EFFECT OF POTASSIUM SOURCES AND BIOCHAR LEVELS ON THE YIELD AND QUALITY OF POTATO

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EFFECT OF POTASSIUM SOURCES AND BIOCHAR LEVELS ON THE YIELD AND QUALITY OF POTATO

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CERTIFICATE

*This is to certify that thesis entitled, "**EFFECT ON POTASSIUM SOURCES AND BIOCHAR LEVELS ON THE YIELD AND QUALITY OF POTATO**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **BIPLOB DAS**, Registration no.* **14-05888** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:
Place: Dhaka, Bangladesh

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Dedicated To

My Beloved Parents

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The Author
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EFFECT OF POTASSIUM SOURCES AND BIOCHAR LEVELS ON THE YIELD AND QUALITY OF POTATO

ABSTRACT

A field experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from November, 2019 to March, 2020 in Rabi season to find out the response of different source of potassium fertilizer and different biochar levels on growth, yield and quality of potato. The experiment had two factors. factor a: potassium: 3 sources; K_1: Muriate of potash (MoP or KCl), K_2: Potassium phosphate (KH_2PO_4) and K_3: Potassium sulfate (K_2SO_4) and factor B: Biochar: 4 levels; B_1: 1.25 t ha^{-1}, B_2: 2.50 t ha^{-1}, B_3: 3.75 t ha^{-1} and B_4: 5.00 t ha^{-1}. The potato variety was BARI Alu-29 (Courage). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three (3) replications. Total 36 plots were made for the experiment with 12 treatments. Source of potassium fertilizer and/or biochar showed significant effect on different morphological, yield and qualitative characters of potato. The maximum number of tubers hill^{-1} (7.44), the maximum weight of tubers hill^{-1} (266.37 g), the highest tuber yield (26.64 t ha^{-1}), the maximum marketable yield (19.07 t ha^{-1}) and the highest specific gravity of tuber were recorded (1.058 g cm^{-3}), the maximum tuber dry matter (21.73%) and the highest starch content on potato (16.77 mg g^{-1} FW) were recorded from B_4 (5.00 t ha^{-1}) treatment. In 36 treatment of combinations, the maximum weight of tuber hill^{-1} (286.00 g), the highest tuber yield (28.60 t ha^{-1}) and the maximum marketable yield (20.48 t ha^{-1}) were observed in KH_2PO_4 and 5.00 t ha^{-1} biochar (K_2B_4) treatment combination. Application of KH_2PO_4 as the source of potassium fertilizer with 5.00 t ha^{-1} of biochar combination seemed to be more suitable for getting higher yield. But when considering quality attributes, the combination of Potassium sulphate with 5.00 t ha^{-1} biochar exhibited highest dry matter content (22.67%), maximum starch content (17.50 mg/g FW), whereas, minimum TSS and reducing sugar content. It is concluded that the application of Potassium phosphate (452.19 kg KH_2PO_4 ha^{-1}) and 5.00 t ha^{-1} of biochar is suitable for higher yield and the application of Potassium sulphate (288.60 kg K_2SO_4 ha^{-1}) and 5.00 t ha^{-1} biochar is applied for good quality potato.

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LIST OF ABBREVIATIONS

ABBREVIATION	ELLABORATION
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agra.	Agricultural
Agron.	Agronomy
Annu.	Annual
Appl.	Applied
Vm	Vermicompost
Biol.	Biology
Chem.	Chemistry
cm	Centi-meter
CV	Coefficient of Variance
DAS	Days After Storage
DAP	Days After Planting
Dev.	Development
Ecol.	Ecology
Environ.	Environmental
etci	and others
Exptl.	Experimental
g	Gram (s)
Hortc.	Horticulture
i.e.	that is
J.	Journal
kg	Kilogram (s)
LSD	Least Significant Difference
M.S.	Master of Science
m^2	Meter squares
mg	Milligram
Nutr.	Nutrition
Physiol.	Physiological
Progress.	Progressive
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
T	Tuber size
Soc.	Society
SRDI	Soil Resource Development Institute
t ha^{-1}	Ton per hectare
UNDP	United Nations Development Programme
Viz	*videlicet* (L.), Namely
%	Percentage
@	At the rate of
μMol	Micromole

LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
BBS	Bangladesh Bureau of Statistics
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAS	Days After Sowing
eds.	editors
et al.	et alia (and others)
etc.	et cetera (and other similar things)
FAO	Food and Agricultural Organization
L.	Linnaeus
LSD	Least Significant Difference
i.e.	id est (that is)
MoP	Muriate of Potash
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	variety
viz.	namely

CHAPTER I

INTRODUCTION

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INTRODUCTION

Potato (*Solanum tuberosum* L.) popularly known as alu 'The king of vegetable', is a tuber crop under the family of Solanaceae. It originated in the central Andean area of South America (Keeps, 1979). It is the 4th world crop after wheat, rice and maize. Bangladesh is the 8th potato producing country in the world (FAOSTAT, 2018). It contributes not only energy but also substantial amount of high-quality protein and essential vitamins, minerals and trace elements to the diet (Horton, 1987).

In Bangladesh, potato ranks 2nd after rice in production (FAOSTAT, 2018). The total area under potato crop, national average yield and total production in Bangladesh are 475488 hectares, 19.925 t ha^{-1} and 9474098 metric tons, respectively (BBS, 2018). It is a staple diet in European countries and its utilization both in processed and fresh food form is increasing considerably in Asian countries. The yield of potato in Bangladesh is very low (19.36 t ha^{-1}) in comparison to that of the other leading potato growing countries of the world, 74.45 t ha^{-1} in Kuwait, 59.53 t ha^{-1} in Belgium, 52.89 t ha^{-1} in France, 51.97 t ha^{-1} in USA, 47.53 t ha^{-1} in Denmark and 46.21 t ha^{-1} in UK (FAOSTAT, 2018).

Bangladesh has a great agro-ecological potential of growing potato. Potato has a great importance in rural economy in Bangladesh. It is not only a cash crop but also an alternative food crop compares to rice and wheat. The area and production of potato in Bangladesh has been increasing during the last decades but the yield per unit area did not change. The organic matter of most of the soils of Bangladesh is below 2% as compared to an ideal minimum value 4% (Bhuiyan, 1994). The reasons for such a low yield of potato in Bangladesh are imbalanced fertilizer application, use of low-quality seed and use of sub-optimal production practices. Available reports indicated that potato production in Bangladesh can be increased by improving cultural practices among which optimization of manure and fertilizer, planting time, spacing and use of optimal sized seed are important which influences the yield of potato (Divis and Barta, 2001).

Potassium is the only essential plant nutrient that is not a constituent of any plant part. Potassium is a key nutrient in the plants tolerance to stresses such as cold/hot temperatures, drought, and wear and pest problems. Potassium (K) in soil is present in three different forms that is total K, exchangeable and K in soil solution (Mengel and Kirkby, 1987). Soil solution K has a high chance of leaching and thus loss from the soil system. Exchangeable K plays an important role in soil plant availability. Potassium from mica as dominant mineral in Nepalese soil (Schrier *et al.*, 1994) and K from mica contributes a part of soil potassium (Mengel and Rahmatullah 1994; Baeumler *et al.*, 1997).

Potassium (K) has a role in decreasing certain plant diseases and in improving tuber quality (Cordova and Valverde, 2001). Potato is highly potassium demanding crop (Ayalew and Beyene, 2011). Foliar application of Potassium had a significant effect on potato plant growth, tuber weight and total yield (Jasim *et al.*, 2013). When increase potassium application then decrease weight loss and rottage of tubers (Singh and Lal, 2012).

Of the essential elements, potassium (K) is the third most likely, after nitrogen and phosphorus, to limit plant productivity (Brady and Weil, 2002). It plays a critical role in lowering cellular osmotic water potentials, thereby reducing the loss of water from leaf stomata and increasing the ability of root cells to take up water from the soil (Havlin *et al.*, 1999) and maintain a high tissue water content even under drought conditions (Marschner, 2002). Potassium is essential for photosynthesis, nitrogen fixation in legumes, starch formation, and the translocation of sugars. As a result of several of these functions, a good supply of this element promotes the production of plump grains and large tubers. When K is deficient, growth is retarded, and net retranslocation of K^+ is enhanced from mature leaves and stems, and under severe deficiency these organs become chlorotic and necrotic (Marschner, 2002). K deficient plants are highly sensitive to fungal attack (Marschner, 2002), bacterial attack, and insect, mite, nematode and virus infestations (Havlin *et al.*, 1999). Potassium deficiency affects nutritional and technological (processing) quality of harvested products particularly fleshy fruits and tubers. In potato tubers, for example, a whole range of quality criteria are affected by the potassium content in tuber tissue (Marschner, 2002).

Biochar application changes different soil physical properties, aggregate structure, increase soil C : N ratio. It reduces soil bulk density, increase soil porosity, cation exchange capacity, soil pH, nutrient availability, increase C content and trap CO_2 gas within soil. Biochar compensate climate change through slower return of terrestrial organic C as CO_2 gas to the atmosphere. It decreases leaching loss which is main problem for N fertilizer by retain water into soil. Biochar has been described as a possible means to upgrade soil fertility as well as other ecosystem services and sequester carbon (C) to mitigate climate change (Sohi *et al.*, 2010). The observed effects on soil fertility have been described mainly by a pH increase in acid soils (Van Zwieten *et al*., 2010) or improved nutrient conservation through cation adsorption (Liang *et al.*, 2006).

Biochar increase N availability into the soil and reduce leaching loss of N by retaining water. Mineralization of N could be enhanced by application of biochar derived from slow pyrolysis rather than fast pyrolysis (Bruun *et al.*, 2012). Nitrogen is of more important for plant growth due to being a part of amino acid, protein and chlorophyll molecule.

OBJECTIVES

1. To find out the suitable source of potassium for better yield and quality of potato.
2. To determine the optimum level of biochar for yield and quality of potato.
3. To explore the suitable combination of potassium source and biochar level on yield and quality of potato.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Potato is an important cash crop of global economic importance. Extensive research work on this crop has been done in several countries, especially in the South East Asia for the improvement of its yield and quality. In Bangladesh recently, it has been drawn attention to improve yield and quality due to increasing its industrial demand. Very few information was available regarding the effect of potassium fertilizer and biochar on soil amendment through carbon sequestration, yield and processing quality of potato varieties. Although this idea was not a recent one but research findings in this regard was scanty. Some of the pertinent works on these technologies reviewed in this chapter.

2.1 Effect of biochar on plant growth parameter

2.1.1 Plant height

Ali (2017) carried out an experiment in Rabi season to observe the effect of biochar on the yield and quality of potato and to find out the optimum dose of biochar along with inorganic fertilizer. The experiment was comprised of 8 treatments; those were, T_1 = Control, T_2 = RFD (Recommended Fertilizer Dose), T_3 = RFD + Biochar @ 5 t ha^{-1}, T_4 = RFD + Biochar @ 10 t ha^{-1}, T_5 = ⅔ of RFD + Biochar @ 5 t ha^{-1}, T_6 = ⅔ of RFD + Biochar @ 10 t ha^{-1}, T_7 = ½ of RFD + Biochar @ 5 t ha^{-1} and T_8 = ½ of RFD + Biochar @ 10 t ha^{-1}. The tested variety was BARI ALU-7 (Daimant). Results showed a significant variation among the treatments in respect of majority of the observed parameters. The tallest plant was recorded from RFD + Biochar @ 10 t ha^{-1} treatment.

Nair *et al.* (2014) conducted an experiment to assess the effect of biochar application in potato production. Four application rates of biochar (0, 2.50, 5.0, or 10.0 t $acre^{-1}$, 0 t $acre^{-1}$ was referred to as control) were applied by hand on April 12, 2012. Each plot was measured 15 ft. by 30 ft. Experimental design was randomized complete block design with four replications. The researchers observed that the tallest plant (47.60 cm) was recorded from 10 t acre^{-1} biochar treated plot. On the other hand, the shortest plant (45.70 cm) was recorded from control plot (no biochar application).

2.2 Effect of biochar on yield contributing parameter

2.2.1 Number of tubers hill^{-1}

Ali (2017) carried out an experiment in Rabi season to observe the effect of biochar on the yield and quality of potato and to find out the optimum dose of biochar along with inorganic fertilizer. The experiment was comprised of 8 treatments; those were, T_1 = Control, T_2 = RFD (Recommended Fertilizer Dose), T_3 = RFD + Biochar @ 5 t ha^{-1}, T_4 = RFD + Biochar @ 10 t ha^{-1}, T_5 = ⅔ of RFD + Biochar @ 5 t ha^{-1}, T_6 = ⅔ of RFD + Biochar @ 10 t ha^{-1}, T_7 = ½ of RFD + Biochar @ 5 t ha^{-1} and T_8 = ½ of RFD + Biochar @ 10 t ha^{-1}. The tested variety was BARI ALU-7 (Daimant). Results showed a significant variation among the treatments in respect majority of the observed parameters. The highest number of tubers hill^{-1} was found from RFD + 5 t biochar ha^{-1} treatment.

Nair *et al.* (2014) conducted an experiment to assess the effect of biochar application in potato production. Four application rates of biochar (0, 2.50, 5.0, or 10.0 t acre^{-1}, 0 t acre^{-1} was referred to as control) were applied by hand. The researchers observed that the highest number of marketable tuber (242 tubers m^{-2}) was recorded from 10 t acre^{-1} biochar treated plot. On the other hand, the lowest number of marketable tuber (227 tubers m^{-2}) was reported from control plot (no biochar application).

2.2.2 Weight of tuber hill^{-1}

Ali (2017) carried out an experiment in Rabi season to observe the effect of biochar on the yield and quality of potato and to find out the optimum dose of biochar along with inorganic fertilizer. The experiment was comprised of 8 treatments; those were, T_1 = Control, T_2 = RFD (Recommended Fertilizer Dose), T_3 = RFD + Biochar @ 5 t ha^{-1}, T_4 = RFD + Biochar @ 10 t ha^{-1}, T_5 = ⅔ of RFD

+ Biochar @ 5 t ha^{-1}, T_6 = ⅔ of RFD + Biochar @ 10 t ha^{-1}, T_7 = ½ of RFD + Biochar @ 5 t ha^{-1} and T_8 = ½ of RFD + Biochar @ 10 t ha^{-1}. The tested variety was BARI ALU-7 (Daimant). Results showed a significant variation among the treatments in respect of majority of the observed parameters. The highest weight of tubers g $hill^{-1}$ was found from RFD + 5 t biochar ha^{-1} treatment.

2.3 Effect of biochar on yield parameter

2.3.1 Potato yield

Das (2018) conducted an experiment to evaluate the effect of variety and biochar on yield and some quality parameters of potato along with soil properties. The experiment was consisted of two factors, *i.e.,* factor A: Potato varieties (3): V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); factor B: Biochar level (5): B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1} and B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}. The investigation revealed that biochar had significant effect on most of the growth, yield and quality contributing parameters of potato studied in this experiment. Results showed that growth, yield and quality contributing parameters of potato increased with increasing biochar level. Among the fifteen treatment combinations, Asterix with biochar level 10 t ha^{-1} performed superior than other combination in most of the parameters and it produced the maximum potato yield (27.33 t ha^{-1}). However, in case of yield, V_3B_4, V_3B_3 and V_3B_2 treatment combinations were statistically similar. Whereas no biochar (B_0) treatment showed the lowest values irrespective of varieties. It was concluded that biochar level @ 5.00 t ha^{-1} would be beneficial for maximizing yield.

Ali (2017) carried out an experiment in Rabi season to observe the effect of biochar on the yield and quality of potato and to find out the optimum dose of biochar along with inorganic fertilizer. The experiment was comprised of 8 treatments; those were, T_1 = Control, T_2 = RFD (Recommended Fertilizer Dose), T_3 = RFD + Biochar @ 5 t ha^{-1}, T_4 = RFD + Biochar @ 10 t ha^{-1}, T_5 = ⅔ of RFD + Biochar @ 5 t ha^{-1}, T_6 = ⅔ of RFD + Biochar @ 10 t ha^{-1}, T_7 = ½ of RFD +

Biochar @ 5 t ha^{-1} and T_8 = ½ of RFD + Biochar @ 10 t ha^{-1}. The tested variety was BARI ALU-7 (Daimant). Results showed a significant variation among the treatments in respect majority of the observed parameters. The maximum yield of tubers (34.10 t ha^{-1}) was produced from RFD + Biochar @ 5 t ha^{-1} treatment. The minimum yield of tubers (16.60 t ha^{-1}) was produced from control treatment.

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The experiment included 12 treatments, which were the combinations between three cultivars of potato *viz.*, Accent, Cara, and Spunta and four amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). The result of the experiment revealed that, the highest potato yield (15.515 t fed^{-1}) was recorded from 'Spunta' potato variety and the lowest potato yield (14.910 t fed^{-1}) was recorded from 'Accent' potato variety. The highest potato yield (17.023 t fed^{-1}) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the lowest potato yield (13.249 t fed^{-1}) was recorded from control plot (no biochar).

Gautam *et al.* (2017) conducted experiments to investigate the biochar amendment of soil and its effect on crop production of smallholder farms in Rasuwa district of Nepal. They reported that the biochar-amended treatment gave around 17.50% to 40% higher yields in case of potato compared to control treatment.

