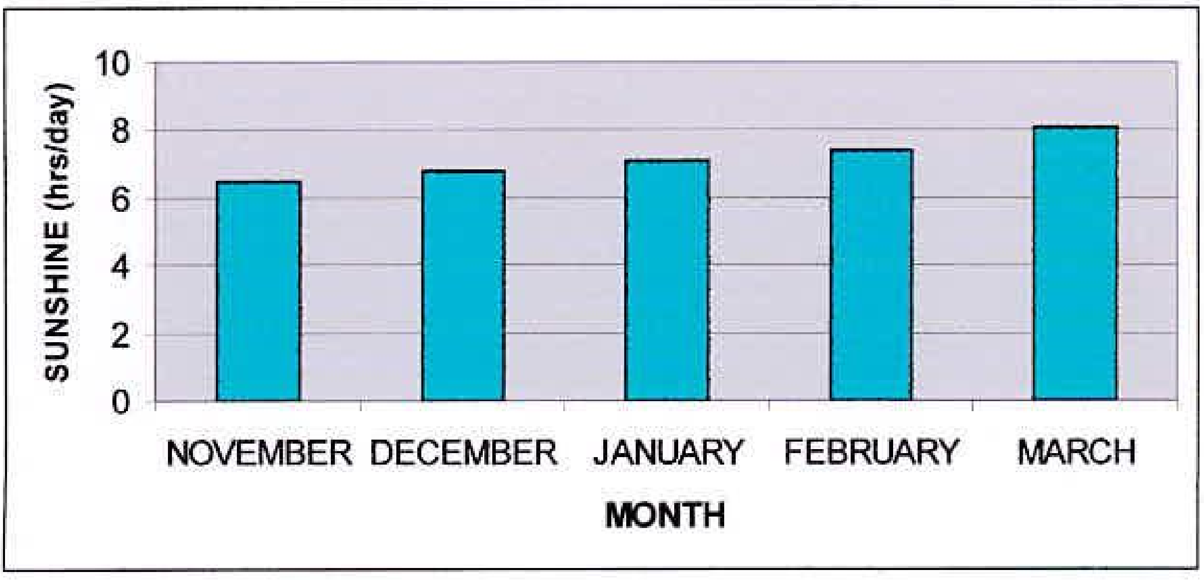


Figure 5. Monthly average sunshine (hrs/day) of the experimental site, Dhaka during the growing period (November, 2007 to March 2008)

3.2 Description of the winter onion variety

Taherpuri is a local, and well adapted variety in our country, a high yielding variety of winter onion was selected for this experiment. This onion variety is well recognized and mostly cultivated in different districts of Bangladesh. The bulbs are highly pungent with pinkish red skin. Nearly 50-60 % bulbs are of single type mature within 90-100 days and yield of bulb is about 14 to 18 t ha^{-1} (Anonymous, 2000). The germination percentage of the seed was 85.

3.3 Raising of seedlings

The land selected for raising seedlings was light in texture and well drained. The land was ploughed well and left for drying for 10 days. Bigger clods were broken into pieces and finally the soil was made loose and friable. All weeds and stubbles were removed and then the soil of seedbeds were mixed with well-decomposed cow dung @ 10 t ha^{-1}; applying Furadan 3 G @ 20 kg ha^{-1} were covered by polythene for two days. The seedbeds were 3 m × 1 m in size with height of about 20 cm. Onion seeds were soaked over night (12 hours) in water and allowed to burgeon in a piece of moist cloth keeping in the sunshade for one day. Then seeds were sown directly in the raised seedbed on 03rd November' 2007 for raising seedlings. Irrigation was provided regularly and seedbeds were always kept free from weeds. The young seedlings were exposed to dew by night and mild sunshine in the morning and evening. To retain the soil moisture and to save the seedlings from direct sunlight and rain, shades were given over the seedbeds. Seedlings were not attacked by any kinds of insects and diseases.

3.4 Treatments of the experiment

The experiment consists of two factors viz. Sulphur (S) and Zinc (Zn). Doses of sulphur were 0, 10, 20, 30 kg/ha and doses of zinc were 0, 1, 3, and 4 kg/ha. So, total numbers of treatment combinations were 16. Details of the treatments are presented below:

T_1 = No Sulphur (S) + No Zinc (Zn)	$S_0 + Zn_0$
T_2 = No S + 1 kg Zn ha^{-1}	$S_0 + Zn_1$
T_3 = No S + 3 kg Zn ha^{-1}	$S_0 + Zn_3$
T_4 = No S + 4 kg Zn ha^{-1}	$S_0 + Zn_4$
T_5 = 10 kg S ha^{-1} + No zinc	$S_{10} + Zn_0$
T_6 = 10 kg S ha^{-1} + 1 kg Zn ha^{-1}	$S_{10} + Zn_1$
T_7 = 10 kg S ha^{-1} + 3 Zn ha^{-1}	$S_{10} + Zn_3$
T_8 = 10 kg S ha^{-1} + 4 kg Zn ha^{-1}	$S_{10} + Zn_4$
T_9 = 20 kg S ha^{-1} + No Zn	$S_{20} + Zn_0$
T_{10} = 20 kg S ha^{-1} + 1 kg Zn ha^{-1}	$S_{20} + Zn_1$
T_{11} = 20 kg S ha^{-1} + 3 kg Zn ha^{-1}	$S_{20} + Zn_3$
T_{12} = 20 kg S ha^{-1} + 4 kg Zn ha^{-1}	$S_{20} + Zn_4$
T_{13} = 30 kg S ha^{-1} + No Zn	$S_{30} + Zn_0$
T_{14} = 30 kg S ha^{-1} + 1 kg Zn ha^{-1}	$S_{30} + Zn_1$
T_{15} = 30 kg S ha^{-1} + 3 kg Zn ha^{-1}	$S_{30} + Zn_3$
T_{16} = 30 kg S ha^{-1} + 4 kg Zn ha^{-1}	$S_{30} + Zn_4$

Sulphur was applied from gypsum and zinc was supplied from zinc oxide

3.5 Design and layout of the experiment

The experiment consisted of 16 treatment combinations and was laid out in Randomized Complete Block Design (RCBD) with 3 replications. An area of 390 m^2 was divided into three equal blocks, representing the replications, each containing 16 plots. Thus, the total numbers of unit plots were 48, each measuring 2 m × 2.5 m (5 m^2). The treatment combinations of the experiment were assigned at random into 16 plots of each at 3 replications. The distance retained between two plots was 100 cm and between blocks was 150 cm. The layout of the experiment is presented in Figure 2.

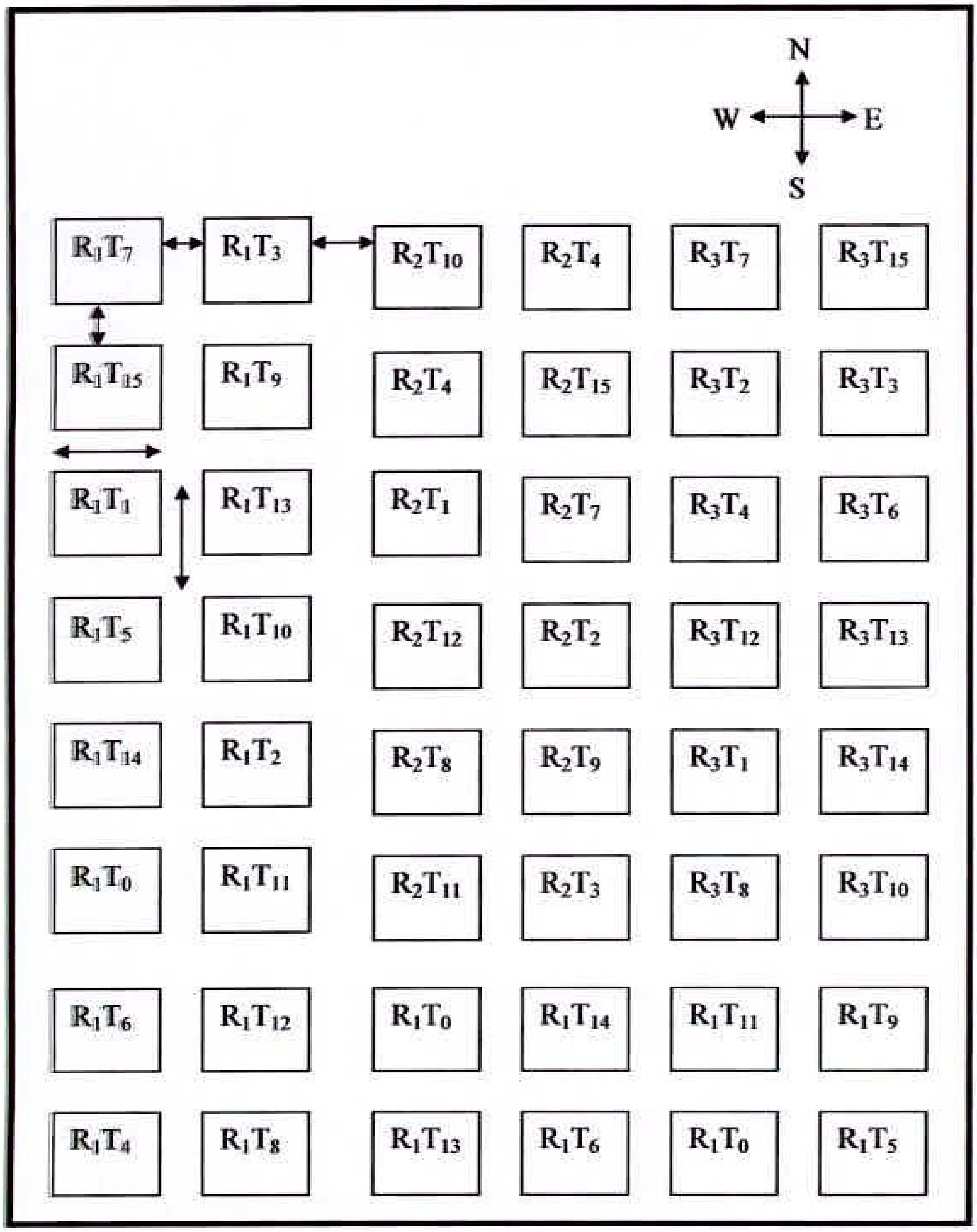


Figure 2. Layout of the experimental field

3.6 Cultivation of winter onion

3.6.1 Preparation of the field

The plot selected for the experiment was opened by a tractor on the 10th December' 2007, afterwards the land was ploughed and cross-ploughed several times with the help of a power tiller followed by laddering to obtain a good tilth. Weeds and stubbles were removed, and the large clods were broken into smaller pieces to obtain a desirable tilth of friable soil for transplanting of seedlings. Finally, the land was leveled and the experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in the following section (3.5). Irrigation and drainage channels were prepared around the plots.

