INFLUENCE OF DIFFERENT LEVELS OF POTASH AND SULFUR ON GROWTH, YIELD, STORAGE LIFE AND NUTRINTS CONTENT OF BARI PIAZ-6

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CERTIFICATE

This is to certify that the thesis entitled **"Influence of Different Levels of Potash and Sulfur on Growth, Yield, Storage Life and Nutrients Content of BARI Piaz-6"** submitted to the Department of Agricultural Chemistry, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **AGRICULTURAL CHEMISTRY**, embodies the result of a piece of bonafide research work carried out by **MD. MAHMUDUL HASAN MANIK**, **Registration No. 15-06707** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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Dedicated to
My
Beloved Parents and
Elder Brothers

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The Author

Influence of Different Levels of Potash and Sulfur on Growth, Yield, Storage Life and Nutrients Content of BARI Piaz-6

ABSTRACT

An experiment was undertaken at the farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during October 2020 to June 2021 to evaluate the influence of different levels (100, 120, 140 and 160 kg K ha^{-1}) of potash and sulfur (5, 15, 25, and 35 kg S ha^{-1}) on growth, yield, storage life and nutrients content of BARI Piaz-6 in Randomized Complete Block Design **(**RCBD) having two factors with three replications. There was no significant difference among the doses of sulfur in the plant height, neck diameter, dry foliage weight $plant^{-1}$ and the percent of weight loss at 1, 2 and 3 months interval with respect to weight of bulb at harvest of BARI Piaz-6. But significant difference was observed in the leaf number, leaf length, bulb diameter, bulb height, individual bulb weight, bulb yield, the concentration of N, P, K and S in bulb of BARI Piaz-6 due to different doses of S. In case the effect of different doses of potassium showed significant variation in the above all parameters of BARI Piaz-6, where the highest and lowest results were obtained at 140 and 100 kg ha^{-1} potassium doses, respectively except the percent weight loss at 1, 2 and 3 months interval with respect to weight of bulb at harvest. The interaction effects of different doses of S and K significantly influenced on all growth and yield data. The highest plant height, leaf number, leaf length, neck diameter, fresh foliage weight, dry foliage weight, bulb diameter, bulb height, individual bulb weight, bulb yield, and P, K, S concentration in bulb were observed at 140 kg ha^{-1} potassium with 35 kg ha^{-1} dose of sulfur and the lowest values of these parameter were found at the lowest doses of S (5 kg S ha^{-1}) and K (100 kg K ha^{-1}) combination. The interaction effect of sulfur and potassium doses significantly differed the percent weight losses with respect to weight of bulb at harvest during storage at 1, 2 and 3 months interval, where the highest weight loss was (11.36 %) and the lowest values of weight loss was 6.69% at 1 month interval. In case of 2 and 3 months interval, the highest weight losses (16.77 and 22.20 %) were found respectively.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Onion (*Allium cepa* L.) belonging to the family Alliaceae is one of the most important spice as well as vegetables crops in the world including Bangladesh. It is one of the most commercial vegetable cum spice crop called as queen of the Kitchen having chromosome number 2n=16 (Behera *et al*., 2022). Among the spices crops grown in Bangladesh onion ranks top in respect of production and second in respect of area (Barman *et al*., 2013). There are more than 500 species under the genus Allium; of these most of them are bulbous plants (Mishu *et al*., 2013). It has been cultivated for 5000 years or more and does not exist as wild species (Brewster, 1994) of the 15 vegetable and spice crops listed by FAO (Mishu *et al*., 2013).

Among all spice crops, onion has great significance for its diversified use. Onion is considered one of the most important vegetable as well as spice crops in the world for its high nutritional value and versatility (Ahmed *et al*., 2013), as it contains large amounts of vitamins, proteins, iron, and calcium. From medical importance, it contains quercetin, which is an anti-oxidant and anti-cancer (AL-Mohammad and AL-Taey, 2019). It contains vitamin-A, vitamin-C, iron and calcium. Onion also reduces blood sugar (Ren *et al*., 2016).

The leading onion growing countries of the world are the Netherlands, Korea, Israel, Japan, Turkey, Syria, Egypt, USA, Lebanon and India (FAO, 2020). In Bangladesh onion occupies an area of 458 thousand acres of land with total production of 1.95 million metric tons of bulb during the year of 2019-20 (BBS, 2020). In 2022, the Bangladesh Bureau of Statistics (BBS) recorded 2.3 million tons of onion production against a demand for 2.6 million tons (BBS, 2022). To meet this shortage, Bangladesh has to import onion every year at the cost of its hard earned foreign currency.

Onion production is greatly influenced by agronomic practices (Mondal *et al*., 1986). The demand for onion is increasing day by day with the increasing

population. This acute situation could be improved by bringing more land under cultivation or by increasing yield through introducing improved varieties or by adopting improved production technologies or by growing onion in other season i.e. during summer-rainy season. The hectare^{-1} yield of onion can be increased by efficient use of plant nutrients (Katwale and Saraf, 1994).

Among the crops, Onions need large amounts of nutrients during their growth period. Chemical fertilizers are one of the main factors that contribute to the growth and production of onions, as onion plants consume large quantities of the major elements nitrogen, phosphorous and potassium, which are among the major nutrients needed by the onion plant in large quantities, and a deficiency of any of them causes a decrease in the growth and yield of the plant (Ali *et al*., 2018).

Among the major nutrients, potassium is needed by the plant for growth and development during the life cycle of the plant. Mainly it participates in some of the vital interactions and physiological activities that occur inside the plant cells, such as the formation of proteins, respiration, photosynthesis, absorption and transfer of ions and resistance to pollution and its resistance to diseases as well as its role in increasing the characteristics of vegetative growth and yield and improving its quality (Bairwa *et al*., 2020). It is also considered as a quality element as it improves quality parameters of many crops including onion. Potassium improves color, glossiness and dry matter accumulation besides improving, it also keeping bulb quality of onion (Dorais *et al*., 2001). Potassium is also important role in respiration, energy storage, protein synthesis and assimilates translocation (Desuki *et al*., 2006). Potassium application also improved the post-harvest life of onion and some other horticultural commodities by reducing rotting, sprouting and weight loss during storage. Potassium is a major plant nutrient, which is needed by the plants in large amount and is supplied by the fertilizer. It is available to the plants in the form of cation (K^+). Actually potassium is essential for a variety of process i.e.

photosynthesis, fruit formation, winter hardiness and disease resistance. It stiffens straw and thus reduces lodging, and plays an important role in protein formation especially in grain filling. Moreover, all the root crops frequently respond to the potassium application (Behera *et al*., 2022).

The productivity and quality of crops can be enhanced by proper nutrient management. Onion is a sulphur loving plant and is required for proper growth and yield in onion (Kumar and Singh, 1995). Sulfur is one of the main elements for plant growth and is the fourth element after N, P and K. It is important for the formation of amino acids, proteins, oils, vitamins and some enzymes, and enters the composition of the protoplasm of cells (Al-Mohammadi *et al*., 2012). Sulfur plays a vital role in the biosynthesis of some amino acids as well as contributes to the formation of chlorophyll, and it is one of the necessary elements to encourage vegetative growth, increase yield and improve quality (AOAC, 1980). Sulphur has been recognized as an important nutrient for higher yield, quality of bulbs and building up sulphur containing aminoacids and also for a good vegetative growth. Sulphur has been found not only to increase the bulb yield but also improve its quality especially pungency and flavour (Jaggi and Dixit, 1999). Sulphur is a constituent of secondary compounds *viz*., alline, cycloalline and thio propanol which not only influence the taste, pungency and medicinal properties of onion besides inducing resistance against pests and diseases (Haris *et al*., 2021). Onion had been reported to required high amount of sulphur than other nutrients while less amount of sulphur whenever be advocated from the optimum doze, it may limits yield and its attributes at any stage of crop production (Mishu *et al*., 2013).

In Bangladesh, the demand of bulb onion is increasing day by day with the over increasing population. Proper nutrient management is urgently needed to increase onion bulb production. Potassium and sulfur are major nutrients which are widely used in onion production to obtain higher yield. Therefore, with

these facts in consideration, the present study was carried out to find the effect of potassium and sulphur on the bulb yield and plant growth parameters with the following objectives:

1. To observe the growth, yield, storage life and nutrient contents of BARI Piaz-6 under different levels of K and S ,
2. To find out the best dose of K and S for maximum yield , and
3. To determine N, P, K and S content in bulb.

CHPTER II

REVIEW OF LITERATURE

Onion (*Allium cepa* L.) is one of the most important vegetable and spices crops in Bangladesh as well as in the world. The response of onion to different potassium and sulfur levels for its successful cultivation has been studied by numerous investigators in various parts of the world. In Bangladesh, there have not enough studies on the influence of either potassium (K) or sulfur (S) application or both in combination on the growth and yield of onion. However, the available research findings in this connection over the world have been reviewed in this chapter under the following headings :

2.1 Effect of potassium

As the cultivable land area is limited in Bangladesh, it is not possible to extend the land under onion cultivation. So, emphasis must be given to increase the productivity of this crop on yield context, which can be made possible with the efficient use of fertilizers namely nitrogen, phosphorus, sulfur and potassium etc. Judicious application of fertilizers may enhance bulb yield significantly. Among the yield promoting factors, application of proper doses of potassium is of great importance. Potassium plays the most important role for the morpho-physiological development of the crop, which ultimately helps in increasing bulb size and total yield.

Al-Amri and Alabdaly (2021) carried out a field experiment to know the response of the local grown red onions to spraying with potassium and organic fertilization under different plant densities. The experiment included two factors, the first is a combination of organic fertilization (20 metric tons ha^{-1}) and spraying with potassium sulfate (0.5) g L^{-1} as follows: (T_0: recommended fertilizer dose and T_1: Cow's manure and T_2: recommended fertilizer amount + spraying with potassium and T_3: cow's manure + half of the number of fertilizers + potassium spray and T_4: Double the recommended amount of cow's

manure + half the amount of fertilizer recommended dose + spraying potassium. The second factor is Planting distances {(S_1: 10 × 10, S_2: 10 × 15 and S_3: 10 × 20) cm}. The results of the study indicated the clear effect of the study factors on the characteristics of vegetative growth, yield and onions' content of total soluble solids (TSS), as the treatment T_4S_3 excelled by giving it the highest content of dry matter and the highest leaf area, the highest percentage of potassium in the leaves and this was positively reflected done by giving the plants of this treatment the highest yield of the plant and reached (5.83 g, 15.26 dm^2 , 1.57% and 108.50 g) in sequence. Hence, reducing the cultivation distances between plants and their interaction with fertilization levels had a positive effect in improving the yield traits, as the T_4S_1 treatment achieved the highest yield for the experimental unit (10.03 kg), compared to T_1S_3-treated plants, which achieved the lowest yield for the experimental unit (4.733 kg).

EL-Desuki *et al*. (2021) carried out two field experiments 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 spraying or soil dressing up to 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.

Rani *et al*. (2020) conducted an on-farm trial to assess the effect of application of potash and spray of N: P:K (18:18:18) on yield, quality and bolting of onion. Farmers were previously applying DAP @ 110 kg ha^{-1} and urea 80 kg ha^{-1}. By

application of MOP @ 100 kg ha^{-1} along with DAP @ 110 kg ha^{-1} and urea 80 kg ha^{-1} gives higher yield and better quality bulb as compared to produce that are getting in control. Although spraying of N: P: K (18:18:18) also increased the yield and quality significantly.

Dilruba *et al.* (2019) conducted an experiment to investigate the effect of different levels of nitrogen and potassium on yield contributing bulb traits of onion cv BARI Piaz-1. All the bulb traits in the experiment were influenced significantly by the individual treatment of different doses of nitrogen and potassium except dry matter content for nitrogen and showed a positive linear relationship. In the experiment, fresh weight of bulb, bulb dry weight, bulb diameter and yield per plot gave almost two times higher performance (35.29 g, 3.21g, 3.98 cm and 1.68 kg, respectively) by the treatment of 100 kg N ha^{-1} than that of no nitrogen application (18.93 g, 1.48 g, 2.02 cm and 0.95 kg , respectively). The performance of the doses of potassium (0 kg K_2O ha^{-1} to 120 kg K_20 ha^{-1}) on bulb characters and yield of onion was less than that of nitrogen. There was no interaction between nitrogen and potassium in the influence of the expression of the characters. Among the combinations, the treatment 100 kg N with 120 kg K_2O ha^{-1} was found to be the best from overall considerations.

Kumara *et al*. (2018) carried out an investigation on "Effect of potassium levels, sources and time of application on yield parameters of onion var. Arka Kalyan". Potassium levels at 200 percent recommanded dose of potash significantly influenced the polar and equatorial diameter of bulb (53.80 and 60.63 mm, respectively), weight of single bulb (105.18 g), bulb yield (20.54 kg/plot and 48.91 t ha^{-1}) and was on par with 150 and 175 percent RDK. Among potassium sources, sulfate of potash (SOP) recorded maximum polar and equatorial diameter of bulb (52.09 and 59.80 mm, respectively) over muriate of potash (MOP) (51.25 and 58.50 mm, respectively). Among potassium sources, SOP recorded significantly higher weight of single bulb and

bulb yield per plot and per hectare (104.52 g, 20.03 kg/plot and 45.38 t ha^{-1} respectively) over MOP (99.96 g, 19.06 kg/plot and 45.38 t ha^{-1} respectively). Significantly higher polar and equatorial diameter of bulb with application of 50 per cent potassium at transplanting and 50 per cent at 30 DAT (51.96 and 59.64 mm, respectively) and was significantly superior over application of 100 per cent potassium at transplanting (51.33 and 58.64 mm, respectively). The weight of single bulb, bulb yield per plot and per hectare was recorded in application of 50 percent potassium at transplanting and 50 percent at 30 DAT (103.54 g, 19.87 kg and 47.31 t ha^{-1}) was significantly superior over application of 100 percent potassium at transplanting (100.94 g, 19.20 kg and 45.74 t ha^{-1}).

Bekele (2018) were undertaken field and laboratory experiments on the yield of Onion (*Allium cepa* L.) owing to several factors; absence of location specific fertilizer recommendation being the major among others. Potassium sulphate fertilizer as TSP was used at 0, 40, 80 and 120 kg ha^{-1} levels with three replications. From the results potassium fertilizer application at different levels showed significant effects on growth, yield and quality parameters i.e. plant height, leaf length, leaf number, sheath length, bolters percentage, days to maturity, harvest index, mean bulb weight, bulb length, bulb diameter, TSS (Brix), DMC (%) and bulb shape index. Similarly, keeping quality of the onion bulbs including bulb sprouts (%), weight loss (%), weeks to 50% bulb sprouts and storage rots (%) were highly influenced by application of K at different levels. Maximum (120 kg ha^{-1}) application of potassium significantly decreased bulb rots (%), bulb sprouts (%), weight loss (%) and prolonged weeks to 50% bulb sprout during the two month storage time at ambient storage temperature and humidity. This could be recommended for the uses by potential onion investors or farmers in the study area.

Fatematuzzohora *et al*. (2018) conducted an experiment to assess the effects of seedling age and potassium fertilizer to improve summer onion production (cv. BARI Piaz-3). The experiment consisted of two factors; Factor A: three

seedling age, *viz*. 35; 40 and 45 days old and Factor B: four different doses of potassium, *viz*. 0; 40; 80 and 120 kg/ha. The experiment was laid out in a randomized complete block design with three replications. The effect of different seedling age and potassium fertilizer and their combined effects showed significant variations in growth and yield of onion. In case of seedling age, the highest plant height (56.58 cm), leaf number (12.37) per plant, leaf length (41.77 cm), yield of bulb per plot (1.96 kg) and yield of bulb (19.64 t/ha) were recorded from 45 days old seedling. In case of different doses of potassium, the highest plant height (58.82 cm), leaf number per plant (13.93), leaf length (43.69 cm), yield of bulb per plot (1.90 kg) and yield of bulb (19.00 t/ha) were recorded from 120 kg K ha^{-1}. Combined effects of seedling age and potassium fertilizer exhibited significant variation on plant height at different days after transplant (DAT), leaf number per plant, leaf length, bulb diameter, pseudostem diameter, fresh weight of bulb, dry weight of bulbs, fresh weight of foliage, dry weight of foliage, yield of bulbs per plot and yield of bulbs (t/ha). The highest bulb yields per plot (2.31 kg) as well as per hectare (23.05 tons) were achieved from the treatment combination of 45 days old seedling and 120 kg K ha^{-1}.

Aftab *et al*. (2017) conducted a field experiment to study the effect of different levels of potassium on growth and yield of onion. Four levels of potassium i.e. 0, 60, 120 and 180 kg ha^{-1} were used as treatments in the experiment. It was observed that there was significant increase in growth and yield of onion in response to different levels of potassium. The results indicated that maximum average bulb weight (78.44 g), maximum bulb diameter (5.20 cm), and maximum yield (24.67 t ha^{-1}) was obtained from 120 kg potassium ha^{-1}) and the lowest was obtained with control. It may be concluded that the highest dose of potassium application is empirical proved 120 kg ha^{-1} which has significant effects on bulb diameter, bulb weight and yield of onion.

Behairy *et al.* (2015). carried out two field experiments to study the effect of different rates of potassium fertilization (0, 150 and 300 kg K_2O /fed.) as potassium sulfate in addition to foliar application by water (control), potassium thiosulfat (KTS) at (1 L/fed.) and potassium thiosulfat 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: (i) 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. (ii) Spraying onion plants with potassium thiosulfate at a rate of (2L/fed.) markedly increased vegetative growth, yield, bulb quality and bulb chemical composition. (iii) The favorable effects of the potassium on the growth, total yield and bulb parameters were obtained when onion plants fertilized with 300 kg K_2O/fed. as potassium sulfate plus high level of foliar application of potassium thiosulfate (2L/fed.).

Milanez-de-Resende and Costa (2014) carried out an experiment to evaluate yield and post-harvest conservation of Vale Ouro IPA-11 onion cultivar regarding to nitrogen and potassium levels. The experimental design was a completely randomized block in a 4 × 3 factorial design, composed of four nitrogen levels (0, 60, 120 and 180 kg ha^{-1}) and three potassium levels (0, 90 and 180 kg ha^{-1}) with three replications. The highest yield of commercial bulbs was achieved at an estimated N level of 172.6 kg ha^{-1}. The lowest yield of noncommercial bulbs was estimated at N level of 147.0 kg ha^{-1}. Lower percentage of smaller bulbs (class 2) were obtained by increasing levels of N x K, with a quadratic effect at the dose of 90 kg ha^{-1} K_2O and minimum production point with 127.6 kg N ha^{-1} (20.3%). Regarding larger caliber bulbs

(class 4), linear effects were found both in the absence and for the level *i.e* 90 kg ha^{-1} of K_2O as levels of N were increased. When the highest level of 180 kg ha^{-1} K_2O was applied, the level of 92.8 kg ha^{-1} of N was estimated as the one that would promote the highest bulb yield of this class (35.4%), and 5.3% was found in the lack of potassium fertilization.

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. The experiment was laid out in a randomized complete block design with three replications. 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); whereas the control treatment gave the shortest plant (38.15 cm), lowest number of leaves $plant^{-1}$ (5.68), diameter of bulb (3.41), individual weight of bulb (35.65g) and gave lowest bulb yield ha^{-1} (9.16 tons).

Timothy (2008) conducted an experiment to find out the effect of three levels of ammonium sulphate (0, 250 and 500 kg/ha) and calcium chloride (0, 115 and 230 kg/ha) on yield and mineral uptake of onion. The results revealed that the ammonium sulphate application increased the bulb yield, whereas calcium chloride treatment had no effect on yield of onion. Similarly, William *et al*. (2008) revealed that, ammonium sulphate could improve in bulb yield of onion.

Study conducted by Aisha and Taalab (2008) showed the response of onion to the different rates of potassium in the form of sulphate of potash. They revealed that the total bulbs yield per unit area and diameter and its average weight increased when potassium was supplemented in the form of sulphate of potash. However, application of different rates of potassium fertilizers (0, 100, 200 and

300 kg of potassium sulphate per fed) on onion productivity. The results indicated the enhanced yield of onion due to potassium fertilizer up to 300 kg/fed (Faten *et al*. 2010).

Boyhan *et al.* (2007) conducted studies to evaluate levels of nitrogen (N), phosphorus (P), and potassium (K) fertilizers and their effect on yield, graded yield, and leaf tissue nutrient status in short-day onions over 6 years. Potassium fertilizer rates from 0 to 177 kg ha^{-1} had a quadratic effect on total yield, with the highest yield of 52,361 kg ha^{-1} with 84 kg ha^{-1} K fertilizer rate. As would be expected, N and P fertilizer rates effected leaf tissue N and P levels, respectively. In addition, N fertilizer rates effected leaf tissue calcium (Ca) and sulfur levels. Potassium fertilizer rates had a significant linear effect on leaf tissue K_3 of 6 years. In addition, K fertilizer rates had a significant effect on leaf tissue P levels. Several fertilizers, including $Ca(NO_3)_2$ and NH_4NO_3, along with complete fertilizers and liquid fertilizers, were used as part of a complete fertilizer program and showed no differences for total yield or jumbo yield 4 of 5 years of evaluation when applied to supply the same amount of N fertilizer. Based on the results of this study, soil test P and K recommendations for onions in Georgia have been cut 25% to 50% across the range of soil test levels.

Desuki *et al*. (2006) studied the response of onion plants cv. Giza-20 to the various doses of potassium application *i.e*. 0, 50, 75, 100 kg potassium sulphate as soil dressing, in addition to the recommended dose of NPK fertilizers. Results indicated that total bulb yield as well as bulb quality were gradually increased with increasing quantity of sulphate of potash.

El-Bassiony (2006) showed that the effect of soil application of potassium sulfate (50, 100, 150 and 200 kg/Fed.) and foliar application of potassium oxide (1g/L). Obtained result indicated that the highest yield and bulb quality were observed due to soil application of 200 kg potassium sulfate/ha.

The experimental results indicated that the combined application of nitrogen and potassium at the rate of 120 kg per ha and 80 kg per ha respectively recorded higher yield of onion i.e. 99.8 q/ha. Increased in yield of aggregation onion was due to the optimum application of nitrogen and potassium fertilizers to onion (Dash *et al*., 2006).

2.2 Effect of potassium on nutrient uptake of crops

Nasreen *et al*. (2007) studied the uptake of nutrients were increased due to application of different levels of nitrogen (0, 80, 120, and from urea) and sulphur (0, 20, 40, and from gypsum) fertilization. The highest uptake of nitrogen and sulphur were recorded at higher levels of nitrogen and sulphur application 160 and 60 kg per ha, respectively in onion var., BARI Piaz-1.

