EFFECT OF POTASSIUM AND SULPHUR ON THE GROWTH AND YIELD OF POTATO (*Solanum tuberosum* L.)

NOWSHIN MOSTARI DINA

DEPARTMENT OF SOIL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

JUNE, 2022

EFFECT OF POTASSIUM AND SULPHUR ON THE GROWTH AND YIELD OF POTATO (*Solanum tuberosum* L.)

BY

NOWSHIN MOSTARI DINA

REGISTRATION NO. : 15-06596

Email: nowshindina1996@gmail.com
Mobile: 01722-584792

A Thesis
Submitted to the Department of Soil Science
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

SOIL SCIENCE

SEMESTER: JANUARY- JUNE, 2021

Approved by:

(Dr. Md. Asaduzzaman Khan)
Professor
Department of Soil Science
SAU, Dhaka
Supervisor

Mst. AfroseJahan
Professor
Department of Soil Science
SAU, Dhaka
Co-Supervisor

Prof. Dr. Mohammad Saiful Islam Bhuiyan
Chairman
Department of Soil Science, SAU, Dhaka
Examination Committee

DEPARTMENT OF SOIL SCIENCE
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar,Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF POTASSIUM AND SULPHUR ON THE GROWTH AND YIELD OF POTATO (*Solanum tuberosum* L.)"** submitted to the **Department of Soil Science**, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (MS)** in **SOIL SCIENCE**, embodies the result of a piece of bonafide research work carried out by **Nowshin Mostari Dina**, Registration No. **15-06596** 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.

June, 2022
Dhaka, Bangladesh

(Dr. Md. Asaduzzaman Khan)
Professor
Department of Soil Science
SAU, Dhaka

Dedicated to

My

Beloved Parents

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the almighty Allah for there ever ending blessings for the successful completion of the research work.

The author wishes to express her gratitude and best regards to his respected Supervisor, ***Dr. Md. Asaduzzaman Khan****, Professor, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.*

The author wishes to express her earnest respect, sincere appreciation and enormous indebtedness to her reverend Co-supervisor, ***Mst. Afrose Jahan****, Professor, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his scholastic supervision, helpful commentary and unvarying inspiration throughout the research work and preparation of the thesis.*

The author feels to express her heartfelt thanks to the honorable Chairman, ***Dr. Mohammad Saiful Islam Bhuiyan,*** *Professor, Department of Soil Science along with all other teachers and staff members of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for their co-operation during the period of the study.*

The author feels proud to express her deepest and endless gratitude to all of her course mates and friends to cooperate and help her during taking data from the field and preparation of the thesis. The author wishes to extend her special thanks to her lab mates, class mates and friends for their keen help as well as heartiest co-operation and encouragement.

The author expresses her heartfelt thanks to her beloved parents, elder Sister and brother and all other family members for their prayers, encouragement, constant inspiration and moral support for her higher study. May Almighty bless and protect them all.

The Author

EFFECT OF POTASSIUM AND SULPHUR ON THE GROWTH AND YIELD OF POTATO (*Solanum tuberosum* L.)

ABSTRACT

The experiment was conducted during November 2021 to February 2022 in the farm of Sher-e-Bangla Agricultural University. The experiment consisted of two factors: Factor A: three K levels *viz*. control K_0 (0 kg K ha^{-1}), K_1 (120 kg K ha^{-1}) and K_2 (160 kg K ha^{-1}) and Factor B: three S levels *viz*. control S_0 (0 kg S ha^{-1}), S_1 (15 kg S ha^{-1}) and S_2 (25 kg S ha^{-1}). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Different potassium and sulphur levels influenced significantly on most of the recorded parameters. In case of different K levels, the highest results regarding growth, yield and yield contributing parameters were obtained from K_2 (160 kg K ha^{-1}) compared to K_1 (120 kg K ha^{-1}) and control. K_2 (160 kg K ha^{-1}) showed the highest number of tuber $hill^{-1}$ (7.47), weight of tuber $hill^{-1}$ (273.90 g), dry weight of 100 g fresh tuber (22.43 g), tuber weight $plot^{-1}$ (14.24 kg) and tuber yield ha^{-1} (28.48 t). Available P, K and S content of post-harvest soil was also highest from K_2 (160 kg K ha^{-1}) treatment whereas pH and OC content were not affected by K treatments. Regarding sulphur treatment, S_1 (15 kg S ha^{-1}) showed best results on most of the yield and yield contributing parameters compared to S_2 (25 kg S ha^{-1}) and control. Treatment S_1 (15 kg S ha^{-1}) showed the highest number of tuber $hill^{-1}$ (7.15), weight of tuber $hill^{-1}$ (252.40 g), dry weight of 100 g fresh tuber (21.41 g), tuber weight $plot^{-1}$ (13.13 kg) and tuber yield ha^{-1} (26.25 t). The S content of postharvest soil affected significantly and S_2 (25 kg S ha^{-1}) treatment gave highest result (28.47 ppm) whereas pH, OC, P and K content were not affected by S treatments. In terms of treatment combination of potassium and sulphur, the treatment combination K_2S_1 showed the highest number of tuber $hill^{-1}$ (7.87), weight of tuber $hill^{-1}$ (285.90 g), dry weight of 100 g fresh tuber (23.62 g), tuber weight $plot^{-1}$ (14.87 kg) and tuber yield ha^{-1} (29.73 t) whereas the lowest was recorded from K_0S_0. The P, K and S content of postharvest soil, significantly affected by interaction of K and S. The highest concentration of N, K and S (24.20 ppm, 1.10 meq/100 g soil, and 29.32 ppm, respectively) was recorded from K_2S_2 while the lowest was from K_0S_0 whereas pH and OC content of postharvest soil did not differ significantly among the treatment combinations. So, the treatment combination of K_2S_1 (160 kg K ha^{-1} with 15 kg S ha^{-1}) can be considered as best compared to the rest of the treatment combinations in terms of potato yield.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
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
FAO	=	Food and Agricultural Organization
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^{o}C	=	Degree Celceous
mg	=	Miligram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to the Solanaceae family and is a widely cultivated tuber crop worldwide. It is the fourth largest world food crop after rice, wheat, and maize (Ahmed *et al*., 2017; Chakraborty *et al*., 2010). Its origin can be traced back to the central Andean region of South America (Keeps, 1979). The crop ranks fourth in the world after wheat, rice, and maize in terms of production. Bangladesh is the seventh largest producer of potatoes globally (FAOSTAT, 2019). Potatoes are not only a source of energy, but they also provide significant amounts of high-quality protein, essential vitamins, minerals, and trace elements that are important for a balanced diet (Horton, 1987). Potatoes are rich in vitamins, especially vitamin C and B, and minerals. Tubers are composed of 70-80% water, 20.6% carbohydrate, 2.1% protein, 0.3% fat, 1.1% crude fibre, and 0.9% ash (Banerjee *et al*., 2016).

In Bangladesh, potato cultivation is the second largest agricultural activity after rice production, in terms of yield. The country has a total area of 0.47 million hectares dedicated to potato farming, with an average yield of 20.41 metric tons per hectare, and a total production of 9.74 million metric tons (BBS, 2019). The production of potatoes is steadily increasing in Bangladesh due to the high demand for the crop, which is also considered a vegetable crop and accounts for 55% of total vegetable production in the country (BBS, 2013). However, the yield of potatoes in Bangladesh is still lower compared to other major potato-growing countries around the world. For example, the USA has a yield of 50.30 metric tons per hectare, Denmark has a yield of 42.48 metric tons per hectare, and the UK has a yield of 36.47 metric tons per hectare, as reported by FAO in 2019.

Potato is a high yielding and exhaustive crop, thus requiring a variety of balanced plant nutrients for growth and development. Nitrogen (N), Phosphorus (P) and Potassium (K) are among the most important elements that are essential for potato productivity. Potassium (K) is an important macro nutrient for vegetable crops, including potato, because plant requirements for K are higher than any other macro nutrient after nitrogen (Bishwoyog and Swarnima, 2016; Farheen *et al.*, 2018). The function of K in photosynthesis is well known and can improve photosynthate translocation, enzyme activities, and the synthesis of proteins, carbohydrates, and fats, and is responsible for higher crop productivity (Mello *et al.*, 2018). Moreover, K is highly involved in potato plant growth and development (Naby *et al.*, 2018; Kumar and Chandra, 2018), and can assist plants in adapting to biotic and abiotic stressors such as pathogens, drought, and extreme temperatures (Naumann *et al.*, 2020). Potassium application significantly increased plant height, leaf area index, average tuber weight, and number of tubers per plant, total yield and marketable yield and specific gravity of the tubers potato (Anwar *et al.*, 2016; Gupta *et al.*, 2017; Gildersleeve *et al.*, 2021).

Sulfur (S) is the fourth most essential nutrient after nitrogen (N), phosphorus (P), and potassium (K) with a direct role in amino acid syntheses, such as methionine, cysteine, and N assimilation. Potato is a fast-growing vegetable crop with a small crop cycle; therefore, nutrient applications at the appropriate time, place, rate, and source are essential (Ayush *et al*., 2023). Gupta *et al*. (2016) reported that application of sulphur has significant and positive effect on total tuber yield, average tuber weight, and number of tubers per plant. Sulfur application improved the quality of potato tubers by increasing the ascorbic acid content and decreasing the reducing sugar content (Meena *et al*., 2018). Zhang *et al*. (2021) reported that sulfur application significantly increased the tuber yield and starch content of potato.

It is evident that uses of potassium and sulphur are very important variables in potato production. The aim of this work was to evaluate the effect of potassium and sulphur on the growth and yield of potato (BARI alu-25; ASTORIX) in Bangladesh with the following objectives:

1. To find out the effect of potassium on growth and yield of potato
2. To find out the effect of sulphur on growth and yield of potato
3. To study the combined effect of potassium and sulphur on growth and yield of potato

CHAPTER II

REVIEW OF LITERATURE

Potato (*Solanum tuberosum* L.) is considered a major food crop in the world. Very few researches are available regarding the requirement of potassium (K) and sulphur (S) for growth, and tuber production of potato. The nitrogen (N), phosphorus (P) and potassium (K) levels on potato has been studied in various part of the world. But very limited studies have been done on this crop in Bangladesh in respect of potassium (K) and sulphur (S) requirement. A brief review of these pertinent to the present study has been given below:

2.1 Effect of potassium (K)

Gutema (2021) conducted an on-farm experiment to assess the effect of potassium fertilizer rate on yield and yield related parameters of 'Irish potato (*SolanumTuberosum* L.). Factorial combinations of two potato varieties (Ararsa and Moti) and five rates of potassium fertilizer (0, 25, 50, 75 and 100 kg K ha^{-1}) were laid out in a randomized complete block design. Analysis of variance showed that the main effects of potassium fertilizer significantly influenced (days to 50% flowering, plant height, number of tuber per plant, number of marketable tuber per plot, marketable tuber yield and total tuber yield) had highly significant ($P<0.01$) while non-significant for days to 90% maturity, number of unmarketable tuber per plant and unmarketable tuber yield. An improved varieties Ararsa and Moti were produce the highest marketable tuber yields of 21.23 t ha^{-1} and 19.50 t ha^{-1}, respectively, with application of 100 kg KCl ha^{-1} and with the application of recommended rate of NP fertilizer while the lowest marketable yields of 15.01 t ha^{-1} and 14.96 t ha^{-1} from Ararsa and Moti Varieties, respectively, were obtained from unfertilized KCl fertilizers treatment, respectively. Therefore, it can tentatively be concluded that application of 100 kg KCl ha^{-1} and recommended rate of NP fertilizer best to optimum tuber production.

Ali *et al*. (2021) carried out a research work to evaluate the effect of soil (S) and foliage (F) applied potassium on the growth, yield, and quality of potato plants. Potassium was added in soil at the recommended rate for all the treatments combining mineral fertilizers with K-feldspar and biofertilizers, while foliar spraying included the application of potassium citrate (PC), potassium silicate (PS), and monopotassium phosphate (MP). The obtained results showed that plant height was highest following treatment with 100% mineral potassium fertilizer under the foliar application of MP, while the content of P, K, and total carbohydrates in leaves also increased with the same fertilization treatment. On the other hand, the highest values for number of stems and fresh and dry weight per plant, as well as the highest nitrogen content in leaves, were obtained after the addition of mineral potassium fertilizer and the foliar spraying of PC, regardless of the growing season. Yield parameters were positively affected by the combination of mineral potassium fertilizers (100% or 80% K_2SO_4 + 20% K-feldspar + biofertilizer) and the foliar spraying of MP, while the total nitrogen, protein, amino acids, potassium, phosphorus, and starch content of tubers were positively affected by the same mineral fertilizer treatments combined with foliar spraying of MP or CP. In conclusion, the application of mineral potassium fertilizer with foliar spraying of MP or CP increased most of the plant growth- and tuber chemical composition-related parameters. These results highlight the importance of potassium fertilizer regimes for achieving high tuber yields and improving the quality of tubers in a sustainable and cost-effective manner.

Gildersleeve *et al*. (2021) carried out a study on the effect of potassium fertilization on the yield and quality of organically grown potato. The study found that the application of potassium sulfate at a rate of 168 kg ha^{-1} significantly increased the total tuber yield, marketable yield, and specific gravity of the tubers.

Molina-Rueda *et al*. (2019) studied the effect of potassium on potato yield and quality parameters in Colombia. The study found that potassium application significantly increased the yield and quality of potato tubers. The results showed that the highest yield per plant and yield per ha was obtained with a potassium application rate of 200 kg MoP ha^{-1}.

Khan *et al*. (2019) conducted an experiment to evaluate the impact of Potassium (K) and Zinc (Zn) on quantitative and qualitative attributes of potato (*Solanum tuberosum* L.). Four K levels (0, 90, 120 and 150 kg ha^{-1}) and three levels of Zn (00, 05 and 10 kg ha^{-1}) were used. The various parameters studied during experiment were tuber yield (t ha^{-1}), total soluble solids (TSS), specific gravity and starch content. Potassium and zinc application at various levels were significant for all parameters. Potassium applied at the rate of 120 kg ha^{-1} increased tuber yield (27.9 ton ha^{-1}), TSS (5.099 °Brix), specific gravity (1.083) and starch content (14.83%). Yield parameter was recorded maximum with 150 kg K ha^{-1}. Application of Zn at 10 kg ha^{-1} maximized tuber yield (26.9 ton ha^{-1}). On the basis of the present research, 120 kg K ha^{-1} and 5 kg Zn ha^{-1} gave maximum yield of potato.

Setu *et al*. (2018) conducted a field experiment in Ethiopia to investigate the effect of phosphorus and potassium fertilizers on growth performance and yield of potato. The experiment was in arrangement of potassium (0, 100, 200 and 300 kg K_2O ha^{-1}) and phosphorus (0, 46, 92, 138, 184 and 230 kg P_2O_5 ha^{-1}). A potato variety, Gudanie (CIP-386423-13) was used. Analysis of the data revealed that the interaction effect of both phosphorus and potassium did not influence the phenotypic, growth parameters and tuber yields of potato, but their main effect is significant influence on days to 50% flowering, physiological maturity, plant height, marketable and total tuber yields, leaf area, above and underground dry biomasses. Optimum above and underground dry biomass (232.11 and 494.74 Mg ha^{-1}), marketable (23.94 kg K_2O ha^{-1}) and total tuber (29.56 kg K_2O ha^{-1}) yields were attained at 200 kg K_2O ha^{-1}; for phosphorus, optimum marketable tuber (23.30 t ha^{-1}), total tuber (28.83 t ha^{-1}) were attained at 138 kg P_2O_5 ha^{-1}. The lowest yield obtained from above ground and underground dry matter, marketable and total tuber in both fertilizers were recorded at zero level.

Fan *et al*. (2018) carried out a study and investigated the effects of different levels of potassium on the growth, yield, and potassium uptake of potato plants. The study found that higher levels of potassium increased the growth and yield of potato plants, but excessive potassium levels negatively affected the yield. Results revealed that MoP 300 kg ha^{-1}, resulted the maximum plant height, leaf and stem number per plant, tuber weight per plant and tuber yield compared to other nutrient doses including control. The study also showed that the highest yield was obtained with a potassium application rate of 300 kg ha^{-1} (MoP), while excessive potassium application (600 kg ha^{-1}) led to a reduction in the growth and yield.

Yakimenko and Naumova (2018) conducted a study was performed to evaluate the effect of K fertilization rates (0, 30, 60, 90, 120 and 150 kg K ha^{-1}) on tuber yield and quality (dry matter, starch, sugar and ascorbic acid content, taste) of two potato cultivars (Roco and Rosara) grown in the micro plot field experiment. The tuber yield of both potato cultivars increased with increase in K application rate up to 2.1 and 2.9 kg m^{-2} for Roco and Rosara, respectively. The results underscore the importance to adjust fertilizer recommendations concerning potassium application rates and source on the basis of biological requirements and intended utilization of individual potato cultivars.

Merino-Gergichevich *et al*. (2017) conducted an experiment to investigate the effects of potassium on the growth, yield, and fruit quality of potato plants. The study found that higher levels of potassium increased the growth and yield of potato plants, but excessive potassium levels negatively affected the fruit quality. The highest plant height, stem number, tuber number per hill, tuber weight per hill, dry matter content of tuber and tuber yield was obtained with a potassium application rate of 200 kg MoP ha^{-1}, while excessive potassium application (300 kg MoP ha^{-1}) led to a reduction in the yield.

