EFFECT OF POTASSIUM AND SULPHUR ON GROWTH, YIELD AND NUTRIENT CONTENT OF BARI PIAZ-4

BY

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of Potassium and Sulphur on Growth, Yield and Nutrient Content of BARI Piaz-4"** submitted to the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRICULTURAL CHEMISTRY**, embodies the result of a piece of *bona fide* research work carried out by **ALMAMUN**, Registration No. **09-03539** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2015
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Dedicated To

My Beloved Parents

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ABSTRACT

An experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2014 to April 2015 to study the growth, yield and nutrient content of onion as influenced by potassium and sulphur. The experiment was laid down in a Randomized Complete Block Design with three replications and consisted of two factors, Factor A (3 Levels of Potassium): K_1 = 140 kg ha^{-1} MOP, K_2 = 160 kg ha^{-1} MOP, K_3 = 180 kg ha^{-1} MOP and Factor B (4 Levels of sulphur): S_0 = Control (no gypsum), S_1 = 130 kg ha^{-1} gypsum, S_2 = 150 kg ha^{-1} gypsum and S_3 = 170 kg ha^{-1} gypsum respectively. In case of potassium, K_2 treatment produced the highest yield (8.32 t ha^{-1}) and K_1 produced the lowest yield (7.85 t ha^{-1}). In case of sulphur, S_2 produced the highest yield (8.79 t ha^{-1}) and S_0 produced the lowest yield (7.09 t ha^{-1}). The treatment combination of K_2S_2 produced the highest yield (9.10 t ha^{-1}) and K_1S_0 produced the lowest yield (6.98 t ha^{-1}). In case the effect of potassium, the highest sodium, phosphorus, potassium, sulphur, and nitrogen in bulb and leaf sample were obtained from K_3 treatment. In case of sulphur, the highest sodium, phosphorus, potassium, sulphur, and nitrogen in bulb and leaf sample were recorded from S_3 treatment. The treatment combination of K_3S_2 showed the maximum amount of sodium, potassium and nitrogen nutrient in bulb and leaf sample. On the other hand the treatment combination of K_2S_3 performed the maximum results for the sulphur and phosphorus content in bulb and leaf sample.

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LIST OF ACRONYMS

ABBREVIATIONS	ELABORATIONS
AEZ	Agro-Ecological Zone
Anon.	Anonymous
ANOVA	Analysis of Variance
@	at the rate of
Adv.	Advanced
Agric.	Agricultural
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
CV	Coefficient of Variation
cv.	Cultivar
df	Degrees of Freedom
DMRT	Duncan's Multiple Range Test
DAT	Days After Transplanting
et al.	and others
etc.	etcetera
MOP	Muriate of Potash
ns	Non Significant
NAA	Naphthalene Acetic Acid
ppm	Parts Per Million
Res.	Research
RH	Relative humidity
Sci.	Science 's

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Onion (*Allium cepa* L.) is an herbaceous biennial plant and a member of the Alliaceae family. Onion is probably a native of Asia (McCollum, 1976). The leading onion producing countries are China, India, United States of America, Turkey, Russia, Pakistan, Japan, Brazil, Spain, Korea, Netherlands, Morocco, Egypt, Nigeria and Italy (FAO, 2015a). In Bangladesh, it is mainly produced in winter season. Onion cultivation during summer season is constrained due to adverse weather along with absence of summer tolerant varieties and proper cultural practices. The average yield of onion in Bangladesh is far below being 4 t ha^{-1} (BBS, 2014) as compared to world average of 17.45 t ha^{-1} (FAO, 2015b). Introducing hot and rain tolerant onion variety in production or manipulation of prevailing summer climatic condition and cultural management might help solving shortage of onion production in the country. Onion is used in the preparation of different kinds of food of our daily diet.

Onion is a thermal and photosensitive crop. In Bangladesh, almost all spicy dishes contain onion as one of the important ingredient. Onions are extensively used in the preparation of curry, chutney and pickle etc. The area under onion was 38 thousand hectares with production of 153 thousand metric tones per annum. Bangladesh largely meets her demand through importing of onion. This could attributed to fewer yields per unit area. This low production of onion is due to improper utilization of fertilizers and growing unsuitable varieties under the agro climatic conditions of an area. Optimum fertilizers application for onion and cultivation of suitable varieties in specific environment are necessary for obtaining good yield of onion. Onion is an exhaustive crop in nature and a crop producing 41 t ha^{-1} would remove 102 kg N, 41 kg P_2O and 112 kg K_2O ha^{-1} from soil (Halliday and Trenkel, 1992). Hence, fertilizers can play an important role in onion production.

There is a significant response of onion to both inorganic and organic fertilizer (Nasreen and Hossain, 2000, Ullah, 2003). Potassium plays an important role on onion production. Generally a heavy dose of fertilizer is recommended for onion cultivation (McGillivray, 1961). Like other tuber and root crops, onion is very responsive to potash. Among the various nutrients required to produce high yield of onion, potassium is considered to be very important element due to its influence for translocation of photosynthates, storage quality, bulb size, bulb numbers and yield per plant (Sangakkara and Piyadasa, 1993). Potassium is one of the three major nutrients taken up by the plant in large quantities and the adequate level of potassium increases crop resistance to various diseases, stalk and stem breakage and at stress conditions (Razzaque *et al.*,1990). Methods of application of potassium fertilizers have great influence on their utilization by the crop. Time of application of potash during the growing period of onion is important in bulb formation. Satter and Haque (1975) reported that split application of nitrogen and potash gave higher weight of winter onion bulb than single application of same dose. There are also several evidences of fixation and leaching loss of potassium from the soil (Huq *et al.*, 1990).

Onion is a bulbous herb having distinctive and pungent odor due to a sulphurous volatile oil knows as allyl propyl disulphide ($C_6H_{12}S_2$). Paterson (1979) showed that sulphur increased bulb size, hastened maturity, increased the sulphur content (pungency) of the bulbs. Nasreen and Imamul (2005) reported that sulphur levels up to 45 kg ha^{-1} increased the S uptake throughout the season and also produce the highest bulb yield. In addition to N, P and K, sulphur has been found to be very beneficial for onion (Balasubramonian *et al.*, 1979). In Bangladesh, particularly in northern region very limited works have been carried out regarding the use of different levels of boron and sulphur other than NPK fertilizers. Onion plants are known for their affinity to sulphur to become a constituent of secondary compounds, i.e. allin, cycloallin, alkaloid (Allyl propyl disulphide) and thiopropanol (Schnug, 1993; Raina and Jaggi, 2008), which are not only govern the taste, pungency and medicinal properties but also important for resistance against pests and diseases (Brown and Morra, 1997). Sulphur is also required for the synthesis of three important essential amino acids such as cystine (27% S), cysteine (26% S) and methionine (21% S) besides increasing allyl propyl disulphide alkaloid (43% S) and the capsaicin, the principle alkaloids responsible for pungency in onion and chilli, respectively (Randle and Bussard, 1993).

Information on effect of combined application of K and S on yield quality and uptake of nutrients in onion is rather limited. Therefore, the present study was initiated to study the effect of K and S application on yield and uptake of nutrients by onion in sandy loam soil.

Objectives :

- To find out the optimum level of potassium and sulphur for maximum growth, yield and nutrient contents of onion
- To find out the suitable interaction effects of potassium and sulphur for maximizing onion production in Bangladesh

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Onion is an important spice crop in Bangladesh. Application of sulphur and potassium fertilizers plays an important role on growth, yield and quality seed production of Onion. The literature dealing with the effects of K and S on the yield and nutrient contents of onion is scarce. However, the relevant literature so far available is reviewed in this chapter.

2.1 Effect of potassium on growth, yield and nutrient content of onion

Islam *et al.* (2008) conducted a field experiment at On Farm Research Division (OFRD) of Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. Six different levels of potash viz. 0, 30, 60, 90, 120 and 150 kg ha^{-1} and three application methods viz. basal, ½ basal + ½ at 20 DAT and basal + at 20 DAT + at 40 DAT were followed. A significant improved in different growth parameters and yield of onion was observed in response to different application methods and levels of potassium. Among the methods the highest bulb yield (11.85 t ha^{-1}) was obtained from three split application of potassium and the lowest (11.49 t ha^{-1}) was obtained from application of basal doses of potassium. Yield contributing characters shows the similar trend of response of K like bulb yield. Three split application of 120 kg ha^{-1} potassium may be considered to be optimum for getting higher yield of summer onion

Siddiquee *et al.* (2008) conducted a field experiment to study the effect of applied potassium fertilizer on growth and yield of two varieties of summer onion at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh during March to June, 2005. In addition to potash, Cowdung, TSP, Gypsum and Zinc oxide were applied @ 5000, 150, 110 and 3 kg ha^{-1} as basal dose during final land preparation and mixed with soil properly. The urea and potash were applied treatment wise as side dressing with three installments at 15 days interval from one week after transplanting. Potash was applied @ 0, 50, 75 and 100 kg K ha^{-1}. The positive effect of applied K was noted on both the varieties of onion. Maximum yield of 9.05 t ha^{-1} was obtained when K was applied to N 53 variety. It was observed that the application of K @ 75 kg ha^{-1} significantly increased the yield of both the varieties of onion

Awatef *et al.* (2015) conducted two field experiments were carried out in the experimental station of National Research Centre at Nubaria, Behira Governorate, Egypt during the two winter seasons of 2011/2012 and 2012/2013 to study the effect of different rates of potassium fertilization (0, 150 and 300 K_2O/fed.) as potassium sulfate in addition to foliar application by water (control), potassium thiosulfate (KTS) at (1 L/fed.) and potassium thiosulfate at (2L/fed.) and their interaction on production and quality of onion cv. "Giza 20". Potassium foliar applications were made 3 times at 15 days intervals during the growing period (30, 45 and 60 days after transplanting). The obtained results showed that, the highest potassium fertilization rate (300 kg K_2O /fed.) gave the tallest plant, the highest number of leaves per plant and the highest fresh weight of leaves as well as the highest total bulb yield/fed. Also, the obtained results reported that the bulb measurements expressed as (bulb length, bulb diameter, average bulb weight, TSS and carbohydrates content, as well as bulb chemical composition (N, P, K and protein) were increased with increasing potassium fertilization rate.

Desuki *et al.* (2006) conducted two field experiments were carried out of the Experimental Station of National Research Center at Shalakan (Kalubia Governorate), Egypt during the two successive winter seasons of 2003/2004 and 2004/2005 to study the response of onion plants cv. Giza-20 to the additional dose of potassium application i. e. 0, 50, 75, 100 kg potassium sulphate (48% K_2O) as soil dressing or 1, 2, 3 L./fed of potassium oxide (36.5% K_2O) as foliar spraying in addition to the recommended dose of NPK fertilizers application. Results indicated that the vegetative growth of onion plants and minerals uptake were increased by adding potassium fertilizer through sprayingor soil dressing upto 2 L/fed of potassium oxide or 75 kg potassium sulphate/fed., respectively. Total bulb yield as well as bulb quality were gradually increased with increasing of potassium application up to 2 L./fed of potassium oxide as foliar application or 75 kg potassium sulphate/fed. as soil dressing in addition of the recommended dose of potassium fertilizers application

Saud *et al.* (2013) conducted a research study the effect of potassium and row spacing on yield of onion was conducted at Dargai Malakand during summer 2012. Potassium levels (0, 40, 80 and 120 kg ha 1) were applied to main plot while row spacing (15, 20 and 25 cm) were kept in sub plot. Phosphorus and potassium were applied at time of planting. The maximum plant height (51.6 cm), number of leaves plant^{-1} (9.89), bulb diameter (5.93), average bulb weight (64.89 g), leaf width (1.33 cm) and yield (22.91 t ha^{-1}) were observed with the application of 120 kg K_2O ha^{-1}. The highest yield was observed with the application of 120 kg ha^{-1} potash application and at 20 cm row spacing. Based on the above result it is recommended that 20 cm row spacing with 120 kg K_2O ha^{-1} should be used for best growth and maximum yield of onion under the agro climatic condition of Dargai at Malakand.

Howlader *et al.* (2010) conducted a field experiment at Spices Research Sub-center Faridpur, during 2009 - 2010 to find out the requirement of P, K & B for higher seed yield of BARI Piaz^{-1}. Different treatments showed significant effect on onion seed yield. The highest seed yield was obtained from T_9 (P50, K120 and B2 kg ha^{-1} + 20% B extra).

Barman *et al.* (2013) conducted an experiment to find out the combined effect of cowdung and potassium on the growth and yield of onion cv. BARI piaz^{-1} at Horticulture Farm, Bangladesh Agricultural University, Mymensingh during the period from December 2010 to March 2011. The two factors experiment had four levels of cowdung, viz., 0, 5, 10 and 20 tons ha^{-1} and four levels of potassium, viz. 0, 50, 150 and 250 kg K ha^{-1}. Doses of cowdung and potassium showed significant variation in respect of all the parameters studied. The combination of 10 tons cowdung and 250 kg K ha^{-1} gave the tallest plant (46.60 cm), the highest number of leaves $plant^{-1}$ (6.40), the highest length of bulb (3.27 cm), the highest diameter of bulb (4.83 cm), individual weight of bulb (51.23 g), dry matter content (12.66%) and yield of bulb ha^{-1} (12.83 tons).

Islam *et al.* (2010) conducted an experiment was conducted to study the effect of mulch (non-mulch and straw mulch) and different levels of nitrogen (0, 40, 80 and 120 kg ha^{-1}) and potassium (0, 37.5, 75 and 112.5 kg ha^{-1}) on the growth and yield of onion. Plants grown with straw mulch gave higher bulb yield (10.89 t ha^{-1}) which showed 13.79% increase over non-mulch. Potassium increased bulb yield compared to control, but its different levels had identical results on yield. Potassium together with mulch also exhibited significant variation on yield and yield components. Plants grown with the highest level of potassium (112.5 kg ha^{-1}) along with straw mulch gave the highest bulb yield (11.58 t ha^{-1}). Nitrogen and potassium as 120 kg N ha^{-1} x 75.0 kg K ha^{-1} gave the highest bulb yield (13.07 t ha^{-1}). Nitrogen and potassium at their maximum levels with straw mulch gave the highest bulb yield (14.67 t ha^{-1}).

