EFFECT OF BIOCHAR AND VERMICOMPOST ON YIELD AND QUALITY OF EXPORT AND PROCESSING POTATO

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EFFECT OF BIOCHAR AND VERMICOMPOST ON YIELD AND QUALITY OF EXPORT AND PROCESSING POTATO

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CERTIFICATE

*This is to certify that thesis entitled, "**EFFECT OF BIOCHAR AND VERMICOMPOST ON YIELD AND QUALITY OF EXPORT AND PROCESSING POTATO**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **MD. REZAUL KARIM**, Registration no. **18-09204** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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Effect of Biochar and Vermicompost On Yield and Quality of Export and Processing Potato

ABSTRACT

The field experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka from November 2019 to February 2020 in Rabi season to find out the effect of biochar and vermicompost on yield and quality of export and processing potato. The experiment had two factors. Factor A: Biochar: 4 levels; B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10.00 t ha^{-1} and Factor B: Vermicompost: 4 levels; V_1: 2.50 t ha^{-1}, V_2: 5.00 t ha^{-1}, V_3: 7.50 t ha^{-1} and V_4: 10.00 t ha^{-1}. The variety was BARI Alu-29 (Courage). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three (3) replications. The different levels of biochar and vermicompost individually and in combination had significant effect on most of the growth, yield and quality contributing parameters of potato. Most of the parameters studied in this experiment were increased with the increasing biochar and vermicompost levels. The biochar level of 7.5 t ha^{-1} produced the maximum yield per plant (270.915 g) whereas, the lowest yield per plant (217.33 g) was obtained from 2.50 t ha^{-1} of biochar application. Similarly, the highest yield $plant^{-1}$ (270 g) was achieved from 10.0 t ha^{-1} of vermicompost application whereas, the lowest yield $plant^{-1}$ (223.42 g) was found from 2.50 t ha^{-1} of vermicompost application. Among the 16 treatment combinations, the maximum average tuber weight (26.60 g) was produced in B_3V_4 while the minimum average tuber weight (17.36 g) was observed in B_1V_1 treatment. The highest tuber yield (292.00 g) was recorded in B_3V_4 treatment combination. The highest marketable yield (262.80 g) was recorded in B_3V_4 combination treatment. In case of dry matter and starch content, biochar @ 10 t ha^{-1} produced the best performance compared to other doses when 10 t ha^{-1} of vermicompost were applied in combination. Although the application of 10 ha^{-1} biochar and 10 ha^{-1} vermicompost showed the maximum yield and quality attributes but the combination of 7.5 ha^{-1} biochar and 7.5 ha^{-1} vermicompost is suitable for producing higher yield and good quality potato. So, this combination could be recommended for getting higher tuber yield,good quality and economically more profitable for farmers.

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LIST OF ABBREVIATIONS

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

LIST OF ABBREVIATIONS

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

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) popularly known as alu 'The king of vegetable', is a tuber crop under the family of Solanaceae. It originated in the central Andean area of South America (Keeps, 1979). It is the fourth world crop after wheat, rice and maize. Bangladesh is the eighth potato producing country in the world. In Bangladesh, potato ranks 2nd after rice in production (FAOSTAT, 2019). The total area under potato crop, national average yield and total production in Bangladesh are 4,61,317 hectares, 20.822 t ha^{-1} and 96,05,624 metric tons, respectively (BBS, 2020). It is a staple diet in European countries and its utilization both in processed and fresh food form is increasing considerably in Asian countries. The yield of potato in Bangladesh is very low (19.36 t ha^{-1}) in comparison to that of the other leading potato growing countries of the world, 50.63 t ha^{-1} in Kuwait, 41.01 t ha^{-1} in Belgium, 41.32 t ha^{-1} in France, 50.30 t ha^{-1} in USA, 42.48 t ha^{-1} in Denmark and 36.47 t ha^{-1} in UK (FAOSTAT, 2019).

Bangladesh has a great agro-ecological potential of growing potato. Potato has a great importance in rural economy in Bangladesh. It is not only a cash crop but also an alternative food crop compares to rice and wheat. The area and production of potato in Bangladesh has been increasing during the last decades but the yield per unit area did not change. The organic matter of most of the soils of Bangladesh is below 2% as compared to an ideal minimum value 4% (Bhuiyan, 1994). The application of chemical fertilizer is badly affecting the texture and structure of the soil, decreasing soil organic matter and hampering soil microorganism activity and soil health (Brady, 1990).

