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

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This is to certify that the thesis entitled, **"EFFECT OF NITROGEN AND SULPHUR 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 **SHAHINUZZAMAN**, Registration No. 00794 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.

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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 nitrogen and sulphur on the growth and yield of onion cv. taherpuri. The soil was silty loam in texture having pH 6.2. The experiment was conducted in a RCBD with three replications. The experiment comprises 4 levels of nitrogen from urea (0 kg, 40 kg, 80 kg and 120 kg N ha^{-1}) and 3 levels of sulphur from gypsum (0 kg, 20 kg and 40 kg S ha^{-1}). The results revealed that different levels of nitrogen and sulphur showed significant variations on the parameters studied during the experiment except plant height (cm) and length of bulb (cm). The treatment of $N_{120}S_{40}$ (120 kg nitrogen + 40 kg sulphur) gave the highest results for all parameters either vegetative or yield contributing characters. The highest plant height (30.19 cm), number of leaves/plant (8.11) and largest leaf length (30.11 cm) were also obtained with the same treatment i.e. $N_{120}S_{40}$. The result indicated that maximum bulb yield (9.81 t ha^{-1}) of onion was obtained with the treatment $N_{120}S_{40}$ receiving 120 kg nitrogen and 40 kg sulphur. The highest concentrations of sulphur in the bulb (1.00 %) and available S in post harvest soil (26.10 ppm) were recorded in the treatment combination of $N_{80}S_{40}$ and $N_{120}S_{40}$, respectively. The highest concentrations of nitrogen in the bulb (2.32 %) and total nitrogen in post harvest soil (0.12 %) were recorded in the treatment combination of $N_{80}S_{40}$ and $N_{120}S_{20}$. So, the fertilizer combinations of nitrogen (120 kg ha^{-1}) and sulphur (40 kg ha^{-1}) not only gave maximum growth and yield of onion but also made the soil fertile and productive.

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Chapter-1

INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important spices as well as vegetable crop 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 114400 ha of lands with an average yield of 2.09 Mt. ha^{-1} (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 tons but total production in the country is 153 thousand metric tons (BBS, 2008). As a result huge amount of onion bulb is imported from neighboring countries like India, Burma, Pakistan and China at the cost of its hard earned foreign currency. Due to limitation of land it is not possible to raise the area of production of the crop horizontally. The productions can however be increased though proper management practices providing inputs especially fertilizer and 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 the cultivation of onion. 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 production of different nutrients used in the country is not well balanced. Nitrogen alone constitutes about 78% of the total nutrients used (Bhuiyan, 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.

Nitrogen plays an important role for the vegetative growth of the crop which ultimately helps in increasing bulb size and total yield. Nitrogen imparts greenness to plants by enhancing chlorophyll synthesis and induces more photosynthetic production per unit photosynthetic area. Onion is also known to be potash loving crop (Rai, 1981).

With a view to generate information on the aspect, a field experiment was carried out at shere-e-Bangla Agricultural University farm to determine the effects of nitrogen and sulphur on the growth and yield of onion. Considering the above conditions the present experiment was carried out with the following objectives;

1. To find out the appropriate dose of nitrogen (N) and sulphur (S) supplied chemical fertilizers for maximum growth and yield of winter onion.

2. To determine the integrated effect of nitrogen and sulphur on onion cultivation.

REVIEW OF LITERATURE

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

2.1 Effect of nitrogen on the growth and yield of onion

Gupta and Gaffer (1980) conducted an experiment to study the effect of different row spacings under different combinations of nitrogen, phosphorus and potassium on the growth and yield of onion. Application of NPK exerted a significant effect on the yield and yield contributing characters of onion. Economic yield was obtained from NPK application @ 46: 36: 36 kg ha^{-1}.

Agarwal *et al.* (1981) observed that with N, P_2O_5 and / or K_2O at 80-160: 40-80: 40-80 kg ha^{-1}, respectively, the highest yield was obtained from plots receiving 160:40:40 or 80:40:80 kg ha^{-1}. The application of nitrogen alone at 80 kg ha^{-1} gave satisfactory yield of 20.02 t ha^{-1} which was the most economic dose.

Rashid (1983) recommended 10 tons of cowdung, 175 kg of Urea, 125 kg of TSP and 150 kg of MP per hectare for successful onion cultivation in Bangladesh.

Patil *et al.* (1983) conducted a trial of NPK with the onion cv. White local. In their experiment, N, P_2O_5 and K_2O were applied at the rate of 75, 150, 75 or 150 and 50 or 100 kg ha^{-1}, respectively. In case of 75 kg N, yield was 222.9 q ha^{-1} while at 150 kg, yield was 311.2 q ha^{-1}. With the increase of phosphorus the yield increased but application of K had little effect on the yield.

Paterson (1984) carried out an experiment in USA with the nitrogen levels of 0 to 56 kg ha^{-1} and observed that premature bolting was reduced as the nitrogen rate was increased. Premature bolting was significantly reduced at 56 kg N ha^{-1}.

Satyanarayana and Arora (1984) reported that onion bulb yield increased with direct application of nitrogen up to 60 kg ha^{-1}. Potash at 40 kg ha^{-1} as K_2O, did not affect bulb yields of onion.

Amin (1985) reported that nitrogen at 60 kg ha^{-1} coupled with potash at 100 kg ha^{-1} gave the best performance in respect of bulb diameter (5.86 cm), bulb weight (64.70 g) and yield of onion (27.47 t ha^{-1}).

Madan and Sandhu (1985) noticed that effective plant growth and maximum bulb yield and dry matter yields were obtained with the application of N: P_2O_5: K_2O at 120: 60: 60 kg ha $^{-1}$, respectively.

Hedge (1986) found that N fertilization increased the bulb yield up to 160 kg ha^{-1} although there was no significant difference between 80 kg N ha^{-1} and 160 kg N ha^{-1}.

Lang (1987) clarified that N fertilizer was required to make up the crop's need at different stages of growth. Flat rate applications of 193 kg N ha^{-1} were followed by considerable losses resulting from irrigation and costs were also higher. Specific application of N @ 105 kg ha^{-1} was found to reduce N losses and costs, but the yield increased.

Saimbhi *et al.* (1987) reported that applying NPK at the highest rate gave greatest bulb size, maximum yield (33.89 t ha^{-1}) and best quality hydrated onions. The highest nutrient combination was 100 kg N, 60 kg P_2O_5 and 60 kg K_2O per hectare.

Srinivas and Nail (1987) reported that the bulb yield increased from 16.51 t ha^{-1} at zero N to 56.30 t ha^{-1} at the highest N rate (200 kg ha^{-1}).

Nehra *et al.* (1988) conducted an experiment with various levels of N and reported that the application of 40 and 80 kg N ha^{-1} significantly increased plant height and number of leaves compared to the control. The differences in the effect between 40 and 80 kg N were not significant except that 80 kg N increased the number of leaves per plant over 40 kg N.

Ahmed *et al.* (1988) studied the effect of 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}).

A field trial was conducted by Soto (1988) with critical level for P, K & S and response to N. The rate was 100 kg ha^{-1} for each of P_2O_5 and K_2O & 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.

Hedge (1988) carried out an experiment with cv. Pusa Red onion and noticed that application of N fertilizer increased bulb yield but not quality. He also showed that the dry matter production in bulb increased due to the uptake of more N, P, K, Ca and Mg nutrients.

Palled *et al.* (1988) conducted a field experiment with N fertilizer. They showed that application of 100 kg N ha^{-1} gave 12.2 and 26.4 % higher yields than 75 and 50 kg N ha^{-1}, respectively. The consumptive use of water increased with increasing frequency.

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.

Duque *et al.* (1989) studied the growth and nitrogen, phosphorus, potassium uptake of onion. The results indicated that the plant demand for N and K was higher during early growth stages, whereas demand for P was continuous throughout the development. Uptake levels were 38.8, 38.6 and 71.3 kg N, P_2O_5 and K_2O, respectively, for the yield of 2.5 t ha^{-1}.

Singh *et al.* (1989) conducted two types of experiments on onion production. They set up two types of land; one without previous green manuring and another was cropped with green manuring by *Sesbania aculata*. A combination of 120 kg N and 50 kg K_2O gave the tallest plants and the greatest number of leaves per plant, maximum bulb weight and bulb diameter and higher bulb yield in the first experiment. Green manuring also greatly enhanced plant growth and bulb yield.

Jayabharathi (1989) reported that the higher yield of onion was obtained by using the highest dose of NPK (75 kg of each nutrient). It was 55-75 % greater than the control. With the application of higher dose of fertilizer, the production of big size bulbs in comparison with medium and small size bulbs were produced significantly greater than bulbs supplied with lower doses.

Maier *et al.* (1990) stated that in onion crop fresh weight (FW) increase was correlated with the increase in N level and the largest bulbs were 25-30 mm in diameter. Nitrogen rates in the ranges 299-358 kg ha^{-1} gave 95 % of maximum yield. Dry matter of bulbs was not affected by N. Bulb size increased as the rate of applied N increased.

Pandey *et al.* (1990) conducted an experiment with various levels of N and reported the highest yield of marketable bulbs (34.97 t ha^{-1}) by transplanting on 1st January and applying 100 kg N ha^{-1}. Transplanting on 15 February and applying 50 kg N ha^{-1} gave the lowest marketable yield (10.38 t ha^{-1}).

Baloch *et al.* (1991) obtained maximum bulb yield (22.66 t ha^{-1}) with the application of 125 kg N + 75 kg K_2O ha^{-1}. The highest plant height (38.5 cm), number of leaves $plant^{-1}$ (7.0), single bulb weight (82 g), vertical bulb diameter (4.80 cm) and horizontal bulb diameter (5.78) were obtained with 125 kg N + 100 kg K_2O ha^{-1}.

Bhordwaj *et al.* (1991) stated that plant height was increased significantly with increasing levels of nitrogen. The main yield contributing components were the number of scalps per plant, size of umbel, but the yield increase beyond 80 kg N ha^{-1} was not significant.

Gaushal *et al.* (1991) stated that increasing N levels increased the bulb yield. The highest yield was recorded at 150 kg N ha^{-1} which was significantly superior to rest of the nitrogen levels. The yield at 100 kg N ha^{-1} was also significantly greater than 50 kg N ha^{-1} and the control.

Kumar and Shama (1991) conducted an experiment with two onion cultivars designated N-53 and N-2-4-1, grown in the *kharif* season and reported that bulb yield increased linearly as N application increased up to 75 kg ha^{-1}. The mean increase in the bulb and plant weight ratio was 1: 2.22 with 25 kg N, compared with 1: 1.95 for untreated controls; higher N rates reduced this ratio.

Jitendra *et al.* (1991) found in their trial of onion CVs. applied N @ 80, 120 and 160 kg ha^{-1}, K_2O @ 100 and $ZnSO_4$ @ 2.5 kg ha^{-1}. Higher N levels increased plant growth and yield. K alone and with Zn also increased plant growth, yield and dry matter contents. The highest yield (32.68 t ha^{-1}) was obtained with the higher rate of N along with K and Zn.

Singh and Sharma (1991) reported that soil moisture regimes and nitrogen application to onion crop affected the diameter of bulb and yield significantly. They also reported that application of nitrogen at 80 kg ha^{-1} caused 38% increase in bulb weight over control.

Pandey *et al.* (1991) studied the effect of four levels of nitrogen (0, 50, 100, 150 kg ha^{-1}), three levels of phosphorus (0, 40 or 80 kg ha^{-1}) and two levels of potash (0 and 50 kg ha^{-1}) the yield and quality of *kharif* onion. They found that the maximum yield and net return were achieved with N: P: K at 105: 40: 50 kg ha^{-1}.

Pandey *et al.* (1992) conducted an experiment to find out the effect of nitrogen and spacing on *kharif* onion cv. Agrifound Dark Red at Jaipur, Rajasthan, India. They found that both 80 and 120 kg N ha^{-1} ha gave significantly higher yields than the lower fertilizer rates, but the higher N rates resulted in significantly larger umbels and less incidence of thrips. The incidence of purple blotch was unaffected by N application.