2.2 Effect of sulphur on growth, yield and nutrient content of onion

Hasan *et al.* (2013) conducted an experiment to study the effect of different doses of sulphur on growth and yield performances of onion. The experiment comprised of five levels of sulphur (0, 20, 40, 60 and 80 kg S ha^{-1}) and was laid out in RCBD design with four replications and other fertilizers were applied according to recommended doses. Individual bulb weight, dry weight of root, dry weight of bulb, dry weight of shoot, dry weight of leaf, total dry matter (TDM), leaf area index (LAI), absolute growth rate (AGR), relative growth rate (RGR), net assimilation rate (NAR), individual bulb weight, bulb yield of onion and sulphur content were increased significantly with the application of sulphur fertilizer. The maximum sulphur content (0.49%) of onion bulb was observed in 40 kg S ha^{-1} followed by 20 kg S ha^{-1}(0.45 %), 60 (0.45%) and 80 kg S ha^{-1} (0.44%) at average of 45 and 85 days after transplanting. Application of 40 kg S ha^{-1} resulted in the highest yield (10.65 t ha^{-1}) among the different doses of sulphur.

Chattopadhyay and Mukhopadhyay (2004) conducted an experiment to study the yield, content and uptake of sulphur at successive stages of growth in onion (cv. Faridpuri) were studied on A1baquept soil with 0, 15, 30, 45, 60, 75 and 90 kg S ha^{-1} application (each year) during the winter seasons of 1995-96, 1996-97 and 1997-98. Sulphur content, @take and yield of onion significantly responded to the application of sulphur fertilizer. Sulphur content in leaves at 45 days after transplanting. Uptake of sulphur elements into the leaves increased up to 75 OAT while bulbs uptake continued to increase up to 110 OAT across the treatments. Increasing the levels of sulphur up to 45 kg ha^{-1} increased the sulphur content, uptake throughout the season and also produced the highest bulb yield.

Luiz *et al.* (2015) conducted a research study evaluated the effects of S dose (0, 15, 30, 45, 60, and 90 kg ha^{-1}) on the soil and the development, productivity, and quality of the 'Perfecta' onion cultivar. The experiment was conducted in Jaboticabal, Brazil, from 30 May to 10 October 2011. Maximum height (0.76 m), number of leaves per plant (7.2), dry weight of leaves (201.6 g), and productivity (79 t ha^{-1}) of the 'Perfecta' onions were obtained with doses of 57, 41, 47, and 45 kg S ha^{-1}, respectively. Onion productivity was 16% lower, when S was not applied. About 47% of total production of bulbs was ranked in classes 3 and 4, with higher commercial value. The highest percentage of bulbs (63%) in classes 3 and 4 was obtained with 47 kg S ha^{-1}. Maximum pungency (1.5 μmol g^{-1}) was obtained with 65 kg S ha^{-1}, ca. 55% higher than when S was not applied. The levels of pyruvic acid, however, were low in all treatments, which ranked the cultivar as very mild with an extra-sweet flavour when provided with up to 90 kg S ha^{-1}.

Chattopadhyay *et al.* (2015) conducted a field experiment was conducted on onion (*Allium cepa* L.) cv. Sukhsagar during the Rabi seasons of $2010^{-1}1$ and

2011- 12 at 'C' Block Farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal to assess the influence of sulphur on growth, yield and quality in onion. The treatments comprised of four levels of sulphur (0, 15, 30 and 45 kg ha^{-1}) as basal application from two sulphur sources viz. gypsum and as elemental sulphur. Pooled results of two year revealed significantly highest total yield (298.81q ha^{-1}) and marketable yield (272.13 q ha^{-1}) with application of elemental sulphur @ 30 kg ha^{-1}. The highest amount of pyruvic acid content in bulb (4.5µmol g^{-1}) and minimal storage loss were also found from the same treatment. The study suggested that soil application of elemental sulphur @ 30 kg ha^{-1} is to be made for better yield, quality and shelf life of onion cultivar Sukhsagar under new alluvial zone of West Bengal.

Rashid (2010) conducted an experiment was conducted at the Horticulture Farm of the Bangladesh Agricultural University, Mymensingh to evaluate the effects of sulphur and GA_3 on the growth and yield performance of onion cv. BARI $Piaz^{-1}$. The experiment included four levels of sulphur viz., 0 (control), 15, 30 and 45 kg ha^{-1} and four concentrations of GA_3 viz., 0 (control), 50, 75, 100 ppm. The experimental findings revealed that sulphur and GA_3 had significant influence on plant height, number of leaves per plant, bulb diameter and length, individual bulb weight, splitted and rotten bulb, bulb dry matter content and bulb yield. The highest bulb yield (13.85 t ha^{-1}) was recorded from 30 kg S ha^{-1}, while the lowest bulb yield (11.20 t ha^{-1}) was obtained from control. The maximum bulb dry matter content (13.50 %) and bulb yield (17.10 t ha^{-1}) were produced from the application of sulphur @ 30 kg ha^{-1} with 100 ppm GA_3.

Zaman *et al.* (2011) conducted an experiment for two consecutive rabi seasons of 2005-06 and 2006-07 at the Regional Agricultural Research Station (RARS), BARI, Jamalpur to find out an optimum dose of sulphur for yield maximization of onion cv. Jamalpur local. There were six levels of sulphur viz., 0, 15, 30, 45, 60, and 75 kg ha^{-1}. A control treatment was in the experiment. The fertilizer package N150P60K120Zn4 B1 kg ha^{-1} was applied to each plot as blanket dose. Results revealed that most of the growth and yield parameters increased progressively with increasing rate of sulphur application. Bulb yield increased with successive increase in the level of sulphur up to 45 kg ha^{-1}. The highest bulb yield (7.05 t ha^{-1} in 2005-06 and 7.22 t ha^{-1} in 2006-07) was achieved at 45 kg S ha^{-1} and the control treatment receiving no fertilizer had the lowest yield (3.21 t ha^{-1} in 2005-06 in and 3.26 t ha^{-1} in 2006-07). The yield benefit for 45 kg sulphur per ha was 34.2 % in 2005-06 and 40.0 % in 2006-07 over no sulphur. Sulphur at 45 kg ha^{-1} produced 54.5% and 54.9 % higher yield over control treatment in both the years.

Tripathy *et al.* (2013) conducted en experiment on onion. Sulphur has been recognised as an important nutrient for higher yield and quality of onion bulbs. Keeping this in view, a field experiment was conducted at AINRP on Onion and Garlic, College of Horticulture, OUAT during rabi, $2010^{-1}1$ to study the effect of sources and levels of sulphur on growth, yield and bulb quality in onion. The treatment consists of two sources of sulphur and four levels of sulphur by adopting Factorial RBD with three replications. The results on vegetative growth (plant height, number of leaves $plant^{-1}$ and neck thickness), yield attributing parameters (bulb weight, equatorial and polar diameter), total bulb yield, Physiological Losses of Weight (PLW) and Total Soluble Solid (TSS) revealed significant variations among the levels of sulphur in onion. Gypsum recorded higher plant height, neck thickness, average bulb weight, polar diameter, total bulb yield and TSS than elemental sulphur. Gypsum as a source of sulphur also reduces the production of doubles and bolter along with better shelf life of onion by reducing PLW, rotting and sprouting. Among the levels of sulphur, irrespective of sources, sulphur @ 30 kg ha^{-1} recorded significantly higher. Total bulb yield (211.23 q ha^{-1}) and TSS (11.90%) than other levels.

Pradhan *et al.* (2015) conducted a field experimentation conducted to examine the nutrient uptake in onion due to application of sulphur (S) was conducted at OUAT and found that application of sulphur (S) @ 45 kg ha^{-1} as gypsum significantly produced maximum bulb yield of 251.10 q ha^{-1} followed by S @ 30 kg ha^{-1} as gypsum (226.07 q ha^{-1}). Significantly maximum uptake of N, P, K, S (14.84, 0.66, 10.08 and 0.85 kg ha^{-1}, respectively) was observed by S @ 45 kg ha^{-1} as elemental sulphur followed by @30 and 45 kg ha^{-1} as gypsum. The results on nutrient uptake by bulbs indicated maximum of 74.66, 7.08, 35.62 & 9.02 kg ha^{-1} NPKS by application of S @ 45 kg ha^{-1} followed by 30 kg ha^{-1} as gypsum. Similar trend was also observed for total nutrient uptake. Thus, it may be concluded that application of S @ 30 or 45 kg ha^{-1} in the form of gypsum not only increases the bulb yield but also higher uptake of nutrients in onion.

Paul *et al.* (2007) conducted an experiment at the Horticulture Farm, Hajee Mohammed Danesh Science and Technology University, Dinajpur from November 2006 to April 2007 to know the effect of boron and sulphur on the growth and yield of onion cv. Taherpuri. The treatment consisted of four levels of each boron (0, 0.5,1 and 2 kg ha^{-1}) and sulphur (0, 15, 30 and 60 kg ha^{-1}). There was a significant influence of boron and sulphur on yield and yield attributes of onion. Boron @ 1 kg ha^{-1} gave the highest yield of bulb (13.19 t ha^{-1}) and sulphur @ 30 kg ha^{-1} produced the highest yield (12.24 t ha^{-1}). However, a combined application of boron and sulphur produced higher yield than boron and sulphur alone. Boron @ 1 kg ha^{-1} together with sulphur @ 30 kg ha^{-1} produced maximum yield of bulb (15.38 t ha^{-1})

Meena and Singh (1998) conducted a pot experiment on the effect of sulphur and zinc application on onion yield on a sandy soil, a sandy clay loam inceptisol and a clayey vertisol during the rabi season raising onion as the test crop. Dry weights were recorded for tops and bulbs separately. The results showed that S and Zn treatments significantly enhanced the dry weight of onion tops and bulbs. A sulphur dose of 20 mg S/kg on S-deficient soils and 10 mg S with 5 mg Zn/kg on low S soil were found appropriate for better onion yields.

A field experiment was conducted by Jaggi and Dixit (2005) in Palampur, Himachal Pradesh, India to investigate the effects of S rates (0, 15, 30 and 60 kg ha^{-1}) and sources (S95 and Gypsum) on the yield performance of onion cv. Patna Red. The fresh and dry weights of onion, yield, plant height, number of leaves per plant and weight per 40 bulbs increased with increasing S rates up to 30 kg ha^{-1}. Gypsum was found more effective than S 95 as the source of S.

A field experiment was conducted by Kumar and Das (2000) on silty loam soil to study the effect of Zn (0, 10 and 20 kg ha^{-1}) and S (0, 20 and 30 kg ha^{-1}) application on their availability in soil in relation to plant height, yield and nutrition of onion cv. N-53. The result showed that the yield of onion was highest (18.04 t ha^{-1}) under the 10 kg ha^{-1} Zn treatment. In respect of combined treatments, the best yield (16.04 t ha^{-1}) was obtained from the Zn 20 S30 treatment

Pena *et al.* (1999) conducted a bag pot experiment on response of onions cv. Texas Early Granex 502 to the application of sulphur, magnesium, zinc and boron in an alkaline soil in Venezuela. Different combinations of fertilizer treatments were applied. The doses of S, Zn, Mg and B were 16 kg ha^{-1}, 2.52 kg ha^{-1}, 8 kg ha^{-1} and 5.25 kg ha^{-1}, respectively, with or without NPK (120 kg N, 60 kg P_2O_5 and 120 kg K_2O, respectively). The application of Zn at 2.52 kg ha^{-1} as zinc sulphate significantly increased the crop yield and bulb weight. The application of Mn and B alone increased the crop yield and bulb weight which was insignificant. The best treatments were, NPK + Zn, NPK + Zn Mg, NPK + B, NPK + Zn B, and NPK + S ZN B.

Khan *et al.* (2007) conducted a field experiment at Spices Research center Bogra, during 2006 - 2007 to find out the requirement of S & Zn for plant height, number of leaves, number of flowers per umbel, number of fruits per umbel, higher seed yield of BARI Piaz–1. The treatments comprised five levels of S at 0, 20, 40, 80 and 100 kg ha^{-1}; and five levels of Zn at 0, 1, 3, 5 and 7 kg ha^{-1} as zinc oxide. The treatment combination of 100 kg S + 5 kg Zn ha^{-1} gave the highest seed yield.

Smriti *et al.* (2002) Conducted a field experiment was conducted 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^{-1} and B at 0, 1 and 2 kg ha^{-1}. Plant height, the number of leaves, leaf length, leaf width, bulb size, bulb weight and bulb yield significantly increased up to 40 kg S ha^{-1} and 1 kg B ha^{-1}. 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^{-1} gave the highest net return and benefit:cost ratio.

A field experiment was conducted by Rashid *et al.* (2007) at Spices Research center Bogra, during 2006 - 2007 to find out the requirement 5 levels of S and B for plant height, number of leaves, number of flowers per umbel, number of fruits per umbel, higher seed yield of BARI Piaz–l. The treatments comprised five levels of S at 0, 20, 40, 80 and 100 kg ha^{-1} and five levels of B at 0, 1, 3, 5 and 7 kg ha^{-1} as borax. The treatment combination of 100 kg S + 5 kg B ha^{-1} gave the highest seed yield.

Chowdhury *et al.* (2004) conducted an experiment at Field Laboratory of USDA Alliums Project, Horticulture Farm, Bangladesh Agricultural University, Mymensingh, during 2003 - 2004 to study the effects of boron and sulphur on seed production of onion (*Allium cepa* L.) cv.Taherpuri. The experiment was conducted with five levels of boron, viz., 0, 1, 2, 3 and 4 kg ha^{-1} and five levels of sulphur, viz., 0, 20, 40, 80 and 160 kg ha^{-1}. The highest seed yield was recorded from 4 kg B ha^{-1}. The positive effects of boron were found in order of 4> 3> 2> 1> 0 kg ha^{-1}. The sulphur at 80 kg ha^{-1} produced the highest seed yield. The positive effects of sulphur were found in order of 80> 40> 20> 160> 0 kg ha^{-1}. Among the treatment combinations, boron at 4 kg ha^{-1} with sulphur of 80 kg ha^{-1} produced the highest seed yield.