The price of inorganic fertilizers is ever increasing day by day. So, the integrated application of inorganic and organic fertilizers, usually termed integrated nutrient management, is widely recognized as a way of enhancing yield and or improving productivity of the soil sustainability. Integrated use of chemical

fertilizers and some of organic source such as cow dung, vermicompost, farm yard manure (FYM), biochar that can increase the effectiveness of fertilizers, yield of potato and may improve soil physical properties. Biochar is the solid product of pyrolysis, which is to be used for environmental management and increase crop production. It is a solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment. Biochar application to soils can potentially aid mitigation of climate change by sequestering carbon (C). (Yamato *et al.,* 2006) revealed that biochar can lead to changes in physical and chemical properties of the soil that resulted in the increased nutrient availability in the soil and increase plant root colonization by mycorrhizal fungi. Biochar additions to agricultural soil have been reported to climate gas emission, as well as improve soil fertility and crop productivity (Lehmann *et al.,* 2003). In addition, biochar also reduces emissions of other greenhouse gases from soil such as nitrous oxide (N_2O) and methane (CH_4) (Rondon et al., 2005). Biochar addition can develop plant productivity directly because of its nutrient content and release characteristics, or indirectly, through improved nutrient conservation.

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

Biochar increase N availability into the soil, reduce leaching loss of N by retaining water. Mineralization of N could be enhanced by application of biochar

derived from slow pyrolysis rather than fast pyrolysis (Bruun et al., 2012). Nitrogen is of more important for plant growth due to being a part of amino acid, protein and chlorophyll molecule.

Vermicompost amendments improve the humification, increase microbial activity and enzymatic production, which, in turn, increase the aggregate stability of soil particle resulting in higher aeration (Tisdale and Oades, 1982). Organic matter has a property of binding mineral particles like magnesium, calcium and potassium in form of colloids of humus and clay, facilitating stable aggregates of soil particles for desired porosity to sustain plant growth. Soil microbial biomass and enzyme activity are important indicators of soil improvement because of addition of organic matter (Perucci, 1990). Apart from these, earthworm casting are reported to contain plant growth promoters such as auxins and cytokinins (Krishnamoorthy and Vajranabhaiah, 1986). Vermicompost improves the physical, chemical and biological properties of soil. There is a good evidence that vermicompost promotes growth of plants and it has been found to have a favorable influence on all yield parameters of crops like wheat, paddy and sugarcane (Ismail, 1993).

Potato needs high amount of nitrogen. Therefore, adequate N fertilization is critical for optimizing potato yield and quality (Westermann *et al.*, 1988). Insufficient available N leads to decreased growth, reduced light interception, limited yield and early crop senescence. Various types of nutrient are needed for growth and development of potato. N is important for its growth, development and protein synthesis. Different studies take places on biochar and vermicompost upon vegetables. The yield of tomato fruit was significantly higher in beds with charcoal than without charcoal (Yilangai *et al.*, 2014). Biochar and vermicompost application increased vegetable yields by 4.7–25.5% as compared to farmers' practices (Vinh et al., 2014). Very little work was done with biochar and vermicompost in potato production in Bangladesh. That is why this experiment was set up study to the effect of biochar and vermicompost on growth, yield and quality of potato.

OBJECTIVES

- To observe the effect of biochar and/or vermicompost on yield and quality of potato.

CHAPTER II

REVIEW OF LITERATURE

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

2.1 Review on effect of biochar on plant growth parameter

2.1.1 Plant height

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

Nair *et al.* (2014) conducted an experiment to assess the effect of biochar application in potato production. Four application rates of biochar (0, 2.50, 5.0, or 10.0 t $acre^{-1}$, 0 t $acre^{-1}$ was referred to as control) were applied by hand on April 12, 2012. Each plot was measured 15 ft. by 30 ft. Experimental design was randomized complete block design with four replications. The researchers

observed that the tallest plant (47.60 cm) was recorded from 10 t acre^{-1} biochar treated plot. On the other hand, the shortest plant (45.70 cm) was recorded from control plot (no biochar application).

2.1.2 Number of stems hill^{-1}

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

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and four amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). The result of the experiment revealed that, the maximum number of stem hill^{-1} (4.78) was recorded from Cara potato variety and the minimum number of stem hill^{-1} (4.27) was recorded from Accent potato variety. On the other hand, the maximum number of stem hill^{-1} (6.11) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the minimum number of stem hill^{-1} (3.11) was recorded from control plot (no biochar).

2.1.3 Number of leaves plant^{-1}

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and four amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). The result of the experiment revealed that, the maximum number of leaves plant^{-1} (58.90) was recorded from Cara potato variety and the minimum number of leaves plant^{-1} (55.12) was recorded from Accent potato variety. The maximum number of leaves plant^{-1} (70.74) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the minimum number of leaves plant^{-1} (42.90) was recorded from control plot (no biochar).

2.2 Review on effect of biochar on plant yield contributing parameter

2.2.1 Number of tubers per hill or per unit area

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

Nair *et al.* (2014) conducted an experiment to assess the effect of biochar application in potato production. Four application rates of biochar (0, 2.50, 5.0, or 10.0 t $acre^{-1}$, 0 t $acre^{-1}$ was referred to as control) were applied by hand. The

researchers observed that the highest number of marketable tuber (242 tubers m^{-2}) was recorded from 10 t $acre^{-1}$ biochar treated plot. On the other hand, the lowest number of marketable tuber (227 tubers m^{-2}) was reported from control plot (no biochar application).