Desuki *et al*. (2006) studied the response of onion plants cv. Giza-20 to the different dose of potassium in the form of potassium sulphate @ 0, 50, 75, 100 kg per ha. Results indicated that the highest nutrient uptake was recorded due to higher dose of sulphate of potassium. Whereas, Sagadraca (1988) reported that potassium content of the onion bulb and leaves were 1.2 and 4.39 percent, respectively due to application of different levels of potassium fertilizers.

Girigowda *et al*. (2005) revealed that uptake of N (182.72 kg ha^{-1}), P_2O_5 (32.5 kg ha^{-1}) and K_2O (157.45 kg ha^{-1}) were significantly higher due to application of (188:75:188 kg NPK ha^{-1}) over (125:50:125 kg NPK ha^{-1} with uptake value of N (133.89 kg ha^{-1}), P_2O_5 24.39 kg ha^{-1} and K_2O (115.61 kg ha^{-1}) in control.

Hariyappa (2003) showed that the potassium and sulphur content of leaf as well as bulb were higher due to application of increased levels of potassium at all the stages of crop growth. The higher uptake of nitrogen (161.47 kg/ha), phosphorus (20.26 kg/ha) and potash (100.76 kg/ha) was recorded when onion was nourished with 125 kg K_2O/ha as compared to control at harvest.

Geeta *et al*. (2000) reported that the application of Farm Yard Manure (FYM) @ 25 t ha^{-1} and potassium fertilizer @ 200 kg per ha in the form of MOP and

interaction effect of both increased the potassium content, potassium uptake by onion crop at harvest. The significance positive correlations were observed between uptake and status of different forms of potassium in the soil.

2.3 Effect of sulphur

From few previous decades, the application of sulphur combination to other fertilizers had taken an admirable position in the production as far as trade, quality and fertilizer use efficiency is concerned. Sulphur is secondary macro-nutrient which have positive effects on the family as well as various variety of onion and whose application leads to several effect on the soil as well as plant's physiology *viz*. reducing soil and plants pH, improving soil water plant relationship, availability of various nutrients such as phosphorous, iron, manganese and zinc etc.

Behera *et al*. (2022) concluded a field experiment to study the "sulphur application in onion for enlargement of bulb". The results indicate that the application of S @ 45 kg ha^{-1} gives early maturity (118 days) with higher bulb diameter both polar (5.16cm) and equatorial (5.63). Significantly recommended practice increases the yield *i.e.*, 216.76 q ha^{-1} compare to the farmers practice *i.e*. 196.23 q/ha. By investing Rs. 1,10,000/- cost of production in recommended practice, gives Rs. 2,14,540/- net return where as farmers practice gives Rs. 1,94,345/- net return. S application significantly increase the B:C ratio from 2.94 (FP) to 2.95 (RP). Hence, the Sulphur application @ 45 kg ha^{-1} may be recommended to the farmers for Onion cultivation to get better growth yield and bulb quality.

Tilahun *et al.* (2021) conducted a field experiment to evaluate the effect of nitrogen and sulfur fertilizers on the growth, yield, quality and nutrient uptake of onion. The experiment consisted of four nitrogen rates (100, 150, 200, and 250 kg N ha^{-1}) and five sulfur rates (0, 15, 30, 45, and 60 kg S ha^{-1}). Bombay Red was used as a testing onion variety. The interaction effect of nitrogen and

sulfur significantly increased plant height, leaf length, leaf diameter, leaf area index, neck diameter, shoot dry weight, bulb fresh weight and bulb dry weight, percent dry matter content, yield and quality parameters. The application of 200 kg N ha^{-1} and 45 kg S ha^{-1} resulted in the highest yield (42.6 t ha^{-1}), the average weight of bulb (193.6 g) and a marketable bulb (99.8%). The highest N uptake (243.3 kg ha^{-1}) and S uptake (31.9 kg ha^{-1}) were obtained by the combined application of 200 kg N ha^{-1} and 45kg S ha^{-1}. The application of 200 kg N ha^{-1} and 45 kg S ha^{-1} can be recommended for high yield and quality onion production in the study area.

Bhashkar and Devi (2021) carried out an experiment to study the effect of different levels of sulphur and magnesium on growth, yield and quality of onion. The experiment was conducted with 10+1 treatments, replicated thrice the treatments were T_1 Control, T_2 RDF (100%), T_3 Sulphur @ 2%, T_4 Sulphur @ 4%, T_5 Sulphur @ 6%, T_6 Sulphur @ 8%, T_7 Magnesium@ 2%, T_8 Magnesium@ 4%, T_9 Magnesium@ 6%, T_{10} Magnesium@ 8%. From the present investigation it is found that treatment T_{10} Magnesium@ 8% was found superior in respect of the parameters plant height (cm), number of leaves per plant, fresh weight of bulb per plant (g), neck thickness (mm), equatorial diameter of bulb (cm), polar diameter of bulb (cm) and bulb yield (q ha^{-1}).

Veer *et al*. (2021) conducted an investigation entitled “Effect of sources and levels of sulphur on growth, yield of garlic (*Allium sativum* L.) Cv. “G-4” to find out the sources and optimum level of sulphur for better vegetative growth and higher yield of garlic. The results of the investigation indicated that different sources and levels of sulphur produced significant effect on growth and yield attributes of garlic. The treatment of gypsum at the level of 40 kg/ha recorded the significant effect on growth and yield parameters like plant height, number of leaves/plant, days required for maturity, neck thickness, length of cloves, diameter of bulb, weight of bulb, number of cloves per bulb, yield per plot and yield per heacter.

Haris *et al*. (2021) conducted a field experiment to study the effect of different levels of sulphur on growth and yield of onion under drip irrigation. The treatments comprised of 7 combinations (0, 15, 30, 45, 60, 75 and 90 kg S/ha) in which sulphur was supplied through gypsum. The results indicated significantly higher bulb yield (61.96 t ha^{-1}) and yield components like average bulb weight, bulb yield per plot and marketable bulb yield was obtained due to application of recommended dosage of fertilizer plus 45 kg S ha^{-1}. The growth components *viz*., plant height, number of leaves, collar thickness and neck thickness showed significant with the application of result in the recommended dosage of fertilizer plus 45 kg S ha^{-1} compared to other levels of sulphur.

Bappy *et al*. (2021) conducted a field experiment to find out the growth and yield of onion as influenced by Sulphur and Boron with mulch materials. The experiment consisted of two factors: Factor A: Four doses of Sulphur and Boron fertilizer *viz*. F_0 = S_0 kg B_0 kg ha^{-1} (Control), F_1 = S_{20} kg B_1 kg ha^{-1}, F_2 = S_{40} kg B_2 kg ha^{-1}, F_3 = S_{60} kg B_3 kg ha^{-1} and Factor B: Four types of mulch *viz*. M_0 = No mulch and no irrigation, M_1 = Black polythene, M_2 = Water hyacinth and M_3 = Rice straw. In case of Sulphur and Boron treatments at 60 days after transplanting (DAT), the highest plant height 53.38 cm, maximum leaf number 10.48, highest bulb length 4.83 cm, maximum neck diameter (1.31 cm), highest dry matter content (15.98%), dry matter content of leaf (24.74%), single bulb weight (39.93 g), yield per plot (0.80 kg) and yield per hectare (9.98 t) were obtained from F_3 treatment. In combined effect, the highest plant height at 60 DAT (55.54 cm), maximum leaf number (11.47), longest bulb length (5.51 cm), highest bulb diameter (6.68 cm), maximum diameter of neck (1.42 cm), dry matter content of leaf (27.48%), single bulb weight (42.40 g), yield per plot (0.85 kg) and yield per hectare (11.21 t) were obtained from F_3M_1 treatment (S_{60} kg ha^{-1} + B_3 kg ha^{-1} with black polythene mulch).

Nahar *et al*. (2020) carried out a field experiment to evaluate the effects of boron and sulphur on growth and yield of summer onion. The experiment

consisted of two-factors, Factor A: four levels of boron *viz*., (i) B_0 = 0 kg B ha^{-1}, (ii) B_1 = 0.5 kg B ha^{-1}, (iii) B_2 = 1.0 kg B ha^{-1}, (iv) B_3 = 1.5 kg B ha^{-1}; and Factor B: four levels of sulphur, *viz*., (i) S_0 = 0 kg S ha^{-1}, (ii) S_1 = 15 kg S ha^{-1}, (iii) S_2 = 30 kg S ha^{-1}, (iv) S_3 = 45 kg S ha^{-1}. BARI Piaz-3, a summer onion variety was used as planting material for this experiment. Results of the experiment revealed that the highest plant height (26.84 cm at 75 DAT), bulb diameter (2.84 cm), individual weight of bulb (21.73 g), percent dry matter (8.28) and yield of bulb (10.88 t ha^{-1}) were obtained when S applied at the rate of 30 kg/ha and the lowest for these parameters were recorded from 0 kg S/ha. Among the treatment combinations, 1.0 kg B ha^{-1} and 30 kg S ha^{-1} produced the maximum values for plant height (29.74 cm at 75 DAT), bulb diameter (3.06 cm), individual weight of bulb (25.83 g), percent dry matter (9.03) and yield of bulb (12.93 t ha^{-1}) while the lowest for these parameters were obtained from the control treatment *i.e.* without boron and sulphur fertilizers.

Przygocka-Cyna *et al*. (2020) conducted a three-year field study with experimental factors consisted of N: 0, 60, 120 and S: 0, 30, 60 kg ha^{-1}. The dynamics of onion total dry weight (TDW), total N uptake (TNU), and total S uptake (TSU) were determined at 10-day intervals. Sulfur uptake increased in onion at day after emergence (DAE) 40, independent of its rate with respect to SN control, resulting in increased N by 50%, and consequently higher yield. The maximum absolute S uptake rate, a factor defining yield, increased progressively with the N rate, but only in the absence of S application. Plants fertilized simultaneously with S and N showed a more complicated impact on S uptake rate. The N rate of 120 kg ha^{-1} resulted in S uptake rate reduced, leading to a yield drop. The expolinear model indicated an onion growth disturbance, revealed under unfavorable growth conditions, leading to yield depression.

Basim *et al*. (2020) conducted a field experiment to know the effect of the combination of sulfur and organic fertilizer on the growth and yield of onion (a local red type) under different plant densities. The experiment included two

factors, first: a combination of fertilizing with decomposing Cow's manure (20 t ha^{-1}) and sulfur (50 kg ha^{-1}) and this factor was distributed as follows (T_0: fertilizer recommendation (NPK 100-100- 120 kg ha^{-1}; it is considered a control). T_1: cow waste + half of the chemical fertilizer recommendation and T_2: fertilizer recommendation + sulfur addition and T_3: Cow's manure + half of the fertilizer recommendation + sulfur addition and T_4: double the recommendation of cow manure (40 t ha^{-1} + half of the fertilizer recommendation + adding sulfur). The second factor: planting distances (S_1:10×10, S_2:10×15, and S_3:10×20) cm. The distance between plants was fixed 10 cm and the dimensions changed between one line and another. The results showed clear significant differences for the two study factors in characteristics of vegetative growth, yield and the content of total soluble solids, as the T_4S_3 treatment exceeded by giving it the highest number of tubular blades, leaf area and the highest percentage of sulfur in the leaves, which was positively reflected on the plant yield and percentage the total soluble solids amounted to (16.57 blades $plant^{-1}$, 15.97 dm^2, 1.70%, 0.64%, 104.50 g, 15.83%), respectively, The treatment of planting distances S_1 achieved significant differences in the total yield (90.39 t ha^{-1} and 8.91 kg) respectively compared to plants of treatment S_3, which achieved(74.29 t ha^{-1} and 5.39 kg).

Rathod *et al*. (2020) conducted an investigation to study the effect of sulphur and zinc containing customized fertilizers on yield, quality and nutrient uptake by onion in Inceptisols. The experiment was laid out in Randomized Block Design with eleven treatments replicated thrice. The soil of experimental site was Inceptisols. The plant samples were collected, analyzed for content and uptake of major and micronutrients. The results revealed that the highest onion bulb yield, bulb weight and nutrient uptake were recorded with application of balanced fertilizer dose of NPKSZn (100:50:50:40:17.50 kg N, P_2O_5, K_2O, S, Zn) followed by application of recommended dose through customized fertilizer grade NPKS Zn + compensation of N and K through conventional fertilizer. Among the customized grades recommended dose applied through

grade III (12:45:00:05:01) and compensation of N and K through conventional source recorded highest onion bulb yield, yield attributes and nutrient uptake by onion. The periodical storage study of onion bulb at 30, 60, 90 and 120 days recorded lowest physiological weight loss in treatments recommended dose of NPKSZn followed by recommended dose of P through NPSZn (compensation of N and K through conventional fertilizers). The balanced application of nutrients (N, P, K, S and Zn) either through conventional or customized fertilizer grades (NPSZn) found beneficial in enhancing onion bulb yield, yield attributing parameters and improvement in onion bulb storage.

Verma *et al*. (2020) carried out an on farm trial to study the effect of Sulphur application on the yield and its attributes at 8 farmers field. Yield attributes for all treatments are significant except neck thickness and neck diameter. Maximum Yield (295 q/ha), bulb size (5.56 cm), neck thickness (5.8 cm) Plant height (51.6 cm), Number of leaves (8.3) and length of leaf (39.9 cm) were recorded from the doze of 30 kg Sulphur per hectare. Economically highest net monitory return of Rs. 132494 per hectare was obtained with the application of Sulphur @30 kg/ha. The application of Sulphur at this rate had been found to be non tedious, economically feasible and more convenient.

Bhalekar *et al*. (2018) reported that application of sulphur (15-45 kg S ha^{-1}) along with recommended dose of NPK fertilizers asbeneficial for improving yield (563.43 q ha^{-1}) and quality parameters of onion bulbs.

Meher *et al.* (2016) conducted an experiment to study the effect of sulphur application on growth, yield and quality of onion. The treatments consisted of six incremental doses of sulphur application (10, 20, 30, 40, 50 and 60 kg ha^{-1}) and no sulphur application (control, 0 kg S ha^{-1}). Treatments were arranged in Randomized Block Design with three replications. Yield, yield attributes and most of the other traits of onion (Agrifound Dark Red) response favourably to the sulphur application in a range of 40 to 60 kg ha^{-1}. Graded level of sulphur application linearly increased the yield up to 50 kg ha^{-1} with bulb yield of 35.5

ton. Maximum pyruvic acid content in onion bulbs was noticed with sulphur application at 40 and 50 kg ha^{-1}. However, application of sulphur did not affect number of scales and TSS content of onion bulb.

Tripathy *et al*. (2016) did not find any significant differences between different sources of sulphur for bulb yield and yield attributes of onion. However, application of gypsum as source of sulphur recorded the maximum polar diameter (3.13 cm), highest equatorial diameter (3.68 cm), highest average bulb weight (48.37 g), per cent of A grade bulbs (10.78%), per cent of B grade bulbs (18.66%), total bulb yield (137.95 q ha^{-1}) and as well as marketable bulb yield (101.39 q ha^{-1}) as compared to elemental sulphur.

Chattopadhyay *et al*. (2015) negotiated the influence of sulphur application through different carriers on yield and yield attributes in onion. Results showed that yield and yield parameters significantly differed with the different sources of sulphur. Among the sources, application of sulphur at 30 kg ha^{-1} through elemental sulphur brought back with the increased yield attributes such as bulb equatorial diameter (5.81), bulb polar diameter (6.32), average bulb weight (55.70 g), highest total yield (298.81q ha^{-1}) and marketable yield of 272.13 q ha^{-1} over gypsum.

Pradhan *et al*. (2015) did not find any significant differences between different carriers of sulphur in response to bulb yield of onion. However, application of sulphur at 45 kg ha^{-1} in the form of gypsum recorded maximum bulb yield (25.11 t ha^{-1}) against application of sulphur through elemental sulphur (22.67 t ha^{-1}).

Ulkey *et al*. (2015) studied effect of potassium and sulphur on growth attributes of onion and reported that application of potassium and sulphur had significant beneficial influence on growth, yield and quality of onion (30 Kg S ha^{-1} + 60 Kg K_2O ha^{-1}).

Bharti and Ram (2014) recorded the maximum values for yield and yield attributes in onion such as individual bulb weight (70.36 g), bulb length (5.82 cm), bulb diameter (6.51 cm) and bulb yield (33.25 t ha^{-1}) with the application of elemental sulphur as a carrier of sulphur against gypsum.

Pariari and Khan (2013) found nitrosulf as superior source of sulphur to obtain better yield in onion. Yield and yield parameters of onion i.e. bulb diameter and bulb length were significantly influenced by sources of sulphur applied. The maximum bulb diameter (6.38 cm) and bulb length (7.89 cm) and bulb yield (30.25 t ha^{-1}) were recorded in treatment involving the application of sulphur in the form of Nitrosulfate (0.5% concentration) over other sources of Sulphur (SSP, K_2SO_4, elemental sulphur).

Mishu *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. However, number of splitted bulb, bulb diameter, neck diameter, and neck bulb ratio were not significantly affected by different doses of sulphur application. Application of 40 kg S ha^{-1} resulted in the highest yield (10.65 t ha^{-1}) among the different doses of sulphur. The present study clearly indicates that sulphur at 40 kg ha^{-1} may be recommended for better growth and yield of onion.

Tripathy *et al*. (2013) conducted a field experiment 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. 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. However, no significant variations were recorded between the sources of sulphur in onion, except bulb weight. 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 plant height (54.51 cm), number of leaves plant^{-1} (14.80), polar diameter (5.17 cm), equatorial diameter (5.17 cm), average bulb weight (60.83 g) , total bulb yield (211.23 q ha^{-1}) and TSS (11.90%) than other levels. However, statistically parity was observed with application of sulphur @15 and 30 kg ha^{-1} for above mentioned parameters. Application of sulphur @ 30 kg ha^{-1} in form of gypsum may be recommended in onion crop for obtaining higher bulb yield having better keeping quality.

Rashid (2010) conducted an experiment to evaluate the effects of sulphur and GA3 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 and four concentrations of GA3 *viz*., 0 (control), 50, 75, 100 ppm. The experimental findings revealed that sulphur and GA3 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) was recorded from 30 kg S/ha, while the lowest bulb yield (11.20 t/ha) was obtained from control. Most of the

parameters showed increasing trend with the higher concentration of GA3. Application of GA3 @ 100 ppm gave the maximum bulb yield (15.23 t/ha), while the minimum value (10.10 t/ha) was observed from control. Almost all the parameters were significantly influenced by combined treatments of sulphur and GA3 except bulb length of onion. The maximum bulb dry matter content (13.50%) and bulb yield (17.10 t/ha) were produced from the application of sulphur @ 30 kg/ha with 100 ppm GA3, while the minimum bulb dry matter content (9.23%) and bulb yield (9.33 t/ha) were recorded from control treatment of sulphur with GA3.

Nasreen *et al*. (2000) conducted field experiments to study the effect of seven levels of sulphur (0, 15, 30, 45, 60, 75 and 90 kg ha^{-1}) on total dry matter (TDM) accumulation pattern, crop growth rate (CGR), relative growth rate (RGR) at various stages of growth, yield components and bulb yield of onion. The accumulation of total dry matter (TDM) and the pattern of dry matter of onion throughout the experimental period showed considerable variation due to sulphur levels. The rate of TDM production was maximum at 60-75 days after transplanting (DAT) irrespective of sulphur levels. CGR values were increased progressively over time reaching peak at 60-75 DAT and thereafter declined sharply till 105 DAT. RGR from its highest value at early growth stage continued to decrease with crop age. The highest TDM, CGR, RGR, yield parameters and bulb yield were obtained from 45 kg S ha^{-1} along with a blanket dose of 120 kg N, 90 kg P_2O_5, 90 kg K_2O, 5 kg Z ha^{-1} plus 5 t cowdung ha^{-1}. The least TDM and bulb yield were recorded for control recorded for control treatment. Application of 45 kg S ha^{-1} also produced marketable bulbs of 50 g size while 71% of the bulbs were of <15 g size in the control plots.

2.4 Effect of sulphur on nutrient uptake of crops

Kala *et al*. (2017) studied the effect of graded doses of sulphur (0, 20 and 40 kg S ha^{-1}) and Boron (0, 0.5 and 1 kg B ha^{-1}) on yield and

nutrient uptake by chickpea. Results revealed that increasing S levels up to 40 kg ha^{-1} significantly increased yield and total uptake of N, P, K, S and B.

Poornima *et al*. (2016) studied effect of potassium and sulphur on nutrient uptake by onion and chilli intercrop in a vertisol and reported that higher uptake of N, P, K and S by onion plant as well as chilli were observed with the individual application of sulphur @ 30 kg ha^{-1} and potassium @100 kg ha^{-1}.

Dash *et al*. (2015) investigated the integrated effect of major (N, P, K), secondary (S) and micronutrient (B and Zn) on yield, nutrient accumulation and uptake by rice. The results revealed highest significant grain yield (76.70 q ha^{-1}) recorded when the crop received all the nutrients (N, P, K, S B and Zn). Combined application of all the nutrients increased nutrient accumulation and uptake.

Pradhan *et al*. (2015) observed no significant difference between different forms of sulphur (gypsum and elemental sulphur) in response to uptake of N, P, K, S by onion leaves. However, supply of sulphur at the rate 45 kg ha^{-1} through elemental sulphur showed the higher uptake of N, P, K, S by onion leaves (14.84, 0.66, 10.08 and 0.85 kg ha^{-1}, respectively). Whereas, the uptake of N, P, K, S by bulbs of onion were greatly influenced by different forms of sulphur. Application of sulphur at the rate 45 kg ha^{-1} in the form of gypsum recorded highest uptake of N, P, K, S (74.66, 7.08, 35.62, 9.02 kg ha^{-1} respectively) over application of elemental sulphur.

Hasan *et al*. (2013) reported the influence of phosphorus (0, 30 60 and 90 kg P ha^{-1} and sulphur (0, 15 and 30 kg S ha^{-1}) on major nutrient contents and their uptake by brinjal and revealed that major nutrient contents and their uptake were significantly influenced by P and S interactions. The gradual increase of major nutrient contents and their uptake were found in S application upto 30 kg ha^{-1}.

Dixit *et al*. (2012) studied the effect of S and Zn on yield and nutrient uptake by hybrid rice grown in sodic soil. Application of 40 kg S ha^{-1} recorded significantly high grain yield and S uptake. Similarly, positive response of hybrid rice to Zn application was also noticed significantly up to the Zn dose at 10 kg ha^{-1}.