2.3 Effect of potassium and sulphur on growth, yield and nutrient content of onion

Islam *et al.* (2007) conducted an experiment on onion. The influence of four levels of fertilizers viz. 0:0:0, 60:65:80, 120:130:160 and 240:260:320 kg ha^{-1} (N:P:K) on growth, yield and yield contributing characters of six onion genotypes viz. Thaherpuri Brown, BARI Onion 1, Faridpuri Bhati, Suksagar, Nasirbala and Pusa Red exhibited distinct variation in respect of all the characters under investigation in the field condition. The fertilizers at 120:130:160 kg ha^{-1} produced the maximum bulb yield (14.9 t ha^{-1}). Genotype Pusa Red gave the maximum bulb yield (17.2 t ha^{-1}) and Faridpuri Bhati had the lowest yield (11.8 t ha^{-1}). Pusa Red along with 120:130:160 kg ha^{-1} produced maximum bulb yield (18.3 t ha^{-1}).

Bagali *et al.* (2012) conducted two field experiments for two seasons (rabi 2004-05 and summer 2005) at Regional Agricultural Research Station Bijapur, on medium deep black soil to study the effect of integrated nutrient management on the growth and yield of onion (cv. Telagi Red). Higher level of inorganics i.e., M3 (162:32:148 kg NPK/ ha) produced significantly higher bulb yield (41.55 t ha^{-1}) which was on par with M_2 i.e., 81:16:74 kg per ha (41.09 t ha^{-1}). When compared to RPP none of the inorganics levels were found significant for growth and yield parameters and yield. With organics, significantly higher and on par bulb yield of 40.56, 41.65 and 40.88 t per ha was recorded with FYM 30 t per ha (S_2), vermicompost @ 6 t per ha (S_4) and poultry manure @ 3 t per ha (S_6) respectively, compared to their respective lower levels. The combination of higher levels of inorganics (M_2 and M_3) with higher levels of organics (S_2, S_4 and S_6) recorded higher bulb yield. When compared to RPP none of the treatment combinations were found significantly different for growth and yield parameters and yield.

Abdulsalam and Hamaiel (2004) carried out a field experiment was during 1999-2000 and 2000-2001, to study the effect of three planting dates

(September 20, October 20 and November 20) and four compound fertilizer rates (F_1= 20% N, 20% P, 20% K .F_2=19% N, 29% P, 11% K, F_3= 14% N, 38% P, 10% K and F_4=16% N, 9% P, 26% K) on vegetative growth, yield, yield quality, mineral composition in bulb onion and chlorophyll a and b in onion leaves. It is concluded from this study that 20 October date and F3 fertilizer Treatment (14% N, 38% P, 10% K) were the most effective for optimal prodution of Hassawi onion. There were significant differences in the vegetative growth yield and yield components between the different planting dates and fertilization. Planting on October 20 gave the better results than other dates, while F_3 (14% N, 38% P, 10% K gave the best results for vegetative growth yield, and yield quality. Also 20 October planting date along with 14% N, 38% P, and 10% K gave better results for number of leaves/plant, leaf area/plant, dry/fresh weight%, average bulb weight (gm), bulb yield kgm^{-2} bulb shape index, N, P, K, chlorophyll a and chlorophyll b contents than other treatments.

Seran *et al.* (2010) carried out an experiment was to find suitable ratio of inorganic fertilizer and compost, which could give an economic yield of onion (cv. Jaffna Local). This experiment was designed in a Randomized Complete Block Design with four replicates. Treatments were recommended dosage of inorganic fertilizers as a control (T_1), ¾ fold of the control treatment + compost (2 t ha^{-1}) (T2), ½ fold of the control treatment + compost (4 t ha^{-1}) (T_3), ¼ fold of the control treatment + compost (6 t ha^{-1}) (T_4) and the compost alone (8 t ha^{-1}) (T_5). These were applied as basal application of fertilizer in this experiment. The results of this study revealed that there were significant ($P<0.05$) differences in the numbers of leaves and roots between the different treatments during the early stage of growth. Relatively higher yield (5.03 t ha^{-1}) was obtained from the plants treated with inorganic fertilizers alone (T_1), whereas compost alone (T_5) produced the lowest yield (3.43 t ha^{-1}). The inorganic fertilizers appear to have compensated with slow release of nutrients from the compost and their combined effects would have increased the yield.

Dharmesh and Harendra (2012) conducted field experiments at Lakhaoti, Bulandshahr (U.P.) during rabi seasons of 2008-09 and 2009-10 to study the effect of potassium and sulphur on yield and uptake of nutrients by onion. The treatments consisted of four levels of K (0, 30, 60 and 90 kg K_2O ha^{-1}) and S (0, 20, 40 and 60 kg ha^{-1}) Results revealed that fresh weight per bulb, bulb and dry matter yield increased significantly with increasing levels of K and S individually as well as in various combinations. Application of K and S increased the content and yield of protein in onion bulbs. The uptake of nutrients, (N, P, K and S) increased significantly with increasing levels of K and S. The synergistic effect of K and S levels was observed on yield and uptake of K and S by onion bulb

Hasan *et al.* (2012) conducted a pot experiment in the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University (BAU), Mymensingh to observe the influence of phosphorus (P) and sulphur (S) on yield, yield attributes and biochemical composition of onion cv. BARI $piaz^{-1}$ during the period from October, 2011 to May, 2012. The experiment was laid out in completely randomized design with 12 treatments and 3 replications using four (0, 30, 60 and 90 kg P ha^{-1}) levels of P and three (0, 15 and 30 kg S ha^{-1}) levels of S. The study revealed that yield and yield attributes such as plant height, no. of leaves, bulb length, bulb diameter, bulb weight, of onion were significantly influenced by P, S and their interactions. The highest values of all the parameters were obtained from P60 and S30 treatments. The results suggest that P and S @ 60 and 30 kg ha^{-1} along with basal doses of other inorganic fertilizers and organic manures can be used to increase onion yield under the agro climatic condition of BAU.

Abraha *et al.* (2013) conducted an experiment on onion. Low soil fertility status is a limiting factor in northern Ethiopia in general and the study area in particular. The objective of this research was, thus, to investigate the effect of three different combinations of N, P, S, Zn fertilizers and compost on yield and growth parameters of "Adama red" onion variety (*Allium cepa* L.). Applied fertilizer rates were N=130, P=20, S=21, Zn=15 and Compost 12000 Kg ha^{-1}. As a result, all combinations of fertilizers including compost gave significantly higher yield as compared to the control (P=0.05). On an average, the study revealed that a considerable response of onion to N-P-S-Zn fertilizers was observed with a maximum average yield of 25377.5 kg ha^{-1}. Accordingly combinations of 130 kg N, 20 kg P, 21 kg S and 15 kg Zn ha^{-1} could be recommended for better yield over others.

Chapter III

Materials & Methods

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in carrying out the experiment.

3.1 Location of the experimental field

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2014 to April 2015. The location of the experimental site was at 23^0 $46^{'}$N latitude and $90^0 22^{'}$E longitudes with an elevation of 8.24 meter from sea level.

3.2 Climate of the experimental area

The experimental area is characterized by subtropical rainfall during the month of May to September and scattered rainfall during the rest of the year. Information regarding average monthly temperature as recorded by Bangladesh Meteorological Department (climate division) during the period of study has been presented in Appendix I.

3.3 Soil of the experimental field

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8-6.5, ECE-25.28 (Haider, 1991). The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.4 Plant materials collection

The onion variety used in the experiment was "BARI Piaz-4". This is a high yielding type variety. The seeds were collected from Spices research division of Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) Joydebpur, Gazipur.

3.5 Characteristics of test variety

"BARI Piaz-4" a modern winter onion variety, was used as the test variety. It has released in 2008 from BARI as the winter variety of onion. It is slightly long, medium size, gray reddish colored pungent variety. Average height of the plant 50-60 cm and each plant contains $10^{-1}2$ leaves. The individual bulb weight is 60-75 gram and yield is 17-22 ton per hectare.

3.6 Treatments of the experiment

The experiment consisted of two factors as follows:

Factor A: Three levels of potassium fertilizer (Muriate of Potash -MOP)

K_1 = 140 kg ha^{-1} MOP
K_2 = 160 kg ha^{-1} MOP
K_3 = 180 kg ha^{-1} MOP

Factor B: Four levels of sulphur fertilizer (Gypsum)

S_0 = Control (No Gypsum)
S_1 = 130 kg ha^{-1} Gypsum
S_2 = 150 kg ha^{-1} Gypsum
S_3 = 170 kg ha^{-1} Gypsum

There were altogether 12 treatments combination used in each block were as follows; K_1S_0, K_1S_1, K_1S_2, K_1S_3, K_2S_0, K_2S_1, K_2S_2, K_2S_3, K_3S_0, K_3S_1, K_3S_2, K_3S_3,

3.7 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) having two factors with three replications. An area of 29.1 m x 10 m was divided into three equal blocks. Each block was consists of 12 plots where 12 treatments were allotted randomly. There were 36 unit plots in the experiment. The size of each plot was 1.8 m x 2 m. The distance between two blocks and two plots were kept 1 m and 0.5 m respectively. A layout of the experiment has been shown in figure 1.

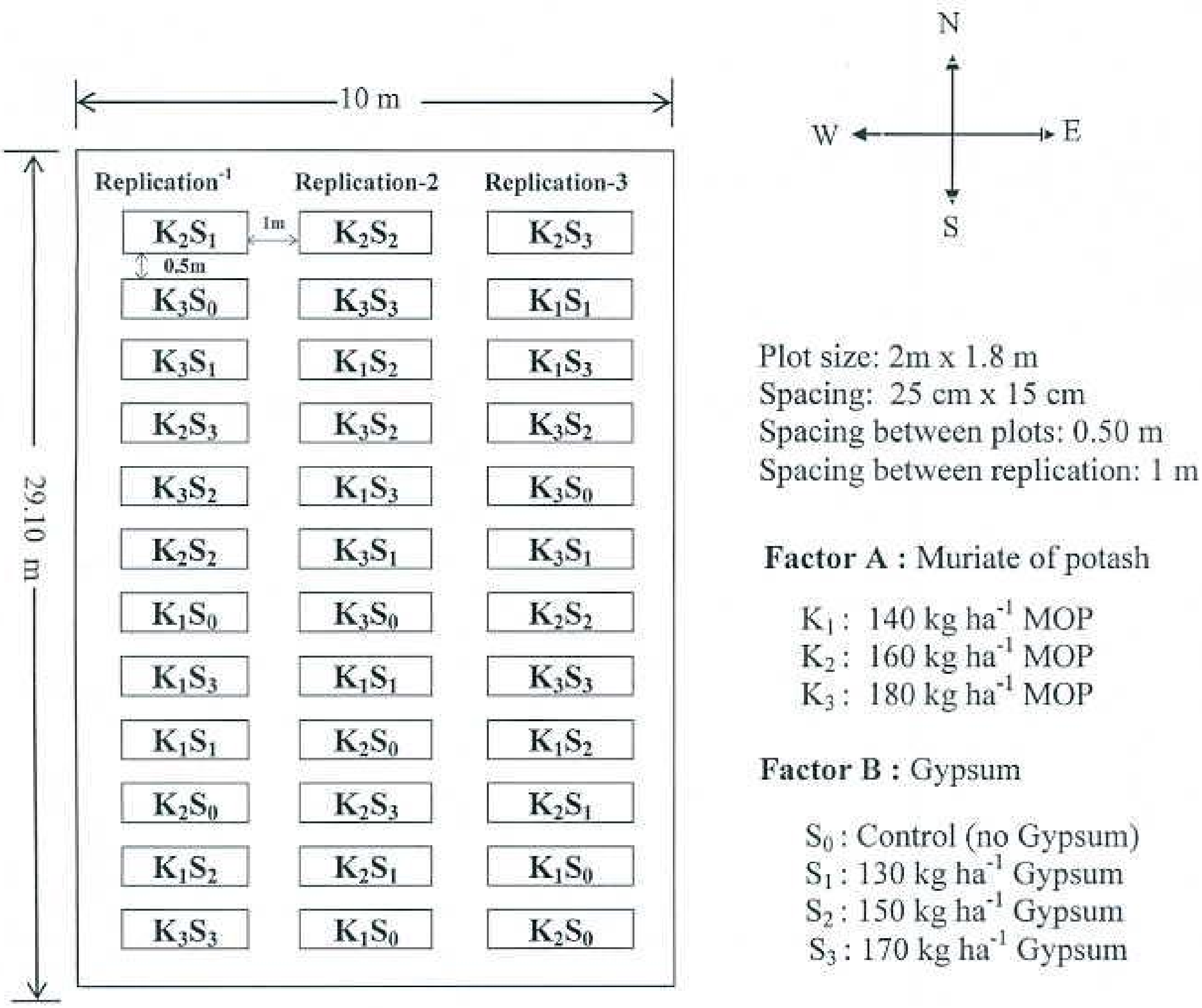


Fig. 1: Field layout of the experimental plot

3.8 Cultivation procedure

3.8.1 Raising of seedlings

The seedbed where seedlings were raised was high land, rich in organic matter, well drained and sunny. Before sowing seeds the land selected for the seedbed were well prepared. The seeds were soaked in water for 15 hours before sowing for a good germination and kept in a piece of cloth for sprouting (Lipe and Skinner, 1979). Sprouted seeds were sown in well prepared 3 m x 1 m size seed bed at the rate of two hundred and fifty (250) grams of seeds on each of the two seedbeds on 20 November 2014. After sowing, seeds were covered with light soil. The emergence of the seedlings took place within 6 to 7 days after sowing. Weeding, mulching and irrigation were done as and when required.

3.8.2 Land preparation

The soil was well prepared and good tilth was ensured for commercial crop production. The land of the experimental field was ploughed with a power tiller on November, 2014. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was made ready. The field layout and design was followed after land preparation.

3.8.3 Manures and fertilizers and its methods of application

Fertilizer	Quantity	Application method and time
Cow dung	7 t ha^{-1}	Basal dose
Urea	240 kg ha^{-1}	20, 30 and 40 DAT
TSP	260 kg ha^{-1}	Basal dose
MOP	160 kg ha^{-1}	As per treatment
Gypsum	150 kg ha^{-1}	As per treatment

Sattar *et al.* (2005).

According to Sattar *et al.* (2005) the entire amount of cow dung and TSP were applied as basal dose during land preparation. Urea and TSP were applied at the rate of 240 kg ha^{-1} and 260 kg ha^{-1} respectively. MOP and gypsum were used as per treatment after transplanting.