2.2.2 Weight of tuber per hill

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

2.3 Review on effect of biochar on plant yield parameter

2.3.1 Potato yield

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

parameters and it produced the maximum potato yield (27.33 t ha^{-1}). However, in case of yield, V_3B_4, V_3B_3 and V_3B_2 treatment combinations were statistically similar. Whereas no biochar (B_0) treatment showed the lowest values irrespective of varieties. It was concluded that biochar level @ 5.00 t ha^{-1} would be beneficial for maximizing yield.

Ali (2017) carried out an experiment in Rabi season to observe the effect of biochar on the yield and quality of potato and to find out the optimum dose of biochar along with inorganic fertilizer. The experiment was comprised of 8 treatments; those were, T_1 = Control, T_2 = RFD (Recommended Fertilizer Dose), T_3 = RFD + Biochar @ 5 ton ha^{-1}, T_4 = RFD + Biochar @ 10 ton ha^{-1}, T_5 = ⅔ of RFD + Biochar @ 5 ton ha^{-1}, T_6 = ⅔ of RFD + Biochar @ 10 ton ha^{-1}, T_7 = ½ of RFD + Biochar @ 5 ton ha^{-1} and T_8 = ½ of RFD + Biochar @ 10 ton ha^{-1}. The tested variety was BARI ALU-7 (Daimant). Results showed a significant variation among the treatments in respect majority of the observed parameters. The maximum yield of tubers (34.10 t ha^{-1}) was produced from RFD + Biochar @ 5 t ha^{-1} treatment. The minimum yield of tubers (16.60 t ha^{-1}) was produced from control treatment.

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

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

2.3.2 Weight of marketable potato yield

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

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and four amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). The result of the experiment revealed that, the highest marketable potato yield (12.411 t fed^{-1}) was recorded from 'Cara' potato variety and the lowest marketable potato yield (11.949 t fed^{-1}) was recorded from 'Accent' potato variety. The highest marketable potato yield

(13.325 t fed^{-1}) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the lowest marketable potato yield (10.835 t fed^{-1}) was recorded from control plot (no biochar).

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

2.3.3 Weight of non-marketable potato yield

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

2.3.4 Grade 'A' potato yield

Das (2018) conducted an experiment to evaluate the effect of variety and biochar on yield and some quality parameters of potato along with soil properties. The experiment was consisted of two factors, *i.e.,* factor A: Potato varieties (3): V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); factor B: Biochar level (5): B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t

ha^{-1} and B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}. The investigation revealed that biochar had significant effect on most of the growth, yield and quality contributing parameters of potato studied in this experiment. Results showed that growth, yield and quality contributing parameters of potato increased with increasing biochar level. Among the fifteen treatment combinations, Asterix with biochar level 10 t ha^{-1} performed superior than other combination in most of the parameters and it produced the maximum grade 'A' potato yield (6.35 t ha^{-1}). Whereas no biochar (B_0) treatment showed the lowest values irrespective of varieties.

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The experiment included 12 treatments, which were the combinations between three cultivars of potato *viz.*, Accent, Cara, and Spunta and four amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). These treatments were arranged in a split plot design with 3 replicates. The result of the experiment revealed that, the highest grade 'A' (tuber above 55 mm diameter) potato yield (2.067 t fed^{-1}) was recorded from 'Accent' potato variety and the lowest grade 'A' potato yield (1.808 t fed^{-1}) was recorded from Cara potato variety. The highest grade 'A' potato yield (2.279 t fed^{-1}) was recorded from control plot (no biochar) and the lowest grade 'A' potato yield (1.713 t fed^{-1}) was recorded from 5.00 m^3 fed^{-1} biochar treated field.

2.3.5 Grade 'B' potato yield

Das (2018) conducted an experiment to evaluate the effect of variety and biochar on yield and some quality parameters of potato along with soil properties. The experiment was consisted of two factors, *i.e.,* factor A: Potato varieties (3): V_1: BARI Alu-29 (Courage), V_2: BARI Alu-28 (Lady Rosetta) and V_3: BARI Alu-25 (Asterix); factor B: Biochar level (5): B_0: 0 t ha^{-1}, B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1} and B_3: 7.50 t ha^{-1} and B_4: 10 t ha^{-1}. The investigation revealed that biochar

had significant effect on most of the growth, yield and quality contributing parameters of potato studied in this experiment. Results showed that growth, yield and quality contributing parameters of potato increased with increasing biochar level. Among the fifteen treatment combinations, Asterix with biochar level 10 t ha^{-1} performed superior than other combination in most of the parameters and it produced the maximum grade 'B' potato yield (6.28 t ha^{-1}). However, in case of yield, V_3B_4, V_3B_3 and V_3B_2 while in case of dry matter content, V_3B_3, V_3B_2 and V_2B_4 combinations were statistically similar. Whereas no biochar (B_0) treatment showed the lowest values irrespective of varieties.