2.3.2 Weight of marketable potato yield

Das (2018) conducted an experiment to evaluate the effect of variety and biochar on yield and some quality parameters of potato along with soil properties. The experiment was consisted of two factors, *i.e.*, factor A: Potato varieties (3): V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); factor B: Biochar level (5): B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1} and B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}. The investigation revealed that biochar had significant effect on most of the growth, yield and quality contributing parameters of potato studied in this experiment. Results showed that growth, yield and quality contributing parameters of potato increased with increasing biochar level. Among the fifteen treatment combinations, Asterix with biochar level 10 t ha^{-1} performed superior than other combination in most of the parameters and it produced the maximum marketable potato yield (21.30 t ha^{-1}). Whereas no biochar (B_0) treatment showed the lowest values irrespective of varieties.

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and four amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). The result of the experiment revealed that, the highest marketable potato yield (12.411 t fed^{-1}) was recorded from 'Cara' potato variety and the lowest marketable potato yield (11.949 t fed^{-1}) was recorded from 'Accent' potato variety. The highest marketable potato yield (13.325 t fed^{-1}) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the lowest marketable potato yield (10.835 t fed^{-1}) was recorded from control plot (no biochar).

Nair *et al.* (2014) conducted an experiment to assess the effect of biochar application in potato production. Four application rates of biochar (0, 2.50, 5.0, or 10.0 t acre^{-1}, 0 t acre^{-1} was referred to as control) were applied by hand on April 12, 2012. Each plot was measured 15 ft. by 30 ft. Experimental design was randomized complete block design with four replications. They found that, the highest marketable tuber weight (36.40 kg m^{-2}) was recorded from 10 t acre^{-1} biochar treated plot. On the other hand, the lowest marketable tuber weight (31.70 kg m^{-2}) was recorded from control plot (no biochar application).

2.3.3 Weight of non-marketable potato yield

Nair *et al.* (2014) conducted an experiment to assess the effect of biochar application in potato production. Four application rates of biochar (0, 2.50, 5.0, or 10.0 t acre^{-1}, 0 t acre^{-1} was referred to as control) were applied by hand on April 12, 2012. Each plot was measured 15 ft. by 30 ft. Experimental design was randomized complete block design with four replications. They found that, the highest non-marketable tuber weight (3.10 kg m^{-2}) was recorded from control plot (no biochar application). On the other hand, the lowest non-marketable tuber weight (1.80 kg m^{-2}) was recorded from 10 t acre^{-1} biochar treated plot. Therefore, it was concluded that, biochar might improve the potato quality, which reduced the non-marketable potato yield.

2.3.4 Grade 'A' potato yield

Das (2018) conducted an experiment to evaluate the effect of variety and biochar on yield and some quality parameters of potato along with soil properties. The experiment was consisted of two factors, *i.e.*, factor A: Potato varieties (3): V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); factor B: Biochar level (5): B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1} and B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}. The investigation revealed that biochar had significant effect on most of the growth, yield and quality contributing parameters of potato studied in this experiment. Results showed that growth, yield and quality contributing parameters of potato increased with increasing biochar level. Among the fifteen treatment combinations, Asterix with biochar level 10 t ha^{-1} performed superior than other combination in most of the parameters and it produced the maximum grade 'A' potato yield (6.35 t ha^{-1}). Whereas no biochar (B_0) treatment showed the lowest values irrespective of varieties.

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The

experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and four amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). These treatments were arranged in a split plot design with 3 replicates. The result of the experiment revealed that, the highest grade 'A' (tuber above 55 mm diameter) potato yield (2.067 t fed^{-1}) was recorded from 'Accent' potato variety and the lowest grade 'A' potato yield (1.808 t fed^{-1}) was recorded from Cara potato variety. The highest grade 'A' potato yield (2.279 t fed^{-1}) was recorded from control plot (no biochar) and the lowest grade 'A' potato yield (1.713 t fed^{-1}) was recorded from 5.00 m^3 fed^{-1} biochar treated field.

2.3.5 Grade 'B' potato yield

Das (2018) conducted an experiment to evaluate the effect of variety and biochar on yield and some quality parameters of potato along with soil properties. The experiment was consisted of two factors, *i.e.*, factor A: Potato varieties (3): V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); factor B: Biochar level (5): B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1} and B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}. The investigation revealed that biochar had significant effect on most of the growth, yield and quality contributing parameters of potato studied in this experiment. Results showed that growth, yield and quality contributing parameters of potato increased with increasing biochar level. Among the fifteen treatment combinations, Asterix with biochar level 10 t ha^{-1} performed superior than other combination in most of the parameters and it produced the maximum grade 'B' potato yield (6.28 t ha^{-1}). However, in case of yield, V_3B_4, V_3B_3 and V_3B_2 while in case of dry matter content, V_3B_3, V_3B_2 and V_2B_4 combinations were statistically similar. Whereas no biochar (B_0) treatment showed the lowest values irrespective of varieties.

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The

experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and 4 amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). These treatments were arranged in a split plot design with 3 replicates. The result of the experiment revealed that, the highest grade 'B' (tubers with diameter between 35–54 mm) potato yield (10.603 t fed^{-1}) was recorded from 'Cara' potato variety while the lowest grade 'B' potato yield (9.88 t fed^{-1}) was recorded from 'Accent' potato variety. The highest grade 'B' potato yield (11.612 t fed^{-1}) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the lowest grade 'B' potato yield (8.556 t fed^{-1}) was recorded from control plot (no biochar).

2.3.6 Grade 'C' potato yield

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and four amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). The result of the experiment revealed that, the highest grade 'C' (tubers with diameter less than 35 mm,) potato yield (3.261 t fed^{-1}) was recorded from 'Spunta' potato variety and the lowest grade 'C' potato yield (2.961 t fed^{-1}) was recorded from 'Accent' potato variety. The highest grade 'C' potato yield (3.698 t fed^{-1}) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the lowest grade 'C' potato yield (2.414 t fed^{-1}) was recorded from control plot (no biochar).

2.4 Effect of biochar on qualitative parameter

2.4.1 Dry matter content in potato

Das (2018) conducted an experiment to evaluate the effect of variety and biochar on yield and some quality parameters of potato along with soil properties. The experiment was consisted of two factors, *i.e.*, factor A: Potato varieties (3): V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); factor B: Biochar level (5): B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1} and B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}. The investigation revealed that biochar had significant effect on most of the growth, yield and quality contributing parameters of potato studied in this experiment. Results showed that growth, yield and quality contributing parameters of potato increased with increasing biochar level. Among the fifteen treatment combinations, Asterix with biochar level 10 t ha^{-1} performed superior than other combination in most of the parameters and it produced the maximum potato dry matter (22.01 %). However, in case of dry matter content V_3B_3, V_3B_2 and V_2B_4 combinations were statistically similar. Whereas no biochar (B_0) treatment showed the lowest values irrespective of varieties. It was concluded that biochar level @ 5.00 t ha^{-1} would be beneficial for maximizing dry matter content. However, in case of quality parameters, 10 t ha^{-1} showed the best performances.

Ali (2017) carried out an experiment in Rabi season to observe the effect of biochar on the yield and quality of potato and to find out the optimum dose of biochar along with inorganic fertilizer. The experiment was comprised of 8 treatments; those were, T_1 = Control, T_2 = RFD (Recommended Fertilizer Dose), T_3 = RFD + Biochar @ 5 t ha^{-1}, T_4 = RFD + Biochar @ 10 t ha^{-1}, T_5 = ⅔ of RFD + Biochar @ 5 t ha^{-1}, T_6 = ⅔ of RFD + Biochar @ 10 t ha^{-1}, T_7 = ½ of RFD + Biochar @ 5 t ha^{-1} and T_8 = ½ of RFD + Biochar @ 10 t ha^{-1}. The tested variety was BARI ALU-7 (Daimant). Results showed a significant variation among the treatments in respect majority of the observed parameters. The maximum value of quality parameter like percentage of dry matter content (23.41) was recorded from RFD + Biochar @ 5-t ha^{-1} treatment.

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and 4 amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). The result of the experiment revealed that, the highest dry matter content of potato (19.87 %) was recorded from 'Spunta' potato variety and the lowest dry matter content of potato (15.58 %) was recorded from 'Accent' potato variety. The highest dry matter content of potato (18.67 %) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the lowest dry matter content of potato (17.38 %) was recorded from control plot (no biochar).

2.4.2 Total soluble solid

Das (2018) conducted an experiment to evaluate the effect of variety and biochar on yield and some quality parameters of potato along with soil properties. The experiment was consisted of two factors, *i.e.*, factor A: Potato varieties (3): V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); factor B: Biochar level (5): B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1} and B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}. The investigation revealed that biochar had significant effect on most of the growth, yield and quality contributing parameters of potato studied in this experiment. Results showed that growth, yield and quality contributing parameters of potato increased with increasing biochar level. Among the fifteen treatment combinations, Asterix with biochar level 10 t ha^{-1} performed superior than other combination in most of the parameters and it produced the maximum total soluble sugar content (5.07° Brix).

2.4.3 Specific gravity

Das (2018) conducted an experiment to evaluate the effect of variety and biochar on yield and some quality parameters of potato along with soil properties. The experiment was consisted of two factors, *i.e.*, factor A: Potato varieties (3): V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); factor B: Biochar level (5): B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1} and B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}. The investigation revealed that biochar had significant effect on most of the growth, yield and quality contributing parameters of potato studied in this experiment. Results showed that growth, yield and quality contributing parameters of potato increased with increasing biochar level. Among the fifteen treatment combinations, Asterix with biochar level 10 t ha^{-1} performed superior than other combination in most of the parameters and it produced the maximum specific gravity (1.09 g cm^{-3}). Whereas no biochar (B_0) treatment showed the lowest values irrespective of varieties.

Ali (2017) carried out an experiment in Rabi season to observe the effect of biochar on the yield and quality of potato and to find out the optimum dose of biochar along with inorganic fertilizer. The experiment was comprised of 8 treatments; those were, T_1 = Control, T_2 = RFD (Recommended Fertilizer Dose), T_3 = RFD + Biochar @ 5 t ha^{-1}, T_4 = RFD + Biochar @ 10 t ha^{-1}, T_5 = ⅔ of RFD + Biochar @ 5 t ha^{-1}, T_6 = ⅔ of RFD + Biochar @ 10 t ha^{-1}, T_7 = ½ of RFD + Biochar @ 5 t ha^{-1} and T_8 = ½ of RFD + Biochar @ 10 t ha^{-1}. The tested variety was BARI ALU-7 (Daimant). Results showed a significant variation among the treatments in respect majority of the observed parameters. The maximum value of quality parameter specific gravity (1.065 g cm^{-3}) was recorded from RFD + Biochar @ 5 t ha^{-1} treatment.

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The

experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and 4 amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). These treatments were arranged in a split plot design with 3 replicates. The result of the experiment revealed that, the highest specific gravity (1.079 g cm^{-3}) was recorded from 'Spunta' potato variety and the lowest specific gravity (1.053 g cm^{-3}) was recorded from 'Accent' potato variety. The highest specific gravity (1.074 g cm^{-3}) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the lowest specific gravity (1.069 g cm^{-3}) was recorded from control plot (no biochar).

2.5 Effect of potassium on growth and yield of potato

Badrunnesa *et al.* (2021) conducted the experiment to assess the effect of potassium sources and vermicompost level on yield and grading of potato tuber. The potato tuber of variety BARI Alu-25 (Asterix) was used as the planting material for this experiment. The experiment consisted of two factors: Factor A: 3 sources of Potassium such as-K_1: KCl, K_2: KNO_3, K_3: K_2SO_4; Factor B: 4 levels of vermicompost such as-Vm_0: 0 t ha^{-1}, Vm_1: 4 t ha^{-1}, Vm_2: 8 t ha^{-1} and Vm_3: 12 t ha^{-1}. The highest yield of potato tubers (27.86 t ha^{-1}) was recorded from K_2SO_4, whereas, the lowest (26.02 t ha^{-1}) was found from KNO_3. The number of tubers $hill^{-1}$, average tuber weight, yield and different categories of potato tuber were increased with the increasing of vermicompost level. Among the 12 treatment combinations, the highest yield of potato tubers (31.17 t ha^{-1}) were found from K_3Vm_3, whereas, the lowest (22.09 t ha^{-1}) was recorded from K_2Vm_0. However, K_1Vm_2, K_1Vm_3, K_3Vm_2, K_3Vm_3 showed statistically similar results regarding yield and grading. So, K_2SO_4 or KCl as a source of potassium and 8 or 12 t K_2SO_4vermicompost t ha^{-1} was found to be better in respect of yield and grading of potato tubers compared to the other treatments. Grading (Canned 20–35 mm; Flakes 35–45; Chips- 45–75 mm; and French fry- >75 mm) of potato tubers due to different sources of potassium was not significant. For Canned, Chips and French fry potato, the highest category (35.56%, 31.69% and 5.25%, respectively) was observed from K_1, whereas, the lowest (34.48%, 30.43% and

5.14%, respectively) was recorded from K_2. But for potato tubers used for flakes, the highest result was recorded from K_2 (29.95%) while lowest (27.51%) from K_1. Among potassium sources, KCl may be economic and will found available for producing good quality potato in Bangladesh.

Roy *et al.* (2007) conducted an experiment to find out the relationship of Nitrogen and potassium on quality of TPS. Three levels of nitrogen (0, 225 and 300 kg N ha^{-1}) and 4 levels of potassium (0, 125, 175 and 225 kg K ha^{-1}) fertilizers were applied to potato mother plants (MF-II) for the production of high-quality True Potato Seed (TPS). The author showed that, increase in K application significantly increased N, P and K concentrations, while decreases in Ca, Mg and Na concentrations in TPS. Increase in N application significantly increased N, P, Ca, Mg and Na concentrations in TPS but K did not increase. Tuber weight was the highest (10.4) when 300 kg N and 125 kg K ha^{-1} were applied. Large TPS also showed high emergence rate (94%), seedling vigor (4.8) and dry matter content (10.5%) in nursery beds when 300 kg N and 125 kg K ha^{-1} was applied. Large TPS always showed better performance than small TPS. In conclusion, the combination of 300 kg N and 125 kg K ha^{-1} was the best combination for application to potato mother plants for the production of high quality TPS.

Karam *et al.* (2005) conducted field experiments in 1999 and 2001 at Tal Amara Research Station in the Bekaa Valley of Lebanon to determine the response of yield and tuber quality of four potato cultivars ('Spunta', 'Derby', 'Shepody' and 'Umatilla') to added potassium rates: K_0 (0 potassium), K_1 (96 kg K ha^{-1}), K_2 (192 kg K ha^{-1}) and K_3 (288 kg K ha^{-1}) in absence of water and nitrogen limitations. Data from this study showed that responsive K treatments were evident in both years. The researchers showed that in some cultivars potassium fertilization significantly increased the yield of medium (25–75 g) and large size tubers (> 75 g) at the cost of small size tubers (< 25 g). The significant increases of tuber yield in response to K rates that were observed in 1999 for 'Spunta' and 'Derby' were associated with a lowering, for the former, and an increase, for the later, in tuber dry matter. Similar increases in tuber yield were obtained in 2001 in the potassium treatments for 'Shepody' and 'Umatilla'. However, while for 'Shepody' tuber yield increase was associated with an increase in dry matter content, no increase in this parameter was obtained with 'Umatilla'. Finally, results showed no significant differences between the two potassium levels K_2 and K_3 either for tuber yield or dry matter content.

Wijkmark *et al.* (2005) showed that, site-specific K fertilizer application led to improved potato quality with regards to after-cooking darkening, strong sogginess and weak sogginess. On the other hand, site-specific K fertilizer application had no influence on yield levels. The economic and qualitative effects of site-specific application of potassium (K) fertilizer to potato fields based from the farmer's perspective was studied in a pilot experiment conducted in Holland, Sweden, during the 2002, 2003 and 2004 cropping seasons. In 2003, three ordinary plot trials with different K fertilizer applications (90, 120 and 150 kg K ha^{-1}) were performed and in 2004, the trial was performed once again, this time in a different field.

Khandakhar *et al.* (2004) conducted a study in strongly acidic sandy loam soil at the Potato Breeder Seed Production farm, BARI, Debigonge, Panchogar, Bangladesh to investigate the effect of different application rates of lime (0, 0.5, 1.0 and 2.0 t ha^{-1}) and potassium fertilizer (0, 60, 80 and 100 kg K ha^{-1}) on tuber yield of potato cv. Cardinal. Lime and potassium treatments significantly increased tuber yield. The highest increased yield was recorded ~86.54% over the control. The optimum rate of lime and potassium in acidic sandy-loam soils that could be recommended for potato cultivation is 2 t ha^{-1} and 100 kg ha^{-1}, respectively.

Moinuddin and Shahid (2004) showed that 8 meq l^{-1} K give the highest tuber yield and percent dry matter content. An experiment was carried out in a sand culture, potato (*Solanum tuberosum* L.) was grown to maturity in the greenhouse to study the effects of factorial application of four levels, each of potassium (K)

(2, 4, 8, and 12 meq L^{-1}) and sulfur (S) (1, 2, 4, and 6 meq L^{-1}), on yield, quality, and storage behavior of tubers. In general, the effect of K was more pronounced than that of S on overall crop performance. Increasing K and S levels in the nutrient medium increased tuber yield as well as dry matter content. As compared to the lowest S levels, application at 4 and 6 meq L^{-1} S enhanced average tuber yield and percent dry matter content by 28 and 0.41%, respectively.

