EFFECT OF BIOCHAR ON SOIL STATUS, YIELD AND PROCESSING QUALITY OF POTATO VARIETIES

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CERTIFICATE

This is to certify that the thesis entitled " ***EFFECT OF BIOCHAR ON SOIL STATUS, YIELD AND PROCESSING QUALITY OF POTATO VARIETIES****" 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 (MS)*** *in* ***AGRONOMY,*** *embodies the results of a piece of bona fide research work carried out by* ***BETHEE RANI DAS,*** *Registration. No.* **12-04874** *under my supervision and guidance. No part of this 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.

Dated:

Dhaka, Bangladesh

(Prof. Dr. Tuhin Suvra Roy)

Supervisor

DEDICATED TO

MY

BELOVED PARENTS

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EFFECT OF BIOCHAR ON SOIL STATUS, YIELD AND PROCESSING QUALITY OF POTATO VARIETIES

ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November, 2017 to April, 2018 to evaluate the effect of variety and biochar on yield and some quality parameters of potato along with soil properties. The experiment is 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}. Fifteen treatment combinations were used under study and was laid out in a randomized complete block design with 3 replications. The present 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. Biochar has also significant positive effect on sol properties such as soil pH, organic carbon and potassium content but not on nitrogen content. The soil properties results exhibited that pH level, organic carbon and potassium content increased with increasing biochar level. Among the fifteen treatment combination, 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}), marketable potato yield (21.30 t ha^{-1}), specific gravity (1.09), potato dry matter (22.01 %), seed potato yield (20.39 t ha^{-1}), grade 'A' potato yield (6.35 t ha^{-1}), grade 'B' potato yield(6.28 t ha^{-1}), French fry (5.70 t ha^{-1})and chips potato yield (9.03 t ha^{-1}), total soluble sugar content (5.07), soil pH (6.61), soil organic carbon content (1.16%) and available potassium content in soil (0.25 %). But in case of yield V_3B_4, V_3B_3, V_3B_2 and in case of dry matter content V_3B_3, V_3B_2 and V_2B_4 combinations are statistically similar. Whereas no biochar (B_0) treatment showed the lowest values irrespective of varieties. It may be concluded that biochar level @ 5.00 t ha^{-1} would be applied for maximizing yield and dry matter content. But in case of quality parameters 10 t ha^{-1} showed the best performances.

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
%	=	Percent
µg	=	Micro gram
^{0}C	=	Degree Celsius
BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
CV%	=	Percentage of coefficient of variance
cv.	=	Cultivar
DAS	=	Days after sowing
et al.	=	And others
G	=	Gram (g)
ha^{-1}	=	Per hectare
HI	=	Harvest Index
Hr	=	Hour
Kg	=	Kilogram
LSD	=	Least Significant Difference
Mm	=	Millimeter
MoP	=	Muriate of Potash
N	=	Nitrogen
No.	=	Number
NPK	=	Nitrogen, Phosphorus and Potassium
NS	=	Non significant
Ppm	=	Parts per million
Q	=	Quintal
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
T	=	Ton
TSP	=	Triple Superphosphate
viz.	=	Videlicet (namely)
Wt.	=	Weight

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum*L.) belonging to the family Solanaceae is cultivated in nearly 150 countries and is the world's single most vital tuberous crop with an important role in the global food network and food security (Sing, 2010). In the world's top 10 potato producing countries, Bangladesh ranks 7th position (FAOSTAT, 2014). The area and production of potato in Bangladesh has been increasing during last decades but the yield per unit area remains more or less static. The yield is very low 19.36 tha^{-1} in comparison to that of the other leading potato growing countries of the world, 74.45 tha^{-1} in Kuwait, 59.53 tha^{-1} in Belgium, 52.89 tha^{-1} in France, 51.97 tha^{-1} in USA, 47.53 tha^{-1} in Denmark and 46.21 tha^{-1} in UK (FAOSTAT, 2014).

Agricultural land in our country has been degraded due to continuous pressure of modern agriculture resulting in decreased soil fertility. Severe degraded land has become the main causes of low crop productivity. Agricultural land that has been intensively cultivated for continuous cultivation of food crops causes severe degradation and further decreases yields (Sitorus *et al.*, 2011). Soils obtaining inorganic fertilizers continuously show a decrease in productivity and tend to suffer secondary nutrient deficiencies as well as micronutrients (Sheth *et al*., 2017). So it is high time concern about soil health for ensuring sustainable crop production. The addition of soil amendment is necessary to restore the fertility of the soil. Biochar is one of the soil amendments that can improve soil fertility (Ding *et al*., 2016 and Hunt *et al*., 2010).

Biochar is an organic amendment used for soil improvement and it is produced by pyrolysis of biomass under low or anaerobic conditions (Nair *et al*., 2014).It is a mixture of char and ash, but it is mainly (70 - 95%) carbon (C). It can be produced using different biomass types, for example, switch grass, corn residue, or hardwoods. It has the potential to mitigate climate change, via carbon sequestration, decrease soil acidity and increase agricultural productivity (Sun and Lu, 2014, Hale, 2013, Jeffery *et al*., 2011, Jha *et al*., 2010, Woolf *et al*., 2010 and Lehmann *et al*., 2009). Historically it is known that the Amazonians used biochar to enhance soil productivity by smoldering agricultural wastes.The term 'biochar' was coined by Read to describe charcoal used for soil improvement (Read *et al*., 2004). Lean and Rind (2008) stated that it is a stable solid, rich in carbon, and can endure in soil for thousands of years. Biochar represents as a stable form of carbon thus provides a good carbon storage strategy as a soil amendment (Galinato *et al*., 2011). Previous studies showed that, it has good effect on some soil physical properties such as reducing soil bulk density (Mukherjee and Lal, 2013, Bussher *et al*., 2011and Mankasingh *et al*., 2011), increases the water retention capacity (Karhu *et al*., 2011 and Vaccari *et al*., 2011) and increases soil pH, EC, CEC of acidity soil (Abewa *et al*., 2014) and reduced fertilizers need. Other it's impacts such as soil's aggregation or porosity greatly depend on soil type, biochar'srates and types (Busscher *et al*., 2011 and Busscher *et al*., 2010). Biochar application to soil can serve as a source of nutrients, C, and habitat for microorganisms, thereby increasing microbial activities in soils (Thies and Rillig, 2009).Changes in soil chemistry regulated by biochar are implicated, with alterations in microbial diversity and activity, with porosity in biochar particles acting as refuges for soil organisms, *e.g.* mycorrhizal fungi (Reverchon *et al*., 2014 and Spokas *et al*., 2012). Biochar also can be a direct nutrient source for plants. It has been found to contain many plant nutrients, including N, P, K, Ca, Mg, S and micronutrients. Total soil nutrient concentrations can be 3 to 5-fold greater relative to the surrounding infertile soil with increased nutrient availability (Glaser *et al*., 2001). It provides protection against some foliar and soil-borne diseases and reduces pressure on forests (Ndameu, 2011).

The stable form of C in biochars is suggested to be resistant to oxidation and therefore inhibiting the formation of CO_2, decreasing the release of CO_2. Most biochar exhibits large surface area ranges from 20 m^2g^{-1} up to 3000 m^2g^{-1}(Chen *et al*., 2008 and Guo *et al*., 2002). The large surface area of biochar will increase the ion exchange capacity and the sorption of nutrients (Lehmann and Joseph, 2009). Biochar reduces leaching loss which is the main problem for N fertilizer by retaining soil water. Biochar mitigate climate change through slower return of terrestrial carbon as CO_2 gas to the atmosphere (Sohi *et al.*, 2010).According to Lehmann *et al.* (2003) biohar addition can improve plant productivity directly because of its nutrient content and release characteristics or indirectly, through improved nutrient retention.Biochar application has resulted in increased nutrient availability in soils and increased nutrient uptake in plant (Novak *et al*., 2009), as well as increased crop productivity such as maize (Cornelissen *et al*., 2013), soybean (Yooyen *et al*., 2015), tomato (Yilangai *et al*., 2014), lettuce and cabbage (Carter *et al*., 2013) and rice yield (Kang *et al*., 2016).

Biochar can play important role for improving yield and quality of potato. Nair (2015), on potato cv. Atlantic, found that there was a general trend of increasing yields with increasing biochar application rates. Graber *et al*. (2010) mentioned that treating tomato plants by biochar positively enhanced plant height and leaf size. Akhtar *et al*. (2014) indicated that addition of biochar increased the soil moisture contents, which consequently improved physiology, yield, and quality of tomato plants. Also, biochar addition to mineral fertilizers significantly increased plant growth (Biederman and Harpole, 2013 and Schulz and Glaser, 2012). In addition, the biochar treatments were found to increase the final vegetative biomass, root biomass, plant height and leaf number of lettuce and cabbage in all the cropping cycles compared to no biochar treatments (Carter *et al*., 2013). Dou *et al*. (2012) revealed that biochar treatment could increase yield, sugar content and appearance quality of sweet potato, which was conducive to bringing more economic profits for farmers, and improving food safety through using organic fertilizers, and finally promoting sustainable crop production. So considering the soil health and beneficial act of biochar the present investigation was undertaken with the following objectives:

i. To observe the performance of potato varieties under biochar treatments
ii. To study the performance of biochar on improving soil physical properties and
iii. To optimize the level of biochar for maximizing potato yield with good quality

CHAPTER 2

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 biochar on soil amendment through carbon sequestration and 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 Biochar

2.1.1 Biochar for crop improvement

The term ‘biochar’ was coined by Read to describe charcoal used for soil improvement (Read *et al*., 2004). Like most charcoal, biochar is produced by pyrolysis of biomass in low or anaerobic conditions and has the potential to mitigate climate change, via carbon sequestration (Woolf *et al*., 2010). It increases pH of acidic soils, agricultural productivity, and provides protection against some foliar and soil-borne diseases and reduces pressure on forests (Ndameu, 2011). It is a stable solid, rich in carbon, and can endure in soil for thousands of years (Leanand Rind, 2008). Historically**,** Pre-Columbian Amazonians were believed to have used biochar to enhance soil productivity. They produced it by smoldering of agricultural wastes. Biochar production and application has been proposed as one of the options that mitigates climate change (Lehmann, 2007) and improving soil fertility and crop productivity (Major *et al*., 2010). Its porosity is very beneficial for improving soil structure and water holding capacity (Karhu *et al*., 2011 and Vaccari *et al*., 2011) hence mitigating the increasing drought stress in dryland agriculture due to climate change.

Biochar is a technology that normally provides conditions suitable for crop improvement by providing the necessary nutrients for growth, development as well as the yield. For instance (Alburquerque *et al*., 2013, Dong *et al*., 2013, Khan *et al*., 2013, Saarnio *et al*., 2013, Rajkovich *et al.,* 2012, Revell *et al.,* 2012, Schulz and Glaser, 2012, Zhang *et al.,* 2012, Vaccari *et al.,* 2011, Van Zwieten *et al*., 2010 and Asai*et al.,* 2009) found from their studies using different methods in biochar study such as greenhouse/glasshouse, field laboratory and microcosm on the effect of biochar on plant and recorded a significant positive change in plant growth and development. But the nature of the plant growth and development is subjected to many factors. In the case of (Rajkovich *et al*., 2012) different types of biochars were applied including corn stover, dairy manure paper sludge, and food. Food for instance included in the Rajkovich *et al*. (2012) study was not specifically stated as to whether it is corn, millet, sorghum (cereal) or root and tubers based food but only stated its source implying it cannot be pinpointed which food biochar is for a specific crop. Schulz and Glaser (2012) and Asai *et al*. (2009) recorded an increase in the yield of oat crop by the use of babecue charcoal. Considering the cost involved in the pyrolysis. Different biomass could have been used to bring out different results in order to make meaningful comparison.

The uses of sewage sludge biochar from waste water treatment from Xianam from the study done by Khan *et al*. (2013) makes a big headway for the area because of its abundance. But the metal and metalloids that contaminate it makes its use as a tool for agricultural development endangered.

Vaccari *et al*. (2011) use special rotary tillage for biochar made from coppiced wood (beech, hazel oak and burch) application and saw a significant growth and yield. But the mode of application of the char though not tiring compared to hand broadcast may increase cost of biochar use which may deter most peasant farmers especially from developing countries from its use if that is it to serve as baseline for enhancing agriculture through the use of biochar. Another issue is the addition of fertilizer to biochar most of the time as found in many researches such as Van Zwieten *et al*., (2010) who used slow pyrolysis method to enhance growth and development of radish. Will the result be same for fast pyrolysis? Broiler chicken feed used by (Revell *et al*.,2012) also has its own problem as far as the constitution of the litter is concerned. Most litter contains a lot more than the fecal matter that is known. This comprises of the saw dust (for example in the deep litter system), the remnants of feed, feathers aside the known normal fecal matters. Therefore broiler litter may differ from unit to unit of a typical poultry farm. There is therefore probability attached to the use of broiler litter as biochar for crop production. It may be different across board. Dong *et al.* (2013) significant improvement in the use bamboo and rice straw biochar calls for further investigation especially using bamboo does not hold plant nutrients or it provides itself. Studies done have demonstrated that biochar can be produced from anything 'organic' such as paper sludge, bamboo, rice straw, poultry litter, sewage sludge, rice husk, cassia stem, palm leaves sawdust, spruce chips corn stover, wood chip, corn and corn stalk, wheat and other agriculture wastes have been used for crop growth and development. The identification of the type of biochar that can be used for specific purpose is imperative for proper identification and documentation.Despite that biochar contributes to plant growth, some studies have shown that biochar application and incorporation to soils sometimes does and some does not enhance or delay crop improvement and production.

Significant crop yield benefits from biochar application to soils have been reported for various crops and plants in different environments (Lehmann and Joseph, 2015). In Amazonia, biochar application in combination with fertilizers sustained crop yields (Steiner *et al*., 2008) due to soil property improvements (Lehmann *et al*., 2003).(Crane-Droesch *et al*., 2013) reported positive crop yield response as a result of biochar application over much of Sub-Saharan Africa, parts of South America, Southeast Asia, and southeastern North America. The observed increase in crop yields in these highly weathered and nutrient-poor soils could be explained by biochar soil amendments improving soil aggregation, increasing nutrients retention, and enhancing soil water holding capacity.

Biochar application has been reported to increase by 10% plant productivity (Liu *et al*., 2013) and 25% for aboveground biomass (Biederman and Harpole, 2013).Yamato *et al.* (2006) explored biochar effect on crop yield and reported increase in maize, cowpea and peanut yield under fertilized conditions due to increased soil pH, cation exchange capacity, nutrient availability and decreased exchangeable Al^{3+} content. Uzoma *et al*. (2011) attributed a 150% and 98% increase in maize grain yield at 15 and 20 t ha^{-1} biochar applications respectively to enhancement of soil physical and chemical properties.

Despite biochar's agronomic benefits, negative effects under biochar amendment on plant productivity have also been reported in peat soils whereas moderate to negative yield response could be observed in most of the leading countries in grain production (Crane-Droesch *et al*., 2013). Significant crop yield decrease in biochar-amended soils has been also attributed to significant increase in soil C: N ratios which in turn couldresult in nitrogen immobilization (Chan *et al.*, 2008 and Bridle and Pritchard, 2004). Zhang *et al*. (2012) investigated the effect of biochar on soil quality, plant yield and the emission of greenhouse gas in a rice paddy study in China and found increase in rice yield due increased soil pH, soil organic carbon, total nitrogen and decreased soil bulk density. Kloss *et al*. (2014) reported a 68 % yield reduction of mustard and barley after biochar application due to significant decrease (Cu, Fe, Mn, Zn) and increases (Mo) in micronutrient concentrations of plant tissues.

Effectiveness of biochar in improving plant productivity is variable (Liu *et al*., 2013) considering variations in climate, soil properties, investigated crops, and experimental conditions (Wang *et al*., 2012). These differences could also be explained by biochar feedstock and pyrolysis processes along with the interactions between soil biotic and abiotic components and biochar occurring when biochar is applied to soil (Sohi *et al*., 2009). In biochar experiments, positive crop productivity occurred in pot experiments more than in field, in acidic than in neutral soils, in sandy than in loam and silt soils (Crane-Droesch *et al*., 2013 and Jeffery *et al*., 2011). In addition, crops grown with biochar resulted with a 10.6% increase on average on dryland soils whereas a 5.6 % increase has been reported for paddy rice (Liu *et al*., 2013). For biochar source’s effects on yield response, poultry litter showed the strongest (significant) positive effect (28%), in contrast to bio-solids, which was the only feedstock showing a statistically significant negative effect (−28%) (Jeffery *et al.,* 2011).

2.1.2. Biochar as a heavy metal sequester and liming of acidic soils

Jiang and Xu (2013) observed a reduction in the concentration of Cu(II) and Pb(II) when soils were treated with biochar in their experiments. It was found that biochar could retain Cu(II) for some days, indicating the long-term immobilization which was complemented by Uchimiya *et al*. (2011) that broiler litter biochar led to a greater enhancement of copper sorption in Norfolk soil than in San Joaquin soil. Lu *et al.* (2012) and Yang *et al.* (2010) found high retention of pesticides and herbicides in the biochar-amended soils increasing its efficacy. Yuan *et al*. (2011) found biochar as neutralizer for acidic soils especially if biomass is a leguminous species. Biochar has been used as a heavy metal sequester and other chemicals such as herbicides, weedicide and insecticides as shown by Jiang and Xu (2013), Lu *et al*. (2012), Uchimiya *et al.* (2011) and Yang *et al*. (2010). Heavy metals such as Cu (II), Pb (II), Cd(II) and high acidic soil are held on and reduced respectively by biochar. This depends on the type of biochar, for instance straw and poultry litter biochar show remarkable results in sequestering heavy metals which is not only interesting but a breakthrough since most acidic soils and heavy metallic compounds that contaminate soils lie fallow and cost a lot of financial resources to rejuvenate them to cultivable fields. Binding of herbicides and insecticides by biochar makes their efficacy high in protecting crops against weeds and insect prone which ultimately increase food production and security.

Application of biochar has been proposed as a means to increase the long-term C sequestration potential and reduce emission of greenhouse gases (Lehmann and Joseph, 2015, Spokas *et al*., 2012 and Lehmann and Rondon, 2006) representing therefore beneficial strategy in mitigating global warming (Zhang *et al*., 2013 and Woolf *et al*., 2010). Biochar potential in sequestering C may be explained by the production of a highlystabilized C by pyrolysis of biomass (Forbes *et al*., 2006) which is very slowly decomposed in soil (Sohi *et al*., 2009). Lehmann and Rondon (2006) reported a 50% loss of biomass C in biochar production, however compared to biomass inputs in agricultural fields, a considerably greater fraction of the stable C remains in soil for longer time periods. Additional potentially benefits of biochar included avoided emission of CO_2 through reduction of fertilizer demands to achieve crop yields by improving soil water and nutrient-retention capacities (Woolf *et al*., 2010). In addition of reduction in emissions of CO_2 (Stewart *et al*., 2013 and Lehmann, 2007), biochar soil amendment may mitigate the emissions of nitrous oxide (N_2O) (Shanthi *et al*., 2013 and Spokas *et al*., 2009) and methane (CH_4) (Leng *et al*., 2012 and Rondon *et al*., 2006) from agricultural soils by improving soil aeration and reducing of changes in land use due to optimization of crop yields.

2.1.3 Anti-leaching and other properties of biochar

Biochar can be labelled as a universal sequester since it can bind itself to almost every substance especially in an aqueous solution and by so doing delaying the movements of such substances from the top soils making its efficacy rate comparatively higher. This is shown in researches conducted by (Abel *et al*., 2013, Jien and Wang, 2013, Morales *et al*., 2013, Borchard *et al.*, 2012, Major*et al*., 2012 and Kameyama *et al*., 2012) and found that leaching of soil nutrients and soil loss significantly reduced and that biochar increases the resident time of some soil nutrients to make it more available for plant use. Castaldi *et al*. (2011) found biochar treatments showed a minimal impact on microbial parameters and GHG fluxes. Kolton *et al*. (2011) found biochar-augmented genera may be at least partially responsible for the beneficial effect of biochar amendment on plant growth and viability. Unger and Killorn (2011 and 2011) found that conditions during pyrolysis influenced how the biochar/fertilizer reacted with the soil. Omil *et al.* (2013) ascertain that soil response to the application of mixed wood ash is greatly influenced by the soil properties, nutrient and soil organic matter dynamics are directly affected by interactions between the ash and soil components and indirectly by soil biological activity and plant growth.

Biochar can enhance plant growth by improving soil physical characteristics (bulk density, water holding capacity, permeability (Asai *et al*., 2009 and Sun and Lu, 2014) and soil chemical characteristics (nutrient retention and availability, CEC, surface areas and pH; (Abel *et al*., 2013). In addition, biochar can improve soil biological properties by increasing diversity of and providing a suitable environment for soil microbial communities (Abujabhah *et al.*, 2016,Tong *et al*., 2014 and Lehmann *et al*., 2011). The apparent high recalcitrance of biochar to chemical and biological processes supports its long term agronomic and environmental benefits environment with residence time on the magnitude of hundreds to thousands of years (Fang *et al*., 2014, Zimmerman, 2010 and Whitman and Lehmann, 2009).

Biochar has a relatively high surface area and has been reported to influence biochar interactions with soil solution substances as well as to provoke a net increase in the total soil-specific surface of biochar-amended soils (Lehmann *et al*., 2009). Biochar bulk density, ranging from 0.08 g cm^{-3} (Gundale and DeLuca, 2006) to 0.43 g cm^{-3} (Pastor-Villegas *et al*., 2006) depending on feedstock biomass and process conditions, islower than that of mineral soil ranging from 1.16 to 2.00 g cm^{-3} (Chaudhari *et al*., 2013). Therefore, a reduction in soil bulk density (Chen *et al*., 2013, Sun *et al*., 2013 and Laird *et al*., 2010) is anticipated due to biochar low bulk density and its highly porous structure (Downie *et al*., 2009). Biochar not only improves soil water movement but also soil water retention characteristics (Lim *et al*., 2016 and Novak *et al*., 2012) because of its highly porous structure (Karhu *et al*., 2011, Asai *et al*., 2009 and Ogawa *et al*., 2006) as production processes induce loss of volatile matter (Brewer and Brown, 2012). Notable differences in water retention has been reported by (Glaser *et al*., 2002) with 18% increase in *terra preta* compared to adjacent soils due to higher biochar concentrations and higher levels of organic matter. There is also evidence that biochar-amended soils display an increase in available moisture for coarse-grained and low organic matter content sandy soils (Liu *et al*., 2012), rather marginal to moderate improvement effect in medium textured soils (Laird *et al*., 2010), and potentially a reduction in moisture retention for clayey soils (Sohi *et al*., 2010). Significant improvements in aggregate stability and accompanying changes in water retention have been linked to biochar application for a clayey soil (Soinne *et al*., 2014 and Sun and Lu, 2014).

Biochar addition to agricultural soils has been proven as an effective and unique opportunity for soil fertility improvements and nutrient-use efficiency (Lehmann and Joseph, 2015). Expectations of increased soil fertility benefits and enhanced plant growth after biochar application arise from the sustainable fertility of the *Terra Preta* soils found in central Amazonia (Glaser *et al*., 2002) which has been attributed to the high contents of black carbon (Lehmann and Joseph, 2015). Biochar application induces changes in soilchemical properties including an increase in soil pH, cation exchange capacity, and nutrient contents (Biederman and Harpole, 2013, Cheng *et al*., 2008 and Liang *et al*., 2006). Biochar has the potential to increase soil pH with an accompanying decrease in the amount of exchangeable Al^{3+} (Brewer and Brown, 2012). Biochar application has been also reported to reduce the mobility of toxic elements in acid soils (Major *et al*., 2010 and Yamato *et al*., 2006) as well as enhance K and P availability (Jeffery *et al*., 2011 and Asai *et al*., 2009). These biochar effects have been reported to reduce lime application needs and to increase crop production in highly weathered infertile tropical soils (Liu *et al*., 2012). Cation exchange capacity is a measure of soil capacity to retain key exchangeable cations in the soil and has been seen to mitigate leaching losses (Sohi *et al*., 2009).The application of biochar in agricultural soils has been shown to increase CEC over time due to biochar surface oxidation and abundance of negatively charged surface functional groups (Cheng *et al.,* 2008).Glaser *et al*. (2002) found that applied biochar can also directly provide readily available nutrients for plant growth. Biochar's porous structure, large surface area, and negative surface charge (Downie *et al*., 2009) increase the cation exchange capacity of the soil and allow for the retention of nutrients (Laird *et al*., 2010). Crop fertilizer requirements can be decreased due to an increase in nutrient use efficiency with biochar addition (Lehmann and Joseph, 2015, Lehmann and Joseph, 2009 and Zheng *et al*., 2013). Biochar application has also been shown to reduce the availability of heavy metals (Komkiene and Baltrenaite, 2016) and organic pollutants such as dioxins , PAHs , pesticides (Zhang *et al*., 2013) due to due its large surface area and high adsorption capacity (Melo *et al.*, 2016, Komnitsas *et al.,* 2015 and Tang*et al*., 2013).

Biochar has the potential to stimulate the activity and diversity of soil microbial community (Zheng *et al*., 2013, Lehmann *et al*., 2011 and Steiner *et al*., 2004) through its porous structure, high cation exchange capacity and high sorption capacity. Biochar's intrinsic properties may enhance nutrient retention and availability to microorganisms (Lehmann *et al*., 2011) and also influence the interactions between soil, plant, and microorganism components (Quilliam *et al*., 2013). In addition, biochar's pore space has been reported to provide a suitable habitat for microorganisms, protecting them from predation and desiccation while supplying C, energy and mineral nutrients (Warnock *et al*., 2007). The application of biochar at high rates has been reported to stimulate changes in soil microbial community composition towards a bacteria-dominated microbial community compared to fungi (Li *et al*., 2015, Gomez *et al*., 2014 and Ippolito *et al*., 2014). This change in microbial community could be explained by the liming potential of biochar (Rousk *et al*., 2010) and addition to labile organic C in soil (Farrell *et al*., 2013) leading to wider C/N ratios (Thies and Rilling, 2009). Furthermore, biochar-amended soils have been found to enhance microbial abundance and growth due to sorption of toxic compounds to biochar (Kasozi *et al*., 2010).