Hariyappa *et al*. (2011) recordedthe higher uptake of N (202.47 kg ha^{-1}), P (25.00 kg ha^{-1}), K (111.13 kg ha^{-1}) and S (43.24 kg ha^{-1}) were recorded with 125 kg K_2O and 30 kg S per hectare. In post-harvest soil maximum available potassium (498.00 kg ha^{-1}) and sulphur (25.16 kg ha^{-1}) content was obtained in the treatment 150 kg K_2O and 30 kg S per hectare.

Karthikeyan and Shukla (2008) studied the effect of interaction between B and S on their uptake and quality parameters of mustard (*Brassica juncea* L.) The interaction effect between boron and sulphur significantly and synergistically influenced the dry matter of crop, which were observed the highest at 60 mg kg^{-1} of S in conjunction with 2 mg kg^{-1} of boron.

Singh and Singh (2005) reported nitrogen, phosphorous and sulphur content and their uptake in the onion were significantly affected by different sources of sulphur. Among the different forms, ammonium sulphate exhibited its superior performance over other sources of sulphur.

2.5 Combined effect of potassium and sulphur

Fanai *et al*. (2021) conducted a field experiment to study the effect of different levels of sulphur and potassium on the properties of the soil as well as on the growth and yield of Onion (*Allium cepa* L.). Experimental layout was done in a Factorial Randomised Block Design (RBD) with 9 treatments which is replicated 3 times. Treatments consists of three levels of potassium i.e. 0, 25 and 50 kg ha^{-1} and three levels of sulphur i.e. 0, 15, 30 kg ha^{-1} where the treatments are assigned randomly. The results indicated that the maximum average plant height (64.02 cm), bulb length (4.99 cm), bulb diameter (6.99

cm), total bulb yield (13.72 q ha^{-1}) showed significantly better results with the treatment T_9 (Potassium at 50 kg ha^{-1} and Sulphur at 30 kg ha^{-1}). The same treatment also showed better results in the physical properties of the post-harvest quality of the soil like increase in % pore space, decrease in bulk and particle density of the soil and also showed a gradual increase on the chemical properties of the soil like increase in pH, OC% and N, P, K, S values in the soil after harvest. Hence the results revealed that the treatment combination i.e. potassium at 50 kg ha^{-1} and sulphur at 30 kg ha^{-1} was found to be the most beneficial and significantly improved the growth parameters and bulb yield of onion.

Ozkan *et al*. (2018) conducted a study with the objective to compare the effects of polyhalite, potassium sulphate (SOP), and potassium chloride (MOP) fertilizers on onion bulb yield, nutrient uptake, and on bulb quality properties. An equal dose of 270 kg K_2O ha^{-1} was applied as MOP, SOP, polyhalite and a mixture of polyhalite and SOP and these were compared against a control which applied nitrogen (N) and phosphorus (P) fertilizers. While MOP increased bulb size and yield by 28%, S fertilizers contributed additional yield increases ranging from 12 to 22% compared to the control. The major effect of all of the fertilizers was that they improved K availability during the onion crop cycle. Polyhalite application resulted in the highest yield, probably due to its slow-release character, providing constant soil K availability throughout the crop cycle. High rates of S application did not correlate with high yield or quality.

Marbong and Swaroop (2018) conducted a field experiment to study the effect of different levels of doses of potassium and sulphur on the soil properties and also on the growth and yield of onion (*Allium cepa* L.). Treatments were assigned randomly which consisted of three levels of potassium *i.e*. 0, 50 and 100 kg ha^{-1} and three levels of sulphur *i.e*. 0, 15 and 30 kg ha^{-1}. The results indicated that the maximum average plant height (60.60 cm), bulb length (6.1

cm), bulb diameter (8.7 cm), total bulb yield (13.55 t ha^{-1}) showed significantly better results with the treatment T_2 (potassium at 100 kg ha^{-1} and sulphur at 30 ha^{-1}). The same treatment also showed better results in the physical properties of the post-harvest quality of the soil like increase in % pore space, decrease in bulk and particle density of the soil and also showed a gradual decrease on the chemical properties of the soil like decrease in pH, OC % and N, P, K, S values in the soil after harvest. Hence the results revealed that the treatment combination T_2 i.e. potassium at 100 kg ha^{-1} and sulphur at 30 kg ha^{-1} was found to be the most beneficial and significantly improved the growth parameters and bulb yield of onion.

El-Morsy *et al*. (2016) carried out a field experiment to study the effect of different combinations among nitrogen, potassium and sulphur levels on growth, yield, and pungency of onion (*Allium cepa* L.) cv. "White Sweet Spanish" compared to control (recommended doses of N, K and S). The results indicated that application of 150% N + 75% K_2O + 200% S of recommended dose was the best treatment where increased fresh weight of leaves, bulbs and total fresh weight as well as the dry weight of the same previous parameters and photosynthetic pigments in the 1st season. Concerning yield and its components, application of 150% N + 75% K_2O + 200% S was the best treatment for increasing the total yield and its components compared to the recommendation treatment and the other treatments. The previous treatment recorded increases of total relative yield by 131.42% and 115.77% in 1st and 2nd seasons, respectively compared to control treatment (recommended dose); increment in marketable yield by 130.95% and 112.08% in 1st and 2nd seasons, respectively; increase in relative yield of both 1st and 2nd grades which increased by 131.04% , 115.22% for the 1st grade in both seasons, respectively, and by 127.89 and 111.77% for the sum of 1st + 2nd grades in the 1st and 2nd seasons, respectively, while application of 150% N + 75% K_2O + 100% S recorded the lowest value of bulb pungency.

Hossiain *et al*. (2010) conducted an experiment to assess the effect of nitrogen, potassium and sulphur on seed yield and seed quality of onion. The experiment was laid out in a randomized complete block design with three replications. Four levels of nitrogen (0 35, 70 and 105 kg ha^{-1}) four levels of potassium (0, 50, 100 and 150 kg ha^{-1}) and four levels of sulfur (0, 12.5, 25 and 37.5 kg ha^{-1}) in combination made eleven treatment combinations. Cow dung 10 tones ha^{-1} and phosphorus 40 kg ha^{-1} were also applied as basal dose. Urea, muriate of potash and gypsum were used as the source of nitrogen, potassium and sulfur respectively. Results showed that plant height, leaf number, days to flowering, umbel diameter, seeds per umbel, seed yield per plant and germination percentage vigor, pure live of seed and electrical conductivity were significantly influenced by different fertilizer combination. Yield and yield components responded well to applied fertilizer. The highest seed yield (408.6 kg ha^{-1}) of onion was recorded at 105, 100, 25 kg N K S ha^{-1}. The eleven treatment combination also produced the high quality onion seed.

CHAPTER III

MATERIALS AND METHODS

The experiment was undertaken in October, 2020 to June 2021 at the farm of Sher-e-Bangla Agricultural University (SAU), Dhaka and in the Department of Agricultural Chemistry, SAU, Dhaka, Bangladesh. The materials and methods followed during entire period of the experiment are described below in the following heads:

3.1 Description of the experimental site

3.1.1 Location

The experiment was undertaken at the farm of Sher-e-Bangla Agricultural University (SAU), Dhaka and in the Department of Agricultural Chemistry, SAU, Dhaka. It is located at $90^0 22'$ E longitude and 23°4l′ N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28. Location of the experimental site presented in Appendix I.

3.1.2 Soil

The soil belongs to "The Modhupur Tract", AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 6.1 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details were presented in Appendix II.

3.1.3 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by 3 distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and

monsoon period from May to October. Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Sher-e-Bangla Agricultural University, presented in Appendix II.

3.2 Plant materials

The high yielding cultivar of Onion BARI Piaz-6 was used as experimental planting material. The seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.3 Experimental details

3.3.1 Treatments

The experiment comprised two factors.

Factor A: Four doses of sulfur

1. S_1 = 5 kg S ha^{-1}
2. S_2 = 15 kg S ha^{-1}
3. S_3 = 25 kg S ha^{-1}
4. S_4 = 35 kg S ha^{-1}

Factor B: Four doses of Potassium

1. K_1= 100 Kg K ha^{-1}
2. K_2= 120 Kg K ha^{-1}
3. K_3= 140 Kg K ha^{-1}
4. K_4= 160 Kg K ha^{-1}

Treatment combination: Sixteen treatment combinations

S_1K_1, S_1K_2, S_1K_3, S_1K_4, S_2K_1, S_2K_2, S_2K_3, S_2K_4, S_3K_1, S_3K_2, S_3K_3, S_3K_4, S_4K_1, S_4K_2, S_4K_3, S_4K_4

3.3.2 Experimental design and layout

The experiment was set in Randomized Complete Block Design **(**RCBD) having two factors with three replications.

Factor 1: Four doses of sulfur (S_1= 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1})

Factor 2: Four doses of Potassium (K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1})

Replication: 3

The four doses of sulfur in combination with four doses of Potassium (4 × 4=16) were randomly assigned to 48 (16 × 3) experimental plots. Each plot was 1m × 1m ($1m^2$) in size. The distance maintained between two plots was 0.50 m and between blocks was 0.75 m.

3.4 Growing of crops

3.4.1 Seed collection

The seeds of the test crop i.e., BARI Piaz-6 was considered as plant materials and seed were collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur.

3.4.2 Raising of seedlings

At first seeds were cleaned and germination test was done. Seeds are sown on 14 November 2020. After germination regularly light irrigation was given to seedlings. Sevin powder also sprayed around seedbed to control ants. Partial shade was provided to protect seedlings from sunlight.

3.4.3 Preparation of the main field

The selected field for the experiment was opened by a tractor and prepared thoroughly by ploughing several times with a power tiller. All weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilth of the soil. Finally, experimental land was divided into unit plots following the design of experiment.

3.4.4 Fertilizers and manure application

According to FRG, (2012) (Fertilizer Recommendation Guide, BARC 2012) the recommended doses of urea as a source of Nitrogen (120 kg N/ha), Triple super phosphate (TSP) as a source of phosphorus (60 kg P/ha), were added to the soil of main experimental plots. According to sulfur and potassium treatments, the required amounts of S and K from gypsum and muriate of potash, respectively were applied at the unit plots. The whole amounts of P, S and K fertilizers were applied at the time of final plot preparation as per treatment of the experiment. The urea fertilizer was applied by 3 splits application during land preparation and at 25 and 45 days after seedlings transplantation.

3.4.5 Transplanting of Seedling

Healthy and disease free 35 days old seedlings were uprooted from the seedbed and transplanted in the plot. The seedbed was watered before uprooting the seedlings and watered immediately after transplanting. The seedlings of onion (BARI Piaz-6) were transplanted in the line to line distance 20 cm and plant to plant distance 10 cm.

3.4.6 Intercultural Operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the Onion.

3.4.6.1 Gap filling

Within 7 days after transplanting, damaged plants were replaced with healthy seedlings from the surplus plants.

3.4.6.2 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots once immediately after transplanting. Stagnant water was effectively drained out at the time of heavy rains.

3.4.6.3 Weeding

Several weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. First weeding was done at 20 days after transplanting (DAT), 2^{nd} and 3^{rd} weeding was done at 35 and 45 DAT, respectively

3.4.6.4 Plant protection

Preventive measure was taken against soil borne insects. Furadan 5G @20 kg ha^{-1} was applied for prevention of cutworms. No insect pest infestation was found in the field after pesticide application. A few days after transplanting some plants were attacked by purple blotch disease caused by *Alternaria puri.* Purple blotch was controlled by spraying Ruvral 50WP four times at 10 days interval after transplanting.

3.5 Harvesting

The crops were harvested when maximum number of plant showed the sign of maturity by yellowing out most of the leaves drying of pseudo stem, thin and

dried outer scale. The tops were removed by cutting off the pseudo stem keeping 2.5 cm with the bulb.

3.6 Data Collection and Recording

Data were recorded on the following parameters from the sample plants during the course of experimentation.

1. Plant height	7. Bulb diameter
2. Leaf number	8. Bulb height
3. Leaf length	9. Individual bulb weight
4. Neck diameter	10. Bulb yield
5. Fresh foliage weight	11. Storage weight of bulb at harvest and 1, 2 & 3 months intervals after harvesting
6. Dry foliage weight	

3.7 Procedure of recording data

3.7.1 Plant height (cm)

The height (cm) of the selected plants in each plot was measured at harvest. The height was measured from the neck of the bulb to the tip of the longest leaf and average the result was done.

3.7.2 Leaf number

The leaf number plant^{-1} of randomly selected plants from each plot was counted and their average was recorded

3.7.3 Leaf length (cm)

The length (cm) of leaf was measured with a centimeter scale from pseudo stem to the tip of the leaf from one selected plants from each plot at harvest and their average was recorded.

3.7.4 Neck diameter (mm)

The neck diameter (mm) plant^{-1} of randomly selected plants from each plot was measured and their average was calculated.

3.7.5 Fresh foliage weight (g plant^{-1})

The fresh foliage weight (g) plant^{-1} of selected five plants from each plot was calculated at harvest and average the result was done.

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

Dry foliage weight (g) of the selected plants in each plot was measured after oven dried and their average was calculated.

3.7.7 Bulb diameter

The diameter (mm) of bulb was measured at the middle portion of bulb from randomly five selected plants with a slide calipers at harvest and their average was recorded.

3.7.8 Bulb height (mm)

The height of bulb in millimeter (mm) was measured with a slide calipers from the neck to the bottom of the bulb from randomly selected plants and their average was taken.

3.7.9 Individual bulb weight (g)

The Individual bulb weight (g) of randomly selected five plants from each plot was measured and their average was calculated.

3.7.10 Bulb yield

The bulb yield (kg) plot^{-1} (1 m^2) was measured at harvest and then it converted into ton per hectre.

3.7.11 Storage weight of bulb at harvest and 1, 2 and 3 months intervals after harvesting

The randomly selected 15 bulbs weight (g) was measured by digital electrical balance at harvest and then it converted to percentage. Thereafter, the selected 15 bulbs were put in storage at wooden boxes and weighing the storage bulbs at

1, 2 and 3 months intervals after harvest and their percent weight loss were calculated with respect to weight of bulb at harvest.

3.7.12 Analysis of different chemical constituents of onion bulb samples

3.7.12.1 Digestion of plant samples with sulfuric acid for N determination

For the determination of nitrogen an amount of 1.0 g bulb sample was taken in a micro kjeldahl flask. One g catalyst mixture (K_2SO_4: $CuSO_4$ $5H_2O$: Se in the ratio of 100: 10: 1), and 10 mL conc. H_2SO_4 were added. The flasks were heated at 160^0 C and added 2 mL H_2O_2 then heating was continued at 360 ^{0}C until the digests become clear and colorless. After cooling, the content was taken into a 100 mL volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.05N H_2SO_4.

The amount of N was calculated using the formula is % N = (T-B) × N × 0.014 × 100 / S

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.7.12.2 Determination of P, S and K

One g sample of onion bulb was analyzed to determine the amount of P, S and K contents therein. The P, S and K were extracted from samples on Di-acid mixture (Conc.HNO_3:60%$HClO_4$=2:1) through wet oxidation method. Then the

contents of P and S were measured by Spectrophotometer and K by Flame Photometer according to the outline of Jackson (1973).

3.8 Statistical Analysis

The collected data were analyzed statistically following RCBD design by MSTAT-C computer package programs developed by Russel (1986). The treatment means were compared by Duncan's Multiple Range Test (DMRT) and regression analysis were performed as and where necessary.

CHAPTER IV

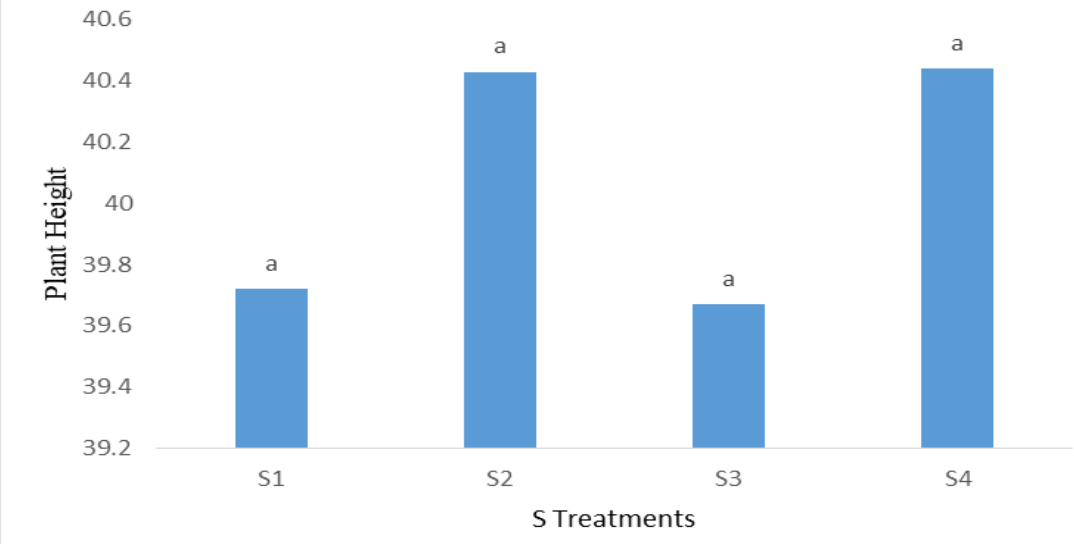
RESULTS AND DISCUSSION

Four doses of sulfur (5, 15, 25 and 35 kg S ha^{-1}) and four doses of potassium (100, 120, 140 and 160 kg K ha^{-1}) have been selected for present experiment in order to observed their effects on growth, yield, storage life and nutrients content of BARI Piaz-6.

4.1 Plant height

Effect of Sulfur

Plant height (cm) of the BARI Piaz-6 was measured at maturity. It was evident from Figure 1 and Appendix V that the height of the onion was not significantly influenced by the application of different doses of sulfur. But the tallest plant (40.44 cm) was found when sulfur was applied 35 kg ha^{-1} and the shortest plant height (39.72 cm) in 5 kg S ha^{-1}. Tilahun *et al*. (2021) conducted a field experiment to evaluate the effect of nitrogen and sulfur fertilizers on the growth, yield, quality and nutrient uptake of onion. The interaction effect of nitrogen and sulfur significantly increased plant height.

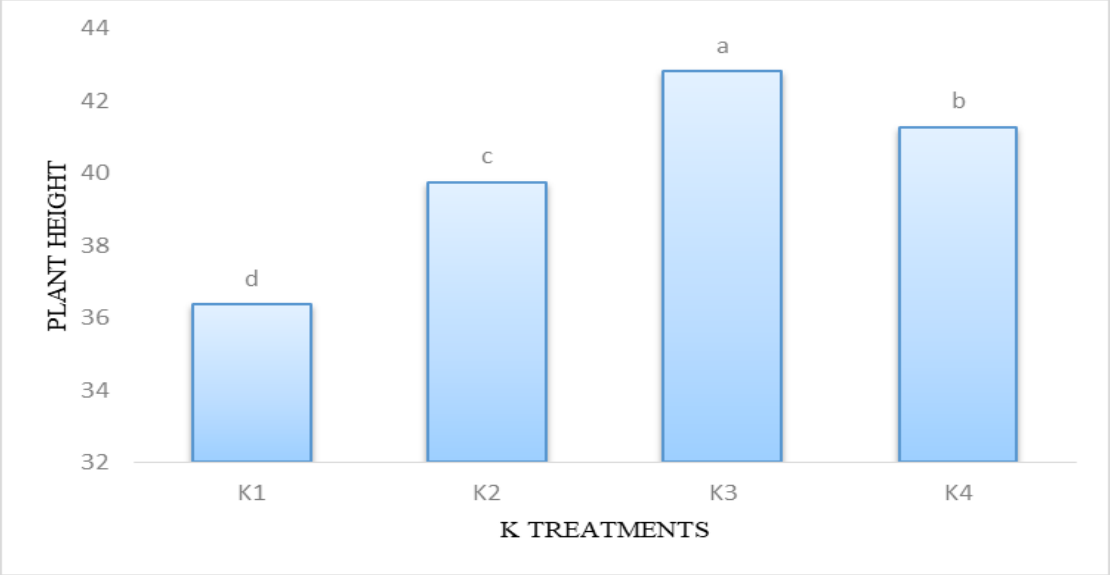


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 1. Effect of different doses of Sulfur on plant height

Effect of potassium

The height of the plant was significantly influenced by different doses of potassium (Figure 2 and Appendix V). The highest plant height (42.83 cm) was observed at 140 kg K ha^{-1} and the shortest plant (36.38 cm) was found at the lowest dose of potassium (100 kg K ha^{-1}). Bekele (2018) stated that potassium fertilizer application at different levels showed significant effects on growth, yield and quality parameters *i.e.* plant height, leaf length, leaf number, sheath length, bulb weight, bulb length, bulb diameter and bulb shape index.



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 2. Effect of different doses of potassium on plant height

Combined effect of sulfur and potassium

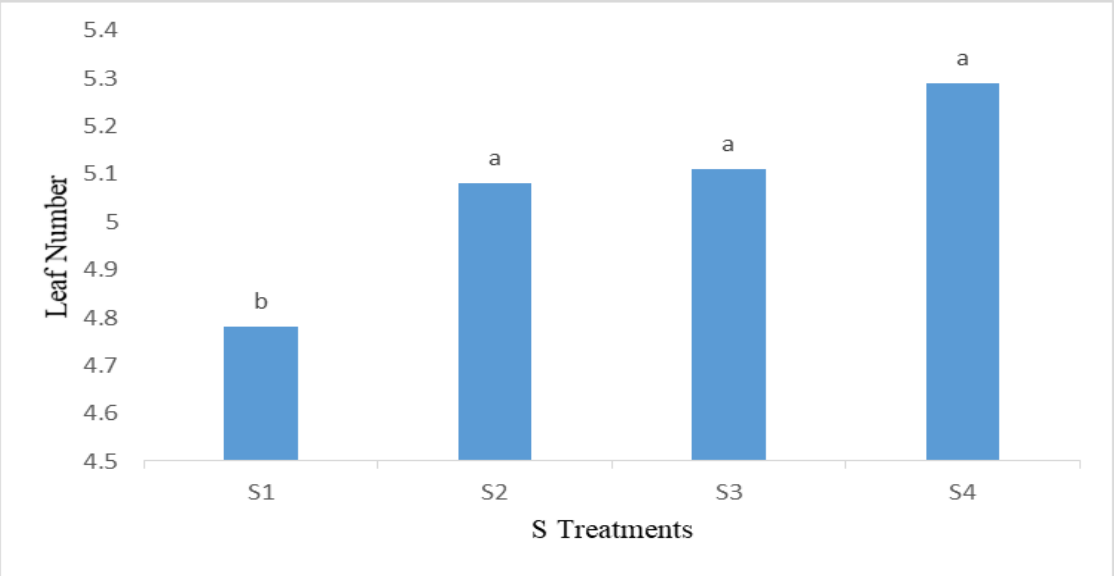
The interaction effect of different doses of S and K significantly influenced plant height of BARI Piaz-6 (Table 1). The highest plant height (43.19 and 43.13 cm) was found at 140 kg K ha^{-1} with 35 and 15 kg S ha^{-1} doses, respectively. The lowest plant height (35.25 cm) was found at the lowest doses of S (5 kg S ha^{-1}) and K (100 kg K ha^{-1}) combination. Similar results reported

that application of K at 125 kg ha^{-1} had showed significantly the highest plants height in onion (Hariyappa, 2003).