3.6.2 Rate of common doses of fertilizers and manures

In this experiment fertilizers and manures (except S and Zinc fertilizers) were applied according to the recommendation rate of BARI which was as follows:

Common doses:

Manures/ fertilizers	Dose/ ha
Urea	260 kg
TSP	220 kg
MP	170 kg
Borax	08 kg
Cow dung	10 tones

3.6.3 Application of fertilizers and manures

The entire quantity of cow dung, TSP, MP, ZnO, Gypsum, Boric acid and ¼ urea are applied during the final land preparation as basal dose. The rest of the urea was applied in three equal installments as top dressing.

3.6.4 Uprooting and transplanting of seedlings

Healthy and disease free uniform sized 35 days old seedlings were uprooted from the seedbeds and transplanted in the main field with the spacing of line to line 25 cm and plant to plant 12 cm in the afternoon on 16th December' 2007. The seedbed was watered before uprooting the seedlings so as to minimize the damage of roots. The seedlings were watered immediately after transplanting. Some seedlings were also transplanted contiguous to the experimental field to be used for gap fillings.

3.6.5 Intercultural operation

After transplanting the seedlings, intercultural operations were done whenever required for getting better growth and development of the plants and so the plants were always kept under careful observation.

3.6.5. a) Gap fillings

Damaged seedlings were replaced by using healthy plants from the excess plants within one week.

3.6.5. b) Weeding and mulching

Weeding was done three times after transplanting to keep the crop free from weeds and mulching was done by breaking the crust of the soil for easy aeration and to conserve soil moisture when needed, especially after irrigation.

3.6.5. c) Irrigation and drainage

The young seedlings in the field were irrigated just after transplanting. Irrigation was provided by a watering can and or hose pump when needed throughout the growing time mainly after top dressing and after weeding. At this time care was taken so that irrigated water could not pass from one plot to another. During each irrigation, the soil was made saturated with water. After rainfall, excess water was drained when necessary.

3.6.5. d) Protection of plants

Against the soil born insect preventive measure was taken. For the prevention of Cutworm (*Agrotis ipsilon*), soil treatment was done with Furadan 3 G @ 20 kg ha^{-1}. Few days after transplanting, some plants were attacked by purple blotch disease caused by *Alternaria porri*. It was controlled by spraying Rovral 50 WP two times at 15 days interval after transplanting.

3.7 Harvesting

The crop was harvested on 10^{th} March 2008 according to their attainment of maturity showing the sign of drying out of most of the leaves and collapsing at the neck of the bulbs.

3.8 Collection of data

Data collection was done from the sample plants on the following parameters at the time of experiment –

1. Plant height (cm)
2. Leaf length (cm)
3. Number of leaves per plant
4. Diameter of bulb per plant (cm)
5. Length of bulb per plant (cm)
6. Weight of single bulb (g)
7. Yield of bulb per hectare (t)
8. Moisture content (%)
9. Dry matter yield per hectare (t)

3.8.1 Plant height (cm)

The height of the randomly selected five plants in each plot was measured after harvesting. The height was measured in centimeter (cm) from the bottom of the bulb to the tip of the longest leaf and average height of the selected five plants was taken to observe the rate of growth.

3.8.2 Leaf length (cm)

The length of leaf was measured in centimeter (cm) from pseudostem to the tip of the leaf from five randomly selected plants after harvesting and their average was recorded.

3.8.3 Number of leaves per plant

Number of leaves per plant was counted after harvesting. Five plants were selected randomly from each plot and averaged.

3.8.4 Diameter of bulb per plant (cm)

At harvest the diameter of bulbs were measured at the middle portion of bulb from five randomly selected plants with a slide calipers and averaged.

3.8.5 Length of bulb per plant (cm)

Length of harvested bulbs was measured with a slide calipers from the neck to the bottom of the bulb from five randomly selected plants and their average was taken.

3.8.6 Weight of individual bulb (g)

After harvesting five plants were randomly selected from each unit plot. By cutting off the pseudostem the top was removed and keeping only 1.5 cm with the bulb. Five bulbs were weighed in an electric balance and their average was considered as the single bulb weight and expressed in gram (g).

3.8.7 Yield of bulb per plot (kg)

Pseudostem and all the leaves were removed from the plants remaining only 1.5 cm neck. Then with a simple balance bulbs weight were taken in kilogram (kg) from each unit plot separately.

3.8.8 Yield of bulb per hectare (t)

Yield obtained from each unit plot was converted to get yield in tones ha^{-1}.

3.8.9 Moisture content (%)

For determination of moisture content and dry matter yield, sliced fresh onion bulbs and leaves from selected five plants were kept in an oven at 70°C temperature for drying. It took 48 hours to reach the constant weight. Three replications were used for the determination of moisture and dry matter and their average was taken and calculated to find out the moisture percentage and dry matter yield.

3.9 Collection of samples

3.9.1 Soil Sample

The initial soil sample was collected randomly from different spots of the field selected for the experiment at 0-15 cm depth before the land preparation and mixed thoroughly to make a composite sample for analysis. Post harvest soil samples were collected from each plot at 0-15 cm depth on 15th March, 2008. The samples were air-dried, ground and sieved through a 2 mm (10 meshes) sieve and kept for analysis.

3.9.2 Plant sample

Plant samples were collected from every individual plot for laboratory analysis at harvest. Five plants were randomly selected from each plot for recording data. After recording data bulbs and leaves were separated and then samples were dried in the electric oven at 70^0 C for 48 hours. After that the samples were ground in an electric grinding machine and stored for chemical analysis. The plant samples were collected by avoiding the border effect for the highest precision. For this the outer two rows and the outer plants of the middle rows were avoided.

3.10 Soil sample analysis

The initial and post harvest soil sample were analyzed for both physical and chemical properties. The properties studied included texture, pH, bulk density, particle density, organic matter, total N, available P, exchangeable K, available S and available Zn. The soil was analyzed by the following standard methods:

3.10.1 Particle size analysis

Particle size analysis of soil sample was done by hydrometer method as outlined by Day (1965) and the textural class was ascertained using USDA textural triangle.

3.10.2 Soil pH

Soil pH was determined by glass electrode pH meter in soil- water suspension having soil: water ratio of 1: 2.5 as outlined by Jackson (1958).

3.10.3 Organic carbon

Soil organic carbon was determined by wet oxidation method described by Walkley and Black (1935).

3.10.4 Organic matter

The organic matter content was determined by multiplying the percent organic carbon with Van Bemmelen factor 1.73 (Piper, 1950).

3.10.5 Total nitrogen

Total nitrogen of soil samples were estimated by Micro-Kjeldahl method where soils were digested with 30% H_2O_2 conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Selenium powder in the ratio of 100: 10: 1, respectively). Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01 N H_2SO_4 (Bremner and Mulvaney, 1982).

3.10.6 Available Phosphorous

Available phosphorous was extracted from the soil by shaking with 0.5 M $NaHCO_3$ solution of pH 8.5 (Olsen *et al.* 1954). The phosphorous in the extract was then determined by developing blue color using $SnCl_2$ reduction of phosphomolybdate complex. The absorbance of the molybdophosphate blue color was measured at 660 nm wave length by spectrophotometer and available P was calculated with the help of a standard curve.

3.10.7 Exchangeable potassium

Exchangeable potassium in the soil sample was extracted with 1N neutral ammonium acetate (NH_4OAC) and exchangeable potassium was determined by ammonium acetate extraction method (Black, 1965).

3.10.8 Available sulphur

Available sulphur was extracted from the soil with Ca $(H_2PO_4)_2.H_2O$ (Fox *et al.*, 1964). Sulphur in the extract was determined by the turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049).

3.10.9 Available Zinc.

Available Zinc was extracted from the soil with sulphuric acid (H_2SO_4). Zinc in the extract was determined by the tubidimetric method.

3.11 Chemical analysis of plant sample

3.11.1 Digestion of plant samples with nitric-perchloric acid mixture

An amount of 0.5g of sub-sample was taken into a dry clean 100 ml Kjeldahl flask, 10 ml of di-acid mixture (HNO_3, $HClO_4$ in the ratio of 2:1) was added and kept for few minutes. Then, the flask was heated at a temperature rising slowly to

200°C. Heating was instantly stopped as soon as the dense white fumes of $HClO_4$ occurred and after cooling, 6ml of 6N HCl were added to it. The content of the flask was boiled until they became clear and colorless. This digest was used for determining P, K, S and Zn.

3.11.2 Phosphorous

Phosphorous in the digest was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer (LKB Novaspec, 4049).

3.11.3 Potassium

Potassium content in the digested plant sample was determined by flame photometer.

3.11.4 Sulphur

Sulphur content in the digest was determined by turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049).