Gupta *et al*. (2017) demonstrated that potassium application had a positive effect on potato growth and yield under different planting densities. The study found that the application of 120 kg K_2O ha^{-1} significantly increased the tuber yield, average tuber weight, and number of tubers per plant, irrespective of the planting density.

Gupta *et al*. (2017) conducted an experiment to study the effect of potassium nutrition on the growth, yield, and quality of potato plants. The study found that potassium application significantly increased the growth, yield and quality of potato tubers. Results also indicated that the highest yield was obtained with a potassium application rate of 100 kg K ha^{-1} compared to 0 and 50 kg K ha^{-1}.

Mohan *et al*. (2017) conducted a field experiment to study the effect of different rates and sources of potassium on growth, yield and quality of potato. Results revealed that highest growth parameters like plant height (49.0), number of branches (2.83), and total dry matter production (6366.04 kg ha^{-1}) recorded with application of 75:75:175 kg ha^{-1}NPK with K as Bio K + Sulphur (S). Significantly lower growth parameters like plant height (31.67), number of branches (1.99), and total dry matter production (2063.02 kg ha^{-1}) recorded in control. Number of tuber and tuber weight per plant were significantly higher due to application of 75:75:175 kg ha^{-1} NPK with K as Bio K + S (4.80 and 560.67) and was on par with 75:75:175 kg ha^{-1} NPK with K as SOP + Sulphur (4.6 and 545.67). Maximum tuber yield was recorded with 75:75:175 kg ha^{-1} N P K with K as Bio-K+ S (31.15t ha^{-1}) and significantly lower tuber yield recorded in absolute control (11.0). Significantly highest protein (8.50%) and starch (79.27%) content were recorded in treatment 75:75:175 kg ha^{-1} NPK with K as Bio K + S. Total N, P, K content in haulm (1.35, 0.27 and 2.87) and tuber (1.34,0.43 and 1.75) was significantly higher due to application of 75:75:175 kg ha^{-1} NPK with K as Bio-K + S and was on par with application of 75:75:175 kg ha^{-1} NPK with K as SOP+S.

Upadhyay and Dubey (2016) reviewed the role of potassium and management in improving the yield, quality, and storability of potato tubers. The study found that appropriate potassium and management is crucial for achieving optimal yield, quality, and storability of potato tubers. The study highlighted the importance of adequate potassium supply throughout the growing season to achieve optimal yield and quality of potato tubers. The study revealed that optimum application of potassium doses resulted maximum yield and quality parameters of potato tubers.

Anwar *et al*. (2016) carried out a study and reported that potassium application significantly increased potato tuber yield, plant height, and leaf area index. The study found that the application of 120 kg K_2O ha^{-1} produced the highest potato yield, which was 44% higher than the control treatment.

Neshev and Manolov (2016) carried out a field experiment included two fertilizer rates - 100 and 200 kg K_2O ha^{-1} supplied as K_2SO_4 or KCl. Potassium fertilization have no effect on seedling emergence but increased K content in roots compared to control. The applied potassium fertilizers increased K content in aboveground biomass compared to control. The high KCl rate at variant KCl (200) increased K content in aboveground biomass up to 5.16%. The fertilization with K_2SO_4 led to slight decrease of N content in the tubers compared to control (2.32%), but the KCl increased tuber N content from 2.60% at variant KCl (100) to 2.89% at KCl (200). The K content in tubers was not considerably influenced by the fertilization.

Marton *et al*. (2015) conducted a study to investigate the effect of potassium supply on the growth, yield, and quality of potato plants. The study found that potassium application significantly increased the growth, yield and quality of potato tubers. The study revealed that the highest yield contributing parameters (tuber number, tuber weight per hill and size of tuber) and yield were obtained with a potassium application rate of 120 kg K ha^{-1} compared to 0, 40, 80 and 160 120 kg K ha^{-1}.

Salim *et al*. (2014) conducted two field experiments to study the effect of foliar spray with potassium nitrate, potassium silicate, potassium chloride and mono potassium phosphate at the rates 1000 ppm and 2000 ppm on growth, yield parameters and some biochemical constituents of potato plant. Plant length, shoot fresh weight, shoot dry weight, total chlorophyll reading, tubers number per plant, tubers weight/plant, yield/plant and yield/plot were recorded and these studied parameters were influenced significantly by different treatments. The higher rate of potassium silicate and potassium nitrate were more effective than the rest treatments on enhancing the vegetative growth parameters and yield components.

Abd-El-Latif (2011) carried out two field experiments on potato (*Solanum tuberosum*, L.) for two successive seasons 2009 and 2010. The study concerned the use of different rates of potassium fertilization (72, 96 and 120 kg K_2O/fed.) under different irrigation schedulings (40, 60 and 80 % from available water) on potato crop in alluvial soil. Generally, in most cases, the treatment of the medium or/and highest soil moisture level (60 and 80 % from available water) gave the highest significant values for plant height, dry matter and K content of potato plant at 90 days from planting and potato yield tuber ton/fed N, P and K contents in tuber in addition to, total soluble solids and protein content in tuber as well as consumptive use. While the lowest one were recorded when the lowest soil moisture level (40% from available water) was applied. Generally, all K rates gave the highest significant values for all parameters under study. The second level of potassium 96 kg K_2O fed^{-1} achieved the highest significant values of dry matter, content of N and K at 90 days from planting as well as N content in tuber. Whereas, the high values of tuber yield, protein content, water use efficiency and consumptive use were obtained when 120 kg K_2O/fed was applied. In most cases, the high levels of potassium under 80 % from available water gave highest significant values for all parameters under study in both seasons.

Sadeghi *et al*. (2010) investigated the effect of potassium on the growth, yield, and nutrient uptake of potato plants. The study found that potassium application significantly increased the growth and yield of potato plants and enhanced nutrient uptake. The study also exhibited that the highest main stem, haulm fresh and dry weight, tuber number and weight per hill were obtained with a potassium application rate of 200 kg MoP ha^{-1}. Results also showed that the highest yield ha^{-1} was obtained with a potassium application rate of 200 kg MoP ha^{-1} compared to 0, 50, 100 and 150 kg MoP ha^{-1}.

Gunadi (2009) conducted an experiment to determine the response of potato to potassium (K) fertilizer sources and application methods. The treatments consisted of two K fertilizer sources (potassium chloride-KCl and potassium sulphate-K_2SO_4), two K rates (150 and 250 kg K_2O ha^{-1}), and three application methods (single, split, and split combined with foliar application). In the single application treatment, K was applied at planting, while in the split application treatment the K was applied half rate at planting and the rest at 6 weeks after planting (WAP). In the split combined with foliar application treatment, the K fertilizer was applied half rate at planting, a quarter rate at 6 WAP and another quarter rate by foliar spraying at 7, 8 and 9 WAP. The results showed that plant height was not significantly affected by the treatment. Potatoes supplied with K_2SO_4 either in split or split combined with foliar application had significantly higher tuber dry weight, and total plant dry weight than those supplied with K fertilizer in single application. Potatoes supplied with K_2SO_4 had a higher tuber yield compared to those fertilized with KCl, especially under split or split combined with foliar application. To attain the same level of tuber yield as in the split combined with foliar application method, the rate of K_2SO_4 should be increased from 150 to 250 kg K_2O ha^{-1} when using single application. It is therefore suggested that K_2SO_4 for potatoes should be used in split application combined with foliar application.

Ruiz-Sanchez and Moreno-Sanchez (2009) investigated the effect of potassium on the growth and yield of potato plants. The study found that potassium application significantly increased the growth and yield of potato plants. They found that the highest yield was obtained with a potassium application rate of 300 kg MoP ha^{-1}.

Hartz and Johnstone (2006) carried out an experiment to evaluate the yield response of potato to potassium fertilization in California. The study found that potassium application had significant effect on growth and yield of potato tubers. The study found that the highest number of tuber per hill, weight of tuber per hill and yield per hectare were obtained with a potassium application rate of 300 kg MoP ha^{-1} compared to 0, 100, 200 and 400 kg MoP ha^{-1}.

Evers *et al*. (2006) conducted an experiment and reviewed the functional-structural modeling of potato plants and the role of potassium in potato growth and development. Results showed that potassium had significant effect on growth and yield of potato. Higher levels of potassium doses (350 kg MoP ha^{-1}) showed higher plant height, leaf number, stem number, tuber number and tuber yield per plant compared to control. Excess potassium dose (550 kg MoP ha^{-1}) gave reduced growth and yield.

Parveen *et al*. (2004) carried out an experiment on the K requirements of potato (*S. tuberosum*) cultivars Kufri Chipsona 1 and Kufri Chipsona 2 (intended for processing) in relation to their processing grade tuber yield and quality parameters. They showed that, 124.5 kg K ha^{-1} give the highest yields of process grade tubers (32.8 and 29.5 t ha^{-1} in Kufri Chipsona 1 and Kufri Chipsona 2, respectively). The K levels (0, 41.5, 83.0, 124.5 and 166 kg K ha^{-1}) affected the yield of process grade tubers in both cultivars. However, K did not significantly affect the quality parameters for processing (tuber dry matter, specific gravity, reducing sugar content and chip colour). The K requirements of Kufri Chipsona 1 and Kufri Chipsona 2 (124.5 kg K ha^{-1}) were 50% higher than the K requirements of table-purpose potato cultivars, such as Kufri Bahar.

Lu, (2003) conducted an experiment with the high-yielding and cold-resistant variety Mila and showed that K fertilizer increase plant height, stem diameter, branches $plant^{-1}$, weight $tuber^{-1}$ and yield $plant^{-1}$. The highest yield was recorded in the treatment with 150 kg K_2O ha^{-1}, followed by the treatment with 60 kg P_2O_5 and 100 kg K_2O ha^{-1}. The highest output: input ratio was noted in the treatment with 150 kg K_2O ha^{-1}, followed by the treatment with 60 kg P_2O_5 and 100 kg K_2O ha^{-1}. K fertilizer increased plant height, stem diameter, branches $plant^{-1}$, weight $tuber^{-1}$ and yield $plant^{-1}$. The highest starch and the highest crude protein contents were found in the treatment with 60 kg P_2O_5 and 100 kg K_2O ha^{-1}, followed by the treatment with 150 kg K_2O ha^{-1}. It is concluded that the balanced application of NPK fertilizers can increase potato yield, improve tuber quality and promote plant growth, thus obtaining higher economic benefits.

Sobhani *et al*. (2002) conducted an experiment to determine the effects of water deficit and potassium nutrition on the yield and agronomic characteristics of potato. Yield and some agronomic characteristics of potato were shown in the experiment. Potassium had a minimal effect on plant height and number of stems and tubers per plant, but increased the average tuber weight. Water deficit decreased crop yield and biological yield, while potassium application increased both yields.

2.2 Effect of sulphur (S)

Ayush *et al*. (2023) conducted a study to determine the effect of different S sources on the potato tuber yield, specific gravity, external tuber quality, and internal tuber quality. In this study, three S sources were applied at two different rates (T_1=45 kg ha^{-1}; T_2=90 kg ha^{-1}). Three S sources were derived from the sulfate of ammonia (AS; SO_4^{2-} source), magnesium sulfate (EPTOP; S^0 source), and gypsum (SO_4^{2-} source). Three potato cultivars were used for this study (Atlantic, Satina, and Red La Soda). The total and marketable yields indicated a positive response to the application of the S sources. Gypsum and EPTOP outperformed AS, and the lower rate (T_1) performed better than the higher rate (T_2). The maximum yield difference between AS and gypsum was 33%.

Zaman *et al*. (2021) conducted a field experiment to study the effect of sulfur on potato yield and quality under different soil types. The study found that the application of 40 kg S ha^{-1} significantly increased the growth and potato yield and quality compared to the control treatment. Application of 40 kg S ha^{-1} also significantly increased fresh and dry weight of haulm and tuber number per hill compared to control. The authors suggested that sulfur application improved the soil fertility and increased the availability of nutrients to the potato plants, which contributed to the improved yield and quality.

Zhang *et al*. (2021) investigated the effect of sulfur fertilization on potato yield and quality under different nitrogen levels. The study found that sulfur application significantly increased the tuber yield and starch content, especially under low nitrogen conditions.

Li *et al*. (2020) conducted a study to investigate the effect of different sulfur application rates on potato yield and quality under different soil types. The study found that the application of 60 kg S ha^{-1} significantly increased the potato yield and quality compared to the control treatment. The authors suggested that sulfur application improved the soil structure and increased the availability of nutrients to the potato plants, which contributed to the improved yield and quality.

Alshammari *et al*. (2020) conducted a study to investigate the effect of sulfur fertilization on potato growth and yield in sandy soils. The study found that the application of sulfur significantly increased the potato yield by 26.3% compared to the control treatment. The authors suggested that sulfur application improved the uptake of other essential nutrients, such as nitrogen and phosphorus, which contributed to the improved yield.

Singh *et al*. (2019) carried out an experiment to study the impact of sulfur on potato growth, yield, and nutrient uptake. The study found that the application of 40 kg S ha^{-1} significantly increased the potato yield and nutrient uptake compared to the control treatment. The authors suggested that sulfur application improved the soil fertility and increased the availability of nutrients to the potato plants, which contributed to the improved yield and nutrient uptake.

Sameh *et al*. (2018) carried out an experiment to focus the highest possible potato productivity per unit of the cultivated area, as well as the high quality of the processed products. Four levels of sulphur fertilizer (0, 100, 200 and 300 kg S $feddan^{-1}$ = 4200 m^2) and two levels of nitrogen fertilizer (100 and 200 kg N $feddan^{-1}$) were applied to the growing potato plants. Most of the studied vegetative growth characters and potato tuber yield (ton/Fed.) were improved by increasing sulfur fertilization levels from 0 up to 300 kg Fed and/or increasing nitrogen fertilization levels from 100 kg up to 200 Fed^{-1} during the two seasons. The best results for the vegetative growth traits and total tuber yield Fed^{-1} could be achieved from the application of 300 kg S Fed^{-1} + 200 kg N Fed^{-1}. Levels of acrylamide in potato processed were significantly increased by increasing nitrogen fertilizer treatments from 100 up to 200 kg N Fed^{-1}. and/or increasing sulphur treatments from 100 kg up to 300 kg S Fed^{-1}.

Arora *et al*. (2018) carried out an experiment to study the impact of different levels of sulfur application on potato yield under different soil types. The study found that the application of 40 kg S ha^{-1} significantly increased the plant height, stem number, tuber number $plant^{-1}$. Application of 40 kg S ha^{-1} significantly increased potato yield by 24.3% compared to the control treatment. The authors suggested that sulfur application improved the soil fertility and increased the availability of nutrients to the potato plants, which contributed to the improved yield.

Fageria *et al*. (2018) reviewed the literature on sulfur nutrition in crop plants, including potatoes. The review found that sulfur is an essential nutrient for plant growth and development, and plays a key role in protein synthesis, enzyme activity, and stress tolerance. The authors suggested that adequate sulfur nutrition is necessary for optimizing crop yield and quality, and that sulfur deficiency can limit potato growth and yield. The review also highlighted the importance of balancing sulfur application with other nutrients, such as nitrogen and phosphorus, to avoid nutrient imbalances and environmental pollution.

Meena *et al*. (2018) reported that sulfur application improved the quality of potato tubers by increasing the ascorbic acid content and decreasing the reducing sugar content. The study found that the application of 40 kg S ha^{-1} produced the highest ascorbic acid content in potato tubers.

Hu *et al*. (2017) conducted a study to investigate the effect of sulfur application on potato yield and starch content. The study found that the application of 60 kg S ha^{-1} significantly increased the potato yield and starch content compared to the control treatment. The authors suggested that sulfur application improved the soil fertility and increased the availability of nutrients to the potato plants, which contributed to the improved yield and starch content.

Muthanna *et al*. (2017) carried out an experiment to study the effect of boron and sulphur application on plant morphology and yield of potato. Out of thirteen treatments one control, one recommended dose of fertilizers (N/P/K: 150/80/120 kg ha^{-1}) and eleven treatment combinations along with recommended dose of fertilizers (RDF) including 3 doses of boron (1 kg, 2 kg and 3 kg); 2 doses of sulphur (30 kg and 40 kg) and their combinations (1 kg boron + 30 kg sulphur, 2 kg boron + 30 kg sulphur, 3 kg boron + 30 kg sulphur, 1 kg boron + 40 kg sulphur, 2 kg boron + 40 kg sulphur and 3 kg boron + 40 kg sulphur) were applied. The study indicated that plant morphology and yield of potato plant were significantly influenced by boron and sulphur application. The minimum days to seedlings emergence and maximum plant height and yield of marketable tubers (17.99 t ha^{-1} and 27.00 t ha^{-1}) were recorded in the plants treated with RDF + 2 kg B + 40 kg S during both year of investigation. RDF + 2 kg B + 40 kg S was also found statistically at par with the maximum values under characters *viz.*, number of sprouts per tuber, stem diameter and number of marketable tubers/hill.

Fares *et al*. (2017) carried out an experiment to investigate the response of potato to sulfur fertilization in sandy and calcareous soils. The study found that the application of 40 kg S ha^{-1} significantly increased the potato yield by 21.4% compared to the control treatment. The authors suggested that sulfur application improved the nutrient uptake by the potato plants, which contributed to the improved yield.