3.8.4 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in 20 December, 2014 maintaining a spacing of 25 cm x 15 cm between the rows and plants, respectively. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.8.5 Intercultural operations

After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants, which are as follows:

3.8.5.1 Gap filling

When the seedlings were well established, the soil around the base of each seedling was pulverized. A few gaps filling was done by healthy seedlings of the same stock where initial planted seedling failed to survive.

3.8.5.2 Weeding and mulching

Numbers of weeding were accomplished as and whenever necessary to keep the crop free from weeds. Mulching was done by breaking the crust of the soil for easy aeration and to conserve soil moisture as and when needed especially after irrigation.

3.8.5.3 Irrigation

Number of irrigation was given throughout the growing period by garden pipe and watering cane. The first irrigation was given immediate after the transplantation where as other were applied when and when required depending upon the condition of soil.

3.8.5.4 Plant protection measure

Preventive measure was taken against soil born insects. For the prevention of cut worm (*Agrotis ipsilon*) soil treatment was done with Furadan 5G at the rate of 20 kg per hectare. Purple blotch caused by *Alternaria pori* was found to attack many plants in the experimental field. It was controlled by spraying Ridomil and Rovral at the rate of 2g/L of water.

3.9 Harvesting

The crop was harvested when 75% of the tops had fallen over (Shalalby *et al.*, 1991). The tops were removed by cutting off the pseudostem keeping 1.0 cm with the bulb.

3.10 Data collection

Five plants were selected randomly from each plot for data collection in such a way that the border effect could be avoided for the highest precision. Data on the following parameters were recorded from the sample plants during the course of experiment.

3.10.1 Plant height

The plant height was measured in centimeters from the base of plant to the terminal growth point of main stem on tagged plants was recorded at 10 days interval starting from 20 days of planting up to 60 days to observe the plant height. The average height was computed and expressed in centimeter.

3.10.2 Number of leaves per plant

The number of leaves per plant was manually counted at 20, 30, 40, 50 and 60 days after transplanting from randomly selected tagged plants. The average of five plants were computed and expressed in average number of leaves per plant.

3.10.3 Individual bulb weight

Five plants were randomly selected from each unit plot. The top was removed by cutting off the pseudostem keeping only 1.0 cm from the bulb. The bulbs were weighted by a simple balance and the average was calculated and expressed in gram.

3.10.4 Weight of leaf

The weight of leaf of the plant was manually measured by a balance scale at 20, 30, 40, 50 and 60 days after transplanting from randomly selected five tagged plants. The leaves were measured and expressed in average weight of leaf of the plant.

3.10.5 Diameter of bulb

Diameter of the harvested bulbs were measured with a slide calipers at the middle portion of five randomly selected plants from each plot and their average was calculated and expressed in cm.

3.10.6 Yield of bulb per plot (kg)

All the leaves with pseudostem were cut off from the plant keeping only 1.0 cm neck and the weight of bulbs were taken by a simple balance in kilogram from each unit plot.

3.10.7 Yield of bulb per hectare (ton)

The yield of bulb per plot was converted in to yield of bulb in tons per hectare. It was measured by the following formula:

$$\text{Yield of bulb (t ha}^{-1}\text{)} = \frac{\text{Bulb yield per unit plot (kg) x 10000}}{\text{Area of unit plot in square meter x 1000}}$$

3.10.8 Chemical analysis of bulb and leaf samples of onion

Different nutrients of bulb and leaf were measured by using different chemical and lab equipment's following the laboratory protocol. The samples were oven dried at 70^0C for 72 hours. Dried plant materials were ground and processed for determination of Na, P, K, S and N content.

3.10.8.1 Preparation of plant extract for the determination of P, Na, K and S.

Preparation of plant extract:

0.25 g of dry onion bulb were weighed, and then transferred into 250 ml Pyrex conical flasks. Then 10 ml 2:1 nitric-perchloric acid mixture was added into each flask and allowed to stand overnight or until the vigorous reaction phase is over. After the preliminary digestion, the conical flasks were placed on a hot plate in digestion chamber and then temperature was raised to 150°C for 1 hour. The temperature was increased slowly up to 300^0C after the digestion the conical flasks were lifted out of the digester and allowed to cool at room temperature. The solution was taken in 100 ml volumetric flask through funnel and volume with distilled water upto the mark (Jackson, 1973).

3.10.8.2 Determination of Phosphorus (P) content of onion bulb and leaf

Principle:

By ascorbic acid blue color method the phosphorus content in onion bulb were determined. This method is based on the principle that in an acid molybdate solution containing orthophosphate ($H_2PO_4^-$) ions, a phosphomolybdate blue complex forms that can be reduced by ascorbic acid and other reducing agents to a molybdenum blue color.

$(NH_4)_6Mo_7O_{24}.4\,H_2O + H_2SO_4 = (NH_4)_2MoS_4$

$(NH_4)_2MoS_4 + H_2PO_4^- = (NH_4)_3PMo_{12}O_{40}$ [Ammonium phosphorus molybdate, oxidized, colorless]

$(NH_4)_3PMo_{12}O_{40} + C_6H_8O_6 =$ Ammonium phosphorus molybdate (Reduced, Blue color)

Reagents:

1. Mixed reagent:

Solution A: About 12.0 g ammonium molybdate [$(NH_4)_6Mo_7O_{24}.4\,H_2O$] was dissolved in 250 ml distilled water.

Solution B: At first 0.2908 g antimony potassium tartarate [$K(SbO)C_4H_4O_6.1/2H_2O$] was dissolved in 1000 ml of 5N H_2SO_4 (148 ml conc. H_2SO_4/Liter) the two solutions were mixed together thoroughly. Then the volume was made to 2000 ml distilled water.

2. Color developing reagent:

About 0.53 g (or.1.06 g or 2.65 g) of ascorbic acid was added to 100 ml (or 200 ml or 500 ml) of the mixed reagent.

Procedure:

20 ml of the extract was pipette out in a 100 ml volumetric flask. Then 20 ml color developing reagent was added slowly and carefully to prevent loss of sample due to excessive foaming. After the evolution of CO; has ceased the flask was shake gently to mix the contents. Distilled water was added to make the volume up to the mark of the flask. By spectrophotometer, the color intensity (% absorbance) was measured at 660 nm.

3.10.8.3 Determination of sodium and potassium (K) content of onion bulb and leaf

Total sodium and potassium content in bulb and leaf samples were determined by flame photometer.

3.10.8.4 Determination of S from onion bulb and leaf samples

Sulphur content was determined from the digest of the plant samples (bulb). The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6 N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

3.10.8.5 Determination of nitrogen (N) content of onion bulb and leaf

The macro Kjeldahl method was used to determine the total nitrogen in onion bulb and leaf samples. Three steps were involved in this method. These are as follows:

1. Digestion: In this step the organic nitrogen was converted to ammonium sulphate by sulphuric acid and digestion accelerators (Catalyst Mixture) at a temperature of 360-440^{0}C.

$$N + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

2. Distillation: In this step, the solution was made alkaline for the

distillation of ammonia. The distillated ammonia was received in boric acid solution.

$$(NH_4)_2SO_4 + NaOH \longrightarrow Na_2SO_4 + NH_3 + H_2O$$

$$NH_3 + H_3BO_3 \longrightarrow (NH_4)_2BO_3 + H_2O$$

3. Titration: To determine the amount of NH_3, ammonium borate was titrated with standard sulfuric acid.

$$(NH_4)_2BO_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4 + H_3BO_3$$

Reagents : 4 % Boric Acid solution, Mixed Indicator (Bromocresol Green And Methyl Red), 4 % Sodium Hydroxide solution, standard Sulfuric Acid solution and 0.05 N Na_2CO_3 solution.

Procedure:

About 0.50 g of oven-dried bulb/ leaf sample was weighed and then transferred into a 250 mL Pyrex Kjeldahl flask. Then 5.0 g catalysts mixer (K_2SO_4: $CuSO_4.5H_2O$: Se =100: 10: 1) was added in to the flask. About 25 mL H_2SO_4 was also added in to the flask. The flask was heated until the solution become clear and then allowed to cool. After digestion, 40% NaOH was added in to the conical flask and attached quickly to the distillation set. Then the flask was heated continuously. In the meantime, 25 mL of 4% boric acid solution and 2-4 drops of mixed indicator was taken in 5% receiver conical flask. After distillation, the distillate was collected into receiver conical flask. The distillate was titrated with standard H_2SO_4 taken from a burette until the green color completely turns to pink. The same procedure was followed for a blank sample. The result was calculated using the following formula –

% N = (T-B) × N × 1.4/S

T = Titration value for sample (ml.), B -= Titration value for blank (ml)

N = Normality of H_2SO_4, S = Weight of the sample (g),

1.4 = Conversion factor

3.11 Statistical analysis

The recorded data on various parameters were statistically analyzed using MSTAT-C statistical package program developed by Russel (1986). The mean for all the treatments was calculated and analysis of variance (ANOVA) for all the characters were performed by F-Difference between treatment means were determined by Least Significance Difference (LSD) according to Gomez and Gomez, (1984) at 5% level of significance.

Chapter IV

Results and Discussion

CHAPTER IV

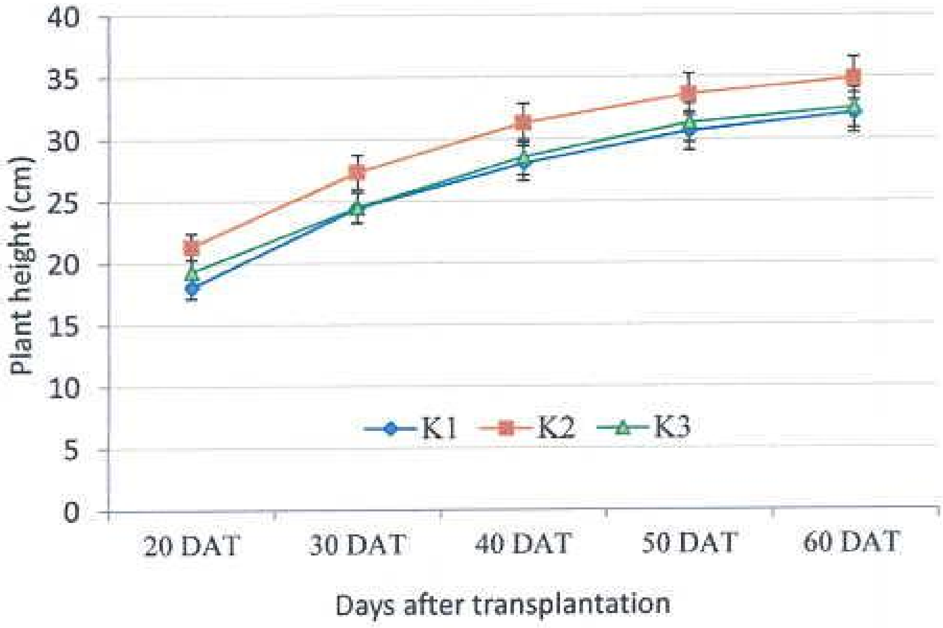
RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results obtained from the study. The results and analysis of the variance of data on different plant growth characteristics and yield behavior obtained from the present investigation have been presented on Figures 2, 3, 4 and 5 and also tables 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 and Appendices III-VIII for clear interpretation and understanding. The results have been presented under the following headings:

4.1 Plant Height

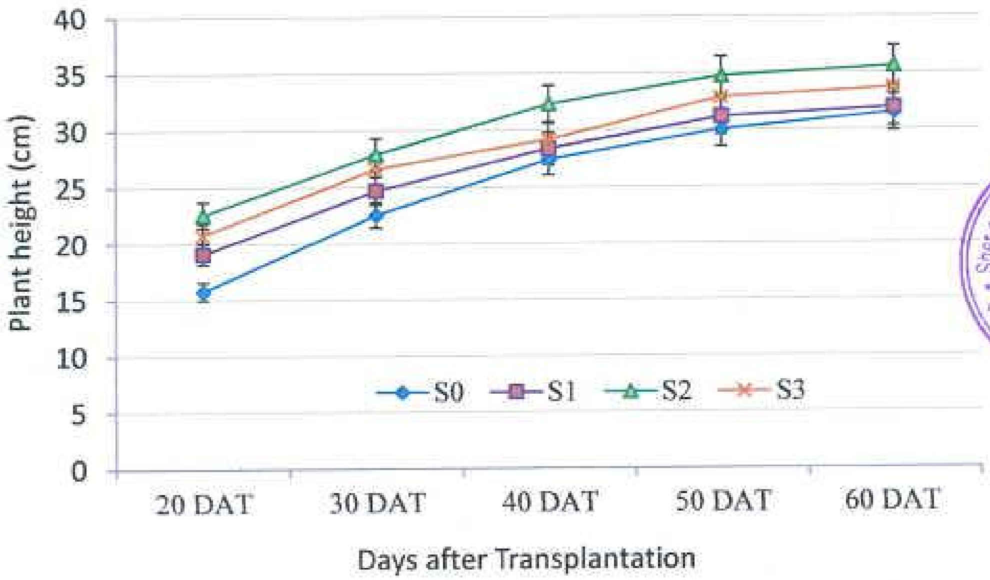
Significant difference was observed due to the application of different levels of potassium at 20, 30, 40, 50 and 60 DAT (Appendix III). At 20 DAT, the highest plant height (21.35 cm) was recorded from K_2 (160 kg ha^{-1} MOP) and the shortest plant (18.05 cm) was found from K_0 (control). At 30 DAT, the longest plant (27.36 cm) was found from K_2 and the shortest plant (24.47 cm) was obtained from K_0. The longest plant (31.32 cm) was recorded from K_2 and the shortest plant (28.06 cm) was found from K_0 at 40 DAT. At 50 DAT, the longest plant (33.60 cm) was obtained from K_2 while the shortest plant (30.65 cm) was found from K_0 (control) treatment. At 60 DAT, the tallest plant (34.87 cm) was obtained from K_2 while the shortest plant (32.12 cm) was found from K_0 (control) treatment (Fig. 2). The increase in plant height might be due to higher intake of potassium from MOP by the plants and more tissue protein synthesis resulting in higher meristemetic growth. Saud *et al.* (2013) observed the maximum plant height observed with the application of potassium. Similar results were also found in Barman *et al.* (2013) and Saud *et al.* (2013).