2.1.4 Some economic benefits of biochar application in crop production

As illustrated above, soil amended biochar improves crop production by increasing growth rate as well as yield. Evidently, for example, Galinato *et al*. (2011) found that it may be profitable to apply biochar as a soil amendment under some conditions if the biochar market price is low enough and that carbon offset market exists. Yoder *et al.* (2011) estimated a quadratic production functions for biochar and bio-oil. The results are used to calculate a product transformation curve that characterizes the yields of bio-oil and biochar that can be produced for a given amount of feedstock, movement along the curve corresponds to changes in temperatures, and it can be used to infer optimal pyrolysis temperature settings for a given ratio of biochar and bio-oil prices. Ninson (2015) in his thesis (unpublished) found that biochar adoption was more profitable in the Kwahu East District of Ghana in the two seasons. Duku *et al.* (2011) did an assessment of biomass resources and concluded that a large availability of biomass in Ghana gives a great potential for bio-fuels production from these biomass resources.

2.2 Plant characteristics

2.2.1 Number of stem hill^{-1}

Investigation carried out by Youseef *et al.* (2017) during the summer seasons 2017 at El-Kassasein Horticulture Experimental Farm, Ismailia Governorate (Egypt), Horticulture Research Institute, Agricultural Research Center to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions.This experiment included 12 treatments, which were the combinations between three 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 maximum stem hill^{-1}(4.78) was recorded fromCara potato variety and the minimum stem hill^{-1}(4.27) was recorded fromAccent potato variety. The maximum stem hill^{-1}(6.11) was recorded from5.00 m^3 fed^{-1} biochar treated field and the minimum stem hill^{-1}(3.11) was recorded fromcontrol plot (no biochar).

The study was conducted by Nair*et al.* (2014) to study the biochar application in potato productionat the ISU Muscatine Island Research and Demonstration Farm, Fruitland, Iowa in 2012. Fourapplication rates of biochar (0, 2.5, 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 measured 15 ft by 30 ft. Experimental design was a randomized complete block design with four replications. They found 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).

2.2.2 Number of leaves hill^{-1}

Investigation carried out by Youseef *et al.* (2017) during the summer seasons 2017 at El-Kassasein Horticulture Experimental Farm, Ismailia Governorate (Egypt), Horticulture Research Institute, Agricultural Research Center to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions.This experiment included 12 treatments, which were the combinations between three 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 maximum leaves plant^{-1}(58.90) was recorded fromCara potato variety and the minimum leaves plant^{-1} (55.12) was recorded fromAccent potato variety. The maximum leaves plant^{-1} (70.74) was recorded from5.00 m^3 fed^{-1} biochar treated field and the minimum leaves plant^{-1}(42.90) was recorded fromcontrol plot (no biochar).

2.2.3 Potato yield

Indawan *et al.* (2018) carried out a field experiment to investigate the This research was conducted at Brawijaya University research station located in Jatikerto Village, Kromengan District of Malang Regency, from March to July, 2017.The plant materials used in this study consisted of 13 cultivars of sweet potato, including seven varieties (Kuninganputih, Beta 1, Beta 2, KuninganMerah, Sari, Boko and Jago) and six clones of TribhuwanaTuggadewi University and Brawijaya University collection (BIS OP- 61-OP-22, 73-6/2, 73 OP-8, BIS OP-61, 73 OP-5, and BIS OP-61-♀-29).The split plot design was used with three replications. The thirteen sweet potato cultivars were placed as main plots and doses of biochar of 0 and 5.00 t ha^{-1} was placed as sub-plots. They reported that, the highest sweet potato yield (21.00 t ha^{-1}) was attained by sweet potato genotypes BIS OP-61-OP-22 and the lowest sweet potato yield (10.55 t ha^{-1}) was attained by sweet potato genotypes73-OP-8. They reported that, the highest sweet potato yield (22.70 t ha^{-1}) was attained by 5 t ha^{-1} biochar and the lowest sweet potato yield (8.03 t ha^{-1}) was attained by control treatment (no biochar).

Hien *et al.* (2017) conducted and experiment to study the effect of bamboo biochar on crop's productivity and quality in the field condition. at Itoshima, Fukuoka city, Japan, in which three root crops namely sweet potato, carrot, and radish were selected and cultivated at three level of bamboo biochar amendment 0% (control), 2% and 4% per soil surface weight (about 30 cm soil depth is expected). They reported that, the highest fresh yield of sweet potato (4.30 kg m^{-2}) was recorded from 4% biochar per soil surface weight and the lowest fresh yield of sweet potato (4.00 kg m^{-2}) was recorded from control (no biochar) plot. They also observed that, 4% biochar per soil surface weight gave 8% more sweet potato than the control treatment. Again the highest fresh yield of carrot (93.60 g $crop^{-1}$) was recorded from 4% biochar per soil surface weight and the lowest fresh yield of carrot (81.90 g $crop^{-1}$) was recorded from control (no biochar) plot. They also observed that, 4% biochar per soil surface weight gave 14.30 % more carrot than the control treatment. In case of radish the highest fresh yield (638.40 g $crop^{-1}$) was recorded from 4% biochar per soil surface weight and the lowest one (433.80 g $crop^{-1}$) was recorded from control (no biochar) plot. They also observed that, 4% biochar per soil surface weight gave 47.20 % more radish than the control treatment.

Investigation carried out by Youseef *et al.* (2017) during the summer seasons 2017 at El-Kassasein Horticulture Experimental Farm, Ismailia Governorate (Egypt), Horticulture Research Institute, Agricultural Research Center to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions.This experiment included 12 treatments, which were the combinations between three 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 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 from5.00 m^3 fed^{-1} biochar treated field and the lowest potato yield (13.249 t fed^{-1}) was recorded fromcontrol plot (no biochar).

Gautam *et al*. (2017) conducted experiments to investigate the biochar amendment of soil and its effect on crop production of small holder farms in Rasuwa district of Nepal and they reported that Clearly, mustard showed the greatest differences in yields due to biochar addition (77% higher) over control treatment. For other crops (potato, radish, garlic and chiraito) the biochar amended treatment gave 17.5 to 40% higher yields compared to control treatment.

A field experiment was conducted by Timilsina *et al.* (2017) to assess the effects of biochar application on soil properties and production of Radish (*Raphanu ssativus* L.) on loamy sand soil. The experiment was conducted using a Randomized Complete Block Design (RCBD) with five levels of biochar (0, 5, 10, 15 and 20 Mg ha^{-1}), each replicated for four times. The results revealed that, the highest biomass yield (63.2 Mg ha^{-1}) was obtained from 20 Mg ha^{-1} biochar application which was similar to 15 Mg ha^{-1} application, but was significantly higher than other treatments. Treatments receiving no biochar had the lowest (36.94 Mg ha^{-1}) yield which was significantly ($p<0.05$) lower than 15 and 20 Mg ha^{-1} biochar application, but was at par with 5 and10 Mg ha^{-1} application. The highest root yield (46.83 Mg ha^{-1}) was obtained from 20 Mg ha^{-1} biochar application which was significantly higher as compared to 0, 5 and 10 Mg ha^{-1}application.

Yang *et al.* (2015) reported that, the yield of the corn on the control soils without biochar weighed 0.5 t ha^{-1}. Obviously, corn stalk-derived biochar (CB) increased the corn yield to 12.18 t ha^{-1}and 12.6 t ha^{-1} by the dosage of 2 t ha^{-1} and 4 t ha^{-1} biochar adding, respectively. Similarly, rice straw-derived biochar (RB) increased the corn yield to 12.36 t ha^{-1}and 12.96 t ha^{-1} by the dosage of 2 t ha^{-1} and 4 t ha^{-1}, respectively. In comparison to the corn yield of 4.2 t ha^{-1} withoutbiochar amendment, CB enhanced the peanut yield to 4.68 t ha^{-1} and 5.1 t ha^{-1} at the dosage of 2 t ha^{-1} and 4 t ha^{-1}, respectively. Likewise, 2 t ha^{-1}and 4 t ha^{-1} RB raised the peanut yield to 4.98 t ha^{-1} and 5.22 t ha^{-1}, respectively. Interestingly, similar to the corn yield, RB could enhance more peanut yield than CB. In addition, the sweet potato yield was also affected by adding biochar. For example, with 2 t ha^{-1} RB 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}. Furthermore, compared with the effect of CB on the corn and the peanut, CB affected much more on sweet potato yield. Even at a dosage of 1 t ha^{-1}, CB could improve sweet potato yield to 39.6 t ha^{-1}. For winter wheat, the yield was 8.6 ± 1.25 and 6.9 ± 2.01 t ha^{-1} with CB addition at rate of 2 t ha^{-1} and 4 t ha^{-1}, respectively. Whereas RB increased the yield from 7.7 ± 0.09 t ha^{-1} to 9.0 ± 0.55 t ha^{-1} with the biochar of 2 t ha^{-1} to 4 t ha^{-1}.

2.2.4 Marketable potato yield

Investigation carried out by Youseef *et al.* (2017) during the summer seasons 2017 at El-Kassasein Horticulture Experimental Farm, Ismailia Governorate (Egypt), Horticulture Research Institute, Agricultural Research Center to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions.This experiment included 12 treatments, which were the combinations between three 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 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 from5.00 m^3 fed^{-1} biochar treated field and the lowest marketable potato yield (10.835 t fed^{-1}) was recorded fromcontrol plot (no biochar).

The study was conducted by Nair*et al.* (2014) to study the biochar application in potato productionat the ISU Muscatine Island Research and Demonstration Farm, Fruitland, Iowa in 2012. Fourapplication rates of biochar (0, 2.5, 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 measured 15 ft by 30 ft. Experimental design was a 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).

2.2.5 Nonmarketable potato yield

The study was conducted by Nair*et al.* (2014) to study the biochar application in potato productionat the ISU Muscatine Island Research and Demonstration Farm, Fruitland, Iowa in 2012. Fourapplication rates of biochar (0, 2.5, 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 measured 15 ft by 30 ft. Experimental design was a randomized complete block design with four replications. They found that, the highest nonmarketable tuber weight (3.10 kg m^{-2}) was recorded from control plot (no biochar application) on the other hand the lowest marketable tuber weight (1.80 kg m^{-2}) was recorded from 10 t acre^{-1} biochar treated plot. So, it might be concluded that, biochar might improve the potato quality which reduce the nonmarketable potato yield.

2.2.6 Grade 'A' potato yield

Investigation carried out by Youseef *et al.* (2017) during the summer seasons 2017 at El-Kassasein Horticulture Experimental Farm, Ismailia Governorate (Egypt), Horticulture Research Institute, Agricultural Research Center to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions.This experiment included 12 treatments, which were the combinations between three 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 '1' (tuber above 55 mm diameter) potato yield (2.067 t fed^{-1}) was recorded from 'Accent' potato variety and the lowest grade '1' potato yield (1.808 t fed^{-1}) was recorded fromCara potato variety. The highest grade '1' potato yield (2.279 t fed^{-1}) was recorded fromcontrol plot (no biochar) and the lowest grade '1' potato yield (1.713 t fed^{-1}) was recorded from5.00 m^3 fed^{-1} biochar treated field.

2.2.7 Grade 'B' potato yield

Investigation carried out by Youseef *et al.* (2017) during the summer seasons 2017 at El-Kassasein Horticulture Experimental Farm, Ismailia Governorate (Egypt), Horticulture Research Institute, Agricultural Research Center to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions.This experiment included 12 treatments, which were the combinations between three 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 '2' (tubers with diameter between 35 - 54 mm) potato yield (10.603 t fed^{-1}) was recorded from 'Cara' potato variety while the lowest grade '2' potato yield (9.88 t fed^{-1}) was recorded from 'Accent' potato variety. The highest grade '2' potato yield (11.612 t fed^{-1}) was recorded from5.00 m^3 fed^{-1} biochar treated field and the lowest grade '2' potato yield (8.556 t fed^{-1}) was recorded fromcontrol plot (no biochar).

2.2.8 Grade 'C' potato yield

Investigation carried out by Youseef *et al.* (2017) during the summer seasons 2017 at El-Kassasein Horticulture Experimental Farm, Ismailia Governorate (Egypt), Horticulture Research Institute, Agricultural Research Center to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions.This experiment included 12 treatments, which were the combinations between three 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 '3' (tubers with diameter less than 35 mm,) potato yield (3.261 t fed^{-1}) was recorded from 'Spunta' potato variety and the lowest grade '3' potato yield (2.961 t fed^{-1}) was recorded from 'Accent' potato variety. The highest grade '3' potato yield (3.698 t fed^{-1}) was recorded from5.00 m^3 fed^{-1} biochar treated field and the lowest grade '3' potato yield (2.414 t fed^{-1}) was recorded fromcontrol plot (no biochar).

2.2.9 Percentage of marketable potato

The study was conducted by Nair*et al.* (2014) to study the biochar application in potato productionat the ISU Muscatine Island Research and Demonstration Farm, Fruitland, Iowa in 2012. Fourapplication rates of biochar (0, 2.5, 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 measured 15 ft by 30 ft. Experimental design was a randomized complete block design with four replications. They found that, the highest marketable tuber number

(242 m^{-2}) was recorded from 10 t acre^{-1} biochar treated plot on the other hand the lowest marketable tuber number (227 m^{-2}) was recorded from control plot (no biochar application).

2.2.10 Dry matter content in potato

Indawan *et al.* (2018) carried out a field experiment to investigate the This research was conducted at Brawijaya University research station located in Jatikerto Village, Kromengan District of Malang Regency, from March to July, 2017.The plant materials used in this study consisted of 13 cultivars of sweet potato, including seven varieties (Kuninganputih, Beta 1, Beta 2, KuninganMerah, Sari, Boko and Jago) and six clones of Tribhuwana Tuggadewi University and Brawijaya University collection (BIS OP- 61-OP-22, 73-6/2, 73 OP-8, BIS OP-61, 73 OP-5, and BIS OP-61-♀-29).The split plot design was used with three replications. The thirteen sweet potato cultivars were placed as main plots and doses of biochar of 0 and 5.00 t ha^{-1} was placed as sub-plots. They reported that, the highest dry matter content (33.36 %) was attained by sweet potato genotypes 73-6/2 and the lowest sweet potato yield (21.77 %) was attained by sweet potato genotypesBeta 1. They reported that, the highest sweet potato yield (32.66 %) was attained by 5 t ha^{-1} biochar and the lowest sweet potato yield (22.72 %) was attained by control treatment (no biochar).

Hien *et al.* (2017) conducted and experiment to study the effect of bamboo biochar on crop's productivity and quality in the field condition. at Itoshima, Fukuoka city, Japan, in which three root crops namely sweet potato, carrot, and radish were selected and cultivated at three level of bamboo biochar amendment 0% (control), 2% and 4% per soil surface weight (about 30 cm soil depth is expected). They reported that, the highest dry matter content of sweet potato (39.60 %) was recorded from 4% biochar per soil surface weight and the lowest dry matter content of sweet potato (32.37 %) was recorded from control (no biochar) plot. The highest dry matter content of carrot (10.70 %) was recorded from 4% biochar per soil surface weight which was statistically similar with 2% biochar per soil surface weight and the lowest dry matter content of carrot (9.90 %) was recorded from control (no biochar) plot. In case of radish, The highest dry matter content (5.90 %) was recorded from 4% biochar per soil surface weight which was statistically similar with 2% biochar per soil surface weight and the lowest dry matter content (5.20 %) was recorded from control (no biochar) plot.

Investigation carried out by Youseef *et al.* (2017) during the summer seasons 2017 at El-Kassasein Horticulture Experimental Farm, Ismailia Governorate (Egypt), Horticulture Research Institute, Agricultural Research Center to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions.This experiment included 12 treatments, which were the combinations between three 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 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 from5.00 m^3 fed^{-1} biochar treated field and the lowest dry matter content of potato (17.38 %) was recorded fromcontrol plot (no biochar).

2.2.11 Specific gravity

Investigation carried out by Youseef *et al.* (2017) during the summer seasons 2017 at El-Kassasein Horticulture Experimental Farm, Ismailia Governorate (Egypt), Horticulture Research Institute, Agricultural Research Center to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions.This experiment included 12 treatments, which were the combinations between three 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) was recorded from 'Spunta' potato variety and the lowest specific gravity (1.053) was recorded from 'Accent' potato variety. The highest specific gravity (1.074) was recorded from5.00 m^3 fed^{-1} biochar treated field and the lowest specific gravity (1.069) was recorded fromcontrol plot (no biochar).

2.2.12 Total soluble solid

Hien *et al.* (2017) conducted and experiment to study the effect of bamboo biochar on crop's productivity and quality in the field condition. at Itoshima, Fukuoka city, Japan, in which three root crops namely sweet potato, carrot, and radish were selected and cultivated at three level of bamboo biochar amendment 0% (control), 2% and 4% per soil surface weight (about 30 cm soil depth is expected). They reported that, the highest total soluble solid content in sweet potato (26.70 g l^{-1}) was recorded from 4% biochar per soil surface weight and the lowest total soluble solid content in sweet potato (13.60 g l^{-1}) was recorded from control (no biochar) plot. Again the highest total soluble solid content in carrot (57.60 g l^{-1}) was recorded from 4% biochar per soil surface weight and the lowest total soluble solid content in carrot (44.30 g l^{-1}) was recorded from 2% biochar per soil surface weight. In case of radish, the highest total soluble solid content (47.60 g l^{-1}) was recorded from 4% biochar per soil surface weight and the lowest total soluble solid content (45.30 g l^{-1}) was recorded from 2% biochar per soil surface weight.

2.2.13 Starch content on potato

Investigation carried out by Youseef *et al.* (2017) during the summer seasons 2017 at El-Kassasein Horticulture Experimental Farm, Ismailia Governorate (Egypt), Horticulture Research Institute, Agricultural Research Center to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions.This experiment included 12 treatments, which were the combinations between three 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 starch content (65.24 %) was recorded from ‘Spunta’ potato variety and the lowest starch content (48.49 %) was recorded from ‘Accent’ potato variety. The highest starch content (59.31 %) was recorded from5.00 m^3 fed^{-1} biochar treated field and the lowest starch content (56.04 %) was recorded fromcontrol plot (no biochar).

2.2.14 Soil pH

Gautam *et al*. (2017) conducted experiments to investigate the biochar amendment of soil and its effect on crop production of small holder farms in Rasuwa district of Nepal and they reported that the soil pH was 5.30 with or without biochar application.

A field experiment was conducted by Timilsina *et al.* (2017) to assess the effects of biochar application on soil properties and production of Radish on loamy sand soil. The experiment was conducted using a Randomized Complete Block Design (RCBD) with five levels of biochar (0, 5, 10, 15 and 20 Mg ha^{-1}), each replicated for four times. The results revealed that, the effect of biochar application on soil pH was not significant among the treatments (7.27-7.67) but it was increased with higher rates of biochar application.

Yang *et al.* (2015) reported that in the corn land soil the maximum soil pH (6.97) was observed when 4 t ha^{-1} rice stalk-derived biochar (RB) was applied while the minimum soil pH (6.81) was observed when 2 t ha^{-1} rice stalk-derived biochar (RB) was applied. In the peanut land soil the maximum soil pH (7.03) was observed when 2 t ha^{-1} rice stalk-derived biochar (RB) was applied while the minimum soil pH (6.19) was observed when 4 t ha^{-1} corn stalk-derived biochar (CB) was applied. In the sweet potato land soil the maximum soil pH (7.15) was observed when 4 t ha^{-1} rice stalk-derived biochar (RB) was applied while the minimum soil pH (7.10) was observed when 2 t ha^{-1} rice stalk-derived biochar (RB) was applied.

The study was conducted by Nair*et al.* (2014) to study the biochar application in potato productionat the ISU Muscatine Island Research and Demonstration Farm, Fruitland, Iowa in 2012. Fourapplication rates of biochar (0, 2.5, 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 measured 15 ft by 30 ft. Experimental design was a randomized complete block design with four replications. They found that, maximum soil pH (5.90) was recorded from 10 t $acre^{-1}$ biochar treated plot on the other hand the minimum soil pH (5.30) was recorded from control plot(no biochar application)..

Two field experiments were conducted by Dou *et al*. (2012) to observe the effects of Biochar, Mokusakueki and Bokashi application on soil nutrients concentrations, yields and qualities of sweet potato. Results showed that soil pH observed in biochar treatment was significant and remarkably higher than Mokusakueki and Bokashi treatments.

2.2.15 Organic carbon content in soil

Gautam *et al*. (2017) conducted experiments to investigate the biochar amendment of soil and its effect on crop production of small holder farms in Rasuwa district of Nepal and they reported that the maximum soil organic matter (1.70 %) was scored by biochar treated plot and the minimum soil organic matter (1.50 %) was scored by no biochar treated plot.

A field experiment was conducted by Timilsina *et al.* (2017) to assess the effects of biochar application on soil properties and production of Radish (*Raphanus sativus* L.) on loamy sand soil. The experiment was conducted using a Randomized Complete Block Design (RCBD) with five levels of biochar (0, 5, 10, 15 and 20 Mg ha^{-1}), each replicated for four times. The results revealed that, the effect of biochar application on soil organic matter was highly significant. The highest (2.915%) soil organic matter was obtained from 20 Mg ha^{-1} biochar application which was significantly higher ($p<0.001$) than other treatments, and it was the lowest (1.165%) from no biochar application, but was at par with 5 Mg ha^{-1} biochar amended soil. Soil treated with 10 and 15 Mg ha^{-1} biochar applications had similar organic matter content ($p>0.01$) but significantly higher ($p<0.001$) than 5 Mg ha^{-1} and soil without biochar applications.

2.2.16 Nitrogen content in soil

Gautam *et al*. (2017) conducted experiments to investigate the biochar amendment of soil and its effect on crop production of small holder farms in Rasuwa district of Nepal and they reported that the highest total nitrogen (1422 ppm) was scored by biochar treated plot and the lowest total nitrogen (1089 ppm) was scored by no biochar treated plot.

A field experiment was conducted by Timilsina *et al.* (2017) to assess the effects of biochar application on soil properties and production of Radish on loamy sand soil. The experiment was conducted using a Randomized Complete Block Design (RCBD) with five levels of biochar (0, 5, 10, 15 and 20 Mg ha^{-1}), each replicated for four times. The results revealed that, the effects of biochar application on nitrogen content in soil were highly significant. Addition of different doses of biochar had higher nitrogen contents of soil compared with without addition of biochar. The highest nitrogen content (1.2 g kg^{-1}) was found from 20 Mg ha^{-1} biochar application which was significantly higher ($p<0.001$) from other treatments. The lowest (0.7 g kg^{-1}) nitrogen content was obtained from without biochar amended soil.

Yang *et al.* (2015) reported that in the corn land soil the maximum nitrogen content (0.078 %) in soil was observed when 4 t ha^{-1} rice stalk-derived biochar (RB) was applied while the minimum nitrogen content (0.041 %) in soil was observed when 2 t ha^{-1} corn stalk-derived biochar (CB) was applied. In the peanut land soil the maximum nitrogen content (0.082 %) in soil was observed when 4 t ha^{-1} corn stalk-derived biochar (CB) was applied while the minimum nitrogen content (0.043 %) in soil was observed when 2 t ha^{-1} rice stalk-derived biochar (RB) was applied. In the sweet potato land soil the maximum nitrogen content (0.072 %) in soil was observed when 2 t ha^{-1} rice stalk-derived biochar (RB) was applied while the minimum nitrogen content (0.065 %) in soil was observed when 4 t ha^{-1} corn stalk-derived biochar (RB) was applied.

2.2.17 Potassium content in soil

Gautam *et al*. (2017) conducted experiments to investigate the biochar amendment of soil and its effect on crop production of small holder farms in Rasuwa district of Nepal and they reported that the highest exchangeable potassium (72.60 ppm) was scored by biochar treated plot and the lowest exchangeable potassium (67.00 ppm) was scored by no biochar treated plot.

A field experiment was conducted by Timilsina *et al.* (2017) to assess the effects of biochar application on soil properties and production of Radish on loamy sand soil. The experiment was conducted using a Randomized Complete Block Design (RCBD) with five levels of biochar (0, 5, 10, 15 and 20 Mg ha^{-1}), each replicated for four times. The results revealed that, the effects of biochar application on available potassium contents in soil was highly significant ($p<0.001$). The increased rates of biochar application increased the available potassium content in soil. The highest available potassium content (12.3 mg kg^{-1}) in soil was found from 20 Mg ha^{-1} biochar application which was consistent with 15 Mg ha^{-1} but significantly higher ($p<0.001$) than other treatments. The lowest available potassium content (7.7 g kg^{-1}) was found from without biochar amended soil and it was significantly ($p<0.001$) lower than other treatments.

Yang *et al.* (2015) reported that in the corn land soil the maximum potassium content (2.50 %) in soil was observed when 4 t ha^{-1} corn stalk-derived biochar (CB) was applied while the minimum potassium content (2.26 %) in soil was observed when 2 t ha^{-1} rice stalk-derived biochar (RB) was applied. In the peanut land soil the maximum potassium content (2.57 %) in soil was observed when 2 t ha^{-1} corn stalk-derived biochar (CB) was applied while the minimum potassium content (2.09 %) in soil was observed when 4 t ha^{-1} corn stalk-derived biochar (CB) was applied. In the sweet potato land soil the maximum potassium content (2.31 %) in soil was observed when 2 t ha^{-1} rice stalk-derived biochar (RB) was applied while the minimum potassium content (2.31 %) in soil was observed when 4 t ha^{-1} corn stalk-derived biochar (RB) was applied.

Two field experiments were conducted by Dou *et al.* (2012) to observe the effects of Biochar, Mokusakueki and Bokashi application on soil nutrients concentrations, yields and qualities of sweet potato. Results showed that the maximum exchangeable potassium (51 mg 100 g^{-1} soil) was recorded from biochar treatment and the minimum one (43 mg 100 g^{-1} soil) was recorded from Mokusakueki treatment.

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 November 21, 2017 to February, 2018.

3.2 Site description

3.2.1 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).