Singh *et al*. (2016) conducted an experiment to study the impact of sulfur and nitrogen fertilization on potato growth, yield, and quality. The study found that the combined application of sulfur and nitrogen significantly increased the potato yield and quality compared to the individual application of either nutrient. The authors suggested that sulfur and nitrogen synergistically improved the soil fertility and increased the availability of nutrients to the potato plants, which contributed to the improved yield and quality.

Liu *et al*. (2016) carried out a study investigate the effect of sulfur application on potato growth, yield, and quality under different irrigation regimes. The study found that the application of 60 kg S ha^{-1} significantly increased the potato yield and quality under both deficit and full irrigation regimes compared to the control treatment. The authors suggested that sulfur application improved the nutrient uptake by the potato plants and enhanced their water use efficiency, which contributed to the improved yield and quality.

Gupta *et al*. (2016) showed that sulfur application had a positive effect on potato growth and yield. The study found that the application of 60 kg S ha^{-1} significantly increased the total tuber yield, average tuber weight, and number of tubers per plant.

Sharma *et al*. (2015) conducted an experiment to evaluate the four potato cultivars (Kufri Chipsona-1, Kufri Chipsona-2, Kufri Jyoti, Kufri Pushkar) under five sulphur (0, 15, 30, 45, and 60 kg ha^{-1}) levels. Significant variations were observed in different varieties of potato for growth parameters, yield attributes, and tuber yield. Maximum number of sprouts was recorded in Kufri Pushkar followed by Kufri Chipsona-1 and lowest in Kufri Jyoti. Kufri Chipsona-2 produced tallest plants and higher number of leaves per plant. Fresh weight of shoot per plant number of tuber per plant (8.33), average tuber weight (167.3g) and total tuber yield (41.90 t ha^{-1}) was recorded maximum with Kufri Pushkar. There was an increase in these parameters with increasing dose of sulphur up to 45 kg ha^{-1}. Further increase in sulphur dose either reduced the values or showed non-significant improvement. Highest number of sprout per tuber (7.5), plant height (41.7, 47.9, 59.2 cm), number of leaves per plant (29.6, 52.0, 76.5), fresh weight of shoot per plant (50.3, 64.2, 76.5 g), tuber per plant (8.58), tuber weight (166.56 g) as well as total tuber yield (37.74 t ha^{-1}) were recorded with 45 kg S ha^{-1}.

Sharma *et al*. (2011) carried out a field experiment to study the effect of five levels of sulphur application on yield and quality attributes of four varieties of potato. Healthy potato tubers of uniform size (40-45 g) were planted at a spacing of 60 cm × 25 cm. Significant variation was observed in different varieties of potato for yield and quality attributes. Maximum tuber yield per plant and large size tuber yield was recorded with cv. Kufri Pushkar. Highest dry matter content, specific gravity, total sugar and starch content were found with Kufri Chipsona-2 followed by Kufri Chipsona-1. Sulphur application in potato showed significant influence on quality and yield. These parameters increased with increasing dose of sulphur up to 45 kg ha^{-1} thereafter it showed non-significant improvement. Highest tuber yield, large size and medium size tuber yield, dry matter content, specific gravity, sugar content and starch content were found with application of 45 kg ha^{-1}sulphur. Kufri Chipsona-1 and Kufri Chipsona-2 were at par to each other and found superior over other varieties as far as quality attributes of the produce are concerned. Kufri Pushkar was superior in terms of yield.

2.3 Combined effect of K and S

Mahmoud *et al*. (2021) conducted a study to investigate the effect of potassium and sulfur fertilization on potato growth, yield, and nutrient uptake under drought stress. The study was conducted in a field in Egypt, and the treatments included three levels of potassium (0, 60, and 120 kg K_2O ha^{-1}) and sulfur (0, 40 and 80 kg S ha^{-1}). The combined application of potassium and sulfur significantly increased the potato yield and nutrient uptake under drought stress compared to the individual application of either nutrient. The authors suggested that the optimal dose of potassium and sulfur for improving potato yield under drought stress was 120 kg K_2O ha^{-1} and 80 kg S ha^{-1}.

Jatoi *et al*. (2020) conducted an experiment to investigate the effect of potassium and sulfur fertilization on potato growth, yield, and nutrient uptake under heat stress conditions. The study was conducted in a greenhouse in Pakistan, and the treatments included three levels of potassium (0, 50, and 100 mg kg^{-1}) and sulfur (0, 30, and 60 mg kg^{-1}) under heat stress conditions. The combined application of potassium and sulfur significantly increased the potato yield and nutrient uptake under heat stress conditions compared to the individual application of either nutrient. The authors suggested that the optimal dose of potassium and sulfur for improving potato yield under heat stress conditions was 100 mg kg^{-1} of potassium and 60 mg kg^{-1} of sulfur.

Gomaa *et al*. (2020) studied the effect of potassium and sulfur fertilization on potato growth, yield, and nutrient uptake under saline conditions. The study found that the combined application of potassium and sulfur significantly increased the potato yield and nutrient uptake under saline conditions compared to the individual application of either nutrient. The combined application of potassium and sulfur at rates of 225 kg ha^{-1} and 75 kg ha^{-1}, respectively, significantly increased the potato yield and nutrient uptake compared to the individual application of either nutrient. The study suggested that the combined application of potassium and sulfur improved the plant's ability to tolerate saline conditions and enhanced their nutrient uptake, which contributed to the improved yield.

Zhang *et al*. (2019) carried out a study to determine the impact of potassium and sulfur fertilization on potato growth, yield, and nutrient uptake under saline-alkali soil conditions. The study was conducted in a greenhouse in China, and the treatments included three levels of potassium (0, 75, and 150 mg kg^{-1}) and sulfur (0, 50, and 100 mg kg^{-1}) under saline-alkali soil conditions. The combined application of potassium and sulfur significantly increased the potato yield and nutrient uptake under saline-alkali soil conditions compared to the control treatment. The authors suggested that the optimal dose of potassium and sulfur for improving potato yield under saline-alkali soil conditions was 150 mg kg^{-1} of potassium and 100 mg kg^{-1}g of sulfur.

Zhang *et al*. (2018) conducted a study to investigate the effect of potassium and sulfur fertilization on potato growth, yield, and quality under different nitrogen rates. The study found that the combined application of potassium and sulfur significantly increased the potato yield and quality under both low and high nitrogen rates compared to the control treatment. Results revealed that the combined application of potassium and sulfur at rates of 225 kg ha^{-1} and 75 kg ha^{-1}, respectively, significantly increased the potato yield and quality under both low and high nitrogen rates compared to the control treatment. The authors suggested that the synergistic effect of potassium and sulfur improved the nutrient uptake and utilization by the potato plants, which contributed to the improved yield and quality.

Yu *et al*. (2017) carried out an experiment to study the impact of potassium and sulfur fertilization on potato growth, yield, and nutrient uptake. The study found that the combined application of potassium and sulfur significantly increased the potato yield and nutrient uptake compared to the individual application of either nutrient. Results indicated that the combined application of potassium and sulfur at rates of 225 kg ha^{-1} and 75 kg ha^{-1}, respectively, significantly increased the potato yield and nutrient uptake compared to the individual application of either nutrient. The authors suggested that the combined application of potassium and sulfur improved the soil fertility and nutrient availability, which contributed to the improved potato growth and yield.

Sarwar *et al*. (2016) investigated from an experiment that the effect of potassium and sulfur fertilization on potato growth, yield, and nutrient uptake under different phosphorus rates. The study was conducted in a field in Pakistan, and the treatments included three levels of potassium (0, 50, and 100 kg K_2O ha^{-1}) and sulfur (0, 40, and 80 kg S ha^{-1}) under low and high phosphorus rates. The combined application of potassium and sulfur significantly increased the potato yield and nutrient uptake under both low and high phosphorus rates compared to the control treatment. The authors suggested that the optimal dose of potassium and sulfur for improving potato yield under low and high phosphorus rates was 100 kg K_2O ha^{-1} and 80 kg S ha^{-1}.

Zhang *et al*. (2015) conducted an experiment to investigate the effect of potassium and sulfur fertilization on potato growth, yield, and quality. The study found that the combined application of potassium and sulfur significantly increased the potato yield and quality compared to the individual application of either nutrient. Results showed that combined application of potassium and sulfur at rates of 225 kg ha^{-1} and 75 kg ha^{-1}, respectively, significantly increased the potato yield and quality compared to the individual application of either nutrient. The authors suggested that the synergistic effect of potassium and sulfur improved the nutrient uptake and utilization by the potato plants, which contributed to the improved yield and quality.

CHAPTER III

MATERIALS AND METHODS

The present study was carried out to study the effect of potassium and sulphur on the growth and yield of potato (*Solanum tuberosum* L.) during the period from November 2021 to February 2022. This chapter deals with experimental period, site, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, intercultural operations, data collection and statistical analysis. The details of experimental materials and methods are described below:

3.1 Experimental site

The experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka. Geographically the experimental area is located at 23°41´N latitude and 90°22´E longitudes at the elevation of 8.6 m above the sea level. The experimental site has been shown in the Appendix I.

3.2 Climate and weather

The experimental field was under subtropical climates characterized by heavy rainfall during the month of April to September and scanty rainfall during October to March. The monthly means of daily maximum, minimum and average temperature, relative humidity, total rainfall and sunshine hours received at the experimental site during the period from November 2021 to February 2022 have been presented in Appendix II.

3.3 Soil characteristics

The experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were silty clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles.

Soil pH was 5.6 and had organic matter 0.78%. The experimental area was flat having available irrigation and drainage system. The experimental site was a medium high land. It was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The physicochemical properties of the soil are presented in Appendix III.

3.4 Planting material

The variety BARI Alu-25 (ASTORIX) was used as the planting material for the present study and was collected from the Tuber Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5 Land preparation

The land of the experimental site was first opened in the first week of November with power tiller. Later on, the land was ploughed and cross-ploughed four times followed by laddering to obtain the desirable tilth. The corners of the land were spaded and weeds and stubbles were removed from the field. The land was finally prepared on 10th November 2021 three days before planting the seed. In order to avoid water logging due to rainfall during the study period, drainage channels were made around the land. The soil was treated with Furadan 5G @10 kg ha^{-1} when the plot was finally ploughed to protect the young seedlings from the attack of cut worm.

3.6 Experimental design and layout

The two-factor experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 replications. The size of the unit plot was 2.5 m × 2.0 m. Block to block and plot to plot distances were 0.5 m and 0.5. Treatments were randomly distributed within the blocks. The plots were raised up to 10 cm. Layout of the experiment is shown in Figure 1.

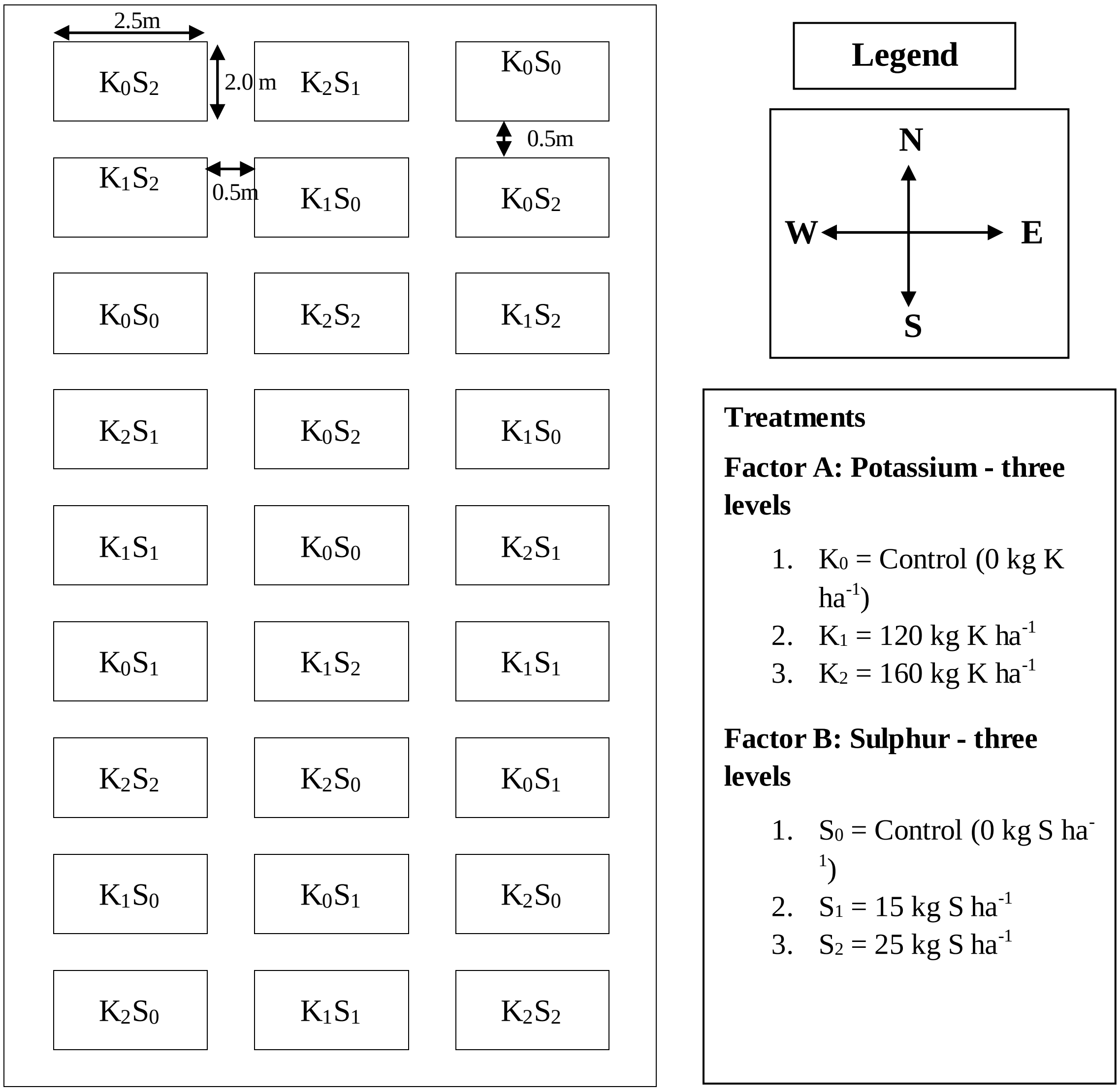

Figure 1. Layout of the experimental plot

3.7 Treatments of the experiment

Factor A: Potassium - three levels

1. K_0 = Control (0 kg K ha^{-1})
2. K_1 = 120 kg K ha^{-1}
3. K_2 = 160 kg K ha^{-1}

Factor B: Sulphur - three levels

1. S_0 = Control (0 kg S ha^{-1})
2. S_1 = 15 kg S ha^{-1}
3. S_2 = 25 kg S ha^{-1}

Treatment combinations: Nine treatment combinations as follows:

K_0S_0, K_0S_1, K_0S_2, K_1S_0, K_1S_1, K_1S_2, K_2S_0, K_2S_1 and K_2S_2.

3.8 Manure and fertilizer application

Cowdung was used as organic manure for all the treatments at the rate of 10 t ha^{-1}. Again, urea, triple superphosphate (TSP), muriate of potash (MoP) and gypsum were considered as inorganic fertilizers which were used as sources of nitrogen, phosphorus, potassium, and sulphur, respectively. MoP and gypsum at varying rates were used as source of potassium (K) according to the treatments assigned. Again, 350 kg urea ha^{-1} from 220 kg TSP ha^{-1} were used for every treatment excluding control. No nutrient was applied at control condition.

Total amount of TSP, MoP, gypsum and half of urea was applied at basal doses during final land preparation. The remaining 50% urea was side dressed in two equal splits at 25 and 45 days after planting (DAP) during first and second earthing up.

3.9 Seed preparation and sowing

The seedling tubers were taken out of the cold store about three weeks before planting. The tubers were kept under diffuse light conditions to have healthy and good sprouts. Planting was done on November 13, 2021. The well sprouted seed tubers were planted at a depth of 5-7 cm in furrow made 60 cm apart. Hill to hill distance was 15 cm. After planting, the seed tubers were covered with soil.

3.10 Intercultural operations

3.10.1 Weeding

Weeding was necessary to keep the plant free from weeds. First weeding was done two weeks after emergence. Another weeding was done before 2^{nd} top dressing of urea.

3.10.2 Earthing up

Earthing up was done twice during growing period. The first earthing up was done at 25 DAP and second earthing up was done after 15 days of first earthing up.

3.10.3 Irrigation

Three irrigations were provided throughout the growing period in controlled way. The first irrigation was given at 25 DAP. Subsequently, another two irrigations were given at 45 and 60 DAP.

3.10.4 Plant protection

Furadan 5G @ 10 kg ha^{-1} was applied in soil at the time of final land reparation on 25 October, 2019 to control cut worm. Dithane M-45 was sprayed in 2 installments at an interval of 15 days from 45 DAP as preventive measure against late blight disease.

3.11 Harvesting

The crop was harvested at 84 DAP. The harvested plants were tagged separately plot wise. Five sample plants were randomly selected from each plot and tagged for recording necessary data and then the all plots was harvested with the help of spade. The maturity of plant was indicated by the plants showing 80 to 90% of leaf senescence and the top started drying. Haulm cutting was done before 7 days of harvesting. The yield of tuber was taken plot wise and converted into tons ha^{-1}. Care was taken to avoid injury in potatoes during harvesting.