Significant difference was observed due to application of different levels of sulphur on plant height at 20, 30, 40, 50 and 60 DAT (Appendix III). At 20 DAT, the tallest plant (22.59 cm) was found from S_2 (150 kg ha^{-1} Gypsum) while the shortest (23.78 cm) plant was recorded from S_0. At 30 DAT, the longest plant (27.91 cm) was recorded from S_2 while the shortest (22.55 cm) plant was obtained from S_0 (control). The



K_1 : 140 kg ha^{-1} MOP K_2 : 160 kg ha^{-1} MOP K_3 : 180 kg ha^{-1} MOP

Fig 2. Effect of potassium on plant height of onion at different days after transplanting



S_0 : Control S_1 : 130 kg ha^{-1} Gypsum S_2 : 150 kg ha^{-1} Gypsum S_3 : 170 kg ha^{-1}

Fig 3. Effect of sulphur on plant height of onion at different days after transplanting

Table 1. Combined effects of potassium and sulphur on plant height (cm) of onion at different days after transplanting (DAT)

Treatments	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
K_1S_0	14.17 d	21.22 d	24.60 c	28.27 c	29.73 b
K_1S_1	17.90 bcd	24.30 bcd	28.57 bc	32.07 bc	33.00 b
K_1S_2	19.96 bc	25.50 bcd	29.23 bc	32.07 bc	32.33 b
K_1S_3	20.18 bc	26.22 abcd	29.83 b	32.73 abc	33.40 b
K_2S_0	17.39 bcd	24.57 bcd	29.67 b	31.60 bc	33.33 b
K_2S_1	20.16 bc	25.60 bcd	28.40 bc	30.60 bc	31.47 b
K_2S_2	26.07 a	31.50 a	36.27 a	38.20 a	40.07 a
K_2S_3	21.77 ab	27.77 ab	30.93 b	34.00 ab	34.60 ab
K_3S_0	15.80 cd	21.87 cd	27.97 bc	30.20 bc	31.33 b
K_3S_1	19.25 bc	24.17 bcd	28.13 bc	30.80 bc	31.30 b
K_3S_2	21.75 ab	26.73 abc	31.40 b	32.47 bc	34.43 ab
K_3S_3	20.42 b	25.87 bcd	26.73 bc	31.80 bc	33.00 b
$LSD_{0.05}$	**4.59**	**5.32**	**4.86**	**5.65**	**6.01**
CV%	**13.86**	**12.37**	**9.79**	**10.37**	**10.70**

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

K_1 : 140 kg ha^{-1} MOP K_3: 180 kg ha^{-1} MOP S_0 : Control (No Gypsum) S_2 : 150 kg ha^{-1} Gypsum

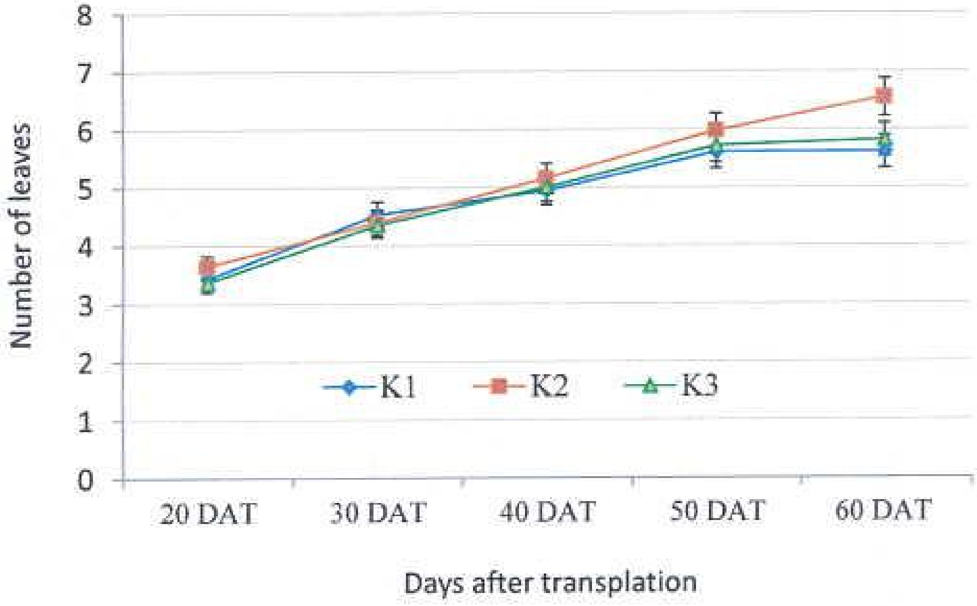
K_2 : 160 kg ha^{-1} MOP S_1 : 130 kg ha^{-1} Gypsum S_3 : 170 kg ha^{-1} Gypsum

longest plant (32.30 cm) was found from S_2 while the shortest (27.41 cm) plant was recorded from S_0 at 40 DAT. At 50 DAT, the highest plant height (34.73 cm) was recorded from S_2 while the shortest plant height (30.02 cm) was found from S_0 (control). At 60 DAT, the highest plant height (35.61 cm) was recorded from S_2 while the shortest plant height (31.47 cm) was found from S_0 (control) treatment (Fig. 3). Smriti *et al.* (2002) observed that highest plant the height significantly increased with the application of sulphur. Related results were also found by Tripathy *et al.* (2013).

Combined effects of potassium and sulphur showed significant difference on plant height at all observations (Appendix III). However at 20 DAT, the longest plant (26.07 cm) was recorded from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the shortest (14.17 cm) plant was found from K_0S_0 (control). At 30 DAT, the longest plant (31.50 cm) was recorded from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) while the shortest plant (21.22 cm) was obtained from K_0S_0 Treatment combination. At 40 DAT, the longest plant (36.27 cm) was obtained from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the shortest plant (24.60 cm) was found from K_0S_0 (control) treatment combination. The longest plant (38.20 cm) was recorded from K_2S_2 while the shortest (28.27 cm) was observed in K_0S_0 (control) at 50 DAT. At 60 DAT, the longest plant (40.07 cm) was recorded from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) while the shortest (29.73 cm) was observed in K_0S_0 (control) control treatment combination (Table 1).

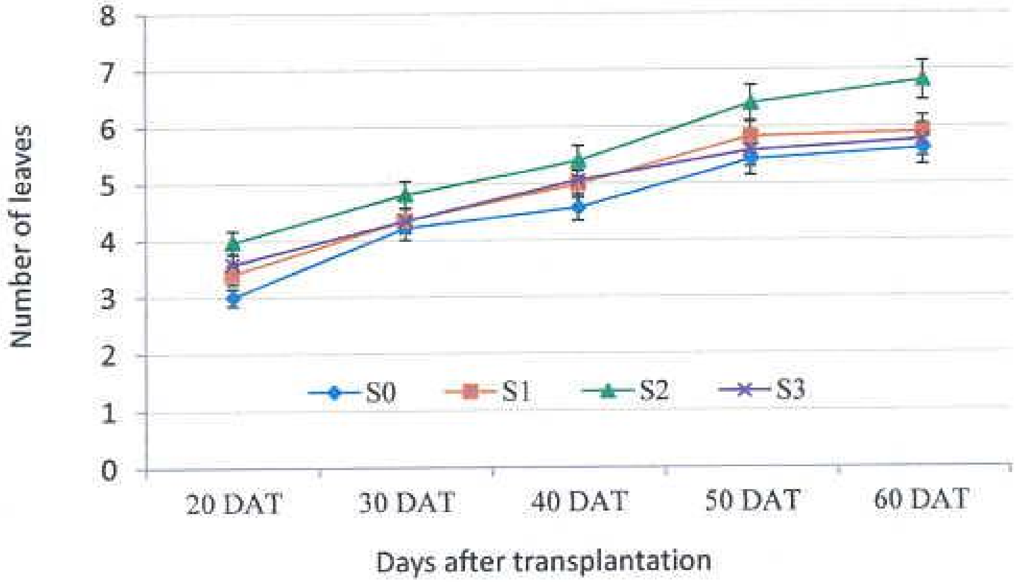
4.2 Number of leaves per plant

The number of leaves per plant had a significant effect on potassium at different growth stages like 30, 40, 50 and 60 DAT except 20 DAT (Appendix IV). Numerically leaf production was increased up to 60 DAT and there after decreased due to senescence. At 30 DAT, the highest number of leaves per plant (4.50) was found from K_2 (160 kg ha^{-1} MOP) treatment and the lowest number of leaves per plant (4.03) was obtained from K_0 treatment. The highest number of leaves per plant (5.16) was recorded from K_2 and the lowest number of leaves per plant (4.95) was found from K_0 (control) treatment at 40 DAT. At 50 DAT, the highest number of leaves per plant (5.98) was obtained from K_2 (160 kg ha^{-1} MOP) while the lowest number of



K_1 : 140 kg ha^{-1} MOP K_2 : 160 kg ha^{-1} MOP K_3 : 180 kg ha^{-1} MOP

Fig 4. Effect of sulphur on leaves per plant of onion at different days after Transplanting



S_0 : Control S_1 : 130 kg ha^{-1} Gypsum S_2 : 150 kg ha^{-1} Gypsum S_3 : 170 kg ha^{-1}

Fig 5. Effect of sulphur on number of leaves per plant of onion at different days after transplanting

Table 2. Combined effects of potassium and sulphur on number of leaves of onion at different days after transplanting (DAT)

Treatments	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
K_1S_0	2.83 c	3.83 b	4.84 b	5.23 b	5.44 b
K_1S_1	3.23 bc	4.56 ab	5.57 ab	5.93 ab	6.14 ab
K_1S_2	3.86 ab	4.93 ab	5.94 ab	6.34 ab	6.55 ab
K_1S_3	3.83 ab	4.80 ab	5.81 ab	6.46 ab	6.67 ab
K_2S_0	3.00 bc	4.26 ab	5.27 ab	6.30 ab	6.51 ab
K_2S_1	3.63 abc	4.00 ab	5.01 ab	6.10 ab	6.31 ab
K_2S_2	4.26 a	5.16 a	6.17 a	7.40 a	7.61 a
K_2S_3	3.73 ab	4.16 ab	5.17 ab	5.23 b	5.44 b
K_3S_0	3.16 bc	4.56 ab	5.57 ab	5.31 b	5.52 b
K_3S_1	3.33 bc	4.50 ab	5.51 ab	5.66 b	5.87 b
K_3S_2	3.80 ab	4.33 ab	5.34 ab	6.70 ab	6.91 ab
K_3S_3	3.20 bc	4.06 ab	5.07 ab	5.60 b	5.81 b
$LSD_{0.05}$	**0.87**	**1.17**	**1.17**	**1.69**	**1.69**
CV%	**14.73**	**11.65**	**15.46**	**12.68**	**13.63**

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

K_1 : 140 kg ha^{-1} MOP K_3 : 180 kg ha^{-1} MOP
K_2 : 160 kg ha^{-1} MOP

S_0 : Control (No Gypsum) S_2 : 150 kg ha^{-1} Gypsum
S_1 : 130 kg ha^{-1} Gypsum S_3 : 170 kg ha^{-1} Gypsum

leaves per plant (5.61) was found from K_0 (control) treatment. At 60 DAT, the highest number of leaves per plant (6.55) was obtained from K_2 (160 kg ha^{-1} MOP) while the lowest number of leaves per plant (5.61) was found from K_0 (control) treatment (Fig. 4). Awatef *et al.* (2015), and Saud *et al.* (2013) also found the highest number of leaves per plant with the application of potassium. Related results were also found by Saud *et al.* (2013). Barman *et al.* (2013) also agreed with this result by their experiments.

Significance difference was observed due to application of different levels of sulphur on number of leaves per plant at 20, 30, 40, 50 and 60 DAT (Appendix IV). At 20 DAT, the highest number of leaves per plant (3.97) was found from S_2 (150 kg ha^{-1} Gypsum) while the lowest number of leaves per plant (3.00) plant was recorded from S_0 (control) Treatment. At 30 DAT, the highest number of leaves per plant (4.81) was recorded from S_2 while the lowest number of leaves per plant (4.22) plant was obtained from S_0 (control). The highest number of leaves per plant (5.40) was found from S_2 (150 kg ha^{-1} Gypsum) while the lowest number of leaves per plant (4.57) plant was recorded from S_0 at 40 DAT. At 50 DAT, the highest number of leaves per plant (6.51) was recorded from S_2 while the lowest number of leaves per plant (5.32) was found from S_0 (control). At 60 DAT, the highest number of leaves per plant (6.81) was recorded from S_2 (150 kg ha^{-1} Gypsum) while the lowest number of leaves per plant (5.61) was found from S_0 (control) treatment (Fig. 5). Rashid (2010) found the highest number of leaves per plant with the application of sulpher. Related results were also found by Smriti *et al.* (2002) and Abdulsalam and Hamaiel (2004)

Combined effects of potassium and sulphur showed significant difference on number of leaves per plant at all observations (Appendix IV). However at 20 DAT, the highest number of leaves per plant (4.26) was recorded from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the lowest number of leaves per plant (2.83) plant was found from K_0S_0 (control). At 30 DAT, the highest number of leaves per plant (5.16) was recorded from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) while the lowest number of leaves per plant (3.83) was obtained from K_0S_0 Treatment combination. At 40 DAT, the highest number of leaves per plant (6.17) was obtained from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the lowest number of leaves per plant (4.84) was found from K_0S_0 (control) treatment combination. The highest number of leaves per plant (7.40) was recorded from K_2S_2 while the lowest number of leaves per plant (5.23) was observed in K_0S_0 (control) at 50 DAT. At 60 DAT, the highest number of leaves per plant (7.61) was recorded from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) while the lowest number of leaves per plant (5.44) was observed in K_0S_0 (control) control treatment combination (Table 2). Islam *et al.* (2007) observed the highest number of leaves per plant with the application of sulpher and potassium.

4.3 Individual bulb weight

In case of bulb weight, significant variation was found due to the application of different levels of potassium (Appendix V). The highest bulb weight (17.33 g) was obtained from K_2 (160 kg ha^{-1} MOP) treatment, while the lowest bulb weight (14.36 g) was found from K_0 (control) treatment, which is statistically identical (15.07 g) to K_3 (180 kg ha^{-1} MOP) treatment (Table 3). Barman *et al.* (2013) also recorded the highest weight of bulb with the application of potassium.