3.2.2 Agro-ecological region

The experimental site belongs to the agro-ecological zone of "Modhupur Tract", AEZ-28 (Anon, 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur 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.

3.2.3 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 01, 2017 to April 30, 2018. 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.

3.2.4 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 selected plot was medium high land.

3.3 Details of the experiment

3.3.1 Treatments

The experiment is consisted of two factors as follows:

Factor A: Potato varieties (3)

i. V_1: BARI Alu-29 (Courage)

ii. V_2: BARI Alu-28 (Lady Rosetta)

iii. V_3: BARI Alu-25 (Asterix)

Factor B: Biochar level (5)

i. B_0: 0 t ha^{-1},

ii. B_1: 2.50 t ha^{-1},

iii. B_2: 5.00 t ha^{-1}

iv. B_3: 7.50 t ha^{-1} and

v. B_4: 10 t ha^{-1}.

3.3.2 Planting material

Three varieties of potato were used as planting materials as follows:

BARI Alu-25 (Asterix)

BARI Alu-28 (Lady Rosetta)

BARI Alu-29 (Courage)

3.3.3 Experimental design and layout

Experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 replications. Distance between row to row was 50 cm and plant to plant distance was 25 cm. Distance between plot to plot was 75 cm. The size of the unit plot was 2 m× 2.5 m.

3.4 Crop management

3.4.1 Collection of seed

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

3.4.2 Preparation of seed

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

3.4.3 Land preparation

The land of the experimental site was first opened in the second week of November with power tiller. Later on, the land was ploughed and cross-ploughed four times followed by laddering to obtain the desirable tilth. The corners of the land were spaded and weeds and stubbles were removed from the field. The land was finally prepared on 18 November, 2017 three days before planting the seed. In order to avoid water logging due to rainfall during the study period, drainage channels were made around the land.

The soil was treated with Furadan 5G @10 kg ha^{-1} when the plot was finally ploughed to protect the young plant from the attack of cut worm.

3.4.4 Manure and fertilizer application

The experimental soil was fertilized with following dose of urea, Triple Superphosphate (TSP), Muriate of Potash (MoP), gypsum, zinc sulphate and boric acid.

Fertilizers	Dose (kg ha^{-1})
Urea	350
TSP	220
MoP	260
Gypsum	120
Zinc Sulphate	12
Boric Acid	6
Cowdung	10 t ha^{-1}

Mondal *et al.*(2011)

The total amount of biochar was applied at 7 days before planting as per treatment. Total amount of triple superphosphate, gypsum, zinc sulphate, magnesium 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.

3.4.5 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 4-5cm depth in soil on November 21, 2017.

3.4.6 Intercultural operations

3.4.6.1 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 30, 45 and 60 DAP, respectively. 2 weeks after seedling emergence and the final one was done before second side dressing of urea.

3.4.6.2 Weeding and mulching

Weeding and mulching were necessary to keep the plots free from weeds and to conserve soil moisture. The newly emerged weed was uprooted at two weeks after emergence of seedling carefully and second one was done before second side dressing of urea. Natural mulching was done for breaking the surface crust as and when needed.

3.4.6.3 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.

3.4.6.4 Plant protection measures

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

3.4.6.5 Haulm cutting

Haulm cutting was done at February 13, 2018 at 85 DAP, when 40-50% plants showed senescence and the tops started drying. After haulm cutting the tubers were kept under the soil for 7 days for skin hardening. The cut haulm was collected, bagged and tagged separately for further data collection.

3.4.6.6 Harvesting of potatoes

Harvesting of potato was done on February 19, 2018 at 7 days after haulm cutting. The potatoes of each plot were separately harvested, bagged and tagged and brought to the laboratory. The yield of potato plant^{-1} was determined in gram. Harvesting was done manually by hand.

3.5 Recording of data

3.5.1 Plant characters

The following data were recorded during experimentation period

i. Number of stem $hill^{-1}$

ii. Number of leaves $hill^{-1}$

iii. Potato yield (t ha^{-1})

iv. Marketable potato yield (t ha^{-1})

v. Percentage of marketable potato

vi. Non-marketable potato yield (t ha^{-1})

vii. Percentage of non-marketable potato

viii. Seed potato yield (t ha^{-1})

ix. Percentage of seed potato

x. Non-seed potato yield (t ha^{-1})

xi. Percentage of non-seed potato

xii. Grade ‘A’ potato yield

xiii. Percentage of Grade ‘A’ potato

xiv. Grade ‘B’ potato yield

xv. Percentage of Grade ‘B’ potato

xvi. Grade ‘C’ potato yield

xvii. Percentage of Grade ‘C’ potato

xviii. Dehydrated potato yield

xix. Percentage of dehydrated potato

xx. French fry potato yield

xxi. Percentage of French fry potato

xxii. Chips potato yield

xxiii. Percentage of chips potato

xxiv. Canned potato yield

xxv. Percentage of canned potato

xxvi. Dry matter of potato

xxvii. Potato firmness

xxviii. Specific Gravity

xxix. Total soluble solid content of potato

xxx. Starch content on potato

3.5.2 Soil Analysis

i. Soil pH

ii. Soil organic carbon

iii. Nitrogen content in soil

iv. Potassium content in soil

3.6 Procedures of data recording

3.6.1 Number of stems hill^{-1}

Number of stem hill^{-1} was counted at an interval of 20 days starting from 25 DAP up to 65 DAP. Stem number hill^{-1} was counted from five randomly sampled plants. It was done by counting total number of stem of all sampled plants then the average data were recorded.

3.6.2 Number of leaves plant^{-1}

Number of leaves hill^{-1} was counted at an interval of 20 days starting from 25 DAP up to 65 DAP. Leaves number hill^{-1} was counted from five randomly sampled plants. It was done by counting total number of leaves of all sampled plants then the average data were recorded.

3.6.3 Yield of tuber (t ha^{-1})

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

3.6.3 Marketable tuber and non-marketable tuber

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

3.6.4 Seed and non-seed potato yield

On the basis of the size of the tuber (28-55mm) the seed type potato tuber were graded.

3.6.5 Grading of tuber (t ha^{-1} and % by weight)

Tubers harvested from each treatment were graded by number on the basis of diameter into the >55 mm, 45-55 mm, 28-45 mm and <28 mm and converted to t ha^{-1} and percentages (Hussain, 1995). A special type of frame (potato riddle) was used to grading of tuber.

3.6.6 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^{0}C for 72 hours. Dry matter content was calculated as the ratio between dry and fresh weight and expressed as a percentage (Barton, 1989).

3.6.7 Potato firmness

The fresh potato tubers were cut into several slices to take the firmness reading by a firmness meter. The reading seems that, how much pressure is taken by the potato tuber slice to make it chips.

3.6.8 Specific Gravity

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

$$\text{Specific gravity} = \frac{\text{Weight of tube in air}}{\text{Weight of tuber in water at } 4^0 \text{ C}}$$

3.6.9 Total soluble solids (TSS)

TSS of harvested tubers was determined in a drop of potato juice by using Hand Solid Refractometer "ERMA" Japan, Range: 0-32%according to (AOAC, 1990) and recorded as % Brix from direct reading of the instrument.

3.6.10 Measurement of starch in potato tubers

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.

3.6.11Soil pH

Soil pH was measured with the help of a glass electrode pH meter using soil water suspension ratio being maintained at 1:2.5 (Jackson, 1962).

3.6.12 Soil organic carbon

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1935).

3.6.13 Total nitrogen

Total nitrogen content of soil was determined followed by the Micro Kjeldahl distillation method.

3.6.14 Exchangeable potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction method and by using flame photometer and calibrated with a standard curve (Page *et al*., 1982).

3.9 Statistical Analysis

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

CHAPTER 4

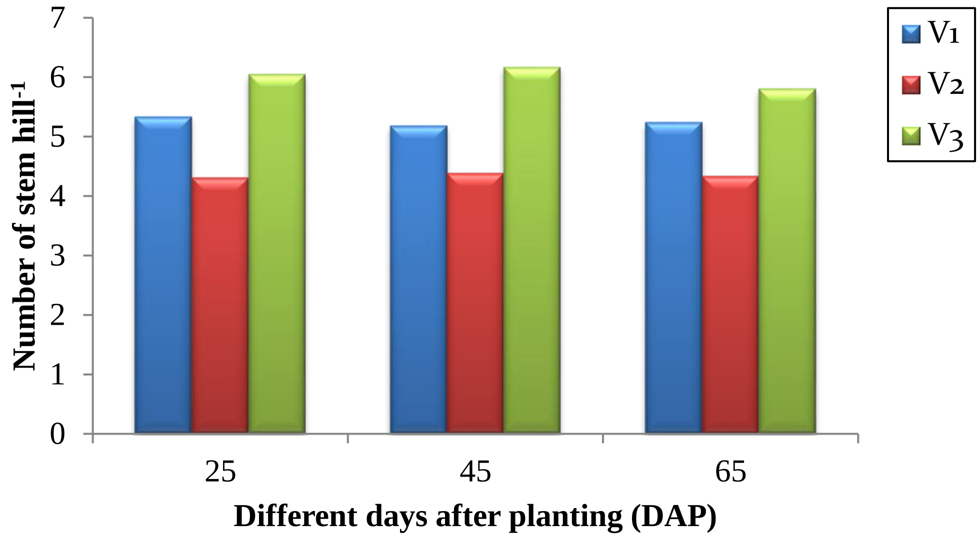
RESULTS AND DISCUSSION

Results obtained from the present study regarding the effect of biochar on soil amendment through carbon sequestration and yield and processing quality of potato varieties have been presented, discussed and compared in this chapter. The analytical results have been presented in Table 1 through Table 11, Figure 1 through Figure 38.

4.1 Number of stems hill^{-1}

4.1.1 Effect of variety

Number of stems hill^{-1} of potato was significantly influenced by varietal variation at 25, 45 and 65 DAP (Days after planting) (Figure 1). The result revealed that at 25, 45 and 65 DAP, the V_3 (Asterix) produced the maximum number of stems hill^{-1} (6.05, 6.17 and 5.80, respectively) and the V_2 (Lady rosseta) produced the minimum number of stems hill^{-1} (4.31, 4.38 and 4.33, respectively). The variation in number of stems hill^{-1} of potato is their genetic characters. It agreed with the result of Youseef *et al.* (2017) who reported that there were significant differences among the three potato cultivars (Accent, Cara and Spunta) with respect to number of stems hill^{-1} of potato Cultivars Cara and Spunta recorded the highest number of stems hill^{-1} whereas Accent cultivar recoded the lowest number of stems hill^{-1}. This might be due to variation in genetic potentiality of the varieties.

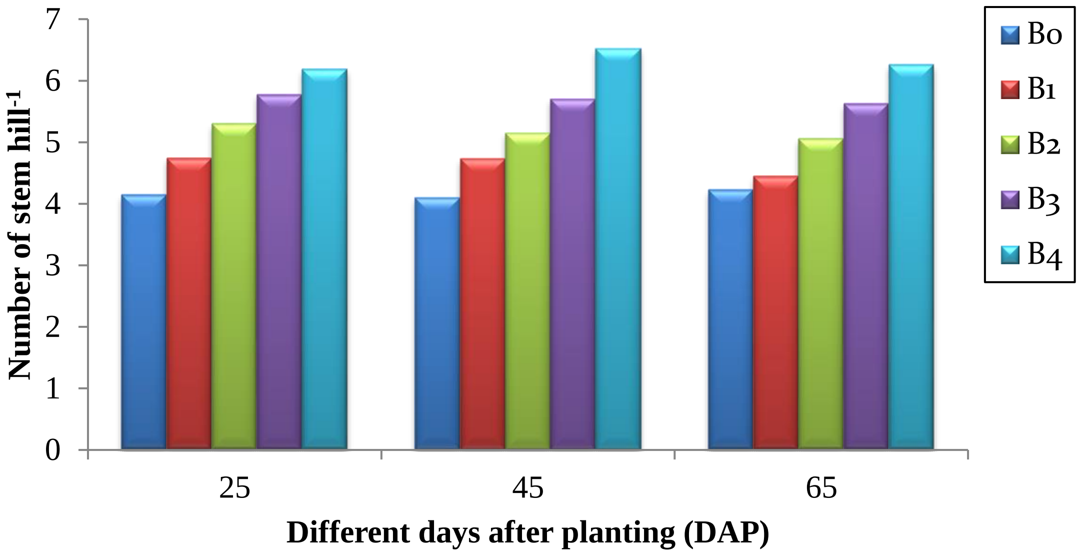


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 1. Effect of variety on the number of stems hill^{-1} of potato at different days after planting (LSD $_{0.05}$= 0.40, 0.46 and 0.42 at 25, 45 and 65 DAP, respectively)

4.1.2 Effect of different levels of biochar

Biochar level had significant effect on number of stems hill^{-1} throughout the growing season (Figure 2). The highest number of stems hill^{-1} (6.19, 6.52 and 6.26 at 25, 45 and 65 DAP, respectively) was obtained in B_4 (10.0 t biochar ha^{-1})treatment and lowest number of stems hill^{-1} (4.15, 4.10 and 4.22 at 25, 45 and 65 DAP, respectively) was obtained in B_0 (0 t biochar ha^{-1}) which was statistically similar with B_1 (2.50 t biochar ha^{-1}). The main reasons for increased number of stems hill^{-1} following biochar application can be attributed to direct alteration of soil chemistry through biochar's inherent characteristics including liming effect in acidic soils, direct nutrient addition through biochar, overall higher nutrient availability and nutrient use efficiency, allocation of chemically active surfaces that influence the dynamics of soil nutrients and modification of physical soil properties that leads to increased root growth and/or water and nutrient retention and plant availability (Jeffery *et al*., 2011, Sukartono*et al*., 2011, Hossain *et al*., 2010, Major *et al*., 2010, Sohi *et al*., 2009, and Lehmann *et al*., 2003). Biederman and Harpole (2013), Schulz and Glaser (2012) and Graber *et al.* (2010), mentioned that treating tomato plants by biochar along with mineral fertilizers significantly increased plant growth. Yilangai *et al*. (2014) reported that biochar usually has the potential of activating soil microorganisms and increasing the water retention capacity of the soil thereby increasing photosynthetic rate and consequent increase in growth of plants. Similar results also reported by (Carter *et al*., 2013 and Hogan, 2011).



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1},B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 2. Effect of biochar on the number of stems hill^{-1} of potato at different days after planting (LSD $_{0.05}$=0.52, 0.59 and 0.54 at 25, 45 and 65 DAP, respectively)

4.1.3 Interaction effect of variety and different levels of biochar

Significant interaction effect between the variety and biochar level was observed at 25, 45 and 65 DAP number of stems hill^{-1} (Table 1). At 25, 45 and 65 DAP, the maximum number of stems hill^{-1}(6.89, 7.78 and 7.33, respectively) was obtained from the V_3B_4 combination which was statistically similar with V_3B_3 and V_1B_4 at 25 DAP. On the other hand the minimum number of stems hill^{-1} (3.11, 3.11 and 3.22, respectively) was obtained from the combinationV_2B_0 which was statistically similar withV_2B_1 at 25, 45 and 65 DAP.

Table 1. Interaction effect of variety and biochar on the number of stems hill^{-1} of potato at different days after planting

Treatment combinations	Number of stems hill^{-1} at different days after planting (DAP)		
	25	45	65
V_1B_0	4.33 ef	4.33 fg	4.56 d
V_1B_1	4.78 d-f	4.78 e-g	4.78 cd
V_1B_2	5.44 cd	5.00 ef	5.07 cd
V_1B_3	5.67 b-d	5.44 c-e	5.54 bc
V_1B_4	6.44 ab	6.33 bc	6.22 b
V_2B_0	3.11 g	3.11 h	3.22 e
V_2B_1	4.00 fg	3.89 gh	3.56 e
V_2B_2	4.33 ef	4.33 fg	4.67 cd
V_2B_3	4.89 d-f	5.11 d-f	5.00 cd
V_2B_4	5.22 c-e	5.45 c-e	5.22 cd
V_3B_0	5.00 de	4.87 e-g	4.89 cd
V_3B_1	5.45 cd	5.52 c-e	5.00 cd
V_3B_2	6.11 a-c	6.11 b-d	5.44 b-d
V_3B_3	6.78 a	6.56 b	6.33 b
V_3B_4	6.89 a	7.78 a	7.33 a
LSD (0.05)	**0.90**	**1.02**	**0.93**
CV (%)	**10.28**	**11.69**	**10.89**

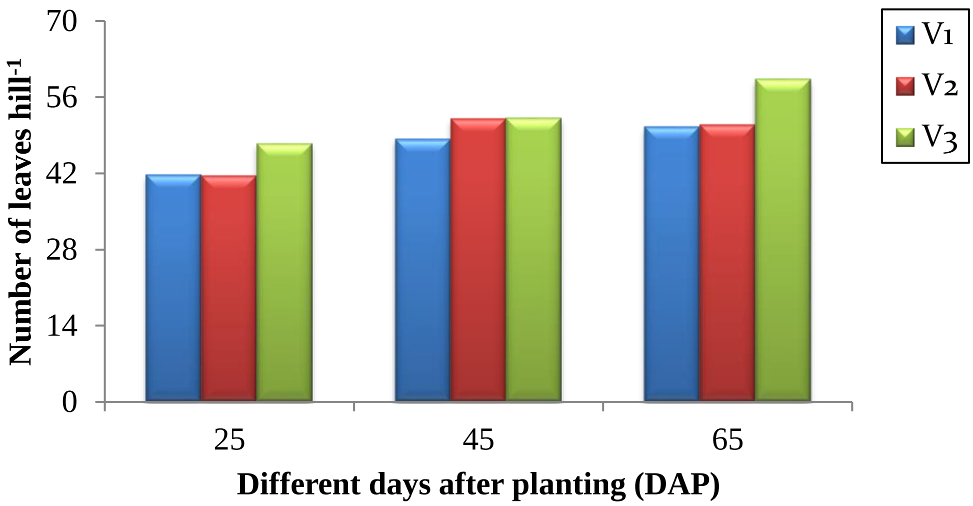
In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1},B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.2 Number of leaves hill^{-1}

4.2.1 Effect of variety

Number of leaves hill^{-1}was significantly influenced by the variety throughout the growing season (Figure 3). At 25, 45 and 65 DAP, the highest number of number of leaves hill^{-1} (47.49, 52.16 and 59.27, respectively) was found in V_3which was statistically similar with V_2 at 45 DAP. At 25 DAP the lowest number of number of leaves hill^{-1} (41.60) was found in V_2 which was statistically similar with V_1. Again the lowest number of leaves hill^{-1} (48.31 and 50.62 at 45 and 65 DAP, respectively) was found in V_1 which was statistically similar with V_2 at 45 and 65 DAP. This might be due to genetic variability of different potato varieties. Youseef *et al.* (2017) reported that there were significant differences among the three potato cultivars (Accent, Cara and Spunta) with respect to number of leaves plant^{-1}.Cultivars Cara and Spunta recorded maximum number of leaves plant^{-1}, whereas Accent cultivar recoded minimum number of leaves plant^{-1}.

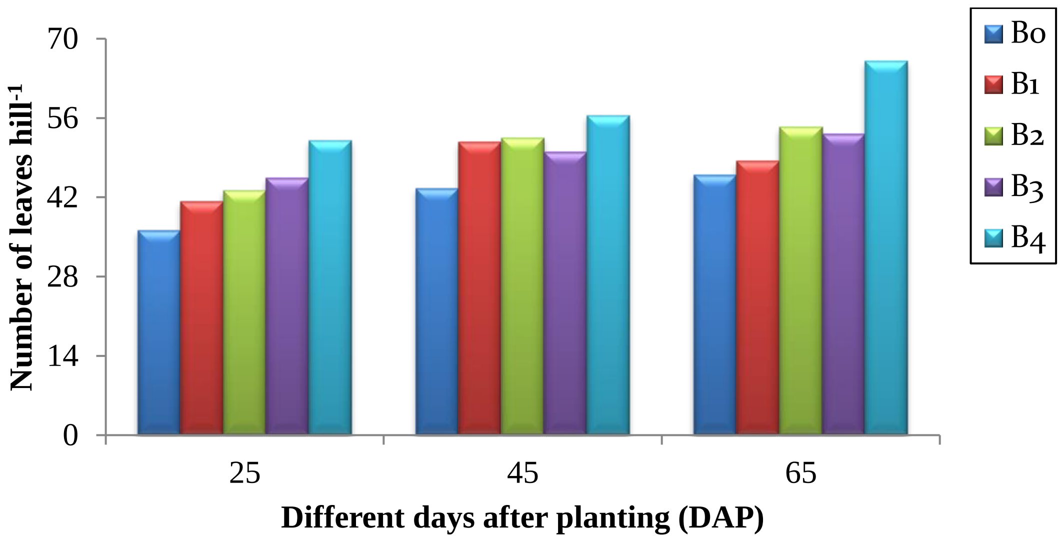


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 3. Effect of variety on the number of leaves hill^{-1} of potato at different days after planting (LSD $_{0.05}$=3.90, 3.83 and 4.37 at 25, 45 and 65 DAP, respectively)

4.2.2 Effect of different levels of biochar

Number of leaves hill^{-1}of potato had significantly influenced by the different biochar levels at 25, 45 and 65 DAP (Figure 4). At 25, 45 and 65 DAP, the maximum number of leaves hill^{-1} (52.04, 56.41 and 66.07, respectively) was found in B_4 treatment which was statistically similar with B_1 and B_2 at 45 DAP while the lowest ones (36.15, 43.56 and 45.96) was found in B_0 treatment which was statistically similar withB_1 only at 65 DAP.Biochar amendment on different soils has led to increased availability and uptake of nutrients by plants which facilitated proliferate leaf production of potato (Hass *et al.*, 2012 and Uzoma *et al.*, 2011). Diatta (2016) reported that biochar application resulted in increased plant available K. Wang *et al.* (2014) reported that addition of peanut shell biochar resulted in decreased soil exchangeable acidity and Al saturation and also increased in exchangeable cations that might be helpful for better growth and development of plant. Graber *et al.* (2010) emphasized that treating tomato plants by biochar positively enhanced leaf size. Carter *et al*. (2013) confirmed that the biochar treatments were increased the leaf number of lettuce and cabbage. These results were also in line with the findings of Youseef *et al.* (2017), Alburquerque *et al.* (2013) Biederman and Harpole (2013), Slavich *et al*. (2013) and Schulz and Glaser (2012) who reported that biochar application enhanced number of leaves plant^{-1}.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 4. Effect of biochar on the number of leaves hill^{-1} of potato at different days after planting (LSD $_{0.05}$=5.04, 4.94 and 5.64 at 25, 45 and 65 DAP, respectively)

4.2.3 Interaction effect of variety and different levels of nitrogen

Interaction effect of variety and different levels of biochar had significant influence on number of leaves hill^{-1} throughout the growing season (Table 2). The result of the investigation showed that, at 25, 45 and 65 DAP treatment combination V_3B_4 produced the maximum number of leaves hill^{-1} (57.89, 60.56 and 73.11, respectively) which was statistically similar with V_1B_4 at 25 DAP; with V_3B_2, V_2B_1, V_2B_4 and V_1B_3 at 45 DAP and with V_2B_4 at 65 DAP and treatment combination V_2B_0 produced the maximum ones(30.67, 42.89 and 40.33, respectively) which was statistically similar with V_1B_2, V_1B_0 and V_2B_1 at 25 DAP; with V_1B_2, V_1B_0, V_1B_1, V_1B_4, V_2B_3, V_3B_0, V_3B_1 and V_3B_3 at 45 DAP and V_2B_1, V_3B_0, V_2B_3, V_1B_2 and V_1B_1 at 65 DAP.

Table 2. Interaction effect of variety and biochar on the number of leaves hill^{-1} of potato at different days after planting

Treatment combinations	Number of leaves hill^{-1} at different days after planting (DAP)		
	25	**45**	**65**
V_1B_0	37.56 d-f	44.66 d	50.11 d-f
V_1B_1	41.22 b-e	49.22 cd	48.22 e-g
V_1B_2	36.55 ef	43.22 d	44.67 fg
V_1B_3	44.00 b-e	54.00 a-c	51.33 d-f
V_1B_4	49.22 ab	50.44 b-d	58.78 b-d
V_2B_0	30.67 f	42.89 d	40.33 g
V_2B_1	37.89 d-f	59.67 a	45.00 fg
V_2B_2	46.78 bc	53.78 a-c	56.44 c-e
V_2B_3	43.67 b-e	45.56 cd	46.33 fg
V_2B_4	49.00 b	58.44 ab	66.33 ab
V_3B_0	40.22 c-e	43.11 d	47.44 e-g
V_3B_1	44.67 b-e	46.33 cd	51.89 d-f
V_3B_2	46.22 b-d	60.33 a	62.00 bc
V_3B_3	48.44 bc	50.44 b-d	61.89 bc
V_3B_4	57.89 a	60.56 a	73.11 a
LSD $_{(0.05)}$	**8.73**	**8.56**	**9.76**
CV (%)	**11.97**	**10.07**	**10.89**

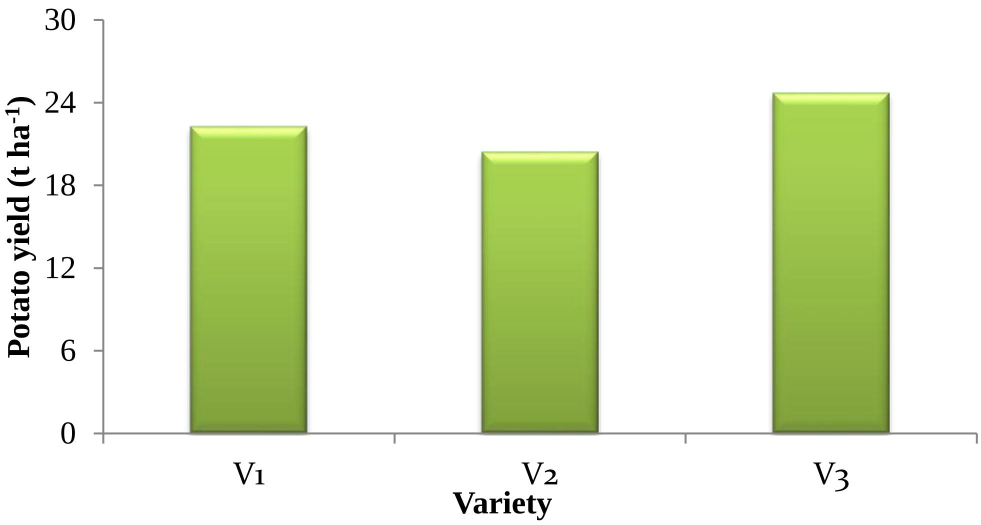
In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.3 Potato yield

4.3.1 Effect of variety

Potato yieldwas significantly influenced by varietal variation (Figure 5). Results showed that, the V_3 produced maximum potato (24.69 t ha^{-1}) followed by V_1 (22.26 t ha^{-1}) and V_2 produced the minimum one (20.44 t ha^{-1}). V_3 produced (20.79 %) more potato than V_2. The variation in the production of potato might be due to genetic constituents of the crops. This might be due to genetic potentiality of potato cultivars. The results of our findings were also in line with the findings of Youseef *et al.* (2017) and Vakis (1990) who found that potato yield varied with varietal variation.