3.12 Data collection

The following parameters were recorded and their mean values were calculated from the sample plants.

3.12.1 Days to 100% emergence

After planting the potato tuber keenly observed the emergence twice in a day (morning and afternoon) until final emergence.

3.12.2 Plant height

Plant height was taken to be the length between the base of the plant to the tip at the time of harvest from randomly selected five plants. The height of each plant of each plot was measured in cm with the help of a meter scale and mean was calculated.

3.12.3 Number of leaves $plant^{-1}$

Number of leaves $plant^{-1}$ was counted from randomly selected five plants at the time of harvest. Leaves number $plant^{-1}$ were recorded by counting all leaves from each plant of each plot and mean was calculated.

3.12.4 Number of main stems $hill^{-1}$

Number of main stems $hill^{-1}$ was counted at the time of harvest from randomly selected five hillsof each replication of each treatment. Stem numbers $hill^{-1}$ was recorded by counting all stem from selected hillsand mean was calculated.

3.12.5 Fresh weight of haulm hill^{-1} (g)

The average weight of haulm was recorded from selected **hills**for each plot at the time of harvesting.

3.12.6 Dry weight of haulm hill^{-1} (g)

The fresh haulms of the sample plants were sun dried for two days and then oven dried at 65°C for 72 hours.

3.12.7 Number of tubers hill^{-1}

The number of tubers hill^{-1} was determined from the average of 5 hills selected from each unit plot.

3.12.8 Weight of tuber hill^{-1}

Five hills were randomly selected from each plot. The total tuber was enumerated and weighted from five hills by using an electronic balance. It was recorded by dividing total fresh weight of tubers by the total number of selected hills.

3.12.9 Dry weight of 100 g fresh tuber

One hundred grams of potatoes from sample plants were sliced, sun dried for 2 days and then dried at 70°C in an oven for 72 hours. Just after oven drying the dried pieces were weighed and were expressed in percentage.

3.12.10 Tuber yield plot^{-1}

Tubers of each plot were collected separately from which yield of tuber was recorded in kilogram.

3.12.11 Tuber yield ha^{-1}

All the tubers weight per plot was recorded and the tuber weight was finally converted into tons ha^{-1}.

3.12.12 Methods of Soil Analysis

3.12.12.1 Soil pH

The pH of the soil was determined with help of a glass electrode pH meter using soil: water ratio being 1: 2.5 (Jackson, 1973).

3.12.12.2 Organic carbon (%)

Organic carbon of soil was determined by Walkley and Black's (1934) wet oxidation method. The underlying principle is to oxidize the organic carbon with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 1N $FeSO_4$ solution. The result was expressed in percentage.

3.12.12.3 Available phosphorus (ppm)

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

3.12.12.4 Available potassium

Five milli-liter of digest sample for the soil was taken and diluted 50 ml volume to make desired concentration so that the absorbance of sample were measured within the range of standard solutions. The absorbance was measured by atomic absorption flame photometer.

3.12.12.5 Available sulphur

Available sulphur in soil was determined by extracting the soil sample with 0.15% $CaCl_2$ solution (Page *et al*., 1982). The S content in the extract was determined turbidimetrically and the intensityof turbid was measured by spectrophotometer at 420 nm length.

3.13 Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out the effect of potassium and sulphur on the growth and yield of potato (*Solanum tuberosum* L.). The results have been presented and discussed through different tables and graphs and possible interpretations have been given under the following headings:

4.1 Growth parameters

4.1.1 Days to 100% emergence

Effect of potassium (K)

Days to 100% emergence of potato (BARI Alu-25; ASTORIX) was influenced significantly by different levels of potassium (Figure 2 and Appendix IV). Results indicated that the treatment K_2 (160 kg K ha^{-1}) showed the minimum days to 100% emergence (16.00 days) which was significantly differed to other treatments. On the other hand, the control treatment K_0 (0 kg K ha^{-1}) showed maximum days to 100% emergence of seedlings (18.00 days) which was significantly differed to other treatments followed by K_1 (120 kg K ha^{-1}). Neshev and Manolov (2016) also found early emergence of potato seedlings with higher doses of potassium which supported the present study.

Effect of sulphur (S)

Significant variation was observed on days to 100% emergence of potato (BARI Alu-25; ASTORIX) influenced by different levels of sulphur (Figure 3 and Appendix IV). The treatment S_1 (15 kg S ha^{-1}) showed the minimum days to 100% emergence (16.44 days) which was statistically identical to S_2 (25 kg S ha^{-1}) treatment whereas the control treatment S_0 (0 kg S ha^{-1}) showed the maximum days to 100% emergence of seedlings (17.67 days). Muthanna *et al*. (2017) also found supported results to the present study.

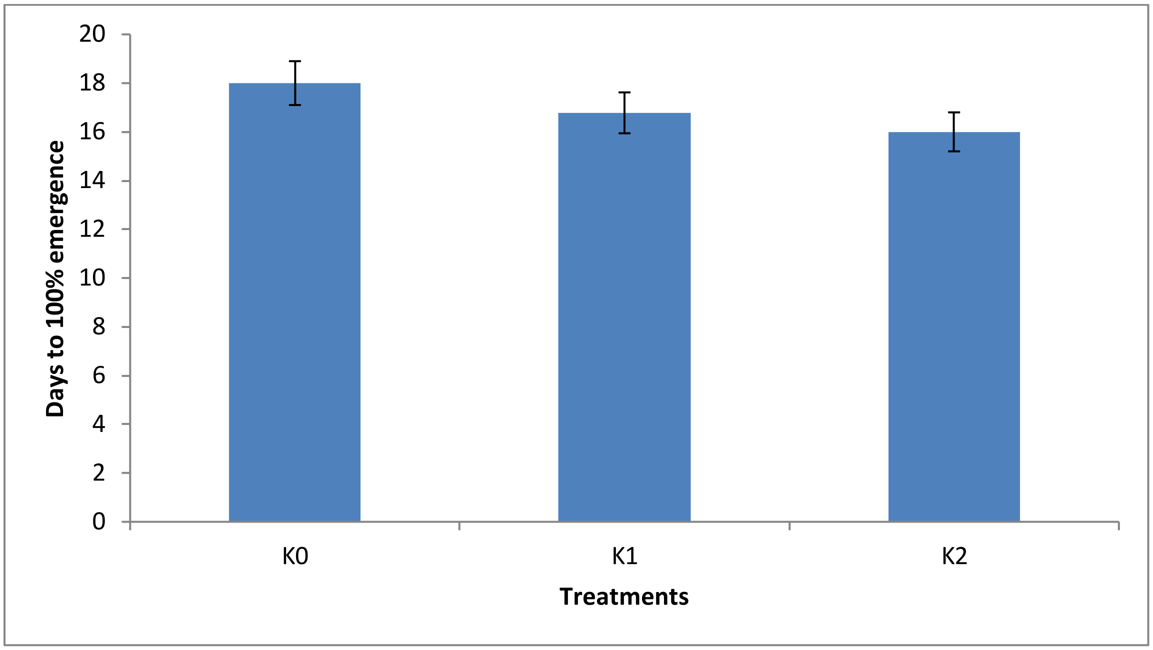

Figure 2. Effect of potassium on (days to 100% emergence of potato (BARI Alu-25)

K_0 = Control (0 kg K ha^{-1}), K_1 = 120 kg K ha^{-1} and K_2 = 160 kg K ha^{-1}

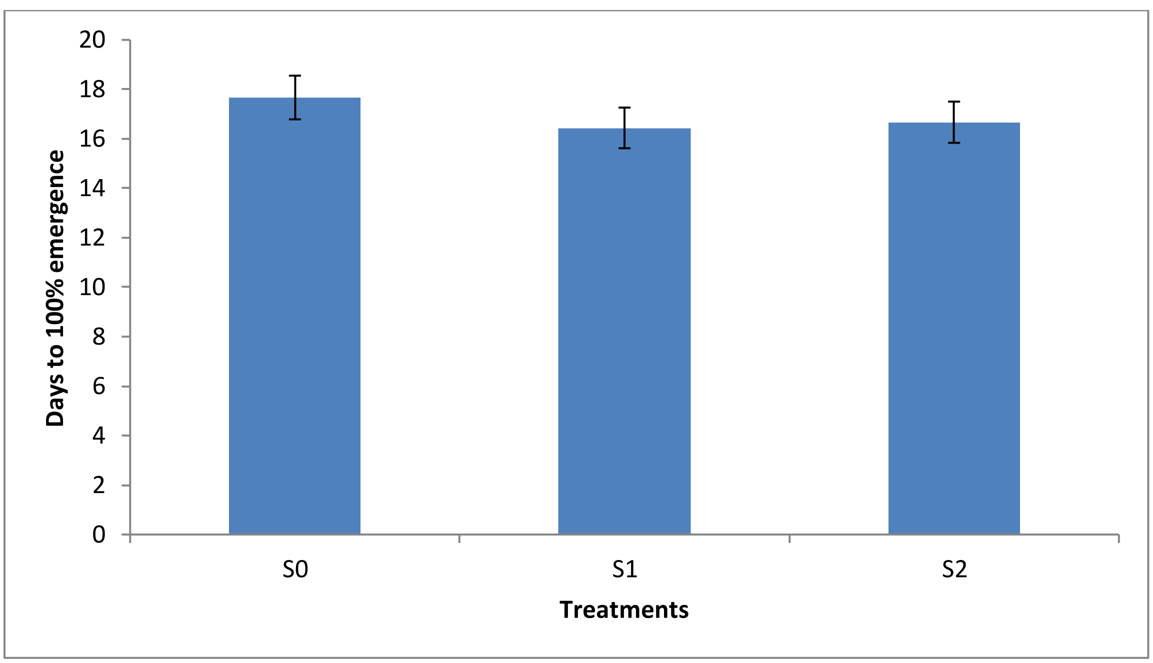

Figure 3. Effect of sulphur on days to 100% emergence of potato (BARI Alu-25)

S_0 = Control (0 kg S ha^{-1}), S_1 = 15 kg S ha^{-1} and S_2 = 25 kg S ha^{-1}

Combined effect of K and S

Days to 100% emergence of potato (BARI Alu-25; ASTORIX) was varied significantly among different treatment combinations of potassium and sulphur (Table 1 and Appendix IV). Results revealed that the minimum days to 100% emergence (15.33 days) was found from the treatment combination of K_2S_1 which was statistically identical to the treatment combination of K_2S_2. Similarly, the treatment combination of K_0S_0 required the maximum days to 100% emergence of seedlings (18.67 days) which was significantly differed to other treatments followed by the treatment combination K_0S_1 and K_0S_2.

4.1.2 Plant height

Effect of potassium (K)

Plant height of potato was significantly influenced by different potassium levels (Figure 4 and Appendix IV). Results revealed that the highest plant height (42.10 cm) was recorded from the treatment K_2 (160 kg K ha^{-1}) that was significantly different with other treatments followed by K_1 (120 kg K ha^{-1}). The lowest plant height at harvest (61.48 cm) was recorded from the control treatment K_0 (0 kg K ha^{-1}). This result was in agreements with the findings ofGutema (2021) and Ali *et al*. (2021) who observed that K application contributed to higher plant height of potato which supported the present findings.

Effect of sulphur (S)

There was significant difference among the different levels of sulphur in respect to plant height of potato (Figure 5 and Appendix IV). Results indicated that the treatment S_2 (25 kg S ha^{-1}) showed the highest plant height at harvest (69.45 cm) which was statistically identical to S_1 (15 kg S ha^{-1}) whereas the control treatment S_0 (0 kg S ha^{-1}) showed the lowest plant height (64.45 cm). The result was similar with the findings of Muthanna *et al*. (2017) and Sharma *et al*. (2015) who found variation in plant height of potato due to different sulphur doses.

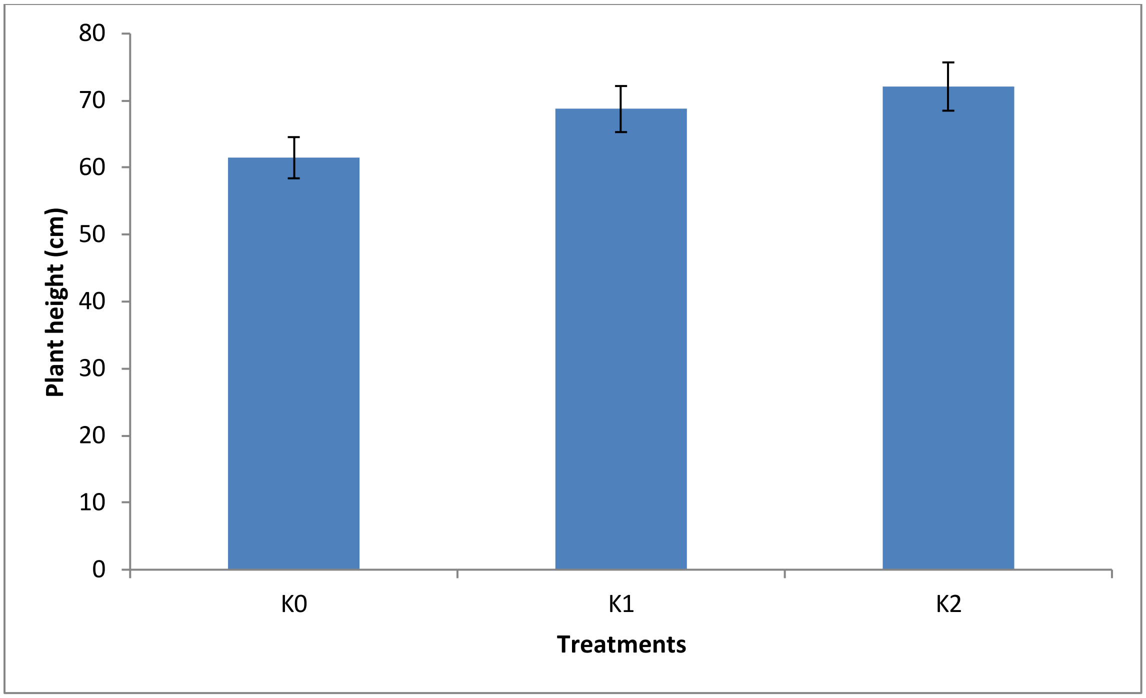

Figure 4. Effect of potassium on plant height of potato (BARI Alu-25)

K_0 = Control (0 kg K ha^{-1}), K_1 = 120 kg K ha^{-1} and K_2 = 160 kg K ha^{-1}

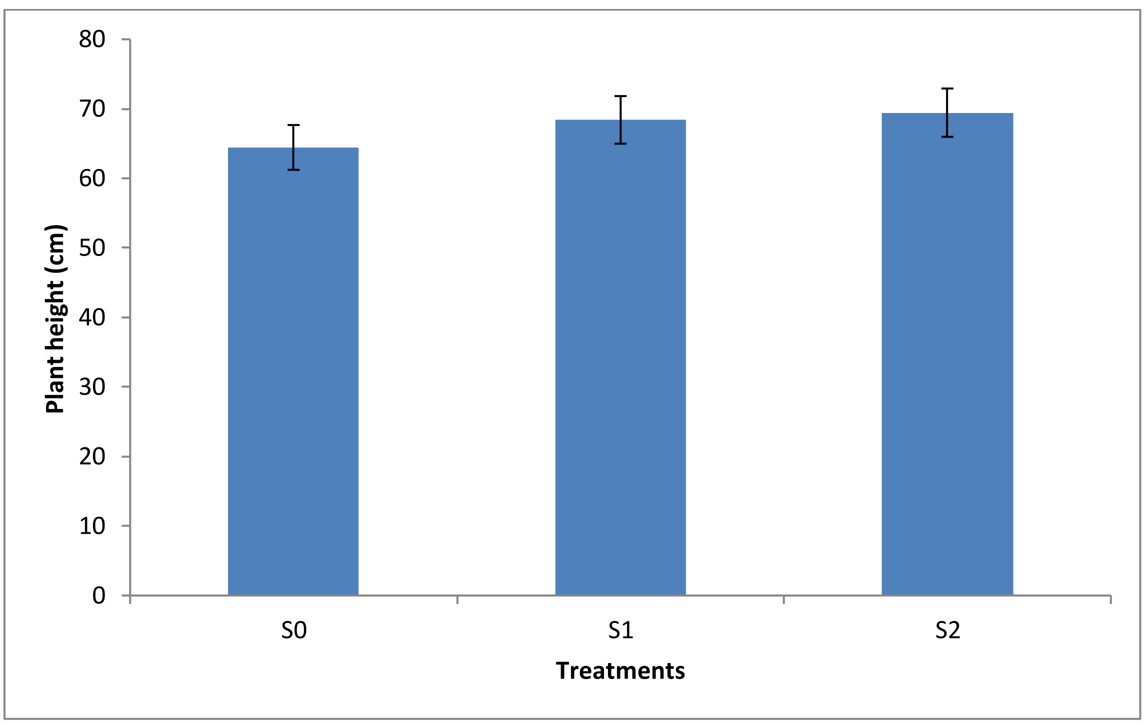

Figure 5. Effect of sulphur plant height of potato (BARI Alu-25)

S_0 = Control (0 kg S ha^{-1}), S_1 = 15 kg S ha^{-1} and S_2 = 25 kg S ha^{-1}

Combined effect of K and S

The treatment combinations of potassium and sulphur had significant effect on plant height of potato (Table 1 and Appendix IV). Results exhibited that the treatment combination of K_2S_2 registered the highest plant height (75.44) cmwhich was statistically similar to the treatment combination of K_2S_1 whereas the lowest plant height (60.67 cm) was found from the treatment combination of K_0S_0 that was significantly similar to K_0S_1 and K_0S_2.