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and 4 amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). These treatments were arranged in a split plot design with 3 replicates. The result of the experiment revealed that, the highest grade 'B' (tubers with diameter between 35–54 mm) potato yield (10.603 t fed^{-1}) was recorded from 'Cara' potato variety while the lowest grade 'B' potato yield (9.88 t fed^{-1}) was recorded from 'Accent' potato variety. The highest grade 'B' potato yield (11.612 t fed^{-1}) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the lowest grade 'B' potato yield (8.556 t fed^{-1}) was recorded from control plot (no biochar).

2.3.6 Grade 'C' potato yield

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and four amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). The result of the experiment revealed that,

the highest grade 'C' (tubers with diameter less than 35 mm,) potato yield (3.261 t fed^{-1}) was recorded from 'Spunta' potato variety and the lowest grade 'C' potato yield (2.961 t fed^{-1}) was recorded from 'Accent' potato variety. The highest grade 'C' potato yield (3.698 t fed^{-1}) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the lowest grade 'C' potato yield (2.414 t fed^{-1}) was recorded from control plot (no biochar).

2.4 Review on effect of biochar on qualitative parameter

2.4.1 Dry matter content in potato

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

Ali (2017) carried out an experiment in Rabi season to observe the effect of biochar on the yield and quality of potato and to find out the optimum dose of biochar along with inorganic fertilizer. The experiment was comprised of 8 treatments; those were, T_1 = Control, T_2 = RFD (Recommended Fertilizer Dose),

T_3 = RFD + Biochar @ 5 ton ha^{-1}, T_4 = RFD + Biochar @ 10 ton ha^{-1}, T_5 = ⅔ of RFD + Biochar @ 5 ton ha^{-1}, T_6 = ⅔ of RFD + Biochar @ 10 ton ha^{-1}, T_7 = ½ of RFD + Biochar @ 5 ton ha^{-1} and T_8 = ½ of RFD + Biochar @ 10 ton ha^{-1}. The tested variety was BARI ALU-7 (Daimant). Results showed a significant variation among the treatments in respect majority of the observed parameters. The maximum value of quality parameter like percentage of dry matter content (23.41) was recorded from RFD + Biochar @ 5-ton ha^{-1} treatment.

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

2.4.2 Total soluble sugar

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

level 10 t ha^{-1} performed superior than other combination in most of the parameters and it produced the maximum total soluble sugar content (5.07° Brix).

2.4.3 Specific gravity

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

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

Youseef *et al.* (2017) carried out an investigation during the summer season of 2017 to study the effect of biochar addition on the production of some potato cultivars (Accent, Cara and Spunta) grown in sandy soil conditions. The experiment included 12 treatments, which were the combinations between three cultivars of potato *viz*., Accent, Cara, and Spunta and 4 amounts of biochar (0.00, 1.25, 2.50, and 5.00 m^3 fed^{-1}). These treatments were arranged in a split plot design with 3 replicates. The result of the experiment revealed that, the highest specific gravity (1.079 g cm^{-3}) was recorded from 'Spunta' potato variety and the lowest specific gravity (1.053 g cm^{-3}) was recorded from 'Accent' potato variety. The highest specific gravity (1.074 g cm^{-3}) was recorded from 5.00 m^3 fed^{-1} biochar treated field and the lowest specific gravity (1.069 g cm^{-3}) was recorded from control plot (no biochar).

2.5 Review on effect of vermicompost on plant growth parameter

2.5.1 Days to emergence

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz*., Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3 - (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz*., V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. Among the 16 treatment combinations, the minimum duration for first emergence (14 days) was recorded from the combination of BARI Alu-28 and vermicompost level 6 t ha^{-1} treatment which was statistically similar with V_3Vm_4 (14.33 days), whereas, the maximum duration for first emergence (18 days) was recorded from the combination of BARI TPS-1 and control (0 t ha^{-1}). The minimum duration for final emergence (16.17 days) was recorded from the combination of BARI Alu-28 and vermicompost level 6 t ha^{-1} treatment. The maximum duration for final

emergence (24.33 days) was recorded from the combination of BARI TPS-1 and control (0 t ha^{-1}) which was statistically similar with V_1Vm_2 (24.33 days).

Islam (2015) carried out an experiment to evaluate the effect of vermicompost on growth and yield of potato. The experiment was consisted of two factors *viz.*, Factor A: three varieties (V_1 = Diamant, V_2 = Cardinal and V_3 = Lady Rosetta) and Factor B: four levels of vermicompost (T_0 = Control, T_1 = Vermicompost at 6 t ha^{-1}, T_2 = Vermicompost at 8 t ha^{-1} and T_3 = Vermicompost at 10 t ha^{-1}). Results revealed that variety and vermicompost individually and their interaction had significant effect on all growth parameters and yield contributing characters of potato. The minimum days to 100% emergence (13.70 days) was found from the treatment combination of V_3T_2 (Lady Rosetta with vermicompost @ 8 t ha^{-1}). Result revealed that the maximum days to 100% emergence (16.30 days) was recorded from V_1T_0 (Diamant with no vermicompost).