4.2 Leaf number

Effect of Sulfur

There was a significant difference in the leaf number due to application of different doses of S (Figure 3 and Appendix V). The maximum leaf number (5.29) was produced at the highest dose of S (35 kg S ha^{-1}), which was statistically similar with 25 and 15 kg S ha^{-1} doses. The minimum leaf number (4.83) was found at the lowest dose of S (5 kg S ha^{-1}). Bappy *et al*. (2021) conducted a field experiment to find out the growth and yield of onion as influenced by Sulphur and Boron with mulch materials. In case of Sulphur and Boron treatments at 60 days after transplanting (DAT), the highest plant height 53.38 cm, maximum leaf number 10.48 found at S_{60} kg B_3 kg ha^{-1}.

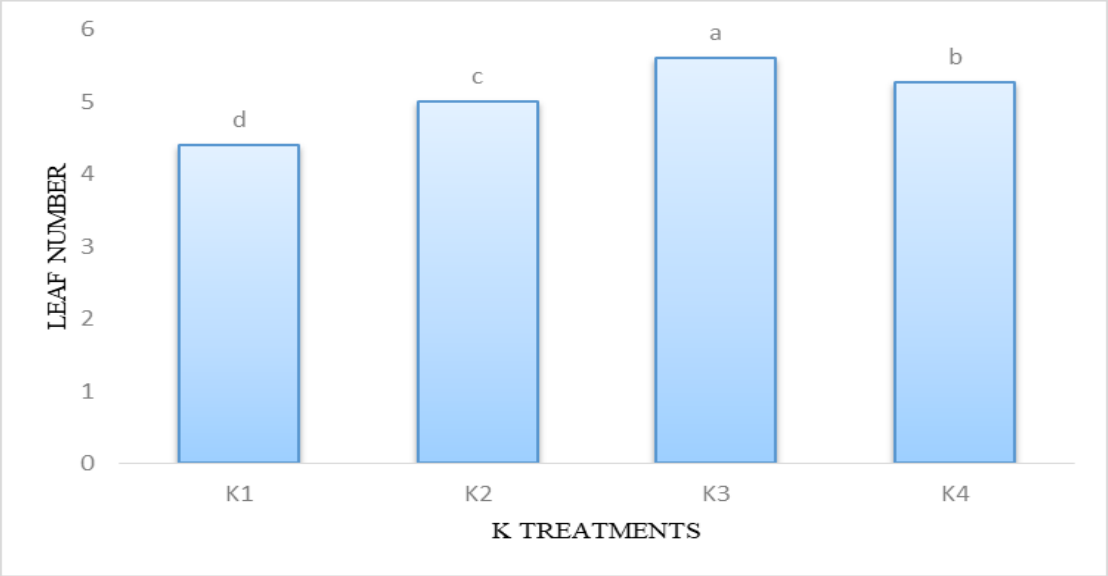


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 3. Effect of different doses of Sulfur on leaf number

Effect of potassium

The different doses of potassium showed significant variation in the number of leaf (Figure 4 and Appendix V). The maximum leaf number (5.60) was produced by 140 kg K ha^{-1} dose of potassium, whereas the lowest dose of potassium (100 kg K ha^{-1}) produced the minimum number of leaf (4.40). Fatematuzzohora *et al*. (2018) conducted an experiment to assess the effect of potassium fertilizer to improve summer onion production. In case of different doses of potassium the highest leaf number per plant (13.93) was recorded from 120 kg K ha^{-1}.



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 4. Effect of different doses of potassium on leaf number

Combined effect of sulfur and potassium

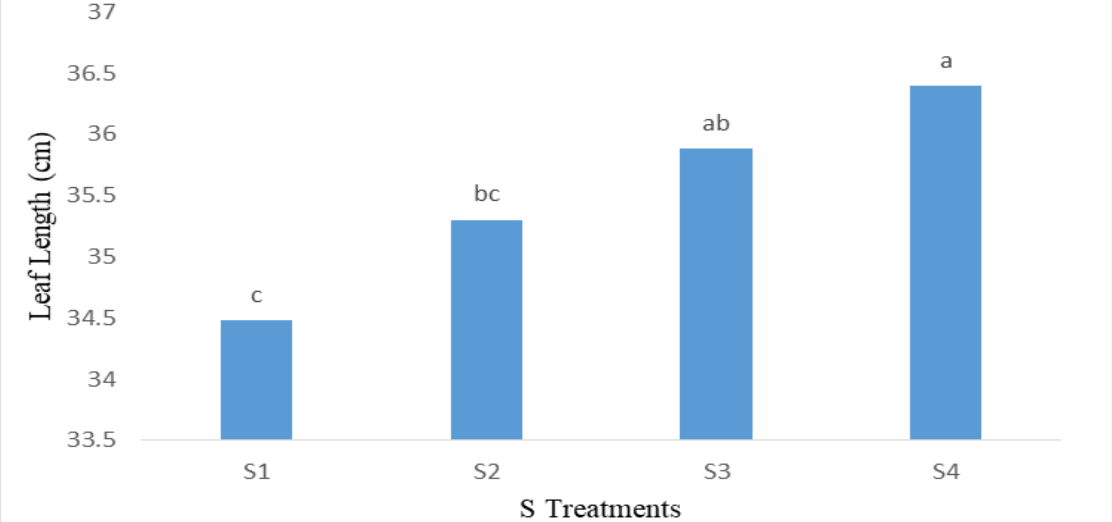
The leaf number of BARI Piaz-6 significantly varied due to different treatment combinations of sulfur and potassium doses (Table 1). The maximum number of leaf (5.80) was found in 140 kg K ha^{-1} with 35 kg S ha^{-1}, which was statistically similar with 140 kg K ha^{-1} at 5 and 15 kg S ha^{-1}. The minimum

number of leaf (3.87) was found at the lowest dose of S and K combination (5 kg S ha^{-1} with 100 kg K ha^{-1}). Similar opinion stated by Bekele (2018).

4.3 Length of leaf

Effect of Sulfur

The different doses of sulfur showed significant variation in the length of leaf (Figure 5 and Appendix V). The highest leaf length (36.39 cm) was produced at S dose of 35 kg ha^{-1}, which was gradually decreased until the lowest dose of S. Nahar *et al*. (2020) carried out a field experiment to evaluate the effects of boron and sulphur on growth and yield of summer onion. Results of the experiment revealed that the highest plant height (26.84 cm at 75 DAT) was obtained when S applied at the rate of 30 kg ha^{-1}.



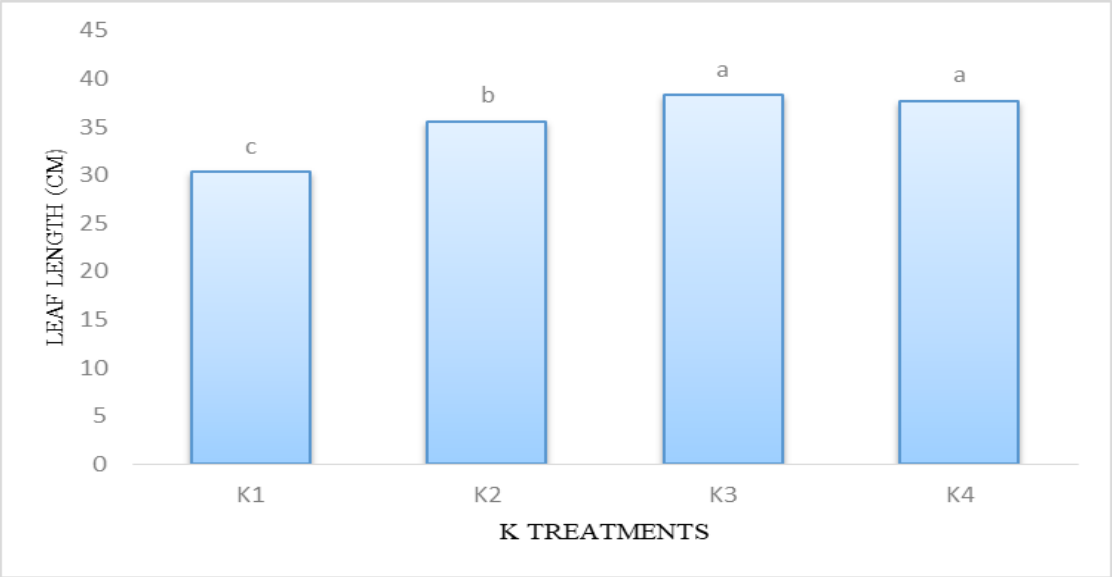
S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 5. Effect of different doses of Sulfur on leaf length

Effect of potassium

There was a significant difference among the potassium doses in the length of leaf (Figure 6). The maximum length of leaf (38.36 cm) was produced by 140

kg K ha^{-1} dose of potassium, which was statistically similar with 160 kg K ha^{-1} dose potassium. The lowest dose of potassium (100 kg K ha^{-1}) produced the minimum length of leaf (30.34 cm). Fatematuzzohora *et al*. (2018) conducted an experiment to assess the effect of potassium fertilizer to improve summer onion production. In case of different doses of potassium the highest leaf length (43.69 cm) was recorded from 120 kg K ha^{-1}.



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 6. Effect of different doses of potassium on leaf length

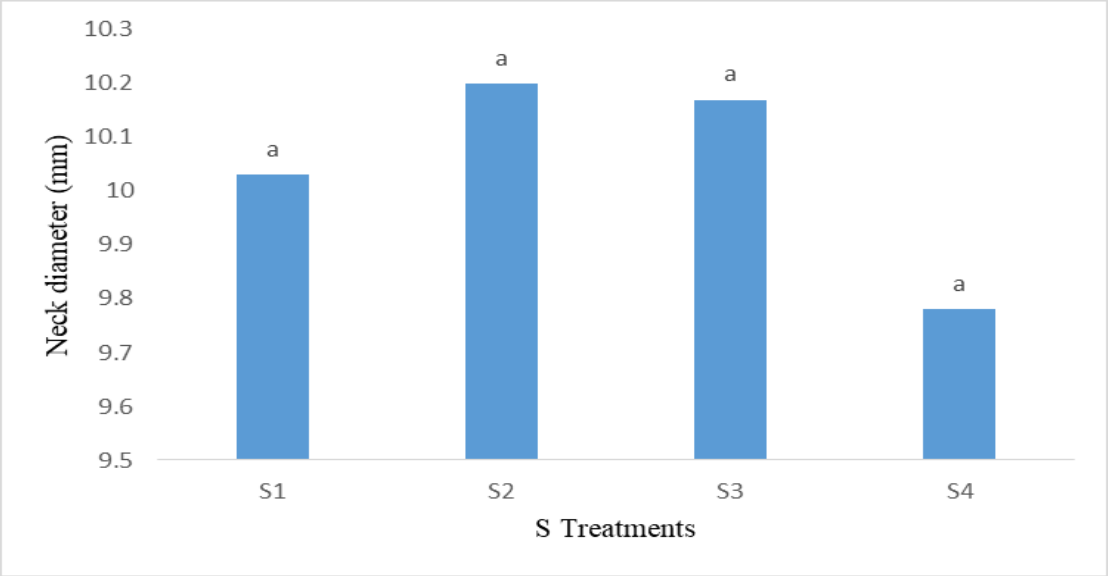
Combined effect of sulfur and potassium

The interaction effect of different doses of S and K significantly influenced leaf length of BARI Piaz-6 (Table 1). The maximum length of leaf (39.03 cm) was found in 35 kg S ha^{-1} with 140 kg K ha^{-1}, which was statistically similar with 160 kg K ha^{-1} in same dose S and also 140 kg K ha^{-1} with 15 and 25 kg S ha^{-1}. The lowest values of leaf length (28.19 and 29.44 cm) were found at 100 kg K ha^{-1} with 5 and 15 kg ha^{-1} sulfur doses, respectively. These results were similar with those reported by EL-Desuki et al. (2006) and Bekele (2018).

4.4 Neck diameter

Effect of Sulfur

There was no significant difference among the doses of sulfur in the neck diameter of BARI Piaz-6 (Figure 7 and Appendix V). The highest neck diameter (10.20mm) found at 15 kg ha^{-1} and the lowest neck diameter (9.78 mm) found at 35 kg ha^{-1} sulfur application. Verma *et al*. (2020) carried out an on farm trial to study the effect of Sulphur application on the yield and its attributes at 8 farmers field. Yield attributes for all treatments are significant except neck thickness and neck diameter.

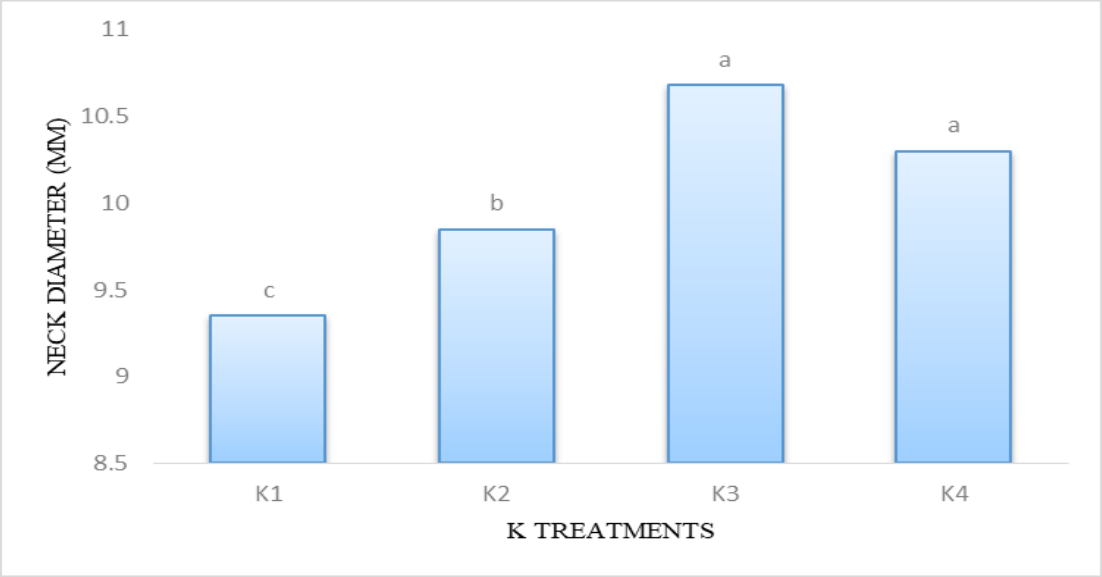


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 7. Effect of different doses of Sulfur on neck diameter

Effect of potassium

But different doses of potassium showed significant variation in the neck diameter of BARI Piaz-6, where the maximum neck diameter (10.68 mm) was produced by 140 kg ha^{-1} K dose, which was statistical similar with 160 kg ha^{-1} K dose (Figure 8 and Appendix V). The lowest dose (100 kg ha^{-1}) of K produced the minimum neck diameter (9.35 mm). This resuts were similar with findings of Dilruba *et al*. (2019).



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 8. Effect of different doses of potassium on neck diameter

Combined effect of sulfur and potassium

The interaction effect of different doses of S and K significantly influenced on neck diameter of BARI Piaz-6 (Table 1). The maximum neck diameter (10.73 mm) of onion was found at 140 kg ha^{-1} potassium with 25 and 35 kg ha^{-1} sulfur treatments combinations, which was statistically similar with 5 and 15 kg/ha sulfur doses in same dose of potassium (140 kg ha^{-1}) and also 160 kg K ha^{-1} with 25 kg S ha^{-1} dose. The minimum neck diameter (9.13 mm) was found at the lowest dose of S and K combination (5 kg S ha^{-1} with 100 kg K ha^{-1}). This results are in agreement with the findings of Marbong and Swaroop (2018).

Table 1. Interaction effects of different doses of sulfur and potassium on plant height, leaf number, leaf length, neck diameter and fresh foliage weight (FFW) of BARI Piaz-6

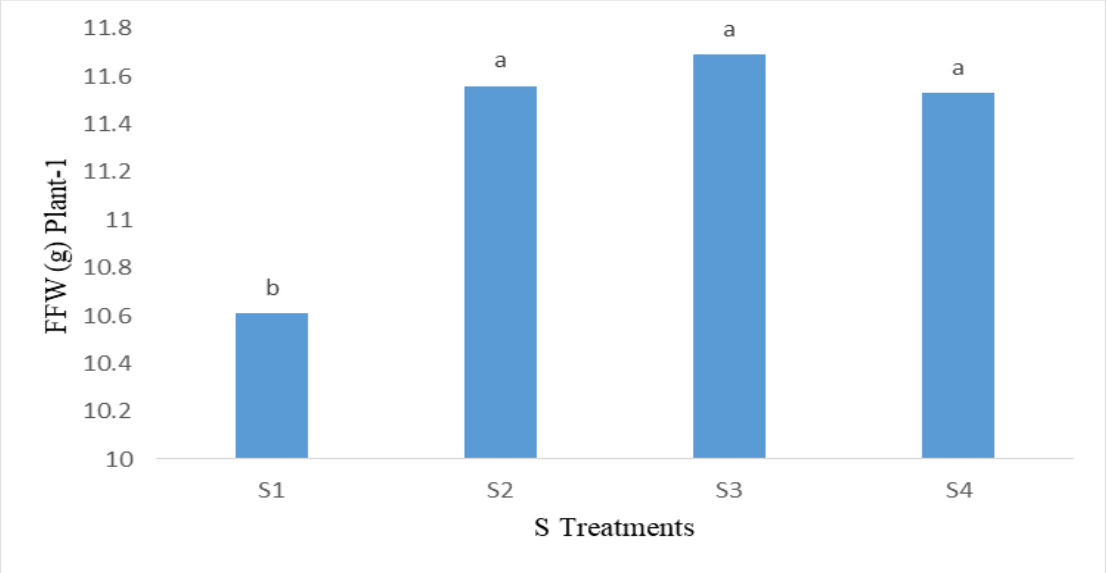
Treatment		Plant height (cm)	Leaf number Plant^{-1}	Leaf length (cm)	Neck diameter (mm)	FFW (g) Plant^{-1}
S doses (kg/ha)	K doses (kg/ha)					
5	100	35.25 f	3.87 g	28.19 e	9.13 d	8.98 i
	120	39.17 cde	4.80 def	34.42 c	10.07 a-d	9.76 fgh
	140	42.70 ab	5.60 ab	37.85 ab	10.60 a	12.18 cd
	160	41.74 abc	4.87 def	37.45 ab	10.20 abc	11.51 d
15	100	36.25 ef	4.40 f	29.44 e	9.53 bcd	9.31 hi
	120	40.95 abc	4.87 def	35.95 bc	10.07 a-d	10.35 efg
	140	43.13 a	5.60 ab	38.30 a	10.67 a	13.66 ab
	160	41.39 abc	5.47 abc	37.51 ab	10.53 ab	12.92 bc
25	100	36.38 ef	4.77 def	31.71 d	9.53 bcd	9.78 gh
	120	39.27 cde	5.07 cde	35.93 bc	9.80 a-d	10.58 e
	140	42.30 abc	5.40 abc	38.26 a	10.73 a	13. 40 ab
	160	40.72 abc	5.20 bcd	37.60 ab	10.60 a	12.61 c
35	100	37.66 def	4.57 ef	32.01 d	9.20 cd	9.77 fgh
	120	39.65 bcd	5.27 bcd	36.12 bc	9.47 cd	10.53 ef
	140	43.19 a	5.80 a	39.03 a	10. 73 a	13.80 a
	160	41.25 abc	5.53 abc	38.39 a	9.87 a-d	12.42 c
Signi. Level		*	*	*	*	**
$LSD_{0.05}$		2.73	0.45	1.83	0.89	0.71
CV(%)		4.09	5.34	3.08	5.32	3.74

** 1 % level of Significance; * 5 % level of Significance; NS Non-significant

4.5 Fresh foliage weight plant^{-1}

Effect of Sulfur

Fresh foliage weight (g) plant^{-1} production was significantly influenced by different doses of sulfur (Figure 9 and Appendix V). The maximum fresh foliage weight (11.69 g) was obtained at 25 kg ha^{-1} dose of S, which was statistically similar with 15 and 35 kg S ha^{-1} doses. The minimum fresh foliage weight (10.61 g) was found at the lowest dose of S (5 kg S ha^{-1}).

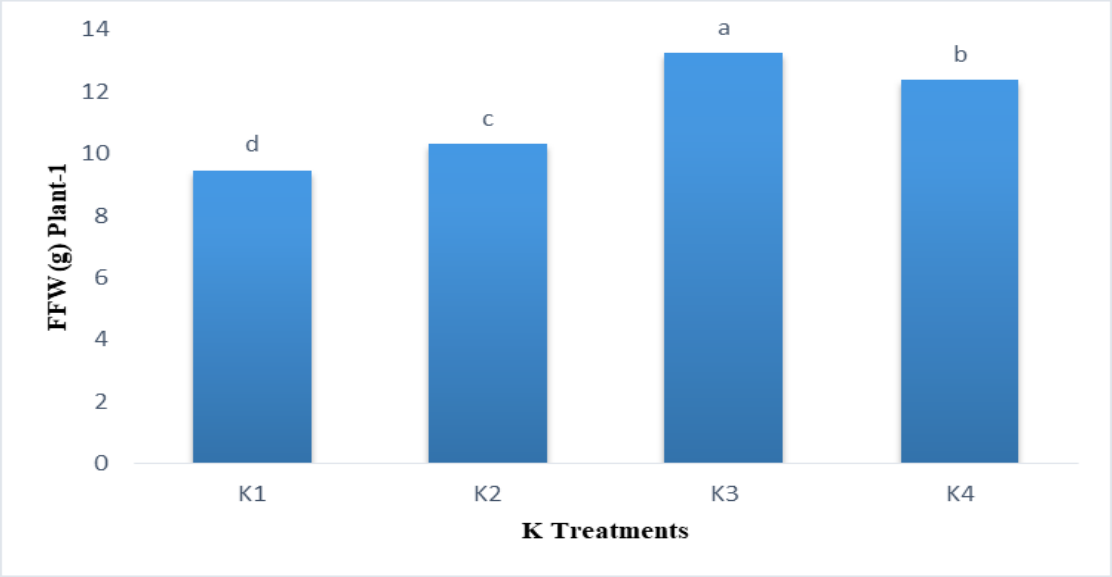


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 9. Effect of different doses of Sulfur on fresh foliage weight plant^{-1}

Effect of potassium

The result presented in Figure 10 and Appendix V shows that fresh foliage weight significantly increased with increasing the K doses upto 140 kg ha^{-1}, where the highest value was 13.26 g plant^{-1} and it was lowest (9.46 g plant^{-1}) at 100 kg ha^{-1} potassium dose.