3.11.5 Nitrogen

Plant samples were digested with 30% H_2O_2, conc. H_2SO_4 and a catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Selenium powder in the ratio of 100: 10: 1, respectively) for the determination of total nitrogen by Micro-Kjeldahl method. Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01 N H_2SO_4 (Bremner and Mulvaney, 1982

3.11.6 Zinc

Zinc content in the digested plant sample was determined by flame photometer

3.12 Statistical analysis

The data obtained from the experiment were analyzed statistically using MSTAT computer package program to find out the significance of the difference among the treatments. The mean values of all the treatment were calculated and analysis of variances for all the characters was performed by the 'F' (variance ratio) test. The significance of the differences among the pairs of treatment means was estimated by the Duncan Multiple Range Test (DMRT) at 1% and 5% level of probability (Gomez and Gomez, 1984) for the interpretation of results.

Chapter 4
Results and Discussion

RESULTS AND DISCUSSION

The present experiment was conducted to investigate the effect of sulphur and zinc on the growth and yield of onion. The results obtained from the experiment have been grouped and are presented under the following sub heads.

4.1 Effect of sulphur and zinc on the growth and yield parameters of onion

Results of the effects of sulphur and zinc on various growth parameters of onion such as plant height, number of leaves/plant and length of leaves has been presented and discussed below:

4.1.1 Plant height

Plant height was recorded at harvest and it was observed that there were significant variations in plant height at different levels of sulphur and zinc application.Single mean effect of different levels of S and Zn were found significant on the plant height. Sulphur level of 20 kg ha^{-1} gave the tallest plant (36.45 cm) followed by the treatments of S_{30} (33.44 cm) and S_{10} (30.26 cm) while S_0 treatment (0 kg sulphur) gave the shortest plant (18.42 cm) (Table 2). On the other hand, the maximum plant height (31.22 cm) (Table 2) was observed with the treatment of Zn_4 (4 kg zinc) and the minimum height (27.78 cm) with Zn_0 treatment (Table 2).

The combine effect of sulphur and zinc was also significant in respect of plant height. However the maximum height (38.28 cm) of the plant was obtained with treatment combination of $S_{20}Zn_3$ which was found to be statistically identical with the treatment combinations of $S_{20}Zn_4$, $S_{20}Zn_1$ and $S_{30}Zn_3$ and produced the highest plant height over rest of the treatments. And the minimum plant height (18.42 cm) was found in S_0Zn_0 treatment (Table 3). A result of present study was in agreement with the findings of Nasiruddin *et al.* (1993) and observed the application of both potassium and sulphur either individually or combined increased the plant height.

4.1.2 Number of leaves plant^{-1}

The leaf production ability of the onion plant was greatly influenced by application of zinc and sulphur. Single effect of sulphur on leaf production was significantly affected by the selected treatments. Sulphur level of S_{20} treatment produced the maximum number of leaves (8.23) while the minimum (6.64) number of leaves were produced with S_0 treatment. On the other hand, maximum number of leaves was observed in the treatment of Zn_4 (7.67) which were statistically identical with Zn_3 (7.51) (Table 2).

Combined effect of sulphur and zinc on the production of leaves/plant has been shown in Table 3. From the result it was observed that there were significant variations among most of the treatment combinations. The treatment combination of $S_{20}Zn_3$ produced the highest (8.72) number of leaves which was identical with the $S_{20}Zn_4$ treatment combination (8.62) while S_0Zn_0 treatment combination produced the lowest number of leaves (6.55) (Table 3).Similar results were reported by Anwer *et al.* (1998) and observed the application of sulphur and zinc increased the number of leaves plant^{-1} along with higher bulb yield of onion with the increasing rates up to 20 kg S and 5 kg Zn ha^{-1} at Jessore area.

4.1.3 Length of leaf

Leaf length was significantly influenced by sulphur and zinc treatments. From the single mean effect of sulphur it was observed that S_{20} treatment i.e. 20 kg of S ha^{-1} gave the highest leaf length (30.71 cm) followed by S_{30} treatment (27.02 cm) which was statistically different. The minimum leaf length was recorded in S_0 treatment where no sulphur was applied. On the other hand, maximum leaf length (26.04 cm) was observed in the treatment of Zn_4 (4 kg of Zn ha^{-1}) followed by Zn_3 treatment with the value of 27.03 cm which was statistically similar (Table 2).

Combined effect of sulphur and zinc on the length of leaves was not significant (Table 3).The maximum leaf length (32.42 cm) was obtained with treatment combination of $S_{20}Zn_3$ which was found statistically similar to the effect of $S_{20}Zn_4$ and $S_{20}Zn_1$. The minimum leaf length (19.46 cm) was found under the treatment combination of S_0Zn_0. Leaf length increased due to the combined application of sulphur and zinc. Kumar *et al.* (1998).

4.1.4 Fresh weight of leaf

Analysis of variance revealed that the effect of sulphur and zinc were significant in respect of fresh weight of leaves plant^{-1} but its combined effect was not significant.

Single effect of different doses of sulphur has been shown in Table 2. It was observed from the result that 20 kg ha^{-1} sulphur level produced the highest fresh weight of leaves (9.22 g) and the lowest fresh weight of leaves (7.46 g) was obtained with sulphur level S_0. On the contrary, single mean effect of different levels of Zn on the average fresh weight of leaves was highly significant. Treatment Zn_3 gave the highest weight of leaves (8.91 g) while Zn_0 treatment gave the lowest (8.09 g) weight of leaves.

Combined effect of sulphur and zinc on the fresh weight of leaves per plant of onion has been shown in Table 3 which was not statistically significant. However, the maximum fresh weight of leaves (9.54 g plant^{-1}) was obtained with treatment combination of $S_{20}Zn_3$. The minimum fresh weight of leaves (7.05g plant^{-1}) was found under the treatment combination of S_0Zn_0. A result of present study was in agreement with the findings of Gamili *et al.* (2000) and observed the application of both sulphur and zinc either individually or combined increased fresh weight of leaf.

4.1.5 Fresh weight of bulb

Significant variation was observed on fresh weight of bulb of onion when different doses of sulphur were applied. The highest fresh weight of bulb (31.30 g plant^{-1}) was recorded under the S_{20} (20 kg S ha^{-1}) treatment which was statistically dissimilar with other treatments. The lowest fresh weight of bulb (25.92 g plant^{-1}) of onion was recorded in the S_0 treatment. On the other hand, the significant effect of Zn alone on fresh weight of bulb of onion. Maximum fresh weight of bulb

(30.53 g) was obtained in the treatment of Zn_3 which was statistically dissimilar with other treatments.

The combined effect of sulphur and zinc on fresh weight of bulb varied significantly among the different treatment combinations (Table 3). The treatment combination of $S_{20}Zn_3$ produced the maximum (33.42 g) fresh weight of bulb which was statistically identical to the treatment combinations of $S_{20}Zn_4$, $S_{20}Zn_1$, $S_{30}Zn_3$ and $S_{30}Zn_4$ while the lowest bulb weight (24.82 g) was obtained with the treatment combination of S_0Zn_0. A result of present study was in agreement with the findings of Gamili *et al.* (2000) and observed the application of both sulphur and zinc either individually or combined increased fresh weight of bulb.

4.1.6 Dry weight of leaf

Significant variation was observed on dry weight leaves of onion when different doses of sulphur were applied. The highest dry weight of leaves (1.12 g $plant^{-1}$) was recorded in the S_{20} treatment (20 kg S ha^{-1}) which was statistically dissimilar with other treatments. The lowest dry weight of leaves per plant of onion (0.61 g $plant^{-1}$) was recorded in the S_0 treatment where no sulphur was applied. On the other hand, the effect of Zn alone on fresh weight of leaves of onion per plant was found significant. Maximum dry weight of leaves (1.00 g) was obtained in the treatment of Zn_3 which was statistically dissimilar with other treatments. The minimum dry weight of leaves (0.71g $plant^{-1}$) was found under the treatment of Zn_0

The combined effect of sulphur and zinc on dry weight of leaves varied significantly among the different treatment combinations. $S_{20}Zn_3$ treatment combination (20 kg S ha^{-1} and 3 kg Zn ha^{-1}) was produced the maximum (1.29 g $plant^{-1}$) dry weight of leaves which was similar to the treatment of $S_{20}Zn_4$. While, the lowest dry weight (0.56 g $plant^{-1}$) was obtained with the control treatment (S_0Zn_0) Table 3.

The results of the present study are also similar to the findings of Mukesh *et al.* (2000) who observed that highest bulb yield (18.4 t ha^{-1}) was found when 10 kg ha^{-1} Zn was applied.

4.1.7 Dry weight of bulb

Significant variation was observed on dry weight bulb of onion when different doses of sulphur were applied. The maximum dry weight of bulb (6.18 g $plant^{-1}$) was recorded under the S_{20} treatment (20 kg S ha^{-1}) which was statistically dissimilar with other treatments. The minimum dry weight of bulb of onion (2.84 g $plant^{-1}$) was recorded in the S_0 treatment. On the other hand, the effect of Zn alone on fresh weight of bulb of onion per plant. Maximum dry weight of bulb (5.65 g $plant^{-1}$) was obtained in the treatment of Zn_4 which was statistically dissimilar with other treatments. The minimum dry weight of leaves (4.64g $plant^{-1}$) was found under the treatment of Zn_0

Significant variation was found under the combined effect of sulphur and zinc on the dry weight of bulb. The maximum dry weight (6.53 g $plant^{-1}$) of bulb was found under the treatment combination of $S_{20}Zn_3$ which was similar to the treatment of $S_{20}Zn_4$. These two treatments produced the maximum dry of weight which were statistically dissimilar with other treatments. While the minimum dry weight (2.51 g $plant^{-1}$) of bulb was observed in control (S_0Zn_0) treatment Table 3. Dry matter accumulation in bulb and bulb quality significantly increased by the application of 50% N through organic manure while the other 50% of recommended N and 100% S &Zn were supplied through chemical fertilizers. (Jayathilake *et al.*, 2003).