2.5.2 Plant height

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz.*, Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3 - (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz.*, V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. BARI Alu-28 cultivated with vermicompost 6 t ha^{-1} performed the best results and the same variety with 4 t ha^{-1} also showed the statistically similar results in terms of growth, most of the yield and quality parameters. Among the 16 treatment combinations, the tallest plant (79.17 cm) was recorded from BARI Alu-28 (Lady Rosetta) with 6 t ha^{-1} of vermicompost application (V_1Vm_4).

Islam (2015) carried out an experiment to evaluate the effect of vermicompost on growth and yield of potato. The experiment was consisted of two factors *viz.*, Factor A: three varieties (V_1 = Diamant, V_2 = Cardinal and V_3 = Lady Rosetta)

and Factor B: four levels of vermicompost (T_0 = Control, T_1 = Vermicompost at 6 t ha^{-1}, T_2 = Vermicompost at 8 t ha^{-1} and T_3 = Vermicompost at 10 t ha^{-1}). Results revealed that variety and vermicompost individually and their interaction had significant effect on all growth parameters and yield contributing characters of potato. The tallest plant (62.6 cm) was recorded from V_2T_3 treatment combination (Cardinal with vermicompost @ 10 t ha^{-1}).

Shirzadi (2015) carried out a study to evaluate the use of organic fertilizers (vermicompost and chicken manure) on plant's height, number and weight of micro tuber Marfona cultivator potato (diameter of 25 to 35 mm). The experiment was comprised of 2 factors: vermicompost in 4 levels (0, 3, 6 and 9 t ha^{-1}) and chicken manure in 4 levels (0, 10, 12 and 14 t ha^{-1}). The result showed that with increasing level of vermicompost fertilizer, plant's height was reduced.

Yourtchi *et al.* (2013) conducted an experiment to study the effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato (cv. Agria). The experimental factors included nitrogen fertilizer with three levels (50, 100 and 150 kg ha^{-1} as urea) and vermicompost with 4 levels *viz*., 0 (control), 4.50, 9, and 12 t ha^{-1}. Results illustrated that the highest value of plant height was found from application of 150 kg N ha^{-1}. Data also demonstrated that vermicompost application @ 12 t ha^{-1} promoted all other traits except plant height in comparison to control treatment.

Venkatasalam *et al*. (2012) conducted a study with FYM and vermicompost for different Indian potato cultivars to compare their effect on potato seed production. Uniform size (20–25 g) sprouted virus free buffer stock tubers of Indian potato cultivars viz., Kufri Ashoka, Kufri Badshah, Kufri Bahar, Kufri Chandramukhi, Kufri Chipsona-1, Kufri Chipsona-2, Kufri Kanchan, Kufri Lalima, Kufri Lauvkar and Kufri Pukhraj were planted (2–3 cm depth) in pots (20 × 20 cm) $^3/_4$th filled with two different organic manures in the ratio of 2:1. The approximate quantity of FYM and vermicompost used per pot was about 300 and 200 g, respectively. The recommended dose of NPK fertilizers (120

N:100 P_2O_5:100 K_2O kg ha^{-1}) was applied in two split doses, 50% N, 100% P and 100% K at the time of planting and remaining 50% of N 45 days after planting (DAP). Results indicated that the plant height was significantly affected by organic manures and varieties. Organic manures significantly influenced the plant height, FYM enhanced the plant height in Kufri Ashoka, Kufri Bahar, Kufri Chandramukhi, Kufri Chipsona-2, Kufri Lalima, Kufri Lauvkar and Kufri Pukhraj; whereas, vermicompost increased the plant height in Kufri Badshah. However, organic manures had no effect on plant height of Kufri Kanchan.

2.5.3 Number of stems $hill^{-1}$

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz*., Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3 - (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz*., V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. Among the 16 treatment combinations, the maximum number of stems $hill^{-1}$ (5.66) was measured from V_3Vm_2 combination (Courage with 2 t ha^{-1} of vermicompost).

Islam (2015) carried out an experiment to evaluate the effect of vermicompost on growth and yield of potato. The experiment was consisted of two factors *viz.*, Factor A: three varieties (V_1 = Diamant, V_2 = Cardinal and V_3 = Lady Rosetta) and Factor B: four levels of vermicompost (T_0 = Control, T_1 = Vermicompost at 6 t ha^{-1}, T_2 = Vermicompost at 8 t ha^{-1} and T_3 = Vermicompost at 10 t ha^{-1}). Results revealed that variety and vermicompost individually and their interaction had significant effect on all growth parameters and yield contributing characters of potato. The number of main stem $hill^{-1}$ of potato (4.80) was achieved from V_2T_3 treatment combination (Cardinal with Vermicompost @10 t ha^{-1}).