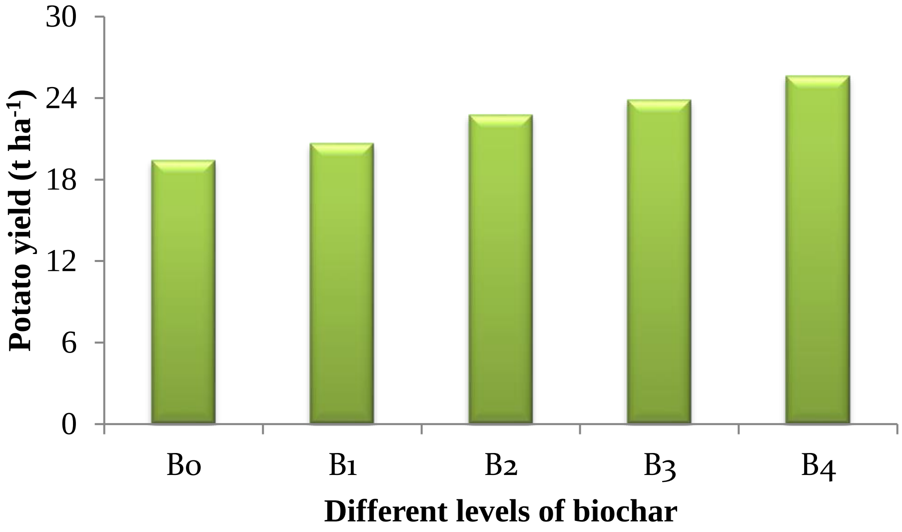


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 5. Effect of variety on the potato yield (LSD $_{0.05}$=1.46)

4.3.2 Effect of different levels of biochar

Biochar level had significant effect on the potato yield (Figure 6). Results revealed that, treatment B_4 produced maximum potato (25.62 t ha^{-1}) which was statistically at par with B_3 (23.88t ha^{-1}) and the minimum one was obtained from B_0 (19.40 t ha^{-1}) which was statistically at par with B_1 (20.65 t ha^{-1}). 32.06 % more potato yield was obtained from the plot treated with 10 t ha^{-1} biochar (B_4) than the plot treated with no biochar (B_0). The higher yield might be attributed to vigorous plant growth, more tuber $plant^{-1}$ and large tuber size.Biochar as a soil conditioner increased soil fertility, reduced fertilizers need while maintaining or improving crop productivity, reduced nutrient leaching, increased microbial activity in soil, improved water retention capacity and water use efficiencies, and cation exchange capacity in both sandy and clay soils which facilitated better photosynthetic activities, partitioning of photosynthates to the sink (storage organ potato tuber) consequently increased potato yield. Biochar has also a potential to significantly improve durability of soil aggregates(Lehmann *et al*., 2009, Jha *et al*., 2010, Jeffery *et al*., 2011, Hale, 2013, Sun and Lu, 2014).Biochar as previously mentioned is an amendment that can be used for enhancing soil moisture content which may increase the crop productivity. 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. Indawan *et al.* (2018) reported that tobacco biochar application increased storage root weight, storage root dry weight and storage root yield. 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 (Claudia,2014 and Getachew, 2016). This might be due to biochar amendment being more effective in enhancing the vegetative growth of plants (Vaccari, 2015). Yilangai *et al*. (2014) reported that tomato yield from beds treated with charcoal was 76% higher than the yield from beds without charcoal. 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. 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 thiswas attributed to increased pH and nutrient retention in soil. Yang *et al.* (2015) reported that, the yield of the corn on the control soils without biochar weighed 0.5 t ha^{-1}. Obviously, corn stalk-derived biochar (CB) increased the corn yield to 12.18 t ha^{-1} and 12.6 t ha^{-1} by the dosage of 2 t ha^{-1} and 4 t ha^{-1} biochar adding, respectively. Likewise, 2 t ha^{-1} and 4 t ha^{-1} RB raised the peanut yield to 4.98 t ha^{-1} and 5.22 t ha^{-1}, respectively. In addition, Yamato *et al.* (2006) revealed that with 2 t ha^{-1} RB 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}.Study conducted by Olmo *et al.* (2014)revealed that biochar increased the yield by about 20%. The results of our findings were accordance with those of Youseef *et al.* (2017), Ding *et al.* (2016), Yang *et al*. (2015), Alburquerque *et al*. (2013), Schulz and Glaser (2012), Hossain *et al*. (2010), Van Zwieten *et al*. (2010), Woolf (2008), Ogawa *et al*. (2006), Yamato *et al.* (2006) and Glaser *et al*. (2002) who reported that biochar application enhanced the yield of potato.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 6. Effect of biochar on the potato yield (LSD $_{0.05}$=1.89)

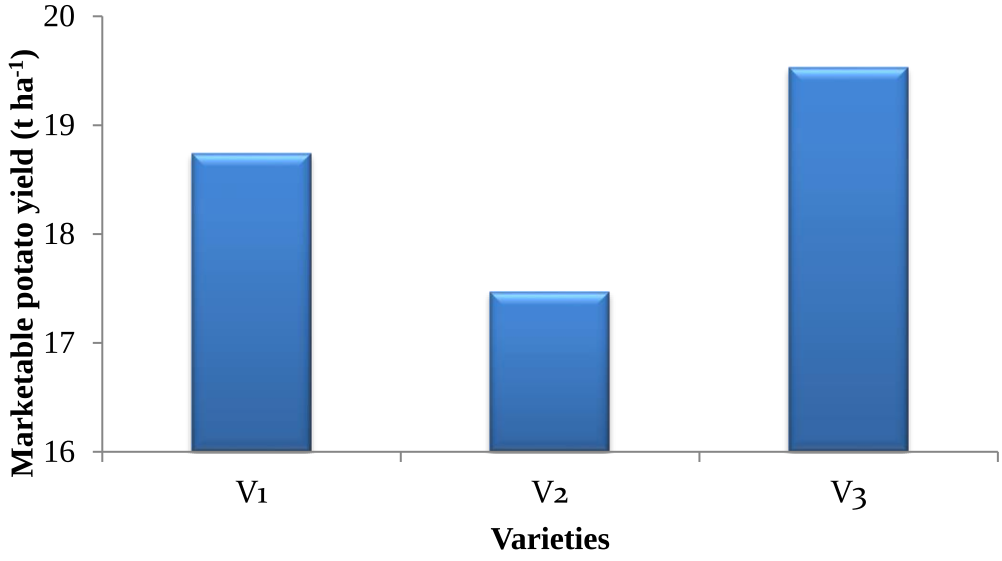
4.3.3 Interaction effect of variety and different levels of biochar

Potato yieldwas significantly influenced by the interaction effect of variety and biochar level (Table 3). The highest potato yield (27.33 t ha^{-1}) was obtained from the V_3B_4 which was statistically at par with V_3B_3, V_3B_2 and V_1B_4 and the lowest potato yield(17.78 t ha^{-1}) was obtained from the V_2B_0which was statistically at par with V_2B_1, V_1B_0, V_1B_1 and V_2B_2. Treatment combination V_3B_4 produced 53.71% more potato than treatment combination V_2B_0.

4.4 Marketable potato yield

4.4.1 Effect of variety

Marketable potato yield was significantly differed by different potato varieties (Figure 7). Results revealed that, the V_3 produced maximum marketable potato (19.53 t ha^{-1}) followed by V_1 (18.74 t ha^{-1}) and V_2 produced the minimum marketable potato (17.47 t ha^{-1}). V_3 produced (11.79 %) more marketable potato than V_2. The variation in the production of potato might be due to genetic constituents of the crops.

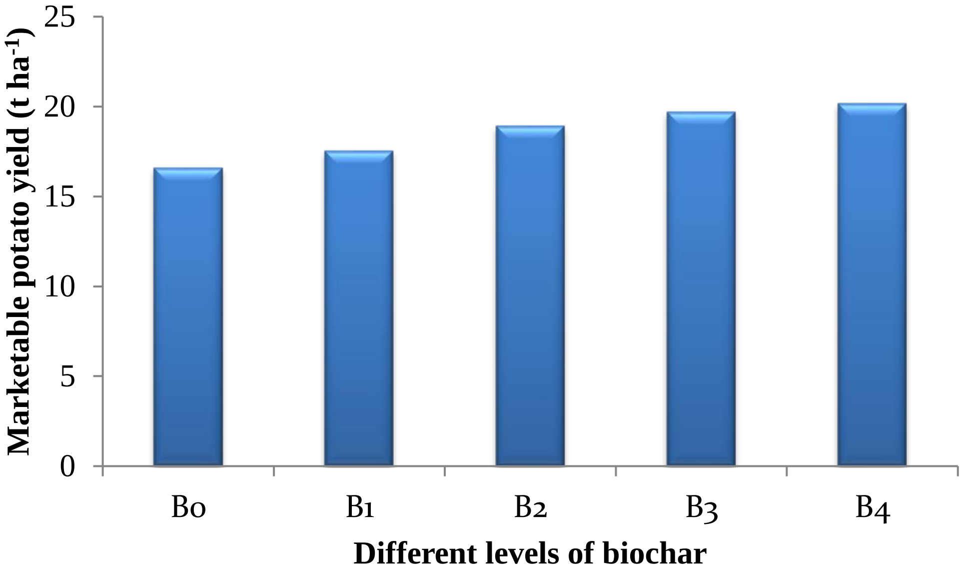


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 7. Effect of variety on the marketable potato yield (LSD $_{0.05}$=0.98)

4.4.2 Effect of different levels of biochar

Biochar level had significant influenced on the marketable potato yield (Figure 8). Results revealed that, treatment B_4 produced maximum marketable potato (20.17 t ha^{-1}) which was statistically at par with B_3 and B_2 and the minimum one was obtained from B_0 (16.59 t ha^{-1}) which was statistically at par with B_1. 21.58 % more marketable potato yield was obtained from the plot treated with 10 t ha^{-1} biochar (B_4) than the plot treated with no biochar (B_0). 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. Lin *et al*. (2012) indicated that biochars produced from Acacia saligna at 380 °C and sawdust at 450 °C contained humics (humic-like and fluvic-like materials) of 17.7 and 16.2 %, respectively. Biochar had potential of nutrient availability and could release large amounts of N (23-635 mg kg^{-1}), P (46-1664 mg kg^{-1}) available K (711 mg kg^{-1}), available Ca (5880 mg kg^{-1}) and available Mg (1010 mg kg^{-1}) (Mukherjee and Zimmerman, 2013 and Zheng *et al.*, 2013). So biochar supplied remarkable amount of essential plant nutrient which facilitated prominent growth and development of plant, trigger the photosynthesis process, better partitioning of photosynthates from source into sink (tuber) consequently produced good sized tuber. Gautam *et al.* (2017), Alburquerque *et al*. (2013) and Asai *et al*. (2009) reported that higher AP 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. 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. 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 $m^3 fed^{-1}$.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 8. Effect of biochar on the marketable potato yield (LSD $_{0.05}$=1.27)

4.4.3 Interaction effect of variety and different levels of biochar

Marketable potato yield was significantly differed by the interaction effect of variety and biochar level (Table 3). The highest marketable potato yield (21.30 t ha^{-1}) was obtained from the V_3B_4 which was statistically at par with V_3B_3, V_3B_2, V_1B_2, V_1B_3 and V_1B_4 and the lowest marketable potato yield (15.61 t ha^{-1}) was obtained from the V_2B_0 treatment combination which was statistically at par with V_1B_0, V_1B_1, V_2B_1, V_2B_2 and V_3B_0. Treatment combination V_3B_4 produced 36.45 % more marketable potato than treatment combination V_2B_0.

4.5 Percentage of marketable potato

4.5.1 Effect of variety

Percentage of marketable potato was significantly differed by different potato varieties (Table 4). Results revealed that, the V_3 produced maximum percentage of marketable potato (69.70 %) followed by V_1 (66.55 %) and V_2 produced the minimum percentage of marketable potato (63.56 %). The variation in the percentage of marketable potato might be due to genetic constituents of the crops.

4.5.2 Effect of different levels of biochar

Biochar level had significant influenced on the percentage of marketable potato (Table 4). Results revealed that, treatment B_4 produced maximum percentage of marketable potato (71.67 %) which was statistically at par with B_3 and B_2 and the B_0 produced the minimum one (61.58 %) which was statistically at par with $B_1$and B_2.

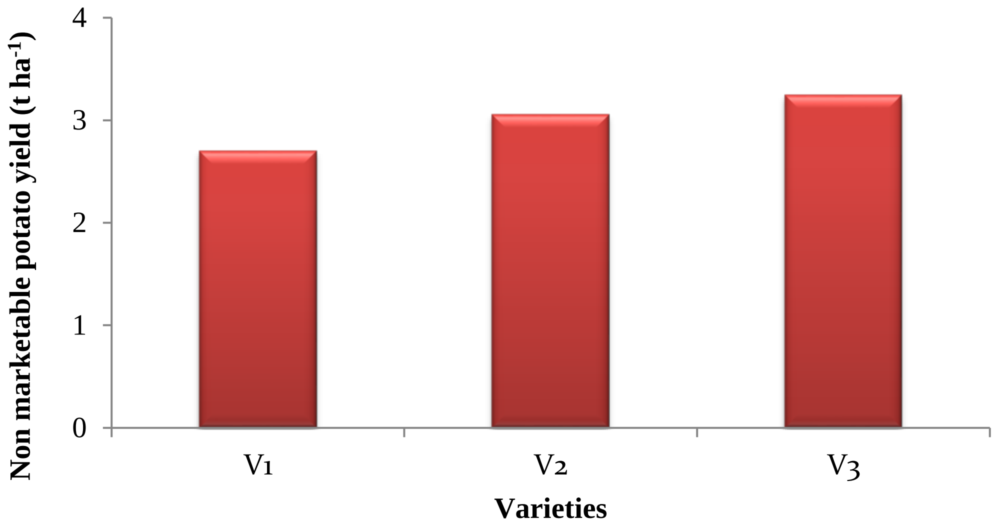
4.5.3 Interaction effect of variety and different levels of biochar

Percentage of marketable potato was significantly differed by the interaction effect of variety and biochar level (Table 5). The highest percentage of marketable potato (76.38 %) was obtained from the V_3B_4 which was statistically at par with V_3B_3, V_3B_2, V_2B_4, V_2B_3, V_1B_4, V_1B_3 and V_1B_2 and the lowest percentage of marketable potato (58.36 %) was obtained from the V_2B_0 treatment combination which was statistically at par with all the treatment combinations except V_1B_4, V_3B_2, V_3B_3 and V_3B_4.

4.6 Nonmarketable potato yield

4.6.1 Effect of variety

Nonmarketable potato yield was significantly varied by different potato varieties (Figure 9). Results exposed that, the V_3 produced maximum nonmarketable potato (3.25 t ha^{-1}) followed by V_2 (3.06 t ha^{-1}) and V_1 produced the minimum nonmarketable potato (2.70 t ha^{-1}). The variation in the production of potato might be due to genetic constituents of the crops.

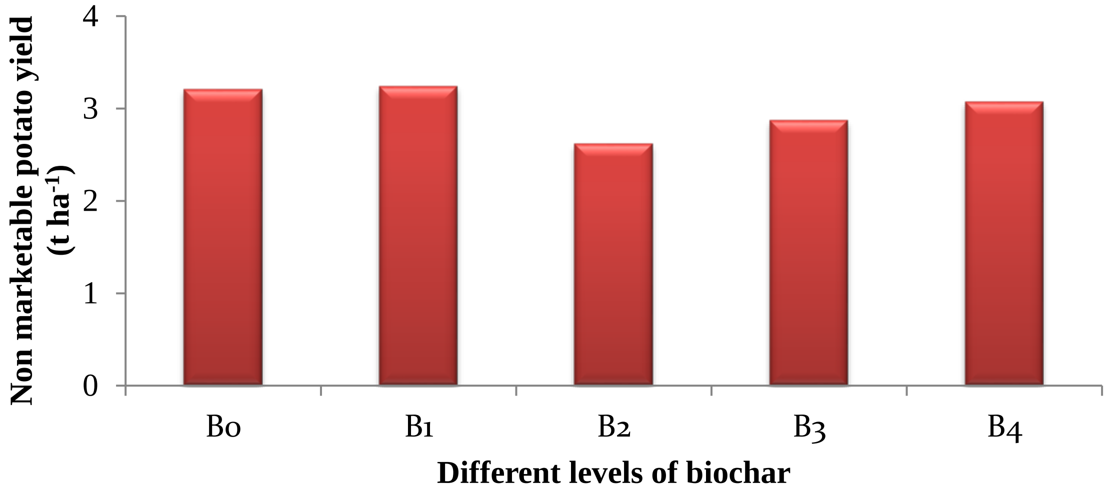


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 9. Effect of variety on the nonmarketable potato yield (LSD $_{0.05}$=0.27)

4.6.2 Effect of different levels of biochar

Biochar level had significant influenced on the nonmarketable potato yield (Figure 10). Results exposed that, treatment B_1 produced maximum nonmarketable potato (3.24 t ha^{-1}) which was statistically similar with B_0 and B_4 and the minimum one was obtained from B_2 (2.62 t ha^{-1}) which was statistically at par with B_3.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 10. Effect of biochar on the nonmarketable potato yield (LSD $_{0.05}$=0.35)

4.6.3 Interaction effect of variety and different levels of biochar

Nonmarketable potato yield was significantly affected by the interaction effect of variety and biochar level (Table 3). The highest nonmarketable potato yield (3.68 t ha^{-1}) was obtained from the V_2B_1 which was statistically similar with V_3B_0, V_3B_3, V_3B_4, V_1B_1, V_2B_0 and V_2B_2 and the lowest nonmarketable potato yield (1.96 t ha^{-1}) was obtained from the V_1B_2 treatment combination which was statistically similar with V_1B_3.

4.7 Percentage of nonmarketable potato

4. 7.1 Effect of variety

Percentage of nonmarketable potato was significantly varied by different potato varieties (Table 4). Results exposed that, the V_2 produced maximum percentage of nonmarketable potato (36.74 %) followed by V_1(34.04 %) and V_3 produced the minimum percentage of nonmarketable potato (28.95 %). The variation in the production of potato might be due to genetic constituents of the crops.

4. 7.2 Effect of different levels of biochar

Biochar level had significant influenced on the percentage of nonmarketable potato (Table 4). Results exposed that, treatment B_0 produced maximum percentage of nonmarketable potato (37.90 %) which was statistically similar with B_1 and B_4 produced the minimum one (28.28 %) which was statistically at par with B_3.

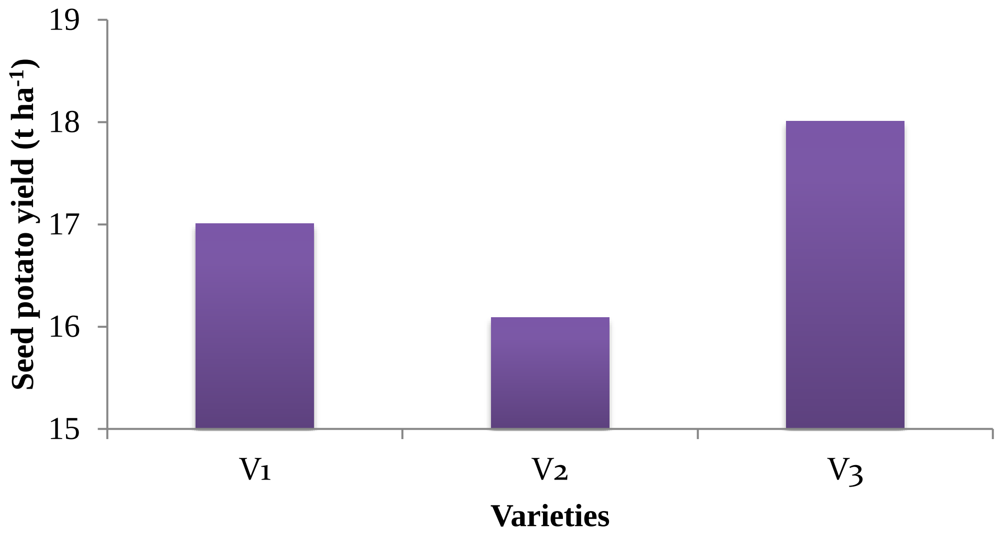
4.7.3 Interaction effect of variety and different levels of biochar

Percentage of nonmarketable potato was significantly affected by the interaction effect of variety and biochar level (Table 5). The highest percentage of nonmarketable potato (41.64 %) was obtained from the V_2B_0 which was statistically similar with V_1B_0, V_1B_1, V_1B_2, V_2B_1 and V_2B_2 and the lowest percentage of nonmarketable potato (23.62 %) was obtained from the V_3B_4 treatment combination which was statistically similar with V_3B_3, V_3B_2, V_1B_3 and V_1B_4.

4.8 Seed potato yield

4.8.1 Effect of variety

Significant variation was found on seed potato yield due to varietal variation of potato (Figure 11). The highest seed potato yield (18.01 t ha^{-1}) was attained by potato variety V_3 followed by V_1 (17.01 t ha^{-1}) and the lowest seed potato yield (16.09 t ha^{-1}) was attained by potato variety V_2 which was statistically similar with V_1.

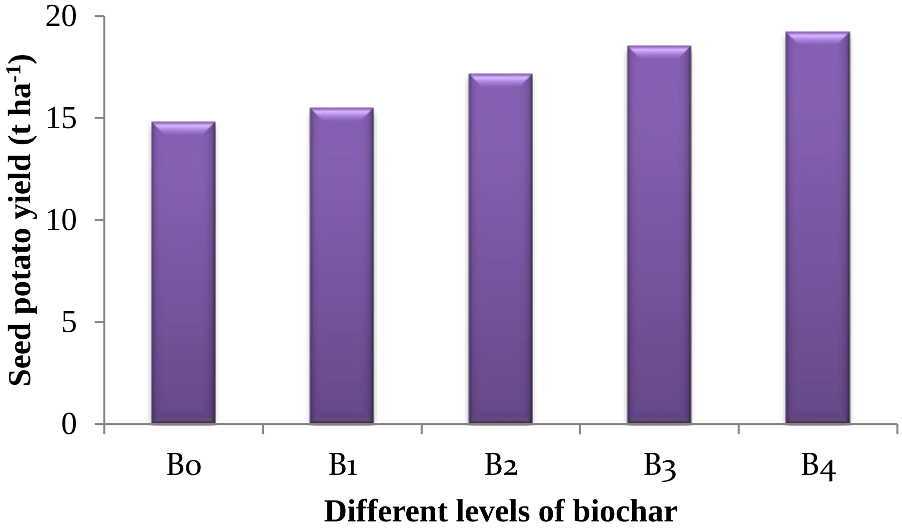


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 11. Effect of variety on the seed potato yield (LSD $_{0.05}$=1.16)

4.8.2 Effect of different levels of biochar

Significant variation was found on seed potato yield due to different biochar levels (Figure 12). The highest seed potato yield (19.21 t ha^{-1}) was attained by B_4 followed by B_3 (18.53 t ha^{-1}) and the lowest seed potato yield (14.80 t ha^{-1}) was attained by B_0which was statistically similar with B_1.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 12. Effect of biochar on the seed potato yield (LSD $_{0.05}$=1.50)

4.8.3 Interaction effect of variety and different levels of biochar

Significant variation was found on seed potato yield due to interaction effect of variety and different biochar levels (Table 3). The highest seed potato yield (20.39 t ha^{-1}) was attained by V_3B_4 which was statistically similar with V_3B_3, V_1B_4, V_1B_3 and the lowest seed potato yield (13.92 t ha^{-1}) was attained by V_2B_0 which was statistically similar with V_2B_1, V_3B_0, V_1B_0 and V_1B_1.

4.9 Percentage of seed potato

4.9.1 Effect of variety

Significant variation was found on percentage of seed potato due to varietal variation of potato (Table 4). The highest percentage of seed potato (100%) was attained by both potato variety V_1 and V_3 and the lowest percentage of seed potato (89.05 %) was attained by potato variety V_2.

4.9.2 Effect of different levels of biochar

Significant variation was not found on percentage of seed potato due to different biochar levels (Table 4). Numerically the highest and lowest percentage of seed potato (97.84 % and 95.33 %, respectively) was attained by B_4 and B_0, respectively.