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 10. Effect of different doses of potassium on fresh foliage weight plant^{-1}

Combined effect of sulfur and potassium

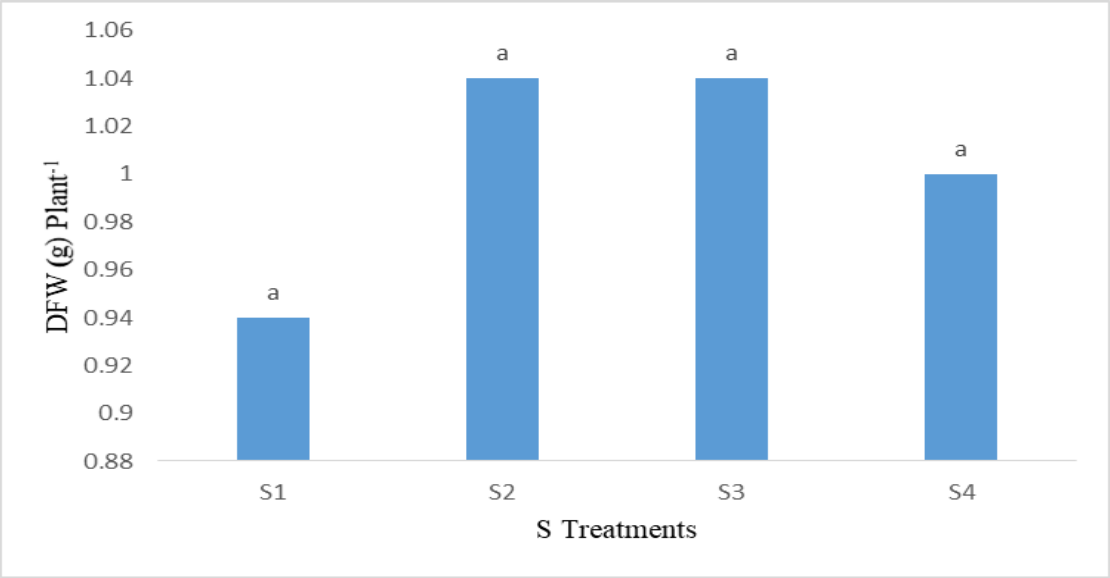
Fresh foliage weight (g) plant^{-1} was significantly influenced by the interaction of sulfur and potassium doses (Table 1). The maximum fresh foliage weight (13.80 g) accumulation was recorded at the combination of 140 kg K ha^{-1} with 35 kg ha^{-1} sulfur and minimum fresh foliage weight (8.98 g) accumulation was observed at the lowest dose of S and K combination (5 kg S ha^{-1} with 100 kg K ha^{-1}). Yadav et al. (2002) reported that more luxuriant growth, more foliage and leaf area due to more supply of K and S nutrients.

4.6 Dry foliage weight plant^{-1}

Effect of Sulfur

Dry foliage weight plant^{-1} (g) of the BARI Piaz-6 was not significantly influenced by different doses of sulfur (Figure 11 and Appendix VI). The highest dry foliage weight plant^{-1} was observed (1.04 gm) at 15 and 25 kg ha^{-1} sulfur application and the lowest dry foliage weight plant^{-1} was observed (0.94 gm) at 5 kg ha^{-1} sulfur application. Pradhan *et al.* (2015) did not find any

significant differences between different carriers of sulphur in response to bulb yield of onion.

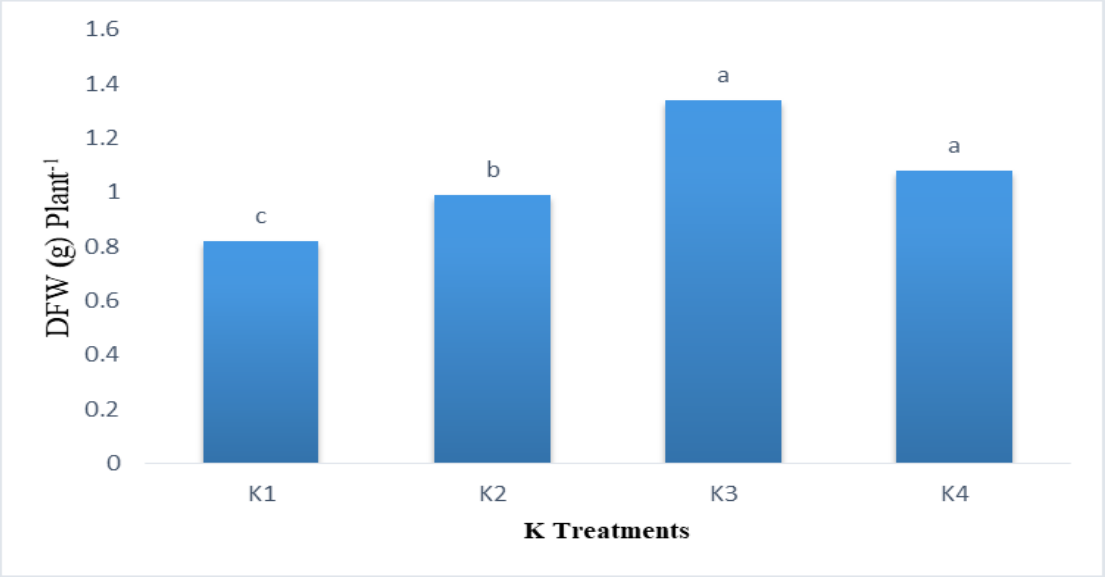


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 11. Effect of different doses of Sulfur on dry foliage weight plant^{-1}

Effect of potassium

Dry foliage weight plant^{-1} (g) was significantly influenced by the different doses of potassium (Figure 12 and Appendix VI). The highest dry foliage weight (1.34 g) was observed at 140 kg K ha^{-1}, which was statistically similar with 160 kg ha^{-1} dose of potassium. The lowest dose of potassium (100 kg K ha^{-1}) produced the minimum dry foliage weight (0.82 g). El-Bassiony (2006) also showed that higher dry foliage weight was obtained at 160 kg ha^{-1} dose of potassium.



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 12. Effect of different doses of potassium on dry foliage weight plant^{-1}

Combined effect of sulfur and potassium

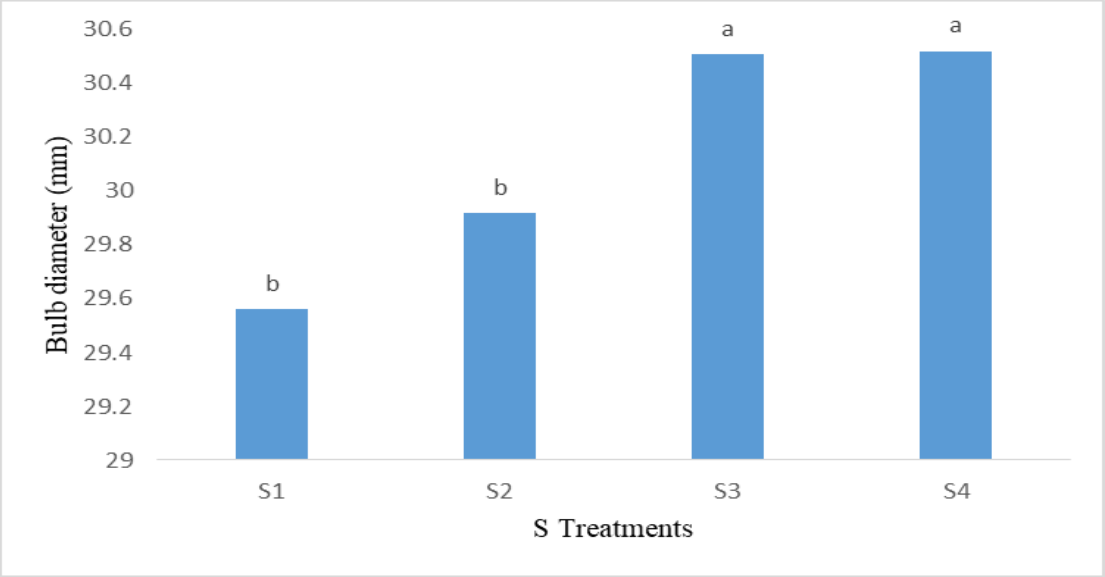
The interaction effect of different doses of S and K significantly influenced on dry foliage weight of BARI Piaz-6 (Table 2). The highest dry foliage weight (1.20 g) was found at 140 kg K ha^{-1} with 35 kg S ha^{-1} dose. The lowest dry foliage weight (0.76 g) was found at the lowest doses of S (5 kg S ha^{-1}) and K (100 kg K ha^{-1}) combination.

4.7 Bulb Diameter

Effect of Sulfur

There was a significant difference among the sulfur doses in the bulb diameter of BARI Piaz-6 (Figure 13 and Appendix VI). The maximum bulb diameter (30.52 mm) was found at 35 kg ha^{-1} dose of S, which was statistically similar with 25 kg S ha^{-1} dose. The minimum bulb diameter (29.56 mm) was obtained at 5 kg ha^{-1} dose of S, which was statistically similar with 15 kg S ha^{-1} dose. Behera *et al*. (2022) concluded a field experiment to study the "sulphur

application in onion for enlargement of bulb". The results indicate that the application of S @ 45 kg ha^{-1} gives higher bulb diameter both polar (5.16cm) and equatorial (5.63).

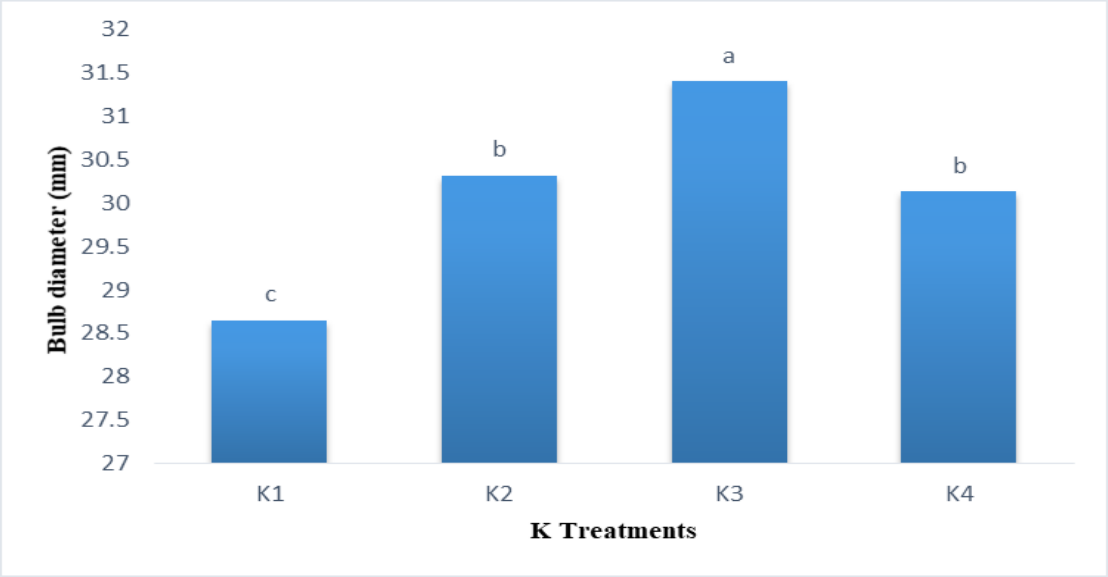


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 13. Effect of different doses of Sulfur on bulb diameter

Effect of potassium

The different doses of potassium showed significant variation in the bulb diameter of BARI Piaz-6 (Figure 14 and Appendix VI). The maximum bulb diameter (31.41 mm) was produced by 140 kg ha^{-1} dose of potassium, whereas the lowest dose of potassium (100 kg ha^{-1}) produced the minimum bulb diameter (28.65 mm). Similarly there is a report that potassium application at 125 kg ha^{-1} showed higher bulb length and bulb diameter when compared with control (Hariyappa, 2003).



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 14. Effect of different doses of potassium on bulb diameter

Combined effect of sulfur and potassium

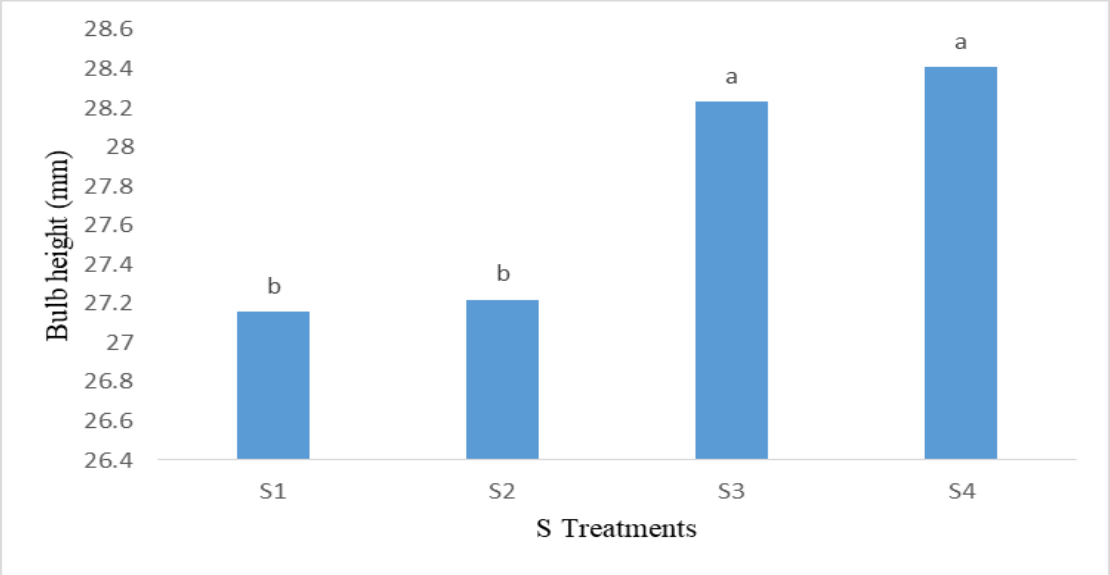
The interaction effect of different doses of S and K was significantly influenced on bulb diameter of BARI Piaz-6 (Table 2). The maximum bulb diameter (32.19 mm) was found at 35 kg S ha^{-1} with 140 kg K ha^{-1}, which was statistically similar with 120 kg K ha^{-1} at same dose S. The lowest values of bulb diameter (28.33 and 28.36 mm) were found at 100 kg K ha^{-1} with 5 and 15 kg ha^{-1} sulfur doses, respectively.

4.8 Bulb height

Effect of Sulfur

The different doses of sulfur were showed significant variation in the bulb height of BARI Piaz-6 (Figure 15 and Appendix VI). The highest bulb height (28.41 mm) was produced at S dose of 35 kg ha^{-1}, which was statistically similar with 25 kg S ha^{-1} dose. The minimum bulb height (27.16 mm) was obtained at 5 kg ha^{-1} dose of S, which was statistically similar with 15 kg S ha^{-1} dose. Behera *et al*. (2022) concluded a field experiment to study the "sulphur

application in onion for enlargement of bulb". The results indicate that the application of S @ 45 kg ha^{-1} gives higher bulb diameter both polar (5.16cm) and equatorial (5.63).

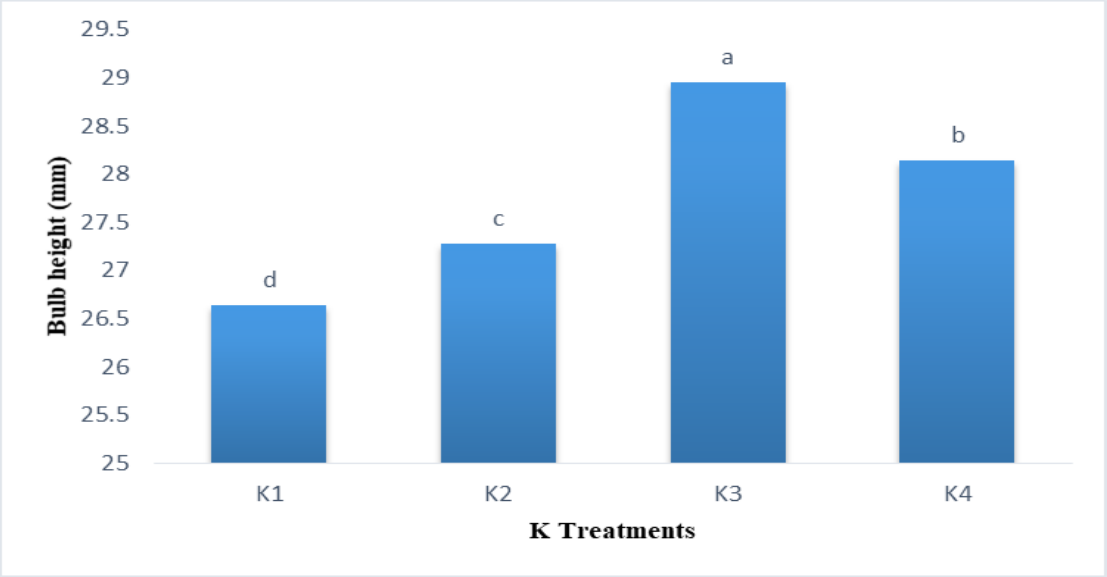


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 15. Effect of different doses of Sulfur on bulb height

Effect of potassium

There was a significant difference among the potassium doses in the bulb height of BARI Piaz-6 (Figure 16 and Appendix VI). The maximum bulb height (28.95 mm) was obtained by 140 kg ha^{-1} dose of and the minimum bulb height (26.64 mm) was found at the lowest dose potassium (100 kg K ha^{-1}). Similarly, there is a report that potassium application at 125 kg ha^{-1} showed higher bulb length and bulb diameter when compared with control (Hariyappa, 2003).



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 16. Effect of different doses of potassium on bulb diameter

Combined effect of sulfur and potassium

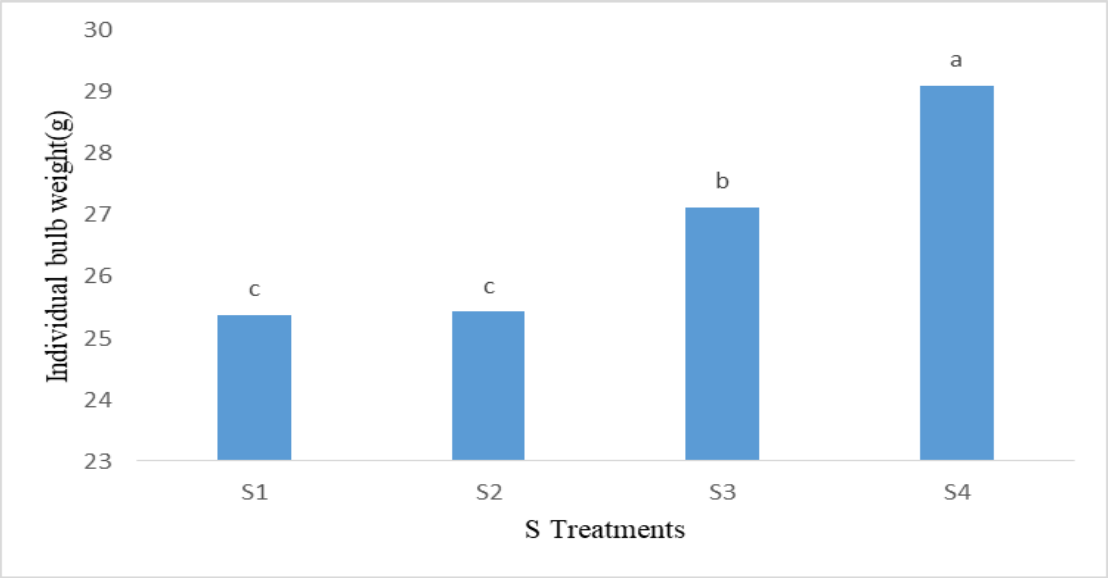
The bulb height indicated a significant variation among the treatment combinations of sulfur and potassium (Table 2). The maximum bulb height (29.75 mm) was found at 35 kg S ha^{-1} with 140 kg K ha^{-1}, which was statistically similar with 160 kg K ha^{-1} at same dose S. The lowest values of bulb height (26.13, 26.33 and 26.43 mm) were found at 100 kg K ha^{-1} with 5, 25 and 35 kg ha^{-1} sulfur doses, respectively; which were statistically similar with 120 kg ha^{-1} K dose at 25 kg ha^{-1} S dose.

4.9 Individual bulb weight

Effect of Sulfur

The individual bulb weight (g) of BARI Piaz-6 at four selected sulfur doses differed significantly due to the mean effect of different potassium doses (Figure 17 and Appendix VI). The highest individual bulb weight (29.11 g) was found at 35 kg ha^{-1} S dose. The lowest individual bulb weight (25.38 g) was recorded at 5 kg ha^{-1} S dose, which was statistically similar with 15 kg ha^{-1} S

dose. Bharti and Ram (2014) recorded the maximum values for yield and yield attributes in onion such as individual bulb weight (70.36 g).