Venkatasalam *et al*. (2012) conducted a study with FYM and vermicompost for different Indian potato cultivars to compare their effect on potato seed

production. Uniform size (20–25 g) sprouted virus free buffer stock tubers of Indian potato cultivars viz., Kufri Ashoka, Kufri Badshah, Kufri Bahar, Kufri Chandramukhi, Kufri Chipsona 1, Kufri Chipsona 2, Kufri Kanchan, Kufri Lalima, Kufri Lauvkar and Kufri Pukhraj were planted (2–3 cm depth) in pots (20 × 20 cm) $^{3}/_{4}$th filled with two different organic manures in the ratio of 2:1. The approximate quantity of FYM and vermicompost used per pot was about 300 and 200 g respectively. The recommended dose of NPK fertilizers (120 N:100 P_2O_5:100 K_2O kg ha^{-1}) was applied in two split doses, 50% N, 100% P and 100% K at the time of planting and remaining 50% of N 45 days after planting (DAP). In general, most of the yield attributing characters of potato was significantly augmented by farmyard manure as compared to vermicompost. Results indicated that the number of stems per plant was significantly influenced by the type of organic manure and not by varieties.

2.5.4 Number of leaves per plant^{-1}

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz*., Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3 - (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz*., V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. Among the 16 treatment combinations, the maximum number of leaves plant^{-1} (62.00) was measured from V_3Vm_2 treatment combination (BARI Alu-29 (Courage) with 2 t ha^{-1} of vermicompost).

Islam (2015) carried out an experiment to evaluate the effect of vermicompost on growth and yield of potato. The experiment was consisted of two factors *viz.*, Factor A: three varieties (V_1 = Diamant, V_2 = Cardinal and V_3 = Lady Rosetta) and Factor B: four levels of vermicompost (T_0 = Control, T_1 = Vermicompost at 6 t ha^{-1}, T_2 = Vermicompost at 8 t ha^{-1} and T_3 = Vermicompost at 10 t ha^{-1}).

Results revealed that variety and vermicompost individually and their interaction had significant effect on all growth parameters and yield contributing characters of potato. The maximum number of leaves plant^{-1} (30.80) was achieved from V_2T_3 treatment combination (Cardinal with Vermicompost @ 10 t ha^{-1}).

Singh and Chauhan (2014) conducted an experiment to observe the impact of organic manures on yield of potato. The results revealed that number of leaves plant^{-1} was higher in treatment (⅓ N-FYM + ⅓ N-Vermicompost + ⅓ N-Neem cake plus agronomic practices).

Yourtchi *et al.* (2013) conducted an experiment to study the effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato (cv. Agria). The experimental factors included nitrogen fertilizer with three levels (50, 100 and 150 kg ha^{-1} as urea) and vermicompost with 4 levels *viz*., 0 (control), 4.5, 9, and 12 t ha^{-1}. Results illustrated that the highest value of leaf area index (LAI) was found from application of 150 kg N ha^{-1}. Data also demonstrated that vermicompost application @ 12 t ha^{-1} promoted leaf area index (LAI) in comparison to control treatment. Furthermore, the interaction effects between different nitrogen rates and vermicompost application significantly improved growth parameters, yield and NPK content of tuber compared with nitrogen and/or vermicompost alone treatments.

Venkatasalam *et al*. (2012) conducted a study with FYM and vermicompost for different Indian potato cultivars to compare their effect on potato seed production. Uniform size (20–25 g) sprouted virus free buffer stock tubers of Indian potato cultivars *viz.,* Kufri Ashoka, Kufri Badshah, Kufri Bahar, Kufri Chandramukhi, Kufri Chipsona-1, Kufri Chipsona-2, Kufri Kanchan, Kufri Lalima, Kufri Lauvkar and Kufri Pukhraj were planted (2–3 cm depth) in pots (20 × 20 cm) $^{3}/_{4}$th filled with two different organic manures in the ratio of 2:1. The approximate quantity of FYM and vermicompost used per pot was about 300 and 200 g respectively. The recommended dose of NPK fertilizers (120 N:100 P_2O_5:100 K_2O kg ha^{-1}) was applied in two split doses, 50% N, 100% P

and 100% K at the time of planting and remaining 50% of N 45 days after planting (DAP). Results indicated that the number of compound leaves per plant was significantly affected by organic manures and varieties.

2.6 Review on effect of vermicompost on plant yield contributing parameter

2.6.1 Number of tuber hill^{-1}

Mostofa (2016) conducted an experiment to assess the effect of vermicompost and tuber size on the yield, specific gravity, dry matter, starch, sugar content, antioxidant and polyphenol activity of potato. The experiment was consisted of two factors, *i.e.*, factor A: - Vermicompost level (Vm-4): Vm_1: 0 t ha^{-1}, Vm_2: 3 t ha^{-1}, Vm_3: 6 t ha^{-1} and Vm_4: 9 t ha^{-1}; factor B: - Tuber size (T-5): T_1: 5–10 g, T_2: 10–20 g, T_3: 20–30 g, T_4: 30–40 g and T_5: >40 g. Results showed that yield and other processing quality parameters increased significantly with increasing vermicompost level irrespective of tuber size. Among the twenty (20) treatment combinations, the maximum number of tubers hill^{-1} (11.57) was recorded from Vm_2T_4.