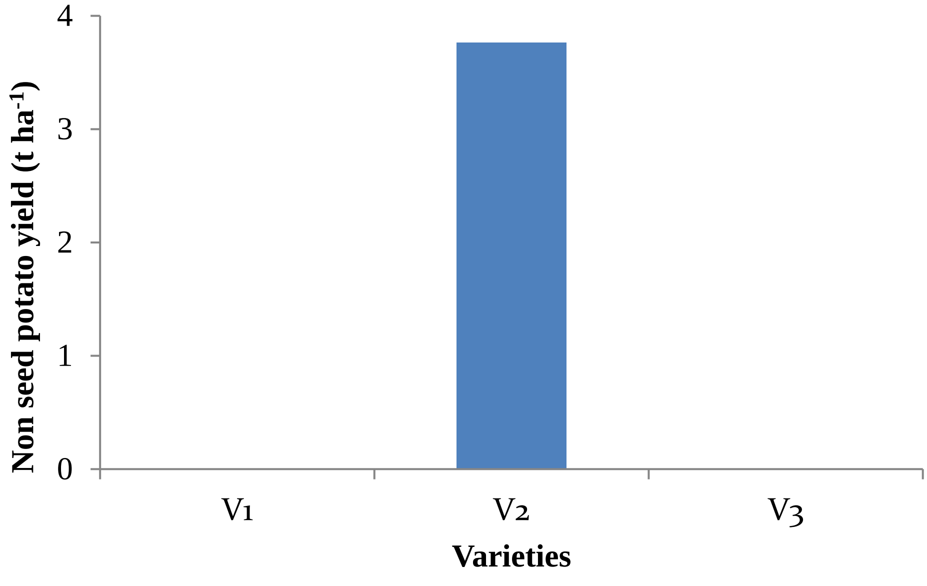
4.9.3 Interaction effect of variety and different levels of biochar

Significant variation was found on percentage of seed potato due to interaction effect of variety and different biochar levels (Table 5). The highest percentage of seed potato (100 %) was attained by both varieties V_1 and V_3 in combination with all the biochar levels and the lowest percentage of seed potato (85.99 %) was attained by V_2B_0 which was statistically similar with potato variety V_2 in combination with rest of the biochar levels.

4.10Non seed potato yield

4.10.1 Effect of variety

Strongly significant variation was found on non seed potato yield due to varietal difference (Figure 13). The highest non seed potato yield (3.76 t ha^{-1}) was produced by potato variety V_2 and other two potato varieties V_1 and V_3 did not produced any non seed potato.

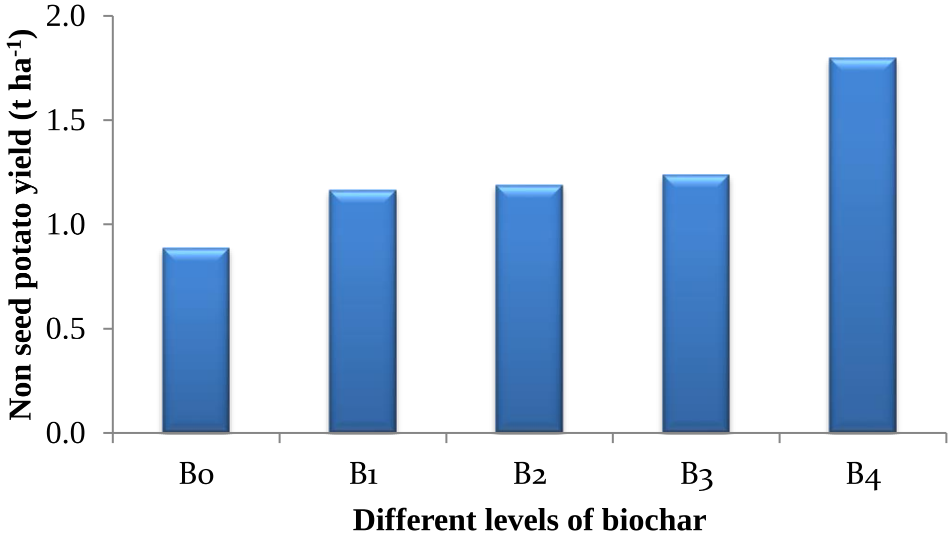


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 13. Effect of variety on the non seed potato yield (LSD $_{0.05}$=0.15)

4.10.2 Effect of different levels of biochar

Significant variation was recorded for non seed potato yield due to different biochar levels (Figure 14). The highest non seed potato yield (1.80 t ha^{-1}) was attained by B_4 and the lowest non seed potato yield (0.89 t ha^{-1}) was attained by B_0.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 14. Effect of biochar on the non seed potato yield (LSD $_{0.05}$=0.20)

4.10.3 Interaction effect of variety and different levels of biochar

Significant variation was recorded for non seed potato yield due to interaction effect of variety and different biochar levels (Table 3). The highest non seed potato yield (5.40 t ha^{-1}) was attained by treatment combination V_2B_4 and all the biochar levels combined with V_1 and V_3 did not produced any non seed potato.

Table 3. Interaction effect of variety and biochar on the yield characters of potato

Treatment combinations	Potato yield (t ha^{-1})	Marketable potato yield (t ha^{-1})	Non marketable potato yield (t ha^{-1})	Seed potato yield (t ha^{-1})	Non seed potato yield (t ha^{-1})
V_1B_0	19.15 g-i	16.45 de	2.85 c-e	14.85 d-f	0.00 d
V_1B_1	20.04 f-i	17.50 c-e	3.26 a-c	15.03 d-f	0.00 d
V_1B_2	22.83 c-f	19.52 a-c	1.96 f	17.41 b-d	0.00 d
V_1B_3	23.59 b-e	19.97 ab	2.39 ef	18.20 a-c	0.00 d
V_1B_4	25.70 a-c	20.24 ab	3.04 b-d	19.56 ab	0.00 d
V_2B_0	17.78 i	15.61 e	3.14 a-d	13.92 f	2.66 c
V_2B_1	18.41 hi	16.52 de	3.68 a	14.75 ef	3.49 b
V_2B_2	20.41 e-i	17.75 c-e	3.22 a-d	16.69 c-e	3.56 b
V_2B_3	21.75 d-g	18.52 b-d	2.61 de	17.42 b-d	3.71 b
V_2B_4	23.84 b-d	18.97 bc	2.63 de	17.69 bc	5.40 a
V_3B_0	21.28 d-h	17.69 c-e	3.63 ab	15.62 c-f	0.00 d
V_3B_1	23.49 b-e	18.55 b-d	2.79 c-e	16.66 c-e	0.00 d
V_3B_2	25.05 a-c	19.50 a-c	2.67 c-e	17.41 b-d	0.00 d
V_3B_3	26.29 ab	20.58 ab	3.60 ab	19.98 ab	0.00 d
V_3B_4	27.33 a	21.30 a	3.54 ab	20.39 a	0.00 d
LSD $_{(0.05)}$	**3.27**	**2.19**	**0.61**	**2.60**	**0.34**
CV (%)	**8.71**	**7.05**	**12.16**	**9.12**	**16.19**

In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.11Percentage of non seed potato

4.11.1 Effect of variety

Strongly significant variation was found on percentage of non seed potato due to varietal difference (Table 4). The highest percentage of non seed potato (10.65 %) was produced by potato variety V_2 and other two potato varieties V_1 and V_3 did not produced any non seed potato.

4.11.2 Effect of different levels of biochar

Significant variation was recorded for percentage of non seed potato due to different biochar levels (Table 4). The highest percentage of non seed potato (4.67 %) was attained by B_0 which was statistically similar with $B_1$and the lowest percentage of non seed potato (2.00 %) was attained by B_4.

Table 4. Effect of variety and biochar on the tuber characters of potato

Treatments	Percentage of marketable potato (%)	Percentage of non marketable potato (%)	Percentage of seed potato (%)	Percentage of non seed potato (%)
Effect of variety				
V_1	66.55 ab	34.04 a	100.00 a	0.00 b
V_2	63.56 b	36.74 a	89.05 b	10.65 a
V_3	69.70 a	28.95 b	100.00 a	0.00 b
LSD (0.05)	**5.24**	**2.87**	**4.11**	**0.55**
CV (%)	**10.51**	**11.56**	**5.70**	**20.64**
Effect of biochar				
B_0	61.58 c	37.90 a	95.33	4.67 a
B_1	63.20 bc	36.21 ab	95.39	4.28 ab
B_2	66.67 abc	33.59 bc	96.19	3.81 b
B_3	69.89 ab	30.23 cd	97.00	3.00 c
B_4	71.67 a	28.28 d	97.84	2.00 d
LSD (0.05)	**6.76**	**3.71**	**NS**	**0.71**
CV (%)	**10.51**	**11.56**	**5.70**	**20.64**

In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.11.3 Interaction effect of variety and different levels of biochar

Significant variation was recorded for percentage of non seed potato due to interaction effect of variety and different biochar levels (Table 5). The highest percentage of non seed potato (14.01 %) was attained by treatment combination V_2B_0 and all the biochar levels combined with V_1 and V_3scored 0 % non seed potato.

Table 5. Interaction effect of variety and biochar on the tuber characters of potato

Treatment combinations	Percentage of marketable potato (%)	Percentage of non marketable potato (%)	Percentage of seed potato (%)	Percentage of non seed potato (%)
V_1B_0	62.98 b-d	39.13 a-c	100.0 a	0.00 e
V_1B_1	64.31 b-d	37.02 a-d	100.0 a	0.00 e
V_1B_2	65.74 a-d	35.69 a-e	100.0 a	0.00 e
V_1B_3	68.69 a-d	28.97 f-h	100.0 a	0.00 e
V_1B_4	71.03 a-c	29.38 e-h	100.0 a	0.00 e
V_2B_0	58.36 d	41.64 a	85.99 b	14.01 a
V_2B_1	61.14 cd	40.29 ab	86.18 b	12.84 a
V_2B_2	63.72 b-d	35.63 a-e	88.57 b	11.43 b
V_2B_3	66.99 a-d	34.29 b-f	91.01 ab	8.99 c
V_2B_4	67.60 a-d	31.84 d-g	93.52 ab	5.99 d
V_3B_0	63.40 b-d	32.92 c-g	100.0 a	0.00 e
V_3B_1	64.16 b-d	31.31 d-g	100.0 a	0.00 e
V_3B_2	70.55 a-c	29.45 e-h	100.0 a	0.00 e
V_3B_3	73.99 ab	27.43 gh	100.0 a	0.00 e
V_3B_4	76.38 a	23.62 h	100.0 a	0.00 e
LSD (0.05)	**11.71**	**6.43**	**9.19**	**1.23**
CV (%)	**10.51**	**11.56**	**5.70**	**20.64**

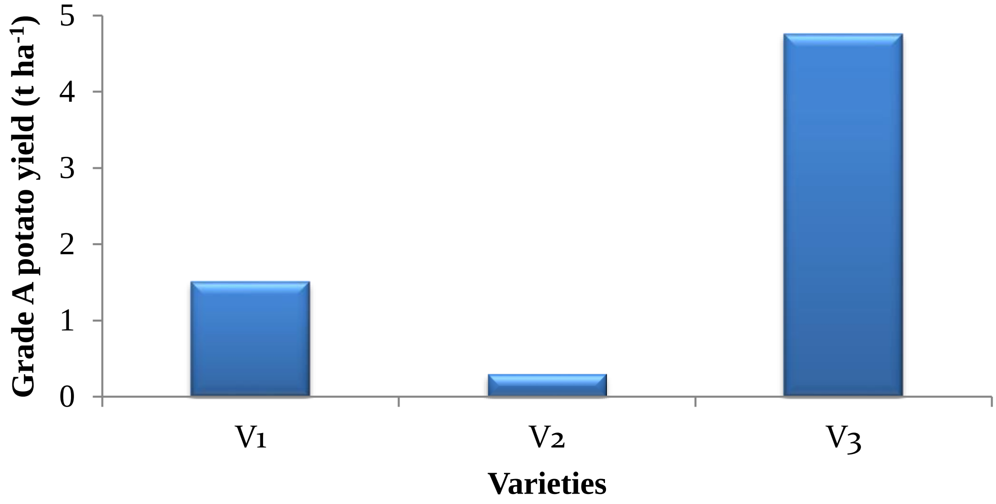
In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.12Grade 'A' potato yield

4.12.1 Effect of variety

The Grade 'A' potato yield was significantly influenced by the variety (Figure 15). The highest Grade 'A' potato yield (4.76 t ha^{-1}) was obtained from V_3 and the lowest Grade 'A' potato yield (0.29 t ha^{-1}) was obtained from V_2. The result of the present investigation was similar with the studies conducted by.

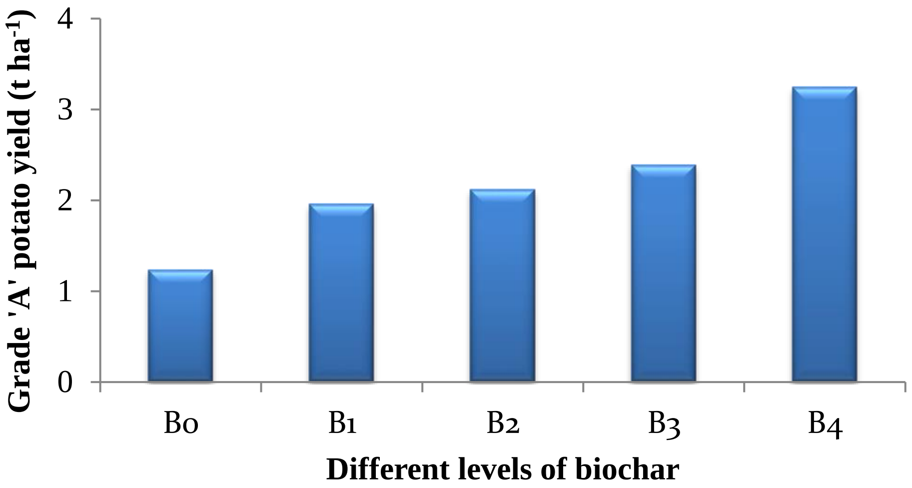


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 15. Effect of variety on the Grade'A' potato yield (LSD $_{0.05}$=0.19)

4.12.2 Effect of different levels of biochar

The Grade 'A' potato yield was significantly influenced by the different biochar levels (Figure 16). The highest Grade 'A' potato yield (3.24 t ha^{-1}) was obtained from B_4 and the lowest Grade 'A' potato yield (1.23 t ha^{-1}) was obtained from B_0. This result had agreements with the findings of Youseef *et al.* (2017) who reported that grade 'A' potato yield was significantly increased with increasing biochar application rates up to 5 m^3fed^{-1}.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 16. Effect of biochar on the Grade'A' potato yield (LSD $_{0.05}$=0.25)

4.12.3 Interaction effect of variety and different levels of biochar

The Grade 'A' potato yield was significantly influenced by the interaction effect of variety and different biochar levels (Table 6). The highest Grade 'A' potato yield (6.35 t ha^{-1}) was obtained from V_3B_4 and the treatment combination V_2B_0 and V_2B_1 failed to produced Grade 'A' potato which was statistically similar with V_2B_2 and V_2B_3.

4.13 Percentage of Grade 'A' potato

4.13.1 Effect of variety

The percentage of Grade 'A' potato was significantly influenced by the variety (Table 7). The highest percentage of Grade 'A' potato (12.19 %) was obtained from V_3 and the lowest percentage of Grade 'A' potato (0.37 %) were obtained from V_2. The result of the present investigation was similar with the studies conducted by.

4.13.2 Effect of different levels of biochar

The percentage of Grade 'A' potato was significantly influenced by the different biochar levels (Table 7). The highest percentage of Grade 'A' potato (7.35 %) was obtained from B_4 and the lowest percentage of Grade 'A' potato (3.45 %) were obtained from B_0. This result had agreements with the findings of

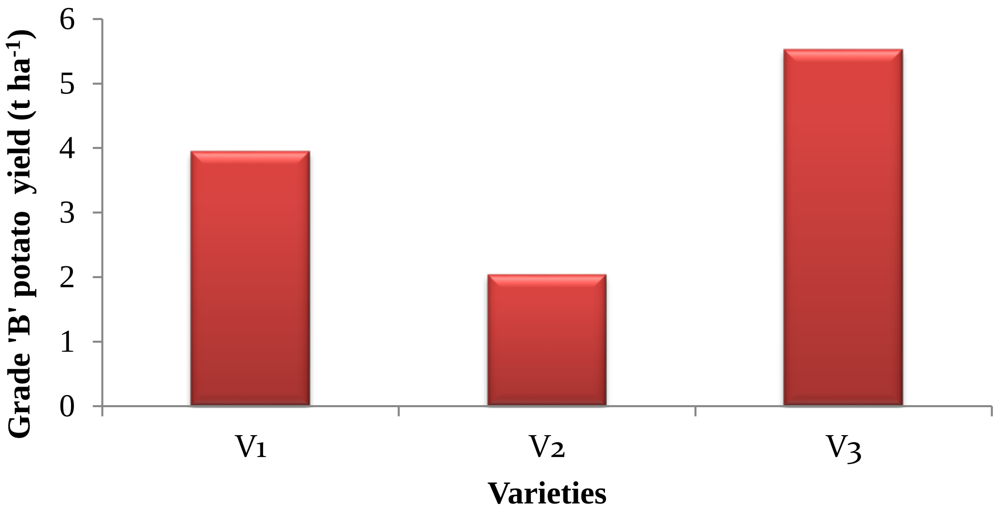
4.13.3 Interaction effect of variety and different levels of biochar

The percentage of Grade 'A' potato was significantly influenced by the interaction effect of variety and different biochar levels (Table 8). The highest percentage of Grade 'A' potato (15.43 %) was obtained from V_3B_4 and the treatment combination V_2B_0 and V_2B_1 failed to produce any grade 'A' potato which was statistically similar with V_2B_2, V_2B_3 and V_2B_4.

4.14Grade 'B' potato yield

4.14.1 Effect of variety

The Grade 'B' potato yield was significantly affected by the variety (Figure 17). The highest Grade 'B' potato yield (5.52 t ha^{-1}) was obtained from V_3 and the lowest Grade 'B' potato yield (2.04 t ha^{-1}) was obtained from V_2. The result of the present investigation was similar with the studies conducted by.



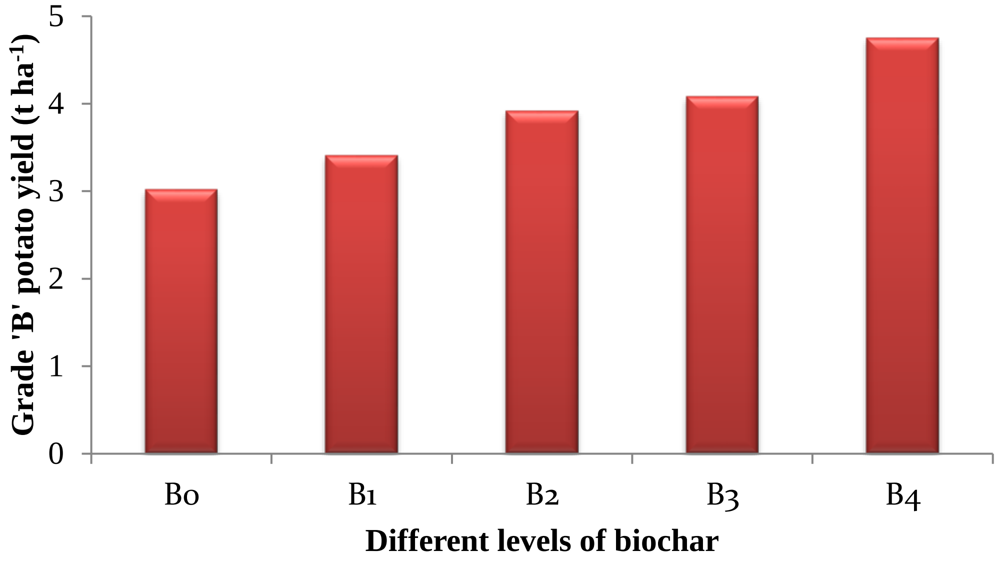
V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 17. Effect of variety on the Grade'B' potato yield (LSD $_{0.05}$=0.35)

4.14.2 Effect of different levels of biochar

The Grade 'B' potato yield was significantly affected by the different biochar levels (Figure 18). The highest Grade 'B' potato yield (4.75 t ha^{-1}) was obtained from $B_4$and the lowest Grade 'B' potato yield (3.02 t ha^{-1}) was obtained from B_0which showed similarity with B_1. This result had agreements with the findings of Youseef *et al.*

(2017) who reported that grade B potato yield was significantly increased with increasing biochar application rates up to 5 m^3 fed^{-1}.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 18. Effect of biochar on the Grade'B' potato yield (LSD $_{0.05}$=0.45)

4.14.3 Interaction effect of variety and different levels of biochar

The Grade 'B' potato yield was significantly affected by the interaction effect of variety and different biochar levels (Table 6). The highest Grade 'B' potato yield (6.28 t ha^{-1}) was obtained from treatment combination V_3B_4 which showed similarity with V_3B_2 and $V_3B_3$and the lowest Grade 'B' potato yield (1.12 t ha^{-1}) was obtained from treatment combination V_2B_0 which showed similarity withV_2B_1.This result had agreements with the findings of ..

4.15 Percentage of Grade 'B' potato

4.15.1 Effect of variety

The percentage of Grade 'B' potato was significantly affected by the variety (Table 7). The highest percentage of Grade 'B' potato (22.24 %) was obtained from V_3 and the lowest percentage of Grade 'B' potato (6.68 %) was obtained from V_2. The result of the present investigation was similar with the studies conducted by.

4.15.2 Effect of different levels of biochar

The percentage of Grade 'B' potato was significantly affected by the different biochar levels (Table 7). The highest percentage of Grade 'B' potato (17.71 %) was obtained from B_4 which was similar with $B_3$and the lowest percentage of Grade 'B' potato (10.52 %) was obtained from B_0. This result had agreements with the findings of

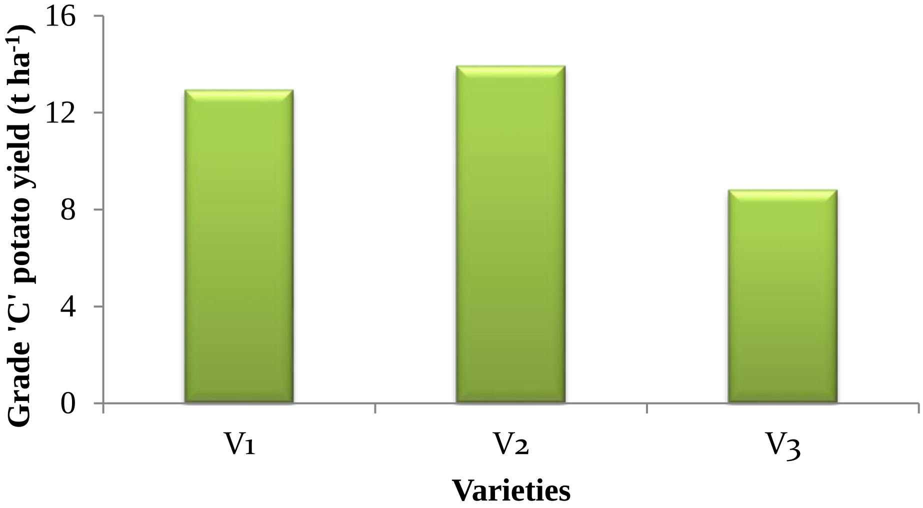
4.15.3 Interaction effect of variety and different levels of biochar

The percentage of Grade 'B' potato was significantly affected by the interaction effect of variety and different biochar levels (Table 8). The highest percentage of Grade 'B' potato (25.25 %) was obtained from treatment combination V_3B_4 which showed similarity with V_3B_2 and V_3B_3 and the lowest percentage of Grade 'B' potato (3.74 %) was obtained from treatment combination V_2B_0 which showed similarity with V_2B_1.

4.16Grade 'C' potato yield

4.16.1 Effect of variety

The Grade 'C' potato yield was significantly varied by the varietal variation (Figure 19). The highest Grade 'C' potato yield (13.93 t ha^{-1}) was obtained from V_2 and the lowest Grade 'C' potato yield (8.79 t ha^{-1}) was obtained from V_3. The result of the present investigation was similar with the studies conducted by.

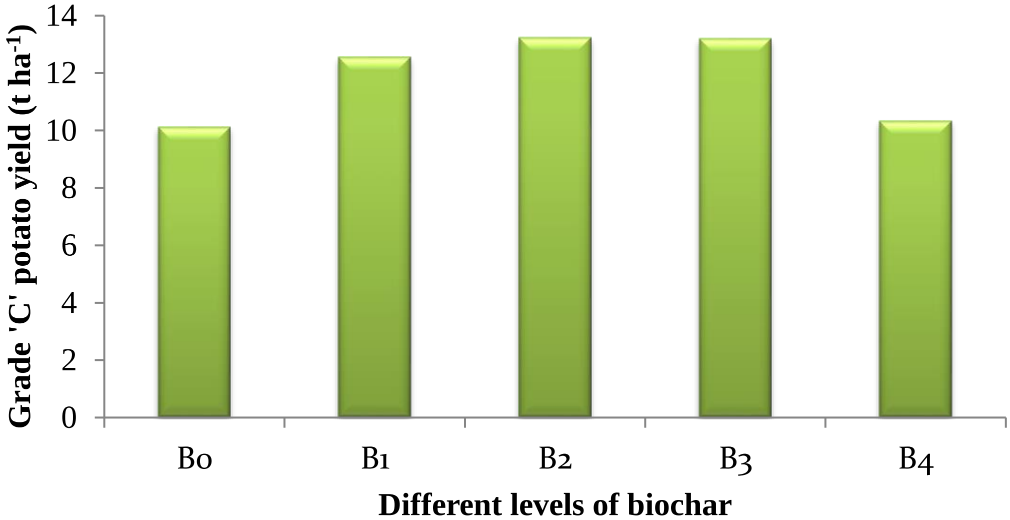


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 19. Effect of variety on the Grade'C' potato yield (LSD $_{0.05}$=0.95)

4.16.2 Effect of different levels of biochar

The Grade 'C' potato yield was significantly varied by the different biochar levels (Figure 20). The highest Grade 'C' potato yield (13.23 t ha^{-1}) was obtained from B_2 which was statistically similar with B_1 and $B_3$and the lowest Grade 'C' potato yield (10.12 t ha^{-1}) was obtained from B_0 which showed similarity with B_4. This result had agreements with the findings of



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 20. Effect of biochar on the Grade'C' potato yield (LSD $_{0.05}$=1.22)

4.16.3 Interaction effect of variety and different levels of biochar

The Grade 'C' potato yield was significantly varied by the interaction effect of variety and different biochar levels (Table 6). The highest Grade 'C' potato yield (15.86 t ha^{-1}) was obtained from treatment combination V_2B_2 which showed similarity with V_2B_3, V_1B_3 and $V_2B_1$and the lowest Grade 'C' potato yield (6.07 t ha^{-1}) was obtained from treatment combination V_3B_4 which showed similarity with V_3B_0.This result had agreements with the findings of ..