The bulb weight varied significantly due to the application of different levels of sulphur (Appendix V). The highest bulb weight (17.62 g) was recorded from S_2 (150 kg ha^{-1} Gypsum) treatment which is statistically simillar (16.21 g) to S_3 (170 kg ha^{-1} Gypsum) and while the lowest bulb weight (11.62 g) was obtained from S_0 treatment (Table 3). Hasan *et al.* (2013) observed the highest weight of bulb with the application of sulpher.

Combined effects of potassium and sulphur showed significant difference on bulb weight (Appendix V). However the highest bulb weight (20.74 g) was recorded from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the lowest bulb weight (10.49 g) was found from K_0S_0 (control) treatment combination (Table 4). Islam *et al.* (2007) also found that the highest weight of bulb with the application of sulpher and potassium.

4.4 Leaf weight

In case of leaf weight, significant variation was found due to the application of different levels of potassium (Appendix V).

The highest leaf weight (0.69 g) was obtained from K_2 (160 kg ha^{-1} MOP) treatment, while the lowest leaf weight (0.55 g) was found from K_0 (control) treatment, which is statistically identical (0.56 g) to K_3 (180 kg ha^{-1} MOP) treatment (Table 3). Awatef *et al.* (2015) observed the highest Fresh weight of leaves with the application of potassium.

The leaf weight varied significantly due to the application of different levels of sulphur (Appendix V). The highest leaf weight (0.80 g) was recorded from S_2 (150 kg ha^{-1} Gypsum) treatment while the lowest leaf weight (0.48 g) was obtained from S_0 treatment (Table 3). Luiz *et al.* (2015) found the highest dry weight of leaves with the application of sulpher

Combined effects of potassium and sulphur showed significant difference on leaf weight (Appendix V). However the highest leaf weight (0.95 g) was recorded from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the lowest leaf weight (0.45 g) was found from K_0S_0 (control) treatment combination (Table 4). Abdulsalam and Hamaiel (2004) also investigated that the highest weight of leaves with the application of sulpher and potassium.

4.5 Bulb diameter

In case of bulb diameter, significant variation was found due to the application of different levels of potassium (Appendix V). The highest bulb diameter (3.41 cm) was obtained from K_2 (160 kg ha^{-1} MOP) treatment, while the lowest bulb diameter (3.06 cm) was found from K_0 (control) treatment, which is statistically identical (3.11 cm) to K_3 (180 kg ha^{-1} MOP) treatment (Table 3). Barman *et al.* (2013) recorded that the highest Diameter of bulb with the application of potassium.

The bulb diameter varied significantly due to the application of different levels of sulphur (Appendix V). The highest bulb diameter (3.58 cm) was recorded from S_2 (150 kg ha^{-1} Gypsum) treatment and while the lowest bulb diameter (2.82 cm) was obtained from S_0 treatment (Table 3). Awatef *et al.* (2015) also observed the highest Diameter of bulb with the application of sulpher. Related results were also found by Saud *et al.* (2013), and Barman *et al.* (2013).

Table 3. Effects of potassium and sulphur on yield characteristics of onion

Treatments	Bulb weight (g)	Leaf weight (g)	Bulb Diameter (cm)	Yield per plot (kg)	Yield per hectare (ton)
K_1	14.36 b	0.55 b	3.06 b	2.82 b	7.85 b
K_2	17.33 a	0.69 a	3.41 a	2.99 a	8.32 a
K_3	15.07 b	0.56 b	3.11 b	2.90 ab	8.07 ab
$LSD_{0.05}$	**2.16**	**0.11**	**0.22**	**0.12**	**0.39**
CV%	**17.10**	**11.90**	**8.36**	**9.28**	**9.28**
S_0	11.62 c	0.48 c	2.82 c	2.55 c	7.09 c
S_1	14.26 b	0.53 b	3.18 b	2.98 b	8.30 b
S_2	17.62 a	0.80 a	3.58 a	3.16 a	8.79 a
S_3	16.21 ab	0.63 b	3.30 b	2.93 b	8.14 b
$LSD_{0.05}$	**2.49**	**0.13**	**0.2641**	**0.1417**	**0.45**
CV%	**17.10**	**11.90**	**8.36**	**9.28**	**9.28**

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

K_1 : 140 kg ha^{-1} MOP K_3 : 180 kg ha^{-1} MOP S_0 : Control (No Gypsum) S_2 : 150 kg ha^{-1} Gypsum

K_2 : 160 kg ha^{-1} MOP S_1 : 130 kg ha^{-1} Gypsum S_3 : 170 kg ha^{-1} Gypsum

Table 4. Combined effects of potassium and sulphur on yield characteristics of onion

Treatments	Bulb weight (g)	Leaf weight (g)	Bulb Diameter (cm)	Yield per plot (kg)	Yield per hectare (ton)
K_1S_0	10.49 d	0.45 c	2.71 e	2.51 e	6.98 e
K_1S_1	14.63 bcd	0.60 c	3.35 bc	2.91 c	8.08 c
K_1S_2	15.08 bc	0.62 bc	3.28 bc	2.98 bc	8.30 bc
K_1S_3	17.24 ab	0.54 c	3.29 bc	2.86 cd	7.96 cd
K_2S_0	12.08 cd	0.63 bc	2.96 cde	2.60 de	7.23 de
K_2S_1	14.49 bcd	0.48 c	3.11 cde	3.14 abc	8.72 abc
K_2S_2	20.74 a	0.95 a	3.91 a	3.27 a	9.10 a
K_2S_3	14.12 bcd	0.67 bc	3.22 bcd	3.01 abc	8.36 abc
K_3S_0	12.30 cd	0.68 bc	2.78 de	2.54 e	7.05 e
K_3S_1	13.67 bcd	0.50 c	3.10 cde	2.91 c	8.09 c
K_3S_2	17.05 ab	0.85 ab	3.57 ab	3.23 ab	8.99 ab
K_3S_3	17.27 ab	0.68 bc	3.40 bc	2.91 c	8.09 c
$LSD_{0.05}$	**4.32**	**0.23**	**0.45**	**0.28**	**0.79**
CV%	**17.10**	**11.90**	**8.36**	**9.28**	**9.28**

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

K_1 : 140 kg ha^{-1} MOP K_3 : 180 kg ha^{-1} MOP S_0 : Control (No Gypsum) S_2 : 150 kg ha^{-1} Gypsum

K_2 : 160 kg ha^{-1} MOP S_1 : 130 kg ha^{-1} Gypsum S_3 : 170 kg ha^{-1} Gypsum

Combined effects of potassium and sulphur showed significant difference on bulb diameter (Appendix V). However the highest bulb diameter (3.91 cm) was recorded from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the lowest bulb diameter (2.71 cm) was found from K_0S_0 (control) treatment combination (Table 4).

4.6 Yield per plot (kg)

Significant variation was found in yield per plot due to the application of different levels of potassium (Appendix V). The highest yield per plot (2.99 kg) was obtained from K_2 (160 kg ha^{-1} MOP) treatment, while the lowest yield per plot (2.82 kg) was found from K_0 (control) treatment, which is statistically similar (2.90 kg) to K_3 (180 kg ha^{-1} MOP) treatment (Table 3).

The yield per plot varied significantly due to the application of different levels of sulphur (Appendix V). The highest yield per plot (3.16 kg) was recorded from S_2 (150 kg ha^{-1} Gypsum) treatment and while the lowest yield per plot (2.55 kg) was obtained from S_0 treatment (Table 3).

Significant variation was found at the time of harvesting due to the application of potassium and sulphur on yield per plot (Appendix V). However the highest yield per plot (3.27 kg) was recorded from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the lowest yield per plot (2.51 kg) was found from K_0S_0 (control) treatment combination which is statistically identical (2.54 kg) to K_3S_0 (180 kg ha^{-1} MOP + 0 kg ha^{-1} Gypsum) treatment combination (Table 4).

4.7 Yield per hectare (ton)

Significant variation was found in yield per hectare due to the application of different levels of potassium (Appendix V). The highest yield per hectare (8.32 ton) was obtained from K_2 (160 kg ha^{-1} MOP) treatment, while the lowest yield per hectare (7.85 ton) was found from K_0 (control) treatment, which is statistically similar (8.07 ton) to K_3 (180 kg ha^{-1} MOP) treatment (Table 3). Islam *et al.* (2008) founded the highest yield of bulb with the application of potassium. Related results were also found by Saud *et al.* (2013)

The yield per plot varied significantly due to the application of different levels of sulphur (Appendix V). The highest yield per hectare (8.79 ton) was recorded from S_2 (150 kg ha^{-1} Gypsum) treatment and while the lowest yield per hectare (7.09 ton) was obtained from S_0 treatment (Table 3). Chattopadhyay *et al.* (2015) observed the highest yield of bulb with the application of sulpher. Related results were also found by Rashid (2010).

Significant variation was found at the time of harvesting due to the application of potassium and sulphur on yield per hectare (Appendix V). However the highest yield per hectare (9.10 ton) was recorded from K_2S_2 (160 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the lowest yield per hectare (6.98 ton) was found from K_0S_0 (control) treatment combination which is statistically identical (7.05 ton) to K_3S_0 (180 kg ha^{-1} MOP + 0 kg ha^{-1} Gypsum) treatment combination (Table 4). Islam *et al.* (2007) observed that the highest Yield of bulb with the application of sulpher and potassium. Dharmesh and Harendra (2012) also recorded the highest Yield of bulb with the combine application of sulpher and potassium.

4.8 Chemical analysis of bulb and leaf samples of onion

The samples were oven dried at 70^0C for 72 hour in agricultural chemistry lab of Sher-e-Bangla agricultural university. Dried plant materials were ground and processed for determination of Na, P, K, S and N content in onion bulb and leaf sample.

4.8.1 Sodium (Na) content in bulb (mg/kg)

Significant variation was found in Na content (mg/kg) in bulb sample due to the application of different levels of potassium (Appendix VI). The highest Na content in bulb sample (24.36 mg/kg) was obtained from K_2 (160 kg ha^{-1} MOP) treatment, while the lowest Na content in bulb sample (14.35 mg) was found from K_0 (control) treatment (Table 5).

The Na content (mg/kg) in bulb sample varied significantly due to the application of different levels of sulphur (Appendix VI). The highest Na content in bulb sample (21.47 mg/kg) was recorded from S_3 (170 kg ha^{-1} Gypsum) treatment which is statistically identical (20.73 mg/kg) to S_2 (150 kg ha^{-1} Gypsum) and while the lowest

Table 5. Effects of potassium and sulphur on sodium and phosphorus content of onion bulb and leaf

Treatments	Na Content in Bulb (mg/kg)	Na Content in Leaf (mg/kg)	P Content in Bulb (mg/kg)	P Content in Leaf (mg/kg)
K_1	14.35 c	36.30 b	28.80 b	7.36 c
K_2	18.59 b	43.40 a	30.66 ab	7.64 b
K_3	24.36 a	43.62 a	32.48 a	8.34 a
$LSD_{0.05}$	**1.14**	**3.29**	**2.80**	**0.13**
CV%	**7.11**	**9.45**	**10.81**	**6.36**
S_0	16.06 c	32.41 c	29.23 b	7.30 c
S_1	18.14 b	41.48 b	30.24 ab	7.73 b
S_2	20.73 a	44.01 a	31.84 a	8.08 a
S_3	21.47 a	45.54 a	31.27 ab	8.02 a
$LSD_{0.05}$	**1.32**	**3.79**	**2.39**	**0.15**
CV%	**7.11**	**9.45**	**10.81**	**6.36**

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

K_1 : 140 kg ha^{-1} MOP K_3 : 180 kg ha^{-1} MOP S_0 : Control (No Gypsum) S_2 : 150 kg ha^{-1} Gypsum

K_2 : 160 kg ha^{-1} MOP S_1 : 130 kg ha^{-1} Gypsum S_3 : 170 kg ha^{-1} Gypsum

Table 6. Combined effects of potassium and sulphur on sodium and phosphorus content of onion bulb and leaf

Treatments	Na Content in Bulb (mg/kg)	Na Content in Leaf (mg/kg)	P Content in Bulb (mg/kg)	P Content in Leaf (mg/kg)
K_1S_0	11.90 f	20.51 f	27.31 d	7.18 f
K_1S_1	14.58 e	40.65 cd	32.22 a-d	7.31 d-f
K_1S_2	14.58 e	40.65 cd	34.11 ab	7.45 de
K_1S_3	16.36 de	43.40 a-d	28.83 b-d	7.52 d
K_2S_0	15.47 de	35.15 e	27.87 cd	7.21 ef
K_2S_1	17.26 d	46.14 ab	34.31 ab	7.25 ef
K_2S_2	19.93 c	45.23 a-c	33.16 a-c	7.82 c
K_2S_3	21.71 bc	46.16 ab	34.76 a	9.07 a
K_3S_0	20.82 bc	41.56 b-d	28.10 cd	8.54 b
K_3S_1	22.60 b	39.74 de	28.17 cd	7.33 d-f
K_3S_2	27.68 a	47.08 a	28.27 cd	8.31 b
K_3S_3	26.34 a	47.06 a	30.66 a-d	8.43 b
$LSD_{0.05}$	**2.29**	**5.38**	**5.61**	**0.26**
CV%	**7.11**	**9.45**	**10.81**	**6.36**

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

K_1 : 140 kg ha^{-1} MOP K_3 : 180 kg ha^{-1} MOP S_0 : Control (No Gypsum) S_2 : 150 kg ha^{-1} Gypsum
K_2 : 160 kg ha^{-1} MOP S_1 : 130 kg ha^{-1} Gypsum S_3 : 170 kg ha^{-1} Gypsum

Na content in bulb sample (16.06 mg) was obtained from S_0 (control) treatment (Table 5). Significant variation was found Na content in bulb sample due to the application of potassium and sulphur (Appendix VI). However the highest Na content in bulb sample (27.68 mg/kg) was recorded from K_3S_2 (180 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) which is statistically identical (26.34 mg/kg) to K_3S_3 (180 kg ha^{-1} MOP + 170 kg ha^{-1} Gypsum) and the lowest Na content in bulb sample (11.90 mg/kg) was found from K_0S_0 (control) treatment combination (Table 6).