Rahim *et al.* (1992) investigated the scope for increasing the total yield and fulfilling the demand of onions during the period of shortage in Bangladesh through the bulb-to-bulb (set) method of production. In a fertilizer trial, onion sets were planted on 6^{th} November at a spacing of 25 × 15 cm supplied with 0-160 kg K ha^{-1} and 0-100 kg N ha^{-1}, half before planting and half 36 days after planting. The combination of the highest application rates of N and K resulted in the yield of 11.11 t ha^{-1} compared with 4.5 t ha^{-1} from unfertilized control plots.

El-Oksh *et al.* (1993) observed that N application had no significant effect on plant height, number of leaves, fresh weight or dry weight, but bulbing ratio (the ratio between bulb and neck diameter) decreased and total chlorophyll content increased with increasing N application. High N increased bulb fresh weight at harvest.

Vachhani and Patel (1993) studied the effect of different levels of NPK on the growth and yield of onion. They found that plant height, number of leaves $plant^{-1}$, bulb weight and yield were the highest with 150 kg N ha^{-1}, although bulb weight and yield with 100 kg N ha^{-1} were not significantly different. Increasing phosphorus application increased the number of leaves per plant and weight, size and yield of bulbs. Application of K increased only the number of leaves per plants.

Singh *et al.* (1994) noticed that total marketable yield and total dry weight production were the best in the plots treated with N at 80 kg ha^{-1}. They also stated that plant mortality increased with increasing rates of N.

Katwale and Saraf (1994) reported that the maximum bulb yield was obtained with the application of NPK at the rate of 125: 60: 100 kg ha^{-1}, respectively. This rate also gave the highest economic return.

Perilas and Nicor (1994) stated that the bulb weights of 12.34 and 45.72 t ha^{-1} were found when 180 and 300 kg N ha^{-1} were applied respectively. They also reported that application of 180 to 240 kg N ha^{-1} showed an appreciable increase in diameter of bulbs from 2.85 (control) to 3.70 cm. The largest bulb diameter of 4.13 cm was observed when 300 kg N ha^{-1} was applied.

Amin *et al.* (1995) worked on onion cv. Taherpuri, planted on 20 December and 20 January and gave 0, 25, 50 or 100 kg N ha^{-1}. Yield was the highest from the planting of 20 December supplied with 100 kg N ha^{-1}. Individual bulb weight was also greater in this treatment.

Singh *et al.* (1996) carried out a field trial in Agra, India to observe the effects of N (0, 60, 120 or 180 kg ha^{-1}) and S (0, 20, 40 or 80 kg ha^{-1}) on the growth of onions (cv. Pusa Red). The yield and plant nitrogen contents significantly increased with increase in nitrogen application. Combined addition of N and S significantly increased its yield.

Harun-or-Rashid (1998) conducted a field trial at Bangladesh Agricultural University, Mymensingh to observe the effect of NPKS on growth and yield of onion at different plant spacing. He stated that the maximum bulb weight (40.50 g) and bulb yield (20.75 t ha^{-1}) were found from the combination of 125-150-150-30 kg N, P_2O_5, K_2O, S ha^{-1}, respectively. Application of NPKS increased the plant height, leaf number, bulb length, bulb diameter and bulb weight as well as the bulb yield. He recommended 100-150-200-30 kg N, P_2O_5, K_2O, S ha^{-1}, respectively for the cultivation of BARI piaz-1 at BAU farm conditions.

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.

Singh and Mohanty (1998) studied the effect of NPK on growth and yield of onion in Orissa, India, in 1995-96. With increasing N level, plant height increased in both the experimental periods. Plant height, bulb girth, number of leaves $plant^{-1}$, bulb weight and highest yield (295.8 q ha^{-1}) were achieved with N and K at 160 and 80 kg/ha, respectively. Based on these results, the recommended rates for commercial onion production in and around Bhubaneswar are 160 kg N, 80 kg K_2O and 60 kg P_2O_5 ha^{-1}.

Kumar *et al.* (1998) carried out an experiment in India during 1993/94 and 1994/95 and observed that N at 150 kg ha^{-1} gave the best results with regard to plant height, length and diameter of the longest leaf, diameter of the thickest stem, number of leaves/plant, plant spread, time to bulb maturity, bulb diameter, bulb FW and DW, length of the longest root, and bulb yield.

Rodriguez *et al.* (1999) carried out experiments during 1993-94 and 1994-95 on onion to find out the effect of nitrogen, phosphorus and potassium rates, sources and forms upon onion (*Allium cepa*) bulb yield and quality. Yield, plant height, leaf number and polar and equatorial diameters were measured with different rates, sources and forms of N, P and K. Significant effects of P and K rates (applied up to 98.2 and 200 kg ha^{-1}, respectively) could not be detected, nor significant interactions between N and P.

Ramamoorthy *et al.* (1999) conducted a field experiment in Bhavanisagar, Tamil Nudu where Onion cv. CO4 was given 0, 30, 60 or 90 kg N ha^{-1} during the *kharif* and summer seasons of 1994 and 1995. They stated that bulb yield increased as N rate increased.

A field trial was conducted by Singh and Chaure (1999) on a sandy loam soil at Bilaspur, India. 5, 6 and 7 weeks old onion seedlings were supplied with N at 50, 100 or 150 kg/ ha in 1989-90 and with N at 50, 100, 150 or 200 kg ha^{-1} in 1990-91 and 1991-92. The optimum seedlings age and N application rate, in terms of leaf length, number of leaves per plant, bolting percentage, bulb weight and bulb yield were 6 weeks and 150 kg ha^{-1}, respectively. At an extra fertilizer rate of N 200 kg ha^{-1}, the additional yield did not compensate for the cost of extra fertilizer.

Singh *et al.* (2000) conducted an experiment at Rajasthan, during summer season of 1993-95. Onion cv. N-53 was grown under factorial combinations of three (3) levels each of nitrogen (50, 75 and 100 kg N), phosphate (13.2, 22.0 and 30.8 kg P) and potash (41.5, 62.2 and 83.0 kg K). It was concluded that onion productivity could be enhanced considerably by application of 100 kg N, 30.8 kg P and 83.0 kg K ha^{-1}.

Hussaini and Amans (2000) carried out a field experiment during the 1993-94 and 1994-95 dry seasons, at Kadawa in the Sudan Savannah ecological zone of Nigeria. They stated that nitrogen application positively increased the bulb yield, average bulb weight, and number of large bulbs per plot and 7-day intervals irrigation produced higher bulb yield, average bulb weight, and number of large bulbs per plot.

Anonymous (2001) conducted an experiment at Spices Research Centre, BARI, Joydebpur during 2000-2001 with four levels of nitrogen (0, 100, 125 and 150 kg

ha^{-1}). Influence of different levels of nitrogen was significant on different parameters of onion studied. But 125 kg ha^{-1} and 150 kg ha^{-1} of nitrogen produced 10.91 t ha^{-1} and 8.70 t ha^{-1} of bulb, respectively while it was 5.74 t ha^{-1} in control.

According to Mohanty and Das (2001), application of 90 kg N and 60 kg K_2O ha^{-1} was better for obtaining higher yield with larger bulbs, while 30 kg ha^{-1} each of N and K_2O was suggested to realize medium bulbs with moderate yield and better keeping quality in long term storage.

In a field experiment conducted by Tiwari *et al.* (2002) in Patharchatta, Uttar Pradesh, India, during the winter seasons of 1995-96, 1996-97, and 1997-98 with three levels of N and its application methods on onion cv. Pusa Red. They stated that 100 kg N ha^{-1} and foliar spray gave the highest yield.

Yadav *et al.* (2002) carried out an investigation on onion cultivars Puna Red, White Marglobe, Nasik Red and Rasidpura Local which were supplied with 50, 100, and 150 kg N and K ha^{-1} in Jaipur, Rajasthan, India during the *rabi* seasons of 1998-2000. Yield, fresh weight of bulb, total soluble solids and allyl propyl disulphide content increased, whereas ascorbic acid content decreased with the increase in N and K rates. Rasidpura Local recorded the highest values for the parameters measured except allyl propyl disulphide content which was highest in Nasik Red.

Muoneke *et al.* (2003) conducted a field trial to investigate the effects of four levels of nitrogen and three levels of phosphorus on growth and keeping quality of onions. They found that application of 90 and 135 kg N ha^{-1} increased the growth and yield but reduced the post harvest storage quality. Phosphorus at 60 kg ha^{-1} increased these attributes but did not influence the keeping quality of the bulbs.

Mandira and Khan (2003) carried out an experiment with different levels of nitrogen (0, 100, 150 and 200 kg ha^{-1}) and potassium (0, 75 and 150 kg ha^{-1}) to study their effect on the growth, yield and yield attributes of onion cv. N-53 in Tripura, India during *rabi* season of 2001. Nitrogen at the rate of 150 kg ha^{-1}, potassium at 75 kg ha^{-1} and their combination recorded the best performance in terms of yield and growth.

Yadav *et al.* (2003) stated that application of 100 kg ha^{-1} N produced significantly higher bulb yields over 50 kg ha^{-1} but 150 kg N ha^{-1} did not significantly increase the bulb yield. They also reported that 150 kg K_2O ha^{-1} produced significantly higher bulb yield compared to lower rates of potash.

Haque *et al.* (2004) investigated the effects of nitrogen and irrigation on the growth and yield of onion cv. BARI Piaz-1 during the rabi season of 2000-01. Plant height, number of leaves per plant, bulb length, bulb diameter, neck thickness, single bulb weight and crop yield increased with increasing rates of N up to 125 kg ha^{-1} and with irrigation at 7-day intervals. Interaction effects between

N rates and irrigation were significant for all the parameters measured except for bulb diameter.

Shrawan *et al.* (2004) studied the effect of NK on the growth and bulb yield of onion crop. They reported that plant height at harvest (51.43 cm), leaf length (28.22 cm), fresh weight of leaves (25.21 g) and total chlorophyll content at 45 days after transplanting (1.33 mg) and 90 days after transplanting (1.67 mg) were the highest upon treatment with the highest nitrogen rate (150 kg N ha^{-1}) and with the highest potassium rate (120 kg K ha^{-1}).

Jilani *et al.* (2004) conducted a field trial to study the effect of different levels of nitrogen on three onion cultivars (Faisalabad Early, Phulkara and Shah Alam). They observed that maximum value cost ratio was found in Shah Alam followed by Faisalabad Early and Phulkara and N at 120 kg ha^{-1} proved to be the best for all the parameters studied.

Yamasaki and Tanaka (2005) investigated the role of N in the flower initiation of Welsh onion (A. fistulosum) cv. Kincho. They found that low N rates retarded the growth but promoted leaf sheath bulbing and bolting of Welsh onions. It also reduced the nitrogen and carbon concentration but increased the C: N ratio in the crop.

Anonymous (2007) conducted an experiment at Spices Research Centre, BARI, Bogra with four levels of nitrogen (0, 50, 100 and 150 kg ha^{-1}), phosphorus (0, 20, 40 and 60 kg ha^{-1}), potassium (0, 50, 100 and 150 kg ha^{-1}) and sulphur (0, 10, 20 and 30 kg ha^{-1}) for *kharif* onion cultivation. Among the fertilizer treatments, $N_{100}P_{40}K_{100}S_{30}$ gave the highest yield (22.33 t ha^{-1}) and the lowest yield (9.67 t ha^{-1}) was obtained in control.