Parveen *et al.* (2004) studied the K requirements of potato (*Solanum tuberosum*) cultivars Kufri Chipsona 1 and Kufri Chipsona 2 (intended for processing) during 2000–01 and 2001–02 in Modipuram, Uttar Pradesh, India, in relation to their processing grade tuber yield and quality parameters. The researchers 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 color). 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.

Song (2004) conducted by a field test with potato cv. Kexin No. 1 on chernozem in Baiyin, Gansu, China. N fertilizer was applied at 0 and 15 kg/mu, and K_2O at 0, 8, 16, 24 and 32 kg/mu. The relationships between application rates and tuber yield were studied. No N application combined with increasing K fertilizer rates did not increase tuber yield. However, combining 15 kg N/mu with increasing rates of K increased tuber yield. The highest fresh tuber yield (2600 kg/mu) was obtained with 12.25 kg K_2O/mu. The optimum applied amount of K_2O was 8.7 kg/mu, resulting in a fresh tuber yield of 2580 kg/mu. [1 mu = 0.067 ha].

Cao (2003) carried out an experiment on Virus-free seed tubers of cv. Kexing which were sown in 1999 in Keshan, Heilongjiang, China. The plants were subjected to 4 fertilizer treatments. The researcher showed that, top dressing of K fertilizer enhanced tuber yield, starch content, tuber size and photosynthetic rate of leaves, chlorophyll content in leaves at late growth stage, as well as prolonged growth period.

Jenkins and Mahmood (2003) examined effects on growth, dry matter partitioning and nutrient uptake in potato plants grown in large pots under different combinations of adequate and deficient levels of nitrogen, phosphorus and potassium. N supply affected the growth of all leaves, with low N reducing both the size of individual leaves and the extent of branch growth. P and K availability affected the growth of later formed leaves and only when both were deficient was branch growth substantially reduced. At later stages of growth, total green leaf area was significantly reduced by deficiency of each of the nutrients. Partitioning of dry matter to tubers was markedly reduced by K deficiency and increased in one experiment by P deficiency. When both P and K were deficient, partitioning approximated that under non-limiting conditions.

Lu (2003) conducted an experiment with the high-yielding and cold-resistant potato variety Mila in field plots in Zijin, Guizhou, China. The researcher showed that K fertilizer increase plant height, stem diameter, branches/plant, weight/tuber and yield/plant, but decreased tubers/hill. 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, weight/tuber and yield/plant, but decreased tubers/hill. 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 was concluded that the balanced application of NPK fertilizers can increase potato yield, improve tuber quality and promote plant growth, thus obtaining higher economic benefits.

Makaraviciute (2003) conducted a field experiment in Lithuania during 2000–2002 to study the effects of various fertilizers on potato tuber yield, starch and dry matter content. The researcher commented that Meteorological conditions during the vegetation period and varietal characteristics significantly affected the starch and dry matter contents of tubers. The fertilizers had no significant effect on these indices. The application of compound mineral fertilizers NPK at 90:90:180 kg ha^{-1} and complex mineral fertilizers NPK at 90:90:180 with microelements resulted in the highest yields (20.6–26.1 t ha^{-1} and 21.4–27.4 t ha^{-1}, respectively). The complex mineral fertilizers with microelements were superior to the compound mineral fertilizers with regard to tuber yield. On average, the highest contents of starch and dry matter were recorded for Lady Rosetta (17.0–17.9% and 23.2–24.21%) and Saturna (17.1–17.4% and 23.5–23.8%). The highest starch and dry matter contents were observed in 2002 (14.9–21.0% and 21.3–27.1%). The application of manure (40 t ha^{-1}) gave the highest starch and dry matter contents (14.9–17.9% and 21.2–24.2%) of tubers in most of the cultivars.

Qin (2003) conducted a field test with cv. Dabaihua in a semiarid region of Dingxi, Gansu, China, to investigate the yield-related indices under different K application rates. The researcher showed that the highest tuber yield can be obtained by 90 kg K_2O ha^{-1}, followed by 75 and 60 kg K_2O ha^{-1}, and the lowest in the control. Seven treatments were used with N : P_2O_5 : K_2O ratios of 0:0:0 (control 1), 90:90:0 (control 2), 90:90:30, 90:90:45, 90:90:60, 90:90:75 and 90:90:90 kg ha^{-1}. The tuber yields in the treatments with K fertilizer were significantly higher than those in the control treatments. The highest tuber yield was recorded at 90 kg K_2O ha^{-1}, followed by 75 and 60 kg K_2O ha^{-1}, and the lowest in the control 1. The highest economic benefits were found for 75 kg K_2O ha^{-1}, followed by 60 and 90 kg K_2O ha^{-1}, and the lowest in the control 1. The highest marketable tuber percentage was found at 75 kg K_2O ha^{-1}, followed by 60 and 90 kg K_2O ha^{-1}, and the lowest in the control 1. The optimum K application rate was 60–90 kg ha^{-1} in this semiarid region.

Suman and Khurana (2003) conducted an experiment with potato cv. Kufri Sutlej in Hisar, by Haryana, India, in 2001, involving 3 fertilizer levels (100:60:60, 125:75:75 and 150 : 90 : 90 kg NPK ha^{-1}), 3 plant spacing (10, 15 and 20 cm) and 2 crop durations (75 and 85 days). They concluded that, decreasing in plant spacing increased stems per unit area, plant height, haulm weight, total as well as number of different size tubers per unit area, and yield of total as well as of > 25–50, > 50–75 and > 75 g size tubers. The fertilizer rates used could not affect any of these parameters. Decrease in plant spacing with an increase in crop duration, there was a significant increase in haulm weight and yield of > 75 g and total tubers, while the other parameters were not affected.

Chettri and Thapa (2002) conducted a field experiment during the rabi season of 2000–01 and 2001–02 in the sandy clay loam soil of West Bengal, India, to investigate the effect of K fertilizer sources (KCl and K_2SO_4) and NPK rates (75 and 100% of the recommended, N : P : K at 180 : 150 : 150 kg ha^{-1}) with or without farmyard manure (FYM) at 10 t ha^{-1} on potato cv. Kufri Badshah production. They concluded that K as K_2SO_4 produced higher dry matter production compared to KCl. The highest dry matter production (360.3, 570.4 and 825.3 g/m at 60, 80 and 100 days after planting), tuber bulking rate (12.83 and 8.78 g/m per day at 80 and 100 days after planting, respectively) and yield (275.7 q ha^{-1}) were obtained with 100% NPK + FYM. Higher nutrient uptake was observed with high or low rates of NPK in combination with FYM.

Lalitha *et al.* (2002) showed that application of 150 kg K ha^{-1} gave the highest tuber yield. The productivity of potato cultivars HPS-1/13 and Kufri Jyothi, propagated through true seeds and seed tubers, was evaluated on Alfisols in Bangalore, Karnataka, India, under 3 K levels (100, 125 and 150 kg ha^{-1}) and 2 S levels (0 and 25 kg ha^{-1}). The tuber yield of both cultivars did not differ significantly (20.22 and 20.08 t ha^{-1} for HPS-1/13 and Kufri Jyothi, respectively). HPS-1/13 produced higher C (25–50 g) and D (< 25 g) grade tubers with higher starch and protein contents, while A (75 g) and B (50–75 g) grade tubers, bulking rate and harvest index was higher with Kufri Jyothi. Dry matter production of

HPS-1/13 was higher than Kufri Jyothi. Application of 25 kg S ha^{-1} increased the yield and quality, but not to the significant levels.

Nandi *et al.* (2002) investigated the effects of different levels of NPK fertilizers on seedling tuber production from true potato seeds on a sandy loam soil. They showed that Tuber yield increased with increasing fertilizer rates up to 210 kg N ha^{-1}, 175 kg P ha^{-1} and 175 kg K ha^{-1}. Increasing the fertilizer rates to 300 kg N ha^{-1}, 250 kg P ha^{-1} and 250 kg K ha^{-1} had no beneficial effect and, in most cases, exhibited a declining trend. Tuber yield increased with increasing fertilizer rates up to 210 kg N ha^{-1}, 175 kg P ha^{-1} and 175 kg K ha^{-1} in all three years of study. The highest yield (17.67 t ha^{-1}) was recorded with the application of 240 kg N ha^{-1}, 200 kg P ha^{-1} and 200 kg K ha^{-1}, which was at par with the yield (17.24 t ha^{-1}) obtained with 210 kg N ha^{-1}, 175 kg P ha^{-1} and 175 kg K ha^{-1}. Based on the pooled data, the optimum fertilizer rates were set at 242 kg N ha^{-1}, 202 kg P ha^{-1} and 202 kg K ha^{-1}, and these rates were expected to yield 14.51 t of tubers ha^{-1}, with a net profit of Rs. 89.173 ha^{-1} and benefit cost ratio of 3.31.

Rahman *et al.* (2002) conducted a study to assess the effects of different levels of cow dung and NPK on growth, yield and postharvest behavior of TPS seedling tubers raised from true potato (*Solanum tuberosum*) seeds. They showed that, moderate dose of cow dung manure (50 t ha^{-1}) and the highest doses of NPK fertilizers (375 kg urea, 225 kg TSP and 300 kg MP ha^{-1}) increase Plant height, foliage coverage, number of seedling tubers per plant, size of seedling tubers and give highest yield 38.91 t ha^{-1}). The yield (37.14 t ha^{-1}) and net return (Tk. 169 110 ha^{-1}) were significantly higher under the treatment combination receiving a moderate dose of cow dung manure (50 t ha^{-1}) and the highest doses of NPK fertilizers (375 kg urea, 225 kg TSP and 300 kg MP ha^{-1}). Use of a moderate dose of NPK fertilizers (275 kg urea, 185 kg TSP and 250 kg MP ha^{-1}) in presence of cow dung manure at 25 t ha^{-1} gave highest (2.36) benefit cost ratio with a moderate investment. The postharvest loss in weight and sprouting of tubers during storage increased significantly with increasing doses of cow dung manure and NPK fertilizers applied during production.

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

Kanzikwera *et al.* (2001) showed that, K application significantly decreased shoot dry matter yield in some genotypes of potato. Field experiments were conducted at Namulonge, Uganda, during 1995–96 and 1999 to assess the effect of N and K on dry matter yield and nutrient partitioning in true potato (*Solanum tuberosum*) seed (TPS) mother plants. Three N (0, 120, 240 kg ha^{-1}) and K (0, 132.8 and 265.6 kg ha^{-1}) rates were applied to mother plants of three potato genotypes, CIP 800212, CIP 381379.9 (Kisoro) and CIP 381403.1. N application, however, had no significant effect on shoot dry matter yield although N × genotype interactions were significant on the parameter. Fresh tuber yield ranged from 21.0 to 37.5 t ha^{-1}, and was significantly ($P \leq 0.05$) increased by both N and K application. Leaf N concentration varied significantly ($P \leq 0.05$) among genotypes and K rates higher than 132.8 kg ha^{-1} increased this parameter in potato genotype CIP 381403. High N and K rates also increased stem N concentration in this genotype. Nitrogen application significantly ($P \leq 0.05$) increased foliar Ca concentration. In genotype CIP 800212, K application depressed foliar Mg concentration in the absence of applied N. Leaf Mg concentration declined at K application rate less than 132.8 kg ha^{-1}. Potassium significantly ($P \leq 0.05$) increased leaf P concentration, while N depressed this parameter. Stem K concentrations varied significantly ($P \leq 0.05$) among the potato genotypes. Nitrogen application increased stem K concentration, while K reduced this parameter. There was significant N × K interaction on stem Mg concentration. Both N and K significantly ($P \leq 0.05$) increased berry P and Ca.

Nitrogen and K were found to have a negative interaction on Ca, Mg, K, N and P concentrations in the leaves, stems and berries of TPS mother plants.

Lalitha *et al.* (2000) conducted a field experiment in Karnataka, India in 1994 to determine the effects of different potassium (100, 125 and 150 kg ha^{-1}) and sulfur rates (0 and 25 kg ha^{-1}) on the concentration and uptake of nutrients of true potato seed and seed tuber cultivars HPS-1/13 and Kufri Jyothi. The researchers showed that, potassium fertilizer application reduce the nitrogen concentration, HPS-1/13 produced more dry matter than Kufri Jyothi. Kufri Jyothi had more nitrogen, phosphorus, potassium and sulfur content than HPS-1/13. However, uptake of these nutrients was higher in HPS-1/13 than in Kufri Jyothi.

CHAPTER III

MATERIALS & METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about 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 period

The experiment was conducted at the Agronomy Research Field, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from 02th November, 2019 to 15th March, 2020.

3.2 Geographical location

The experimental area was situated at $23^{0}77'$N latitude and $90^{0}33'$E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.3 Agro-Ecological Region

The experimental site belongs to the agro-ecological zone of “Madhapur Tract”, AEZ-28 (Anon, 1988a). This was a region of complex relief and soils developed over the Madhapur clay, where floodplain sediments buried the dissected edges of the Madhapur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon, 1988b). The experimental site is shown in the map of AEZ of Bangladesh in Appendix I.

3.4 Climate of the experimental site

Experimental site was located in the sub-tropical monsoon climatic zone, set a parted by winter during the months from November, 2019 to February, 2020. Plenty of sunshine and moderately low temperature prevails during experimental period, which is suitable for potato growing in Bangladesh. The weather data during the study period at the experimental site are shown in Appendix II.

3.5 Soil

Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish-brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood levels. The soli data during the study period at the experimental site are shown in Appendix III.

3.6 Experimental treatments

The experiment consisted of two factors such as potassium sources and biochar levels. The treatments were as follows:

Factor A: Three different types of potassium fertilizer

i. K_1: Muriate of potash (MoP or KCl) (125kg K ha^{-1} i.e., 250 kg KCl ha^{-1}),

ii. K_2: Potassium phosphate (KH_2PO_4) (125kg K ha^{-1} i.e., 452.19 kg KH_2PO_4 ha^{-1}) and

iii. K_3: Potassium sulfate (K_2SO_4) (125kg K ha^{-1} i.e., 288.60 kg K_2SO_4 ha^{-1})

Factor B: Four different levels of Biochar

i. B_1: 1.25 t ha^{-1},

ii. B_2: 2.50 t ha^{-1},

iii. B_3: 3.75 t ha^{-1} and

iv. B_4: 5.00 t ha^{-1}.

Treatment combinations are as: K_1B_1, K_1B_2, K_1B_3, K_1B_4, K_2B_1, K_2B_2, K_2B_3, K_2B_4, K_3B_1, K_3B_2, K_3B_3 and K_3B_4.

3.7 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three (3) replications. Total 36 unit plots were made for the experiment with 12 treatments. The size of each unit plot was 2.6 m × 1.2 m. Distance maintained between replication and plots were 1.0 m and 0.8 m. The final layout of the experimental plots has been shown in (Appendix IV).

3.8 Planting material

The planting materials comprised the certified seed tubers of potato variety. The variety was BARI Alu-29 (Courage).

3.9 Collection of tubers

The variety of seed potato (certified seed) was collected from, Tuber Crops Research Centre (TCRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Individual weight of seed potato was 60–70 g.

3.10 Crop management

3.10.1 Preparation of tuber

Collected seed tubers were kept in room temperature to facilitate sprouting. Finally sprouted potato tubers were used as planting material.

3.10.2 Land preparation

The land of the experimental site was first opened in 02 November 2019 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, 2019 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 insecticides (Bifar 5G @ 4 kg ha^{-1}) at the time of final plot preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.10.3 Manure and fertilizer application

The crop was fertilized as per recommendation of TCRC (2004). The experimental soil was fertilized with following dose of urea, triple super phosphate (TSP), gypsum, zinc sulphate and boric acid.

Fertilizers	Dose (kg ha^{-1})
Cow dung	10,000
Urea	325
TSP	220
Gypsum	120
Zinc Sulphate	14
Boric Acid	6

Source: Mondal *et al.*, 2011.

Cow dung was applied 10 days before final plot preparation. Total amount of triple superphosphate, gypsum, zinc sulphate, boric acid 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 35 and 50 days after planting (DAP) during first and second earthing up. Different types of potassium fertilizer were applied as per treatment advised.

3.10.4 Biochar application

The total amount of biochar was applied at 7 days before planting as per treatment.

3.10.5 Planting of seed tuber

The well sprouted healthy and uniform sized potato tubers were planted according to treatment. Seed potatoes were planted in such a way that potato does not go much under soil or does not remain in shallow. On an average, potatoes were planted at 4-5 cm depth in soil on 15th November, 2019.

3.11 Intercultural operations

3.11.1 Weeding

Weeding was necessary to keep the plant free from weeds. The newly emerged weeds were uprooted carefully from the field after complete emergence of sprouts and afterwards when necessary.

3.11.2 Irrigation

Just after full emergence the crop was irrigated by flooding at 15 days after planting (DAP) so that uniform growth and development of the crop was occurred and also moisture status of soil retain as per requirement of plants. The second, third and fourth irrigation were done at 25, 45 and 65 DAP, respectively.