Table 6. Interaction effect of variety and biochar on the yield characters of potato

Treatment combinations	Grade'A' Potato yield (t ha^{-1})	Grade'B' potato yield (t ha^{-1})	Grade'C' potato yield (t ha^{-1})
V_1B_0	0.58 hi	3.41 f	11.15 ef
V_1B_1	1.24 fg	3.47 f	12.42 c-e
V_1B_2	1.35 f	3.67 f	13.71 b-d
V_1B_3	1.85 e	3.75 ef	15.51 ab
V_1B_4	2.52 d	5.43 bc	11.89 d-f
V_2B_0	0.00 j	1.12 h	11.08 ef
V_2B_1	0.00 j	1.89 gh	14.31 a-c
V_2B_2	0.23 ij	2.24 g	15.86 a
V_2B_3	0.38 ij	2.39 g	15.36 ab
V_2B_4	0.86 gh	2.54 g	13.02 c-e
V_3B_0	3.12 c	4.52 de	8.13 gh
V_3B_1	4.63 b	4.87 cd	10.90 ef
V_3B_2	4.77 b	5.84 ab	10.12 fg
V_3B_3	4.94 b	6.10 ab	8.74 g
V_3B_4	6.35 a	6.28 a	6.07 h
LSD (0.05)	**0.43**	**0.78**	**2.12**
CV (%)	**11.83**	**12.22**	**10.67**

In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.17 Percentage of Grade 'C' potato

4.17.1 Effect of variety

The percentage of Grade 'C' potato was significantly varied by the varietal variation (Table 7). The highest percentage of Grade 'C' potato (92.23 %) was obtained from V_2 and the lowest percentage of Grade 'C' potato (66.83 %) was obtained from V_3. The result of the present investigation was similar with the studies conducted by.

4.17.2 Effect of different levels of biochar

The percentage of Grade 'C' potato was significantly varied by the different biochar levels (Table 7). The highest percentage of Grade 'C' potato (85.11 %) was obtained from B_2 which was statistically similar with B_1 and B_2 and the lowest percentage of Grade 'C' potato (78.29 %) was obtained from B_0 which showed similarity with B_4.

Table 7. Effect of variety and biochar on the tuber characters of potato

Treatments	Percentage of Grade'A' potato (%)	Percentage of Grade'B' potato (%)	Percentage of Grade'C' potato (%)
Effect of variety			
V_1	3.51 b	14.75 b	82.87 b
V_2	0.37 c	6.68 c	92.23 a
V_3	12.19 a	22.24 a	66.83 c
LSD (0.05)	**0.49**	**1.47**	**4.65**
CV (%)	**12.13**	**13.47**	**7.70**
Effect of biochar			
B_0	3.45 e	10.52 c	78.29 b
B_1	4.50 d	13.06 b	81.61 ab
B_2	5.19 c	14.72 b	79.16 ab
B_3	6.28 b	16.78 a	85.11 a
B_4	7.35 a	17.71 a	79.04 b
LSD (0.05)	**0.63**	**1.89**	**6.00**
CV (%)	**12.13**	**13.47**	**7.70**

In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.17.3 Interaction effect of variety and different levels of biochar

The percentage of Grade 'C' potato was significantly varied by the interaction effect of variety and different biochar levels (Table 8). The highest percentage of Grade 'C' potato (95.78 %) was obtained from treatment combination V_2B_2 which showed similarity with V_2B_1, V_1B_3, V_2B_0, V_2B_3 and $V_2B_4$and the lowest percentage of Grade 'C' potato (59.61 %) was obtained from treatment combination V_3B_4 which showed similarity with V_3B_0 and V_3B_1.

Table 8. Interaction effect of variety and biochar on the tuber characters of potato

Treatment combinations	Percentage of Grade'A' potato (%)	Percentage of Grade'B' potato (%)	Percentage of Grade'C' potato (%)

V_1B_0	1.48 i	10.10 cd	77.57 cd
V_1B_1	2.71 h	12.95 c	84.23 bc
V_1B_2	2.78 h	13.09 c	77.65 cd
V_1B_3	4.71 g	17.64 b	89.61 ab
V_1B_4	5.87 f	19.95 b	85.29 bc
V_2B_0	0.00 j	3.74 e	87.51 a-c
V_2B_1	0.00 j	6.85 de	92.77 ab
V_2B_2	0.48 ij	7.12 d	95.78 a
V_2B_3	0.61 ij	7.79 d	92.86 ab
V_2B_4	0.75 ij	7.93 d	92.21 ab
V_3B_0	8.87 e	17.71 b	69.78 d-f
V_3B_1	10.78 d	19.37 b	67.82 d-f
V_3B_2	12.33 c	23.95 a	64.05 ef
V_3B_3	13.51 b	24.92 a	72.87 de
V_3B_4	15.43 a	25.25 a	59.61 f
LSD $_{(0.05)}$	**1.09**	**3.28**	**10.39**
CV (%)	**12.13**	**13.47**	**7.70**

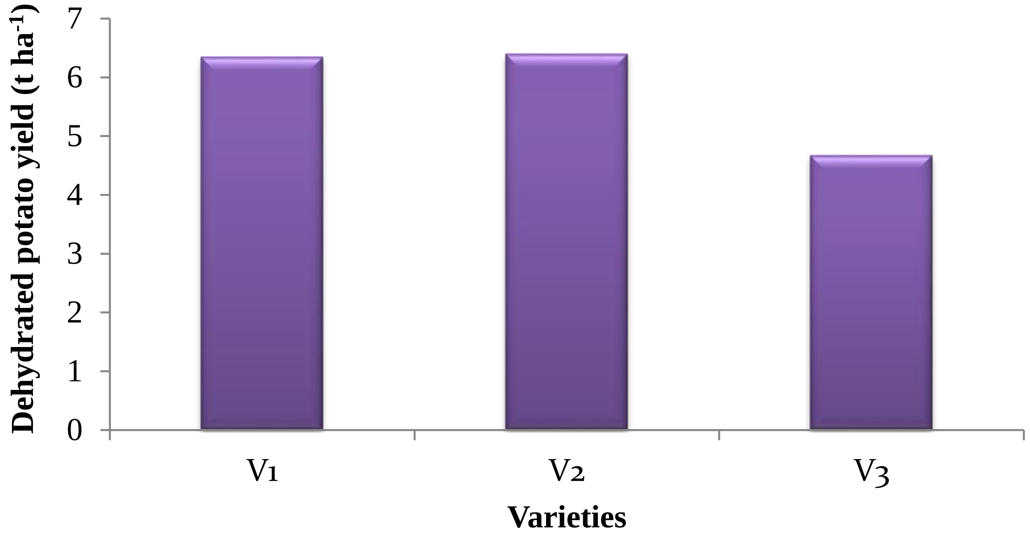
In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.18 Dehydrated potato yield

4.18.1 Effect of variety

Dehydrated potato yield was significantly differed by the varietal difference (Figure 21). The highest dehydrated potato yield (6.39 t ha^{-1}) was recorded from the V_2 followed by V_1 (6.35 t ha^{-1}) whereas the lowest one (4.67 t ha^{-1}) was recorded from V_3.

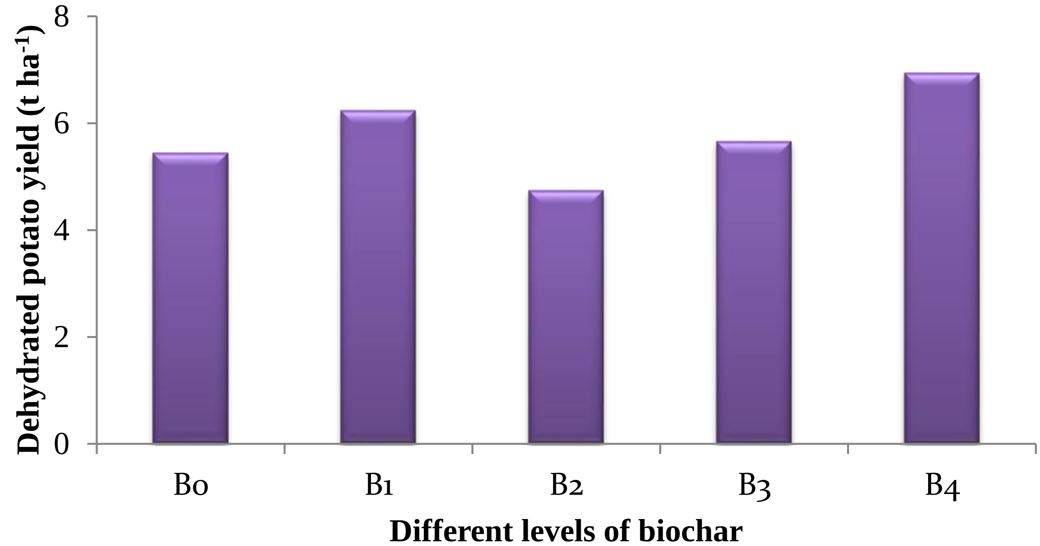


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 21. Effect of variety on the dehydrated potato yield (LSD $_{0.05}$=0.49)

4.18.2 Effect of different levels of biochar

Dehydrated potato yield was significantly differed by the different biochar levels (Figure 22). The highest dehydrated potato yield (6.94 t ha^{-1}) was recorded from the B_4 whereas the lowest one (4.74 t ha^{-1}) was recorded from B_2.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 22. Effect of biochar on the dehydrated potato yield (LSD $_{0.05}$=0.63)

4.18.3 Interaction effect of variety and different levels of biochar

Dehydrated potato yield was significantly differed by the interaction effect of variety and different biochar levels (Table 9). The highest dehydrated potato yield (10.09 t ha^{-1}) was recorded from the treatment combination V_2B_4 whereas the lowest one (4.04 t ha^{-1}) was recorded from V_3B_2 which was statistically similar with V_3B_4, V_3B_3, V_3B_1 and V_2B_2.

4.19 Percentage of dehydrated potato

4.19.1 Effect of variety

Percentage of dehydrated potato was significantly differed by the varietal difference (Table 10). The highest percentage of dehydrated potato (33.92 %) was recorded from the V_1whereas the lowest one (27.74 %) was recorded from V_2 followed by V_3 (29.35 %).

4.19.2 Effect of different levels of biochar

Percentage of dehydrated potato was significantly differed by the different biochar levels (Table 10). The highest percentage of dehydrated potato (33.60) was recorded from the B_3 which was statistically at par withB_1, B_4 and B_0whereas the lowest one (26.84) was recorded from B_2which was statistically at par with B_0 and B_4.

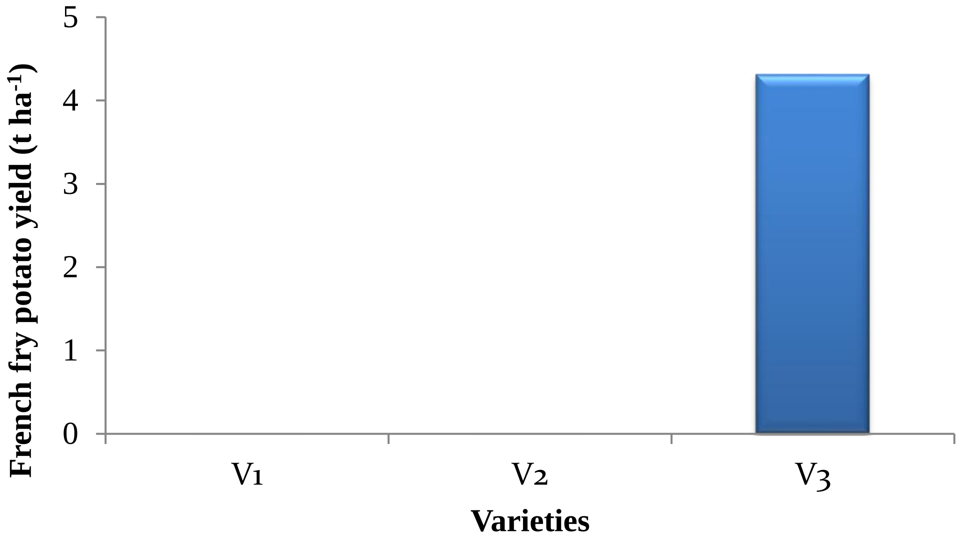
4.19.3 Interaction effect of variety and different levels of biochar

Percentage of dehydrated potato was significantly differed by the interaction effect of variety and different biochar levels (Table 11). The highest percentage of dehydrated potato (38.36 %) was recorded from the treatment combination V_1B_3 which was statistically at par with V_1B_0, V_1B_1 and V_3B_3whereas the lowest one (25.45 %) was recorded from V_2B_2which was statistically similar with rest of the treatment combinations except V_1B_0, V_1B_1, V_3B_3 and V_1B_3.

4.20 French-fry potato yield

4.20.1 Effect of variety

French-fry potato yield was significantly influenced by the potato variety (Figure 23). The highest french-fry potato yield (4.32t ha^{-1}) was recorded from the V_3 and Both the variety V_1 and V_2 did not produce any french-fry potato.

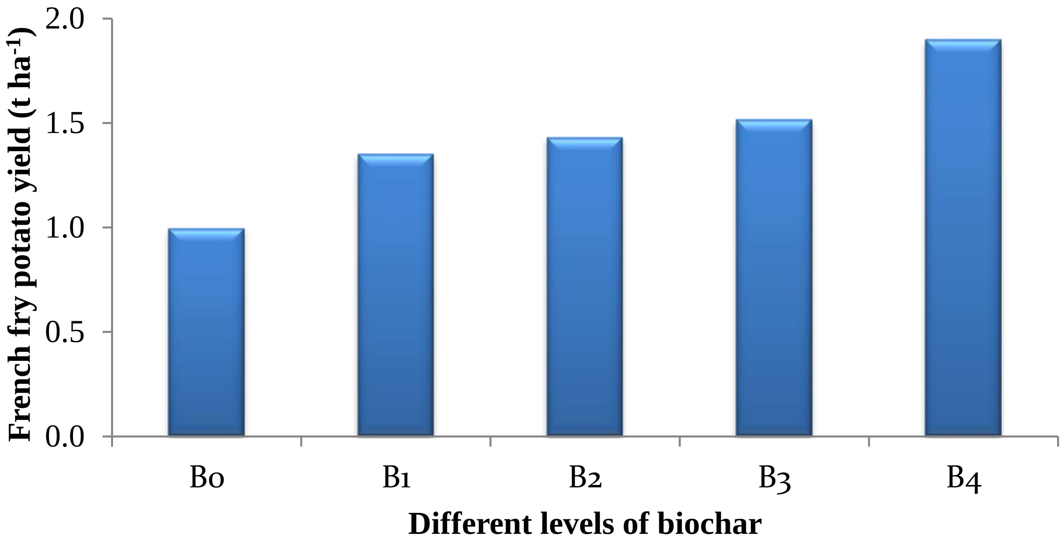


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 23. Effect of variety on the French fry potato yield (LSD $_{0.05}$=0.24)

4.20.2 Effect of different levels of biochar

French-fry potato yield was significantly influenced by the different biochar levels (Figure 24). The highest french-fry potato yield (1.90 t ha^{-1}) was recorded from the B_4treatment whereas the lowest one (0.99 t ha^{-1}) was recorded from B_0 treatment.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 24. Effect of biochar on the French fry potato yield (LSD $_{0.05}$=0.30)

4.20.3 Interaction effect of variety and different levels of biochar

French-fry potato yield was significantly influence by the interaction effect of variety and different biochar levels (Table 9). The highest french-fry potato yield (5.70 t ha^{-1}) was recorded from the treatment combination V_3B_4whereas V_1 and V_2 in combination with all the biochar levels did not produce any french-fry potato.

4.21Percentage of french-fry potato

4.21.1 Effect of variety

Percentage of french-fry potato was significantly influenced by the potato variety (Table 10). The highest percentage of french-fry potato (11.28 %) was found from the V_3on the other hand both the variety V_1 and V_2 did not produce any french-fry potato.

4.21.2 Effect of different levels of biochar

Percentage of french-fry potato was significantly influenced by the different biochar levels (Table 10). The highest percentage of french-fry potato (5.24 %) was found from the B_4 treatment whereas the lowest one (2.71 %) was found from B_0 treatment.

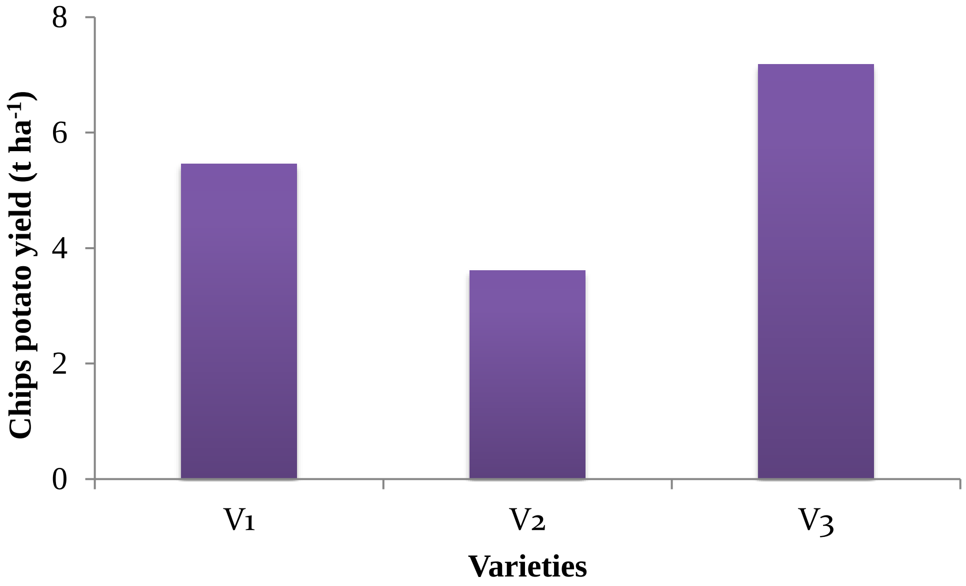
4.21.3 Interaction effect of variety and different levels of biochar

Percentage of french-fry potato was significantly influence by the interaction effect of variety and different biochar levels (Table 11). The highest percentage of french-fry potato (15.73 %) was recorded from the treatment combination V_3B_4 whereas V_1 and V_2 in combination with all the biochar levels did not produce any french-fry potato.

4.22 Chips potato yield

4.22.1 Effect of variety

Potato variety exerted significant influence on chips potato yield (Figure 25). The highest chips potato (7.19 t ha^{-1}) was produced by the V_3 and the lowest chips potato (3.61 t ha^{-1}) was produced by the V_2.

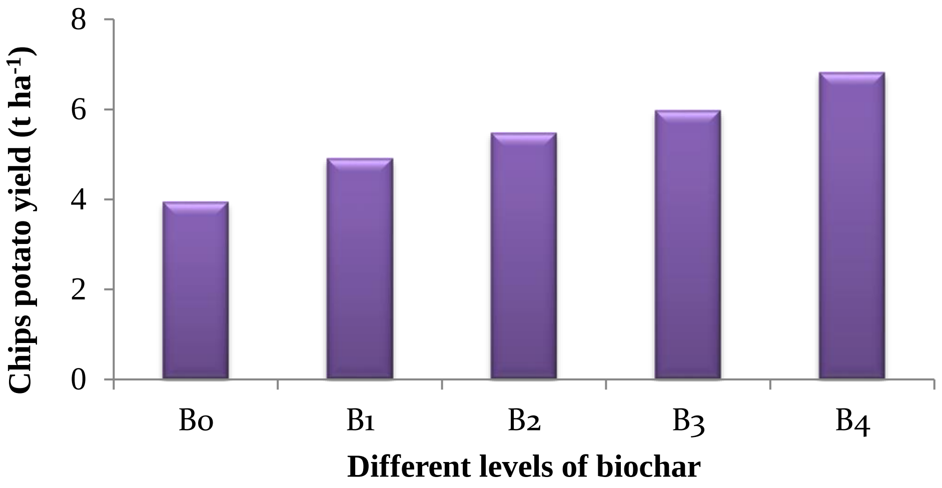


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 25. Effect of variety on the chips potato yield (LSD $_{0.05}$=0.38)

4.22.2 Effect of different levels of biochar

Biochar levels exerted significant influence on chips potato yield (Figure 26). The highest chips potato (6.82 t ha^{-1}) was produced by the B_4 and the lowest chips potato (3.94 t ha^{-1}) was produced by the treatment B_0.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 26. Effect of biochar on the chips potato yield (LSD $_{0.05}$=0.50)

4.22.3 Interaction effect of variety and different levels of biochar

Interaction effect of variety and different biochar levels exerted significant influence on chips potato yield (Table 9). The highest chips potato (9.03 t ha^{-1}) was produced by the treatment combination V_3B_4 and the lowest chips potato (2.08 t ha^{-1}) was produced by the treatment combination V_2B_0.

4.23 Percentage of chips potato

4.23.1 Effect of variety

Potato variety exerted significant influence on percentage of chips potato (Table 10). The highest percentage of chips potato (29.25 %) was produced by the V_3 and the lowest percentage of chips potato (14.61 %) was produced by the V_2.

4.23.2 Effect of different levels of biochar

Biochar levels exerted significant influence on percentage of chips potato (Table 10). The highest percentage of chips potato (28.39 %) was produced by the B_4 and the percentage of chips potato (15.84 %) was produced by the treatment B_0which showed statistical similarity with B_1.

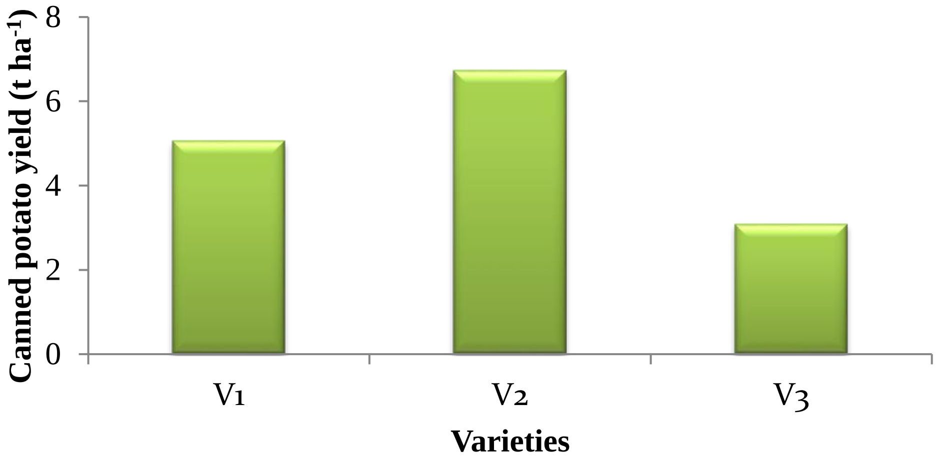
4.23.3 Interaction effect of variety and different levels of biochar

Interaction effect of variety and different biochar levels exerted significant influence on percentage of chips potato (Table 11). The highest percentage of chips potato (37.46 %) was produced by the treatment combination V_3B_4 which showed statistical similarity with V_3B_3 and the lowest percentage of chips potato (10.90 %) was produced by the treatment combination V_2B_0 which showed statistical similarity with V_2B_1 and V_2B_2.

4.24 Canned potato yield

4.24.1 Effect of variety

Potato variety exerted significant difference on canned potato yield (Figure 27). The highest canned potato (6.74 t ha^{-1}) was produced by the $V_2$and the lowest canned potato (3.09 t ha^{-1}) was produced by the V_3.

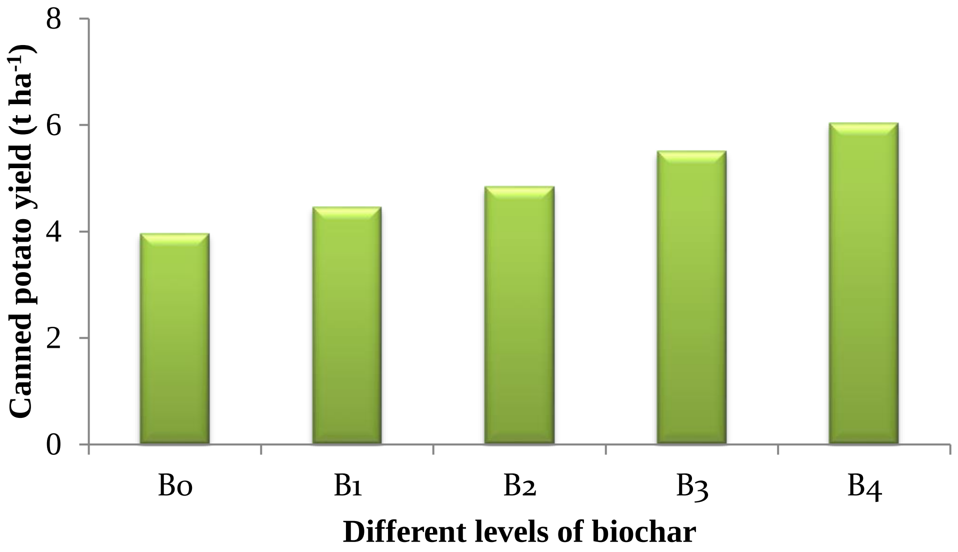


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 27. Effect of variety on the canned potato yield (LSD $_{0.05}$=0.34)

4.24.2 Effect of different levels of biochar

Biochar levels exerted significant difference on canned potato yield (Figure 28). The highest canned potato (6.04 t ha^{-1}) was produced by the B_4 and the lowest canned potato (3.96 t ha^{-1}) was produced by the treatment B_0.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 28. Effect of biochar on the canned potato yield (LSD $_{0.05}$=0.44)

4.24.3 Interaction effect of variety and different levels of biochar

Interaction effect of variety and different biochar levels exerted significant difference on canned potato yield (Table 9). The highest canned potato (8.10 t ha^{-1}) was produced by the treatment combination V_2B_4 and the lowest canned potato (2.46 t ha^{-1}) was produced by the treatment combination V_3B_0 which was statistically similar with V_3B_1.