2.2 Effect of Sulphur on the Growth and Yield of Onion

Yasin and Bufler (2007) conducted an experiment designed to relate features of S metabolism to the dormant and/or sprouting states of onion bulbs (*Allium cepa* L.) during storage at 18 degrees 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). The determination of initial sprout growth was based on measurements of sprout leaf elongation. Two long-day cultivars ('Golden Bear F< sub>1</ sub>' and 'Copra F< sub>1</ sub>'), with a clear period of dormancy, were chosen for these experiments. Changes in total sulphur content showed no clear relationship to either the dormant or the sprouting phase, whereas the sulphate content of each bulb part studied tended to be lowest at the transition from dormancy to sprouting. EPY, as an equivalent to flavour precursor content and pungency, increased in the inner scale of both cultivars throughout dormancy, and initial sprout growth. In contrast, EPY was lowest in the sprout leaves and stem plate at the end of dormancy in 'Copra F< sub>1</ sub>', but 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 remobilisation and reallocation of sulphur compounds within the onion bulb during dormancy and initial sprouting.

Channagoudar and Janawade (2006) carried out a field experiment 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 sulphur (S) (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 with 1.5 IW/CPE ratio irrigation schedule compared to 0.9, 1.1 and 1.3 IW/CPE ratios. 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 ratio. 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 par 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 sulphur (S< sub>95</ sub> and gypsum) on onion (Allium cepa) under acidic soil and to work out their optimum doses. Fertilizer Testing Model was used to know the differences in the fertilizers at linear and curvature levels. The other statistical tools like't' test considered linearity and curvature independently. The results showed the superiority of gypsum both at linear and curvature level by 0.0721 and 0.00066 tonne/ha. Multifertilizer Response Model was used to work out the optimum dose of fertilizers. 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 were worked out to be Rs 60 911 and 81 306, respectively. The study clearly indicates that gypsum is a superior sulfur source for onion crop.

Qureshi and Lawande (2006) determined the effects of sulphur on the yield, quality and storability of onion cv. B 780 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^{-1}. The highest bulb yield of 39.1 t/ha was recorded with the application of 75 kg S ha^{-1}. Sulfur content in bulbs increased by 48.0% due to the application of 75 kg S ha^{-1} over the NPK treatment. Pyruvic acid concentration increased from 3.3 p mol/ml with 75 kg S ha^{-1}. Storage losses were reduced by 10.4% over a period of 6 months due to the application of 45 kg S ha^{-1} in comparison to only the NPK treatment. Simple linear regression analysis revealed significant negative correlation between the storage losses of onion bulbs taken as dependent variable and pyruvic acid and total soluble solids as independent variables.

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 sulphate) 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 sulphate 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 sulphur 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 in 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 colour, compared with S-treated plants.

Nagaich *et al.* (1999) conducted an experiment during 1995-96 and 1996-97 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) 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 at 0, 40, 80 or 120 kg/ha to Nasik Red onions. Bulb yields increased with S rate and were the 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 BAU 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}).

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 increased by 22.48 percent with the application of sulphur at 17 kg ha^{-1}.

Aulakh *et al.* (1977) reported that S content in plant foliage during active growth and at maturity had significant correlation with crop yield. The S content below0.2% in the plant tissue at the pre-flowering stage of brassica was threshold level, below which the crop yield and quality were adversely affected.

Misra and Prasad (1966) conducted a field trail with sulphur fertilizer on pungency and yield of onion. They observed that suitable dressing of sulphur fertilizer improved growth, yield, pungency and also increases the availability of trace element.

Jasa and Roboptokva (1957) while working with fertilizer on onion observed that both types and rates of fertilizer affected the plant growth and its development.

Thomkpson and Kelly (1957) reported that is an association between the pungency and content of sulphur in onion. The higher the content of sulphur the greater the pungency or the stronger the flavour. The content of sulphur (pungency) was also found to be associated with good keeping quality.

Chapter-3

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.

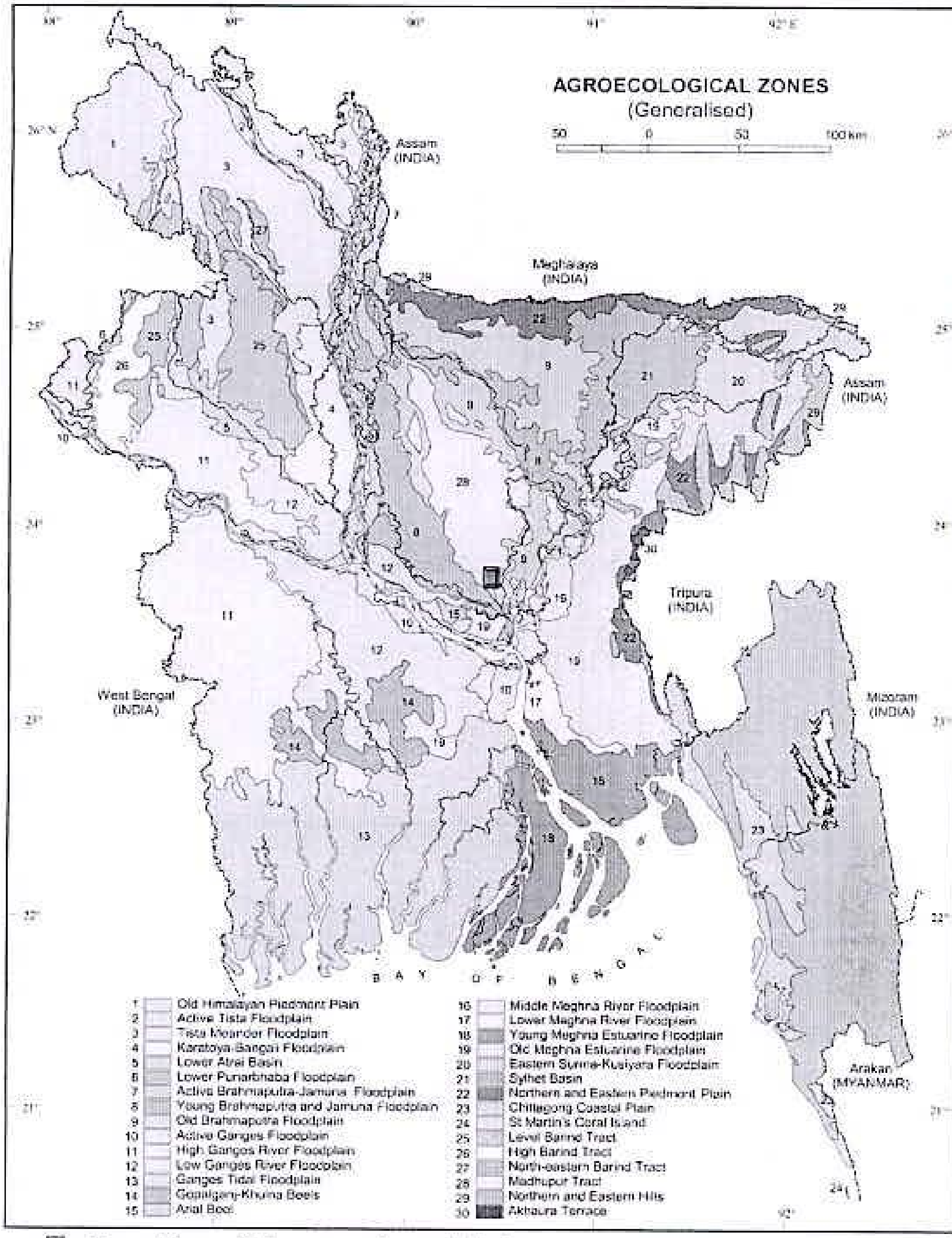
3.1 Description of the experimental site

3.1.1 Location

The research work relating to the study of the effect of nitrogen and sulphur on the growth and yield of onion was conducted on the Farm division of Sher-e-Bangla Agricultural University, Dhaka-1207 during the *rabi* season of December, 2008. 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. The soil is characterized by heavy clays within 50 cm from the surface and is acidic in nature. 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	29.14
% Silt	41.75
% Clay	29.11
2. Soil texture	Clay loam
B. Chemical properties	
1. Soil pH	6.16
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)	45
8. Available S (ppm)	23.74

3.1.3 Climate

The experimental area has sub tropical climate characterized by heavy rainfall during May to September and scantly 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 2008-09. 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 harvesting. The monthly maximum and minimum temperature, humidity and rainfall of the site during the experimental period are given in appendix Table 1.

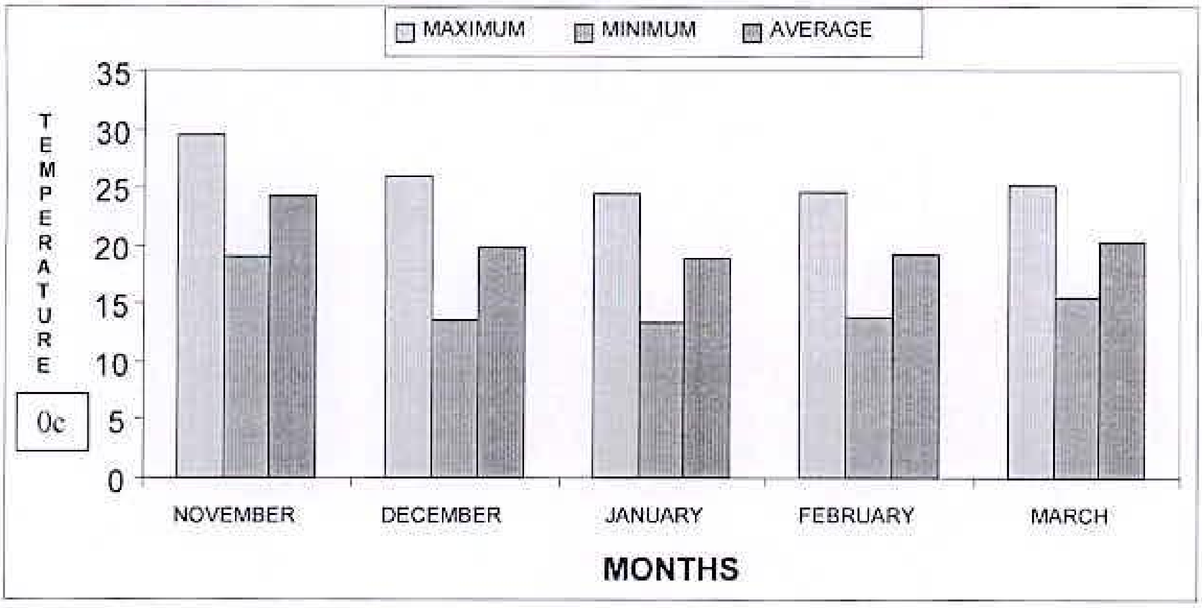


Figure 2. Monthly average, maximum and minimum air temperature (°C) of the experimental site, Dhaka during the growing time (November, 2008 to March 2009)

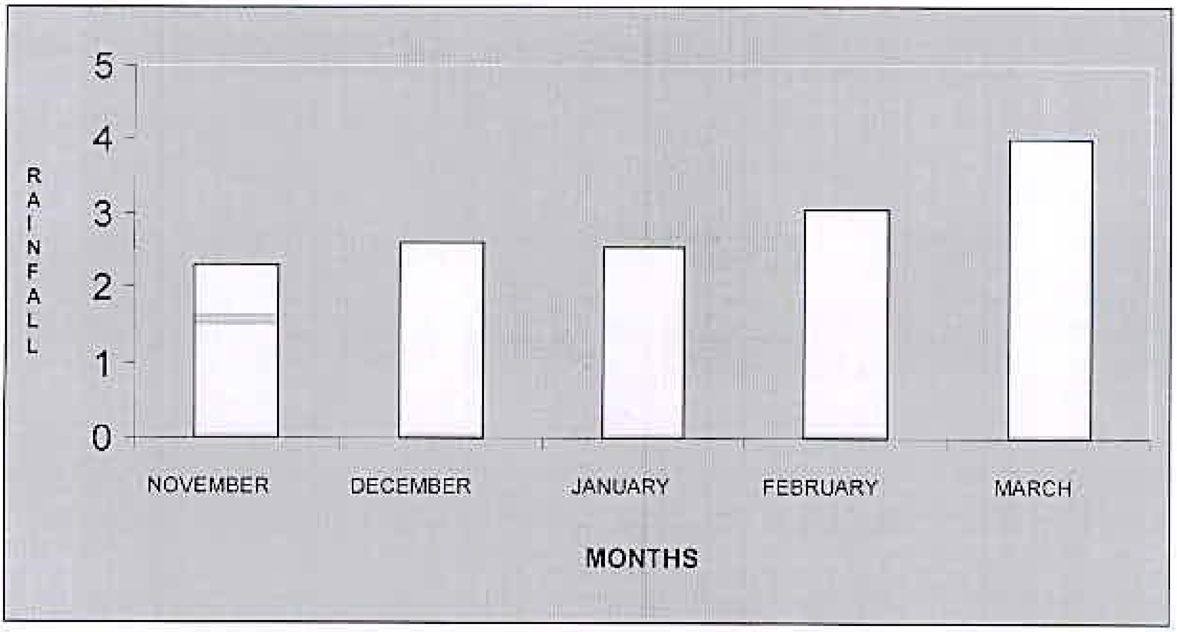


Figure 3. Monthly total rainfall (mm) of the experimental site, Dhaka during the growing period (November, 2008 to March 2009)