4.1.3Number of leaves hill^{-1}

Effect of potassium (K)

Different potassium levels showed significant variation on number of leaves hill^{-1}of potato (Figure 6 and Appendix IV). It was observed that the highest number of leaves hill^{-1}(71.95) was recorded from the treatment K_2 (160 kg K ha^{-1}) that was significantly different to other treatments followed by K_1 (120 kg K ha^{-1}) whereas the lowest number of leaves hill^{-1}(61.05) was recorded from the control treatment K_0 (0 kg K ha^{-1}). The result obtained from the present study was similar with the findings of Setu *et al*. (2018), Fan *et al*. (2018) and Anwar *et al*. (2016); they reported that leaf number or leaf area of potato influenced significantly due to different potassium doses.

Effect of sulphur (S)

Significant difference on number of leaves hill^{-1} of potato was recorded due to application of different sulphur levels (Figure 7 and Appendix IV). Results showed that the highest number of leaves hill^{-1} (69.69) was recorded from the treatment S_2 (25 kg S ha^{-1}) which was statistically identical with S_1 (15 kg S ha^{-1}) whereas the lowest number of leaves hill^{-1} (64.25) was recorded from the control treatment S_0 (0 kg S ha^{-1}). The result from the present study was in agreement with the findings of Sharma *et al*. (2015); they reported that application of sulphur contributed to increase leaf number of potato compared to control.

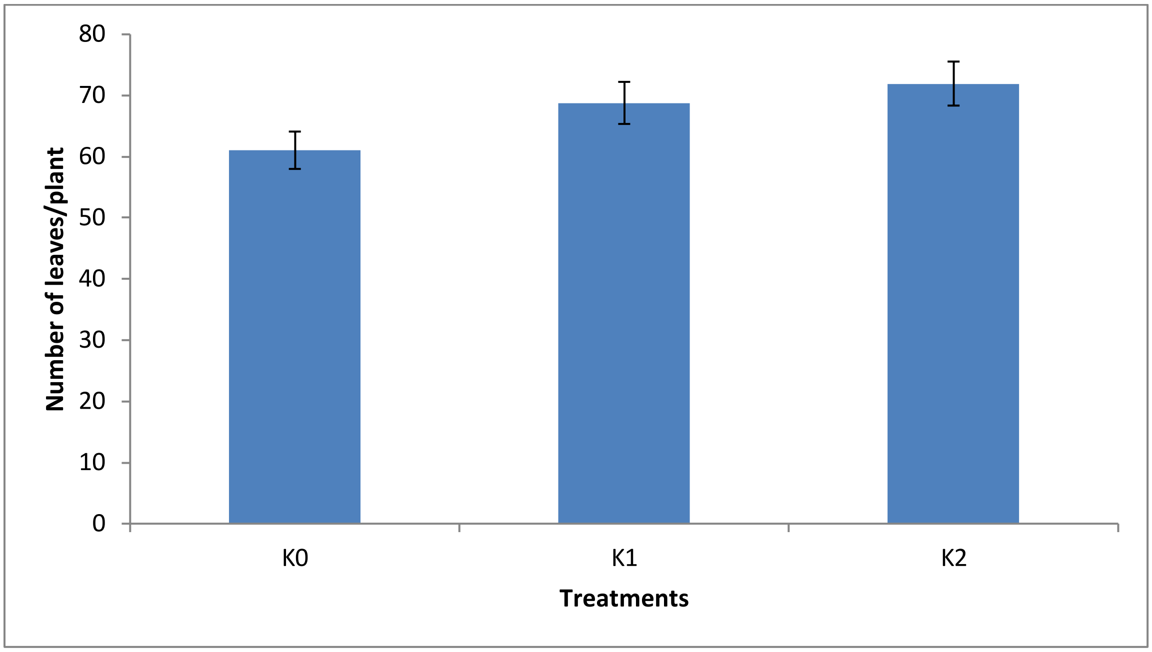

Figure 6. Effect of potassium on number of leaves plant^{-1}) of potato (BARI Alu-25

K_0 = Control (0 kg K ha^{-1}), K_1 = 120 kg K ha^{-1} and K_2 = 160 kg K ha^{-1}

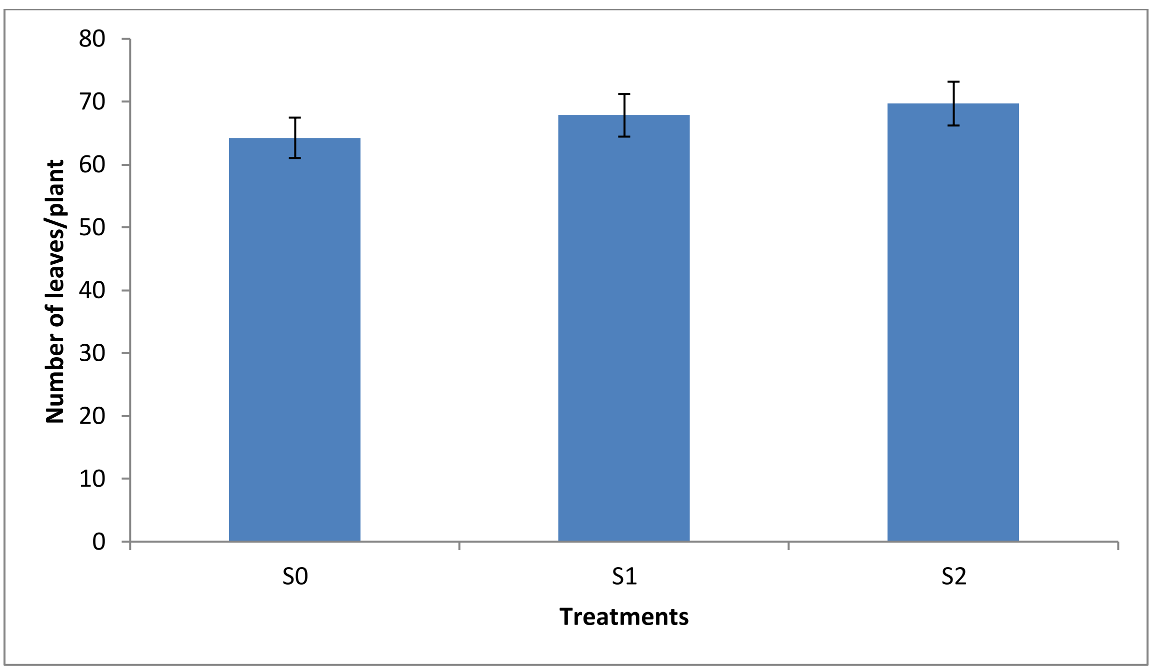

Figure 7. Effect of sulphur on number of leaves plant^{-1} of potato (BARI Alu-25)

S_0 = Control (0 kg S ha^{-1}), S_1 = 15 kg S ha^{-1} and S_2 = 25 kg S ha^{-1}

Combined effect of K and S

Different combinations of potassium and sulphur gave statistically significant influence on number of leaves hill^{-1}of potato (Table 1 and Appendix IV). The treatment combination of K_2S_2 showed the highest number of leaves hill^{-1}(75.12) that was significantly identical with K_2S_1. The treatment combination of K_1S_1 and K_1S_2 also showed comparatively higher number of leaves hill^{-1} which was statistically similar with K_2S_2. The treatment combination K_0S_0 gave the lowest number of leaves hill^{-1} (59.28) which was statistically similar with treatment combinations of K_0S_1 and K_0S_2.

Table 1. Effect of potassium and sulphur combination on growth parameters (days to 100% emergence, plant height, number of leaves plant^{-1}) of potato (BARI Alu-25; ASTORIX)

Treatments	Growth Parameters		
	Days to 100% emergence	Plant height (cm)	Number of leaves plant^{-1}
K_0S_0	18.67 a	60.67 f	59.28 d
K_0S_1	17.67 b	61.48 ef	60.14 d
K_0S_2	17.67 b	62.28 ef	63.72 cd
K_1S_0	17.33 bc	65.44 de	66.12 bc
K_1S_1	16.33 e	70.14 bc	70.00 ab
K_1S_2	16.67 de	70.63 bc	70.24 ab
K_2S_0	17.00 cd	67.24 cd	67.36 bc
K_2S_1	15.33 f	73.62 ab	73.36 a
K_2S_2	15.67 f	75.44 a	75.12 a
$LSD_{0.05}$	0.569	4.314	5.254
CV(%)	4.36	8.94	11.47

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

K_0 = Control (0 kg K ha^{-1}), K_1 = 120 kg K ha^{-1} and K_2 = 160 kg K ha^{-1}

S_0 = Control (0 kg S ha^{-1}), S_1 = 15 kg S ha^{-1} and S_2 = 25 kg S ha^{-1}

4.1.4 Number of main stems hill^{-1}

Effect of potassium (K)

There was a significant variation on number of main stems hill^{-1} of potato influenced by different levels of potassium (Table 2 and Appendix V). The highest number of main stems hill^{-1} (6.99) was recorded from the treatment K_2 (160 kg K ha^{-1}) that was significantly differed to other treatments followed by K_1 (120 kg K ha^{-1}) whereas the lowest number of main stems hill^{-1} (3.98) was recorded from the control treatment K_0 (0 kg K ha^{-1}). Ali *et al*. (2021) and Fan *et al*. (2018) also found similar result with the present study and reported that application of different dose of K showed significantly increased number of main stem hill^{-1} of potato.

Effect of sulphur (S)

Significant variation was observed on number of main stems hill^{-1} of potato by different levels of sulphur (Table 2 and Appendix V). The highest number of main stems hill^{-1} (6.16) was recorded from the treatment S_1 (15 kg S ha^{-1}) which was statistically identical to S_2 (25 kg S ha^{-1}) whereas the control treatment S_0 (0 kg S ha^{-1}) registered the lowest number of main stems hill^{-1} (5.32). Similar findings were also observed by Arora *et al*. (2018) and they reported that number of main stems hill^{-1} was significantly increased by application of sulphur compared to control.

Combined effect of K and S

Significant influence was found on number of main stems hill^{-1} of potato by treatment combinations of potassium and sulphur (Table 2 and Appendix V). Results indicated that the treatment combination of K_2S_1 registered the highest number of main stem hill^{-1} (7.44) that was statistically identical to K_2S_2. The lowest number of main stem hill^{-1} (3.88) was recorded from the treatment combination of K_0S_0 which was statistically identical with treatment combinations of K_0S_1 and K_0S_2.

4.1.5 Fresh weight of haulm hill^{-1}

Effect of potassium (K)

Different potassium levels showed significant variation on fresh weight of haulm hill^{-1} of potato (Table 2 and Appendix V). It was observed that the highest fresh weight of haulm hill^{-1} (178.90 g) was recorded from the treatment K_2 (160 kg K ha^{-1}) which was statistically identical with K_1 (120 kg K ha^{-1}) whereas the lowest fresh weight of haulm hill^{-1} (159.30 g) was recorded from the control treatment K_0 (0 kg K ha^{-1}). The result obtained from the present study was similar with the findings of Sadeghi *et al.* (2010); they reported that higher doses of potassium significantly increased haulm fresh weight of potato.

Effect of sulphur (S)

Significant difference on fresh weight of haulm hill^{-1}of potato was recorded due to application of different sulphur levels (Table 2 and Appendix V). Results showed that at the highest fresh weight of haulm hill^{-1}(173.50 g) was recorded from the treatment S_1 (15 kg S ha^{-1}) which was statistically identical with S_2 (25 kg S ha^{-1}) whereas the lowest fresh weight of haulm hill^{-1} (166.40 g) was recorded from the control treatment S_0 (0 kg S ha^{-1}). The result from the present study was in agreement with the findings of Zaman *et al.* (2021); they reported that application of sulphur contributed to increase haulm fresh weight of potato.

Combined effect of K and S

Different combinations of potassium and sulphur gave statistically significant influence on fresh weight of haulm hill^{-1}of potato at different growth stages (Table 2 and Appendix V). The treatment combination of K_2S_1 showed the highest fresh weight of haulm hill^{-1} (182.60 g) which was statistically similar to the treatment combination of K_2S_1. The treatment combination K_0S_0 gave the lowest fresh weight of haulm hill^{-1} (155.90 g) which was statistically identical with the treatment combination of K_0S_1 and K_0S_2.

4.1.6 Dry weight of haulm hill^{-1}

Effect of potassium (K)

Different potassium levels showed significant variation on dry weight of haulm hill^{-1}of potato (Table 2 and Appendix V). It was observed that the highest dry weight of haulm hill^{-1} (30.04 g) was recorded from the treatment K_2 (160 kg K ha^{-1}) that was significantly different to other treatments followed by K_1 (120 kg K ha^{-1}) whereas the lowest dry weight of haulm hill^{-1} (20.97 g) was recorded from the control treatment K_0 (0 kg K ha^{-1}). The result obtained from the present study was similar with the findings of Sadeghi *et al*. (2010); they reported that haulm dry weight of potato influenced significantly due to different potassium doses.

Effect of sulphur (S)

Significant difference on dry weight of haulm hill^{-1}of potato was recorded due to application of different sulphur levels (Table 2 and Appendix V). Results showed that the highest dry weight of haulm hill^{-1} (32.60 g) was recorded from the treatment S_1 (15 kg S ha^{-1}) which was statistically identical with S_2 (25 kg S ha^{-1}) whereas the lowest dry weight of haulm hill^{-1} (18.76 g) was recorded from the control treatment S_0 (0 kg S ha^{-1}). The result from the present study was in agreement with the findings of Zaman *et al*. (2021); they reported that application of different sulphur levels significantly influence haulm dry weight and 40 kg S ha^{-1} contributed to increased haulm dry weight of potato.

Combined effect of K and S

Different combinations of potassium and sulphur gave statistically significant influence on dry weight of haulm hill^{-1} of potato at harvest stage (Table 2 and

Appendix V). The treatment combination of K_2S_1 showed the highest dry weight of haulm hill^{-1} (75.12 g) that was significantly identical with K_2S_2. The treatment combination K_0S_0 gave the lowest dry weight of haulm hill^{-1} (59.28 g) that was significantly different to other treatment combinations.

Table 2. Effect of potassium and sulphur on growth parameters (number of main stem hill^{-1}, fresh weight of haulm hill^{-1}, dry weight of haulm hill^{-1}) of potato (BARI Alu-25; ASTORIX)

Treatments	Growth Parameters		
	Number of main stems hill^{-1}	Fresh weight of haulm hill^{-1} (g)	Dry weight of haulm hill^{-1} (g)
Effect of Potassium			
K_0	3.98 c	159.30 b	20.97 c
K_1	6.56 b	173.60 a	27.61 b
K_2	6.99 a	178.90 a	30.04 a
$LSD_{0.05}$	0.311	5.781	2.068
CV(%)	7.52	10.69	8.27
Effect of Sulphur			
S_0	5.32 b	166.40 b	22.94 b
S_1	6.16 a	173.50 a	28.16 a
S_2	6.05 a	171.90 a	27.52 a
$LSD_{0.05}$	0.328	4.042	1.910
CV(%)	7.52	10.69	8.27
Combined effect of Potassium and Sulphur			
K_0S_0	3.88 e	155.90 e	18.76 f
K_0S_1	4.12 e	161.70 e	22.27 de
K_0S_2	3.94 e	160.30 e	21.87 e
K_1S_0	5.88 d	169.80 d	24.32 cd
K_1S_1	6.92 b	176.20 bc	29.62 b
K_1S_2	6.88 b	174.60 cd	28.90 b
K_2S_0	6.20 c	173.40 cd	25.75 c
K_2S_1	7.44 a	182.60 a	32.60 a
K_2S_2	7.32 a	180.80 ab	31.78 a
$LSD_{0.05}$	0.314	5.778	2.068
CV(%)	7.52	10.69	8.27

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

K_0 = Control (0 kg K ha^{-1}), K_1 = 120 kg K ha^{-1} and K_2 = 160 kg K ha^{-1}

S_0 = Control (0 kg S ha^{-1}), S_1 = 15 kg S ha^{-1} and S_2 = 25 kg S ha^{-1}

4.2 Yield contributing parameters

4.2.1 Number of tubershill^{-1}

Effect of potassium (K)

The effect of potassium on number of tubershill^{-1} of potato was significant (Table 3 and Appendix VI). Results revealed that the treatment K_2 (160 kg K ha^{-1}) registered the highest number of tubers hill^{-1} (7.47) followed by K_1 (120 kg K ha^{-1}). On the other hand the lowest number of tubers hill^{-1} (6.12) was given by the control treatment K_0 (0 kg K ha^{-1}). Ali *et al*. (2021) and Gildersleeve *et al*. (2021) also found similar result with the present study and noticed that application of different doses of K increased number tubershill^{-1} of potato compared to control. Similar result was also observed by Merino-Gergichevich *et al*. (2017) and Gupta *et al*. (2017).