3.11.3 Mulching

Mulching were necessary to keep the pots to conserve soil moisture. Natural mulching was done for breaking the surface crust as and when needed.

3.11.4 Earthing up

Earthing up process was done in the plot at two times, during crop growing period. First was done at 35 DAP and second was at 50 DAP.

3.11.5 Plant protection measures

Dithane M-45 was applied at 30 and 60 DAP as a preventive measure for controlling fungal infection. Ridomil Gold (0.25%) was sprayed at 45, 55, 65 and 75 DAP to protect the crop from the attack of late blight.

3.11.6 Haulm cutting

Haulm cutting was done at 13th February, 2020 at 90 DAP, when 40-50% plants showed senescence and the tops started drying. After haulm cutting the tubers were kept under the soil for 10 days for skin hardening. The cut haulm was collected, bagged and tagged separately for further data collection.

3.11.7 Harvesting of potatoes

Harvesting of potato was done on 23th February, 2020 at 10 days after haulm cutting. The potatoes of each plot were separately harvested, bagged and tagged and brought to the laboratory. The yield of potato $plot^{-1}$ was determined in gram. Harvesting was done manually by hand.

3.12 Recording of data

The following data were recorded during experimentation period:

i. Plant height (cm),
ii. Number of tubers $hill^{-1}$,
iii. Average weight of tuber (g),
iv. Weight of tuber $hill^{-1}$ (g)
v. Tuber yield (t ha^{-1}),
vi. Marketable yield (t ha^{-1}),
vii. Non-marketable yield (t ha^{-1}),
viii. Specific Gravity (g cm^{-3}),
ix. Dry matter content (%),
x. Total soluble solid (˚brix)
xi. Starch content (mg g^{-1} FW),
xii. Reducing sugar (mg g^{-1} FW),
xiii. Yield of potato for chips production (t ha^{-1}),
xiv. Yield of potato for French fry production (t ha^{-1}),
xv. Yield of potato for flakes production (t ha^{-1}) and
xvi. Yield of potato for canned production (t ha^{-1}).

3.13 Experimental measurements

A brief outline of the data recording procedure followed during the study is given below:

3.13.1 Plant height (cm)

Plant height refers to the length of the plant from ground level to the tip of the tallest stem. It was measured at an interval of 15 days starting from 30 DAP till 60 DAP.

3.13.2 Number of tubers hill^{-1}

Number of tubers hill^{-1} was counted at harvest. Tuber numbers hill^{-1} was recorded by counting all tubers from each plant.

3.13.3 Average weight of tuber (g)

Average tuber weight was measured by using the following formula-

$$Average\ tuber\ weight\ (g) = \frac{Yield\ of\ tuber\ hill^{-1}\ (g)}{\text{Number of tubers hill}^{-1}}$$

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

Tubers of each plot were collected separately from which weight of tuber hill^{-1} was recorded in gram.

3.13.5 Tuber yield (t ha^{-1})

Tubers of each plot were collected separately from which yield of tuber hill^{-1} was recorded in gram and converted to ton hectare^{-1}.

3.13.6 Marketable yield and non-marketable yield (t ha^{-1})

On the basis of weight, the tubers have been graded into marketable tuber (> 20 g) and non-marketable tuber (< 20 g) and converted to percentages (Hussain, 1995).

3.13.7 Specific Gravity (g cm^{-3})

It was measured by using the following formula (Gould, 1995)-

$$\text{Specific gravity (g cm}^{-3}\text{)} = \frac{\text{Weight in air}}{\text{Weight in water at }4^{0}\text{ C}}$$

3.13.8 Dry matter content (%)

The samples of tuber were collected from each treatment. After peel off the tubers the samples were dried in an oven at 72°C for 72 hours. Dry matter content was calculated as the ratio between dry and fresh weight and expressed as a percentage (Barton and Longman, 1989).

3.13.9 Total soluble solids (˚brix)

TSS of harvested tubers was determined in a drop of potato juice by using Hand Sugar Refrectometer "ERMA" Japan, Range: 0-32% according to (AOAC, 1990) and expressed as BRIX value.

3.13.10 Starch content (mg g^{-1} FW)

The residue remained after extraction for sugar, was washed for several times with water to ensure that there was no more soluble sugar in the residues. After that using tap water and mark up to 250 ml beaker. Stir well on a magnetic stirrer. Then 0.5 mL solution was taken from the beaker into 3 test tubes. 0.5 mL was taken during the stirring. Then boiling the test tubes for 10 min at 100˚C. 1 mL Amyloglucosidase solution was added and mix well and heat at 50-60˚C for 2 hrs in hot water. After cooling, a 0.5 mL Copper solution was added and mix well, heat at 100C for 10 min., cool in tap water again added 0.5 mL Nelson solution, mix well and added 7 mL distilled water, mix well (Final volume = 9.5 mL), and measure the absorbance at 660 nm (Abs4). Calculate starch content using the glucose standard curve.

3.13.11 Reducing sugar (mg g^{-1} FW)

3.13.11.1 Extraction of sugar

For the analysis of sugar content like glucose and sucrose potato flesh was extracted. For each extraction, 1.0 g fresh sample of chopped potato was taken from uniform tuber samples. Sugar was extracted using 5ml of 80% ethanol heat at 80°C for 30 min using a dry block heat bath and the extracts was centrifuged at 5000 rpm for 10 min and decanted the supernatant. 8ml 80% EtOH, was added and it was repeated 4 and 5 for 3 times in total. All the supernatants were mixed well and the final volume was made up to 25 mL using 80% EtOH. The residue is used for starch analysis.

3.13.11.2 Reducing sugar determination (glucose)

Reducing sugar was estimated by the photometric adaptation of the Somogyi method with some modification. Copper solution and Nelson reagent and standard glucose solution (0.5 ml) were used. Amount of 3 ml sample solution was put into a small glass container. Then it was completely dried up on an electric heater, 3 ml distilled water was added, and then mixed well. Then .5ml solution was taken from this, two times and was put in different test tubes. In one test tube, 0.5 ml Copper solution was added and was boiled (100°C) for 10 min. After boiling, immediately the test tube was cooled in tap water. 0.5 ml Nelson reagent in the test tube was added, and mixed them well. After 20 min, 8 ml distilled water was added and mixed well (Total volume = 9.5 ml). 33 After that the absorbance at 660 nm (Abs1) was measured and the reducing sugar content was calculated.

3.13.12 Grading of tuber (t ha^{-1})

Tubers harvested from each treatment were graded by weight on the basis of diameter into the < 30 mm, 30-45 mm, 45-75 mm and > 75 mm and converted to t ha^{-1} (Hussain, 1995). A special type of frame (potato riddle) was used to grading of tuber.

3.14 Statistical Analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package programme. The significant differences among the treatment means were compared by Least Significant Different (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

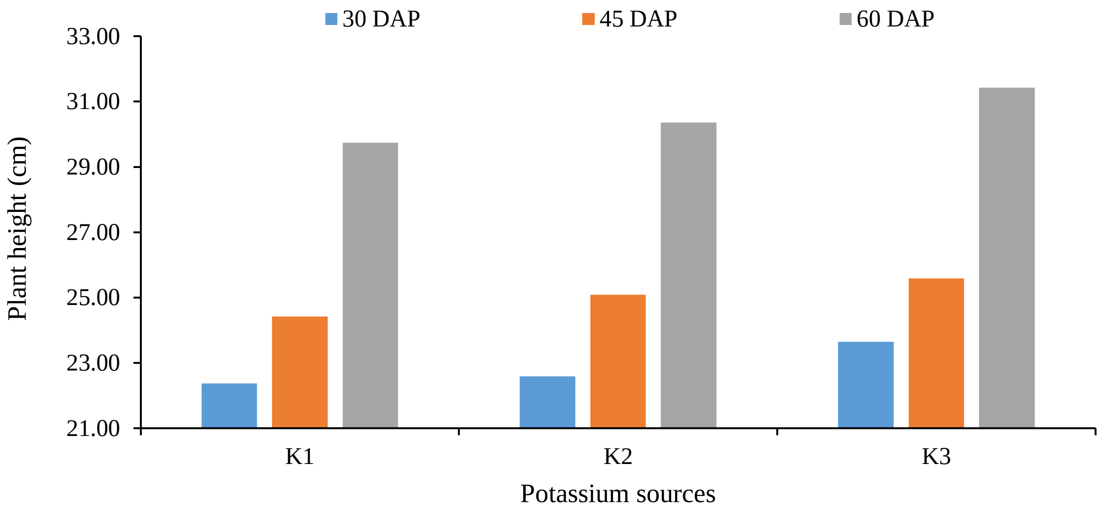
RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of potassium sources and biochar levels on yield and quality of potato. The results obtained from the study have been presented, discussed and compared in this chapter through tables and figures. The analysis of variance of data in respect of all the parameters has been shown in Appendix V to IX. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings. The analytical results have been presented in Table 1 through Table 9 and Figure 1 through Figure 10.

4.1 Plant height (cm)

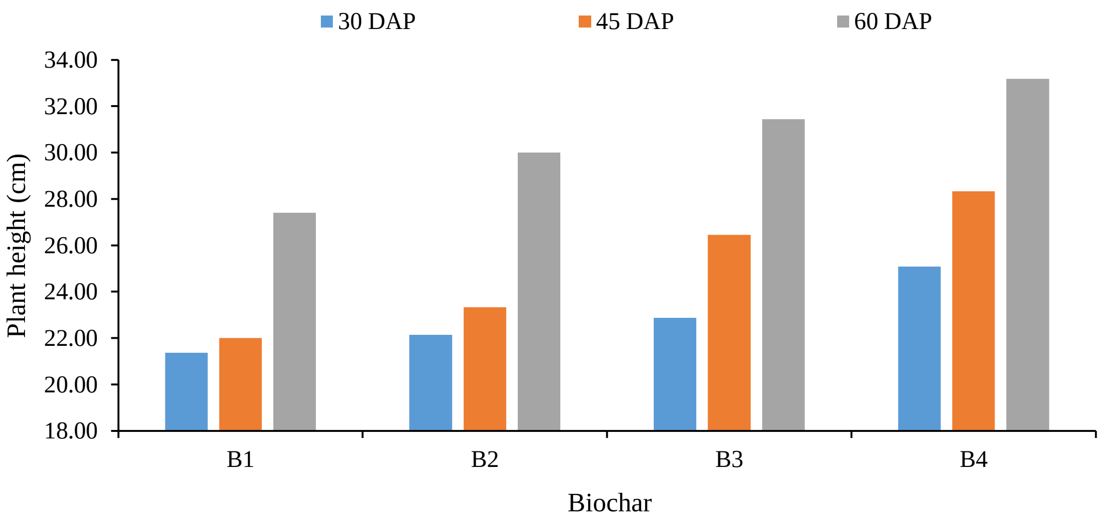
4.1.1 Effect of potassium sources

The plant height of potato was measured at 30, 45 and 60 DAP. It was evident from Figure 1 and Appendix V that the height of plant was significantly influenced by sources of potassium at all the sampling dates. At 30 DAP, K_2SO_4 fertilizer (K_3) application showed the longest plant (23.64 cm) whereas, the shortest plant (22.37 cm) was found from KCl fertilizer (K_1) application which was statistically identical to K_2 (22.58 cm). At 45 DAP, K_2SO_4 fertilizer (K_3) application showed the longest plant (25.58 cm) which was statistically identical to K_2 (25.08 cm) whereas, the shortest plant (24.42 cm) was found from KCl fertilizer (K_1) application. At 60 DAP, K_2SO_4 fertilizer (K_3) application showed the longest plant (31.43 cm) which was statistically identical to K_2 (30.36 cm) whereas, the shortest plant (29.74 cm) was found from KCl fertilizer (K_1) application. The result obtained from the present study was similar with Rahman *et al.* (2002) and Lu (2003).



Note: K_1 – KCl, K_2 – KH_2PO_4 and K_3 – K_2SO_4.

Figure 1. Effect of potassium sources on plant height of potato (LSD value = 1.03, 1.21 and 1.53 at 30, 45 and 60 DAP, respectively)



Note: B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1} and B_4 - 5.00 t ha^{-1}.

Figure 2. Effect of biochar on plant height of potato (LSD value = 1.03, 1.21 and 1.53 at 30, 45 and 60 DAP, respectively)

4.1.2 Effect of biochar levels

Plant height due to different levels of biochar applications was significantly influenced at days after planting (DAP) (Figure 2 and Appendix V). At 30 DAP, the longest plant (25.08 cm) was recorded from B_4 (5.00 t ha^{-1}) treatment whereas, the shortest plant (21.37 cm) was recorded from B_1 (1.25 t ha^{-1}) treatment which was statistically similar to B_2 (22.14 cm). The longest plant (28.33 and 33.18 cm at 45 and 60 DAP, respectively) was recorded from B_4 (5.00 t ha^{-1}) treatment whereas, the shortest plant (22.00 and 27.41 cm at 45 and 60 DAP, respectively) was recorded from B_1 (1.25 t ha^{-1}) treatment. The results were conformity with the findings of Afrina (2017).

4.1.3 Interaction effect of potassium sources and biochar levels

Significant variation of plant height was found due to interaction effect of potassium sources and biochar levels in all the studied durations (Table 1 and Appendix V). At 30 DAP, the longest plant (27.07 cm) was measured from K_3B_4 combination and the shortest plant (20.83 cm) from K_1B_1 treatment combination which was statistically similar to K_3B_1 (21.67 cm) and K_2B_1 (21.60 cm). At 45 DAP, the longest plant (28.33 cm) was measured from K_3B_4 combination which was statistically identical to K_1B_4 (28.33 cm), K_2B_4 (28.33 cm), K_3B_3 (27.67 cm) and similar to K_2B_3 (27.00 cm) whereas, the shortest plant (21.67 cm) from K_1B_1 treatment combination. At 60 DAP, the longest plant (34.53 cm) was measured from K_3B_4 combination which was statistically identical to K_2B_4 (32.67 cm) and similar to K_1B_4 (32.33 cm), K_3B_3 (32.33 cm) whereas, the shortest plant (26.00 cm) from K_1B_1 treatment combination.

Table 1. Interaction effects of potassium sources and biochar on plant height of potato

Treatment combination	Plant height (cm) at		
	30 DAP	45 DAP	60 DAP
K_1B_1	20.83 e	21.67 e	26.00 f
K_1B_2	21.93 cd	23.00 d	29.83 cd
K_1B_3	22.63 c	24.67 c	30.80 bc
K_1B_4	24.07 b	28.33 a	32.33 ab
K_2B_1	21.60 de	22.00 de	27.73 e
K_2B_2	22.00 cd	23.00 d	29.83 cd
K_2B_3	22.63 c	27.00 ab	31.20 b
K_2B_4	24.10 b	28.33 a	32.67 a
K_3B_1	21.67 de	22.33 d	28.50 cd
K_3B_2	22.50 c	24.00 c	30.33 bc
K_3B_3	23.33 bc	27.67 a	32.33 ab
K_3B_4	27.07 a	28.33 a	34.53 a
LSD (0.05)	**0.83**	**0.98**	**1.14**
CV (%)	**8.26**	**11.27**	**10.83**

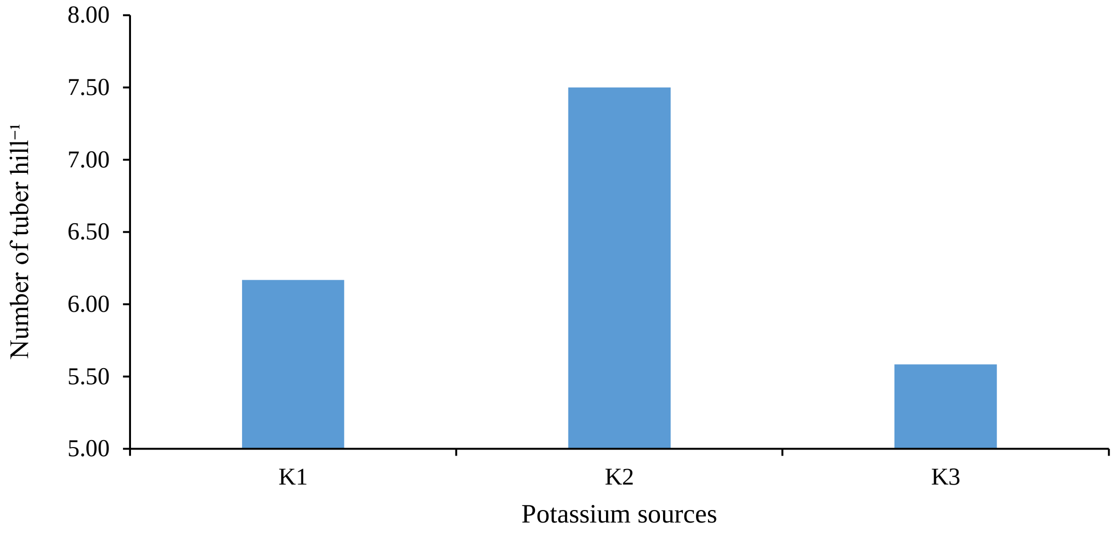
In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: K_1 – KCl, K_2 – KH_2PO_4, K_3 – K_2SO_4 and B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1}, B_4 - 5.00 t ha^{-1}

4.2 Number of tubers $hill^{-1}$

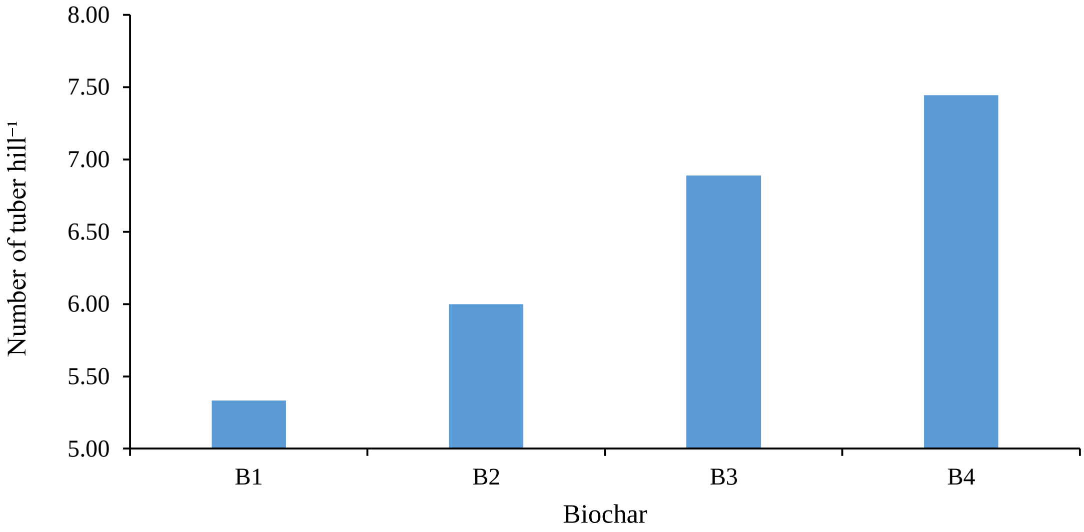
4.2.1 Effect of potassium sources

Number of tubers $hill^{-1}$ significantly influenced by different potassium fertilizer (Appendix VI and Figure 3). The maximum number of tubers $hill^{-1}$ (7.50) was recorded from K_2 treatment. The minimum number of tubers $hill^{-1}$ (5.58) was found from K_3 treatment. The result obtained from the present study was similar with Qin (2003) and Rahman *et al.* (2002).