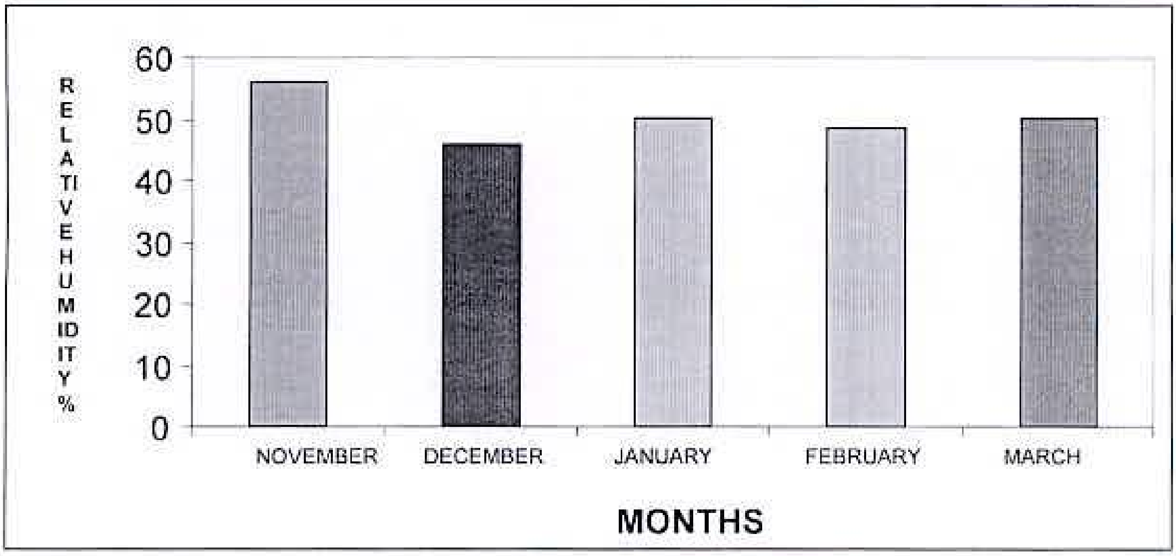


Figure 4. Monthly average relative humidity (%) of the experimental site, Dhaka during the growing period (November, 2008 to March 2009)

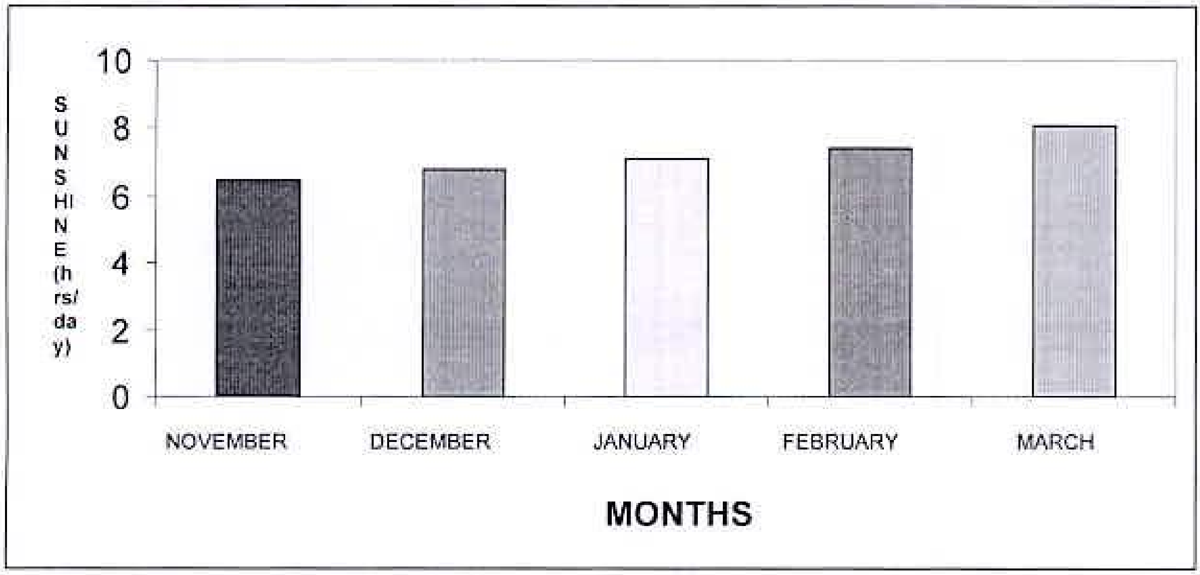


Figure 5. Monthly average sunshine (hrs/day) of the experimental site, Dhaka during the growing period (November, 2008 to March 2009)

3.2 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 03^{rd} 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.

3.3 Treatments of the experiment

The experiment consists of two factors viz. mitrogen (N) and Sulphur (S).

Details of the treatments are presented below:

Factor A: Nitrogen levels

N_0 = 0 kg N ha^{-1}

N_1 = 40 kg N ha^{-1}

N_2 = 80 kg N ha^{-1}

N_3 = 120 kg N ha^{-1}

Factor B: Potassium levels

S_0 = 0 kg S ha^{-1}

S_1 = 20 kg S ha^{-1}

S_2 = 40 kg S ha^{-1}

Treatment combinations of nitrogen and sulphur

T_1 = No Nirogen + No Sulphur (S)

T_2 = No N + 20 kg S ha^{-1}

T_3 = No N + 40 kg S ha^{-1}

T_4 = 40 kg N ha^{-1} + No Sulphur (S)

T_5 = 40 kg N ha^{-1} + 20 kg S ha^{-1}

T_6 = 40 kg N ha^{-1} + 40 kg S ha^{-1}

T_7 = 80 kg N ha^{-1} + No Sulphur (S)

T_8 = 80 kg N ha^{-1} + 20 kg S ha^{-1}

T_9 = 80 kg N ha^{-1} + 40 kg S ha^{-1}

T_{10} = 120 N ha^{-1} + No Sulphur (S)

T_{11} = 120 N ha^{-1} + 20 kg S ha^{-1}

T_{12} = 120 N ha^{-1} + 40 kg S ha^{-1}

3.4 Design and layout of the experiment

The experiment consisted of 16 treatment combinations 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 6.

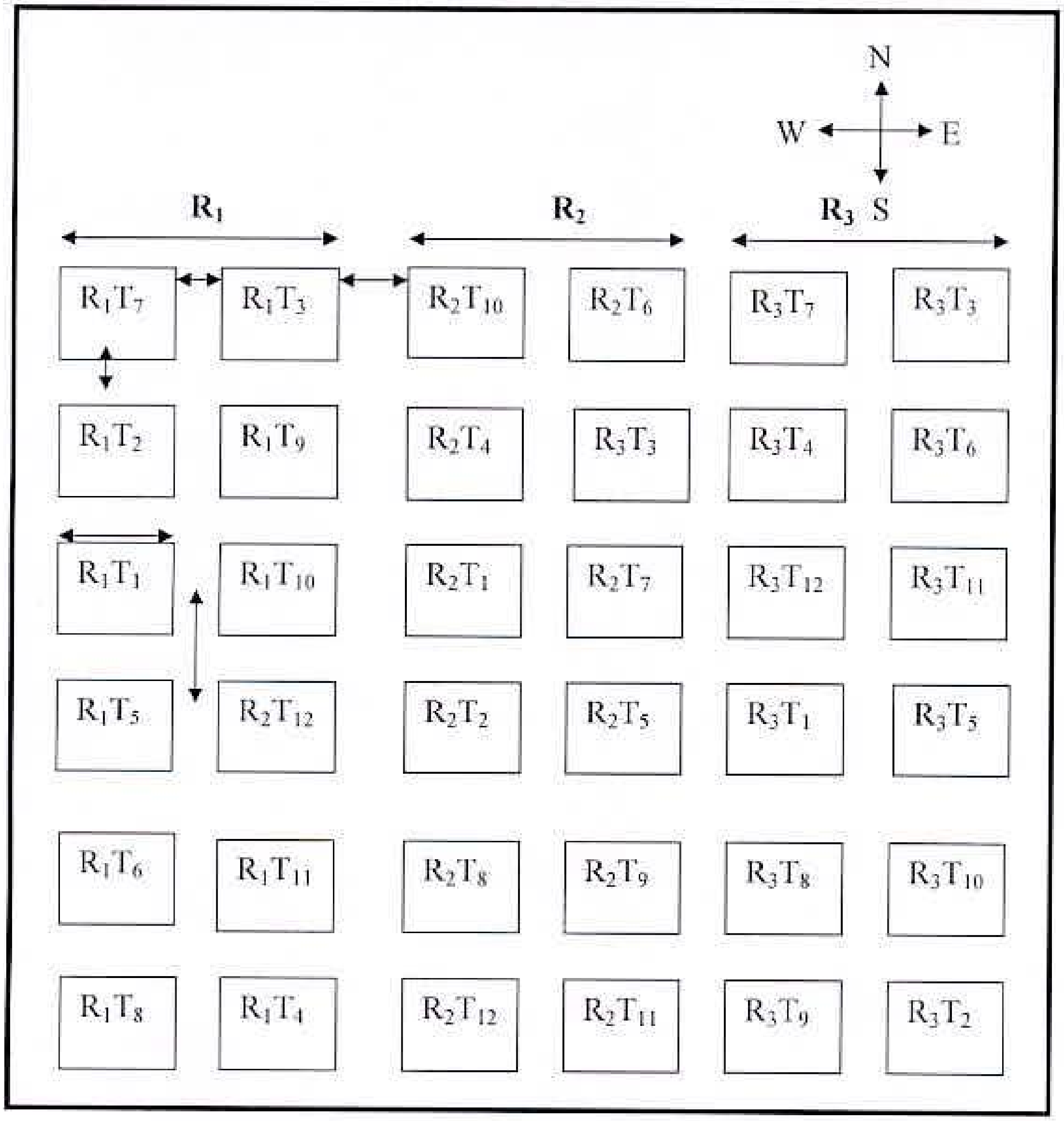


Figure 6. Layout of the experimental field

Plot size: 2.5 m x 2 m (5 m^2)

Plot to plot distance: 1 m

Block to block distance: 1.5 m

3.5 Cultivation of onion

3.5.1 Preparation of the field

The plot selected for the experiment was opened by a tractor on the 12^{th} December' 2008, 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.

3.5.2 Rate of manures and fertilizers

In this experiment manures and fertilizers were used according to the recommendation of BARI as follows:

Common doses:

Manures/ fertilizers	Dose/ ha
Urea	as required
TSP	220 kg
MP	170 kg
Borax	08 kg
Cow dung	10 tons
Gypsum	as required.

3.6.3 Application of manures and fertilizers

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 will be applied in three equal installments will be applied as top dressing.