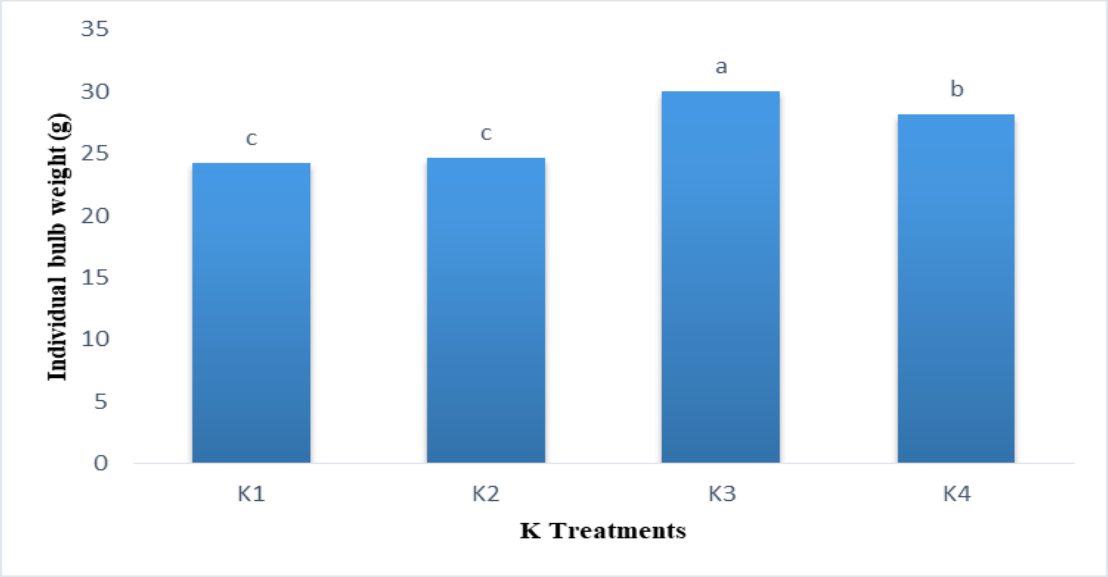


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 17. Effect of different doses of Sulfur on individual bulb weight

Effect of potassium

A highly significant variation in individual bulb weight of BARI Piaz-6 variety was observed at four selected K doses due to the mean effect of different sulfur doses (Figure 18 and Appendix VI). The highest individual bulb weight (30.01 g) was recorded at 140 kg ha^{-1} K dose and it was lowest (24.21 g) at 100 kg ha^{-1} K dose, which was statistically similar with 120 kg ha^{-1} K dose. Bekele (2018) stated that there was statistically highly significant ($p<0.001$) difference encountered in mean bulb weight due to application of K at different levels.



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 18. Effect of different doses of potassium on individual bulb weight

Combined effect of sulfur and potassium

It was evident from the Table 2 that interaction of sulfur and potassium doses significantly affected the individual bulb weight. The highest individual bulb weight (33.40 g) was found at 35 kg S ha^{-1} with 140 kg K ha^{-1} dose. The lowest values of individual bulb weight (22.40 and 22.93 g) were found at 5 kg S ha^{-1} with 100 and 120 kg ha^{-1} K doses, respectively. These results are in harmony with those reported by EL-Desuki et al. (2006) and Bekele (2018).

Table 2. Interaction effects of different doses of sulfur and potassium on dry foliage weight (DFW), bulb diameter, bulb height, individual bulb weight and bulb yield of BARI Piaz-6

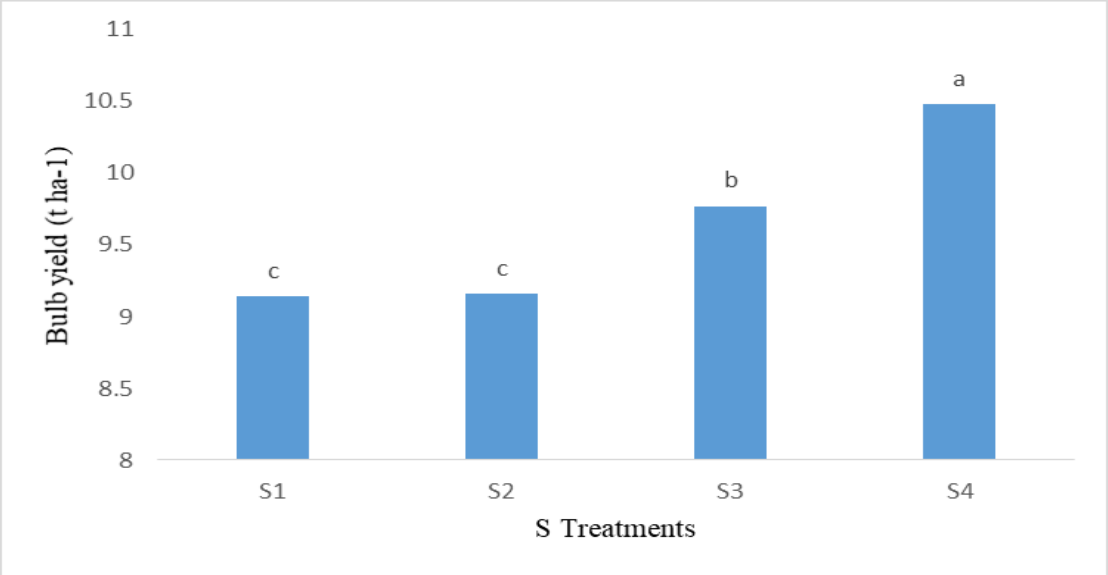
Treatment		DFW (g) Plant^{-1}	Bulb diameter (mm)	Bulb height (mm)	Individual bulb weight (g)	Bulb yield (t ha^{-1})
S doses (kg/ha)	K doses (kg/ha)					
5	100	0.76 f	28.33 f	26.13 f	22.40 i	8.06 i
	120	0.89 c-f	29.22 ef	26.78 ef	22.93 i	8.26 i
	140	1.10 ab	31.28 b	28.16 bcd	28.75 cd	10.35 cd
	160	1.02 a-e	30.23 cd	27.61 de	27.67 de	9.96 de
15	100	0.83 ef	28. 36 f	27.67 de	25.17 gh	9.09 fgh
	120	0.98 b-e	30.72 bc	27.97 cd	26.06 efg	9.38 ef
	140	1. 10 ab	31.28 b	29.06 ab	30.27 bc	10.90 bc
	160	1.16 ab	31.12 b	28.22 bcd	27.00 ef	9.72 ef
25	100	0.86 def	28.94 ef	26. 33 f	23.78 hi	8.56 hi
	120	1.07 abc	29.17 ef	26.44 f	23.91 hi	8.63 ghi
	140	1.14 ab	30.89 bc	28.83 abc	27.63 de	9.94 de
	160	1.10 ab	29.83 de	27.22 def	26.21 efg	9.44 ef
35	100	0.85 def	28. 94 ef	26.43 f	25.51 fgh	9.18 fg
	120	1.02 a-e	32.18 a	27.94 cd	25.74 fg	9.27 f
	140	1.20 a	32.19 a	29.75 a	33.40 a	12.02 a
	160	1.05 a-d	29.33 e	29.51 a	31.79 b	11.44 b
Signi. Level		*	**	**	**	**
$LSD_{0.05}$		0.18	0.82	0.97	1.60	0.57
CV(%)		11.05	1.63	2.10	3.58	3.55

** 1 % level of Significance; * 5 % level of Significance; NS Non-significant

4.10 Bulb yield

Effect of Sulfur

The different doses of sulfur were showed significant variation in the bulb yield (t/ha) of BARI Piaz-6 (Figure 19 and Appendix VI). The highest bulb yield (10.48 t ha^{-1}) was found at 35 kg ha^{-1} S dose and the lowest bulb yield (9.14 t ha^{-1}) was recorded at 5 kg ha^{-1} S dose, which was statistically similar with 15 kg ha^{-1} S dose. Mishu *et al*. (2013) conducted an experiment to study the effect of different doses of sulphur on growth and yield performances of onion. Application of 40 kg S ha^{-1} resulted in the highest yield (10.65 t ha^{-1}) among the different doses of sulphur which support the present study.

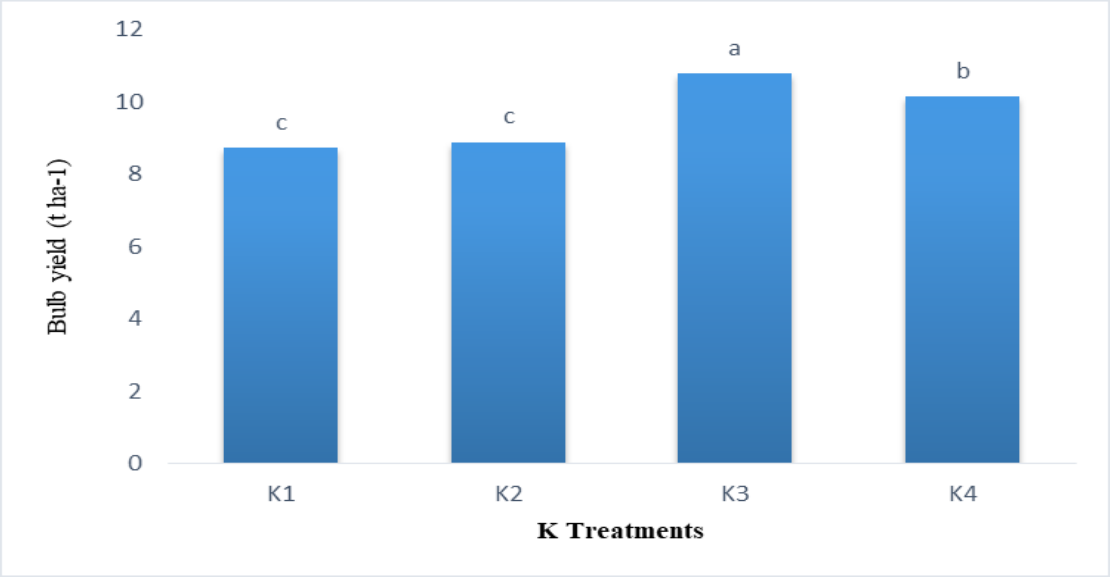


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 19. Effect of different doses of Sulfur on bulb yield

Effect of potassium

There was a significant difference among the potassium doses in the bulb yield of BARI Piaz-6 (Figure 20 and Appendix VI). The highest bulb yield (10.80 t ha^{-1}) was recorded at 140 kg ha^{-1} K dose and it was lowest (8.72 t ha^{-1}) at 100 kg ha^{-1} K dose, which was statistically similar with 120 kg ha^{-1} K dose. The results are in also in confirmation with the findings of Bekele (2018).



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 20. Effect of different doses of potassium on bulb yield

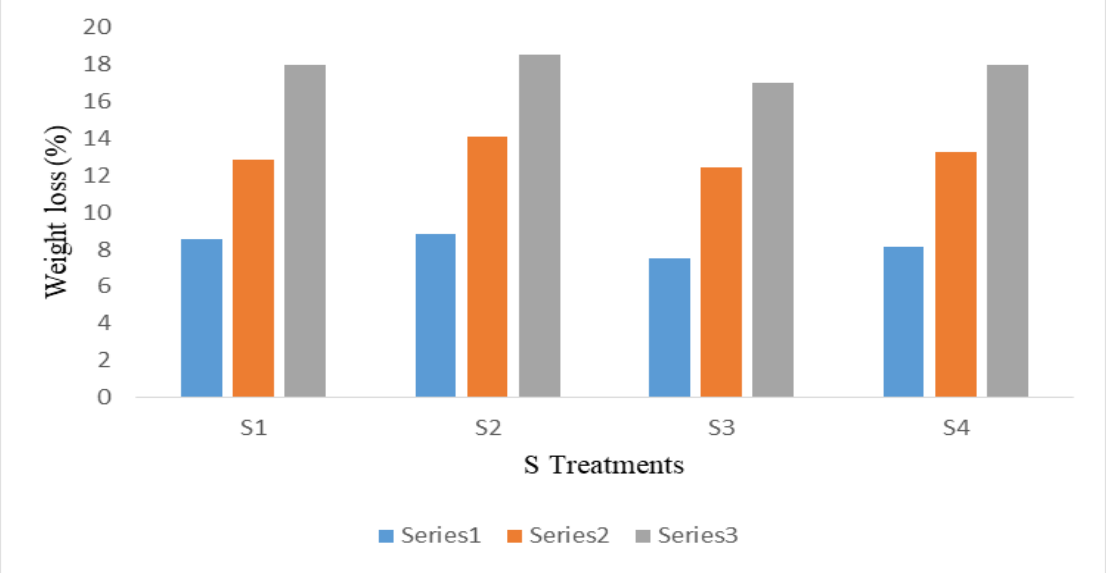
Combined effect of sulfur and potassium

The interaction effect of different doses of S and K significantly influenced on bulb yield of BARI Piaz-6 (Table 2). The maximum bulb yield (12.02 t ha^{-1}) was found at 35 kg S ha^{-1} with 140 kg K ha^{-1} dose. The lowest value of bulb yield (8.06 t ha^{-1}) was found at 5 kg S ha^{-1} with 100 kg K ha^{-1} and it was statistically similar at 5 kg S ha^{-1} with 120 kg ha^{-1} K dose. The increase in mean bulb weight with the supply of K and S nutrients could be due to more luxuriant growth, more foliage and leaf area and higher supply of photosynthates which helped in producing bigger bulb, hence resulting in higher yields. Similar results are reported that a significantly higher yield of bulb (24.7 t ha^{-1}) and fresh weight of bulbs (49.53 g) with application of 150 kg of K_2O ha^{-1} over other potassium levels (Yadav et al., 2002).

4.11 Weight losses of onion during storage at 1, 2 and 3 months interval

Effect of Sulfur

The percent weight losses of the BARI Piaz-6 were measured during storage at 1, 2 and 3 months interval with respect to weight of bulb at harvest. It was evident from Figure 21 and Appendix VII that the percent weight loss of the BARI Piaz-6 was not significantly influenced by different doses of sulfur during storage at 1, 2 and 3 months interval. But the highest weight losses were found in 15 kg ha^{-1} sulfur dose and the lowest weight losses also observed in 25 kg ha^{-1} sulfur dose at 1, 2 and 3 months interval (Figure 21 and Appendix VII).



S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

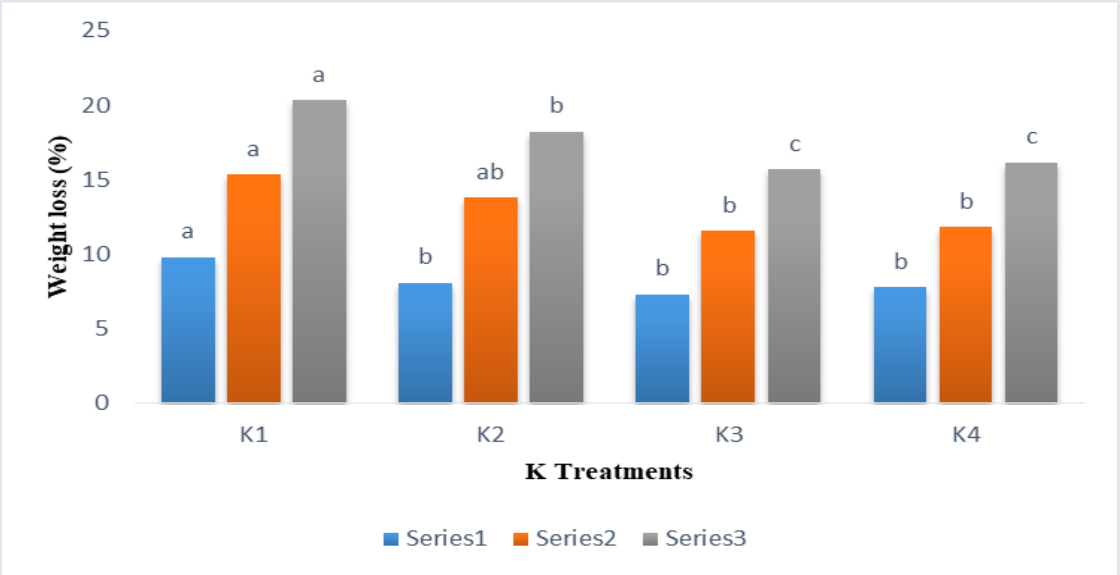
Series 1: Weight loss after 1 month of storage, Series 2: Weight loss after 2 month of storage, Series 3: Weight loss after 3 month of storage

Figure 21. Effect of different doses of Sulfur on weight loss after storage

Effect of potassium

The percent weight losses during storage at 1, 2 and 3 months interval were significantly influenced by different doses of potassium. The highest weight losses were found in 100 kg ha^{-1} K dose and the lowest weight losses observed

in 140 kg ha^{-1} K dose at 1, 2 and 3 months interval (Figure 22 and Appendix VII). Bekele (2018) reported that maximum application of potassium significantly decreased bulb rots (%), weight loss (%) and prolonged storage time at ambient storage temperature and humidity.



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Series 1: Weight loss after 1 month of storage, Series 2: Weight loss after 2 month of storage, Series 3: Weight loss after 3 month of storage

Figure 22. Effect of different doses of potassium on weight loss after storage

Combined effect of sulfur and potassium

It was evident from the Table 3 that interaction of sulfur and potassium doses significantly differed the percent weight losses during storage at 1, 2 and 3 months interval of BARI Piaz-6. In case of one month interval, the highest weight loss (11.36 %) was found at 15 kg S ha^{-1} with 100 kg K ha^{-1} dose and the lowest values of weight losses (6.69 and 7.24 %) were found at 140 kg K ha^{-1} with 25 and 15 kg ha^{-1} S doses, respectively. In case of 2 and 3 months interval, the highest weight losses (16.77 and 22.20 %) were found at 35 kg S

ha^{-1} with 100 kg K ha^{-1} dose, respectively. The lowest weight loss (10.22 %) was found in 160 kg K ha^{-1} with 25 kg ha^{-1} S dose at 2 months interval and 14.08 % weight loss in 140 kg K ha^{-1} with 5 kg ha^{-1} S dose at 3 months interval during storage (Table 3). These results confirmed the findings of Singh and Dankhar (1991) and Bekele (2018).

Table 3. Interaction effects of different doses of sulfur and potassium on weight losses of onion bulb during storage at 1, 2 and 3 months interval of BARI Piaz-6

Treatment		Weight losses of onion bulb during storage (%)		
S doses (kg/ha)	**K doses (kg/ha)**	**At 1 month interval**	**At 2 months interval**	**At 3 months interval**
5	100	10.61 ab	14.05 abc	18.04 b-e
	120	8.53 abc	13.78 abc	16.65 cde
	140	7.52 bc	11.77 abc	14.08 e
	160	7.50 bc	11.80 abc	15.36 de
15	100	11.36 a	15.90 ab	20.82 ab
	120	8.62 abc	14.40 abc	19.77 abc
	140	7.24 c	12.07 abc	16.35 cde
	160	8.07 bc	13.99 abc	17.10 b-e
25	100	8.38 abc	14.63 abc	20.37 abc
	120	7.42 bc	13.60 abc	18.55 a-d
	140	6.69 c	11.23 bc	17.60 b-e
	160	7.64 bc	10.22 c	15.29 de
35	100	8.90 abc	16.77 a	22.20 a
	120	7.77 bc	13.53 abc	17.96 b-e
	140	7.81 bc	11.28 bc	16.69 cde
	160	8.03 bc	11.43 bc	14.97 de
Signi. Level		*	*	**
$LSD_{0.05}$		2.75	4.28	3.48
CV(%)		20.00	19.51	11.87

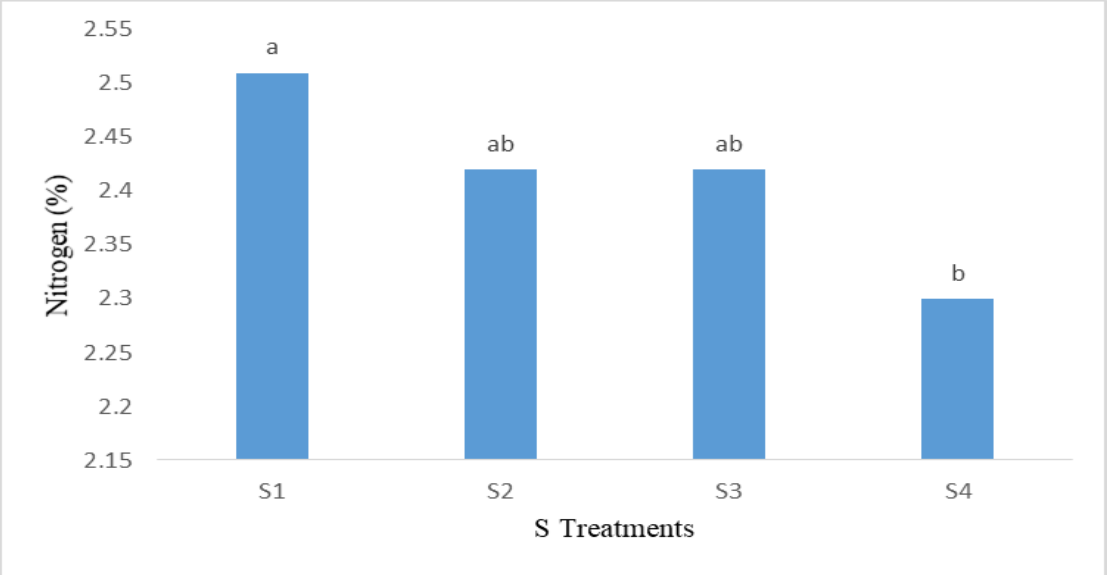
** 1 % level of Significance; * 5 % level of Significance

4.12 N, P, K and S concentrations in onion bulb

4.12.1.Nitrogen content

Effect of Sulfur

The percent content of nitrogen (N) in bulb of BARI Piaz-6 significantly varied grown due to the effect of different sulfur doses. The highest content of N (2.51%) found at 5 kg S ha^{-1} dose and the lowest (2.30%) at 35 kg ha^{-1} S dose (Figure 23 and Appendix VIII). Pradhan *et al*. (2015) observed no significant difference between different forms of sulphur (gypsum and elemental sulphur) in response to uptake of N, P, K, S by onion.

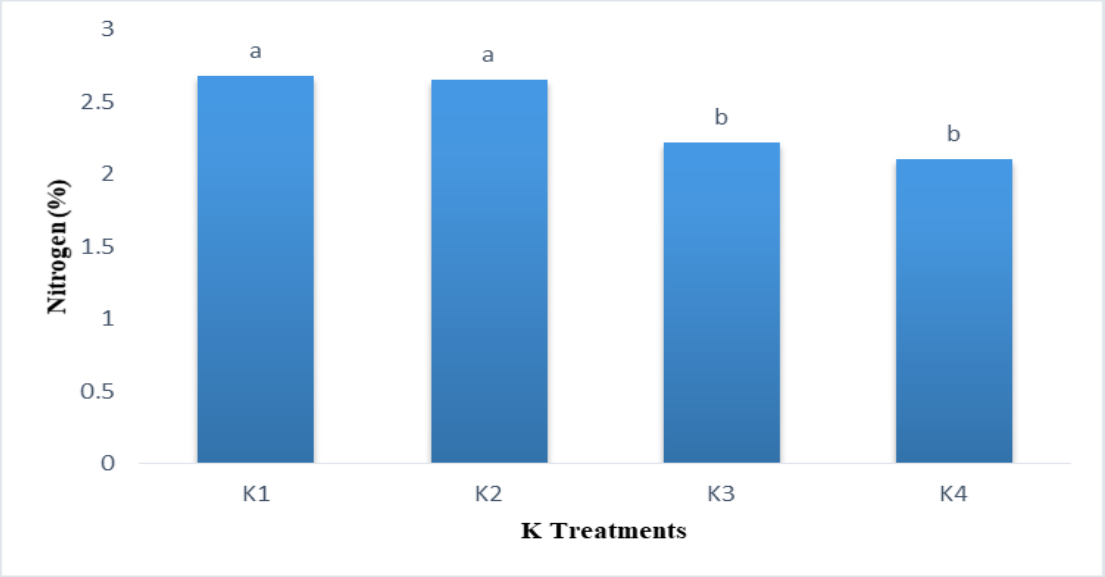


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 23. Effect of different doses of Sulfur on N content in bulb

Effect of potassium

The nitrogen content in onion significantly varied due to the effect of different doses of potassium; where the N content in bulb decreased with the increasing doses of potassium (Figure 24 and Appendix VIII).