Table 9. Interaction effect of variety and biochar on the yield characters of potato

Treatment combinations	Dehydrated potato yield (t ha^{-1})	French fry potato yield (t ha^{-1})	Chips potato yield (t ha^{-1})	Canned potato yield (t ha^{-1})
V_1B_0	5.64 cd	0.00 d	4.43 f-h	3.87 fg
V_1B_1	7.22 b	0.00 d	5.09 ef	4.43 ef
V_1B_2	5.62 cd	0.00 d	5.52 e	4.70 e
V_1B_3	6.75 b	0.00 d	5.73 de	5.82 cd
V_1B_4	6.49 bc	0.00 d	6.55 cd	6.48 c
V_2B_0	5.47 cd	0.00 d	2.08 j	5.55 d
V_2B_1	6.44 bc	0.00 d	3.15 i	6.38 c
V_2B_2	4.56 d-f	0.00 d	3.71 hi	6.40 c
V_2B_3	5.41 cd	0.00 d	4.23 gh	7.26 b
V_2B_4	10.09 a	0.00 d	4.88 e-g	8.10 a
V_3B_0	5.21 de	2.98 c	5.30 e	2.46 h
V_3B_1	5.05 d-f	4.06 b	6.47 cd	2.57 h
V_3B_2	4.04 f	4.29 b	7.19 bc	3.42 g
V_3B_3	4.82 d-f	4.55 b	7.95 b	3.44 g
V_3B_4	4.23 ef	5.70 a	9.03 a	3.54 g
LSD (0.05)	**1.09**	**0.53**	**0.86**	**0.76**
CV (%)	**11.19**	**21.87**	**9.46**	**9.18**

In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.25 Percentage of canned potato

4.25.1 Effect of variety

Potato variety exerted significant difference on percentage of canned potato (Table 10). The highest percentage of canned potato (51.91 %) was produced by the $V_2$and the lowest percentage of canned potato (28.99 %) was produced by the V_3.

4.25.2 Effect of different levels of biochar

Biochar levels exerted significant difference on percentage of canned potato (Table 10). The highest percentage of canned potato (52.86 %) was produced by the B_4 and the lowest percentage of canned potato (30.45 %) was produced by the treatment B_0.

Table 10. Effect of variety and biochar on the tuber characters of potato

Treatments	Percentage of dehydrated potato (%)	Percentage of French fry potato (%)	Percentage of chips potato (%)	Percentage of canned potato (%)
Effect of variety				
V_1	33.92 a	0.00 b	20.90 b	42.19 b
V_2	27.74 b	0.00 b	14.61 c	51.91 a
V_3	29.35 b	11.28 a	29.25 a	28.99 c
LSD (0.05)	3.10	0.62	1.94	2.70
CV (%)	13.67	21.94	11.99	8.78
Effect of biochar				
B_0	29.79 ab	2.710 c	15.84 d	30.45 d
B_1	31.14 a	3.557 b	18.29 cd	36.08 c
B_2	26.84 b	3.614 b	20.18 c	41.33 b
B_3	33.60 a	3.670 b	25.24 b	44.44 b
B_4	30.32 ab	5.243 a	28.39 a	52.86 a
LSD (0.05)	4.00	0.80	2.50	3.48
CV (%)	13.67	21.94	11.99	8.78

In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.25.3 Interaction effect of variety and different levels of biochar

Interaction effect of variety and different biochar levels exerted significant difference on percentage of canned potato (Table 11). The highest percentage of canned potato (66.62 %) was produced by the treatment combination V_2B_4 and the lowest percentage of canned potato (19.84 %) was produced by the treatment combination V_3B_0 which was statistically similar with V_3B_1.

Table 11. Interaction effect of variety and biochar on the tuber characters of potato

Treatment combinations	Percentage of dehydrated potato (%)	Percentage of French fry potato (%)	Percentage of chips potato (%)	Percentage of canned potato (%)
V_1B_0	34.40 a-c	0.00 d	15.72 fg	34.73 g
V_1B_1	38.18 a	0.00 d	18.07 ef	40.83 ef
V_1B_2	27.46 d	0.00 d	20.95 de	43.17 de
V_1B_3	38.36 a	0.00 d	24.72 b-d	44.05 de
V_1B_4	31.20 b-d	0.00 d	25.03 b-d	48.18 cd
V_2B_0	28.48 cd	0.00 d	10.90 h	36.79 fg
V_2B_1	26.78 d	0.00 d	11.23 h	44.87 de
V_2B_2	25.45 d	0.00 d	12.10 gh	54.20 bc
V_2B_3	26.87 d	0.00 d	16.16 fg	57.09 b
V_2B_4	31.11 b-d	0.00 d	22.67 cd	66.62 a
V_3B_0	26.48 d	8.13 c	20.89 de	19.84 j
V_3B_1	28.46 cd	10.67 b	25.56 bc	22.53 ij
V_3B_2	27.60 cd	10.84 b	27.50 b	26.62 hi
V_3B_3	35.56 ab	11.01 b	34.83 a	32.18 gh
V_3B_4	28.66 b-d	15.73 a	37.46 a	43.78 de
LSD $_{(0.05)}$	**6.94**	**1.38**	**4.33**	**6.03**
CV (%)	**13.67**	**21.94**	**11.99**	**8.78**

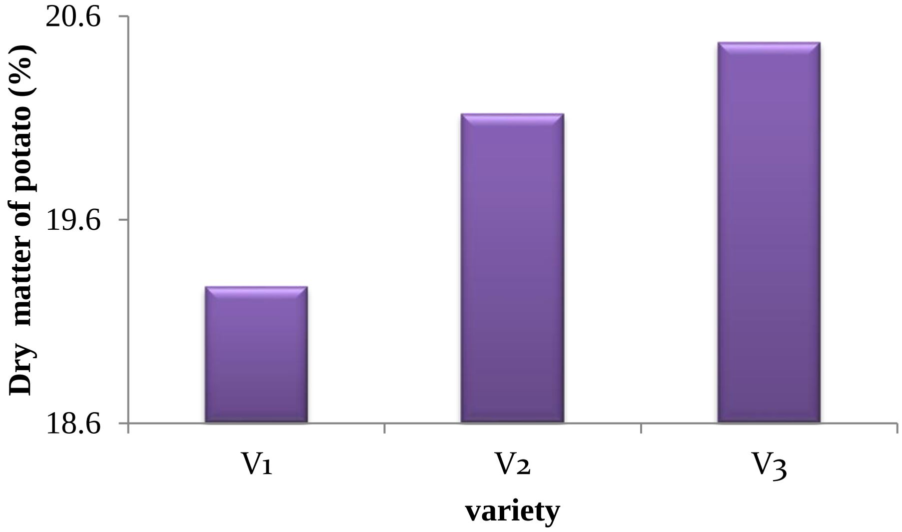
In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.26 Dry matter of potato

4.26.1 Effect of variety

The percentage of potato dry mater was significantly varied by the varietal variation (Figure 29). The highest percentage of potato dry mater (20.47 %) was obtained from V_3followed by V_2 (20.12 %) and the lowest percentage of potato dry mater (19.27 %) was obtained from V_1. The result of the present investigation was similar with the studies conducted by Youseef *et al.* (2017) who reported that the increases in total dry weight of potato varieties Cara and Spunta cvs. may be due to that both potato cvs. Cara and Spunta recorded the maximum values of number of stems, leaves and as well as leaf area plant^{-1}.

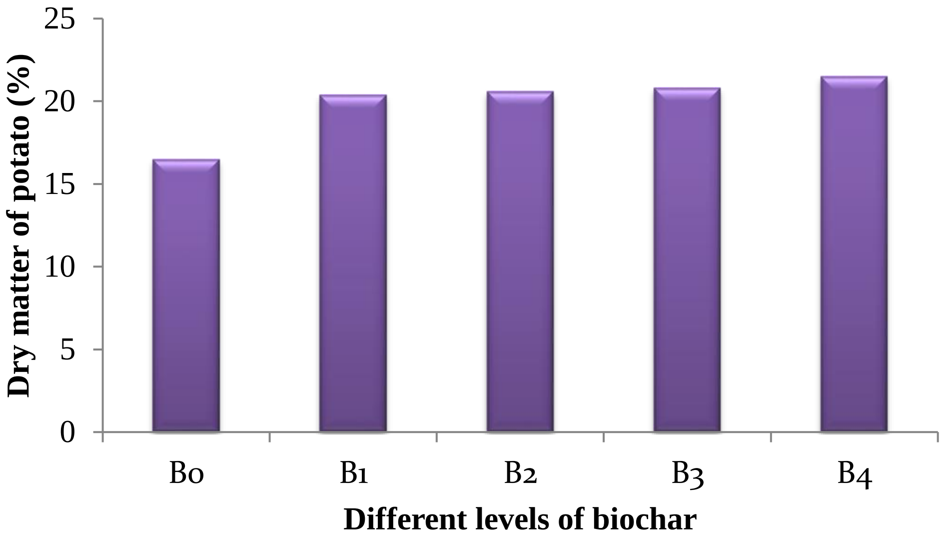


V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix)

Figure 29. Effect of variety on the dry matter of potato (LSD $_{0.05}$=0.39)

4.26.2 Effect of different levels of biochar

The percentage of potato dry mater was significantly varied by the different biochar levels (Figure 30). The highest percentage of potato dry mater (21.50 %) was obtained from $B_4$and the lowest percentage of potato dry mater (16.48 %) was obtained from B_0. This result had agreements with the findings of 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 lea f area plant^{-1}.



B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

Figure 30. Effect of biochar on the dry matter of potato (LSD $_{0.05}$=0.50)

4.26.3 Interaction effect of variety and different levels of biochar

The percentage of potato dry mater was significantly varied by the interaction effect of variety and different biochar levels (Table 13). The highest percentage of potato dry mater (22.01 %) was obtained from treatment combination V_3B_4 which showed similarity with V_3B_3, V_3B_2, V_2B_4, V_2B_3 and $V_1B_4$and the lowest percentage of potato dry mater (16.23 %) was obtained from treatment combination V_1B_0 which showed similarity with V_2B_0 and V_3B_0.Similar findings was also reported by Youseef *et al.*(2017) who reported that the increases in total dry weight were about 85.28 and 75.55% for Cara cv. applied with 5 m^3fed^{-1} of biochar and 75.04 and 63.20% for Spunta cv. applied with 5 m^3fed^{-1}. of biochar, over the Accent cv. grown without biochar.

4.27 Potato firmness

4.27.1 Effect of variety

Potato variety exerted significant difference on potato firmness (Table 12). The maximum potato firmness (36.76) was scored by the V_3 followed by V_2 (35.23) and the lowest potato firmness (31.01) was scored by the V_1.

4.27.2 Effect of different levels of biochar

Biochar levels exerted significant difference on potato firmness (Table 12). The highest potato firmness (37.02) was scored by the B_4 which was statistically similar with B_3 and B_2 and the lowest potato firmness (31.57) was scored by the treatment B_0 which was statistically similar with B_1 and B_2.

4.27.3 Effect of different levels of biochar

Interaction effect of variety and different biochar levels exerted significant difference on potato firmness (Table 13). The highest potato firmness (38.60) was scored by the treatment combination V_3B_4 which was statistically similar with V_3B_3, V_3B_2, V_3B_1, V_3B_0, V_2B_4, V_2B_3, V_2B_2 and V_1B_4 and the lowest potato firmness (27.58) was scored by the treatment combination V_1B_0 which was statistically similar with V_1B_1, V_1B_2, V_2B_0 and V_2B_1.

4.28 Specific gravity

4.28.1 Effect of variety

Specific gravity was not significantly differed by different potato varieties (Table 12). Numerically the maximum and minimum specific gravity(1.082 and 1.075, respectively)was scored by V_3 and V_1. The variation in the specific gravity might be due to genetic constituents of the crops.

4.28.2 Effect of different levels of biochar

Biochar level had significant influenced on the specific gravity(Table 12). Results revealed that, treatment B_4scored maximum specific gravity(1.090) which was statistically at par with B_1, B_2 and B_3 and the B_0 scored the minimum one (1.055) which was statistically differed with rest of the biochar treatments.

4.28.3 Interaction effect of variety and different levels of biochar

Specific gravity was significantly differed by the interaction effect of variety and biochar level (Table 13). The highest specific gravity (1.092) was scored by the V_3B_4 treatment combination which was statistically at par with rest of the treatment combinations except V_1B_0, V_1B_1, V_2B_0 and $V_3B_0$and the lowest one (1.053) was scored by the V_1B_0 treatment combination which was statistically at par with V_2B_0 and V_3B_0.

4.29 Total soluble solid

4.29.1 Effect of variety

Total soluble solid was not significantly varied by different potato varieties (Table 12). Results exposed that, numerically the maximum and minimum total soluble solid (4.64 and 4.33, respectively) was found from V_3 and V_2, respectively. The variation in the production of potato might be due to genetic constituents of the crops.

4.29.2 Effect of different levels of biochar

Biochar level had significant influenced on the total soluble solid (Table 12). Results exposed that, treatment B_0 produced maximum total soluble solid (4.87) which was statistically similar with $B_1$and B_2 and B_4produced the minimum one (4.07) which was statistically at par with B_3. Similar findings were reported by Youseef *et al.* (2017) who reported that biochar at 2.5 $m^3 fed^{-1}$decreasedthe total soluble solid content in potato. Akhtar *et al*. (2014) found that biochar addition improved quality of tomato fruits.

4.29.3 Interaction effect of variety and different levels of biochar

Total soluble solid was significantly affected by the interaction effect of variety and biochar level (Table 13). The highest total soluble solid (5.07) was obtained from the V_3B_0 which was statistically similar with V_3B_1, V_3B_2, V_3B_3, V_2B_2, V_2B_0, V_1B_1, V_1B_0 and $V_1B_2$and the lowest total soluble solid (3.87) was obtained from the V_2B_4 treatment combination which was statistically similar with V_3B_4, V_3B_3, V_2B_3, V_2B_2, V_2B_1, V_1B_4, V_1B_3 and V_1B_2.

4.30 Starch content on potato

4.30.1 Effect of variety

Significant variation was found on starch content on potato due to varietal variation (Table 12). The highest starch content on potato (14.97 %) was attained by potato variety V_3followed by V_2 (14.67 %) and the lowest starch content on potato (14.39 %)

was attained by potato variety V_1 followed by V_2 (14.67 %).

4.30.2 Effect of different levels of biochar

Significant variation was found on starch content on potato due to different biochar levels (Table 12). The highest starch content on potato (15.55 %) was attained by B_4 and the lowest starch content on potato (13.16 %) was attained by potato variety B_0. Similar findings were also reported by Youseef *et al.* (2017) who reported that biochar at 2.5 m^3fed^{-1} increased starch content in potato. Akhtar *et al.* (2014) found that biochar addition improved quality of tomato fruits.

Table 12. Effect of variety and biochar on the qualitative characters of potato

Treatments	Potato firmness	Specific gravity	Total soluble solid	Starch content on potato (%)
Effect of variety				
V_1	31.01 b	1.075	4.49	14.39 b
V_2	35.23 a	1.080	4.33	14.67 ab
V_3	36.76 a	1.082	4.64	14.97 a
LSD (0.05)	**2.32**	**NS**	**NS**	**0.32**
CV (%)	**9.01**	**0.48**	**10.37**	**2.95**
Effect of biochar				
B_0	31.57 b	1.055 b	4.87 a	13.16 c
B_1	32.54 b	1.081 a	4.71 a	14.74 b
B_2	34.49 ab	1.084 a	4.57 ab	14.84 b
B_3	36.06 a	1.086 a	4.23 bc	15.10 b
B_4	37.02 a	1.090 a	4.07 c	15.55 a
LSD (0.05)	**2.99**	**0.01**	**0.45**	**0.42**
CV (%)	**9.01**	**0.48**	**10.37**	**2.95**

In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.30.3 Interaction effect of variety and different levels of biochar

Significant variation was found on starch content on potato due to interaction effect of variety and different biochar levels (Table 13). The highest starch content on potato (16.12 %) was attained by V_3B_4 and the lowest starch content on potato (12.89 %) was attained by V_1B_0 which was statistically similar with V_2B_0 and V_3B_0.

Table 13. Interaction effect of variety and biochar on the qualitative characters of potato

Treatment combinations	Percentage of potato dry matter (%)	Potato firmness	Specific gravity	Total soluble solid	Starch content on potato (%)
V_1B_0	16.23 e	27.58 f	1.053 c	4.87 ab	12.89 e
V_1B_1	19.42 d	29.43 ef	1.075 b	4.67 ab	14.55 d
V_1B_2	19.48 d	30.72 d-f	1.079 ab	4.53 a-c	14.60 cd
V_1B_3	19.97 cd	32.84 b-e	1.080 ab	4.25 bc	14.70 b-d
V_1B_4	21.25 ab	34.47 a-e	1.089 ab	4.13 bc	15.23 b-d
V_2B_0	16.41 e	32.28 c-f	1.055 c	4.67 ab	13.14 e
V_2B_1	20.62 bc	32.50 c-f	1.083 ab	4.60 a-c	14.75 b-d
V_2B_2	21.11 b	36.19 a-c	1.085 ab	4.43 a-c	14.89 b-d
V_2B_3	21.21 ab	37.21 a-c	1.089 ab	4.11 bc	15.26 b-d
V_2B_4	21.25 ab	37.98 ab	1.089 ab	3.87 c	15.30 bc
V_3B_0	16.79 e	34.84 a-d	1.056 c	5.07 a	13.44 e
V_3B_1	21.13 b	35.69 a-d	1.085 ab	4.87 ab	14.91 b-d
V_3B_2	21.17 ab	36.55 a-c	1.087 ab	4.73 ab	15.02 b-d
V_3B_3	21.26 ab	38.13 a	1.089 ab	4.33 a-c	15.34 b
V_3B_4	22.01 a	38.60 a	1.092 a	4.20 bc	16.12 a
LSD $_{(0.05)}$	**0.87**	**5.18**	**0.02**	**0.78**	**0.72**
CV (%)	**2.62**	**9.01**	**0.48**	**10.37**	**2.95**

In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.31 Soil pH

4.31.1 Effect of different levels of biochar

Significant variation was found on soil pH of the soils collected from the experimental plot due to different biochar levels (Table 14). The highest soil pH (6.55) was recorded when the plots treated with 10 t ha^{-1} biochar (B_4) and the lowest one (5.72) was recorded when the plot treated with no biochar (B_0). Biochar with a high liming equivalence typically increases the pH value in acidic soils, whereas the actual increase is dependent on the pH-buffering capacity of the respective soil (Mukherjee and Lal, 2014). The liming effect of biochar is positive for acidic soils, especially if they are affected by metal toxicity or nutrient deficiencies. Further, pH in soil increases more when biochar rich in ash is used. In case of disproportionally high soil pH values, liming effect can also have adverse effects (Alburquerque *et al*., 2014). The increase in pH value following biochar application is usually higher in sandy and loamy soils than in clayey soils (De Gryze, 2010). The buffering capacity of a finely textured clay soil is usually higher than that of a coarse-textured soil. This entails that larger amounts of liming resources for clayey soils are required in order to raise the pH to a certain value when compared to a soil with low buffering capacity. Increases in soil pH have been observed in response to peanut biochar addition under greenhouse conditions (Chang *et al*., 2016, Jiang *et al*., 2014, Wang *et al*., 2014, Yuan and Xu, 2011 and Novak *et al.*, 2009) and in response to pine biochar (Wang *et al.*, 2016andRobertson *et al*., 2012). Gautam *et al.* (2017) and (Barrow, 2012) reported that the increase in soil pH could be due to the alkaline nature of biochar which, upon addition to the soil could have contributed towards reducing the acidic level of soil. The alkaline nature of biochar resulted in a rise of soil pH (Streubel *et al*., 2011, Shinogi and Kanri, 2003 and Abe *et al*., 1998). Most biochars have high pH (8-10) which has been shown to have a liming effect, increasing pH in sandy soils 0.5 to 1 unit following additions of 5 to 20 Mg ha^{-1} (Streubel *et al*., 2011, Collins, 2009, Novak *et al*., 2009 and Rodriquez *et al*., 2009). Rodriguez *et al*. (2009) used biochar produced from sugarcane bagasse to increase soil pH from 4.0-4.5 to 6.0-6.5 in a maize trial in Colombia. The result of our experiment was in line with the findings of Indawan *et al.* (2018), Yang *et al.* (2015), Collins *et al.* (2013), Dou *et al*. (2012) and (Moses, 2011)reported that Biochar had the potentiality to increase soil pH.

4.31.2 Interaction effect of variety and different levels of biochar

Significant variation was found on soil pH of the soils collected from the experimental plot due to interaction effect of variety and different biochar levels (Table 15). The highest soil pH (6.61) was attained by treatment combination V_2 B_4 and the lowest one (5.56) was attained by treatment combination V_3B_0.

4.32 Organic carbon content in soil

4.32.1 Effect of different levels of biochar

The organic carbon content in soil collected from the experimental plot was significantly influenced by the different biochar levels (Table 14). The highest organic carbon (0.82) was obtained where 10 t ha^{-1} biochar (B_4) was applied and the lowest organic carbon (0.45) was obtained where no biochar (B_0) was applied. Diatta (2016) reported that biochar application to soils significantly increased total soil C compared to un-amended soils. Xu *et al*. (2015) found that addition of peanut shell biochar increased total soil C while Wang *et al.* (2016) observed similar results after application of pine biochar. The increases in total soil C in biochar-amended soils are readily explained by the large addition of C with biochar treatments. High inputs of C also may limit the decomposition of native soil organic matter because of change in C/N ratio, contributing to the greater concentrations of C in soil (Krapfl *et al*., 2014 and Lehmann *et al*., 2006). Timilsina *et al*. (2017) reported that the highest (2.915%) soil organic matter was obtained from 20 Mg ha^{-1} biochar application which was significantly higher than other treatments, and it was the lowest (1.165%) from no biochar application. The increase in soil organic matter in our study was due to increase in organic carbon as biochar application rate increased. Lehmann (2007) and Van Zwieten *et al.* (2010) reported high organic carbon in soil treated with biochar. The results of our findings were in line with the findings of Indawan *et al.* (2018), Yang *et al.* (2015), Borchard *et al.* (2014), Zheng *et al*. (2013) and Baronti *et al*. (2010) who reported that soil amended with biochar increased the soil organic carbon.

4.32.2 Interaction effect of variety and different levels of biochar

The organic carbon content in soil collected from the experimental plot was significantly influenced by the interaction effect of variety and different biochar levels

(Table 15). The highest organic carbon (0.88) was obtained from V_2B_4 treatment combination which was statistically similar with $V_3B_4$and the lowest value for organic carbon (0.43) was obtained from treatment combination V_2B_0 which was statistically similar with V_3B_0 and V_1B_0.

4.33Nitrogen content in soil

4.33.1 Effect of different levels of biochar

The nitrogen content in soil was not significantly affected by the different biochar levels (Table 14). Numerically the highest nitrogen content in soil (0.040 %) was obtained from B_1, B_2 and B_4 and the lowest nitrogen content in soil (0.034 %) was obtained from B_0treatment. Similar results were not also reported by Timilsina *et al*. (2017) who concluded that the effects of biochar application on nitrogen content in soil were highly significant. Addition of different doses of biochar had higher nitrogen contents of soil compared with without addition of biochar. The highest nitrogen content (1.2 g kg^{-1}) was found from 20 Mg ha^{-1} biochar application. The lowest (0.7 g kg^{-1}) nitrogen content was obtained from without biochar amended soil. The observed increase in N contents of soil due to application of biochar could be due to the presence of high contents of N in biochar. Chan *et al*. (2008) and Lehmann *et al.* (2003) also reported the addition of biochar to soil increased total N in soil. Diatta (2016) reported that biochar application to soils significantly increased total soil N compared to un-amended soils. Xu *et al.* (2015) revealed that addition of peanut shell biochar increased total soil N while Wang *et al.* (2016) observed similar results after application of pine biochar. Greater total soil N in biochar-amended soils also could be a result of N immobilization (Lehmann *et al*., 2003, Rajkovich *et al*., 2012 and Wang *et al*., 2015) due to the high C/N ratio of the peanut shell and mixed pine wood biochars inducing enhanced microbial biomass and activity (Brantley *et al*., 2015). The results was also coincide with the findings of Indawan *et al.* (2018), Yang *et al.* (2015), Collins *et al.* (2013), Dou *et al*. (2012), Streubel *et al*. (2011), Novak *et al*. (2009), Warnock *et al*. (2007), DeLuca *et al*. (2006), Liang *et al.* (2006), Oguntunde *et al.* (2004) and Glaser *et al.*(2002).

4.33.2 Interaction effect of variety and different levels of biochar

The nitrogen content in soil was not significantly affected by the interaction effect of variety and different biochar levels (Table 15). Numerically the highest nitrogen content in soil (0.047 %) was obtained from treatment combination V_1B_4 and the lowest nitrogen content in soil (0.030 %) was obtained from V_2B_4 and V_3B_0 treatment combinations.

4.34 Potassium content in soil

4.34.1 Effect of different levels of biochar

The potassium content in soil was significantly varied by the different biochar levels (Table 8). The highest potassium content in soil(0.215 %) was obtained from B_4 and the lowest potassium content in soil (0.120 %) was obtained from B_0. This result had agreements with the findings of Timilsina *et al*. (2017) and Diatta (2016) who reported that peanut shell biochar application resulted in increased plant available K. Wang *et al*. (2014) reported that addition of peanut shell biochar resulted in decreased soil exchangeable acidity and Al saturation and also increased in exchangeable cations specially K. The increase in available K is explained by the high content of K in peanut shell biochar. Indawan *et al.* (2018)showed that the biochar application increased K_2O content in soil (2.5%) compare to that of no biochar treated soil. Biochar induced changes in soil properties such as cation exchange capacity and exchangeable cations (Kim *et al*., 2016). Application of biochar 5 t ha^{-1} in this trial improved potassium exchangeable in their study. Timilsina *et al*. (2017) reported that the highest available potassium content (12.3 mg kg^{-1}) in soil was found from 20 Mg ha^{-1} biochar application The lowest available potassium content (7.7 g kg^{-1}) was found from without biochar amended soil. The observed increase in K contents of soil due to application of biochar could be due to the presence of high contents of K in biochar. Chan *et al.* (2008) also reported the addition of biochar to soil increased available K of soil. The result of our investigation also reported by Yang *et al.* (2015), Zheng *et al*. (2013), Dou *et al*. (2012) and Baronti *et al*. (2010) who reported that biochar application in soil increased available K in soil.