3.5.4 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 18^{th} December' 2008. 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.

3.5.5 Intercultural operation

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

3.5.5. a) Gap fillings

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

3.5.5. 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.

3.5.5. 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.

3.5.5. 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.

3.6 Harvesting

The crop was harvested on 12th March 2009 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.

3.7 Collection of data

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

1. Plant height (cm)
2. Number of leaves/plant
3. Length of leaves/plant (cm)
4. Fresh weight of leaves/plant (g)
5. Fresh weight of bulb/plant (g)
6. Dry weight of leaves/plant (g)
7. Dry weight of bulb/plant (g)
8. Diameter of bulb (cm)
9. Length of bulb (cm)
10. Yield of bulb (t/ha)

3.7.1 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.

3.7.3 Number of leaves per plant

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

3.7.2 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.

3.7.3 Fresh weight of leaves plant^{-1} (g)

Fresh weight of leaves plant^{-1} (g) was measured using electrical balance.

3.7.4 Fresh weight of bulb plant^{-1} (g)

Fresh weight of bulb plant^{-1} (g) was measured using electrical balance.

3.7.5 Dry weight of leaves plant^{-1} (g)

Dry weight of leaves plant^{-1} (g) was measured using electrical balance after drying the bulb in the desiccator.

3.7.6 Dry weight of bulb plant^{-1} (g)

Dry weight of bulb plant^{-1} (g) was measured using electrical balance after drying the bulb in the desiccator.

3.7.7 Diameter of bulb (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.

3.7.8 Length of bulb (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.

3.7.9 Yield of bulb (t/ha)

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

3.7.10 Length of bulb per plant (cm)

After removing the leaves the length of bulb was measured in centimeter (cm) from pseudostem to the base of the bulb from five randomly selected plants after harvesting and their average was recorded.

3.7.11 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).

3.7.12 Yield of bulb per plot (kg) and per hectare (t/ha)

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 and then converted to ton per hectare.

3.8 Collection of samples

3.8.1 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 17th March, 2009. The samples were air-dried, ground and sieved through a 2 mm (10 meshes) sieve and kept for analysis.

3.8.2 Plant sample

Plant samples were collected from every individual plot for laboratory analysis at the harvesting stage of the crop. Five plants were randomly selected from each plot for recorded 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.

3.9 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:

3.9.1 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.

3.9.2 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).

3.9.3 Organic carbon

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

3.9.4 Organic matter

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

3.9.5 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).

3.9.6 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.

3.9.7 Exchangeable potassium

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

3.9.8 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 Hunter (1980) using a Spectrophotometer (LKB Novaspec, 4049).

3.10 Chemical analysis of plant sample

3.10.1 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.

3.10.2 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).

3.10.3 Potassium

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

3.10.4 Sulphur

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

3.10.5 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 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

The present experiment was conducted to investigate the effect of nitrogen and sulphur 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 nitrogen and sulphur on the growth parameters of onion

Results of the effects of nitrogen and sulphur treatments on various growth parameters of onion such as plant height, number of leaves plant^{-1} and length of leaves has been presented and discussed below:

4.1.1 Plant height

Plant height at harvest varied significantly due to different levels of nitrogen and sulphur application. Nitrogen level of 120 Kg ha^{-1} gave the tallest plant (28.21 cm) followed by N_{80} (23.87 cm) and N_{40} (18.01 cm) while N_0 (0 kg nitrogen) gave the shortest plant (20.42 cm). On the other hand, the maximum height (23.09 cm) of the plant was obtained with the treatment of S_3 (40 kg sulphur) and the minimum height (20.61 cm) with S_0 (0 kg sulphur) (Table 2). Similar result was found by A combination of 120 kg N and 50 kg K_2O gave the tallest plants and the greatest number of leaves per plant, maximum bulb weight and bulb diameter and higher bulb yield in the first experiment. Nehra *et al.* (1988) conducted an experiment with various levels of N and reported that the application of 40 and 80 kg N ha^{-1} significantly increased plant height compared to the control.

The combined effect of nitrogen and sulphur was insignificant in respect of plant height. However, the maximum height (30.19 cm) of the plant was obtained with treatment combination of $N_{120}S_{40}$ (120 kg N and 40 kg S). The second highest height of onion was found from $N_{120}S_{20}$ (120 kg N and 20 kg S) which was found to be statistically identical with the treatments of $N_{120}S_{0}$, $N_{80}S_{20}$. And the minimum plant height (15.10 cm) was found in the treatment of N_0S_0 i.e. control (Table 3 and fig. 7).

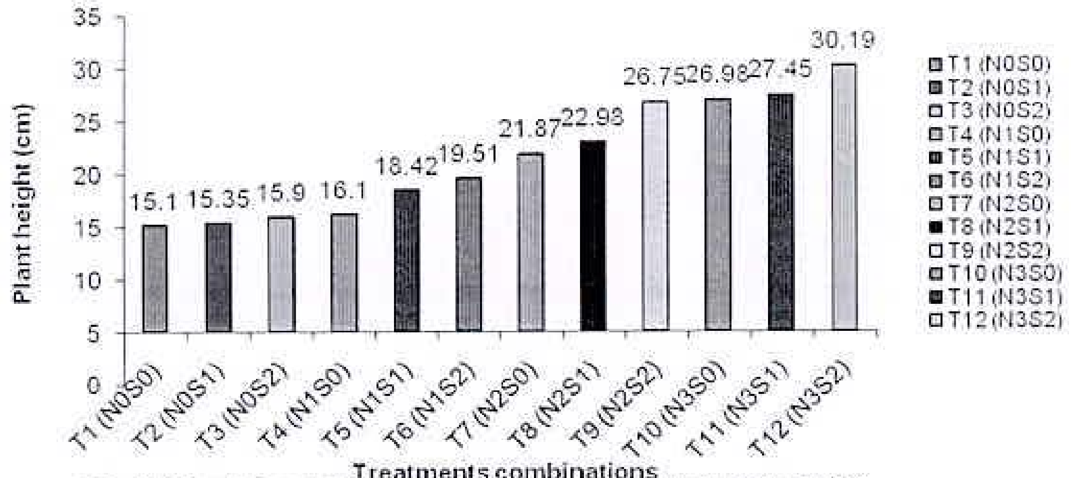


Fig. 7. Combined effects of nitrogen and sulphur on plant height (cm)

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

Nitrogen (kg ha^{-1})	Plant height (cm)	Number of leaves/plant	Length of leaves/plant (cm)	Fresh weight of leaves/plant (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)
N_0	15.45d	5.21c	15.49c	5.50b	20.77d	0.61d	2.12c	2.12c	1.86c	3.47c
N_{40}	18.01c	6.61b	20.71b	6.27b	24.98c	0.90c	4.52b	2.63b	2.43b	6.54b
N_{80}	23.87b	7.61a	27.25a	7.56a	28.71b	0.97b	5.71a	3.31a	2.96a	7.49a
N_{120}	28.21a	7.85a	27.62a	7.81a	29.02a	1.12a	5.30a	3.39a	2.68ab	8.05a
LSD	1.766	0.60	1.54	1.03	1.67	0.05	0.504	0.15	0.448	0.793
Level of significance	**	**	**	**	**	**	**	**	**	**
Sulphur (kg ha^{-1})										
S_0	20.01b	6.55	21.33b	6.37	24.82	0.71c	3.89b	2.66c	2.22a	5.13c
S_{20}	21.05ab	6.79	23.00a	6.75	25.95	0.92b	4.46ab	2.85b	2.50a	6.49b
S_{40}	23.09a	7.13	23.99a	7.23	26.81	1.00a	4.88a	3.08a	2.73a	7.55a
LSD	2.068	0.70	1.78	1.21	1.93	0.06	0.59	1.176	0.524	1.06
Level of significance	**	NS	**	NS	NS	**	**	**	NS	**
CV(%)	5.51	5.86	6.08	10.15	4.06	7.63	4.98	4.55	12.03	7.14

** = Significant at 1% level

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

4.1.2 Number of leaves plant^{-1}

The leaf production of the onion plant varied significantly due to application of nitrogen but not to sulphur. Nitrogen level of N_{120} (120 kg N) produced the maximum number of leaves (7.85) while the minimum (5.21) number of leaves was produced with N_0. On the other hand, maximum number of leaves was observed in the treatment of S_{40} (7.13) and minimum in the S_0 (6.55) (Table 2 and fig. 8). Jaggi (2005) found similar result that showed that 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 40 kg/ha.

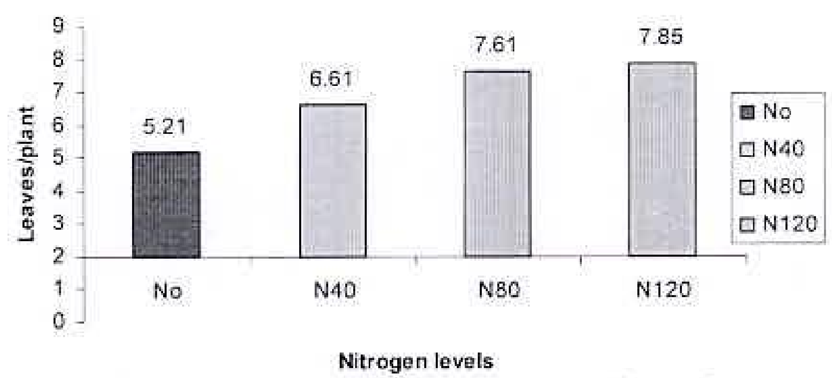


Fig. 8. Effect of nitrogen levels on leaves/plant of onion

Combined effects of nitrogen and sulphur on the production of leaves/plant have been shown in **Table 3.** From the result it was observed that there was significant variation among the treatment combinations. The treatment combination of $N_{80}S_{40}$ produced the highest (8.72) number of leaves while N_0S_0 i.e. control produced the lowest number of leaves (5.10). According to Anwer *et al.* (1998) the application of nitrogen, sulphur increased the number of leaves plant^{-1} with the increasing rates up to 150 kg N, 20 kg S ha^{-1} at Jessore area and Nehra *et al.* (1988) conducted an experiment with various levels of N and reported that the application of 40 and 80 kg N ha^{-1} significantly increased plant height and number of leaves compared to the control.

4.1.3 Length of leaf (cm)

Leaf length was also significantly influenced by nitrogen and sulphur treatments. From the single mean effect of nitrogen we observed that N_{120} i.e. 120 kg of N gave the largest leaf length (27.62 cm) followed by N_{80} (80 kg of nitrogen) with the value of 27.25 cm. The minimum leaf length was recorded in N_0 i.e. control treatment. On the other hand, maximum leaf length (23.99 cm) was observed in the treatment of S_{40} i.e. 40 kg of S followed by S_{20} with the value of 23.00 cm. These two treatments were statistically identical (Table 2).

Combined effects of nitrogen and sulphur on the length of leaves have been shown in **Table 3**. The maximum leaf length (28.15 cm) was obtained with treatment combination of $N_{80}S_{40}$. The minimum leaf length (15.12 cm) was found in the treatment of N_0S_0 i.e. control.

4.2 Effect of nitrogen and sulphur on the yield and yield attributing characters of onion

4.2.1 Fresh weight of leaf (g)

Analysis of variance revealed that the effects of nitrogen and sulphur were significant in respect of fresh weigh of leaves $plant^{-1}$.

Single effect of different doses of nitrogen has been shown in Table 2. It was observed from the result that nitrogen level of 120 kg produced the highest fresh weight of leaves (7.81 g) and the lowest fresh weight of leaves (5.50 g) was obtained with nitrogen level N_0 i.e. 0 kg of nitrogen. On the other hand, single mean effects of different levels of had no significant effect on the average fresh weight of leaves. However, sulphur at S_{40} level gave the highest weight of leaves (7.23 g) while S_0 gave the lowest (6.37 g). The result was in conformity with Jaggi (2005) who showed that 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 40 kg/ha.