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 24. Effect of different doses of potassium on N content in bulb

Combined effect of sulfur and potassium

The interaction effect of sulfur and potassium doses on content of N in onion was found significant. The highest N content (2.80%) found in BARI Piaz-6 at 120 kg K ha^{-1} dose with 5 and 25 kg S ha^{-1} doses. It was lowest (2.10%) at 160 kg ha^{-1} potassium dose with 5, 15, 25 and 35 kg ha^{-1} doses of sulfur and also at 140 kg ha^{-1} potassium dose with 25 and 35 kg ha^{-1} doses of sulfur (Table 4).

Table 4. Interaction effects of different doses of sulfur and potassium on percent N, P, K and S contents in bulb of BARI Piaz-6

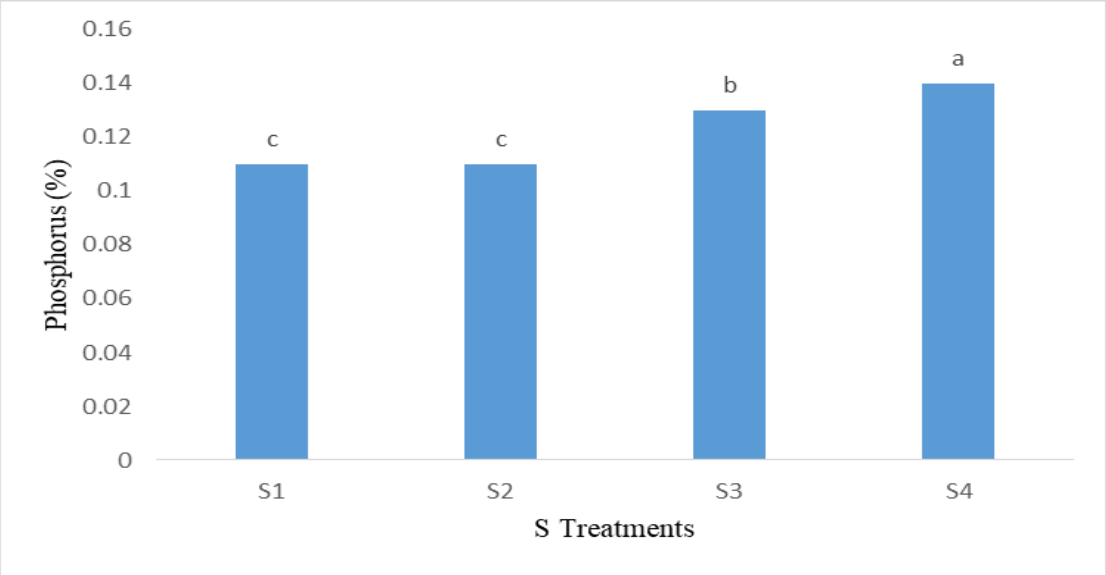
Treatment		Nutrients content in bulb			
S doses (kg/ha)	**K doses (kg/ha)**	N (%)	P (%)	K (%)	S (%)
5	100	2.68 ab	0.09 f	1.38 h	0.10 h
	120	2.80 a	0.10 ef	2.34 e	0.10 h
	140	2.45 bc	0.12 cd	3.07 c	0.12 f
	160	2.10 d	0.12 cd	3.23 b	0.12 f
15	100	2.68 ab	0.11 de	1.41 h	0.11 g
	120	2.68 ab	0.11 de	2.45 d	0.12 f
	140	2.22 cd	0.14 c	3.35 a	0.15 d
	160	2.10 d	0.10 ef	3.24 b	0.15 d
25	100	2.68 ab	0.11 de	1.57 g	0.14 e
	120	2.80 a	0. 13 c	2.46 d	0.15 d
	140	2.10 d	0.14 c	3.39 a	0.16 c
	160	2.10 d	0.11 de	3.14 bc	0.15 d
35	100	2.68 ab	0.11 de	1.73 f	0.14 e
	120	2.33 cd	0.17 b	2.46 d	0.16 c
	140	2.10 d	0.21 a	3.40 a	0.19 a
	160	2.10 d	0.11 de	3.16 bc	0.17 b
Signi. Level		*	**	**	**
$LSD_{0.05}$		0.27	0.016	0.11	0.009
CV(%)		6.68	3.19	2.47	2.79

** 1 % level of Significance; * 5 % level of Significance

4.12.2. Phosphorus content

Effect of Sulfur

The effect of sulfur doses showed significant variation of P concentration in onion bulb, where the P concentration increased with the increasing doses of sulfur (Figure 25 and Appendix VIII). The highest content of P (0.14%) found at 35 kg S/ha dose and the lowest (0.11%) at 5 and 15 kg/ha S dose.

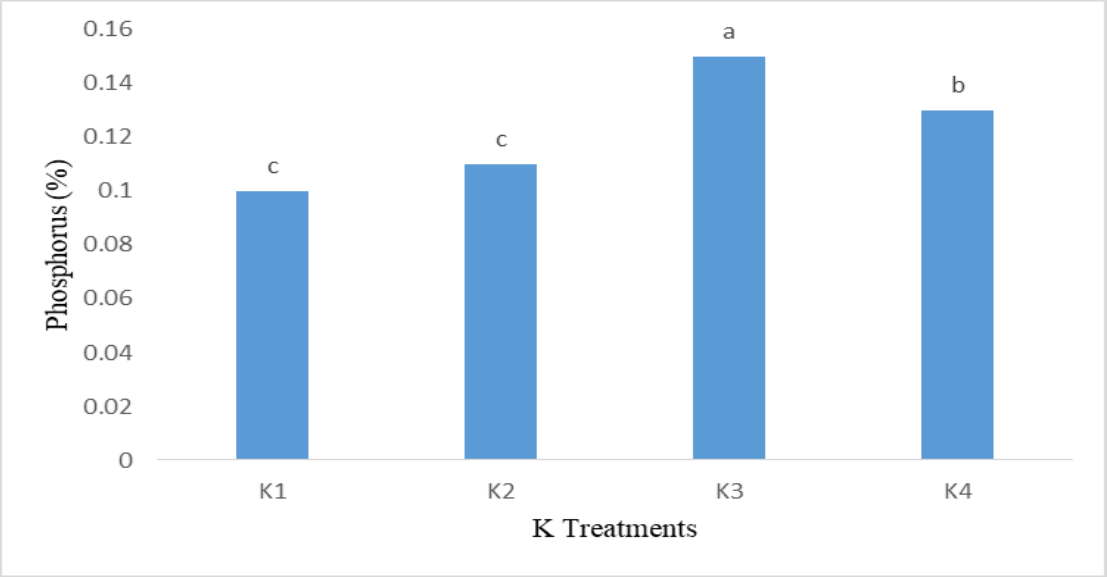


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 25. Effect of different doses of Sulfur on P Content in bulb

Effect of potassium

The effect of different doses of potassium showed significant variation of the P concentration in onion bulb (Figure 26 and Appendix VIII). Among the different doses of potassium, 140 kg K ha^{-1} dose showed the highest P concentration (0.15%) and the lowest P concentration (0.10%) was observed at 100 kg K ha^{-1} dose.



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 26. Effect of different doses of potassium on P content in bulb

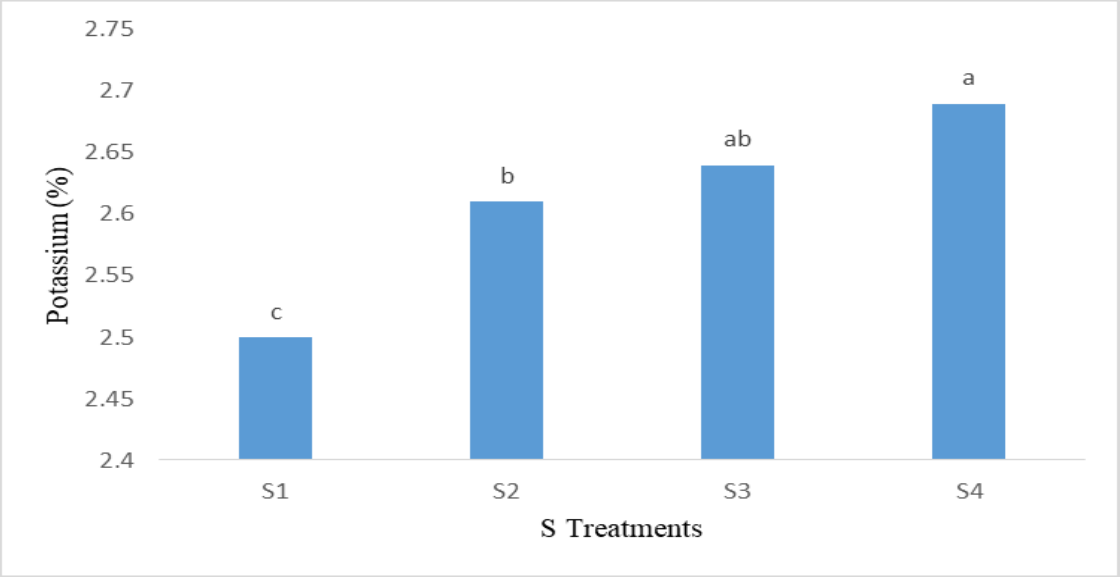
Combined effect of sulfur and potassium

Interaction effect of different doses of sulfur and potassium on the P concentration in onion was observed significant (Table 4). The highest concentration of P in onion (0.21%) was found at 35 kg/ha sulfur with 140 kg ha^{-1} potassium and the lowest P concentration (0.09%) was observed at 5 kg ha^{-1} sulfur with 100 kg/ha potassium.

4.12.3. Potassium content

Effect of Sulfur

It appears from the results presented in Figure 27 and Appendix VIII that there was a significant variation in potassium (%) content in BARI Piaz-6 due to different doses of sulfur under mean effect of different potassium doses, where the K content increased (2.50 – 2.69%) with the increasing doses of sulfur. Pradhan *et al*. (2015) observed no significant difference between different forms of sulphur (gypsum and elemental sulphur) in response to uptake of N, P, K, S by onion.

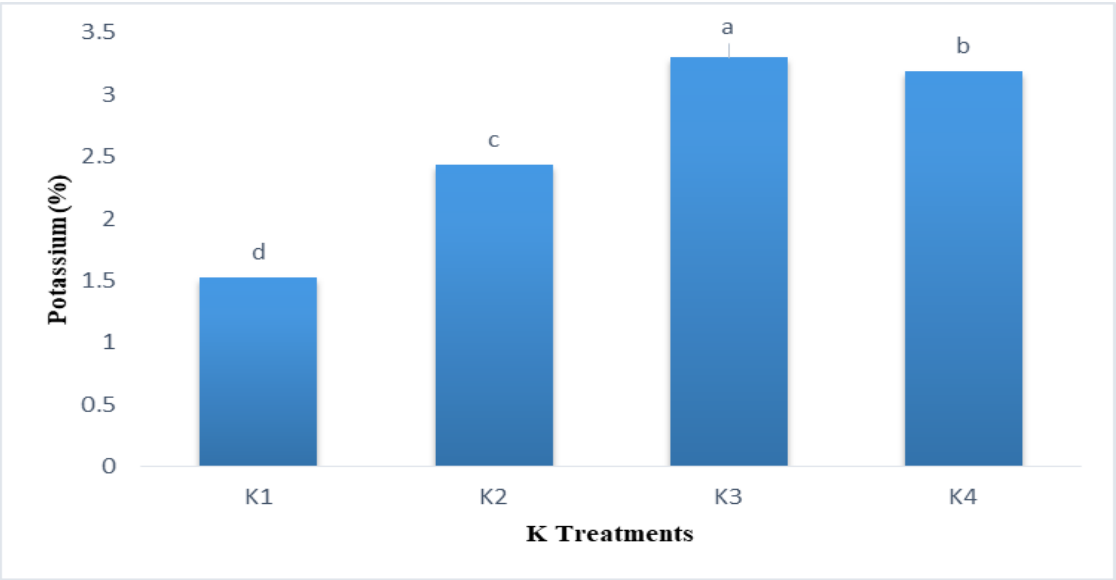


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 27. Effect of different doses of Sulfur on K content in bulb

Effect of potassium

The Potassium contents in plant of onion also significantly varied due to the effect of different doses of potassium (Figure 28 and Appendix VIII). The highest K content in onion (3.30%) was recorded at 140 kg ha^{-1} K dose and it was lowest (1.52%) at 100 kg ha^{-1} K dose.



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 28. Effect of different doses of potassium on K content in bulb

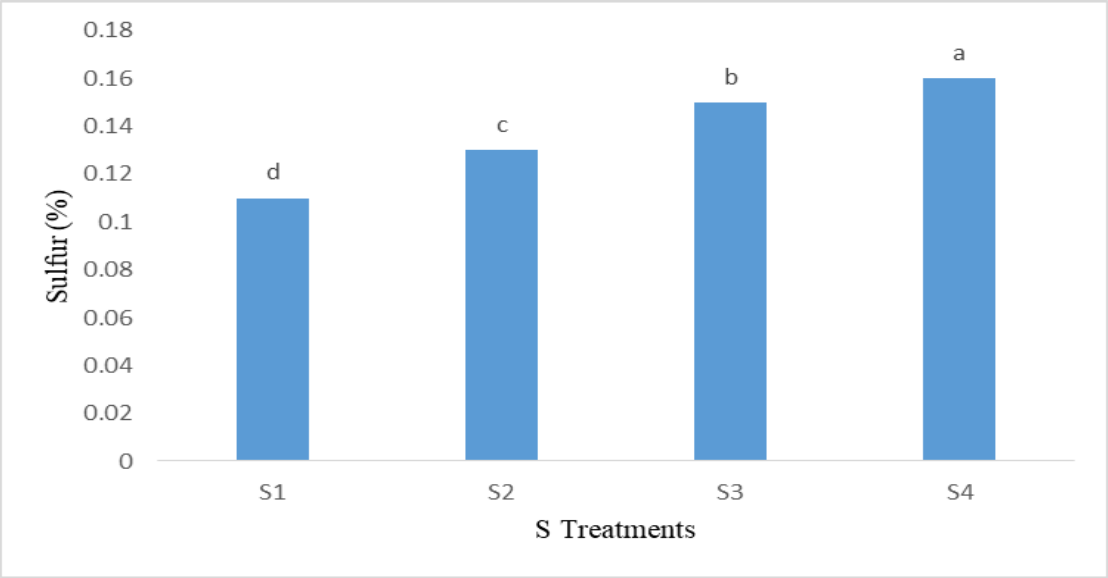
Combined effect of sulfur and potassium

The interaction effect of different doses of S and K was significantly influenced on K concentration in bulb of BARI Piaz-6 (Table 4). The highest K concentration (3.40%) was found at 140 kg ha^{-1} potassium dose with 35 kg ha^{-1} S dose, which was statistically similar with 15 and 25 kg ha^{-1} sulfur doses at same dose of potassium (140 kg ha^{-1}). The lowest K concentration (1.38%) was found at 100 kg ha^{-1} potassium dose with 5 kg ha^{-1} S dose, which was statistically similar with 15 sulfur doses at same dose of potassium (100 kg ha^{-1}).

4.12.4. Sulfur content

Effect of Sulfur

The percent content of S in bulb of onion significantly varied due to different doses of sulfur under mean effect of different potassium doses, where the S content increased (0.11 – 0.16%) with the increasing doses of sulfur (Figure 29 and Appendix VIII). Singh and Singh (2005) reported nitrogen, phosphorous and sulphur content and their uptake in the onion were significantly affected by different levels of sulphur.

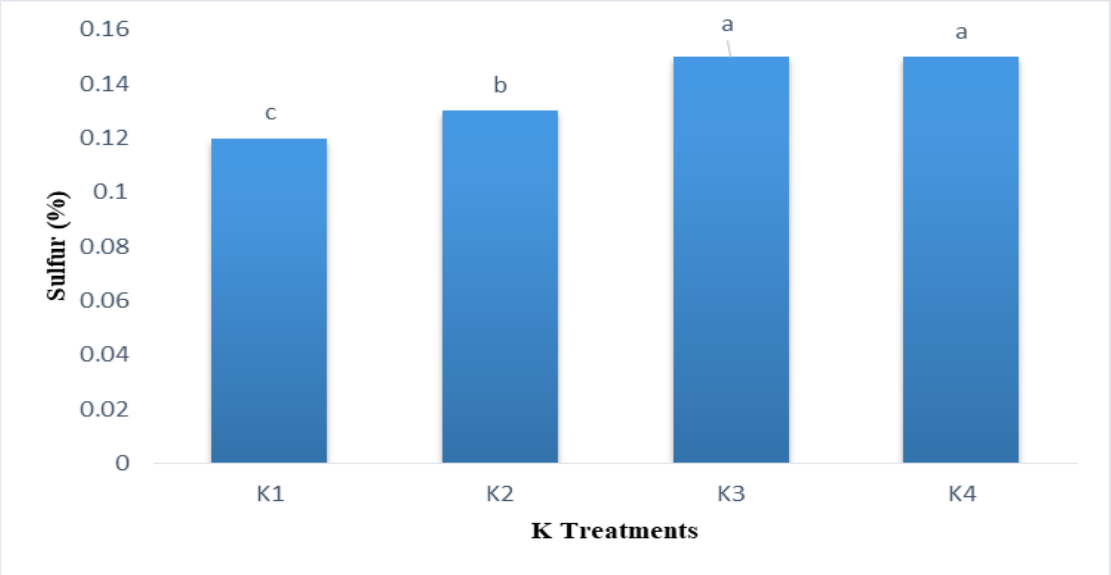


S_1 = 5 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 25 kg S ha^{-1} and S_4 = 35 kg S ha^{-1}

Figure 29. Effect of different doses of Sulfur on S content in bulb

Effect of potassium

The S content in bulb of onion significantly varied due to the effect of different doses of potassium, where the highest S content (0.15%) was found at 140 kg ha^{-1} potassium dose, which was statistically similar with 160 kg ha^{-1} potassium dose and the lowest S content at 100 kg K ha^{-1} dose (Figure 30 and Appendix VIII).



K_1= 100 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1} and K_4 = 160 kg K ha^{-1}

Figure 30. Effect of different doses of potassium on S content in bulb

Combined effect of sulfur and potassium

The interaction effect of different doses of sulfur and potassium on the S concentration in onion was observed significant (Table 4). The highest S concentration (0.19%) in bulb of BARI Piaz-6 was found at 35 kg ha^{-1} sulfur with 140 kg ha^{-1} potassium and the lowest S concentration (0.10%) was observed at 5 kg ha^{-1} sulfur with 100 and 120 kg ha^{-1} doses of potassium.

The presented data in the Table 7 and 8 clearly showed that the more application doses of K and S increased the uptake of P, K and S content in bulb of onion than the lower doses of K and S. These results are in harmony with those reported by EL-Desuki et al. (2006), Nagaich et al. (1999) and Sing and Verma (2001).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was undertaken at the farm of Sher-e-Bangla Agricultural University (SAU) and in the Department of Agricultural Chemistry, SAU, Dhaka, Bangladesh during October 2020 to June 2021 to observe the influence of different levels of potash and sulfur on growth, yield, storage life and nutrients content of BARI Piaz-6. The experiment was conducted using four levels of sulfur (5, 15, 25, and 35 kg S ha^{-1}) and four levels of potassium (100, 120, 140 and 160 kg K ha^{-1}). The experiment was set in Randomized Complete Block Design **(**RCBD) having two factors with three replications.

Data were noted specifically number of leaves, length of leaves (cm), neck diameter (mm), fresh foliage weight (g), dry foliage weight (g), diameter of bulb (cm), bulb height (cm), individual bulb weight (gm), bulb yield (t ha^{-1}), weight loss during storage and NPKS concentration in bullb. The collected data were evaluated and the differences between the means were evaluated by Duncan's Multiple Range Test. The experimental results are summarized as follows.

There was no significant difference among the doses of sulfur in the plant height, neck diameter, dry foliage weight $plant^{-1}$ and the percent weight loss at 1, 2 and 3 months interval with respect to weight of bulb at harvest of BARI Piaz-6.

The tallest plant (40.44 cm) was found when sulfur was applied 35 kg ha^{-1} and the shortest plant height (39.72 cm) in 5 kg S ha^{-1}. The highest neck diameter (10.20 mm) found at 15 kg ha^{-1} and the lowest neck diameter (9.78 mm) found at 35 kg ha^{-1} sulfur application. The highest dry foliage weight $plant^{-1}$ was observed (1.04 gm) at 15 and 25 kg ha^{-1} sulfur application and the lowest dry foliage weight $plant^{-1}$ was observed (0.94 gm) at 5 kg ha^{-1} sulfur application. The highest weight losses were found in 15 kg ha^{-1} sulfur dose and the lowest

weight losses also observed in 25 kg ha^{-1} sulfur dose at 1, 2 and 3 months interval.But significant difference was observed in the leaf number, leaf length, bulb diameter, bulb height, individual bulb weight, bulb yield, the concentration P, K and S in bulb of BARI Piaz-6 due to different doses of S. The maximum leaf number (5.29) was produced at the highest dose of S (35 kg S ha^{-1}). The minimum leaf number (4.83) was found at the lowest dose of S (5 kg S ha^{-1}). The highest leaf length (36.39 cm) was produced at S dose of 35 kg ha^{-1} and the lowest leaf length (34.48 cm) was produced at S dose of 5 kg ha^{-1}. The maximum bulb diameter (30.52 mm) was found at 35 kg ha^{-1} dose of S and the minimum bulb diameter (29.56 mm) was obtained at 5 kg ha^{-1} dose of S. The highest bulb height (28.41 mm) was produced at S dose of 35 kg ha^{-1} and the minimum bulb height (27.16 mm) was obtained at 5 kg ha^{-1} dose of S. The highest individual bulb weight (29.11 g) was found at 35 kg ha^{-1} S dose and the lowest individual bulb weight (25.38 g) was recorded at 5 kg ha^{-1} S dose. The highest bulb yield (10.48 t ha^{-1}) was found at 35 kg ha^{-1} S dose and the lowest bulb yield (9.14 t ha^{-1}) was recorded at 5 kg ha^{-1} S dose. The highest content of N (2.51%) found at 5 kg S ha^{-1} dose and the lowest (2.30%) at 35 kg ha^{-1} S dose. The highest content of P (0.14%) found at 35 kg S ha^{-1} dose and the lowest (0.11%) at 5 and 15 kg ha^{-1} S dose. The highest content of K (2.69%) found at 35 kg S ha^{-1} dose and the lowest (2.50%) at 35 kg ha^{-1} S dose. The highest content of S (0.16%) found at 35 kg S ha^{-1} dose and the lowest (0.11%) at 5 kg ha^{-1} S dose.