4.1.8 Bulb diameter

Bulb diameter of onion was influenced by the single effect of sulphur and zinc. It is revealed from the study that sulphur and zinc have a positive role on bulb diameter of onion. Single mean effect of different levels of S and Zn were found significant on the plant height. Sulphur level of 30 kg ha^{-1} gave the highest bulb diameter (4.08 cm) followed by the treatment of S_{20} (4.07 cm) and S_{10} (3.23 cm) while S_0 gave the lowest bulb diameter (2.52cm) where no sulphur was applied (Table2). On the other hand, the maximum bulb diameter (3.69 cm) (Table 2) was obtained with the treatment of Zn_3 and the minimum height (3.22 cm) with Zn_0 (Table 2).

There was a significant variation of bulb diameter among the 16 different treatment combinations. Result showed that treatment combination of $S_{20}Zn_3$ gave the highest bulb diameter (4.43 cm) followed by the treatment combinations of $S_{20}Zn_4$ and $S_{30}Zn_3$ where bulb diameter was 4.39 cm and 4.25 cm, respectively which are statistically identical. The lowest bulb diameter (2.43 cm) was obtained under S_0Zn_0 treatment combination. It was observed that combined application of sulphur and zinc increased bulb diameter (Table 3). Haque *et al.* (2004) affirmed that bulb diameter increased with the application of S.

4.1.9 Bulb length

The variations in respect of bulb length due to the effects of different levels of sulphur and zinc were found to be statistically significant. The maximum length of bulb (3.25 cm) was observed from the plants grown with S_{20} treatment (20 kg ha^{-1}) which was statistically similar with S_{30} (30 kg ha^{-1}) treatment. The control treatment produced the minimum length (2.22cm) of bulb. On the other hand, the maximum bulb length (3.06 cm) (Table 2) was obtained with the treatment of Zn_3 and the minimum height (2.47 cm) with Zn_0 treatment (Table 2).

Combined application of sulphur and zinc showed significant variations in respect of bulb length of onion. Among the different treatment combinations, the highest bulb length (3.62 cm) was obtained under the treatment combination of $S_{20}Zn_3$ which was statistically similar with the treatment combinations of $S_{20}Zn_4$, $S_{30}Zn_3$ and $S_{30}Zn_4$ which produced the bulb length 30.50 cm, 30.44 cm and 3.37 cm respectively (Table 3). On the contrary, the treatment combination (S_0Zn_0) where no sulphur and zinc were applied gave the lowest bulb length (2.09 cm) of onion. Probably combination of Sulphur and Zinc supplied the necessary requirements for the proper vegetative growth of plant that helps in obtaining the highest bulb length. Meena and Singh (1998) affirmed that bulb length increased with the application of S and Zn.

4.1.10 Yield of bulb per hectare

Yield of onion bulb per plot as affected by different levels of sulphur and zinc with their combination effects have been presented in Table 2 & 3. The combined effect of different doses of sulphur and zinc treatment combinations on the yield of bulb of onion was significant (Table 3). The highest yield of bulb (12.04 t ha^{-1}) was recorded with the treatment combination of $S_{20}Zn_3$. On the other hand, the lowest yield of bulb (6.83 t ha^{-1}) was found in S_0Zn_0 treatment combination. The yield of bulb per hectare increased significantly by the application of different levels of sulphur. Maximum yield (10.90 t ha^{-1}) of bulb was obtained with the highest sulphur level S_{20} treatment and the minimum yield (7.25 t ha^{-1}) under the treatment of S_0. The yield of bulb also increased significantly by the application of different doses of zinc. The highest yield (10.07 t ha^{-1}) was obtained by application of Zn_3 while the minimum yield (8.50 t ha^{-1}) was obtained in Zn_0 treatment.

The combined effects of sulphur and zinc had a significant influence on bulb yield of onion. It was noticed that some treatment combinations of sulphur and zinc produced higher yield than sulphur and zinc alone (Table 4). 20 kg sulphur and 3 kg zinc produced the maximum yield (12.04 t/ha), while the lowest yield (6.83 t/ha) was obtained from the treatment combination of $S_0Zn_0$where no sulphur and zinc were applied.

The results presented in this study are in good conformity with other researchers. The results of the present study are similar to the findings of Peterson (1979) who observed that the yield was increase by 22.48 percent with the application of sulphur at 17 kg ha^{-1}. Ahmed *et al.* (1988) observed that different levels of nitrogen (0, 60 and 120 kg ha^{-1}) and sulphur (0, 12, 24 and 36 kg ha^{-1}) on local cv. Faridpur Bhati. Both nitrogen and sulphur significantly increased the yield.

In this study it was observed that treatment $S_{20}Zn_3$ always produce better performance over the growth parameters and yield. So this treatment combination of sulphur and zinc may be helpful for onion cultivation.

Table 2. Single effect of sulphur and zinc on the growth and yield of onion

Sulphur (kg ha^{-1})	Plant height (cm)	Number of leaves/plant	Length of leaves/plant (cm)	Fresh weight of leaves/pant (g)	Fresh weight of bulb/plant (g)	Dry weight of leaves/plant (g)	Dry weight of bulb/plant (g)	Diameter of bulb (cm)	Length of bulb (cm)	Yield of bulb (t/ha)
S_0	20.42	6.64	18.65	7.46	25.92	0.61	2.84	2.52	2.22	7.25
S_{10}	30.26	7.15	26.56	8.70	28.59	0.90	5.82	3.23	2.71	9.12
S_{20}	36.45	8.23	30.71	9.22	31.30	1.12	6.18	4.07	3.25	10.90
S_{30}	33.44	7.55	27.02	9.14	30.23	0.97	6.08	4.08	3.16	10.76
LSD	1.79	0.23	1.54	0.28	1.67	0.05	0.22	0.16	0.12	0.44
Level of significance	**	**	**	**	**	**	**	**	**	**
Zinc (kg ha^{-1})										
Zn_0	27.78	7.12	24.32	8.09	26.78	0.71	4.64	3.22	2.47	8.50
Zn_1	30.78	7.27	26.04	8.68	28.89	0.92	5.17	3.43	2.82	9.59
Zn_3	30.78	7.31	27.03	8.91	30.53	1.00	5.47	3.69	3.06	10.07
Zn_4	31.22	7.67	27.56	8.83	29.85	0.97	5.65	3.57	2.99	9.87
LSD	2.07	0.26	1.78	0.33	1.93	0.06	0.25	0.19	0.14	0.51
Level of significance	**	**	**	**	**	**	**	**	**	**
CV(%)	7.14	4.79	7.08	5.02	6.89	5.48	4.98	5.73	5.22	6.59

** = Significant at 1% level

NS = Not significant, CV= Co-efficient of variation

Table 3. Combined effect of sulphur and zinc on the growth and yield of onion

Treatment combinations (A×B)	Plant height (cm)	Number of leaves/plant	Length of leaves/plant (cm)	Fresh weight of leaves/pant (g)	Fresh weight of bulb/plant (g)	Dry weight of leaves/plant (g)	Dry weight of bulb/plant (g)	Diameter of bulb (cm)	Length of bulb (cm)	Yield of bulb (t/ha)
T_1 (S_0Zn_0)	20.42	6.55	18.46	7.05	24.82	0.56	2.51	2.43	2.09	6.83
T_2 (S_0Zn_1)	22.38	6.68	19.70	7.49	25.87	0.62	2.78	2.55	2.20	7.20
T_3 (S_0Zn_3)	19.02	6.78	22.00	7.70	26.50	0.64	3.06	2.58	2.28	7.50
T_4 (S_0Zn_4)	21.87	6.55	21.46	7.60	26.51	0.63	3.02	2.54	2.32	7.47
T_5 ($S_{10}Zn_0$)	26.87	6.92	24.30	8.21	27.00	0.72	5.01	2.99	2.50	8.50
T_6 ($S_{10}Zn_1$)	30.87	7.09	26.41	8.67	27.97	0.91	5.40	3.00	2.66	9.04
T_7 ($S_{10}Zn_3$)	31.01	7.03	27.28	9.01	29.80	1.01	6.00	3.50	2.91	9.50
T_8 ($S_{10}Zn_4$)	32.34	7.59	28.28	8.94	29.61	0.99	6.89	3.46	2.77	9.47
T_9 ($S_{20}Zn_0$)	34.44	7.66	27.41	8.53	27.50	0.80	5.51	3.47	2.62	9.01
T_{10} ($S_{20}Zn_1$)	35.81	7.93	30.81	9.38	31.11	1.16	6.30	4.01	3.26	11.02
T_{11} ($S_{20}Zn_3$)	38.28	8.72	32.42	9.54	33.42	1.29	6.53	4.43	3.62	12.04
T_{12} ($S_{20}Zn_4$)	37.27	8.62	32.22	9.42	33.18	1.22	6.41	4.39	3.50	11.53
T_{13} ($S_{30}Zn_0$)	31.42	7.38	26.11	8.58	27.81	0.79	5.55	3.99	2.70	9.67
T_{14} ($S_{30}Zn_1$)	34.11	7.41	27.26	9.21	30.62	1.01	6.20	4.18	3.16	11.11
T_{15} ($S_{30}Zn_3$)	34.84	7.61	26.42	9.40	32.40	1.06	6.30	4.25	3.44	11.26
T_{16} ($S_{30}Zn_4$)	33.42	7.82	28.31	9.39	30.11	1.05	6.28	3.90	3.37	11.03
LSD	3.58	0.46	4.23	0.94	3.33	0.10	0.43	0.33	0.24	0.88
Level of significance	*	*	NS	NS	**	**	**	**	**	*
CV(%)	7.14	4.79	7.08	5.02	6.89	5.48	4.98	5.73	5.22	6.59

* = Significant at 5% level, ** = Significant at 1% level
NS = Not significant, CV= Co-efficient of variation

4.2 Effect of sulphur and zinc on the moisture content of leaf and bulb of onion.

4.2.1 Moisture content in leaf

Single mean effect of different levels of S and Zn were not significant on the moisture content of leaves of onion. Sulphur level of 0 kg ha^{-1} gave the highest moisture content in bulb (91.75%) while S_{20} treatment gave the lowest moisture content (89.32) (Table 4).On the other hand, the highest moisture content (90.75%) (Table 4) was recorded with the treatments of Zn_0 and the lowest moisture content (89.09%) with Zn_3 treatment (Table 4).