Effect of sulphur (S)

Sulphur fertilizer had significant effect on number of tubers hill^{-1} of potato (Table 3 and Appendix VI). Results showed that the highest number of tubers hill^{-1} (7.15) was recorded from the treatment S_1 (15 kg S ha^{-1}) that was significantly same to the treatment S_2 (25 kg S ha^{-1}) whereas the lowest number of tubers hill^{-1} (6.40) was recorded from the control treatment S_0 (0 kg S ha^{-1}). Zaman *et al*. (2021), Arora *et al*. (2018) and Gupta *et al*. (2016) also found similar result with the present study and reported that application of S had significant effect to produce the higher number of tuber hill^{-1} of potato.

Combined effect of K and S

Combined effect of potassium and sulphur on the number of tubershill^{-1}of potato showed significant variation (Table 3 and Appendix VI). Results exhibited that the treatment combination K_2S_1 exposed the highest number of tubers hill^{-1} (7.87) that was statistically identical to the treatment combination of K_2S_2. Reversely, the lowest number of tubers hill^{-1} (5.94) was recorded from the treatment combination of K_0S_0 that was significantly similar to K_0S_1 and K_0S_2.

4.2.2 Weight of tuber hill^{-1} (g)

Effect of potassium (K)

The weight of potato tubers hill^{-1}affected significantly due to application of different levels of potassium (Table 3 and Appendix VI). The highest weight of tubers hill^{-1} (273.90 g) was recorded from the treatmentK_2 (160 kg K ha^{-1}) that was significantly differed to other treatments followed by K_1 (120 kg K ha^{-1}) whereas the lowest weight of tubers hill^{-1} (192.60 g) was recorded from the control treatment K_0 (0 kg K ha^{-1}). Fan *et al.* (2018), Merino-Gergichevich *et al.* (2017) and Gupta *et al.* (2017) also found higher tubers weight per hill with the application of K compared to control which supported the present study.

Effect of sulphur (S)

Application of different levels of sulphur gave significant effect on weight of tubers hill^{-1} of potato (Table 3 and Appendix VI). The highest weight of tubers hill^{-1} (252.40 g) was recorded from the treatment S_2 (25 kg S ha^{-1}) which was statistically identical with S_2 (25 kg S ha^{-1}) whereas the lowest weight of tubers hill^{-1} (222.20 g) was recorded from the control treatment S_0 (0 kg S ha^{-1}). Gupta *et al.* (2016) and Sharma *et al.* (2015) also recorded similar result with the present study and they reported that sulphur had significant effect to increase weight of tubers hill^{-1}.

Combined effect of K and S

Weight of tuber hill^{-1}of potato influenced significantly due to different combination of potassium and sulphur (Table 3 and Appendix VI). The highest weight of tubers hill^{-1} (285.90 g) was recorded from the treatment combination of K_2S_1 that was significantly identical to K_2S_2. The lowest weight of tubers hill^{-1}

(169.20 g) was recorded from the treatment combination of K_0S_0 that was significantly differed to other treatment combinations.

4.2.3 Dry weight of 100 g fresh tuber (g)

Effect of potassium (K)

Significant variation was found on dry weight of 100 g fresh tuber (g) of potato by the application of different potassium levels (Table 3 and Appendix VI). Results exhibited that the highest dry weight of 100 g fresh tuber (22.43 g) was recorded from the treatment K_2 (160 kg K ha^{-1}) that was significantly differed to other treatments followed by K_1 (120 kg K ha^{-1}) whereas the lowest dry weight of 100 g fresh tuber (18.50 g) was recorded from the control treatment K_0 (0 kg K ha^{-1}). Similar result was also observed by Yakimenko and Naumova (2018) and Merino-Gergichevich *et al*. (2017) who obtained positive effect with K application on dry matter content of fresh tuber.

Effect of sulphur (S)

Significant variation was recorded on dry weight of 100 g fresh tuber (g) of potato as influenced by the application of different levels of sulphur (Table 3 and Appendix VI). The highest dry weight of 100 g fresh tuber (21.41 g) was recorded from the treatment S_1 (15 kg S ha^{-1}) which was statistically identical with S_2 (25 kg S ha^{-1}) whereas the lowest dry weight of 100 g fresh tuber (19.49 g) was recorded from the control treatment S_0 (0 kg S ha^{-1}). The result obtained from the present study was similar with the findings of Sharma *et al*. (2011); they reported that S had significant effect on dry matter content of fresh tuber and S has significant contribution to increase dry matter content of potato compared to control.

Combined effect of K and S

Dry weight of 100 g fresh tuber of potato varied significantly among the different combination of potassium and sulphur (Table 3 and Appendix VI). The highest dry weight of 100 g fresh tuber (23.62 g) was recorded from the treatment combination of K_2S_1 that was significantly similar to the treatment combination of K_2S_2. Again, the lowest dry weight of 100 g fresh tuber (17.96 g) was recorded from the treatment combination of K_0S_0 which was statistically similar to K_0S_1 and K_0S_2.

Table 3. Effect of potassium and sulphur on yield contributing parameters of potato (BARI Alu-25; ASTORIX)

Treatments	Yield contributing parameters		
	Number of tubershill^{-1}	Weight of tubershill^{-1} (g)	Dry weight of 100 g fresh tuber (g)
Effect of Potassium			
K_0	6.12 c	192.60 c	18.50 c
K_1	6.95 b	256.60 b	20.98 b
K_2	7.47 a	273.90 a	22.43 a
$LSD_{0.05}$	0.391	8.187	1.138
CV(%)	5.63	9.24	6.47
Effect of Sulphur			
S_0	6.40 b	222.20 b	19.49 b
S_1	7.15 a	252.40 a	21.41 a
S_2	6.98 a	248.50 a	21.01 a
$LSD_{0.05}$	0.435	8.132	1.149
CV(%)	5.63	9.24	6.47
Combined effect of Potassium and Sulphur			
K_0S_0	5.94 f	169.20 e	17.96 e
K_0S_1	6.30 ef	208.00 d	18.80 de
K_0S_2	6.12 f	200.70 d	18.73 de
K_1S_0	6.52 de	245.40 c	19.67 d
K_1S_1	7.28 b	263.50 b	21.80 bc
K_1S_2	7.04 bc	261.00 b	21.48 c
K_2S_0	6.75 cd	251.90 c	20.84 c
K_2S_1	7.87 a	285.90 a	23.62 a
K_2S_2	7.78 a	283.90 a	22.83 ab
$LSD_{0.05}$	0.391	8.187	1.138
CV(%)	5.63	9.24	6.47

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

K_0 = Control (0 kg K ha^{-1}), K_1 = 120 kg K ha^{-1} and K_2 = 160 kg K ha^{-1}

S_0 = Control (0 kg S ha^{-1}), S_1 = 15 kg S ha^{-1} and S_2 = 25 kg S ha^{-1}

4.3 Yield parameters

4.3.1Tuber weight plot^{-1} (kg)

Effect of potassium (K)

Application of different levels of potassium showed significant difference among the treatments on tuber yield plot^{-1} of potato (Table 4 and Appendix VII). The highest tuber yield plot^{-1} (14.24 kg) was recorded from the K_2 (160 kg K ha^{-1}) which was statistically identical with K_1 (120 kg K ha^{-1}) whereas the lowest tuber yield plot^{-1} (10.02 kg) was recorded from the control treatment K_0 (0 kg K ha^{-1}).

Effect of sulphur (S)

Application of different levels of sulphur had significant influence on tuber yield plot^{-1} of potato (Table 4 and Appendix VII). The treatmentS_1 (15 kg S ha^{-1}) gave the highest tuber yield plot^{-1} (13.13 kg) which was statistically identical with S_2 (25 kg S ha^{-1}) whereas the lowest tuber yield plot^{-1} (11.55 kg) was given by the control treatment S_0 (0 kg S ha^{-1}).

Combined effect of K and S

Different combination of potassium and sulphur showed significant variation on tuber yield plot^{-1} of potato (Table 4 and Appendix VII). The treatment combination of K_2S_1 recorded the highest tuber yield plot^{-1} (14.87 kg) which was statistically similar withK_2S_2, K_1S_1 and K_1S_2. The lowest tuber yield plot^{-1} (8.80 kg) was recorded from the treatment combination of K_0S_0 which was significantly differed to other treatment combinations.

4.3.2 Tuber yield ha^{-1} (kg)

Effect of potassium (K)

Tuber yield ha^{-1} of potato influenced significantly due to application of different levels of potassium (Table 4 and Appendix VII). Results showed that the highest fruit yield ha^{-1} (28.48 t) was recorded from the treatment K_2 (160 kg K ha^{-1}) that was significantly differed to other treatments followed by K_1 (120 kg K ha^{-1}) whereas the lowest fruit yield ha^{-1} (20.03 t) was recorded from the control treatment K_0 (0 kg K ha^{-1}). Ali *et al*. (2021), Molina-Rueda *et al*. (2019) and Fan *et al*. (2018) found considerable influence of potassium on tuber yield of potato and they recorded the higher fruit yield with the application of potassium where no potassium application showed considerable lower potato yield.

Effect of sulphur (S)

Application of different levels of sulphur showed significant variation on tuber yield ha^{-1} of potato (Table 4 and Appendix VII). Results revealed that the treatment S_1 (15 kg S ha^{-1}) registered the highest tuber yield ha^{-1} (26.25t) that was statistically identical to the treatment S_2 (25 kg S ha^{-1}). The lowest tuber yield ha^{-1} (23.11t) was given by the control treatment S_0 (0 kg S ha^{-1}). Zaman *et al*. (2021), Li *et al*. (2020) and Sameh *et al*. (2018) reported that that sulfur application improved the soil structure and increased the availability of nutrients to the potato plants, which contributed to the improved yield and quality which supported the present findings.

Combined effect of K and S

Significant variation was recorded on tuber yield ha^{-1} of potato by different combination of potassium and sulphur (Table 4 and Appendix VII). Results exhibited that the treatment combination K_2S_1 gave the highest tuber yield ha^{-1} (29.73 t) and this treatment combination was significantly same to K_2S_2. In contrast, the lowest tuber yield ha^{-1} (17.60 t) was recorded from the treatment combination of K_0S_0 that was significantly different from other treatment combinations. The result obtained from the present study was conformity with the findings of Mahmoud *et al*. (2021), Gomaa *et al*. (2020) and Zhang *et al*. (2019); they obtained higher potato yield with the combined application of potassium and sulphur.

Table 4. Effect of potassium and sulphur on yield parameters of potato (BARI Alu-25; ASTORIX)

Treatments	Yield parameters	
	Tuber weight $plot^{-1}$ (kg)	Tuber yield ha^{-1} (t)
Effect of Potassium		
K_0	10.02 b	20.03 c
K_1	13.34 a	26.69 b
K_2	14.24 a	28.48 a
$LSD_{0.05}$	1.364	1.377
CV(%)	8.76	8.72
Effect of Sulphur		
S_0	11.55 b	23.11 b
S_1	13.13 a	26.25 a
S_2	12.92 a	25.84 a
$LSD_{0.05}$	0.967	0.999
CV(%)	8.76	8.72
Combined effect of Potassium and Sulphur		
K_0S_0	8.80 d	17.60 e
K_0S_1	10.82 c	21.63 d
K_0S_2	10.44 c	20.87 d
K_1S_0	12.76 b	25.52 c
K_1S_1	13.70 ab	27.40 b
K_1S_2	13.57 ab	27.14 b
K_2S_0	13.10 b	26.20 bc
K_2S_1	14.87 a	29.73 a
K_2S_2	14.76 a	29.52 a
$LSD_{0.05}$	1.364	1.377
CV(%)	8.76	8.72

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

K_0 = Control (0 kg K ha^{-1}), K_1 = 120 kg K ha^{-1} and K_2 = 160 kg K ha^{-1}

S_0 = Control (0 kg S ha^{-1}), S_1 = 15 kg S ha^{-1} and S_2 = 25 kg S ha^{-1}

4.4Quality parameters of postharvest soil

4.4.1 pH status of postharvest soil

Effect of potassium (K)

Non-significant influence was found on pH value of post harvest soil by different levels of potassium (Table 5 and Appendix VIII). However, the highest pH value (6.24) was recorded from the control treatment K_0 (0 kg K ha^{-1}) followed by K_1 (120 kg K ha^{-1}) whereas the lowest pH value (6.22) was recorded from the treatment K_2 (160 kg K ha^{-1}).

Effect of sulphur (S)

Application of different levels of sulphur gave non-significant variation on pH value of post harvest soil (Table 5 and Appendix VIII). However, the control treatment S_0 (0 kg S ha^{-1}) showed the highest pH value (6.27) followed by S_1 (15 kg S ha^{-1}) while the treatment S_2 (25 kg S ha^{-1}) registered the lowest pH value (6.19).

Combined effect of K and S

Combined effect of potassium and sulphur showed non-significant effect on pH value of post harvest soil (Table 5 and Appendix VIII). However, the highest pH value (6.28) was recorded from the treatment combination of K_0S_0 whereas the lowest pH value (6.18) was recorded from the treatment combination of K_2S_2.

4.4.2Organic carbon content of postharvest soil

Effect of potassium (K)

Non-significant influence was found on organic carbon content of post harvest soil by different levels of potassium (Table 5 and Appendix VIII). However, the highest organic carbon content (0.64%) was recorded from the treatment K_2 (160 kg K ha^{-1}) followed by K_1 (120 kg K ha^{-1}) whereas the lowest organic carbon content (0.53%) was recorded from the control treatment K_0 (0 kg K ha^{-1}).

Effect of sulphur (S)

Application of different levels of sulphur gave non-significant variation on organic carbon content of post harvest soil (Table 5 and Appendix VIII). However, the treatment S_2 (25 kg S ha^{-1}) showed the highest organic carbon content (0.60%) followed by S_1 (15 kg S ha^{-1}) while the control treatment S_0 (0 kg S ha^{-1}) registered the lowest organic carbon content (0.57%).

Combined effect of K and S

Combined effect of potassium and sulphur showed non-significant effect on organic carbon content of post harvest soil (Table 5 and Appendix VIII). However, the highest organic carbon content (0.65%) was recorded from the treatment combination of K_2S_2 whereas the lowest organic carbon content (0.51%) was recorded from the treatment combination of K_0S_0.

4.4.3Available phosphorus (P) content in postharvest soil

Effect of potassium (K)

Significant variation was found on P content of post harvest soil by different levels of potassium (Table 5 and Appendix VIII). The highest P content (23.98 ppm) was achieved by the treatment K_2 (160 kg K ha^{-1}) that was significantly different to other treatments followed by K_1 (120 kg K ha^{-1}). Again, the control treatment K_0 (0 kg K ha^{-1}) recorded the lowest P content (18.74 ppm).

Effect of sulphur (S)

Application of different levels of sulphur gave non-significant effect on P content of post harvest soil (Table 5 and Appendix VIII). However, the highest P content

(22.06 ppm) was found from the treatmentS_2 (25 kg S ha^{-1}) whereas the lowest P content (21.27 ppm) was recorded from the control treatment S_0 (0 kg S ha^{-1}).

Combined effect of K and S

P content of post harvest soil influenced significantly due to different combination of potassium and sulphur (Table 5 and Appendix VIII). The highest P content (24.20 ppm) was recorded from the treatment combination of K_2S_2 and statistically similar result was shown by K_2S_1 with K_2S_0 treatment combination. The lowest P content (18.40 ppm) was recorded from the treatment combination of K_0S_0 that was significantly identical to the treatment combination of $K_0S_1$and K_0S_2 treatment combination.

4.4.4 Available potassium (K) content in postharvest soil

Effect of potassium (K)

Significant variation was observed on K content of post harvest soil by application of different levels of potassium (Table 5 and Appendix VIII). The highest K content (1.04 meq/100 g soil) was recorded from the treatment K_2 (160 kg K ha^{-1}) that was significantly different to other treatments whereas the control treatment K_0 (0 kg K ha^{-1}) gave the lowest K content (0.76 meq/100 g soil) which was statistically identical with K_1 (120 kg K ha^{-1}).

Effect of sulphur (S)

Application of different levels of sulphur gave non-significant effect on K content of post harvest soil (Table 5 and Appendix VIII). However, the treatmentS_2 (25 kg S ha^{-1}) showed the highest K content (0.93 meq/100 g soil) whereas the control treatment S_0 (0 kg S ha^{-1}) recorded the lowest K content (0.84 meq/100 g soil).

Combined effect of K and S

Combined effect of potassium and sulphur showed significant effect on K content of post harvest soil (Table 5 and Appendix VIII). The highest K content (1.10 meq/100 g soil) was given by the treatment combination of K_2S_2 which was statistically similar to K_2S_1. Then again, the treatment combination K_0S_0 showed the lowest K content (0.72 meq/100 g soil) that was statistically similar to K_0S_1 and K_0S_2 treatment combination.

4.4.5 Available sulphur (S) content in postharvest soil

Effect of potassium (K)

Significant variation was observed on S content of post harvest soil by different levels of potassium (Table 5 and Appendix VIII). Results exhibited that the highest S content (26.39 ppm) was recorded from the treatment K_2 (160 kg K ha^{-1}) which was statistically identical to K_1 (120 kg K ha^{-1}) while the control treatment K_0 (0 kg K ha^{-1}) recorded the lowest S content (24.06 ppm) in post harvest soil.