Ferdous (2015) conducted an experiment to evaluate the effect of variety and vermicompost on the yield, sugar and antioxidant activity of potato and their performance under ambient storage condition. The experiment was consisted of two factors, *i.e.*, Factor A: four potato varieties; V_1: BARI TPS-1, V_2: BARI Alu-28 (Lady Rosetta), V_3: BARI Alu-25 (Asterix) and V_4: BARI Alu-29 (Courage); Factor B: four vermicompost level; M_1: 0 t ha^{-1}, M_2: 2 t ha^{-1}, M_3: 4 t ha^{-1} and M_4: 6 t ha^{-1}. The study revealed that vermicompost had significant effect on most of the yield and quality contributing parameters. Results demonstrated that yield and other parameters increased with increasing vermicompost level. Among the sixteen-treatment combination, Lady Rosetta with vermicompost @ 6 t ha^{-1} showed the maximum no. of tubers hill^{-1} (11.30).

Islam (2015) carried out an experiment to evaluate the effect of vermicompost on growth and yield of potato. The experiment was consisted of two factors *viz.*,

Factor A: three varieties (V_1 = Diamant, V_2 = Cardinal and V_3 = Lady Rosetta) and Factor B: four levels of vermicompost (T_0 = Control, T_1 = Vermicompost at 6 t ha^{-1}, T_2 = Vermicompost at 8 t ha^{-1} and T_3 = Vermicompost at 10 t ha^{-1}). Results revealed that variety and vermicompost individually and their interaction had significant effect on all growth parameters and yield contributing characters of potato. The results obtained in terms of the highest number of tubers $hill^{-1}$ (8.1) was from V_1T_2 treatment combination (Diamant with Vermicompost @ 8 t ha^{-1}).

Shirzadi (2015) carried out a study to evaluate the use of organic fertilizers (Vermicompost and Chicken manure) on the plant's height, number and weight of micro tuber Marfona cultivator potato (diameter of 25 to 35 mm). The experiment was comprised of two factors: vermicompost in 4 levels (0, 3, 6 and 9 t ha^{-1}) and chicken manure in 4 levels (0, 10, 12 and 14 t ha^{-1}). The highest number of tubers with a diameter of 25–35mm belonged to 12 tons chicken manure treatment without vermicompost.

Yourtchi *et al.* (2013) conducted an experiment to study the effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato (cv. Agria). The experimental factors included nitrogen fertilizer with three levels (50, 100 and 150 kg ha^{-1} as urea) and vermicompost with four levels *viz*., 0 (control), 4.5, 9, and 12 t ha^{-1}. Results illustrated that the highest value of total number of tubers was found from application of 150 kg N ha^{-1}. Data also demonstrated that vermicompost application @ 12 t ha^{-1} promoted total number of tubers in comparison to control treatment. Furthermore, the interaction effects between different nitrogen rates and vermicompost application significantly improved growth parameters, yield and NPK content of tuber compared with nitrogen and/or vermicompost alone treatments.

Venkatasalam *et al*. (2012) conducted a study with FYM and vermicompost for different Indian potato cultivars to compare their effect on potato seed production. Uniform size (20–25 g) sprouted virus free buffer stock tubers of

Indian potato cultivars viz., Kufri Ashoka, Kufri Badshah, Kufri Bahar, Kufri Chandramukhi, Kufri Chipsona 1, Kufri Chipsona 2, Kufri Kanchan, Kufri Lalima, Kufri Lauvkar and Kufri Pukhraj were planted (2–3 cm depth) in pots (20 × 20 cm) $^{3}/_{4}$th filled with two different organic manures in the ratio of 2:1. The approximate quantity of FYM and vermicompost used per pot was about 300 and 200 g respectively. The recommended dose of NPK fertilizers (120 N:100 P_2O_5:100 K_2O kg ha^{-1}) was applied in two split doses, 50% N, 100% P and 100% K at the time of planting and remaining 50% of N 45 days after planting (DAP). In general, most of the yield attributing characters of potato was significantly augmented by farmyard manure as compared to vermicompost. The maximum number of tubers per plant was recorded in Kufri Lalima (18.20) with FYM, whereas they were minimum in Kufri Lauvkar (4.80) with vermicompost. The effect of vermicompost on number of tubers per plant was as par with FYM in most of the varieties.

2.6.2 Weight of tuber $hill^{-1}$

Mostofa (2016) conducted an experiment to assess the effect of vermicompost and tuber size on the yield, specific gravity, dry matter, starch, sugar content, antioxidant and polyphenol activity of potato. The experiment was consisted of two factors, *i.e.*, factor A: - Vermicompost level (Vm-4): Vm_1: 0 t ha^{-1}, Vm_2: 3 t ha^{-1}, Vm_3: 6 t ha^{-1} and Vm_4: 9 t ha^{-1}; factor B: - Tuber size (T-5): T_1: 5–10 g, T_2: 10–20 g, T_3: 20–30 g, T_4: 30–40 g and T_5: >40 g. Results showed that yield and other processing quality parameters increased significantly with increasing vermicompost level irrespective of tuber size. Among the twenty (20) treatment combinations, vermicompost at the rate of 9 t ha^{-1} with tuber size >40 g produced the maximum weight of tuber $hill^{-1}$ (671.36 g).