The effect of combined use of sulphur and zinc on the moisture content of leaf of onion is presented in Table 5. The study revealed that there were insignificant differences between the sixteen treatment combinations. The highest moisture percentage (92.00 %) was obtained in S_0Zn_0 treatment combination and the lowest (86.47 %) moister content was found in treatment combination ($S_{20}Zn_3$).

4.2.2 Moisture content in bulb

Single mean effect of different levels of S and Zn were not significant on the moisture content of bulb of onion. Sulphur level of 0 kg ha^{-1} gave the highest moisture content in bulb (88.30%) while S_{10} (10 kg sulphur) gave the lowest moisture content (79.80) (Table 4).On the other hand, the highest moisture content (83.17) (Table 4) was recorded with the treatments of Zn_0 (0 kg zinc) and the lowest moisture content (80.62%) with Zn_4 treatment (Table 4).

Sixteen different treatment combinations were taken to evaluate the effect of combined use of sulphur and zinc on the moisture content of bulb of onion is presented in Table 5. The percent moisture was varied among the different treatments but various combinations of fertilizer treatment results insignificant variation. The lowest (77.00 %) moister content was recorded in the treatment combination of $S_{10}Zn_4$. On the other hand, the highest moisture content (89.88 %) was observed in control (S_0Zn_0) treatment.

Table 4. Single effect of sulphur and zinc on the moisture content the leaf and Bulb of onion.

Sulphur (kg ha^{-1})	**% of moisture**	**% of moisture**
	Leaf	**Bulb**
S_0	91.75	88.30
S_{10}	89.75	79.80
S_{20}	87.60	80.43
S_{30}	89.32	79.91
LSD $_{0.05/\ 0.01\%}$	1.54	3.25
Level of significance	NS	NS
Zinc (kg ha^{-1})		
Zn_0	90.75	83.17
Zn_1	89.46	82.33
Zn_3	89.09	82.33
Zn_4	89.11	80.62
LSD$_{0.05/\ 0.01\%}$	1.77	3.76
Level of significance	NS	NS
CV(%)	3.06	4.75

NS = Not significant, CV= Co-efficient of variation

Table 5. Combined effect of sulphur and zinc on the leaf and bulb of onion

Treatment combinations (A×B)	Moisture %	
	Leaf	Bulb
T_1 (S_0Zn_0)	92.00	89.88
T_2 (S_0Zn_1)	91.72	89.25
T_3 (S_0Zn_3)	91.86	88.45
T_4 (S_0Zn_4)	91.60	85.63
T_5 ($S_{10}Zn_0$)	91.20	81.75
T_6 ($S_{10}Zn_1$)	89.50	80.60
T_7 ($S_{10}Zn_3$)	89.51	79.86
T_8 ($S_{10}Zn_4$)	88.79	77.00
T_9 ($S_{20}Zn_0$)	89.02	80.80
T_{10} ($S_{20}Zn_1$)	87.28	79.74
T_{11} ($S_{20}Zn_3$)	86.47	80.46
T_{12} ($S_{20}Zn_4$)	87.28	80.74
T_{13} ($S_{30}Zn_0$)	90.79	80.23
T_{14} ($S_{30}Zn_1$)	89.00	79.75
T_{15} ($S_{30}Zn_3$)	88.72	80.55
T_{16} ($S_{30}Zn_4$)	88.80	79.14
$LSD_{0.05/0.01\%}$	4.21	8.37
Level of significance	NS	NS
CV(%)	3.06	4.75

NS = Not significant, CV= Co-efficient of variation

4.3. Nutrient concentrations in the bulb of onion as affected by single and combined use of sulphur and zinc

4.3.1. Nitrogen content

N concentration of bulb was significantly influenced by the application of different levels of sulphur (Table 6). The highest nitrogen concentration in onion bulb (2.19 %) was recorded in S_{20} treatment which showed similar result with S_{30} (30 kg/ha) treatment. On the other hand, the lowest nitrogen concentration in onion bulb (1.49 %) was recorded in S_0 treatment.

N concentration of bulb was significantly influenced by the application of different levels of zinc (Table 6). The highest nitrogen concentration in onion bulb (2.07 %) was recorded in Zn_4 treatment which showed similar result with Zn_3 treatment. On the other hand, the lowest nitrogen concentration in onion bulb (1.71 %) was recorded in Zn_0 treatment.

Table 7 represents the effect of combined use of sulphur and zinc in response to nitrogen content in bulb at the harvest of onion. There was a significant variation in the nitrogen content of bulb among the different treatments. The highest nitrogen concentration (2.35%) was recorded in the $S_{20}Zn_3$ treatment combination which was statistically identical with of $S_{20}Zn_4$, $S_{30}Zn_3$ and $S_{30}Zn_4$ treatment combinations. On the other hand, lowest nitrogen concentration (1.43 %) was found in S_0Zn_0 treatment combination.

Chellamuthu *et al.* (1988) found that application of farm yard manure as well as ammonium sulphate significantly increased the total nitrogen content of soil.

4.3.2 Phosphorus content

P concentration of bulb was significantly influenced by application of different levels of sulphur (Table 6). The highest phosphorus concentration in onion bulb (0.16 %) was recorded in S_{20} treatment, which showed similar result with S_{30} treatment. On the other hand, the lowest potassium concentration in onion bulb (0.08 %) was recorded in S_0 treatment.

Phosphorus concentration of bulb was significantly influenced by the application of different levels of zinc (Table 6). The highest phosphorus concentration in onion bulb (0.15 %) was recorded in Zn_4 treatment which showed similar result with Zn_3 treatment. On the other hand, the lowest phosphorus concentration in onion bulb (0.10 %) was recorded in Zn_0 treatment.

The phosphorus content of bulb as improved by different combinations of sulphur and zinc showed significant variation. With the 16 different treatments, the highest phosphorous concentration (0.18 %) was recorded in the treatment combinationof $S_{20}Zn_3$ and $S_{30}Zn_0$. On the contrary, the lowest phosphorous concentration (0.07 %) was found in S_0Zn_0 treatment combination (Table 7).

4.3.3 Potassium content

K concentration of bulb was significantly influenced by application of different levels of sulphur (Table 6). The highest potassium concentration in onion bulb (1.73 %) was recorded in S_{30} treatment which showed similar result with S_{20} treatment. On the other hand, the lowest potassium concentration in onion bulb (1.05 %) was recorded in S_0 treatment.

Potassium concentration of bulb was significantly influenced by the application of different levels of zinc (Table 6). The highest potassium concentration in onion bulb (1.61 %) was recorded in Zn_3 treatment which showed similar result with Zn_4 treatment. On the other hand, the lowest potassium concentration in onion bulb (1.31 %) was recorded in Zn_0 treatment.

Statistically insignificant variation was recorded regarding potassium concentration in the bulb after harvest of onion on different doses of sulphur and zinc treatment combination (Table 7). The highest potassium concentration (1.86 %) was recorded in $S_{30}Zn_4$ treatment combination and it was similar with the $S_{20}Zn_3$ treatment combination which was showed (1.85 %).The lowest potassium concentration (0.90 %) under the treatment combination.

4.3.4 Sulphur content

Sulphur concentration of bulb was significantly influenced by application of different levels of sulphur (Table 6). The highest sulphur concentration in onion bulb (0.92 %) was recorded in S_{20} treatment which showed similar result with S_{30} treatment. On the other hand, the lowest sulphur concentration in onion bulb (0.46 %) was recorded in S_0 treatment.

Sulphur concentration of bulb was significantly influenced by the application of different levels of zinc (Table 6). The highest sulphur concentration in onion bulb (0.84 %) was recorded in Zn_3 treatment which showed similar result with Zn_4 treatment. On the other hand, the lowest sulphur concentration in onion bulb (0.67 %) was recorded in Zn_0 treatment.

Effect of combined use of sulphur and zinc on sulphur concentration in the bulb of onion is presented in Table 7. There was a statistically remarkable variation in respect of sulphur content after harvest among the 16 different treatment combinations. The highest sulphur concentration (1.02 %) was observed in $S_{20}Zn_3$ treatment combination which was statistically similar with $S_{20}Zn_4$ treatment combination with a value of 0.98 %. In contrast, the lowest sulphur concentration (0.42 %) was found in S_0Zn_0 treatment combination. This might be due to the fact that, the combined effect of sulphur and zinc played positive effect on sulphur concentration in the bulb of winter onion up to a certain limit.

4.3.5 Zinc content

Zinc concentration of bulb was significantly influenced by application of different levels of sulphur (Table 6). The highest zinc concentration in onion bulb (0.61%) was recorded in S_{20} treatment, which showed similar result with S_{30} treatment. On the other hand, the lowest zinc concentration in onion bulb (0.23 %) was recorded in S_0 treatment.

Zinc concentration of bulb was significantly influenced by the application levels of zinc (Table 6). The highest zinc concentration in onion bulb (0.56 %) was recorded in Zn_4 treatment which showed similar result with Zn_3 treatment. On the other hand, the lowest sulphur concentration in onion bulb (0.21 %) was recorded in Zn_1 treatment.

The combine effect of sulphur and zinc also showed significant variation in Zn content in bulb of onion. Maximum zinc content (0.77%) was observed in the $S_{20}Zn_3$ treatment combination which was statistically similar to the $S_{20}Zn_4$ treatment combination with a concentration of 0.71% while the lowest Zn concentration (0.11%) was observed in S_0Zn_0 treatment combination (Table 7).