Effect of sulphur (S)

Application of different levels of sulphur gave significant effect on S content of post harvest soil (Table 5 and Appendix VIII). Results showed that the highest S content (28.47 ppm) was recorded from the treatmentS_2 (25 kg S ha^{-1}) which was statistically identical with S_1 (15 kg S ha^{-1}) whereas the control treatment S_0 (0 kg S ha^{-1}) showed the lowest S content (21.30 ppm) in post harvest soil.

Combined effect of K and S

Combined effect of potassium and sulphur showed significant effect on S content of post harvest soil (Table 5 and Appendix VIII). Results revealed that the treatment combination K_2S_2 indicated the highest S content (29.32 ppm) that was statistically similar to the treatment combinationK_1S_2 whereas the treatment combination of K_0S_0 registered the lowest S content (19.83 ppm) that was significantly different toother treatment combinations.

Table 5. Effect of potassium and sulphur on quality of post harvest soil of potato field

Treatments	Quality of post harvest soil				
	pH	Organic carbon (%)	Available phosphorus (ppm)	Available potassium (meq/100 g soil)	Available sulphur (ppm)
Effect of Potassium					
K_0	6.24	0.53	18.74 c	0.76 b	24.06 b
K_1	6.23	0.59	22.23 b	0.88 b	25.41 a
K_2	6.22	0.64	23.98 a	1.04 a	26.39 a
$LSD_{0.05}$	0.167^{NS}	0.161^{NS}	0.976	0.134	1.344
CV(%)	3.21	2.89	7.28	5.46	6.83
Effect of Sulphur					
S_0	6.27	0.57	21.27	0.84	21.30 c
S_1	6.23	0.59	21.62	0.89	26.10 b
S_2	6.19	0.60	22.06	0.93	28.47 a
$LSD_{0.05}$	0.164^{NS}	0.154^{NS}	0.962^{NS}	0.095^{NS}	1.344
CV(%)	3.21	2.89	7.28	5.46	6.83
Combined effect of Potassium and Sulphur					
K_0S_0	6.28	0.51	18.40 d	0.72 f	19.83 g
K_0S_1	6.24	0.55	19.30 d	0.77 ef	24.87 d
K_0S_2	6.20	0.54	18.52 d	0.78 ef	27.48 bc
K_1S_0	6.27	0.57	21.80 c	0.83 de	21.33 f
K_1S_1	6.24	0.58	22.75 bc	0.88 d	26.30 c
K_1S_2	6.19	0.62	22.14 c	0.92 cd	28.60 ab
K_2S_0	6.25	0.62	23.62 ab	0.98 bc	22.74 e
K_2S_1	6.22	0.64	24.12 a	1.03 ab	27.12 c
K_2S_2	6.18	0.65	24.20 a	1.10 a	29.32 a
$LSD_{0.05}$	0.163^{NS}	0.166^{NS}	0.976	0.093	1.377
CV(%)	3.21	2.89	7.28	5.46	6.83

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

K_0 = Control (0 kg K ha^{-1}), K_1 = 120 kg K ha^{-1} and K_2 = 160 kg K ha^{-1}

S_0 = Control (0 kg S ha^{-1}), S_1 = 15 kg S ha^{-1} and S_2 = 25 kg S ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

Different levels of potassium (K) showed significant variation on most of the studied parameters regarding growth, yield contributing parameters and yield of potato. Regarding growth parameters influenced by K, the minimum days to 100% seedling emergence (16.00 days) was recorded from the treatment K_2 (160 kg K ha^{-1}) whereas the maximum (18.00 days) was found from the control treatment K_0 (0 kg K ha^{-1}). Again, the highest plant height (72.10), the highest number of leaves plant^{-1} (71.95), number of main stem hill^{-1} (6.99), fresh weight of haulm hill^{-1} (178.90 g) and dry weight of haulm hill^{-1} (30.04 g) were recorded from the treatment K_2 (160 kg K ha^{-1}) whereas control treatment K_0 (0 kg K ha^{-1}) gave the lowest plant height (61.48), the highest number of leaves plant^{-1} (61.05), number of main stems hill^{-1} (3.98), fresh weight of haulm hill^{-1} (159.30 g) and dry weight of haulm hill^{-1} (20.97 g).Regarding yield contributing parameters and yield of potato, K_2 (160 kg K ha^{-1}) treatment showed the highest number of tubers hill^{-1} (7.47), weight of tubers hill^{-1} (273.90 g), dry weight of 100 g fresh tuber (22.43 g), tuber weight plot^{-1} (14.24 kg) and tuber yield ha^{-1} (28.48 t) whereas control treatment K_0 (0 kg K ha^{-1}) gave the lowest number of tubers hill^{-1} (6.12), weight of tubers hill^{-1} (192.60 g), dry weight of 100 g fresh tuber (18.50 g), tuber weight plot^{-1} (10.02 kg) and tuber yield ha^{-1} (20.03 t). In terms of nutrient content in post harvest soil; P, K and S content affected significantly by different K levels but pH and organic carbon (OC) did not differ significantly. Treatment K_2 (160 kg K ha^{-1}) showed the highest P, K and S content (23.98 ppm, 1.04meq/100 g soil, and 26.39 ppm, respectively) whereas control treatment K_0 (0 kg K ha^{-1}) showed the lowest P, K and S content (18.74ppm, 0.76 meq/100 g soil, and 24.06 ppm, respectively) in post harvest soil.

Different sulphur (S) levels showed significant variation on growth, yield contributing parameters and yield of potato. In case of growth parameters, the minimum days to 100% seedling emergence (16.44 days) was recorded from the S_1 (15 kg S ha^{-1}) whereas the maximum (17.67 days) was found from the control treatment S_0 (0 kg S ha^{-1}). Again, the highest plant height (69.45) and number of leaves $plant^{-1}$ (69.69) were recorded from the treatment S_2 (25 kg S ha^{-1}) but the highest number of main stems $hill^{-1}$ (6.16), fresh weight of haulm $hill^{-1}$ (173.50 g) and dry weight of haulm $hill^{-1}$ (28.16 g) were recorded from the treatment S_1 (15 kg S ha^{-1}) whereas control treatment S_0 (0 kg S ha^{-1}) gave the lowest plant height (64.45), number of leaves $plant^{-1}$ (64.25), number of main stems $hill^{-1}$ (5.32), fresh weight of haulm $hill^{-1}$ (166.40 g) and dry weight of haulm $hill^{-1}$ (22.94 g). Regarding yield contributing parameters and yield of potato, S_1 (15 kg S ha^{-1}) treatment showed the highest number of tubers $hill^{-1}$ (7.15), weight of tuber $hill^{-1}$ (252.40 g), dry weight of 100 g fresh tuber (21.41 g), tuber weight $plot^{-1}$ (13.13 kg) and tuber yield ha^{-1} (26.25 t) whereas control treatment S_0 (0 kg S ha^{-1}) gave the lowest number of tuber $hill^{-1}$ (6.40), weight of tuber $hill^{-1}$ (222.20 g), dry weight of 100 g fresh tuber (19.49 g), tuber weight $plot^{-1}$ (11.55 kg) and tuber yield ha^{-1} (23.11 t). In terms of nutrient content in post harvest soil; S content affected significantly by different S levels but pH, organic carbon (OC), P and K did not differ significantly. Treatment S_2 (25 kg S ha^{-1}) showed the highest S content (28.47 ppm) whereas control treatment S_0 (0 kg S ha^{-1}) showed the lowest S content (21.30 ppm) in post harvest soil.

Different growth, yield contributing parameters and yield of potato influenced significantly due to treatment combination of K and S. Considering growth parameters, the minimum days to 100% seedling emergence (15.33 days) was recorded from the treatment combination of K_2S_1 whereas the maximum (18.67 days) was found from K_0S_0. Again, the highest plant height (75.44) and number of leaves $plant^{-1}$ (75.12)were recorded from the treatment combination K_2S_2 while the highest number of main stem hill^{-1} (7.44), fresh weight of haulm hill^{-1} (182.60 g) and dry weight of haulm hill^{-1} (32.60 g) were recorded from the treatment combination K_2S_1 whereas thetreatment combination K_0S_0 gave the lowest plant height (60.67), the highest number of leaves plant^{-1} (59.28), number of main stem hill^{-1} (3.88), fresh weight of haulm hill^{-1} (155.90 g) and dry weight of haulm hill^{-1} (18.76 g). Regarding yield contributing parameters and yield of potato, the treatment combination K_2S_1 showed the highest number of tuber hill^{-1} (7.87), weight of tuber hill^{-1} (285.90 g), dry weight of 100 g fresh tuber (23.62 g), tuber weight plot^{-1} (14.87 kg) and tuber yield ha^{-1} (29.73 t)the treatment combination K_0S_0 gave the lowest number of tuber hill^{-1} (5.94), weight of tuber hill^{-1} (169.20 g), dry weight of 100 g fresh tuber (17.96 g), tuber weight plot^{-1} (8.80 kg) and tuber yield ha^{-1} (17.60 t). In terms of nutrient content in post harvest soil; P, K and S content affected significantly by different K and S combinations but pH and organic carbon (OC) did not differ significantly. Treatment combination K_2S_2 showed the highest P, K and S content (24.20 ppm, 1.10meq/100 g soil, and 29.32 ppm, respectively) whereas K_0S_0 showed the lowest P, K and S content (18.40, 0.72meq/100 g soil, and 19.836 ppm, respectively) in post harvest soil.

Conclusion

From the present study, the following conclusion may be drawn –

1. Individual effect of potassium (K) and sulphur (S) showed significant variation for all the growth, yield contributing parameters and yield of potato.
2. Application of K_2 (160 kg K ha^{-1}) was the suitable doses of potassium which gave the highest yield of potato (28.48 t ha^{-1}) compared to K_1 (120 kg K ha^{-1}) control K_0 (0 kg K ha^{-1}).
3. Application of S_1 (15 kg S ha^{-1}) was most suitable regarding highest yield of potato (26.25 t ha^{-1}) compared to S_2 (25 kg S ha^{-1}) and control S_0 (0 kg S ha^{-1}).

4. The combined effect of potassium and sulphur enhanced growth, yield and yield attributes of potato.
5. K_2 (160 kg K ha^{-1}) in combination with S_1 (15 kg S ha^{-1}) gave highest yield of potato (29.73 t ha^{-1}) compared to other treatment combinations.

Recommendation

Further research works at different regions of the country are needed to be carried out for the confirmation of the present findings.

REFERENCES

Abd-El-Latif, K.M. (2011). Response of potato plants to potassium fertilizer rates and soil moisture deficit. *Adv. Appl. Sci. Res*. **2**(2): 388-397.

Ahmed, B., Sultana, M., Chowdhury, M.A.H., Akhter, S. and Alam, M.J. (2017). Growth and yield performance of potato varieties under different planting dates. *Bangladesh Agron. J*. **20**(1): 25-29.

Ali, M.M.E., Petropoulos, S.A., Selim, D.A.H., Elbagory, M., Othman, M.M., Omara, A.E.D. and Mohamed, M.H. (2021). Plant growth, yield and quality of potato crop in relation to potassium fertilization. *J. Agron*. **11**: 675.

Alshammari, M. A., AL-Shoaibi, A. A. and Al-Ghamdi, A. A. (2020). The effect of sulfur fertilization on growth and yield of potato in sandy soils. *Saudi J. Biol. Sci*. **27**(10): 2814-2820.

Anwar, H., Hussain, S., Ashraf, U., Ali, H. H., Rehman, S. U. and Fahad, S. (2016). Effect of potassium fertilization on growth, yield and quality of potato (*Solanum tuberosum* L.). *J. soil Sci. Plant Nutr*. **16**(4): 1037-1047. doi: 10.4067/S0718-95162016005000074

Arora, D., Choudhary, A. K. and Patel, V. K. (2018). Effect of sulphur on growth and yield of potato (*Solanum tuberosum* L.) under different soil types. *J. Pharmacog. Phytochem*. **7**(1): 22-25.

Ayush, K.S., Amanpreet, K.S. and Simranpreet, K.S. (2023). Potato (*Solanum tuberosum* L.) Yield response to different sulfur rates and sources. *Hort. Sci*. **58**(1):47–54.

Banerjee, H., Sarkar, S., Deb, P., Dutta, S. K., Ray, K., Rana, L. and Majumdar, K. (2016). Impact of zinc fertilization on potato (*Solanum tuberosum* L.)

yield, zinc use efficiency, quality and economics in entisol of West Bengal. *J. Indian Soc. Soil Sci*. **64**(2): 176-182.

BBS (Bangladesh Bureau of Statistics). (2013). Monthly Statistical Year Book. Ministry of Planning, Govt. Peoples Repub. Bangladesh. P. 64.

BBS (Bangladesh Bureau of Statistics). (2019). Monthly statistical Year Book. Ministry of Planning, Govt. Peoples Repub. Bangladesh. P. 78.

Bishwoyog, B. andSwarnima, K. (2016). Effect of potassium on quality and yield of potato tubers - A Review. *Int. J. Agric. Environ. Sci*. **3**: 7–12.

Chakraborty, S., Chakraborty, N. and Datta, A. (2010). Increased nutritive value of transgenic potato by expressing a nonallergenic seed albumin gene from maranthushypochondriacus. *Proc. Natl. Acad. Sci*. **97**: 3724-3729.

Evers, J.B., Vos, J. and Fournier, C. (2006). Functional-structural potato plant modelling: a review. *Annals Appl.Biol*. **149**: 127–151. doi: 10.1111/j.1744-7348.2006.00075.x

Fageria, N. K., Baligar, V. C. and Li, Y. C. (2018). The role of sulfur nutrition in crop plants: A review. *J. Plant Nutr*. **41**(9): 1215-1231. https://doi.org/10.1080/01904167.2018.1484264

Fan, X., Xu, G. and Liu, X. (2018). Effects of potassium levels on growth, yield and potassium uptake of potato. *J. Soil Sci. Plant Nutr*. **18**: 731–740. doi: 10.4067/S0718-95162018005002201

FAO (Food and Agricultural Organization). (2019). Production Year Book no. 65. Food and Agriculture Organization, FAO, Rome, Italy. p. 64.

FAOSTAT (FAO Statistics Division). (2019). Statistical Database. Food and Agricultural Organization of the United Nations, Rome, Italy.

Fares, A., Abd El-Aziz, N. G., El-Tohamy, W. A. and El-Ghamry, A. M. (2017). Response of potato to sulfur fertilization in sandy and calcareous soils. *J. Plant Nutr*. **40**(8): 1171-1181.

Farheen, N.; Iqbal, M.M.; Fatima, B.; Kashif, M.R. andMaqshoof, (2018). A. Modeling the potassium requirements of potato crop for yield and quality optimization. *Asian J. Agric. Biol*. **6**: 169–180.

Gildersleeve, R., Clough, G. H., Murphy, K. M. and Porter, G. A. (2021). Potassium fertilization improves yield and quality of organically grown potato. *Hort. Sci*. **56**(2): 271-278. doi: 10.21273/HORTSCI15372-20

Gomaa, M. A., Wahba, M. A. and El-Metwally, I. M. (2020). Effect of potassium and sulfur fertilization on potato yield, quality, and nutrient uptake under saline conditions. *J. Plant Nutr*. **43**(1): 87-99.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedure for agricultural research. second edn. Intl. Rice Res. Inst., John Wiley and Sons. New York. Pp. 1-340.

Gunadi, N. (2009). Response of potato to potassium fertilizer sources and application methods in andisols of West Java. *Indonesian J. Agril. Sci*. **10**(2): 65-72.

Gupta, N., Kumar, A. and Kumar, V. (2017). Potassium nutrition and its effect on growth, yield and quality of potato (*Solanum tuberosum* L.). *Indian J. Agric. Sci*. **87**: 862–866.

Gupta, S., Srivastava, A. K., Singh, R. and Singh, V. P. (2016). Effect of sulphur fertilization on growth, yield and quality of potato (*Solanum tuberosum* L.). *J. Plant Nutr*. **39**(6): 807-814. doi: 10.1080/01904167.2015.1090636

Gupta, S., Srivastava, A. K., Singh, V. P., Singh, R. and Gupta, S. K. (2017). Response of potato (*Solanum tuberosum* L.) to potassium fertilization under different planting densities. *J. Plant Nutr*. **40**(1): 38-45. doi: 10.1080/01904167.2016.1186623

Gutema, C. (2021). Effect of Potassium Fertilizer Rate on Growth, Yield and Yield Related Parameters of 'Irish Potato (*Solanum tuberosum* L.) at Bale Highlands. *J.Agril. Res*. **6**(1): 000257.

Hartz, T.K., and Johnstone, P.R. (2006). Yield response of potato to potassium fertilization in California. *Hort. Technol*. **16**: 650–655.

Horton, D. (1987). Potatoes: Production, marketing and programs for developing countries. Westview Press, London. Pp.19-24.

Hu, L., Zhang, L., Zhang, X., and Wang, X. (2017). Effect of sulfur application on potato yield and starch content. *J. Northeast Agric. Univ*. **24**(4): 26-30. https://doi.org/10.7685/jnau.201612011

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi, 498.

Jatoi, S. A., Liu, X., Chen, L., Zhang, Q. and Pan, J. (2020). Combined application of potassium and sulfur improves potato growth, yield, and quality under heat stress conditions. *J. Plant Nutr.* **43**(16): 2378-2389.