Note: K_1 – KCl, K_2 – KH_2PO_4 and K_3 – K_2SO_4.

Figure 3. Effect of potassium sources on number of tuber hill^{-1} of potato (LSD value = 0.58)



Note: B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1} and B_4 - 5.00 t ha^{-1}.

Figure 4. Effect of biochar on number of tuber hill^{-1} of potato (LSD value = 0.58)

4.2.2 Effect of biochar levels

Number of tubers hill^{-1} significantly influenced by the different levels of biochar applications (Figure 4 and Appendix VI). The maximum (7.44) number of tubers was produced from B_4 (5.0 t ha^{-1}) treatment which was statistically identical to B_3 (6.89), whereas the minimum (5.33) was produced from B_1 (1.25 t ha^{-1}) treatment. The results were conformity with the findings of Afrina (2017).

4.2.3 Interaction effect of potassium sources and biochar levels

In respect of tuber number hill^{-1} due to different potassium sources and biochar levels was found statistically significant (Table 2 and Appendix VI). The maximum (8.00) number of tuber was found from K_2B_4 treatment combination which was statistically identical to K_2B_3 (7.67) and similar to K_1B_4 (7.33), K_2B_2 (7.33), K_2B_1 (7.00), K_3B_4 (7.00). The minimum (5.00) number of tuber was from K_1B_1 treatment combination.

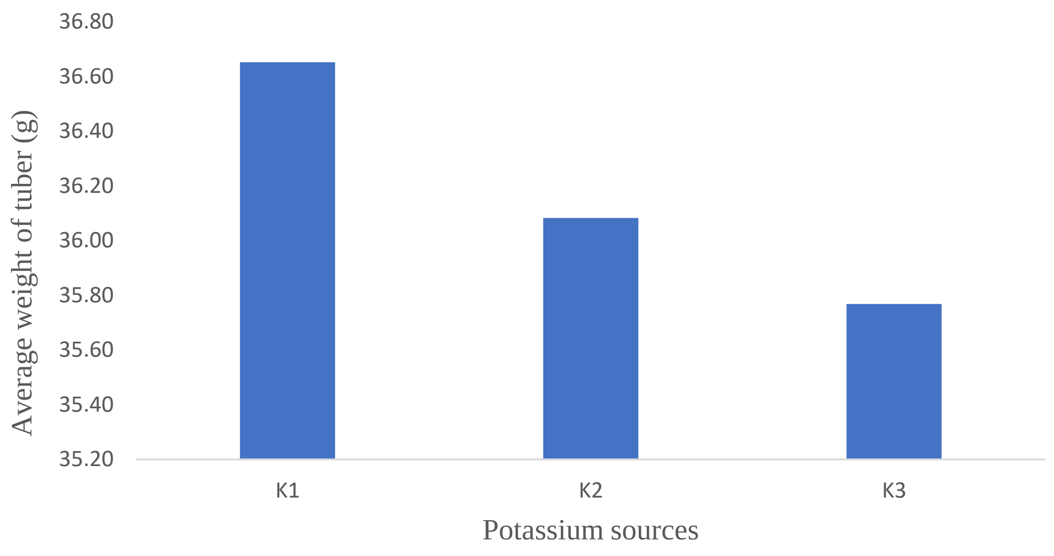
4.3 Average weight of tuber (g)

4.3.1 Effect of potassium sources

The average weight of tuber varied non-significantly due to different potassium fertilizer (Appendix VI and Figure 5). The highest average weight of tuber (36.65 g) was recorded from KCl (K_1) treatment whereas, the lowest (35.77 g) was obtained from K_2SO_4 (K_3) treatment. The results were supported by the findings of Sobhani *et al.* (2002).

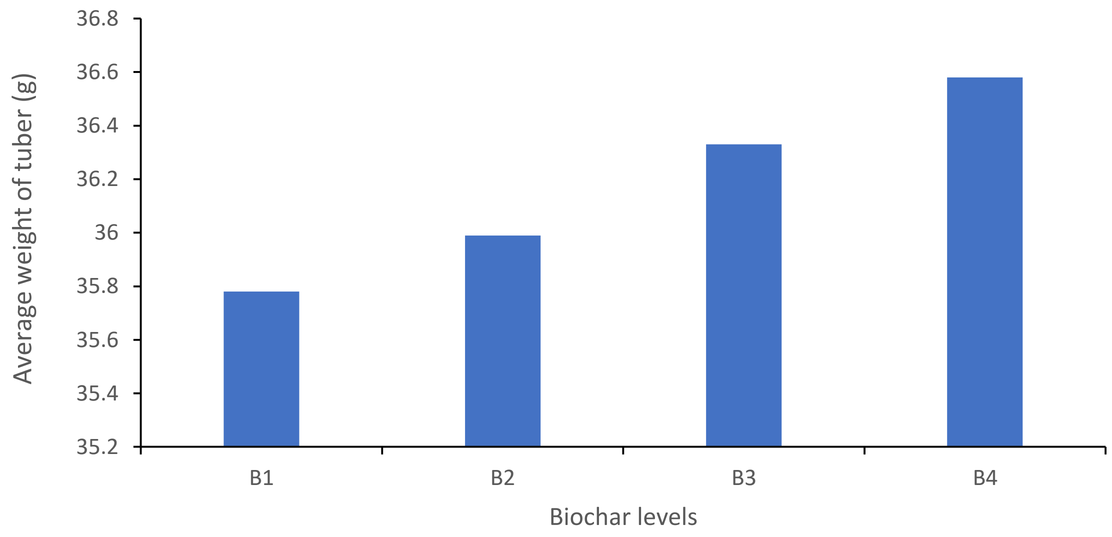
4.3.2 Effect of biochar levels

Average weight of tuber non-significantly varied among the different levels of biochar applications (Figure 6 and Appendix VI). The highest average weight of tuber (36.58 g) was observed from B_4 (5.00 t ha^{-1}) while the lowest (35.78 g) was observed from B_1 (1.25 t ha^{-1}) treatment. The result obtained from the present study was dissimilar with Afrina (2017).



Note: K_1 – KCl, K_2 – KH_2PO_4 and K_3 – K_2SO_4.

Figure 5. Effect of potassium sources on average weight of tuber of potato (LSD value = Non-significant)



Note: B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1} and B_4 - 5.00 t ha^{-1}.

Figure 6. Effect of biochar on average weight of tuber of potato (LSD value = Non-significant)

4.3.3 Interaction effect of potassium sources and biochar levels

Interaction of different potassium sources and biochar levels had non-significant effect on average weight of tuber (Table 2 and Appendix VI). The numerically the highest average weight of tuber (37.06 g) was recorded in K_1B_1 treatment combination. On the other hand, the numerically lowest average weight of tuber (35.41 g) was observed in K_3B_4 treatment combination.

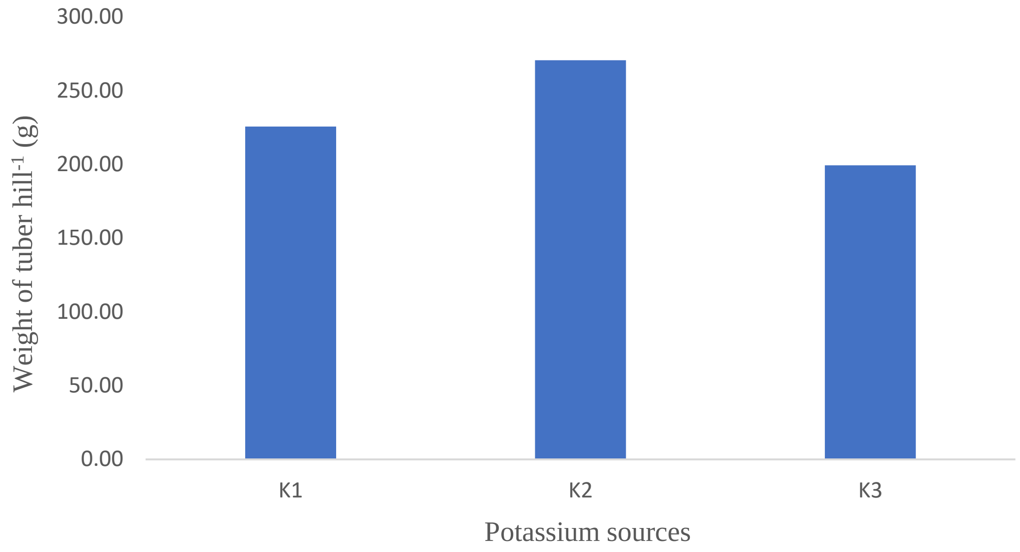
4.4 Weight of tuber hill^{-1} (g)

4.4.1 Effect of potassium sources

Different potassium fertilizer had significant effect on the weight of tuber hill^{-1} (Appendix VI and Figure 7). The maximum weight of tuber hill^{-1} (270.51 g) was obtained from KH_2PO_4 (K_2) treatment. On the other hand, the minimum weight of tuber hill^{-1} (199.37) was found from K_2SO_4 (K_3) treatment. Sobhani *et al.* (2002) supported these findings.

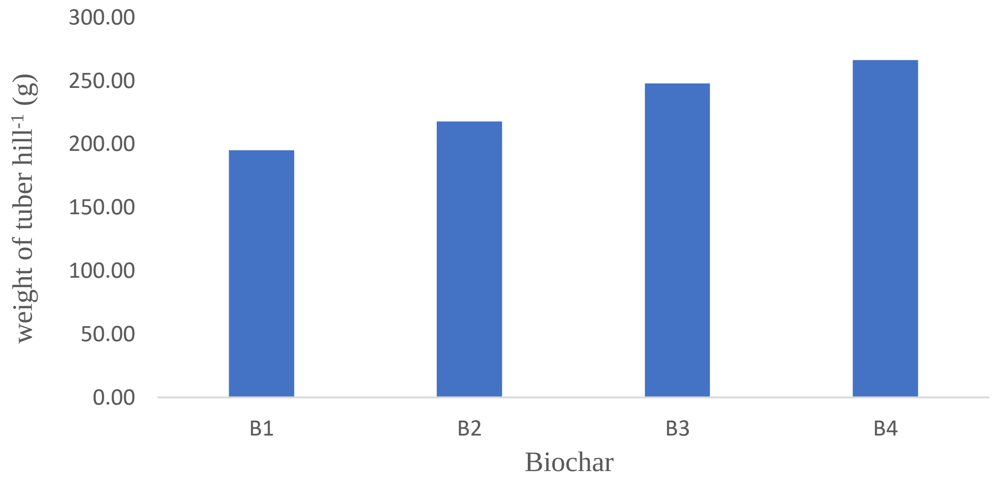
4.4.2 Effect of biochar levels

Biochar levels had significant effect on the weight of tuber hill^{-1} (Figure 8 and Appendix VI). Results revealed that, treatment B_4 (5.00 t ha^{-1}) produced maximum weight of tuber hill^{-1} (266.37 g) which was statistically identical to B_3 (249.07 g) treatment whereas, the minimum (195.24 g) one was obtained from B_1 (1.25 t ha^{-1}). It observed that 26.06 % more weight of tuber was obtained from the plot treated with 5.00 t ha^{-1} biochar (B_4) than the plot treated with 1.25 t ha^{-1} biochar (B_1). The higher yield might be attributed to vigorous plant growth, more tuber plant^{-1} and large tuber size. Indawan *et al.* (2018) reported that tobacco biochar application increased storage root weight, storage root dry weight and storage root yield.



Note: K_1 – KCl, K_2 – KH_2PO_4 and K_3 – K_2SO_4.

Figure 7. Effect of potassium sources on weight of tuber hill^{-1} of potato (LSD value = 13.89)



Note: B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1} and B_4 - 5.00 t ha^{-1}.

Figure 8. Effect of biochar on weight of tuber hill^{-1} of potato (LSD value = 13.89)

4.4.3 Interaction effect of potassium sources and biochar levels

Interaction of different potassium sources and biochar levels had significant effect on weight of tuber hill^{-1} (g) (Table 2 and Appendix VI). The maximum weight of tuber hill^{-1} (286.00 g) was recorded in K_2B_4 treatment combination. On the other hand, the minimum weight of tuber hill^{-1} (144.36 g) was observed in K_3B_1 treatment combination.

Table 2. Interaction effects of potassium sources and biochar on number of tuber hill^{-1}, average weight of tuber and weight of tuber hill^{-1} of potato

Treatment combination	Number of tubers hill^{-1}	Average weight of tuber (g)	Weight of tuber hill^{-1} (g)
K_1B_1	5.00 f	37.06	185.30 h
K_1B_2	5.67 e	36.88	208.99 g
K_1B_3	6.67 bc	36.50	243.33 e
K_1B_4	7.33 ab	36.17	265.25 c
K_2B_1	7.00 a–c	36.58	256.06 d
K_2B_2	7.33 ab	36.08	264.59 c
K_2B_3	7.67 a	35.92	275.39 b
K_2B_4	8.00 a	35.75	286.00 a
K_3B_1	4.00 g	36.09	144.36 i
K_3B_2	5.00 f	36.02	180.10 h
K_3B_3	6.33 cd	35.55	225.15 f
K_3B_4	7.00 a–c	35.41	247.87 e
LSD $_{(0.05)}$	**0.36**	**NS**	**7.16**
CV (%)	**6.82**	**10.26**	**9.26**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: K_1 – KCl, K_2 – KH_2PO_4, K_3 – K_2SO_4 and B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1}, B_4 - 5.00 t ha^{-1}

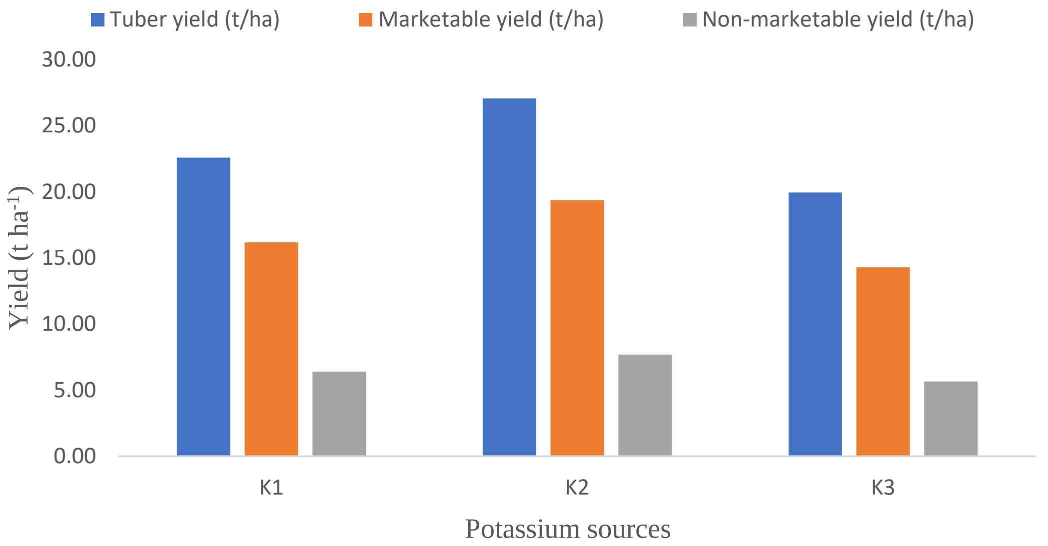
4.5 Tuber yield (t ha^{-1})

4.5.1 Effect of potassium sources

Application of different potassium sources had significant effect on the yield of tuber (Appendix VII and Figure 9). The highest tuber yield (27.05 t ha^{-1}) was obtained from KH_2PO_4 (K_2) treatment while, the lowest (19.94 t ha^{-1}) was found from K_2SO_4 (K_3) treatment. The results were in conformity with the findings of Badrunnesa *et al.* (2021) and Chettri and Thapa (2002) who also showed superior performance of K_2SO_4 as potassium fertilizer in case of potato tuber yield compared with other sources.