4.4 Nutrient concentrations in the leaf of onion as affected by single and combined use of sulphur and zinc

4.4.1 Nitrogen content

Single mean effect of different levels of S and Zn were found significant on the nitrogen concentration of onion leaves. Sulphur level of 20 kg ha^{-1} gave the highest nitrogen concentration in onion leaves (2.82%) followed by S_{30} treatment (2.75%) and S_{10} treatment (2.59%) while S_0 treatment gave the lowest nitrogen concentration (2.02%) in Table 6. On the contrary, the highest concentration (2.65%) (Table 6) was recorded with the treatment of Zn_3 and the lowest N concentration (2.34%) with Zn_0 (Table 6).

The effect of combined use of sulphur and zinc in response to nitrogen content in leaf at the harvest of onion had been presented in Table 7. There was a significant variation in the nitrogen content of leaf among the different treatment combinations. The highest nitrogen concentration (2.98%) was recorded in $S_{20}Zn_3$ treatment combination which was statistically identical with $S_{20}Zn_4$, $S_{30}Zn_3$ and $S_{30}Zn_4$ treatment combinations. On the other hand, the lowest nitrogen concentration (2.01%) was found in S_0Zn_0 treatment combination.

4.4.2 Phosphorus content

Single mean effect of different levels of S and Zn were found significant on the phosphorus concentration of onion leaves. Sulphur level of 20 kg ha^{-1} gave the highest phosphorus concentration in onion leaves (0.19%) followed by S_{30} treatment (0.18%) and S_{10} treatment (0.15%) while S_0 treatment gave the lowest phosphorus concentration (0.08%) (Table 6).On the other hand, the highest phosphorus concentration (0.16%) (Table 6) was recorded with the treatments of Zn_3, Zn_1 and Zn_4.The lowest phosphorus concentration (0.13%) with Zn_0 treatment (Table 6).

The phosphorus content of leaf is improved by different treatment combinations of sulphur and zinc showed a significant variation which is presented in Table 7. From the 16 different treatment combinations, the highest phosphorous concentration (0.20%) was recorded in $S_{20}Zn_3$ and $S_{20}Zn_4$ treatment combinations which were statistically similar with $S_{20}Zn_4$ and $S_{30}Zn_4$ treatment combination. On the contrary, the lowest phosphorous concentration (0.07%) was found in S_0Zn_0 treatment combination (Table 7).

4.4.3 Potassium content

Single mean effect of different levels of S and Zn were found significant on the potassium concentration of onion leaves. Sulphur level of 20 kg ha^{-1} gave the highest potassium concentration in onion leaves (2.62%) followed by S_{30} treatment (2.58%) and S_{10} treatment (0.2.31%) while S_0 treatment (0 kg sulphur) gave the lowest potassium concentration (1.61%) (Table 6).On the other hand, the highest potassium concentration (2.47%) (Table 6) was recorded with the treatments of Zn_3 (3 kg zinc) and the lowest potassium concentration (1.97%) with Zn_0 treatment.

Statistically significant variation was recorded regarding potassium concentration in the leaf after harvest of onion on different doses of sulphur and zinc (Table 7). The highest potassium concentration (2.88%) was recorded in $S_{30}Zn_4$ treatment combination and it was similar with the $S_{20}Zn_3$ treatment combination which showed 2.80% and 2.76%, respectively and the lowest K concentration (1.56%) was obtained in S_0Zn_0 treatment combination (Table 7).

4.4.4 Sulphur content

Single mean effect of different levels of S and Zn were found significant on the sulphur concentration of onion leaves. Sulphur level of 20 kg ha^{-1} gave the highest sulphur concentration in onion leaves (0.92%) followed by S_{30} treatment (0.89%) and S_{10} treatment (0.83%) while S_0 treatment gave the lowest sulphur concentration (0.47%) (Table 6).On the other hand, the highest sulphur concentration (0.84%)

(Table 6) was recorded with the treatments of Zn_3 and the lowest sulphur concentration (0.65%) with Zn_0 treatment (Table 6).

Effect of combined use of sulphur and zinc on sulphur concentration in the leaf of onion is presented in Table 7. There was a statistically remarkable variation in sulphur content after harvest among the 16 different treatments. The highest sulphur concentration (1.03%) was observed in the treatment $S_{20}Zn_3$ which was statistically similar with treatment combinations of $S_{20}Zn_1$, $S_{20}Zn_4$ and $S_{30}Zn_1$ with a value of 0.97%, 0.98% and 0.99%, respectively. In contrast, the lowest sulphur concentration (0.43%) was found in S_0Zn_0 treatment combination (Table 7).

4.4.5 Zinc content

Single mean effect of different levels of S and Zn were found significant on the zinc concentration of onion leaves. Sulphur level of 20 kg ha^{-1} gave the highest zinc concentration in onion leaves (0.59%) followed by S_{30} (0.56%) and S_{10} (0.28%) while S_0 gave the lowest zinc concentration (0.16%) (Table 6).On the other hand, the highest zinc concentration (0.23%) (Table 6) was recorded with the treatments of Zn_3 and the lowest zinc concentration (0.15%) with Zn_0 treatment (Table 6).

The combined effect of sulphur and zinc in the leaf of onion showed significant variation among the 16 treatment combinations. Maximum zinc concentration (0.81%) was observed in $S_{30}Zn_4$ treatment combination which was similar with the treatment combinations of $S_{30}Zn_3$ and $S_{20}Zn_3$ whereas the lowest Zn concentration (0.15%) was found in S_0Zn_0 treatment combination (Table 7).

Table 6. Single effect of S and Zn on the nutrient concentrations in leaf and bulb of onion.

Sulphur (kg ha^{-1})	Concentration in leaf (%)					Concentration in bulb (%)				
	N	P	K	S	Zn	N	P	K	S	Zn
S_0	2.02	0.08	1.61	0.47	0.16	1.49	0.08	1.05	0.46	0.23
S_{10}	2.59	0.15	2.31	0.83	0.28	2.06	0.12	1.51	0.79	0.31
S_{20}	2.82	0.19	2.62	0.92	0.59	2.19	0.16	1.71	0.92	0.61
S_{30}	2.75	0.18	2.58	0.89	0.56	2.14	0.15	1.73	0.88	0.60
LSD	0.091	0.0167	0.0746	0.0373	0.020	0.075	0.014	0.059	0.0264	0.039
Level of significance	*	*	*	**	*	**	*	*	**	*
Zinc (kg ha^{-1})										
Zn_0	2.34	0.13	1.97	0.65	0.15	1.71	0.10	1.31	0.67	0.25
Zn_1	2.57	0.16	2.27	0.80	0.18	2.03	0.13	1.49	0.75	0.21
Zn_3	2.65	0.16	2.47	0.84	0.23	2.06	0.14	1.61	0.84	0.33
Zn_4	2.61	0.16	2.43	0.81	0.21	2.07	0.15	1.59	0.80	0.56
LSD	0.1055	0.019	0.086	0.043	0.021	0.086	0.0167	0.0681	0.030	0.021
Level of significance	*	*	*	**	*	**	*	*	*	*
CV(%)	4.31	7.00	4.84	6.77	5.01	5.65	7.16	5.93	4.96	3.87

* = Significant at 5% level, ** = Significant at 1% level

NS = Not significant, CV= Co-efficient of variation

Table 7. Effect of combined use of sulphur and zinc on the nutrient concentrations in leaf and bulb of onion

Treatment combinations (A×B)	Concentrations in leaf (%)					Concentrations in bulb (%)				
	N	P	K	S	Zn	N	P	K	S	Zn
T_1 (S_0Zn_0)	2.01	0.07	1.56	0.43	0.15	1.43	0.07	0.90	0.42	0.11
T_2 (S_0Zn_1)	2.00	0.09	1.60	0.48	0.22	1.49	0.07	0.99	0.46	0.07
T_3 (S_0Zn_3)	2.03	0.10	1.69	0.51	0.14	1.50	0.08	1.11	0.49	0.09
T_4 (S_0Zn_4)	2.04	0.09	1.62	0.49	0.13	1.56	0.09	1.20	0.47	0.11
T_5 ($S_{10}Zn_0$)	2.31	0.14	2.02	0.69	0.27	1.93	0.10	1.36	0.70	0.25
T_6 ($S_{10}Zn_1$)	2.59	0.15	2.20	0.79	0.31	2.11	0.11	1.50	0.77	0.21
T_7 ($S_{10}Zn_3$)	2.71	0.16	2.50	0.89	0.41	2.10	0.14	1.66	0.88	0.33
T_8 ($S_{10}Zn_4$)	2.73	0.16	2.54	0.94	0.60	2.12	0.14	1.52	0.84	0.26
T_9 ($S_{20}Zn_0$)	2.50	0.15	2.11	0.73	0.61	1.78	0.11	1.48	0.76	0.26
T_{10} ($S_{20}Zn_1$)	2.91	0.18	2.70	0.97	0.71	2.31	0.17	1.73	0.94	0.68
T_{11} ($S_{20}Zn_3$)	2.98	0.20	2.88	1.03	0.77	2.35	0.18	1.85	1.02	0.77
T_{12} ($S_{20}Zn_4$)	2.90	0.20	2.81	0.98	0.58	2.30	0.11	1.79	0.98	0.71
T_{13} ($S_{30}Zn_0$)	2.55	0.15	2.20	0.78	0.60	1.71	0.18	1.50	0.80	0.56
T_{14} ($S_{30}Zn_1$)	2.79	0.19	2.59	0.99	0.75	2.24	0.16	1.76	0.84	0.54
T_{15} ($S_{30}Zn_3$)	2.89	0.17	2.80	0.94	0.78	2.29	0.16	1.81	0.97	0.44
T_{16} ($S_{30}Zn_4$)	2.78	0.18	2.76	0.84	0.86	2.32	0.16	1.86	0.91	0.59
LSD	0.18	0.03	0.14	0.07	0.21	0.14	0.02	0.20	0.05	0.02
Level of significance	*	*	*	**	*	**	**	NS	**	*
CV(%)	4.31	7.00	4.84	6.77	5.01	5.65	7.16	5.93	4.96	3.87

* = Significant at 5% level, ** = Significant at 1% level
NS = Not significant, CV= Co-efficient of variation

4.6 Nutrient status of soil after harvest of onion as affected by sulphur and zinc

4.6.1 Soil pH

Single mean effect of different levels of S and Zn was not found significant on the P^H in post harvest soil. Sulphur level of 20 kg ha^{-1} gave the highest P^H in post harvest soil (6.18) followed by S_{10} treatment (5.9) and S_{30} treatment (5.81) while S_0 treatment gave the lowest P^H (5.56) (Table 8).On the other hand, the highest P^H (5.96) (Table 8) was recorded with the treatments of Zn_4 and the lowest zinc concentration (5.77) with Zn_0 treatment (Table 8).