4.8.2 Sodium (Na) content in leaf (mg/kg)

Significant variation was found in Na content in leaf sample due to the application of different levels of potassium (Appendix VI). The highest Na content in leaf sample (43.62 mg/kg) was obtained from K_3 (180 kg ha^{-1} MOP) treatment which is statistically identical (43.40 mg/kg) to K_2 (160 kg ha^{-1} MOP) treatment, while the lowest Na content in leaf sample (36.30 mg/kg) was found from K_0 (control) treatment (Table 5).

The Na content in leaf sample varied significantly due to the application of different levels of sulphur (Appendix VI). The highest Na content in leaf sample (45.54 mg/kg) was recorded from S_3 (170 kg ha^{-1} Gypsum) treatment which is statistically identical (44.01 mg/kg) to S_2 (150 kg ha^{-1} Gypsum) and while the lowest Na content in leaf sample (32.41 mg/kg) was obtained from S_0 (control) treatment (Table 5).

Significant variation was found Na content in leaf sample due to the application of potassium and sulphur (Appendix VI). However the highest Na content in leaf sample (47.08 mg/kg) was recorded from K_3S_2 (180 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) which is statistically identical (47.06 mg/kg) to K_3S_3 (180 kg ha^{-1} MOP + 170 kg ha^{-1} Gypsum) and the lowest Na content in leaf sample (20.51 mg/kg) was found from K_0S_0 (control) treatment combination (Table 6).

4.8.3 Phosphorus (P) content in bulb (mg/kg)

Significant variation was found in P content in bulb sample due to the application of different levels of potassium (Appendix VI). The highest P content in bulb sample (32.48 mg/kg) was obtained from K_3 (180 kg ha^{-1} MOP) treatment while the lowest P content in bulb sample (28.80 mg/kg) was found from K_0 (control) treatment (Table 5). Awatef *et al.* (2015) observed that the highest Phosphorus (P) content of bulb with the application of potassium. Related results were found by Pradhan *et al.* (2015).

The P content in bulb sample varied significantly due to the application of different levels of sulphur (Appendix VI). The highest P content in bulb sample (31.84 mg/kg) was recorded from S_2 (150 kg ha^{-1} Gypsum) treatment while the lowest P content in bulb sample (29.23 mg/kg) was obtained from S_0 (control) treatment (Table 5). Dharmesh and Harendra observed the highest Phosphorus (P) content of bulb with the application of potassium and Sulpher.

Significant variation was found P content in bulb sample due to the application of potassium and sulphur (Appendix VI). However the highest P content in bulb sample (36.76 mg/kg) was recorded from K_2S_3 (160 kg ha^{-1} MOP + 170 kg ha^{-1} Gypsum) and the lowest P content in bulb sample (27.31 mg/kg) was found from K_0S_0 (control) treatment combination (Table 6).

4.8.4 Phosphorus (P) content in leaf (mg/kg)

Significant variation was found in P content in leaf sample due to the application of different levels of potassium (Appendix VI). The highest P content in leaf sample (8.34 mg/kg) was obtained from K_3 (180 kg ha^{-1} MOP) treatment while the lowest P content in leaf sample (7.36 mg/kg) was found from K_0 (control) treatment (Table 5).

The P content in leaf sample varied significantly due to the application of different levels of sulphur (Appendix VI). The highest P content in leaf sample (8.08 mg/kg) was recorded from S_2 (150 kg ha^{-1} Gypsum) treatment which is statistically identical (8.02 mg/kg) to S_3 (170 kg ha^{-1} Gypsum) and while the lowest P content in leaf sample (7.30 mg/kg) was obtained from S_0 (control) treatment (Table 5).

Significant variation was found P content in leaf sample due to the application of potassium and sulphur (Appendix VI). However the highest P content in leaf sample 9.07 mg/kg) was recorded from K_2S_3 (160 kg ha^{-1} MOP + 170 kg ha^{-1} Gypsum) and the lowest P content in leaf sample (7.18 mg/kg) was found from K_0S_0 (control) treatment combination (Table 6).

4.8.5 Potassium (K) content in bulb (mg/kg)

Significant variation was found in K content in bulb sample due to the application of different levels of potassium (Appendix VII). The highest K content in bulb sample (49.35 mg/kg) was obtained from K_3 (180 kg ha^{-1} MOP) treatment while the lowest K content in bulb sample (36.70 mg/kg) was found from K_0 (control) treatment (Table 7). Awatef *et al.* (2015) observed the highest Potassium (K) content of bulb with the application of potassium. Related results were also supported by Pradhan *et al.* (2015)

The K content in bulb sample varied significantly due to the application of different levels of sulphur (Appendix VII). The highest K content in bulb sample (45.52 mg/kg) was recorded from S_2 (150 kg ha^{-1} Gypsum) which is statistically identical to S_1 and S_2 treatment while the lowest K content in bulb sample (35.75 mg/kg) was obtained from S_0 (control) treatment (Table 7). Dharmesh and Harendra (2012) found the highest Potassium (K) content of bulb with the application of potassium and sulpher.

Significant variation was found K content in bulb sample due to the application of potassium and sulphur (Appendix VII). However the highest K content in bulb sample (53.93 mg/kg) was recorded from K_3S_2 (180 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the lowest K content in bulb sample (30.21 mg/kg) was found from K_0S_0 (control) treatment combination (Table 8).

4.8.6 Potassium (K) content in leaf (mg/kg)

Significant variation was found in K content in leaf sample due to the application of different levels of potassium (Appendix VII). The highest K content in leaf sample (52.49 mg/kg) was obtained from K_3 (180 kg ha^{-1} MOP) treatment while the lowest K content in leaf sample (36.26 mg/kg) was found from K_0 (control) treatment (Table 7).

The K content in leaf sample varied significantly due to the application of different levels of sulphur (Appendix VII). The highest K content in leaf sample (47.65 mg/kg) was recorded from S_2 (150 kg ha^{-1} Gypsum) treatment which is statistically identical to S_3 (170 kg ha^{-1} Gypsum) and S_1 (130 kg ha^{-1} Gypsum) and while the lowest K content in leaf sample (40.96 mg/kg) was obtained from S_0 (control) treatment (Table 7).

Significant variation was found K content in leaf sample due to the application of potassium and sulphur (Appendix VII). However the highest K content in leaf sample 54.04 mg/kg) was recorded from K_3S_2 (180 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the lowest K content in leaf sample (34.55 mg/kg) was found from K_0S_0 (control) treatment combination (Table 8).

4.8.7 Sulphur (S) content in bulb (mg/kg)

Significant variation was found in S content in bulb sample due to the application of different levels of potassium (Appendix VII). The highest S content in bulb sample (104.80 mg/kg) was obtained from K_3 (180 kg ha^{-1} MOP) treatment while the lowest S content in bulb sample (77.27 mg/kg) was found from K_0 (control) treatment (Table 7).

The S content in bulb sample varied significantly due to the application of different levels of sulphur (Appendix VII). The highest S content in bulb sample (114.4 mg/kg) was recorded from S_3 (170 kg ha^{-1} Gypsum) which is statistically identical (104.10 mg/kg) to S_2 (150 kg ha^{-1} Gypsum) treatment while the lowest S content in bulb sample (71.23 mg/kg) was obtained from S_0 (control) treatment (Table 7). Hasan *et al.* (2013) observed that the application of sulpher increase the Sulphur content of bulb. Same types of results were found by Pradhan *et al.* (2015).

Significant variation was found S content in bulb sample due to the application of potassium and sulphur (Appendix VII). However the highest S content in bulb sample (121.40 mg/kg) was recorded from K_2S_3 (160 kg ha^{-1} MOP + 170 kg ha^{-1} Gypsum) and the lowest S content in bulb sample (53.30 mg/kg) was found from K_0S_0 (control) treatment combination (Table 8). Dharmesh and Harendra (2012) founded that application of sulpher and potassium also increases the Sulphur content of bulb.

Table 7. Effects of potassium and sulphur on potassium and sulphur content of onion bulb and leaf

Treatments	K Content in Bulb (mg/kg)	K Content in Leaf (mg/kg)	S Content in Bulb (mg/kg)	S Content in Leaf (mg/kg)
K_1	36.70 c	36.26 c	77.27 b	76.26 b
K_2	41.97 b	47.75 b	93.01 a	87.73 b
K_3	49.35 a	52.49 a	104.80 a	104.60 a
$LSD_{0.05}$	**2.231**	**2.49**	**11.88**	**12.63**
CV%	**6.17**	**6.48**	**15.30**	**16.66**
S_0	35.75 b	40.96 b	71.23 c	71.05 c
S_1	44.65 a	45.98 a	77.02 c	78.73 bc
S_2	44.77 a	47.65 a	102.10 b	92.62 b
S_3	45.52 a	47.42 a	114.40 a	115.80 a
$LSD_{0.05}$	**2.57**	**2.88**	**11.72**	**14.58**
CV%	**6.17**	**6.48**	**15.30**	**16.66**

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

K_1 : 140 kg ha^{-1} MOP K_3 : 180 kg ha^{-1} MOP
K_2 : 160 kg ha^{-1} MOP

S_0 : Control (No Gypsum) S_2 : 150 kg ha^{-1} Gypsum
S_1 : 130 kg ha^{-1} Gypsum S_3 : 170 kg ha^{-1} Gypsum

Table 8. Combined effects of potassium and sulphur on potassium and sulphur content of onion bulb and leaf

Treatments	K Content in Bulb (mg/kg)	K Content in Leaf (mg/kg)	S Content in Bulb (mg/kg)	S Content in Leaf (mg/kg)
K_1S_0	30.21 e	34.55 e	53.30 d	50.72 d
K_1S_1	39.55 d	36.23 de	72.29 cd	65.66 cd
K_1S_2	39.92 d	36.81 de	75.40 cd	69.27 c
K_1S_3	37.12 d	37.45 d	108.10 ab	109.4 ab
K_2S_0	36.37 d	37.57 d	73.06 cd	63.88 cd
K_2S_1	45.15 c	50.17 c	76.26 cd	68.77 c
K_2S_2	40.48 d	52.11 abc	110.30 ab	98.99 b
K_2S_3	45.90 c	51.15 bc	121.40 a	119.3 a
K_3S_0	40.67 d	50.76 c	94.32 bc	98.54 b
K_3S_1	49.26 bc	51.52 abc	95.50 bc	101.8 ab
K_3S_2	53.93 a	54.04 a	115.40 ab	109.6 ab
K_3S_3	53.55 ab	53.65 ab	113.80 ab	108.6 ab
$LSD_{0.05}$	**4.461**	**2.597**	**23.76**	**17.76**
CV%	**6.17**	**6.48**	**15.30**	**16.66**

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

K_1 : 140 kg ha^{-1} MOP K_3 : 180 kg ha^{-1} MOP S_0 : Control (No Gypsum) S_2 : 150 kg ha^{-1} Gypsum

K_2 : 160 kg ha^{-1} MOP S_1 : 130 kg ha^{-1} Gypsum S_3 : 170 kg ha^{-1} Gypsum

4.8.8 Sulphur (S) content in leaf (mg/kg)

Significant variation was found in S content in leaf sample due to the application of different levels of potassium (Appendix VII). The highest S content in leaf sample (104.60 mg/kg) was obtained from K_3 (180 kg ha^{-1} MOP) treatment while the lowest S content in leaf sample (76.26 mg/kg) was found from K_0 (control) treatment (Table 7).

The S content in leaf sample varied significantly due to the application of different levels of sulphur (Appendix VII). The highest S content in leaf sample (115.80 mg/kg) was recorded from S_3 (170 kg ha^{-1} Gypsum) treatment while the lowest S content in leaf sample (71.05 mg/kg) was obtained from S_0 (control) treatment (Table 7).

Significant variation was found S content in leaf sample due to the application of potassium and sulphur (Appendix VII). However the highest S content in leaf sample 119.30 mg/kg) was recorded from K_2S_3 (160 kg ha^{-1} MOP + 170 kg ha^{-1} Gypsum) and the lowest S content in leaf sample (50.72 mg/kg) was found from K_0S_0 (control) treatment combination (Table 8). Luiz *et al.* (2015) application of sulpher and potassium increases the Sulphur content of leaf.

4.8.9 Nitrogen (N) Content in bulb (mg/kg)

Significant variation was found in N content in bulb sample due to the application of different levels of potassium (Appendix VIII). The highest N content in bulb sample (0.95 mg/kg) was obtained from K_3 (180 kg ha^{-1} MOP) treatment while the lowest N content in bulb sample (0.78 mg/kg) was found from K_0 (control) treatment (Table 9). Islam *et al.* (2010) observed that the highest Nitrogen (N) content of bulb with the application of potassium.

The N content in bulb sample varied significantly due to the application of different levels of sulphur (Appendix VIII). The highest N content in bulb sample (0.96 mg/kg) was recorded from S_3 (170 kg ha^{-1} Gypsum) which is statistically identical (0.92 mg/kg) to S_2 (150 kg ha^{-1} Gypsum) treatment while the lowest N content in bulb sample (0.77 mg/kg) was obtained from S_0 (control) treatment (Table 9). Awatef *et al.* (2015) also agreed with the results that highest number of Nitrogen (N) content of bulb with the application of sulpher.