In case the effect of different doses of potassium showed significant variation in the above all parameters of BARI Piaz-6. The highest plant height (42.83 cm) was observed at 140 kg K ha^{-1} and the shortest plant (36.38 cm) was found at the lowest dose of potassium (100 kg K ha^{-1}). The maximum leaf number (5.60) was produced by 140 kg K ha^{-1} dose of potassium, whereas the lowest dose of potassium (100 kg K ha^{-1}) produced the minimum number of leaf (4.40). The maximum length of leaf (38.36 cm) was produced by 140 kg K ha^{-1} dose of potassium and the lowest dose of potassium (100 kg K ha^{-1}) produced

the minimum length of leaf (30.34 cm). The maximum neck diameter (10.68 mm) was produced by 140 kg ha^{-1} K dose and the lowest dose (100 kg ha^{-1}) of K produced the minimum neck diameter (9.35 mm). The highest fresh foliage weight $pant^{-1}$ was 13.26 g $plant^{-1}$ at 140 kg ha^{-1} potassium dose and it was lowest (9.46 g) at 100 kg ha^{-1} potassium dose. The highest dry foliage weight (1.34 g) was observed at 140 kg K ha^{-1} and the lowest dose of potassium (100 kg K ha^{-1}) produced the minimum dry foliage weight (0.82 g). The maximum bulb diameter (31.41 mm) was produced by 140 kg ha^{-1} dose of potassium, whereas the lowest dose of potassium (100 kg ha^{-1}) produced the minimum bulb diameter (28.65 mm). The maximum bulb height (28.95 mm) was observed by 140 kg ha^{-1} dose of and the minimum bulb height (26.64 mm) was found at the lowest dose potassium (100 kg K ha^{-1}). The highest individual bulb weight (30.01 g) was recorded at 140 kg ha^{-1} K dose and it was lowest (24.21 g) at 100 kg ha^{-1} K dose. The highest bulb yield (10.80 t ha^{-1}) was recorded at 140 kg ha^{-1} K dose and it was lowest (8.72 t ha^{-1}) at 100 kg ha^{-1} K dose. The highest weight losses were found in 100 kg ha^{-1} K dose and the lowest weight losses observed in 140 kg ha^{-1} K dose at 1, 2 and 3 months interval. The highest content of N (2.68%) found at 100 kg K ha^{-1} dose and the lowest (2.10%) at 160 kg ha^{-1} K dose. The highest P concentration (0.15%) was observed at 140 kg K ha^{-1} K dose and the lowest P concentration (0.10%) was observed at 100 kg K ha^{-1} dose. The highest K content in onion (3.30%) was recorded at 140 kg ha^{-1} K dose and it was lowest (1.52%) at 100 kg ha^{-1} K dose. The highest S content (0.15%) was found at 140 kg ha^{-1} potassium dose and the lowest S content (0.12%) at 100 kg K ha^{-1} dose.

The interaction effects of different doses of S and K significantly influenced on all growth and yield data. The highest plant height (43.19 and 43.13 cm) was found at 140 kg K ha^{-1} with 35 and 15 kg S ha^{-1} doses, respectively. The lowest plant height (35.25 cm) was found at the lowest doses of S (5 kg S ha^{-1}) and K (100 kg K ha^{-1}) combination. The maximum number of leaf (5.80) was found in 140 kg K ha^{-1} with 35 kg S ha^{-1} and the minimum number of leaf (3.87) was

found at the lowest dose of S and K combination (5 kg S ha^{-1} with 100 kg K ha^{-1}). The maximum length of leaf (39.03 cm) was found in 35 kg S ha^{-1} with 140 kg K ha^{-1} and the lowest values of leaf length (28.19 cm) were found at 100 kg K ha^{-1} with 5 kg ha^{-1} sulfur dose. The maximum neck diameter (10.73 mm) of onion was found at 140 kg ha^{-1} potassium with 25 and 35 kg ha^{-1} sulfur treatments combinations the minimum neck diameter (9.13 mm) was found at the lowest dose of S and K combination (5 kg S ha^{-1} with 100 kg K ha^{-1}). The maximum fresh foliage weight (13.80 g) accumulation was recorded at the combination of 140 kg K ha^{-1} with 35 kg ha^{-1} sulfur and minimum fresh foliage weight (8.98 g) accumulation was observed at the lowest dose of S and K combination (5 kg S ha^{-1} with 100 kg K ha^{-1}). The highest dry foliage weight (1.20 g) was found at 140 kg K ha^{-1} with 35 kg S ha^{-1} dose and the lowest dry foliage weight (0.76 g) was found at the lowest doses of S (5 kg S ha^{-1}) and K (100 kg K ha^{-1}) combination. The maximum bulb diameter (32.19 mm) was found at 35 kg S ha^{-1} with 140 kg K ha^{-1} and the lowest values of bulb diameter (28.33 and 28.36 mm) were found at 100 kg K ha^{-1} with 5 and 15 kg ha^{-1} sulfur doses, respectively. The maximum bulb height (29.75 mm) was found at 35 kg S ha^{-1} with 140 kg K ha^{-1} and the lowest values of bulb height (26.13, 26.33 and 26.43 mm) were found at 100 kg K ha^{-1} with 5, 25 and 35 kg ha^{-1} sulfur doses, respectively. The highest individual bulb weight (33.40 g) was found at 35 kg S ha^{-1} with 140 kg K ha^{-1} dose and the lowest values of individual bulb weight (22.40 and 22.93 g) were found at 5 kg S ha^{-1} with 100 and 120 kg ha^{-1} K doses, respectively. The maximum bulb yield (12.02 t ha^{-1}) was found at 35 kg S ha^{-1} with 140 kg K ha^{-1} dose and the lowest value of bulb yield (8.06 t ha^{-1}) was found at 5 kg S ha^{-1} with 100 kg K ha^{-1}. the highest weight loss (11.36 %) was found at 15 kg S ha^{-1} with 100 kg K ha^{-1} dose and the lowest values of weight losses (6.69 and 7.24 %) were found at 140 kg K ha^{-1} with 25 and 15 kg ha^{-1} S doses, respectively. In case of 2 and 3 months interval, the highest weight losses (16.77 and 22.20 %) were found at 35 kg S ha^{-1} with 100 kg K ha^{-1} dose, respectively. The lowest weight loss (10.22 %) was found in 160 kg

K ha^{-1} with 25 kg ha^{-1} S dose at 2 months interval and 14.08 % weight loss in 140 kg K ha^{-1} with 5 kg ha^{-1} S dose at 3 months interval during storage. The highest N content (2.80%) found in BARI Piaz-6 at 120 kg K ha^{-1} dose with 5 and 25 kg S ha^{-1} doses. It was lowest (2.10%) at 160 kg/ha potassium dose with 5, 15, 25 and 35 kg ha^{-1} doses of sulfur and also at 140 kg ha^{-1} potassium dose with 25 and 35 kg ha^{-1} doses of sulfur. The highest concentration of P in onion (0.21%) was found at 35 kg/ha sulfur with 140 kg ha^{-1} potassium and the lowest P concentration (0.09%) was observed at 5 kg ha^{-1} sulfur with 100 kg ha^{-1} potassium. The highest K concentration (3.40%) was found at 140 kg ha^{-1} potassium dose with 35 kg ha^{-1} S dose and the lowest K concentration (1.38%) was found at 100 kg ha^{-1} potassium dose with 5 kg ha^{-1} S dose. The highest S concentration (0.19%) in bulb of BARI Piaz-6 was found at 35 kg ha^{-1} sulfur with 140 kg ha^{-1} potassium and the lowest S concentration (0.10%) was observed at 5 kg ha^{-1} sulfur with 100 and 120 kg ha^{-1} doses of potassium.

From the results the following conclusions and recommendation may be made -

- The effect of different doses of sulfur and potassium were showed significant variation in the all growth and yield parameters of BARI Piaz-6, where the highest results were obtained at 35 kg/ha sulfur dose and 140 kg/ha potassium dose and also their combination.
- The significantly highest concentration of P, K and S in bulb of BARI Piaz-6 were found at 35 kg/ha sulfur dose and 140 kg/ha potassium dose and also their combination.
- The higher doses of potassium application significantly decreased bulb weight loss (%) in storage, where the lowest weight loss (10.22 %) and (14.08 %) were found in 160 kg K/ha with 25 kg/ha S dose at 2 months interval and in 140 kg K/ha with 5 kg/ha S dose at 3 months interval during storage, respectively.

- Optimization of different doses of potassium and sulfur fertilizers for the different varieties of onion under different agro-ecological conditions should be needed to understand their yield and storage performance.

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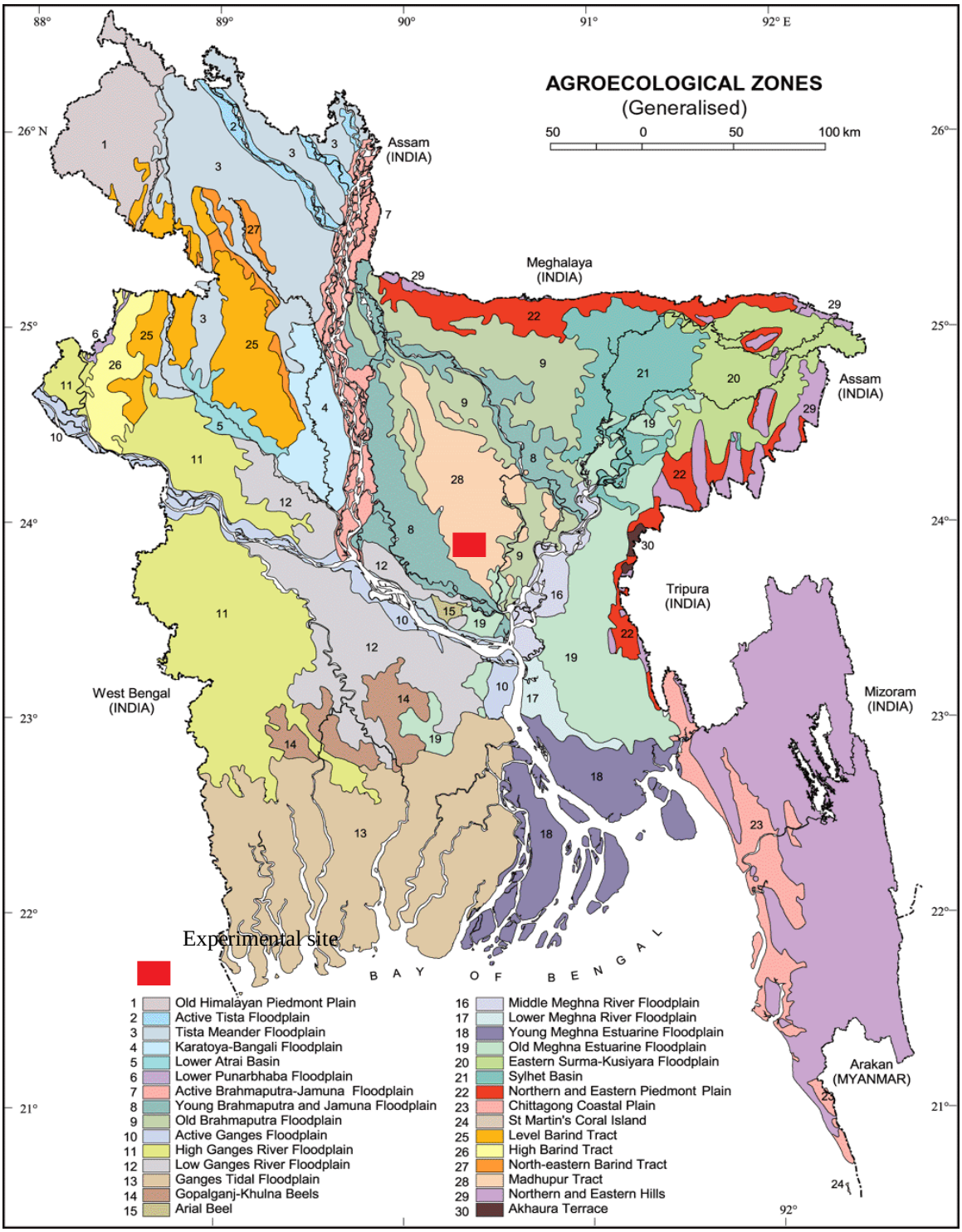
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2020 to March 2021.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2020	November	24.20	9.00	17.10	52.44	0
2020	December	23.70	7.60	16.65	59.40	0
2021	January	21.64	12.85	15.25	46.30	4
2021	February	24.40	16.44	16.42	51.28	1
2021	March	25.5	17.1	20.5	60.2	10

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

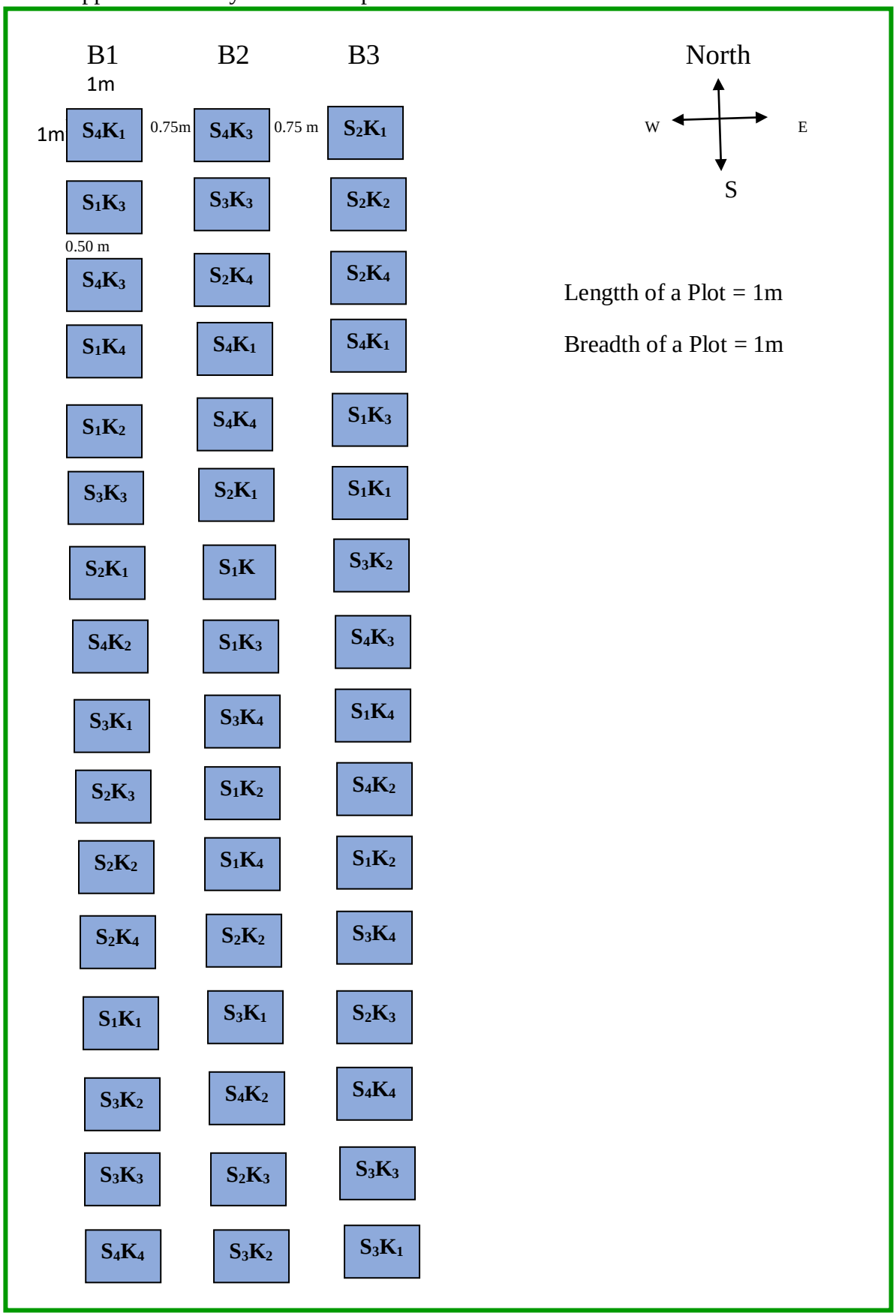
Morphological features	**Characteristics**
Location	Agronomy field , SAU, Dhaka
AEZ	Modhupur Tract (AEZ-28)
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Moderate
Cropping pattern	Not Applicable

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	25
%Silt	45
% Clay	30
Textural class	Silty Clay
pH	6
Organic carbon (%)	0.47
Organic matter (%)	0.80
Total N (ppm)	0.04
Available P (ppm)	22
Exchangeable K (me/100 g soil)	0.121
Available S (ppm)	16
Available Zn (ppm)	1.31
Available B (ppm)	0.16

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field



Appendix V. Effects of different doses of sulfur and potassium on plant height, leaf number, leaf length, neck diameter and fresh foliage weight (FFW) of BARI Piaz-6

Treatment	**Plant height (cm)**	**Leaf number Plant^{-1}**	**Leaf length (cm)**	**Neck dia-meter (mm)**	**FFW (g) Plant^{-1}**
S doses (kg/ha)					
5	39.72	4.78 b	34.48 c	10.03	10.61 b
15	40.43	5.08 a	35.30 bc	10.20	11.56 a
25	39.67	5.11 a	35.88 ab	10.17	11.69 a
35	40.44	5.29 a	36.39 a	9.78	11.53 a
Signi. Level	NS	**	**	NS	**
$LSD_{0.05}$	-	0.23	0.91	-	0.35
CV(%)	4.09	5.34	3.08	5.32	3.74
K doses (kg/ha)					
100	36.38 d	4.40 d	30.34 c	9.35 c	9.46 d
120	39.76 c	5.00 c	35.61 b	9.85 b	10.30 c
140	42.83 a	5.60 a	38.36 a	10.68 a	13.26 a
160	41.28 b	5.27 b	37.74 a	10.30 a	12.37 b
Signi. Level	**	**	**	**	**
$LSD_{0.05}$	1.36	0.23	0.91	0.45	0.35
CV(%)	4.09	5.34	3.08	5.32	3.74

Appendix VI. Effects of different doses of sulfur and potassium on dry foliage weight (DFW), bulb diameter, bulb height, individual bulb weight and bulb yield of BARI Piaz-6

Treatment	**DFW (g) Plant^{-1}**	**Bulb diameter (mm)**	**Bulb height (mm)**	**Individual bulb weight (g)**	**Bulb yield (t ha^{-1})**
S doses (kg/ha)					
5	0.94	29.56 b	27.16 b	25.38 c	9.14 c
15	1.04	29.92 b	27.22 b	25.44 c	9.16 c
25	1.04	30.51 a	28.23 a	27.13 b	9.77 b
35	1.00	30.52 a	28.41 a	29.11 a	10.48 a
Signi. Level	NS	**	**	**	**
$LSD_{0.05}$	-	0.41	0.49	0.80	0.29
CV(%)	11.05	1.63	2.10	3.58	3.55
K doses (kg/ha)					
100	0.82 c	28.65 c	26.64 d	24.21 c	8.72 c
120	0.99 b	30.32 b	27.28 c	24.66 c	8.89 c
140	1.34 a	31.41 a	28.95 a	30.01 a	10.80 a
160	1.08 a	30.13 b	28.14 b	28.17 b	10.14 b
Signi. Level	**	**	**	**	**
$LSD_{0.05}$	0.09	0.41	0.49	0.80	0.29
CV(%)	11.05	1.63	2.10	3.58	3.55

Appendix VII. Effects of different doses of sulfur and potassium on weight losses of onion bulb during storage at 1, 2 and 3 months interval of BARI Piaz-6

Treatment	Weight losses of onion bulb during storage (%)		
	At 1 month interval	At 2 months interval	At 3 months interval
S doses (kg/ha)			
5	8.54	12.85	17.95
15	8.82	14.09	18.51
25	7.53	12.42	17.03
35	8.13	13.25	17.95
Signi. Level	NS	NS	NS
$LSD_{0.05}$	-	-	-
CV(%)	20.00	19.51	11.87
K doses (kg/ha)			
100	9.81 a	15.34 a	20.36 a
120	8.08 b	13.83 ab	18.23 b
140	7.32 b	11.59 b	15.68 c
160	7.81 b	11.86 b	16.18 c
Signi. Level	*	*	**
$LSD_{0.05}$	1.38	2.14	1.74
CV(%)	20.00	19.51	11.87

** 1 % level of Significance; * 5 % level of Significance; NS Non-significant

Appendix VIII. Effects of different doses of sulfur and potassium on percent N, P, K and S contents in bulb of BARI Piaz-6

Treatment	Nutrients content in bulb			
	N (%)	P (%)	K (%)	S (%)
S doses (kg/ha)				
5	2.51 a	0.11 c	2.50 c	0.11 d
15	2.42 ab	0.11 c	2.61 b	0.13 c
25	2.42 ab	0.13 b	2.64 ab	0.15 b
35	2.30 b	0.14 a	2.69 a	0.16 a
Signi. Level	*	**	**	**
$LSD_{0.05}$	0.13	0.008	0.05	0.008
CV(%)	6.68	3.19	2.47	2.79
K doses (kg/ha)				
100	2.68 a	0.10 c	1.52 d	0.12 c
120	2.65 a	0.11 c	2.43 c	0.13 b
140	2.22 b	0.15 a	3.30 a	0.15 a
160	2.10 b	0.13 b	3.19 b	0.15 a
Signi. Level	**	**	**	**
$LSD_{0.05}$	0.13	0.008	0.05	0.008
CV(%)	6.68	3.19	2.47	2.79

Appendix IX. Some photos document during experiment