4.5.2 Effect of biochar levels

Application of different biochar levels had significant effect on the yield of tuber (Figure 10 and Appendix VII). Results revealed that, treatment B_4 (5.00 t ha^{-1}) produced the highest tuber yield (26.64 t ha^{-1}) which was statistically identical to B_3 (24.80 t ha^{-1}) treatment whereas, the minimum (19.52 t ha^{-1}) one was obtained from B_1 (1.25 t ha^{-1}). Gautam *et al.* (2017) indicated that the application of biochar along with FYM in fertile soils in hill farming systems of small holder farmers generally increased the crop yields in biochar and compost amended soils (Getachew, 2016 and Claudia, 2014). This might be due to biochar amendment being more effective in enhancing the vegetative growth of plants (Vaccari, 2015). Yang *et al.* (2015) reported that, the yield of the corn on the control soils without biochar weighed 0.5 t ha^{-1}. Study conducted by Olmo *et al.* (2014) revealed that biochar increased the yield by about 20%. Yilangai *et al*. (2014) reported that application of biochar together with nitrogen fertilizer enhanced biochar effect on crop growth and yield. This may be because biochar serves as a carrier substrate for nitrogen (N) which increases the effectiveness of biochar by retaining and preventing the leaching of N beyond the reach of plants. Biochar has also a potential to significantly improve durability of soil aggregates (Sun and Lu, 2014; Hale, 2013; Jeffery *et al*., 2011; Jha *et al*., 2010 and Lehmann *et al*., 2009). Another study on maize reported by Major *et al*. (2010) showed that maize increased to about 140% during the fourth year of biochar application and this was attributed to increased pH and nutrient retention in soil. Chan *et al*. (2008) reported 96% increase in radish yields from application of biochar in a greenhouse experiment and suggested that this increased yield was largely due to the ability of biochar to increase N availability. In addition, Yamato *et al*. (2006) revealed that with 2 t ha^{-1} addition, sweet potato yield was 37.62 t ha^{-1} and with 4 t ha^{-1} biochar that was 38.94 t ha^{-1} while without biochar the yield was only 33 t ha^{-1}.



Note: K_1 – KCl, K_2 – KH_2PO_4 and K_3 – K_2SO_4.

Figure 9. Effect of potassium sources on the yield of potato (LSD value = 0.96, 1.65 and 0.64)

4.5.3 Interaction effect of potassium sources and biochar levels

Interaction between different potassium sources and biochar levels played an important role for promoting the yield. Yield of tuber was significantly influenced by the interaction effects of different potassium sources and biochar levels (Appendix VII and Table 3). Among the treatments, the highest (28.60 t ha^{-1}) tuber yield was observed in KH_2PO_4 and 5.00 t ha^{-1} biochar (K_2B_4) treatment combination which was statistically similar to K_2B_3 (27.54 t ha^{-1}) treatment combination. On the other hand, the lowest (14.44 t ha^{-1}) tuber yield was found from K_2SO_4 and 1.25 t ha^{-1} biochar (K_3B_1) treatment combination.

4.6 Marketable yield (t ha^{-1})

4.6.1 Effect of potassium sources

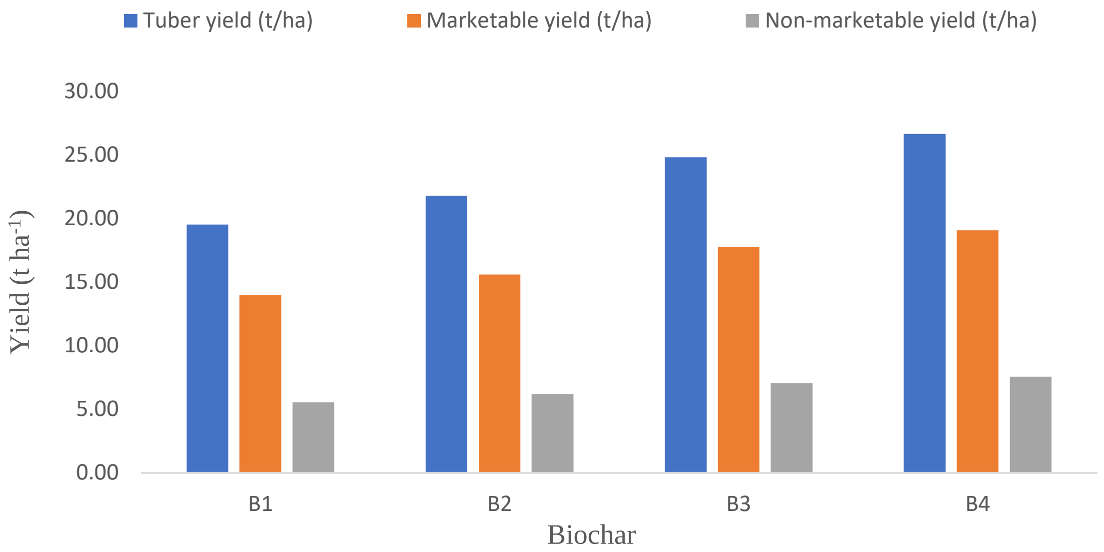
There was significant variation in marketable yield of potato (Appendix VII and Figure 9). K_2 treatment produced the maximum marketable yield (19.37 t ha^{-1}) of potato whereas, the minimum (14.27 t ha^{-1}) was produced by K_3 treatment.

4.6.2 Effect of biochar levels

Different levels of biochar had significant influenced on the marketable yield of potato (Figure 10 and Appendix VII). Results revealed that, treatment B_4 (5.00 t ha^{-1}) produced maximum marketable yield (19.07 t ha^{-1}) which was statistically identical to B_3 (17.75 t ha^{-1}) whereas, the minimum (13.98 t ha^{-1}) one was obtained from B_1 (1.25 t ha^{-1}). Marketable yield of potato was obtained 25.31 % more from the plot treated with 5.00 t ha^{-1} biochar (B_4) than the plot treated with 1.25 t ha^{-1} biochar (B_1). Gautam *et al.* (2017) reported that higher levels of the biochar amended soils could be due to improved availability of phosphorous as a result of biochar addition which also could be the reason for better production of marketable potato. Timilsina *et al*. (2017) and Collins *et al*. (2013) also reported that increased biochar application had increased quality potato tuber. Youseef *et al.* (2017) reported that marketable yield was significantly increased with increasing biochar application rates up to 5 m^3 fed^{-1}. Ding *et al.* (2016) reported that organic matter and inorganic salt, such as humic-like and fluvic-like substances and available N, P, and K, can serve as fertilizer and be assimilated by plants and microorganisms. Chan *et al*. (2008) reported significant increase in radish yields from application of biochar and this increased yield was due to the biochar's ability to increase N availability to plants.

4.6.3 Interaction effect of potassium sources and biochar levels

Interaction of potassium sources and biochar levels had significant effect on marketable yield of potato (Table 3 and Appendix VII). The maximum marketable yield (20.48 t ha^{-1}) was recorded in K_2B_4 combination treatment. On the other hand, the minimum marketable yield (10.34 t ha^{-1}) was observed in K_3B_1 combination treatment.



Note: B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1} and B_4 - 5.00 t ha^{-1}.

Figure 10. Effect of biochar on the yield of potato (LSD value = 0.96, 1.65 and 0.64)

4.7 Non-marketable yield (t ha^{-1})

4.7.1 Effect of potassium sources

There was significant variation in non-marketable yield of potato (Appendix VII and Figure 9). K_2 treatment produced the numerically the highest non-marketable yield (7.68 t ha^{-1}). On the other hand, the numerically the lowest non-marketable yield (5.66 t ha^{-1}) was produced by K_3 treatment.

4.7.2 Effect of biochar levels

Biochar levels had significant influenced on the non-marketable yield of potato (Figure 10 and Appendix VII). Results exposed that, treatment B_4 (5.00 t ha^{-1}) produced the highest non-marketable potato (7.56 t ha^{-1}) which was statistically identical to B_3 (7.04 t ha^{-1}) and the lowest (5.54 t ha^{-1}) one was obtained from B_2 (1.25 t ha^{-1}).

Table 3. Interaction effects of potassium sources and biochar on the yield of potato

Treatment combination	Tuber yield (t ha^{-1})	Marketable yield (t ha^{-1})	Non-marketable yield (t ha^{-1})
K_1B_1	18.53 g	13.27 g	5.26 h
K_1B_2	20.90 f	14.96 f	5.94 g
K_1B_3	24.33 d	17.42 d	6.91 e
K_1B_4	26.52 bc	18.99 bc	7.53 c
K_2B_1	25.61 cd	18.33 cd	7.27 cd
K_2B_2	26.46 bc	18.94 c	7.51 c
K_2B_3	27.54 ab	19.72 b	7.82 b
K_2B_4	28.60 a	20.48 a	8.12 a
K_3B_1	14.44 h	10.34 h	4.10 j
K_3B_2	18.01 g	12.90 g	5.11 i
K_3B_3	22.52 e	16.12 e	6.39 f
K_3B_4	24.79 d	17.75 d	7.04 de
LSD $_{(0.05)}$	**1.51**	**0.75**	**0.27**
CV (%)	**6.29**	**5.04**	**5.37**

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: K_1 – KCl, K_2 – KH_2PO_4, K_3 – K_2SO_4 and B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1}, B_4 - 5.00 t ha^{-1}

4.7.3 Interaction effect of potassium sources and biochar levels

Interaction of different potassium sources and biochar levels had significant effect on non-marketable yield of potato (Table 3 and Appendix VII). The highest non-marketable potato (8.12 t ha^{-1}) was recorded in K_2B_4 combination treatment. On the other hand, the lowest non-marketable yield of potato (4.10 t ha^{-1}) was observed in K_3B_1 combination treatment.

4.8 Specific gravity (g cm^{-3})

4.8.1 Effect of potassium sources

In present study potassium sources had not significant effect on specific gravity (Appendix VII and Table 4). Numerically, the highest specific gravity (1.064 g cm^{-3}) was obtained from K_2SO_4 (K_3) whereas, the lowest (1.043 g cm^{-3}) specific gravity was found from KH_2PO_4 (K_2). Similar findings were also reported by Parveen *et al.* (2004).

Table 4. Effects of potassium sources on the processing qualities of potato

Potassium sources	Specific gravity (g cm^{-3})	Dry matter content (%)	Total soluble solid (°brix)	Starch content (mg g^{-1} FW)	Reducing sugar (mg g^{-1} FW)
K_1	1.051	20.72 b	5.65 a	14.48 b	0.295 b
K_2	1.043	19.51 c	5.47 b	15.43 ab	0.443 a
K_3	1.064	21.84 a	5.38 b	16.33 a	0.398 a
LSD $_{(0.05)}$	**NS**	**0.74**	**0.12**	**1.11**	**0.052**
CV (%)	**3.28**	**8.37**	**5.51**	**8.29**	**6.18**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: K_1 – KCl, K_2 – KH_2PO_4 and K_3 – K_2SO_4.

4.8.1 Effect of biochar levels

Specific gravity of tuber varied non-significantly with different levels of biochar application (Table 5 and Appendix VIII). Numerically, the highest specific gravity of tuber was recorded (1.058 g cm^{-3}) from B_4 (5.00 t ha^{-1}) treatment while, the lowest (1.047 g cm^{-3}) was found from B_1 (1.25 t ha^{-1}) treatment. Similar findings were also reported by Bethee (2018) and Afrina (2017) who reported that biochar at 10.00 t ha^{-1} increased specific gravity in potato.

4.8.3 Interaction effect of potassium sources and biochar levels

The specific gravity of tuber due to different potassium sources and levels of biochar application was found statistically non-significant (Table 6 and Appendix VIII). Numerically, the highest (1.070 g cm^{-3}) specific gravity of tuber exhibited by K_3B_4. On the other hand, numerically the lowest (1.041 g cm^{-3}) specific gravity of tuber was exhibited by K_2B_1.

4.9 Dry matter content (%)

4.9.1 Effect of potassium sources

Tuber dry matter content showed significant variations among the different potassium fertilizer (Appendix VIII and Table 4). The maximum dry matter content of tuber (21.84 %) was recorded from K_3 treatment. The minimum tuber dry matter content (19.51 %) was recorded from K_2 treatment. Chettri and Thapa (2002) reported similar findings which are in conformity of these results.

4.9.2 Effect of biochar levels

Tuber dry matter content (%) of potato significantly influenced different levels of biochar application (Table 5 and Appendix VIII). The maximum tuber dry matter (21.73%) was recorded from B_4 (5.00 t ha^{-1}) treatment which was statistically similar to B_3 (21.00 %) and the lower tuber dry matter (19.61 %) was recorded from B_1 (1.25 t ha^{-1}) treatment. This result had agreements with the findings of Afrina (2017) and Youseef *et al.* (2017) who reported that the increases of potato dry matter may be attributed to that fertilizing with biochar positively increased number of main stems, leaves and tubers, as well as leaf area plant^{-1}.

4.9.3 Interaction effect of potassium sources and biochar levels

Interaction of different potassium sources and levels of biochar application had significant effect of tuber dry matter content (%) of potato (Table 6 and Appendix VIII). The maximum tuber dry matter of (22.67 %) was recorded in K_3B_4 combination treatment. On the other hand, the minimum tuber dry matter of potato (18.37 %) was observed in K_2B_1 combination treatment.

Table 5. Effects of biochar on the processing qualities of potato

Biochar	Specific gravity (g cm^{-3})	Dry matter content (%)	Total soluble solid (°brix)	Starch content (mg g^{-1} FW)	Reducing sugar (mg g^{-1} FW)
B_1	1.047	19.61 c	5.69 a	14.33 b	0.470 a
B_2	1.052	20.40 b	5.62 a	14.73 b	0.407 b
B_3	1.054	21.00 ab	5.41 b	15.80 ab	0.350 c
B_4	1.058	21.73 a	5.28 c	16.77 a	0.287 d
LSD $_{(0.05)}$	**NS**	**0.74**	**0.12**	**1.11**	**0.052**
CV (%)	**3.28**	**8.37**	**5.51**	**8.29**	**6.18**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1} and B_4 - 5.00 t ha^{-1}.

4.10 Total soluble solid (°brix)

4.10.1 Effect of potassium sources

Different potassium fertilizer had significantly between themselves regarding TSS (Appendix VIII and Table 4). The maximum TSS (5.65%) was recorded from KCl (K_1) fertilizer application. On the other hand, the minimum TSS (5.38%) was obtained from the K_2SO_4 (K_3) fertilizer application which was statistically identical to K_2 (5.47 %) treatment.

4.10.2 Effect of biochar levels

Biochar levels had significant influenced on the total soluble solid (Table 5 and Appendix VIII). Results exposed that, treatment B_1 (1.25 t ha^{-1}) produced the highest total soluble solid (5.69 %) which was statistically identical to B_2 (5.62 %) treatment and the lowest one (5.28 %) which was statistically at par with B_4 (5.00 t ha^{-1}). Similar findings were reported by Youseef *et al.* (2017) who reported that biochar at 2.5 m^3 fed^{-1} decreased the total soluble solid content in potato. Akhtar *et al*. (2014) found that biochar addition improved quality of tomato fruits.

4.10.3 Interaction effect of potassium sources and biochar levels

Significant variation was found among different potassium sources and levels of biochar application on total soluble solid of tuber (Table 6 and Appendix VIII). The highest (5.81 %) total soluble solid of tuber exhibited by K_1B_1 which was statistically identical to K_1B_2 (5.80 %) and K_2B_1 (5.73 %). On the other hand, the lowest (5.18 %) total soluble solid was exhibited by K_2B_4 combination treatment.

4.11 Starch (mg g^{-1} FW)

4.11.1 Effect of potassium sources

Significant variation was found on starch content on potato due to different potassium fertilizer application (Table 4 and Appendix VIII). The highest starch content on potato (16.33 mg g^{-1} FW) was attained by K_3 (K_2SO_4) treatment which was statistically similar to K_2 (15.43 mg g^{-1} FW). On the other hand, the lowest starch content on potato (14.48 mg g^{-1} FW) was attained by K_1 (KCl) treatment. Similar findings were also reported by Lu (2003) who stated that potassium fertilizer increased starch content in potato.