Combined application of sulphur and zinc showed insignificant effect respecting soil pH after harvest of onion is presented in Table 9. Soil pH was varied significantly at 5.49 to 6.32. The highest pH of the soil (6.32) was recorded in $S_{10}Zn_4$ treatment combination and the lowest pH value (5.49) was recorded in (S_0Zn_0) treatment combination where no sulphur and zinc were applied which was statistically similar with treatment combinations of $S_{20}Zn_1$, $S_{20}Zn_3$ and $S_{20}Zn_4$.

4.6.2 Organic matter content of soil

Single mean effect of different levels of S and Zn were found significant on the organic matter of post harvest soil of onion. Sulphur level of 20 kg ha^{-1} gave the highest organic matter in post harvest soil (1.46) followed by S_{30} treatment (0.97) and S_{10} treatment (1.26) while S_0 treatment gave the lowest organic matter (0.93) (Table 8).On the other hand, the highest organic matter (1.21) (Table 8) was recorded with the treatments of Zn_3 and the lowest organic matter (1.04) with Zn_0 treatment (Table 8).

A significant variation was observed in organic matter content in soil after harvest of onion. Among the different treatment combinations the highest organic matter content (1.60%) was obtained where 20 kg S and 3 kg Zn were applied which was statistically identical with $S_{20}Zn_4$ treatment combination (1.57% OM). On the other hand, the lowest OM content (0.86%) was observed in the S_0Zn_4 treatment combination (Table 9).

4.6.3 Total nitrogen content of soil

Single mean effect of different levels of S and Zn were found significant on the nitrogen content of post harvest soil of onion. Sulphur level of 30 kg ha^{-1} gave the highest nitrogen content in post harvest soil (0.10) while S_0, S_{20} and S_{10} treatments gave the lowest nitrogen content (0.09) (Table 8).On the other hand, the highest nitrogen content (0.10) (Table 7) was recorded with the treatment of Zn_3 and the lowest organic matter (0.09) with Zn_0 treatment (Table 8).

Total nitrogen content of soil after harvest of onion was influenced by different doses of sulphur and zinc showed a statistically significant variation (Table 9). The highest N content (0.11%) of soil was observed in $S_{30}Zn_1$ treatment combination and it was statistically similar (0.10%) with the $S_{30}Zn_4$ treatment combination. The next highest N concentration was obtained from treatment combinations of $S_{20}Zn_3$, $S_{20}Zn_4$ and S_0Zn_4. In contrast, the lowest N content (0.07%) was obtained in the $S_{10}Zn_1$ treatment combination. This may be due to the fact that highest yield was obtained by uptake more amount of nitrogen from soil by plant.

4.6.4 Phosphorous content of soil

Single mean effect of different levels of S and Zn were found significant on the available phosphorus content of post harvest soil of onion cultivation. Sulphur level of 20 kg ha^{-1} gave the highest the available phosphorus content in post harvest soil (21.40) followed by the treatments of S_{30} (18.99) and S_{10} (18.27) while S_0 treatment (0 kg sulphur) gave the lowest the available phosphorus content (16.39) (Table 8).On the other hand, the highest the available phosphorus content (20.34) (Table 8) was recorded with the treatments of Zn_3 (3 kg zinc) and the lowest the available phosphorus content (16.77) with Zn_0 treatment where no zinc was applied (Table 8).Different treatment combinations of sulphur and zinc on the available phosphorous content of soil after harvest of onion showed significant variation is presented in Table 9. It was revealed from the study that the performances of the most of the treatment combination differ significantly from each other. Among the different treatment combinations $S_{20}Zn_3$ showed the highest P content (24.03 ppm) in soil after the harvest of onion. On the other hand, the lowest P content (16.25 ppm) was observed in S_0Zn_0 treatment combination.

4.6.5 Potassium content of soil

Single mean effect of different levels of S and Zn were found significant on the available potassium content of post harvest soil of onion. Sulphur level of 20 kg ha^{-1} gave the highest the available potassium content in post harvest soil (0.22 mg kg^{-1}) followed by the treatment of S_{30} (0.20 mg kg^{-1}) and S_{10} (0.18 mg kg^{-1}) while S_0 treatment gave the lowest the available potassium content (0.14 mg kg^{-1}) (Table 8).On the other hand, the highest the available potassium content (0.21 mg kg^{-1}) (Table 8) was recorded with the treatments of Zn_4 and the lowest the available potassium content (0.15 mg kg^{-1}) with Zn_0 treatment (Table 8).

The combined effect of sulphur and zinc treatment combinations showed significant differences in respect of K content of soil after harvest of onion (Table 9). However, the lowest K content of crop-harvested soil (0.12 mg kg^{-1}soil) was recorded in S_0Zn_0 treatment combination. The highest K content (0.25 mg kg^{-1}soils) was recorded with $S_{20}Zn_4$ treatment combination followed by 0.24 mg kg^{-1} soil in $S_{20}Zn_3$ treatment combination.

4.6.6 Sulphur content of soil

Single mean effect of different levels of S and Zn were found significant on the available sulphur content of post harvest soil of onion. Sulphur level of 30 kg ha^{-1} gave the highest the available sulphur content in post harvest soil (23.47 mg kg^{-1}) followed by the treatments of S_{20} (19.97 mg kg^{-1}) and S_{10} (19.73 mg kg^{-1}) while S_0 treatment gave the lowest the available sulphur content (18.33 mg kg^{-1}) (Table 8).On the other hand, the highest the available sulphur content (22.78 mg kg^{-1}) (Table 8) was recorded with the treatments of Zn_3 and the lowest the available sulphur content (17.63 mg kg^{-1}) with Zn_0 treatment (Table 8).

Statistically significant difference was obtained in the S content of soil after harvest of onion. Application of 30 kg S and 3 kg Zn showed the highest S content (26.00 mg kg^{-1}) in soil. The next highest S content (24.28 mg kg^{-1}) was found in treatment combination ($S_{30}Zn_4$) receiving 30 kg S and 4 kg Zn. On the contrary, the lowest S content (15.49 mg kg^{-1}) was observed in the S_0Zn_0 treatment combination (Table 9).

4.6.7 Zinc content of soil

Single mean effect of different levels of S and Zn were found significant on the available zinc content of post harvest soil of onion. Sulphur level of 20 kg ha^{-1} gave the highest the available zinc content in post harvest soil (3.90 mg kg^{-1}) followed by the treatments of S_{10} (3.15 mg kg^{-1}) and S_{30} (2.89 mg kg^{-1}) while S_0 treatment gave the lowest the available zinc content (2.56 mg kg^{-1}) (Table 8).On the other hand, the highest the available zinc content (3.83 mg kg^{-1}) (Table 8) was recorded with the treatments of Zn_3 and the lowest the available zinc content (3.00 mg kg^{-1}) with Zn_1 treatment (Table 8).

Significant variation was observed in the combine effect of sulphur and zinc in respect of zinc content of soil. Among the 16 treatment combinations, $S_{20}Zn_4$ treatment combination shows the highest Zn content (4.59 mg kg^{-1}) in the soil after harvest of onion when the lowest Zn content (2.46 mg kg^{-1}) was observed in the S_0Zn_0 treatment combination (Table 9).

Table 9. Combined effect of sulphur and zinc on the pH, OM, total N, available P, K, S and Zn in the soil after harvest of onion

Treatment combination (A×B)	pH	Organic Matter (%)	Total N (%)	Available P (mg kg^{-1})	Available K (mg kg^{-1})	Available S (mg kg^{-1})	Available Zn (mg kg^{-1})
T_1 (S_0Zn_0)	5.49	1.02	0.08	16.25	0.12	15.49	2.46
T_2 (S_0Zn_1)	5.53	0.94	0.08	17.11	0.14	16.11	2.56
T_3 (S_0Zn_3)	5.61	0.88	0.10	17.20	0.16	21.43	2.57
T_4 (S_0Zn_4)	5.62	0.86	0.09	15.00	0.15	20.29	2.88
T_5 ($S_{10}Zn_0$)	5.82	1.08	0.09	16.28	0.15	17.00	3.15
T_6 ($S_{10}Zn_1$)	5.90	1.20	0.07	17.48	0.19	20.48	3.00
T_7 ($S_{10}Zn_3$)	5.86	1.36	0.08	18.91	0.20	21.44	3.81
T_8 ($S_{10}Zn_4$)	6.32	1.40	0.08	20.43	0.21	20.03	3.75
T_9 ($S_{20}Zn_0$)	5.97	1.18	0.08	17.44	0.16	18.52	3.92
T_{10} ($S_{20}Zn_1$)	6.05	1.50	0.08	22.11	0.21	18.11	3.80
T_{11} ($S_{20}Zn_3$)	6.24	1.60	0.09	24.03	0.24	22.28	4.46
T_{12} ($S_{20}Zn_4$)	6.31	1.57	0.09	22.11	0.25	21.00	4.59
T_{13} ($S_{30}Zn_0$)	5.82	0.86	0.07	17.11	0.17	19.49	2.88
T_{14} ($S_{30}Zn_1$)	5.83	1.08	0.11	19.43	0.22	24.11	3.26
T_{15} ($S_{30}Zn_3$)	5.69	0.98	0.10	21.22	0.19	26.00	3.96
T_{16} ($S_{30}Zn_4$)	5.92	0.98	0.08	18.22	0.23	24.28	4.11
LSD	0.38	0.14	0.01	2.15	0.03	2.13	1.86
Level of significance	NS	**	**	**	**	*	*
CV(%)	3.53	7.87	5.16	6.89	6.69	7.29	5.11

* = Significant at 5% level, ** = Significant at 1% level
NS = Not significant, CV= Co-efficient of variation

Table 8. Single effect of S and Zn on the pH, Organic matter, total N, available P, K, S and Zn in the soil after harvest of onion.