The combine effect of nitrogen and sulphur on fresh weight of leaves varied significantly among the different treatment combinations (Table 3). The treatment combination of $N_{120}S_{40}$ produced the highest (8.55 g) fresh weight of leaves while the lowest (5.22 g) was obtained with the combination of N_0S_0 i.e. control.

4.2.2 Fresh weight of bulb (g)

A significant variation was observed in terms of fresh weight of bulb due to N and S application. Single effect of different doses of nitrogen has been shown in Table 2 and fig. 9. It was observed from the result that nitrogen level of 120 kg produced the highest fresh weight of bulb (29.02 g) and the lowest fresh weight of bulb (20.77 g) was obtained with nitrogen level N_0 i.e. 0 kg of nitrogen. On the other hand, single mean effect of different levels of S on the average fresh weight of bulb was highly significant. Sulphur at S_{40} level gave the highest weight of bulb (26.81 g) while S_0 gave the lowest (24.82 g). Losak (2005) and Jaggi (2005) found similar result that showed that the fresh weights of onion yield increased with increasing S rates up to 40 kg/ha.

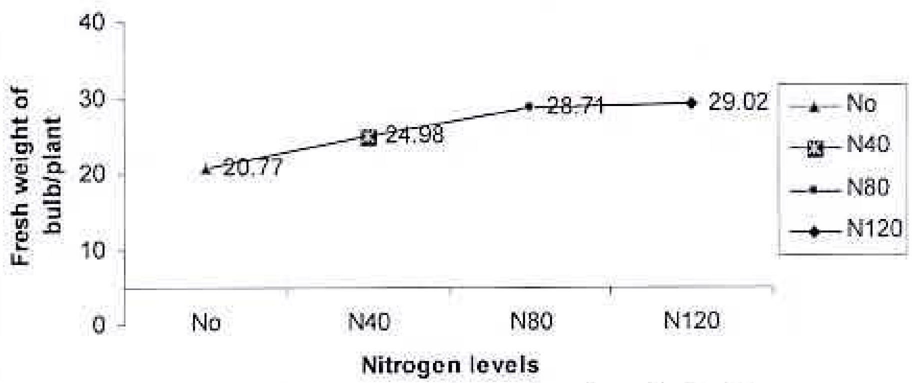


Fig.9. Effect of nitrogen levels on fresh weight of bulb/plant

The combined effect of nitrogen and sulphur on fresh weight of bulb varied significantly among the different treatment combinations (Table 3). The treatment combination of $N_{120}S_{40}$ produced the highest (30.66 g) fresh weight of bulb while the lowest (20.00 g) was obtained with the combination of N_0S_0 i.e. control.

4.2.3 Dry weight of leaf (g)

Levels of N and S had a significant effect on dry weight of leaves of onion. Single effect of different doses of nitrogen has been shown in Table 2. It was observed from the result that nitrogen level of 120 kg (N_{120}) produced the highest dry weight of leaves (1.22 g) and the lowest dry weight of leaves (0.66 g) was obtained with nitrogen level N_0 i.e. 0 kg of nitrogen. Singh *et al.* (1994) noticed the similar result in that total marketable yield and total dry weight production were the best in the plots treated with N at 80 kg and 120 kg ha^{-1}. On the other hand, sulphur at S_{40} level gave the highest weight of dry leaves (1.10 g) while S_0 gave the lowest (0.71 g).

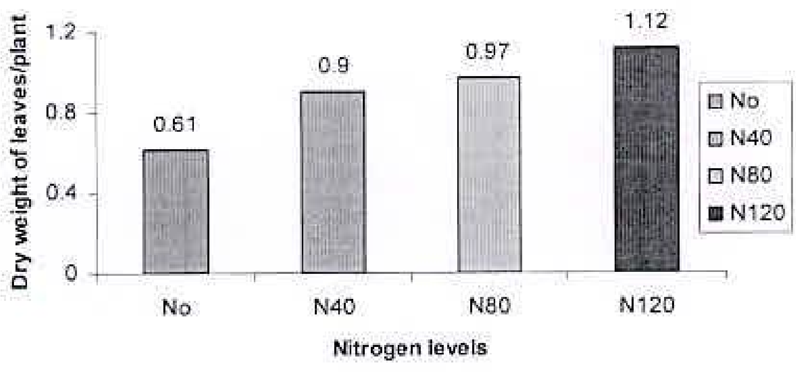
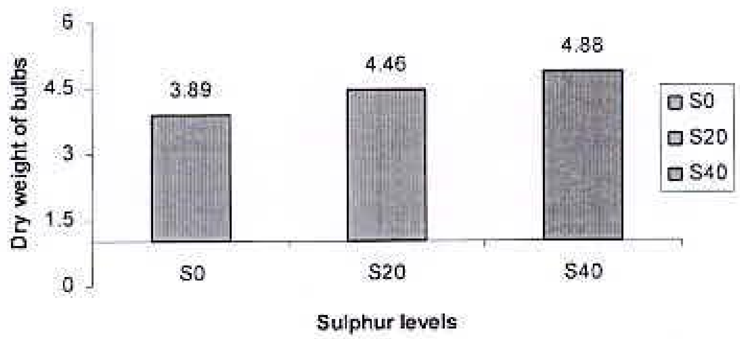


Fig. 10. Effect of nitrogen on dry weight of leaves/plant of onion

The combined effect of nitrogen and sulphur on dry weight of leaves varied significantly among the different treatment combinations. The treatment combination of $N_{120}S_{40}$ (120 kg N and 40 kg S) produced the highest (1.36 g) dry weight of leaves while, the lowest dry weight (0.38 g) was obtained with the control treatment (N_0S_0) (Table 3).

4.2.4 Dry weight of bulb (g)

There were significant variations in dry weight of bulbs due to application of N and S individually. Single effect of different doses of nitrogen has been shown in Table 2 and fig 11. It was observed from the result that nitrogen level of 120 (N_{120}) kg produced the highest dry weight of bulb (5.30 g) and the lowest dry weight of bulb (2.12 g) was obtained with nitrogen level N_0 i.e. 0 kg of nitrogen. The result was in good conformity with Singh *et al.* (1994) who noticed that total marketable yield and total dry weight production were the best in the plots treated with N at 80 kg ha^{-1}. On the other hand, sulphur at S_{40} level gave the highest weight of bulb (4.88 g) which was statistically similar to S_{20} and different from S_0 which gave the lowest (3.89 g).



Fig, 11. Effect of sulphur levels on dryweight of bulbs of onion

The interaction effect of nitrogen and sulphur on the dry weight of bulb showed significant variation. The maximum dry weight (6.51 g) of bulb was found in the treatment of $N_{40}S_{40}$. While the minimum bulbs dry weight (2.11 g) was observed in control (N_0S_0) treatment (Table 3 and fig. 12). Similar result was found by Singh *et al.* (1989) who conducted two types of experiments on onion productionand showed that 120 kg N and 36 kg S gave maximum bulb weight and higher bulb yield in their first experiment.

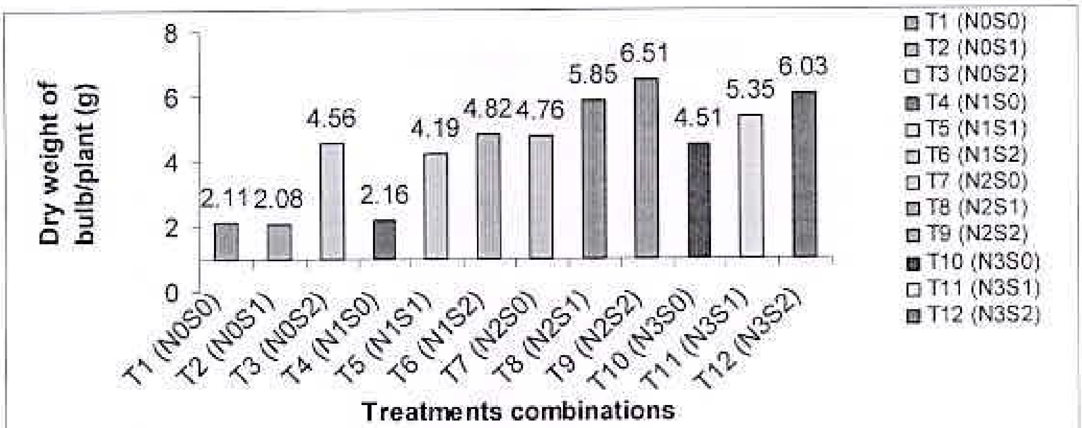


Fig. 12. Combined effects of nitrogen and sulphur on dry weight of bulb/plant (g)

4.2.5 Bulb diameter (cm)

Single effect of different doses of nitrogen has been shown in **Table 2**. It was observed from the result that nitrogen level of 120 (N_{120}) kg produced the highest bulb diameter (3.39 cm) which was statistically similar to that obtained from 80 (N_{80}) (3.31 cm) and the lowest diameter of bulb (2.12 cm) was obtained with nitrogen level N_0 i.e. 0 kg of nitrogen (fig.13). On the other hand, single mean effect of different levels of S on the average diameter of bulb was highly significant. Sulphur at S_{40} level gave the highest diameter of bulb (3.08 cm) and S_0 gave the lowest (2.66 cm). Singh *et al.* (1989) conducted two types of experiments on onion production and showed that 120 kg N gave bulb diameter and higher bulb yield in their first experiment.

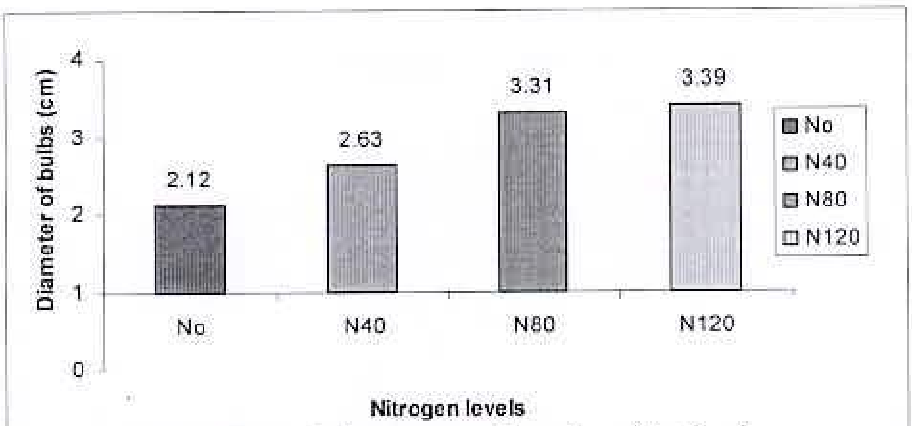


Fig. 13. Effect of nitrogen on diameter of bulb of onion

Bulb diameter of onion was influenced by the integrated use of nitrogen and sulphur. It is revealed from the study that nitrogen and sulphur have a positive role on bulb diameter of onion. There was a significant variation of bulb diameter among the 12 different treatments. Result showed that treatment $N_{120}S_{40}$ gave the highest bulb diameter (3.81 cm) followed by the treatments of $N_{80}S_{40}$ (3.55cm). Lowest bulb diameter (2.03 cm) was obtained under N_0S_0 i.e. (control) treatment (Table 3 and fig. 14).