Table 9. Effects of potassium and sulphur on nitrogen content of onion bulb and leaf

Treatments	N Content in Bulb (mg/kg)	N Contentin Leaf (mg/kg)
K_1	0.78 c	0.73 c
K_2	0.91 b	0.86 b
K_3	0.95 a	0.90 a
$LSD_{0.05}$	**0.031**	**0.037**
CV%	**4.96**	**5.24**
S_0	0.77 c	0.72 c
S_1	0.86 b	0.81 b
S_2	0.92 a	0.88 a
S_3	0.96 a	0.91 a
$LSD_{0.05}$	**0.043**	**0.043**
CV%	**4.96**	**5.24**

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

K_1: 140 kg ha^{-1} MOP K_3: 180 kg ha^{-1} MOP S_0: Control (No Gypsum) S_2: 150 kg ha^{-1} Gypsum

K_2: 160 kg ha^{-1} MOP S_1: 130 kg ha^{-1} Gypsum S_3: 170 kg ha^{-1} Gypsum

Table 10. Combined effects of potassium and sulphur on nitrogen content of onion bulb and leaf

Treatments	N Content in Bulb (mg/kg)	N Content in Leaf (mg/kg)
K_1S_0	0.63 g	0.58 g
K_1S_1	0.76 f	0.71 f
K_1S_2	0.86 e	0.81 e
K_1S_3	0.85 e	0.80 e
K_2S_0	0.81 ef	0.76 ef
K_2S_1	0.87 de	0.82 de
K_2S_2	0.94 cd	0.89 cd
K_2S_3	1.02 ab	0.97 ab
K_3S_0	0.87 de	0.82 de
K_3S_1	0.94 bcd	0.89 bcd
K_3S_2	1.02 a	0.97 a
K_3S_3	0.97 abc	0.93 abc
$LSD_{0.05}$	**0.075**	**0.075**
CV%	**4.96**	**5.24**

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

K_1 : 140 kg ha^{-1} MOP　K_3 : 180 kg ha^{-1} MOP　S_0 : Control (No Gypsum)　S_2 : 150 kg ha^{-1} Gypsum

K_2 : 160 kg ha^{-1} MOP　S_1 : 130 kg ha^{-1} Gypsum　S_3 : 170 kg ha^{-1} Gypsum

Significant variation was found N content in bulb sample due to the application of potassium and sulphur (Appendix VIII). However the highest N content in bulb sample (1.02 mg/kg) was recorded from K_3S_2 (180 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the lowest N content in bulb sample (0.63 mg/kg) was found from K_0S_0 (control) treatment combination (Table 10). Dharmesh and Harendra (2012) recorded the highest Nitrogen (N) content of bulb with the application of potassium and sulpher.

4.8.10 Nitrogen (N) Content in leaf (mg/kg)

Significant variation was found in N content in leaf sample due to the application of different levels of potassium (Appendix VIII). The highest N content in leaf sample (0.90 mg/kg) was obtained from K_3 (180 kg ha^{-1} MOP) treatment while the lowest N content in leaf sample (0.73 mg/kg) was found from K_0 (control) treatment (Table 9).

The N content in leaf sample varied significantly due to the application of different levels of sulphur (Appendix VIII). The highest N content in leaf sample (0.91 mg/kg) was recorded from S_3 (170 kg ha^{-1} Gypsum) treatment which is statistically identical (0.88 mg/kg) to S_2 (150 kg ha^{-1} Gypsum) treatment while the lowest N content in leaf sample (0.72 mg/kg) was obtained from S_0 (control) treatment (Table 9). Luiz *et al.* (2015) found that the highest Nitrogen (N) content of leaf with the application of sulpher.

Significant variation was found N content in leaf sample due to the application of potassium and sulphur (Appendix VIII). However the highest N content in leaf sample (0.97 mg/kg) was recorded from K_3S_2 (180 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum) and the lowest N content in leaf sample (0.58 mg/kg) was found from K_0S_0 (control) treatment combination (Table 10).

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Agronomy Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2014 to April 2015 to find out the effect of different levels of potassium and sulphur on the growth, yield and mineral content of onion. The experiment consisted of two factors: Factor A: Three levels of potassium. The treatments are K_1: 140 kg ha^{-1} MOP, K_2: 160 kg ha^{-1} MOP, K_3: 180 kg ha^{-1} MOP. Factor B: Four levels of sulphur. The treatments are S_0: Control (No Gypsum); S_1: 130 kg ha^{-1} Gypsum; S_2: 150 kg ha^{-1} Gypsum and S_3: 170 kg ha^{-1} Gypsum. There were 12 treatment combinations. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth and yield contributing characters and yield were recorded to find out the optimum level of potassium and sulphur of onion production.

In case of single effect of potassium, at 60 days after transplanting the tallest plant height (34.87 cm), maximum number of leaves per plant (6.55), maximum bulb weight (17.33 g), maximum leaf weight (0.69 g), maximum bulb diameter (3.41 cm), maximum yield per plot (2.99 kg), maximum yield per hectare (8.07 ton) were recorded from K_2 treatment that is 160 kg ha^{-1} MOP. Again maximum Na content in bulb (24.36 mg), maximum Na content in leaf (43.40 mg), maximum P content in bulb (32.48 mg), maximum P content in leaf (8.34 mg), maximum K content in bulb (49.35 mg), maximum K content in leaf (52.49 mg), maximum S content in bulb (104.80 mg), maximum S content in leaf (104.60 mg), maximum N content in bulb (0.95 mg), maximum N content in leaf (0.90 mg) were recorded from K_3 treatment that is 180 kg ha^{-1} MOP. The shortest plant height (32.12 cm), minimum number of leaves per plant (5.61), minimum bulb weight (14.36 g), minimum leaf weight (0.55 g), minimum bulb diameter (3.06 cm), minimum yield per plot (2.82 kg), minimum yield per hectare (7.85 ton), minimum Na content in bulb (14.35 mg), minimum Na content in leaf (36.30 mg), minimum P content in bulb (28.80 mg), minimum P content in leaf (7.36 mg), minimum K content in bulb (36.70 mg), minimum K content in leaf (36.26 mg), minimum S content in bulb (77.27 mg), minimum S content in leaf (76.26 mg), minimum N content in bulb (0.78 mg), minimum N content in leaf (0.73 mg) were recorded from K_0 treatment that is control.

In case of single effect of sulphur, at 60 days after transplanting the longest plant height (35.61 cm), maximum number of leaves per plant (6.61), maximum bulb weight (17.62 g), maximum leaf weight (0.80 g), maximum bulb diameter (3.58 cm), maximum yield per plot (3.16 kg), maximum yield per hectare (8.79 ton) were recorded from S_2 treatment that is 150 kg ha^{-1} Gypsum. Again maximum Na content in bulb (21.47 mg), maximum Na content in leaf (45.54 mg), maximum K content in bulb (45.52 mg), maximum K content in leaf (47.65 mg), maximum S content in bulb (114.40 mg), maximum S content in leaf (115.80 mg), maximum N content in bulb (0.96 mg), maximum N content in leaf (0.91 mg) were recorded from S_3 treatment that is 170 kg ha^{-1} Gypsum but maximum P content in bulb (31.27 mg), maximum P content in leaf (8.02 mg) were obtained from S_2 treatment that is 150 kg ha^{-1} Gypsum. The shortest plant height (31.47 cm), minimum number of leaves per plant (5.61), minimum bulb weight (11.62 g), minimum leaf weight (0.48 g), minimum bulb diameter (2.82 cm), minimum yield per plot (2.55 kg), minimum yield per hectare (7.09 ton), minimum Na content in bulb (16.06 mg), minimum Na content in leaf (32.41 mg), minimum P content in bulb (29.23 mg), minimum P content in leaf (7.30 mg), minimum K content in bulb (35.75 mg), minimum K content in leaf (40.96 mg), minimum S content in bulb (71.23 mg), minimum S content in leaf (71.05 mg), minimum N content in bulb (0.77 mg), minimum N content in leaf (0.72 mg) were recorded from K_0 treatment that is control.

In case of combined effect of potassium and sulphur, at 60 days after transplanting the tallest plant height (40.07 cm), maximum number of leaves per plant (7.61), maximum bulb weight (20.74 g), maximum leaf weight (0.95 g), maximum bulb diameter (3.91 cm), maximum yield per plot (3.27 kg), maximum yield per hectare (9.10 ton) were recorded from K_2S_2 treatment combination that is 180 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum. Again maximum Na content in bulb (27.68 mg), maximum Na content in leaf (47.08 mg), maximum K content in bulb (53.93 mg), maximum K content in leaf

(54.04 mg), maximum N content in bulb (1.02 mg), maximum N content in leaf (0.97 mg) were recorded from K_3S_2 treatment combination that is 180 kg ha^{-1} MOP + 150 kg ha^{-1} Gypsum and maximum P content in bulb (34.76 mg), maximum P content in leaf (9.07 mg), maximum S content in bulb (121.40 mg), maximum S content in leaf (119.3 mg) were obtained from K_2S_3 treatment combination that is 160 kg ha^{-1} MOP + 170 kg ha^{-1} Gypsum. The shortest plant height (29.73 cm), minimum number of leaves per plant (5.44), minimum bulb weight (10.49 g), minimum leaf weight (0.45 g), minimum bulb diameter (2.71 cm), minimum yield per plot (2.51 kg), minimum yield per hectare (6.98 kg), minimum Na content in bulb (11.90 mg), minimum Na content in leaf (20.51 mg), minimum P content in bulb (27.31 mg), minimum P content in leaf (7.18 mg), minimum K content in bulb (30.21 mg), minimum K content in leaf (34.55 mg), minimum S content in bulb (53.30 mg), minimum S content in leaf (50.72 mg), minimum N content in bulb (0.78 mg), minimum N content in leaf (0.73 mg) were recorded from K_0S_0 treatment combination that is control.

Conclusion

Based on the result of the present study it was found that application of 160 kg ha^{-1} MOP and 150 kg ha^{-1} gypsum (K_2S_2) treatment combination performed the highest yield (9.10 t ha^{-1}) for onion production. For the mineral like sodium (Na), potassium (P) and nitrogen (N) content in onion bulb and leaf, 180 kg ha^{-1} MOP and 150 kg ha^{-1} gypsum (K_3S_2) had the highest effect. On the other hand 160 kg ha^{-1} MOP and 170 kg ha^{-1} gypsum (K_2S_3) gives the highest result for phosphorus (P) and sulphur (S) content in both bulb and leaf sample of onion.

Recommendation

In this experiment onion yield and yield contributing characters were the highest under the application of potassium and sulphur up to a certain levels. If more potassium is applied then yield reduced but mineral content like sodium (Na), potassium (K) and nitrogen (N) were increased. On the other hand phosphorus (P) and sulphur (S) were decreased. So, further research is needed for justification of the present study.

Chapter VI

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CHAPTER VI

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Appendices

APPENDICES

Appendix I. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from October 2014 to April 2015

Month	Air temperature (^0C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
October ,14	29.18	18.26	81	39
November,14	25.82	16.04	78	0
December,14	22.4	13.5	74	0
January,15	24.5	12.4	68	0
February ,15	27.1	16.7	67	3
March ,15	31.4	19.6	54	11
April , 15	35.3	22.4	51	15

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka

Appendix II. Results of morphological, mechanical and chemical analysis of soil of the experimental plot

A. Morphological Characteristics

Morphological features	Characteristics
Location	Research Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow redbrown terrace soil
Land Type	Medium high land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood Level	Above flood level
Drainage	Well drained

B. Mechanical analysis

Constituents	Percentage (%)
Sand	27
Silt	43
Clay	30

C. Chemical analysis

Soil properties	Amount
Soil pH	5.8
Organic carbon (%)	0.45
Total nitrogen (%)	0.03
Available P (ppm)	20
Exchangeable K (%)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix-III. Analysis of variance of data on plant height at different DAT of onion plant

Source of variation	Degrees of freedom (df)	Mean square of plant height at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	42.115	41.436	67.059	85.695	102.063
Factor A (Potassium)	2	33.139**	33.064**	36.950**	18.254*	26.490*
Factor B (Sulphur)	3	75.545**	49.222**	40.369**	37.999**	31.992*
Interaction (A X B)	6	3.416*	3.824*	12.098*	7.866*	11.986*
Error	22	7.351	9.900	8.239	11.136	12.585

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-IV. Analysis of variance of data on number of leaves per plant at different DAT of onion plant

Source of variation	Degrees of freedom (df)	Mean square of number of leaves at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	0.760	3.523	5.704	14.741	17.824
Factor A (Potassium)	2	0.263*	0.093*	0.033*	0.080*	0.583*
Factor B (Sulphur)	3	1.488**	0.604*	1.027*	1.688*	2.612*
Interaction (A X B)	6	0.163*	0.544*	0.222*	0.757*	0.897*
Error	22	0.265	0.482	0.600	1.055	1.003

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-V. Analysis of variance of data on different yield characteristics of onion plant

Source of variation	Degrees of freedom (df)	Mean square of				
		Bulb weight (g)	Leaf weight (g)	Bulb diameter	Yield per plot (kg)	Yield per hectare (ton)
Replication	2	25.023	0.032	0.208	0.081	0.626
Factor A (Potassium)	2	3.162*	0.065**	0.060**	0.089*	0.688*
Factor B (Sulphur)	3	60.791**	0.129**	0.913**	0.601**	4.637**
Interaction (A X B)	6	11.732*	0.031*	0.126*	0.020*	0.154*
Error	22	6.515	0.020	0.073	0.073	0.563

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-VI. Analysis of variance of data on sodium and phosphorus content of onion bulb and leaf

Source of variation	Degrees of freedom (df)	Mean square of			
		Na content in Bulb (mg)	Na content in leaf (mg)	P content in Bulb (mg)	P content in leaf (mg)
Replication	2	16.000	36.000	16.000	36.00
Factor A (Potassium)	2	302.699**	208.157**	40.630**	3.031**
Factor B (Sulphur)	3	55.266**	316.764**	11.958*	1.156**
Interaction (A X B)	6	4.271*	75.268**	26.266*	0.665*
Error	22	1.842	15.102	10.979	0.245

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-VII. Analysis of variance of data on potassium and sulphur content of onion bulb and leaf

Source of variation	Degrees of freedom (df)	Mean square of			
		K Content in Bulb (mg)	K Content in leaf (mg)	S Content in Bulb (mg)	S Content in leaf (mg)
Replication	2	16.000	36.000	29.788	0.867
Factor A (Potassium)	2	484.804**	835.963**	2284.339**	2444.279**
Factor B (Sulphur)	3	193.296**	87.462**	3912.310**	3466.598**
Interaction (A X B)	6	20.364**	32.468**	624.789**	671.343**
Error	22	6.941	8.692	196.876	222.517

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-VIII. Analysis of variance of data on nitrogen content of onion bulb and leaf

Source of variation	Degrees of freedom (df)	Mean square of	
		N Content in Bulb (mg)	N Content in leaf (mg)
Replication	2	0.002	0.002
Factor A (Potassium)	2	0.101**	0.101**
Factor B (Sulphur)	3	0.063**	0.063**
Interaction (A X B)	6	0.003*	0.003*
Error	22	0.002	0.002

** : Significant at 1% level of probability; * : Significant at 5% level of probability