Keeps, M. S. (1979). Production of field crops. 6th edn. tata mc-graw hill publishing co. ltd., New Delhi. P. 369.

Khan, M. W., Rab, A., Ali, R., Sajid, M., Aman, F. Khan, I., Hussain, I. and Ali, A. (2019). Effect of potassium and zinc on growth yield and tuber quality of potato. *Sarhad J. Agric*. **35**(2): 330-335.

Kumar, U. and Chandra, G. (2018). A brief review of potash management in potato (*Solanum tuberosum* L.). *J. Pharmacogn. Phytochem*. **7**: 1718–1721.

Li, X., Liu, W., Tian, G., Wu, W., Li, B., and Wang, Y. (2020). Effects of sulfur fertilization on potato yield and quality under different soil types. *Agron. J*., **112**(6): 5381-5390.

Liu, X., Yang, Y., Li, X., Zhang, Y., Zhang, X., and Wang, L. (2016). Effects of sulfur application on potato yield, water use efficiency, and starch quality under different irrigation regimes. *Frontiers Plant Sci*. **7**: 1465. https://doi.org/10.3389/fpls.2016.01465

Lu, Y.G. (2003). Effects of K fertilizer application on potato yield in high altitude localities. *Chinese Potato J*. **17**(2): 67-69.

Mahmoud, E. A., Elsayed, S. A., and Abd El-Aal, M. S. (2021). Response of potato crop to potassium and sulfur fertilization under water deficit conditions. *J. Agril*. **11**(2): 128.

Márton, L., Bonis, P. and Vago, I. (2015). The effect of potassium supply on the growth, yield and quality of potato (*Solanum tuberosum* L.). *Plant Soil Environ*. **61**: 191–196. doi: 10.17221/111/2015-PSE

Meena, R. S., Kumar, S. and Yadav, A. K. (2018). Sulphur application improves the quality of potato (*Solanum tuberosum* L.) tubers by reducing the reducing sugar content and increasing the ascorbic acid content. *J. Plant Nutr*. **41**(1): 41-49. doi: 10.1080/01904167.2017.1351673

Mello, S.D.C., Pierce, F.J., Tonhati, R.; Almeida, G.S., Neto, D.D., Pavuluri, K. (2018). Potato Response to polyhalite as a potassium source fertilizer in Brazil: yield and quality. *Hort. Sci*., **53**: 373–379.

Meriño-Gergichevich, C., Alberdi, M. and Ivanov, A.G. (2017). Effects of potassium on growth, yield and fruit quality of *Solanum tuberosum* cv. Mondial. *J. Soil Sci. Plant Nutr.*, **7**: 858–871. doi: 10.4067/S0718-95162017000300014

Mohan, G.L., Channakeshava, S., Prakash, N.B., Bhairappanavar, S.T. and Tambat, B. (2017). Effect of Different Rates and Sources of Potassium on Growth, Yield and Quality of Potato (*Solanum tuberosum* L.). *Int. J. Curr. Microbiol. App. Sci*. **6**(11): 443-452.

Molina-Rueda, J.J., Arroyave-Jaramillo, R., and Lopez-Granados, F. (2019). Effect of potassium on potato yield and quality parameters in Colombia. *J. Soil Sci. Plant Nutr*. **19**: 106–117. doi: 10.1007/s42729-018-0053-7

Muthanna, M.A., Anil, K.S., Tiwari, A., Jain, V.K. and Padhi, M. (2017). Effect of Boron and Sulphur Application on Plant Growth and Yield Attributes of Potato (*Solanum tuberosum* L.). *Int. J. Curr. Microbiol. Appl. Sci*. **6**(10): 399-404.

Naby, H.M.A.; El-Gamily, E.L.; Allah, A.A.A.G. (2018). Response of Potato Plants to Sources and Rates of Potassium Fertilizer. *J. Plant Prod*., **9**: 67–71.

Naumann, M.; Koch, M.; Thiel, H.; Gransee, A.; Pawelzik, E. (2020). The Importance of Nutrient Management for Potato Production Part II: Plant Nutrition and Tuber Quality. *Potato Res*., **63**: 121–137.

Neshev, N. and Manolov, I. (2016). Potassium fertilizer rate and source influence content, uptake and allocation of nitrogen, phosphorus and potassium in potato plants. 4th Conference with International Participation Conference VIVUS-on Agriculture, Environmentalism, Horticulture and Floristics, Food Production and Processing and Nutrition. 20th and 21st April 2016, Biotechnical Centre Naklo, Strahinj 99, Naklo, Slovenia, p. 6.

Olsen. S. R., Cole, C. V., Watanabe, F. S. and Dean. L. A. (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. U. S. Dept. *Agric. Cire*. P. 929.

Parveen, K., Pandey, S.K., Singh, S.V., Sanjay, R. and Dinesh, K. (2004). Effect of potassium fertilization on processing grade tuber yield and quality parameters in potato (*Solanum tuberosum*). *Indian J. Agric. Sci*. **74**(4): 177-179.

Ruiz-Sanchez, M.C. and Moreno-Sanchez, R. (2009). Effect of potassium on growth and yield of potato (*Solanum tuberosum* L.). *J. Plant Nutr*. **32**: 175–193. doi: 10.1080/01904160903308084

Sadeghi, M., Akbari, G.A., and Jalilian, J. (2010). Effect of potassium on growth, yield and nutrient uptake of potato (*Solanum tuberosum* L.). *J. Plant Nutr.*,**33**: 807–819. doi: 10.1080/01904161003788509

Salim, B.B.M., Abd El-Gawad, H.G. and Abou El-Yazied, A. (2014). Effect of foliar spray of different potassium sources on growth, yield and mineral composition of potato (*Solanum tuberosum* L.). *Middle East J. Appl. Sci*. **4**(4): 1197-1204.

Sameh, A.M.M., Lamia M.H. and Nashwa, A.E. (2018). Effect of different levels of sulphur and nitrogen fertilizers on potato productivity, acrylamide formation and amino acids content in processed potatoes. *Middle East J. Agric. Res*. **07**(4): 1626-1646.

Sarwar, M., Farooq, M., Hussain, M. and Arif, M. S. (2016). Combined application of potassium and sulfur improves potato yield and quality under low and high phosphorus regimes. *J. Plant Nutr.* **39**(14): 1994-2003.

Setu, H., Dechassa, N. and Alemayehu, Y. (2018). Influence of phosphorus and potassium fertilizers on growth and yield of potato (*Solanum tuberosum* L.) at Assosa, BenishangulGumuz Regional State, Western Ethiopia. Journal of Soil Science and Environmental Management. **9**(6): pp. 81-90.

Sharma, D.K., Kushwah, S.S. and Verma, K.S. (2015). Effect of sulphur on growth, yield and economics of potato cultivars. *Annals Plant Soil Res*. **17**(1): 45-49.

Sharma, D.K., Kushwah, S.S., Nema, P.K. and Rathore, S.S. (2011). Effect of Sulphur on Yield and Quality of Potato *(Solanum tuberosum* L.). *Int. J. Agric. Res*. **6**(2): 143-148.

Singh, R. K., Singh, R., Yadav, A., Singh, A. and Kumar, A. (2019). Impact of sulfur on potato growth, yield and nutrient uptake. *J. Plant Nutr.* **42**(15): 1778-1785.

Singh, Y., Singh, B., Ladha, J. K. and Khind, C. S. (2016). Interactive effect of sulfur and nitrogen fertilization on potato growth, yield, and quality. *J. Plant Nutr.* **39**(8): 1174-1183. https://doi.org/10.1080/ 01904167. 2015.1125701

Sobhani, A.R. Rahimian,H., Majidi,E. and Noormohamadi, G. (2002) Effects of water deficit and potassium nutrition on yield and some agronomic characteristics of potato. *J. Agric. Sci. Islamic Azad Univ*. **8**(3): Ar23-Ar34, 3-4.

Walkley, A.J. and Black, I.A. (1934). Estimation of soil organic carbon by the chromic acid titration method (Wet Oxidation Method). Soil Sci. **37**: 29-38.

Upadhyay, A. and Dubey, A.K. (2016). Potassium management for improving yield, quality and storability of potato. *Potato J*. **43**: 61–72. doi: 10.9734/PJ/2016/25971

Yakimenko, V.N. and Naumova, N.B. (2018). Potato tuber yield and quality under different potassium application rates and forms in West Siberia. *Agric. Res.* **64**(3): 128-136.

Yu, J., Li, C., Yang, J., Huang, C. and Huang, J. (2017). Effects of potassium and sulfur fertilizers on potato growth, yield, and nutrient uptake. *Plo S one J.* **12**(5): 63-71.

Zaman, M., Alam, M. J., Jahan, M. S., Hasan, M. A. and Islam, M. M. (2021). Effect of sulfur on potato yield and quality under different soil types. *J. Plant Nutr.* **44**(4): 647-657.

Zhang, J., Li, T., Li, B. and Li, X. (2021). Sulfur application improves potato yield and quality by affecting nitrogen metabolism. *Agron. J.* **11**(6): 1179. doi: 10.3390/agronomy11061179

Zhang, X., Huang, W., Li, W. and Zhao, X. (2019). Effect of potassium and sulfur fertilizers on potato growth, yield, and quality under saline-alkali soil conditions. *Commun. Soil Sci. Plant Anal.* **50**(22): 2906-2915.

Zhang, X., Li, W., Yang, Y., Wu, Q. and Zhao, X. (2015). Effect of potassium and sulfur fertilizers on potato growth, yield, and quality. *Commun. Soil Sci. Plant Anal.* **46**(5): 614-624.

Zhang, X., Wang, X., Li, W., Wang, H. and Wu, Q. (2018). Effect of potassium and sulfur fertilizers on potato growth, yield, and quality under different nitrogen rates. *Commun. Soil Sci. Plant Anal.* **49**(18): 2316-2326.

APPENDICES

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

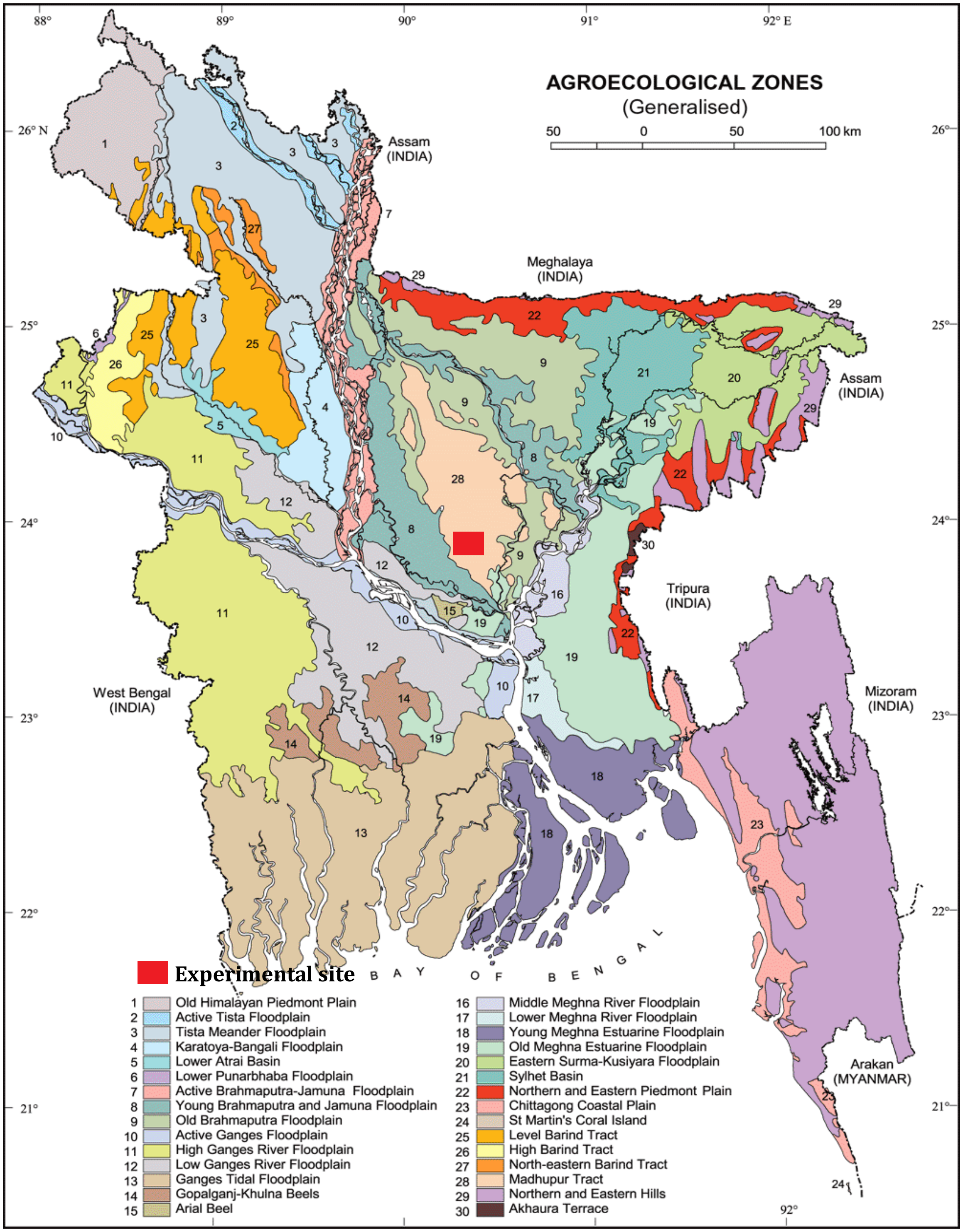

Fig. 7. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2021 to February 2022.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2021	November	28.60	8.52	18.56	56.75	14.40
2021	December	25.50	6.70	16.10	54.80	0.0
2022	January	23.80	11.70	17.75	46.20	0.0
2022	February	22.75	14.26	18.51	37.90	0.0

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 Farm, SAU, Dhaka
AEZ	Modhupur Tract (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	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (USDA)
pH	6.20
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Analysis of variance for the effect of potassium and sulphur on growth parameters (days to 100% emergence, plant height, number of leaves plant^{-1}) of potato (BARI Alu-25; ASTORIX)

Sources of variation	Degrees of freedom	Mean square of Growth parameters		
		Days to 100% emergence	Plant height (cm)	Number of leaves hill^{-1}
Replication	2	0.314	5.219	6.371
Factor A	2	12.348*	42.712*	21.317*
Factor B	2	17.19*	87.321*	64.170*
AB	4	1.581**	7.344*	5.326**
Error	16	0.036	2.071	3.071

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Analysis of variance for the effect of potassium and sulphur on growth parameters (number of main stem hill^{-1}, fresh weight of haulm hill^{-1}, dry weight of haulm hill^{-1}) of potato (BARI Alu-25; ASTORIX)

Sources of variation	Degrees of freedom	Mean square of Growth parameters		
		Number of main stem hill^{-1}	Fresh weight of haulm hill^{-1} (g)	Dry weight of haulm hill^{-1} (g)
Replication	2	0.102	5.389	2.036
Factor A	2	8.374*	102.473*	16.371*
Factor B	2	14.318*	318.271*	103.512*
AB	4	2.244**	41.836*	11.244*
Error	16	0.011	3.718	0.476

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Analysis of variance for the effect of potassium and sulphur on yield contributing parameters of potato (BARI Alu-25; ASTORIX)

Sources of variation	Degrees of freedom	Mean square of Yield contributing parameters		
		Number of tuber hill^{-1}	Weight of tuber hill^{-1} (g)	Dry weight of 100 g fresh tuber
Replication	2	0.371	6.714	2.109
Factor A	2	8.715*	87.934*	13.563*
Factor B	2	26.311*	518.72*	47.524*
AB	4	4.387**	26.391*	7.679*
Error	16	0.017	7.458	0.144

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Analysis of variance for the effect of potassium and sulphur on yield parameters of potato (BARI Alu-25; ASTORIX)

Sources of variation	Degrees of freedom	Mean square of Yield parameters	
		Tuber weight $plot^{-1}$ (kg)	Tuber yield ha^{-1} (t)
Replication	2	1.036	1.014
Factor A	2	16.722*	52.754*
Factor B	2	64.381*	185.29*
AB	4	7.753*	18.812*
Error	16	0.207	0.211

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Analysis of variance for the effect of potassium and sulphur on quality of post harvest soil of potato field

Sources of variation	Degrees of freedom	Mean square of Quality parameters of post harvest soil				
		pH	Organic carbon (%)	Available phosphorus (ppm)	Available potassium (meq/100 g soil)	Available sulphur (ppm)
Replication	2	0.011	0.001	0.352	0.014	0.246
Factor A	2	1.052^{NS}	0.214^{NS}	7.371*	1.426**	6.537*
Factor B	2	2.319^{NS}	0.366^{NS}	18.01^{NS}	3.211^{NS}	24.014*
AB	4	0.107^{NS}	0.107^{NS}	3.216**	0.746**	4.218**
Error	16	0.003	0.003	0.106	0.001	0.211

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Plate 1. Layout of experimental field

Plate 2. Field preview at seedling emergence stage

Plate 3. Field preview of the experiment field showing sign board at vegetative stage

Plate 4. Field visit with supervisor

Plate 5. Harvested potato from the experiment field