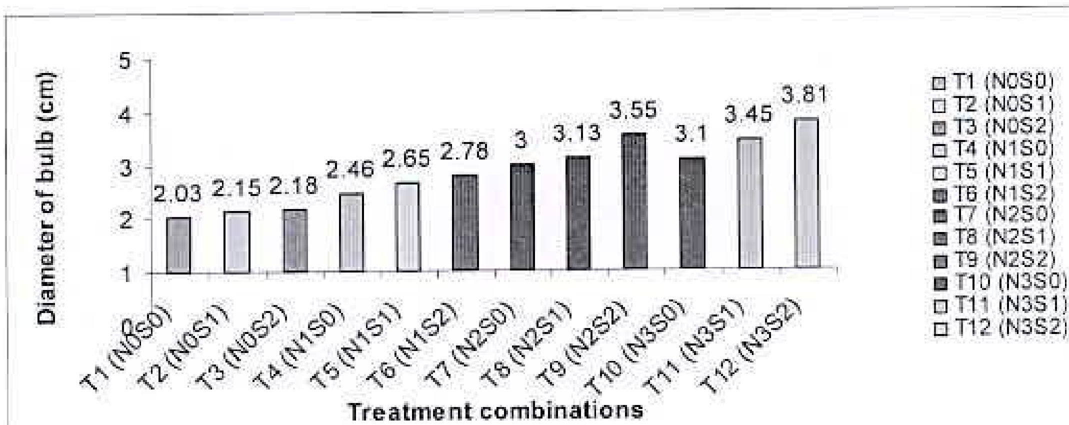


Fig. 14. Combined effects of nitrogen and sulphur on diameter of bulb (cm) of onion

4.2.6 Bulb length (cm)

Application of N showed a significant variation in bulb length (cm) but S application did not show any such variation. The highest length of bulb (2.96cm) was found with the treatment N_{80}. Considering the interaction effects, highest bulb length (3.25 cm) was achieved under treatment $N_{120}S_{40}$ (120 kg N and 40 kg S) (Table 3). On the contrary, control treated plot (N_0S_0) gave the lowest bulb length (1.86 cm) of onion. Probably integration of nitrogen and sulphur supplied the necessary requirements for the proper vegetative growth of plant that helps in obtaining the highest bulb length.

Table 3. Combined effect of nitrogen and sulphur 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/plant (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)
(N_0S_0)	15.10f	5.10d	15.46f	5.22f	20.00e	0.56i	2.11e	2.03f	1.86	3.15f
(N_0S_1)	15.35f	5.19d	15.70f	5.49f	20.95e	0.62gh	2.08e	2.15f	1.71	3.39f
(N_0S_2)	15.90f	5.35d	15.33f	5.78ef	21.36e	0.64gh	4.56d	2.18f	2.00	3.86ef
(N_1S_0)	16.10ef	5.78d	16.42f	5.98def	24.16d	0.63gh	2.16e	2.46e	2.25	4.86e
(N_1S_1)	18.42de	6.92c	22.30de	6.33cdef	24.91d	0.72g	4.19d	2.65de	2.50	6.81cd
(N_1S_2)	19.51d	7.13bc	23.41cd	6.49cdef	25.86cd	0.91de	4.82cd	2.78d	2.55	7.96b
(N_2S_0)	21.87c	7.25bc	25.28bc	6.92cde	27.55bc	1.01ef	4.76cd	3.00c	2.62	6.39d
(N_2S_1)	22.98c	7.48abc	26.37b	7.22cde	28.85ab	0.99ef	5.85ab	3.13c	3.01	7.95b
(N_2S_2)	26.75b	7.93ab	27.10ab	8.10ab	30.66a	0.80d	6.51a	3.55b	3.25	8.55b
(N_3S_0)	26.98b	8.05a	27.62ab	7.36abc	27.66bc	1.16c	4.51d	3.10c	2.15	6.11d
(N_3S_1)	27.45b	7.56abc	28.15ab	7.96ab	29.11ab	1.29ab	5.35bc	3.45b	2.28	7.81bc
(N_3S_2)	30.19a	8.11a	30.11a	8.55a	29.36ab	1.22a	6.03a	3.81a	3.10	9.81a
LSD	2.352	0.799	3.96	1.37	3.33	0.10	0.672	0.199	0.596	0.793
Level of significance	NS	*	**	*	**	**	**	**	NS	**
CV(%)	5.51	5.86	6.08	10.15	4.06	7.63	4.98	4.55	12.03	7.14

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

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

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.2.7 Yield of bulb (t/ha)

A significant variation in bulb yield was observed due to the application of nitrogen and sulphur (Table 2) and the yield of onion increased significantly with increased N levels upto 80 kg N ha^{-1} and the maximum yield (8.05 t ha^{-1}) was obtained with 120 kg N ha^{-1}. On the other hand, the yield of onion increased significantly with increased S levels upto 40 kg S ha^{-1} and maximum yield (7.55 t ha^{-1}) was obtained at this rate. Considering the single effect of N and S levels, the lowest yields (3.47 and 5.13 t ha^{-1}) were obtained with N_0 and S_0 treatments, respectively.

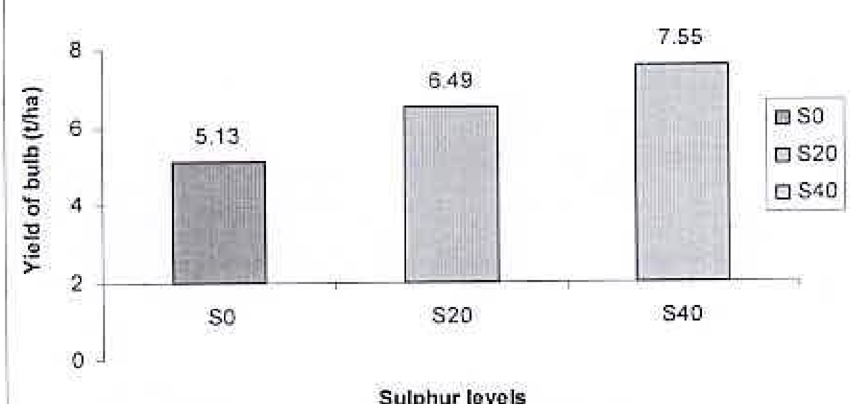


Fig. 15. Effect of sulphur levels on yield of bulb of onion

Integrated application of nitrogen and sulphur showed insignificant variations in respect of yield of onion. Among the different treatments, highest yield (9.81 t/ha) was achieved under treatment $N_{120}S_{40}$ (120 kg N and 40 kg S). On the contrary, control treated plot (N_0S_0) gave the lowest yield (3.15 t/ha) of onion (Table 3 and fig. 16). Probably integration of nitrogen and sulphur supplied the necessary requirements for the proper vegetative growth of plant that helps in obtaining the highest yield. 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 Sg ha^{-1}) on local cv. Faridpur Bhati. Both nitrogen and sulphur significantly increased the yield. According to Anwer *et al.* (1998) the application of nitrogen, phosphorus, sulphur, nitrogen and sulphur 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.

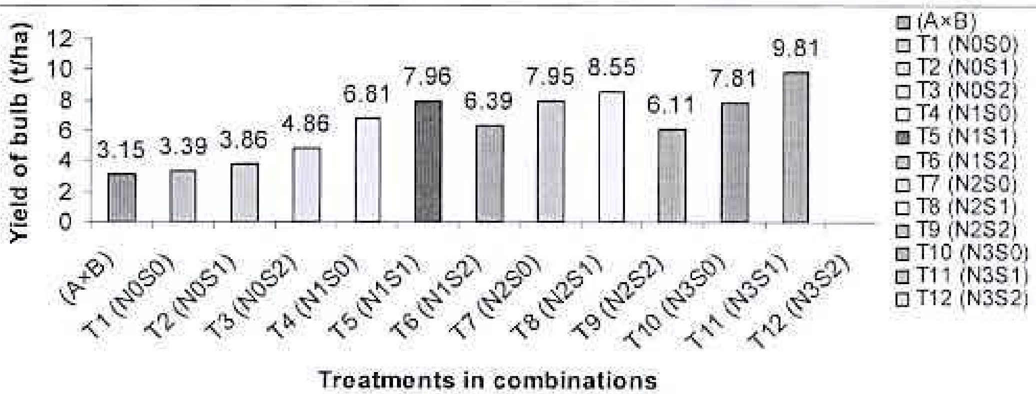


Fig. 16. Combined effect of nitrogen and sulphur on yield of bulb (t/ha) of onion

4.2.8 Moisture content in leaf (%)

The effect of integrated use of nitrogen and sulphur on the moisture content of leaf of onion is presented in Table 4. The study revealed that there were insignificant differences between the sixteen treatment combinations. The highest moisture percentage (92.00 %) was obtained in control (N_0S_0) treatment receiving no fertilizer and the lowest (86.47 %) moisture content was found in treatment ($N_{120}S_{40}$).

4.2.9 Moisture content in bulb (%)

Sixteen different treatments were taken to evaluate the effect of integrated use of nitrogen nitrogen and sulphur on the moisture content of bulb of onion is presented in Table 4. 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 treatment $N_{120}S_{40}$ (120 kg N and 40 kg S). On the other hand, the highest moisture content (89.88 %) was observed in control (N_0S_0) treatment where no fertilizer was applied.

Table 4. Combined effect of nitrogen and sulphur on the leaf and bulb of onion

Treatment combinations (A×B)	Moisture %	
	Leaf	Bulb
T_1 (N_0S_0)	92.00	89.88
T_2 (N_0S_1)	91.72	89.25
T_3 (N_0S_2)	91.86	88.45
T_4 (N_1S_0)	91.60	85.63
T_5 (N_1S_1)	91.20	81.75
T_6 (N_1S_2)	89.50	80.60
T_7 (N_2S_0)	89.51	79.86
T_8 (N_2S_1)	88.79	77.00
T_9 (N_2S_2)	89.02	80.80
T_{10} (N_3S_0)	87.28	79.74
T_{11} (N_3S_1)	86.47	80.46
T_{12} (N_3S_2)	87.28	80.74
LSD	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 integrated use of nitrogen and sulphur

4.3.1 Nitrogen content

Table 5 represents the effect of integrated use of nitrogen and sulphur 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 (2.32%) was recorded in the treatment N_2S_2 (80 Kg N and 40 kg S) which were statistically identical with treatments of N_2S_1, N_3S_2 and N_3S_1. On the other hand, lowest nitrogen concentration (1.40 %) was found in treatment N_0S_0 (control).

4.3.2 Phosphorus content

The phosphorus content of bulb as improved by different combinations of nitrogen and sulphur showed significant variation. With the 12 different treatments, the highest phosphorous concentration (0.22 %) was recorded in the treatment N_3S_2. On the contrary, the lowest phosphorous concentration (0.07 %) was found in control treated plot (N_0S_0) (Table 5).

4.3.3 Potassium content

Statistically insignificant variation was recorded regarding potassium concentration in the bulb after harvest of onion on different doses of nitrogen and sulphur (Table 5). The highest potassium concentration (1.83 %) was recorded in treatment N_3S_2 and it was identical with the treatments of N_2S_2 and N_3S_1 which shows 1.80 % and

1.89%. Controlled treated plot (N_0S_0) showed lowest potassium concentration (0.85 %).

4.3.4 Sulphur content

Effect of integrated use of nitrogen and sulphur on sulphur concentration in the bulb of onion is presented in Table 5. There was a statistically remarkable variation in respect of sulphur content after harvest among the 12 different treatments. The highest sulphur concentration (1.00 %) was observed in the treatment N_2S_2 which was statistically similar with treatment N_3S_2 and N_2S_1 with a value of 0.99 % and 0.96. In contrast, the lowest sulphur concentration (0.40 %) was found in treatment N_3S_2 (control). This might be due to the fact that, the combined effect of nitrogen and sulphur played positive effect on sulphur concentration in the bulb of summer onion up to a certain limit.

4.4 Nutrient concentrations in the leaf of onion as affected by integrated use of nitrogen and sulphur

4.4.1 Nitrogen content (%)

The effect of integrated use of nitrogen and sulphur in response to nitrogen content in leaf at the harvest of onion had been presented in Table 5. There was a significant variation in the nitrogen content of leaf among the different treatments. The highest nitrogen concentration (2.92%) was recorded in the treatment N_2S_2 which was statistically identical with treatments of N_3S_2 and N_2S_1. On the other hand, lowest nitrogen concentration (1.96%) was found in control treatment N_0S_0. Similar result was obtained by Amin *et al.* (1995) who showed that the yield and plant nitrogen contents significantly increased with increase in nitrogen application.