Table 14. Effect of biochar on the soil characters of the experimental plots

Treatments	pH	Organic carbon on potato	Nitrogen content (%)	Potassium content (%)
B_0	5.72 e	0.45 e	0.034	0.120 e
B_1	5.95 d	0.52 d	0.040	0.151 d
B_2	6.25 c	0.64 c	0.040	0.165 c
B_3	6.40 b	0.73 b	0.039	0.179 b
B_4	6.55 a	0.82 a	0.040	0.215 a
LSD (0.05)	**0.03**	**0.03**	**NS**	**0.01**
CV (%)	**0.57**	**4.95**	**7.78**	**6.39**

In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

4.34.2 Interaction effect of variety and different levels of biochar

The potassium content in soil was significantly varied by the interaction effect of variety and different biochar levels (Table 15). The highest potassium content in soil(0.234 %) was obtained from treatment combination V_3B_4 and the lowest potassium content in soil (0.111 %) was obtained from treatment combination V_2B_0 which showed similarity with V_1B_0.

Table 15. Interaction effect of variety and biochar on the soil characters of experimental plots

Treatment combinations	pH	Soil organic carbon	Nitrogen content (%)	Potassium content (%)
V_1B_0	5.63 h	0.46 g-i	0.033	0.123 ij
V_1B_1	5.94 g	0.49 gh	0.040	0.144 gh
V_1B_2	6.20 f	0.59de	0.040	0.148 g
V_1B_3	6.35 e	0.63 d	0.040	0.172 d-f
V_1B_4	6.49 bc	0.72 bc	0.047	0.213b
V_2B_0	5.96 g	0.43 i	0.040	0.111 j
V_2B_1	5.97 g	0.55 ef	0.040	0.160 fg
V_2B_2	6.19 f	0.62d	0.040	0.177 de
V_2B_3	6.41 d	0.77 b	0.037	0.186 cd
V_2B_4	6.61 a	0.88 a	0.030	0.198bc
V_3B_0	5.56 i	0.45 hi	0.030	0.128 hi
V_3B_1	5.97 g	0.51 fg	0.040	0.147 g
V_3B_2	6.35 e	0.69 c	0.040	0.169 ef
V_3B_3	6.45 cd	0.76 b	0.040	0.179 de
V_3B_4	6.54 b	0.84 a	0.043	0.234 a
LSD (0.05)	**0.05**	**0.05**	**NS**	**0.02**
CV (%)	**0.57**	**4.95**	**7.78**	**6.39**

In a column the mean having the same letter(s) don't differ significantly at 5% level of probability

V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy Research Field, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November, 2017 to April, 2018 in Rabi season.The experimental area is situated at $23^0$77‘N latitude and $90^0$33‘E longitude at an altitude of 8.6 meter above the sea level. The experimental site belongs to the agro-ecological zone of “Madhupur Tract”, AEZ-28. 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 experiment is 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_3:7.50t $ha^{-1}$and B_4: 10 t ha^{-1}. Fifteen treatment combinations were used under study. Experiment was provoked inRandomized Completely Block Design (RCBD) with3 replications. The allocated plots were fertilized by recommended doses except treatment. All the intercultural operations and plant protection measures were taken as per when needed. Data on different yield, yield contributing characters, processing and storage parameters were collected and analyzed by using MSTAT-C program and means were compared by LSD technique at 5% level of probability.

Results revealed that, the maximum number of stems $hill^{-1}$(5.80), number of leaves $hill^{-1}$ (59.27), potato yield (24.69 t ha^{-1}), marketable potato yield (19.53 t ha^{-1}), non marketable potato yield (3.25t ha^{-1}), seed potato yield (18.01 t ha^{-1}), grade ‘A’ potato yield (4.76 t ha^{-1}), grade ‘B’ potato yield (5.52 t ha^{-1}), French fry potato yield (4.32 t ha^{-1}), chips potato yield (7.19 t ha^{-1}), percentage of marketable potato (69.70 %), percentage of grade ‘A’ potato (12.19%), percentage of grade ‘B’ potato (22.24 %), percentage of French fry potato (11.28 %), percentage of chips potato (29.25 %), dry matter of potato (20.47 %) andfirmness of potato (36.76) was recorded from potato variety Asterix (V_3). While the maximum non seed potato yield (3.76 t ha^{-1}), grade ‘C’ potato yield (13.93 t ha^{-1}), dehydrated potato yield (6.93 t ha^{-1}), canned potato yield (6.74 t ha^{-1}), percentage of non-marketable potato yield (36.74 %), percentage of non-seed potato (10.65 %), percentage of grade ‘C’ potato (92.23 %) and percentage of canned potato (51.91%) was recorded from potato variety Lady Rosetta (V_2). Again the maximum percentage of seed potato (100 %) was recorded from both the potato varieties Courage (V_1) and Asterix (V_3). The maximum percentage of dehydrated potato (33.92 %) was recorded from potato varietyCourage (V_1).On the other hand the minimum number of stems hill^{-1}(4.33), potato yield (20.44 t ha^{-1}), marketable potato yield (17.47 t ha^{-1}), seed potato yield (16.09 t ha^{-1}), grade 'A' potato yield (0.29 t ha^{-1}), grade 'B' potato yield (2.04 t ha^{-1}), chips potato yield (3.61 t ha^{-1}), percentage of marketable potato (63.56 %), percentage of seed potato yield (89.05 %), percentage of grade 'A' potato (0.37 %), percentage of grade 'B' potato (6.68 %), percentage of dehydrated potato (27.74 %) and percentage of chips potato (14.61 %) was recorded from potato variety Lady Rosetta (V_2).The minimum number of leaves hill^{-1}(50.62), non-marketable potato yield (2.70 t ha^{-1}), percentage of canned potato (42.19 %), dry matter of potato (19.27 %) andfirmness of potato (31.01) was recorded from potato variety Courage (V_1). The minimum grade 'C' potato yield (8.79 ta ha^{-1}), dehydrated potato yield (4.67 t ha^{-1}), canned potato yield (3.09 t ha^{-1}), percentage of non-marketable potato (28.95 %) and percentage of grade 'C' potato (66.83 %) was recorded from potato varieties Asterix (V_3). Potato varieties Courage (V_1) and Asterix (V_3) did not produced non seed potato and percentage of non-seed potato. Potato varieties Courage (V_1) and Lady Rosetta (V_2) did not produced French fry potato yield and percentage of French fry potato.

Biochar level significantly influenced potato growth, yield, yield contributing characters, quality and soil character of potato. Results exposed that, the maximum number of stems hill^{-1}(6.52 at 45 DAP), number of leaves hill^{-1} (66.07), potato yield (25.62 t ha^{-1}), marketable potato yield (20.17 t ha^{-1}), seed potato yield (19.21 t ha^{-1}), non-seed potato yield (1.80 t ha^{-1}), grade 'A' potato yield (3.24 t ha^{-1}), grade 'B' potato yield (4.75 t ha^{-1}), dehydrated potato yield (6.94 t ha^{-1}), French fry potato yield (1.90 t ha^{-1}), chips potato yield (6.82 t ha^{-1}), canned potato yield (6.04 t ha^{-1}), percentage of marketable potato (71.67 %), percentage of grade 'A' potato (7.35 %), percentage of grade 'B' potato (17.71 %), percentage of French fry potato (5.24 %), percentage of chips potato (28.39 %), percentage of canned potato (52.86 %), dry matter of potato (21.50 %),firmness of potato (37.02), specific gravity of potato (1.09), soil pH (6.55), organic carbon in soil (0.82), available potassium content in soil (0.215 %) was recorded from 10 t ha^{-1} biochar (B_4). While the maximum non-marketablepotatoyield (3.24t ha^{-1}) was recorded from 2.5 t ha^{-1}biochar (B_1). The maximum grade 'C' potato yield (13.23 ha^{-1}) was recorded from 5 t ha^{-1} biochar (B_2).The maximum percentage of grade 'C' potato percentage (85.11 %) and percentage of dehydrated potato (33.60 %) was recorded from 7.50 t ha^{-1} biochar (B_3).The maximum percentage of non-marketable potato (37.90 %), percentage of non-seed potato (4.67 %) and total soluble solid (4.87) was recorded from 0 t ha^{-1} biochar (B_0). On the other hand the minimum number of stems $hill^{-1}$ (4.22), number of leaves $hill^{-1}$ (45.96), potato yield (19.40 t ha^{-1}), marketable potato yield (16.59 t ha^{-1}), seed potato yield (14.80 t ha^{-1}), non seed potato yield (0.89 t ha^{-1}), grade 'A' potato yield (1.23 t ha^{-1}), grade 'B' potato yield (3.02 t ha^{-1}), grade 'C' potato yield (10.12 t ha^{-1}), French fry potato yield (0.99 t ha^{-1}), chips potato yield (3.94 t ha^{-1}), canned potato yield (3.96 t ha^{-1}), percentage of marketable potato (61.58 %), percentage of grade 'A' potato (3.45 %), percentage of grade 'B' potato (10.52 %),percentage of grade 'C' potato (78.29 %), percentage of French dry potato (2.71 %), percentage of chips potato (15.84 %),percentage of canned potato (30.45 %), dry matter of potato (16.48 %), firmness of potato (31.57), specific gravity of potato (1.06), soil pH (5.72), soil organic carbon (0.45 %) and available potassium content in soil (0.120 %) was recorded from 0 t ha^{-1} biochar (B_0). The minimum non-marketable potato yield (2.62 t ha^{-1}), dehydrated potato yield (4.74 t ha^{-1}) and percentage of dehydrated potato (26.84 %) were recorded from 5 t ha^{-1} biochar (B_2).The minimum percentage of non-marketable potato (28.28 %), percentage of non-seed potato (2.00 %) and total soluble solid (4.07) was recorded from 10 t ha^{-1} biochar (B_4).

Interaction effect of potato variety and biochar level significantly influenced potato growth, yield, yield contributing characters, quality and soil character of potato. Results exposed that, the maximum number of stems $hill^{-1}$ (7.78at 45 DAP),number of leaves $hill^{-1}$ (73.11), potato yield (27.33 t ha^{-1}), marketable potato yield (21.30 t ha^{-1}), seed potato yield (20.39 t ha^{-1}), grade 'A' potato yield (6.35 t ha^{-1}), grade 'B' potato yield (3.28 t ha^{-1}), French fry potato yield (5.70 t ha^{-1}), chips potato yield (9.03 t ha^{-1}), dry matter of potato (22.01 %), percentage of marketable potato (76.38 %), percentage of grade 'A' potato (15.43 %), percentage of grade 'B' potato (25.25 %), percentage of French fry potato (15.73 %), percentage of chips potato (37.46 %), firmness of potato (38.60), specific gravity of potato (1.09) and organic carbon in soil (0.88) was recorded from potato variety Asterix (V_3) along with 10 t ha^{-1} biochar (B_4). While the maximum non-marketable potato yield (3.68 t ha^{-1}) was recorded from potato variety Lady Rosetta (V_2) in combination with 2.5 t ha^{-1} biochar (B_1). The maximum non-seed potato yield (5.40 t ha^{-1}), dehydrated potato yield (10.09 t ha^{-1}), canned potato yield (8.10 t ha^{-1}), percentage of canned potato (66.62 %) and soil pH (6.61) was recorded from potato variety Lady Rosetta (V_2) in combination with 10 t ha^{-1} biochar (B_4). The maximum grade 'C' potato yield (15.86 ha^{-1}) and percentage of grade 'c' potato (95.78 %) was recorded from potato variety Lady Rosetta (V_2) in combination with 5 t ha^{-1} biochar (B_2).The maximum percentage of non-marketable potato (41.64 %) and percentage of non-seed potato (14.01) was recorded from potato variety Lady Rosetta (V_2) in combination with 0 t ha^{-1} biochar (B_0). The maximum percentage of dehydrated potato (38.36 %) was recorded from potato variety Courage (V_1) along with 7.50 t ha^{-1} biochar (B_3).The maximum available potassium content in soil (0.234%) was recorded from potato variety Courage (V_1) and Asterix (V_3) along with 10.00 t ha^{-1} biochar (B_4). The maximum percentage of seed potato (100%) was recorded from potato varieties Courage (V_1) and Asterix (V_3) along with all the biochar levels. The maximum total soluble solid (5.07) was recorded from Asterix (V_3) along with 0 t ha^{-1} biochar (B_0). The minimum number of stems $hill^{-1}$ (3.22), number of leaves $hill^{-1}$ (42.89), potato yield (17.78 t ha^{-1}), marketable potato yield (15.61 t ha^{-1}), seed potato yield (13.92 t ha^{-1}), grade 'B' potato yield (1.12 t ha^{-1}), chips potato yield (2.08 t ha^{-1}), dry matter of potato (16.41 %), percentage of marketable potato (58.36 %), percentage of seed potato (85.99%), percentage of grade 'B' potato (3.74 %), percentage of chips potato (10.90 %), organic carbon in soil (0.43) and available potassium content in soil (0.111 %) was recorded from potato variety Lady Rosetta (V_2) along with 0 t ha^{-1} biochar (B_0). While the minimum non-marketable potato yield (1.96 t ha^{-1}) was recorded from potato variety Courage (V_1)in combination with 5 t ha^{-1} biochar (B_2). The minimum non seed potato yield (0 t ha^{-1}) and percentage of non-seed potato (0 %) was produced bypotato variety Courage (V_1) and Asterix (V_3) along with all the biochar levels. The minimum grade 'A' potato yield (0 t ha^{-1}) and (0 %) was produced bypotato variety Lady Rosetta (V_2) along with 0 and 2.50 t ha^{-1} biochar levels.The minimum grade ‘C’ potato yield (6.07 t ha^{-1}), percentage of non-marketable potato (23.62 %) and percentage of grade ‘C’ potato (59.61 %) was produced bypotato variety Asterix (V_3) along with 10 t ha^{-1} biochar levels. The minimum French fry potato yield (0 t ha^{-1})and percentage of French fry potato (0 %) was produced bypotato variety Courage (V_1) and Lady Rosetta (V_2) along with all the biochar levels. The minimum canned potato yield (2.46 t ha^{-1}), percentage of canned potato (19.84 %) and soil pH (5.56) was produced by potato variety Asterix (V_3) along with 0 t ha^{-1} biochar level.The minimum percentage of dehydrated potato (25.45 %) was produced by potato variety Lady Roseta (V_2) along with 5 t ha^{-1} biochar level (B_2).The minimum potato firmness (27.58) and specific gravity (1.05) was recorded from potato variety Courage and 0 t ha^{-1} biochar levels. The minimum total soluble solid (3.87) was recorded from Lady Roseta (V_2)along with 10 t ha^{-1} biochar level (B_4).

From the above summery of this experiment it may be concluded that biochar had significant positive role on soil health by increasing soil pH, in case of slightly acidic soil, increasing organic carbon () and potassium content () over control soil and also producing good quality potato with higher dry matter content, higher specific gravity, higher starch content and lower total soluble solid content over control soil. From this experiment biochar level @ 10 t ha^{-1} showed the best performance. For maximizing yield and increased dry matter content, specific gravity and starch content and also decreased total soluble solid. So the Bangladesh potato grower may use biochar for increasing yield and quality of potato in addition to conventional fertilizer management practices.

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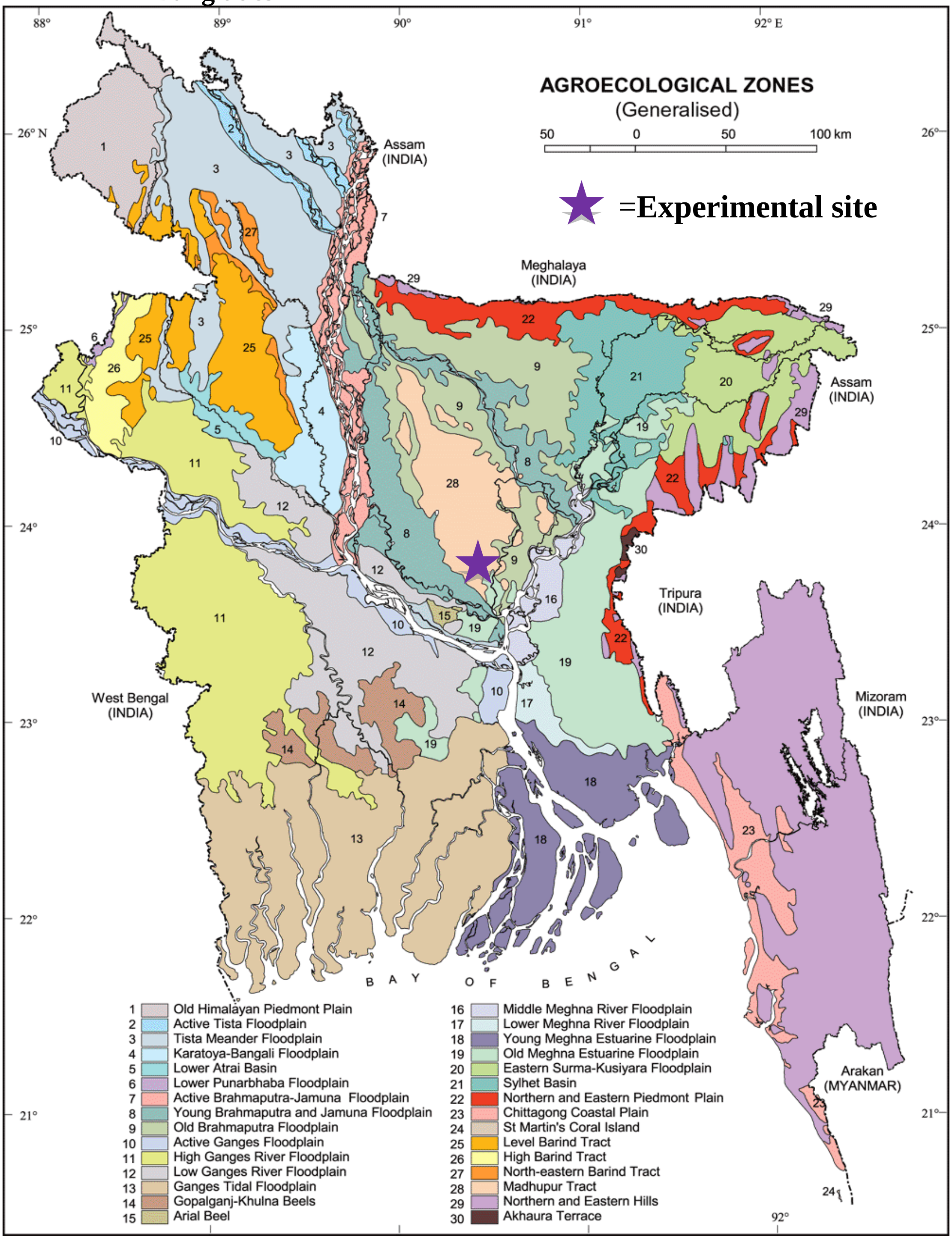
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total weeding (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Appendix III. Monthly meteorological information during the period from November, 2017 to April, 2018

	Month	Air temperature (^{0}C)	Relative humidity	Total rainfall

		Maximum	Minimum	(%)	(mm)
2017	November	28.89	11.88	56.58	51
	December	25.13	8.98	69.85	1.21
2018	January	23.97	9.28	71.09	Trace
	February	25.12	13.89	76.99	Trace
	March	29.21	14.09	75.89	1.01
	April	30.85	16.96	65.98	63.00

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV.Analysis of variance of the data on number of stem hill^{-1} of potato as influenced by combined effect of different varieties and biochar levels

Source of variation	df	Mean square of number of stem hill^{-1} at different days after planting (DAP)		
		25	45	65
Replication	2	0.54	0.46	0.62
Variety(A)	2	11.39*	12.03*	8.20*
Biochar (B)	4	5.91*	7.68*	6.34*
Variety (A) X Biochar (B)	8	0.07*	0.17*	0.27*
Error	28	0.29	0.36	0.31

*Significant at 5% level of significance
^{NS} Non significant

Appendix V. Analysis of variance of the data on number of leaves hill^{-1} of potato as influenced by combined effect of different varieties and biochar levels

Source of variation	df	Mean square of number of leaves hill^{-1} at different days after planting (DAP)		
		25	45	65
Replication	2	39.52	124.71	100.86
Variety(A)	2	170.22*	72.26*	362.42*
Biochar (B)	4	304.86*	198.87*	544.56*
Variety (A) X Biochar (B)	8	33.70*	110.91*	82.06*
Error	28	27.22	26.21	34.08

*Significant at 5% level of significance
^{NS} Non significant

Appendix VI.Analysis of variance of the data on yield characters of potato as influenced by combined effect of different varieties and biochar levels

Source of variation	df	Mean square of				
		Potato yield	Marketable potato yield	Non marketable potato yield	Seed potato yield	Non seed potato yield

Replication	2	40.37	46.24	0.26	14.96	0.22
Variety(A)	2	68.13*	16.07*	1.15*	13.78*	70.81*
Biochar (B)	4	55.66*	20.18*	0.61*	32.49*	1.00*
Variety (A) X Biochar (B)	8	0.57*	0.22*	0.74*	0.75*	1.00*
Error	28	3.83	1.72	0.13	2.42	0.04

*Significant at 5% level of significance
NS Non significant

Appendix VII.Analysis of variance of the data on yield characters of potato as influenced by combined effect of different varieties and biochar levels

Source of variation	df	Mean square of		
		Grade'A' Potato yield	Grade'B' potato yield	Grade'C' potato yield
Replication	2	0.01	0.39	1.76
Variety(A)	2	80.03*	45.78*	111.35*
Biochar (B)	4	4.77*	3.95*	21.45*
Variety (A) X Biochar (B)	8	0.56*	0.48*	4.56*
Error	28	0.07	0.22	1.61

*Significant at 5% level of significance
NS Non significant

Appendix VIII.Analysis of variance of the data on yield characters of potato as influenced by combined effect of different varieties and biochar levels

Source of variation	df	Mean square of			
		Dehydrated potato yield	French fry potato yield	Chips potato yield	Canned potato yield
Replication	2	0.93	0.06	0.45	0.06
Variety(A)	2	14.2*	93.08*	47.96*	50.14*
Biochar (B)	4	6.20*	0.95*	10.66*	6.12*
Variety (A) X Biochar (B)	8	5.11*	0.95*	0.33*	0.46*
Error	28	0.42	0.10	0.26	0.21

*Significant at 5% level of significance
NS Non significant

Appendix IX.Analysis of variance of the data on yield characters of potato as influenced by combined effect of different varieties and biochar levels

Source of variation	df	Mean square of			
		Percentage of marketable potato	Percentage of non - marketable potato	Percentage of seed potato	Percentage of non-seed potato
Replication	2	129.15	27.50	42.41	0.225
Variety(A)	2	141.13*	234.89*	599.22*	567.468*
Biochar (B)	4	164.93*	144.53*	10.42^{NS}	10.301*
Variety (A) X Biochar (B)	8	6.89*	4.61*	10.42*	10.301*
Error	28	49.04	14.77	30.19	0.537

*Significant at 5% level of significance
NS Non significant

Appendix X. Analysis of variance of the data on yield characters of potato as influenced by combined effect of different varieties and biochar levels

Source of variation	df	Mean square of		
		Percentage of Grade'A' potato	Percentage of Grade'B' potato	Percentage of Grade'C' potato
Replication	2	0.24	2.46	171.97
Variety(A)	2	562.01*	908.02*	2475.12*
Biochar (B)	4	20.77*	75.37*	70.34*
Variety (A) X Biochar (B)	8	3.90*	8.29*	58.62*
Error	28	0.42	3.85	38.59

*Significant at 5% level of significance
^{NS} Non significant

Appendix XI.Analysis of variance of the data on yield characters of potato as influenced by combined effect of different varieties and biochar levels

Source of variation	df	Mean square of				
		Percentage of potato dry matter	Percentage of dehydrated potato	Percentage of French fry potato	Percentage of chips potato	Percentage of canned potato
Replication	2	1.61	5.39	0.28	2.54	99.02
Variety(A)	2	5.73*	154.01*	635.82*	808.44*	1985.68*
Biochar (B)	4	35.58*	53.63*	7.59*	237.35*	648.17*
Variety (A) X Biochar (B)	8	0.44*	32.15*	7.59*	12.75*	45.09*
Error	28	0.27	17.19	0.68	6.70	12.99

*Significant at 5% level of significance
^{NS} Non significant

Appendix XII.Analysis of variance of the data on yield characters of potato as influenced by combined effect of different varieties and biochar levels

Source of variation	df	Mean square of			
		Potato firmness	Specific gravity	Total soluble sugar	Starch content on potato
Replication	2	47.04	0.00	0.08	0.36
Variety(A)	2	133.15*	0.00[NS]	0.35[NS]	1.23*
Biochar (B)	4	47.36*	0.002*	1.00*	7.39*
Variety (A) X Biochar (B)	8	1.93*	0.00*	0.01*	0.08*
Error	28	9.576	0.00	0.22	0.19

*Significant at 5% level of significance
[NS] Non significant

Appendix XIII.Analysis of variance of the data on soil characters in potato fieldas influenced by combined effect of different varieties and biochar levels

Source of variation	df	Mean square of			
		pH	Organic carbon	Nitrogen content	Potassium content
Replication	2	0.001	0.000	0.00	0.000
Variety(A)	2	0.041*	0.025*	0.00[NS]	0.000*
Biochar (B)	4	1.010*	0.201*	0.00 [NS]	0.011*
Variety (A) X Biochar (B)	8	0.035*	0.006*	0.00 [NS]	0.000*
Error	28	0.001	0.001	0.00	0.000

*Significant at 5% level of significance
[NS] Non significant