4.11.2 Effect of biochar levels

Significant variation was found on starch content on potato due to different biochar levels (Table 5 and Appendix VIII). The highest starch content on potato (16.77 mg g^{-1} FW) was attained by B_4 (5.0 t ha^{-1}) which was statistically similar to B_3 (15.80 mg g^{-1} FW). On the other hand, the lowest starch content on potato (14.33 mg g^{-1} FW) was attained by B_1 (1.25 t ha^{-1}) which was statistically similar to B_2 (14.73 mg g^{-1} FW). Similar findings were also reported by Bethee (2018) and Youseef *et al.* (2017) who reported that biochar at 2.5 m^3 fed^{-1} increased starch content in potato. Akhtar *et al.* (2014) found that biochar addition improved quality of tomato fruits.

4.11.3 Interaction effect of potassium sources and biochar levels

Significant variation was found on starch content on potato due to interaction effect of different potassium fertilizer and levels of biochar application (Table 6 and Appendix VIII). The highest starch content on potato (17.50 mg g^{-1} FW) was attained by K_3B_4 treatment combination which was statistically similar to K_3B_3 (16.90 mg g^{-1} FW). On the other hand, the lowest starch content on potato (13.70 mg g^{-1} FW) was attained by K_1B_1 which was statistically identical with K_1B_2 (13.80 mg g^{-1} FW) and which was statistically similar with K_1B_3 (14.10 mg g^{-1} FW) and K_2B_1 (14.20 mg g^{-1} FW).

4.12 Reducing sugar (mg g^{-1} FW)

4.12.1 Effect of potassium sources

Reducing sugar (mg g^{-1} FW) was significantly influenced by different potassium fertilizer application (Table 4 and Appendix VIII). The maximum reducing sugar value (0.443 mg g^{-1} FW) was recorded from the "KH_2PO_4 application" (K_2) which was statistically identical with K_3 (0.398 mg g^{-1} FW) whereas, the minimum (0.295 mg g^{-1} FW) was found from the "KCl application" (K_3).

4.12.2 Effect of biochar levels

Reducing sugar (mg g^{-1} FW) was significantly influenced by different levels of biochar application (Table 5 and Appendix VIII). The maximum reducing sugar value (0.470 mg g^{-1} FW) was recorded from the "biochar 1.25 t ha^{-1}" (B_1) treatment whereas, the minimum (0.287 mg g^{-1} FW) was found from the "biochar 5.00 t ha^{-1} (B_4) treatment. Reducing sugar content decrease with the increasing biochar levels.

4.12.3 Interaction effect of potassium sources and biochar levels

Interaction of different potassium application and biochar levels had significant effect of reducing sugar content (mg g^{-1} FW) of potato (Table 6 and Appendix VIII). The maximum reducing sugar content (0.510 mg g^{-1} FW) was recorded in K_2B_1 which was statistically identical with K_2B_2 (0.490 mg g^{-1} FW) and K_3B_1 (0.490 mg g^{-1} FW) whereas, the lowest value of potato (0.200 mg g^{-1} FW) was observed in K_1B_4 combination treatment.

Table 6. Interaction effects of potassium sources and biochar on the processing qualities of potato

Treatment combination	Specific gravity (g cm^{-3})	Dry matter content (%)	Total soluble solid (°brix)	Starch content (mg g^{-1} FW)	Reducing sugar (mg g^{-1} FW)
K_1B_1	1.045	19.38 g	5.81 a	13.70 e	0.410 b
K_1B_2	1.047	20.50 e	5.80 a	13.80 e	0.320 de
K_1B_3	1.052	21.00 d	5.59 bc	14.10 de	0.250 f
K_1B_4	1.060	22.00 b	5.41 de	16.30 bc	0.200 g
K_2B_1	1.041	18.37 h	5.73 a	14.20 de	0.510 a
K_2B_2	1.043	19.23 g	5.63 b	14.60 d	0.490 a
K_2B_3	1.044	19.88 f	5.33 e	16.40 bc	0.420 b
K_2B_4	1.045	20.54 e	5.18 f	16.50 bc	0.350 d
K_3B_1	1.054	21.09 cd	5.52 c	15.10 cd	0.490 a
K_3B_2	1.064	21.48 c	5.43 cd	15.80 c	0.410 bc
K_3B_3	1.067	22.13 b	5.32 e	16.90 ab	0.380 c
K_3B_4	1.070	22.67 a	5.25 e	17.50 a	0.310 e
LSD $_{(0.05)}$	**NS**	**0.42**	**0.09**	**0.74**	**0.031**
CV (%)	**3.28**	**8.37**	**5.51**	**8.29**	**6.18**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: K_1 – KCl, K_2 – KH_2PO_4, K_3 – K_2SO_4 and B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1}, B_4 - 5.00 t ha^{-1}

4.13 Grading of potato (t ha^{-1})

4.13.1 Yield of potato for canned production (t ha^{-1}) (20–30 mm)

4.13.1.1 Effect of potassium sources

The yields of potato for canned production (< 30 mm) was non-significantly varied by the different potassium fertilizer application (Table 7 and Appendix IX). Numerically, the maximum canned production (6.76 t ha^{-1}) was obtained from K_2 treatment and the minimum (4.98 t ha^{-1}) was obtained from K_3 treatment. Badrunnesa *et al.* (2021) also stated non-significant influence of potassium fertilizer source on canned potato production.

4.13.1.2 Effect of biochar levels

The yields of potato for canned production (< 30 mm) was significantly varied by the different biochar levels (Table 8 and Appendix IX). The maximum canned production (6.66 t ha^{-1}) was obtained from B_4 (5.00 t ha^{-1}) treatment and the minimum (4.88 t ha^{-1}) was obtained from B_1 (1.25 t ha^{-1}) treatment.

4.13.1.3 Interaction effect of potassium sources and biochar levels

The yields of potato for canned production (< 30 mm) due to different potassium fertilizer and levels of biochar application was found statistically significant (Table 9 and Appendix IX). The maximum (7.15 t ha^{-1}) canned production exhibited by K_2B_4 treatment combination which was statistically similar to K_2B_3 (6.88 t ha^{-1}) treatment combination whereas, the minimum (3.61 t ha^{-1}) was exhibited by K_3B_1 treatment combination.

4.13.2 Yields of potato for flakes production (t ha^{-1}) (30–45 mm)

4.13.2.1 Effect of potassium sources

The yields of potato for flakes production (30–45 mm) was significantly influenced by the different potassium fertilizer application (Table 7 and Appendix IX). The highest flakes production (12.17 t ha^{-1}) was obtained from K_2 treatment and the lowest ones (8.97 t ha^{-1}) was obtained from K_3 treatment. Badrunnesa *et al.* (2021) showed similar results on influence of potassium fertilizer sources on flakes production.

Table 7. Effects of potassium sources on the yield of potato for different processing purpose

Potassium sources	Yield of potato for canned production (t ha^{-1}) (20–30 mm)	Yield of potato for flakes production (t ha^{-1}) (30–45 mm)	Yield of potato for chip production (t ha^{-1}) (45–75 mm)	Yield of potato for French fry production (t ha^{-1}) (> 75 mm)
K_1	5.64 b	10.16 b	6.77 b	NF
K_2	6.76 a	12.17 a	8.12 a	NF
K_3	4.98c	8.97 c	5.98 c	NF
LSD $_{(0.05)}$	**0.39**	**1.25**	**0.44**	**-**
CV (%)	**7.51**	**8.26**	**7.49**	**-**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: K_1 – KCl, K_2 – KH_2PO_4 and K_3 – K_2SO_4.
NF = Not found

4.13.2.2 Effect of biochar levels

The yields of potato for flakes production (30–45 mm) was significantly influenced by the different biochar levels (Table 8 and Appendix IX). The highest flakes production (11.99 t ha^{-1}) was obtained from B_4 (5.00 t ha^{-1})

treatment which was statistically identical with B_3 (11.16 t ha^{-1}) treatment. On the other hand, the lowest flakes production (8.79 t ha^{-1}) was obtained from B_1 (1.25 t ha^{-1}) treatment which was statistically identical with B_2 (9.81 t ha^{-1}) treatment. This result had agreements with the findings of Youseef *et al.* (2017) who reported that potato yield for flakes production was significantly increased with increasing biochar application rates up to 5 $m^3 fed^{-1}$.

4.13.2.3 Interaction effect of potassium sources and biochar levels

The yields of potato for flakes production (30–45 mm) due to different potassium fertilizer and levels of biochar application was found statistically significant (Table 9 and Appendix IX). The highest (12.87 t ha^{-1}) flakes production exhibited by K_2B_4 treatment combination which was statistically similar to K_2B_3 (12.39 t ha^{-1}) treatment combination whereas, the lowest ones (6.50 t ha^{-1}) was exhibited by K_3B_1 treatment combination.

Table 8. Effects of biochar on the yield of potato for different processing purpose

Biochar	Yield of potato for canned production (t ha^{-1}) (20–30 mm)	Yield of potato for flakes production (t ha^{-1}) (30–45 mm)	Yield of potato for chip production (t ha^{-1}) (45–75 mm)	Yield of potato for French fry production (t ha^{-1}) (> 75 mm)
B_1	4.88 d	8.79 b	5.86 d	NF
B_2	5.45 c	9.81 b	6.54 c	NF
B_3	6.20 b	11.16 a	7.44 b	NF
B_4	6.66 a	11.99 a	7.99 a	NF
LSD $_{(0.05)}$	0.39	1.25	0.44	-
CV (%)	7.51	8.26	7.49	-

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1} and B_4 - 5.00 t ha^{-1}.
NF = Not found

4.13.3 Yields of potato for chips production (t ha^{-1}) (45–75 mm)

4.13.3.1 Effect of potassium sources

The yields of potato for chips production (45–75 mm) was significantly affected by the different potassium fertilizer application (Table 7 and Appendix IX). The maximum chips production (8.12 t ha^{-1}) was obtained from K_2 treatment. On the other hand, the minimum chips production (5.95 t ha^{-1}) was obtained from K_3 treatment.

4.13.3.2 Effect of biochar levels

The yields of potato for chips production (45–75 mm) was significantly affected by the different biochar levels (Table 8 and Appendix IX). The maximum chips production (7.99 t ha^{-1}) was obtained from B_4 (5.00 t ha^{-1}) treatment. On the other hand, the minimum chips production (5.86 t ha^{-1}) was obtained from B_1 (1.25 t ha^{-1}) treatment. This result had agreements with the findings of Youseef *et al.* (2017) who reported that chips production was significantly increased with increasing biochar application rates up to 5 m^3 fed^{-1}.

4.13.3.3 Interaction effect of potassium sources and biochar levels

The yields of potato for chips production (45–75 mm) due to different potassium fertilizer and levels of biochar application was found statistically significant (Table 9 and Appendix IX). The maximum (8.58 t ha^{-1}) chips production exhibited by K_2B_4 treatment combination. On the other hand, the minimum (4.33 t ha^{-1}) was exhibited by K_3B_1 treatment combination.

Table 9. Interaction effects of potassium sources and biochar on the yield of potato for different processing purpose

Treatment combination	Yield of potato for canned production ($t\ ha^{-1}$) (20–30 mm)	Yield of potato for flakes production ($t\ ha^{-1}$) (30–45 mm)	Yield of potato for chip production ($t\ ha^{-1}$) (45–75 mm)	Yield of potato for French fry production ($t\ ha^{-1}$) (> 75 mm)
K_1B_1	4.63 g	8.34 f	5.56 h	NF
K_1B_2	5.22 f	9.40 e	6.27 g	NF
K_1B_3	6.08 d	10.95 d	7.30 e	NF
K_1B_4	6.63 bc	11.94 bc	7.96 c	NF
K_2B_1	6.40 cd	11.52 cd	7.68 d	NF
K_2B_2	6.61 bc	11.91 bc	7.94 c	NF
K_2B_3	6.88 ab	12.39 ab	8.26 b	NF
K_2B_4	7.15 a	12.87 a	8.58 a	NF
K_3B_1	3.61 h	6.50 g	4.33 i	NF
K_3B_2	4.50 g	8.10 f	5.40 h	NF
K_3B_3	5.63 e	10.13 e	6.75 f	NF
K_3B_4	6.20 d	11.15 cd	7.44 e	NF
LSD $_{(0.05)}$	**0.33**	**0.81**	**0.17**	**-**
CV (%)	**7.51**	**8.26**	**7.49**	**-**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: K_1 – KCl, K_2 – KH_2PO_4, K_3 – K_2SO_4 and B_1 – 1.25 t ha^{-1}, B_2 – 2.50 t ha^{-1}, B_3 – 3.75 t ha^{-1}, B_4 - 5.00 t ha^{-1}
NF = Not found

CHAPTER V

SUMMARY AND CONCLUSION

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The field experiment was conducted at the experimental plot of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from November, 2019 to March, 2020 in Rabi season to find out the response of potassium fertilizer source and different biochar levels on growth, yield and quality of potato. The experiment had two factors. Factor A: potassium: 3 sources; K_1: Muriate of potash (MoP or KCl), K_2: Potassium phosphate (KH_2PO_4) and K_3: Potassium sulfate (K_2SO_4) and Factor B: Biochar: 4 levels; B_1: 1.25 t ha^{-1}, B_2: 2.50 t ha^{-1}, B_3: 3.75 t ha^{-1} and B_4: 5.00 t ha^{-1}. The test variety was BARI Alu-29 (Courage). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three (3) replications. Total 36 unit pots was made for the experiment with 12 treatments. Data on different growth and yield parameter of potato were recorded and significant variation was recorded for different treatment.

In case of potassium sources, the tallest plant (23.64, 25.58 and 31.43 cm at 30, 45 and 60 DAP, respectively) was recorded from K_2SO_4 fertilizer treatment whereas, the shortest plant (22.37, 24.42 and 29.74 cm at 30, 45 and 60 DAP, respectively) was recorded from KCl fertilizer treatment. The highest average weight of tuber (26.650 g) was recorded from KCl (K_1) treatment whereas, the lowest (25.77 g) was obtained from K_2SO_4 (K_3) treatment. The maximum number of tubers $hill^{-1}$ (7.50), the maximum weight of tuber $hill^{-1}$ (286.00 g), The highest tuber yield (14.47 t ha^{-1}), the maximum marketable yield (9.69 t ha^{-1}) and numerically the highest non-marketable yield (4.77 t ha^{-1}) of potato was recorded from KH_2PO_4 (K_2) treatment. On the other hand, the minimum number of tubers $hill^{-1}$ (5.58), the minimum weight of tuber $hill^{-1}$ (143.54), the lowest tuber yield (10.62 t ha^{-1}), the minimum marketable yield (6.16 t ha^{-1}) and numerically the lowest non-marketable yield (4.46 t ha^{-1}) was found from K_2SO_4 (K_3) treatment. Numerically, the highest specific gravity (1.064 g cm^{-3}) and the maximum dry matter content of tuber (21.84%) was obtained from K_2SO_4 (K_3) treatment whereas, the lowest specific gravity (1.043 g cm^{-3}) was found from KH_2PO_4 (K_2) and the minimum tuber dry matter content (20.72%) was recorded from K_1 treatment. The maximum TSS (5.65%) was recorded from KCl (K_1) fertilizer application. On the other hand, the minimum TSS (5.38%) was obtained from the K_2SO_4 (K_3) fertilizer application. The highest starch content on potato (16.33 mg g^{-1} FW) was attained by K_3 (K_2SO_4) treatment and the lowest starch content on potato (14.48 mg g^{-1} FW) was attained by K_1 (KCl) treatment. The maximum reducing sugar value (0.443 mg g^{-1} FW) was recorded from the "KH_2PO_4 application" (K_2) whereas, the minimum reducing sugar value (0.295 mg g^{-1} FW) was found from the "KCl application" (K_3). Numerically, the maximum canned production (5.02 t ha^{-1}), the highest flakes production (6.52 t ha^{-1}) and the maximum chips production (2.93 t ha^{-1}) was obtained from K_2 treatment whereas; the minimum canned production (4.71 t ha^{-1}), the lowest flakes production (4.08 t ha^{-1}) and the minimum chips production (1.83 t ha^{-1}) was obtained from K_3 treatment.