4.4.2 Phosphorus content (%)

The phosphorus content of leaf as improved by different combinations of nitrogen and sulphur showed a significant variation which is presented in Table 5. From the 16 different treatments, the highest phosphorous concentration (0.21%) was recorded in the treatment of N_2S_2 which is statistically identical with N_3S_2 and N_3S_1. On the contrary, the lowest phosphorous concentration (0.06%) was found in control treatment (N_0S_0) (Table 5).

4.4.3 Potassium content (%)

Statistically significant variation was recorded regarding potassium concentration in the leaf after harvest of onion on different doses of nitrogen and sulphur (Table 5). The highest potassium concentration (2.90%) was recorded in treatment N_2S_2 and it was identical with the treatments of N_3S_2 which shows 2.85% and the lowest K concentration (1.51%) was obtained in the control treatment.

4.4.4 Sulphur content (%)

Effect of integrated use of nitrogen and sulphur on sulphur concentration in the leaf of onion is presented in Table 5. There was a statistically remarkable variation in sulphur content after harvest among the 12 different treatments. The highest sulphur concentration (1.01%) was observed in the treatment N_3S_2 which was statistically similar with treatment N_2S_2, N_3S_1 with a value of 0.95% and 0.99%, respectively. In contrast, the lowest sulphur concentration (0.35%) was found in treatment N_0S_0 (control).

Table 5. Effect of integrated use of nitrogen and sulphur on the nutrient concentrations in leaf and bulb of onion

Treatment combinations (N X S)	Concentrations in leaf					Concentrations in bulb				
	N	P	K	S	Zn	N	P	K	S	Zn
T_1 (N_0S_0)	1.96	0.06	1.51	0.35	0.14	1.40	0.07	0.85	0.40	0.09
T_2 (N_0S_1)	1.98	0.08	1.55	0.66	0.20	1.46	0.08	0.90	0.43	0.11
T_3 (N_0S_2)	1.99	0.09	1.62	0.48	0.13	1.47	0.08	1.02	0.55	0.10
T_4 (N_1S_0)	2.25	0.12	2.00	0.38	0.25	1.90	0.11	1.30	0.70	0.24
T_5 (N_1S_1)	2.54	0.14	2.15	0.71	0.30	2.08	0.12	1.42	0.77	0.22
T_6 (N_1S_2)	2.65	0.15	2.44	0.82	0.39	2.07	0.15	1.60	0.88	0.36
T_7 (N_2S_0)	2.45	0.16	2.03	0.39	0.59	1.75	0.12	1.40	0.78	0.36
T_8 (N_2S_1)	2.86	0.17	2.72	0.88	0.65	2.28	0.18	1.70	0.96	0.66
T_9 (N_2S_2)	2.92	0.21	2.90	0.95	0.72	2.32	0.17	1.80	1.00	0.79
T_{10} (N_3S_0)	2.51	0.17	2.21	0.52	0.58	1.68	0.19	1.52	0.82	0.56
T_{11} (N_3S_1)	2.74	0.20	2.55	0.99	0.72	2.21	0.20	1.79	0.86	0.59
T_{12} (N_3S_2)	2.85	0.18	2.85	1.01	0.77	2.26	0.22	1.83	0.99	0.66
LSD	0.17	0.03	0.14	0.07	0.20	0.13	0.02	0.20	0.06	0.04
Level of significance	*	*	*	**	*	**	**	NS	**	*
CV(%)	3.99	6.65	4.14	5.77	5.01	5.05	4.48	5.13	4.96	3.81

* = 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 nitrogen and sulphur

4.6.1 Soil pH

Integrated application of nitrogen and sulphur showed insignificant effect respecting soil pH after harvest of onion is presented in Table 6. Soil pH was varied significantly at 5.50 to 6.20. The highest pH of the soil (6.20) was recorded in treatment N_3S_2 and the lowest pH value (5.50) was observed in control treatment (N_0S_0).

4.6.2 Organic matter content of soil (%)

A significant variation was observed in organic matter content in soil after harvest of onion. Among the different treatments the highest organic matter content (1.33%) was obtained where 80 kg N and 40 kg S were applied which was statistically identical with the treatment of N_1S_1 and N_2S_1 (1.23% and 1.23% OM). On the other hand, the lowest OM content (0.98%) was observed in the N_0S_1 treatment (Table 6).

4.6.3 Total nitrogen content of soil (%)

Total nitrogen content of soil after harvest of onion was influenced by different doses of nitrogen and sulphur showed a statistically significant variation (Table 6). The highest N content (0.12%) of soil was observed in case of treatment N_3S_1 (120 kg N & 20 kg S) and it was followed by the treatment N_0S_2 and N_1S_0 with the value of 1.10% in both the cases. In contrast, the lowest N content (0.07%) was obtained in the N_0S_0 treatment where no fertilizer was applied. 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 (ppm)

Different combinations of nitrogen and sulphur on the available phosphorous content of soil after harvest of onion showed significant variation is presented in Table 6. It was revealed from the study that the performances of the most of the treatment differ significantly from each other. Among the different treatments, N_2S_2 treatment showed the highest P content (24.13 ppm) in soil after the harvest of onion. On the other hand, the lowest P content (16.15 ppm) was observed in the treatment N_0S_0 receiving no fertilizer.

4.6.5 Potassium content of soil (meq/100 g soil)

The combined effect of nitrogen and sulphur showed significant differences in respect of K content of soil after harvest of onion (Table 6). However, the lowest K content of crop-harvested soil (0.12 meq/100 g soil) was recorded in the treatment N_0S_0 (control) and the highest K content (0.24 meq/100 g soil) was recorded with N_2S_2 followed by 0.22 meq/100 g soil in treatment N_3S_1.

4.6.6 Sulphur content of soil (ppm)

Statistically significant difference was obtained in the sulphur content of soil after harvest of onion. Application of 120 kg N and 40 kg S showed the highest S content (26.10 ppm) in soil. The next highest S content (24.12 ppm) was found in treatment (N_3S_1) receiving 120 kg N and 20 kg S. On the contrary, the lowest S content (15.50 ppm) was observed in the N_0S_0 treatment where no fertilizer was applied (Table 6).

Table 6. Combined effect of nitrogen and sulphur on the pH, OM, total N, available P, K, S and Zn in the soil after harvest of onion

Treatment combination (N×S)	pH	OM	Total N	Available P	Available K	Available S	Available Zn
T_1 (N_0S_0)	5.50	0.99	0.07	16.15	0.12	15.50	2.47
T_2 (N_0S_1)	5.52	0.98	0.09	17.00	0.14	16.12	2.58
T_3 (N_0S_2)	5.60	0.92	0.10	17.15	0.16	21.44	2.59
T_4 (N_1S_0)	5.80	1.01	0.10	16.21	0.15	17.01	3.18
T_5 (N_1S_1)	5.89	1.23	0.08	17.41	0.19	20.47	3.05
T_6 (N_1S_2)	5.87	1.16	0.09	18.79	0.20	21.46	3.85
T_7 (N_2S_0)	5.95	1.08	0.08	17.32	0.16	18.54	3.94
T_8 (N_2S_1)	5.80	1.23	0.08	22.01	0.21	18.12	3.82
T_9 (N_2S_2)	5.64	1.33	0.09	24.13	0.24	22.23	4.48
T_{10} (N_3S_0)	5.77	0.89	0.08	17.01	0.17	19.46	2.90
T_{11} (N_3S_1)	6.10	1.11	0.12	19.33	0.22	24.12	3.28
T_{12} (N_3S_2)	6.20	1.00	0.09	21.31	0.19	26.10	3.99
LSD	0.35	0.15	0.01	2.15	0.03	2.13	1.82
Level of significance	NS	**	**	**	**	*	*
CV(%)	3.09	3.77	2.11	4.59	5.45	4.29	4.56

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

In this study it was observed that treatment N_3S_2 (120 kg N and 40 kg S) always produce better performance over the growth parameters and yield. So this treatment combination of nitrogen and sulphur may be helpful for onion cultivation.

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 nitrogen and sulphur on the growth, yield and yield contributing parameters of onion.

The data were collected plot wise for plant height, leaf length, number of leaves $plant^{-1}$, fresh weight of leaves $plant^{-1}$, fresh weight of bulb $plant^{-1}$, dry weight of leaves $plant^{-1}$, dry weight of bulb $plant^{-1}$, bulb diameter, length of bulb and yield. The post harvest soil samples were analyzed for pH, organic matter, N, P, K, S and Zn contents. The collected data on different parameters were statistically analyzed following F-test and the mean comparison was made by DMRT at 5% and 1% level. The salient results of the experiment are stated below:

The results obtained from the experiment revealed that the effect of integrated use of nitrogen and sulphur significantly influenced the plant height of onion. The maximum height (30.19 cm) of the plant was obtained with treatment combination of $N_{120}S_{40}$ and produced the highest plant height over rest of the treatments. And the minimum plant height (15.10 cm) was observed in the treatment of N_0S_0 (control). Incase of leaves number the treatment combination of $N_{120}S_{40}$ produced the highest (8.11) number of leaves which was identical to the treatment of $N_{120}S_0$. Again the treatment N_0S_0 i.e. control produced the lowest number of leaves (5.10). The minimum leaf length (15.12 cm) was recorded in treatment N_0S_0 (0 kg N and

0 kg S/ha) (control). On the other hand, maximum leaf length (30.11 cm) was observed in the treatment combination of $N_{120}S_{40}$ i.e. 120 kg of N and 40 kg S followed by $N_{120}S_0$ with the value of 28.15 cm cm. These two treatments were statistically identical.

The treatment of $N_{120}S_{40}$ (120 kg nitrogen + 40 kg sulphur) gives the highest results for all parameters either vegetative or yield contributing characters. The highest plant height (30.19 cm), number of leaves/plant (8.11) and largest leaf length (30.11 m) were also obtained with the same treatment i.e. $N_{120}S_{40}$. The result indicated that maximum bulb yield (9.81 t ha^{-1}) onion was obtained with treatment $N_{120}S_{40}$ receiving 120 kg nitrogen and 40 kg sulphur which was statistically different from all other treatment. Combined effect of nitrogen and sulphur fertilizers on the nitrogen and sulphur content in onion bulb and post harvest soil of onion field was significantly influenced. The highest concentrations of sulphur in the bulb (1.00 %) and available S in post harvest soil (26.10 ppm) were recorded in the treatment combination of N_2S_2 and N_3S_2, respectively. The highest concentrations of nitrogen in the bulb (2.32 %) and total nitrogen in post harvest soil (0.12 %) were recorded in the treatment combination of N_2S_2 and N_3S_1. Thus the findings of the experiment suggested that integrated use of 120 kg nitrogen with 40 kg sulphur produced maximum growth and yield of onion in red terrace soil.

The N, P, K, S contents in bulb and leaf of onion plants were influenced significantly by the integrated application of Nitrogen and Sulphur. The highest P, K content in bulb (0.22%, 1.83%, respectively) was recorded in N_3S_2 and Zn content (0.79%) was recorded in N_2S_2 and in leaf (0.21%, 2.90%, respectively) was recorded in N_3S_2 (120 kg N + 40 kg S). The lowest 0.07% P, 0.85% K, and 0.09% Zn in bulb and 0.06% P, 1.51% K in leaf were obtained with control treatment. The soil properties such as organic matter content, total nitrogen, available phosphorus, potassium, Nitrogen and Sulphur were increased after the harvest of crop, compared the nutrient status of the initial soil.

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 120 kg N and 40 kg S showed better performance in the major parameters i.e. plant height, number of leaves, length of leaves, bulb diameter and yield. But there was least difference between N_3S_2 and N_2S_2 treatments. So the treatment N_2S_2 appears to be very promising in terms of cost of production due to requirement of less fertilizer. The findings of the study also emphasizes on doing further research on the other production side of onion for the farmers of the country.

Chapter 6

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