Sulphur (kg ha^{-1})	pH	Organic Matter (%)	Total N (%)	Available P (mg kg^{-1})	Available K (mg kg^{-1})	Available S (mg kg^{-1})	Available Zn (mg kg^{-1})
S_0	5.56	0.93	0.09	16.39	0.14	18.33	2.56
S_{10}	5.90	1.26	0.09	18.27	0.18	19.73	3.15
S_{20}	6.18	1.46	0.09	21.40	0.22	19.97	3.90
S_{30}	5.81	0.97	0.10	18.99	0.20	23.47	2.89
LSD	0.12	0.07	0.01	0.08	0.02	1.07	1.76
Level of significance	NS	**	**	**	**	*	*
Zinc (kg ha^{-1})							
Zn_0	5.77	1.04	0.09	16.77	0.15	17.63	3.15
Zn_1	5.82	1.18	0.09	19.00	0.19	19.70	3.00
Zn_3	5.89	1.21	0.10	20.34	0.19	22.78	3.83
Zn_4	5.96	1.20	0.09	18.94	0.21	21.40	3.76
LSD	0.14	0.09	0.007	1.25	0.019	1.23	0.56
Level of significance	NS	**	**	**	**	*	*
CV(%)	3.53	7.87	5.16	6.89	6.69	7.29	5.11

* = Significant at 5% level, ** = Significant at 1% level

NS = Not significant, CV= Co-efficient of variation

Chapter 5

Summary and Conclusion

SUMMARY AND CONCLUSION

The present experiment was carried out at Sher-e-Bangla Agricultural University Farm (Tejgaon series under AEZ No. 28), Dhaka-1207 during the *Rabi* season of 2008 to investigate the effect of sulphur and zinc on the growth, yield and yield contributing parameters on onion cv. *taharpuri*. The soil was silty loam in texture having pH 5.6 and organic matter (1.17%). There were sixteen treatments of the experiment. The results obtained from the experiment revealed that the effect of combined use of sulphur and zinc significantly influenced the plant height of onion. The maximum height (38.28 cm) of the plant was obtained with treatment combination of $S_{20}Zn_3$ which was found to be statistically identical with the treatments of $S_{20}Zn_4$, $S_{20}Zn_1$ & $S_{30}Zn_3$ and produced the highest plant height over rest of the treatments. And the minimum plant height (18.42 cm) was observed in the treatment of S_0Zn_0 (control). Incase of leaves number the treatment combination of $S_{20}Zn_3$ produced the highest (8.72) number of leaves which was identical to the treatment of $S_{20}Zn_4$. Again the treatment S_0Zn_0 i.e. control produced the lowest number of leaves (6.55). The minimum leaf length was recorded in treatment S_0 (control). On the other hand, maximum leaf length (27.56 cm) was observed in the treatment of Zn_4 followed by Zn_3 with the value of 27.03 cm. These two treatments were statistically identical.

Diameter of bulb, length of bulb, weight of bulb and bulb yield of onion responded significantly to the combined use of sulphur and zinc. Treatment receiving 20 kg S + 3 kg Zn ha^{-1} gave the highest bulb diameter, length of bulb, fresh weight of bulb, dry weight of bulb as well as highest bulb yield (12.04 t ha^{-1}). Statistically identical performance was obtained from treatment combination of $S_{20}Zn_4$ which produced bulb yield at 11.53 t ha^{-1}. Combined application of sulphur and zinc significantly influenced the moisture content of bulb and leaf of onion. The lowest (77.00 %) moister content was recorded in $S_{10}Zn_4$ treatment combination. On the other hand, the highest moisture content (89.88 %) was observed in control (S_0Zn_0) treatment and in leaf of onion. The highest moisture percentage (92.00 %) was obtained in control (S_0Zn_0) treatment combination receiving no fertilizer and the lowest (86.47%) moister content was found in treatment ($S_{20}Zn_3$).

The N, P, K, S and Zn contents in bulb and leaf of onion plants were influenced significantly by the integrated application of sulphur and zinc. The highest N, P, K, S and Zn content in bulb (2.35%, 0.18%, 1.85%, 1.2% and 0.77%, respectively) and in leaf (2.98%, 0.20%, 2.88%, 1.03% and 0.81%, respectively) was recorded in $S_{20}Zn_3$ treatment combination. The lowest 1.43% N, 0.07% P, 0.90% K, 0.42% S and 0.11% Zn in bulb and 2.01% N, 0.07% P, 1.56% K, 0.43% S and 0.15% Zn in leaf were obtained with control treatment.

The ultimate findings of this experiment which was on the growth and yield of onion were found to be greatly increased in all parameters of the study. The results of the study also indicate that 20 kg S and 3 kg Zn showed better performance in the major parameters i.e. plant height, number of leaves, length of leaves, bulb diameter and yield. This treatment appears to be very promising. The findings of the study also emphasizes on conducting further research on the other production side of onion for the farmers of Bangladesh.

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Appendices

APPENDICES

Appendix I. Monthly record of air temperature (°C), relative humidity (%), rainfall (mm) and sunshine hours during the period of experiment (November, 2007 to March, 2008).

Months	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (hrs.)
	Max.	Min.	Average			
November	29.52	18.99	24.25	56.20	2.3	6.50
December	25.91	13.55	19.73	45.79	2.61	6.79
January	24.38	13.32	18.85	50.29	2.54	7.12
February	24.63	13.79	19.21	48.54	3.06	7.39
March	25.1	15.49	20.29	50.10	4.01	8.10

Source: Weather Yard, Department of Irrigation and Water Management, Records of climatological observations (monthly) Station: Sher-e-Bangla Agricultural University

Appendix II Analysis of variance of the data on bulb yield and other yield contributing character of onion as affected by sulphur and zinc

Source of variation (SV)	Degrees of freedom	Mean squares									
		Plant height (cm)	Number of leaves/plant	Length of leaves/plant (cm)	Fresh weight of leaves/pant (gm)	Fresh weight of bulb/plant (gm)	Dry weight of leaves/plant (gm)	Dry weight of bulb/plant (gm)	Diameter of bulb (cm)	Length of bulb (cm)	Yield of bulb (t/ha)
Replication	2	7.66	0.16	20.25	0.29	0.001	8.26	0.07	0.07	0.04	0.87
Sulphur	3	580.79**	5.41**	207.76**	7.95**	0.54**	65.78**	30.79**	6.73**	2.69**	35.06**
Zinc	3	30.16**	0.69**	24.44**	1.64	0.19	31.98**	2.32**	0.48**	0.81**	5.89**
Sulphur × Zinc	9	4.46*	0.17*	2.65NS	0.02NS	0.01**	2.85**	0.30**	0.14**	0.07**	0.65*
Error	30	4.62	0.07	3.45	0.12	0.002	3.99	0.06	0.04	0.02	0.28

* = Significant at 5% level of probability
** = Significant at 1% level of probability
NS = Non significant

Appendix III Analysis of variance of the data on the nutrient concentration in bulb and leaf in onion as affected by sulphur and zinc

Source of variation (SV)	Degrees of freedom	Mean squares									
		Leaf					Bulb				
		N	P	K	S	Zn	N	P	K	S	Zn
Replication	2	0.083	0.001	0.245	0.001	0.002	0.045	0.001	0.095	0.002	0.001
Sulphur	3	1.589**	0.023**	0.614**	0.508*	0.330	1.239**	0.016**	0.207**	0.532**	0.360*
Zinc	3	0.232**	0.003**	0.611**	0.003*	0.071*	0.360**	0.005**	0.225**	0.064**	0.031*
Sulphur × Zinc	9	0.029NS	0.000NS	0.059**	0.013*	0.021*	0.048**	0.001**	0.010NS	0.005**	0.002*
Error	30	0.012	0.00	0.008	0.002	0.001	0.008	0.00	0.005	0.001	0.00

*= Significant at 5% level of probability

**= Significant at 1% level of probability

NS=Not significant

Appendix IV Analysis of variance of the data on pH, OM, N, P, K, S and Zn in the soil after harvest of onion as affected by sulphur and zinc

Source of variation (SV)	Degrees of freedom	Mean squares						
		pH	OM	N	P	K	S	Zn
Replication	2	0.106	0.001	0.005	2.228	0.001	7.03	3.01
Sulphur	3	0.784**	0.766**	0.002*	51.455**	0.013**	57.302*	21.07*
Zinc	3	0.083**	0.079**	0.020*	26.200**	0.007**	59.542*	14.06*
Sulphur × Zinc	9	0.035NS	0.046**	0.031*	6.451*	0.001	4.400*	1.03*
Error	30	0.022	0.008	0.007	1.673	0.000	1.641	1.01

*= Significant at 5% level of probability
**= Significant at 1% level of probability
NS=Not significant