In case of different biochar levels, the tallest plant (25.08 cm) at 30 DAP, was recorded from B_4 (5.00 t ha^{-1}) treatment whereas, the shortest plant (21.37 cm) was recorded from B_1 (1.25 t ha^{-1}) treatment which was statistically similar to B_2 (22.14 cm). The tallest plant (28.33 and 33.18 cm at 45 and 60 DAP, respectively) was recorded from B_4 (5.00 t ha^{-1}) treatment whereas, the shortest plant (22.00 and 27.41 cm at 45 and 60 DAP, respectively) was recorded from B_1 (1.25 t ha^{-1}) treatment. The maximum average weight of tuber (26.58 g) was observed from B_1 (1.25 t ha^{-1}) treatment while the minimum average weight of tuber (25.78 g) was observed from B_4 (5.00 t ha^{-1}) treatment. The maximum number of tubers $hill^{-1}$ (7.44), the maximum weight of tubers $hill^{-1}$ (191.93 g), the highest tuber yield (26.64 t ha^{-1}), the maximum marketable yield (19.07 t ha^{-1}) and the highest non-marketable potato yield (7.56 t ha^{-1}) was recorded from B_4 (5.00 t ha^{-1}) treatment. Whereas, the minimum number of tubers $hill^{-1}$ (5.33), the minimum weight of tubers $hill^{-1}$ (141.91 g), the minimum tuber yield (10.50

t ha^{-1}), the minimum marketable potato yield (6.67 t ha^{-1}) and the minimum non-marketable potato yield (3.83 t ha^{-1}) was obtained from B_1 (1.25 t ha^{-1}) treatment. Numerically, the highest specific gravity of tuber (1.058 g cm^{-3}), the maximum dry matter content of tuber (21.73%), the highest total soluble solid (5.69%) and the highest starch content of potato (16.77 mg g^{-1} FW) was recorded from B_4 (5.00 t ha^{-1}) treatment. While, the lowest specific gravity of tuber (1.047 g cm^{-3}), the lowest tuber dry matter (19.61%), the lowest total soluble solid (5.28%) and the lowest starch content on potato (14.33 mg g^{-1} FW) was attained by B_1 (1.25 t ha^{-1}) treatment. The maximum reducing sugar value (0.470 mg g^{-1} FW) was recorded from the biochar 1.25 t ha^{-1} (B_1) treatment whereas, the minimum reducing sugar value (0.287 mg g^{-1} FW) was found from the biochar 5.00 t ha^{-1} (B_4) treatment. The maximum canned production (5.52 t ha^{-1}), the highest flakes production (5.99 t ha^{-1}) and the maximum chips production (2.69 t ha^{-1}) was obtained from B_4 treatment (5.00 t ha^{-1}). On the other hand, minimum canned production (4.08 t ha^{-1}), the lowest flakes production (4.43 t ha^{-1}) and the minimum chips production (1.99 t ha^{-1}) was obtained from B_1 (1.25 t ha^{-1}) treatment.

Interaction effect of potassium fertilizer source and different biochar level was significant in most of the parameters under study. At 30 DAP, the tallest plant (27.07 cm) was measured from K_3B_4 combination and the shortest plant (20.83 cm) from K_1B_1 treatment combination. At 45 DAP, the tallest plant (28.33 cm) was measured from K_3B_4 combination whereas, the shortest plant (21.67 cm) from K_1B_1 treatment combination. At 60 DAP, the tallest plant (34.53 cm) was measured from K_3B_4 combination whereas, the shortest plant (26.00 cm) from K_1B_1 treatment combination. The maximum number of tuber (8.00) was found from K_2B_4 treatment combination and the minimum number of tuber (5.00) was recorded from K_1B_1 treatment combination. Numerically, the highest average weight of tuber (27.06 g) was recorded in K_1B_1 treatment combination. On the other hand, numerically the lowest average weight of tuber (25.41 g) was observed in K_3B_4 treatment combination. The maximum weight of tuber hill^{-1}

(206.00 g), the highest tuber yield (15.24 t ha^{-1}) and the maximum marketable yield (10.21 t ha^{-1}) was observed in KH_2PO_4 and 5.00 t ha^{-1} biochar (K_2B_4) treatment combination. On the other hand, the minimum weight of tuber $hill^{-1}$ (104.36 g), the lowest tuber yield (7.72 t ha^{-1}) and the minimum marketable yield (4.48 t ha^{-1}) was observed in K_2SO_4 and 1.25 t ha^{-1} biochar (K_3B_1) treatment combination. The highest non-marketable potato yield (5.53 t ha^{-1}) was recorded in K_3B_4 combination treatment. On the other hand, the lowest non-marketable yield of potato (3.24 t ha^{-1}) was observed in K_3B_1 combination treatment. Numerically, the highest specific gravity (1.070 g cm^{-3}) and the maximum dry matter content of tuber (22.67%) was exhibited by K_3B_4 combination. On the other hand, numerically the lowest specific gravity (1.041 g cm^{-3}) and the minimum tuber dry matter content of potato (18.37%) was exhibited by K_2B_1. The highest total soluble solid (5.81%) of tuber was exhibited by K_1B_1, On the other hand, the lowest total soluble solid (5.18%) was recorded from K_2B_4 combination treatment. The highest starch content of potato (17.50 mg g^{-1} FW) was attained by K_3B_4 treatment combination and the lowest starch content of potato (13.70 mg g^{-1} FW) was attained by K_1B_1. The maximum reducing sugar content (0.510 mg g^{-1} FW) was recorded in K_2B_1 whereas, the lowest value of reducing sugar content of potato (0.200 mg g^{-1} FW) was observed in K_1B_4 combination treatment. The maximum canned production (5.78 t ha^{-1}) was exhibited by K_3B_4 treatment combination whereas, the highest flakes production (6.87 t ha^{-1}) and the maximum chips production (3.09 t ha^{-1}) was exhibited by K_2B_4 treatment combination. On the other hand, the minimum canned production (3.49 t ha^{-1}), the lowest flakes production (2.92 t ha^{-1}) and the minimum chips production (1.31 t ha^{-1}) was exhibited by K_3B_1 treatment combination.

Based on the experimental results, it may be concluded that-

i) The effect of different potassium fertilizers and biochar levels had positive effect on morphological and growth characters, yield and qualitative attributes of potato.

ii) Application of KH_2PO_4 as the source of potassium fertilizer with 5.00 t ha^{-1} of biochar combination seemed to be more suitable for getting higher amount and quality tuber yield of potato for the farmer.

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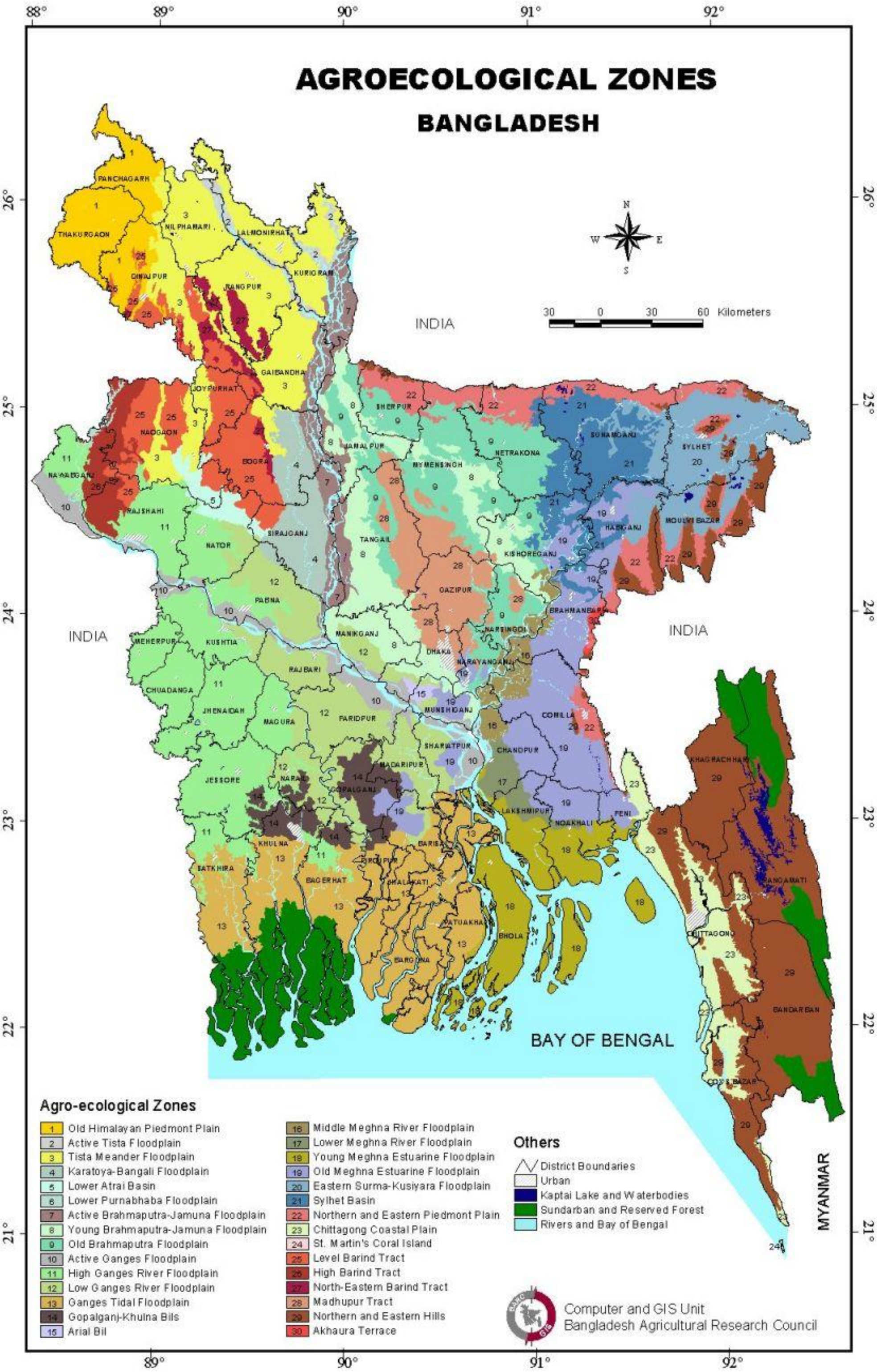
APPENDICES

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh



Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from November, 2019 to February, 2020

Month	Air temperature (°C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
November, 2019	31.82	14.04	81	24
December, 2019	23.40	10.50	87	5
January, 2020	20.18	7.04	88	0
February, 2020	18.20	9.70	82	15

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

Appendix III. Characteristics of experimental fields soil was analysed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Madhupur 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	Boro rice-Fallow-Aman rice

B. Physical properties of the initial soil

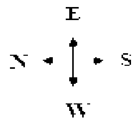
Characteristics	Value
%Sand	27
%Silt	43
%clay	30

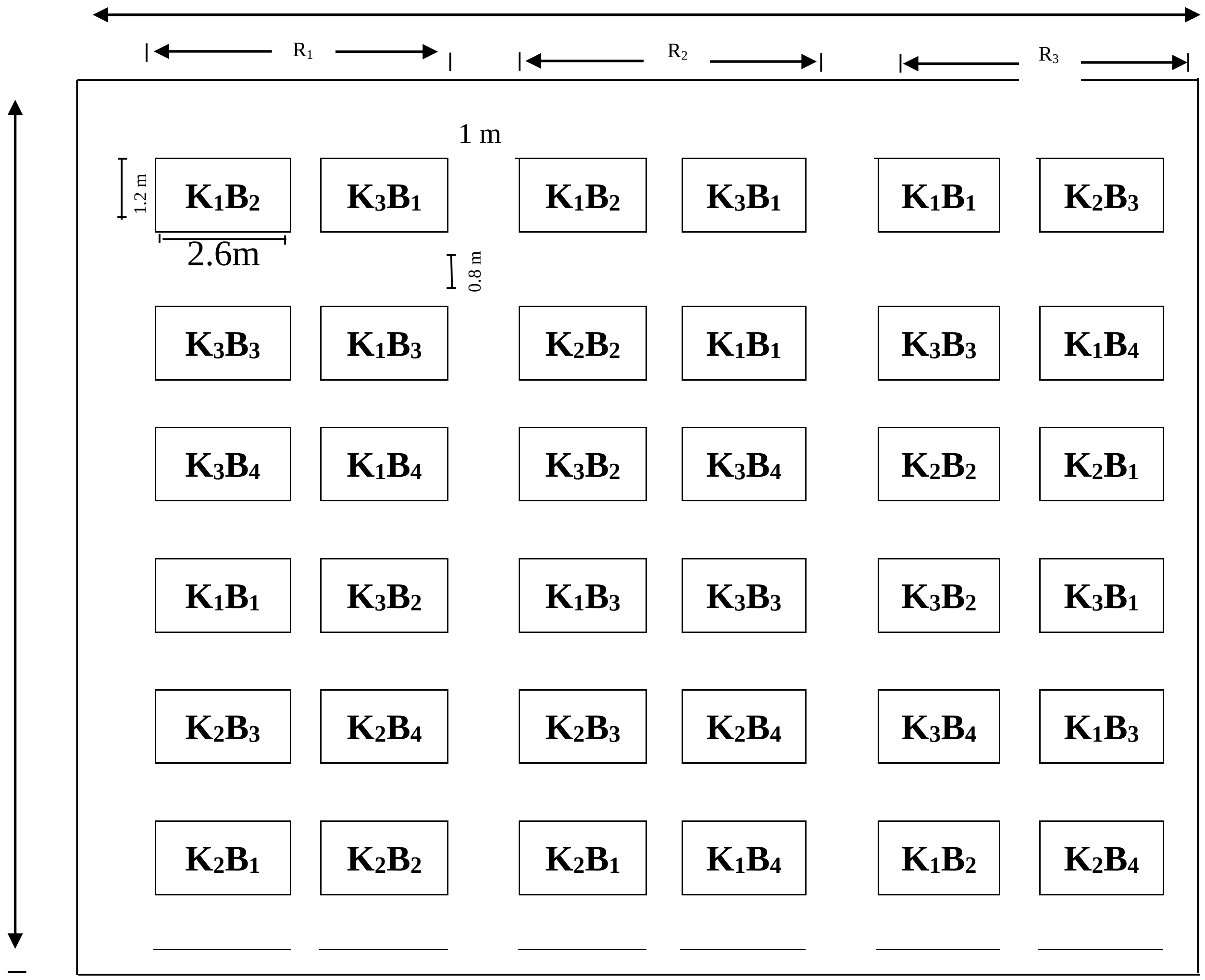
C. Chemical properties of the initial soil

Characteristics	Value
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (meq/ 100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI), Farmgate, Dhaka.

Appendix IV: Field layout of the two-factor experiment in Randomized Complete Block Design (RCBD)





Number of treatment combinations = 12
Plot spacing: = 0.8 m
Between replication = 1.0 m

Factor A: Types of potassium fertilizer
K_1 = KCl @250 kg KCl ha^{-1}
K_2 = KH_2PO_4 @452.19 kg KH_2PO_4 ha^{-1}
K_3 = K_2SO_4 @288.60 kg K_2SO_4 ha^{-1}

Factor B: Biochar levels
B_1 = 1.25 t ha^{-1}
B_2 = 2.50 t ha^{-1}
B_3 = 3.75 t ha^{-1}
B_4 = 5.00 t ha^{-1}

Appendix V. Analysis of variance (mean square) of plant height at different DAS

Source of variation	Degrees of freedom	Plant height		
		30 DAS	45 DAS	60 DAS
Replication	2	5.852	80.983	156.225
Potassium (A)	2	10.897*	49.245*	170.324*
Biochar (B)	3	6.051*	49.026*	110.420*
A×B	6	0.549**	3.452**	9.923**
Error	22	1.305	8.520	29.517

*** and ** indicate significant at 5% and 1% level of probability, respectively.**

Appendix VI. Analysis of variance (mean square) of yield components

Source of variation	Degrees of freedom	No. of tuber hill^{-1}	Average weight of tuber	Weight of tuber hill^{-1}
Replication	2	0.239	7.238	1.646
Potassium (A)	2	13.411*	571.676^{NS}	207.136*
Biochar (B)	3	16.141**	546.668^{NS}	167.304**
A×B	6	0.396*	8.145^{NS}	0.001**
Error	22	0.283	0.825	6.063

*** and ** indicate significant at 5% and 1% level of probability, respectively**

NS = non-significant

Appendix VII. Analysis of variance (mean square) of yield

Source of variation	Degrees of freedom	Tuber yield	Marketable yield	Non-marketable yield
Replication	2	1.970	41.200	149.040
Potassium (A)	2	50.408*	119.856*	205.300^{NS}
Biochar (B)	3	9.672*	26.023*	79.191*
A×B	6	0.577*	6.475*	3.825*
Error	22	2.327	13.856	25.211

*** and ** indicate significant at 5% and 1% level of probability, respectively**

NS = non-significant

Appendix VIII. Analysis of variance (mean square) of processing qualities

Source of variation	Degrees of freedom	Specific gravity	Dry matter content	Total soluble solid	Starch content	Reducing sugar
Replication	2	156.208	80.330	31.342	28.073	35.054
Potassium (A)	2	62.519^{NS}	65.135*	8.090**	46.212*	37.946*
Biochar (B)	3	3.558^{NS}	11.910**	2.122**	25.339*	27.845**
A×B	6	3.345^{NS}	2.393**	1.673**	2.480*	2.737**
Error	22	20.387	48.889	20.423	10.007	14.829

*** and ** indicate significant at 5% and 1% level of probability, respectively**

NS = non-significant

Appendix IX. Analysis of variance (mean square) of yield of potato for different processing purpose

Source of variation	Degrees of freedom	Yield of potato for canned production (< 30 mm)	Yield of potato for flakes production (30-45 mm)	Yield of potato for chip production (45-75 mm)	Yield of potato for French fry production (> 75 mm)
Replication	2	2.765	7.313	6.516	0.002
Potassium (A)	2	0.633^{NS}	145.606*	53.933*	0.001^{NS}
Biochar (B)	3	1.753*	12.964**	3.034*	0.001^{NS}
A×B	6	0.355*	3.995**	6.954**	0.002^{NS}
Error	22	0.365	0.310	0.585	0.002

*** and ** indicate significant at 5% and 1% level of probability, respectively**

NS = Non-significant