Ferdous (2015) conducted an experiment to evaluate the effect of variety and vermicompost on the yield, sugar and antioxidant activity of potato and their performance under ambient storage condition. The experiment was consisted of two factors, *i.e.*, Factor A: four potato varieties; V_1: BARI TPS-1, V_2: BARI Alu-

28 (Lady Rosetta), V_3: BARI Alu-25 (Asterix) and V_4: BARI Alu-29 (Courage); Factor B: four vermicompost level; M_1: 0 t ha^{-1}, M_2: 2 t ha^{-1}, M_3: 4 t ha^{-1} and M_4: 6 t ha^{-1}. The study revealed that vermicompost had significant effect on most of the yield and quality contributing parameters. Results demonstrated that yield and other parameters increased with increasing vermicompost level. Among the sixteen treatment combinations, Asterix with vermicompost @ 4 t ha^{-1} produced the maximum weight of tuber hill^{-1} (450.20 g).

Islam (2015) carried out an experiment to evaluate the effect of vermicompost on growth and yield of potato. The experiment was consisted of two factors *viz.*, Factor A: three varieties (V_1 = Diamant, V_2 = Cardinal and V_3 = Lady Rosetta) and Factor B: four levels of vermicompost (T_0 = Control, T_1 = Vermicompost at 6 t ha^{-1}, T_2 = Vermicompost at 8 t ha^{-1} and T_3 = Vermicompost at 10 t ha^{-1}). Results revealed that variety and vermicompost individually and their interaction had significant effect on all growth parameters and yield contributing characters of potato. The results obtained in terms of the highest weight of tuber hill^{-1} (343.3 g) was from Diamant with vermicompost @ 8 t ha^{-1} (V_1T_2).

Shirzadi (2015) carried out a study to evaluate the use of organic fertilizers (Vermicompost and Chicken manure) on the plant's height, number and weight of micro tuber Marfona cultivator potato (diameter of 25 to 35 mm). The experiment was comprised of two factors: vermicompost in four levels (0, 3, 6 and 9 t ha^{-1}) and chicken manure in 4 levels (0, 10, 12 and 14 t ha^{-1}). The highest weight of tubers with a diameter of 25–35mm belonged to 12 tons chicken manure treatment without vermicompost.

Yourtchi *et al.* (2013) conducted an experiment to study the effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato (cv. Agria). The experimental factors included nitrogen fertilizer with three levels (50, 100 and 150 kg ha^{-1} as urea) and vermicompost with four levels *viz.*, 0 (control), 4.5, 9, and 12 t ha^{-1}. Results illustrated that the highest value of total tuber weight was found from application of 150 kg N ha^{-1}. Data

demonstrated that vermicompost application @ 12 t ha^{-1} promoted total tuber weight in comparison to control treatment. Furthermore, the interaction effects between different nitrogen rates and vermicompost application significantly improved growth parameters, yield and NPK content of tuber compared with nitrogen and/or vermicompost alone treatments.

Venkatasalam *et al*. (2012) conducted a study with FYM and vermicompost for different Indian potato cultivars to compare their effect on potato seed production. Uniform size (20–25 g) sprouted virus free buffer stock tubers of Indian potato cultivars viz., Kufri Ashoka, Kufri Badshah, Kufri Bahar, Kufri Chandramukhi, Kufri Chipsona 1, Kufri Chipsona 2, Kufri Kanchan, Kufri Lalima, Kufri Lauvkar and Kufri Pukhraj were planted (2–3 cm depth) in pots (20 × 20 cm) $^{3}/_{4}$th filled with two different organic manures in the ratio of 2:1. The approximate quantity of FYM and vermicompost used per pot was about 300 and 200 g respectively. The recommended dose of NPK fertilizers (120 N:100 P_2O_5:100 K_2O kg ha^{-1}) was applied in two split doses, 50% N, 100% P and 100% K at the time of planting and remaining 50% of N 45 days after planting (DAP). In general, most of the yield attributing characters of potato was significantly augmented by farmyard manure as compared to vermicompost. Results indicated that tuber weight was significantly affected by organic manures and varieties. The effect of vermicompost on weight of tuber per plant was inferior compared to FYM. FYM statistically increased per plant tuber yield in almost all the varieties except Kufri Chipsona-2 and the maximum tuber yield per plant was recorded in Kufri Chipsona-1 (132 g).

2.6.3 Average tuber weight (g)

Mostofa (2016) conducted an experiment to assess the effect of vermicompost and tuber size on the yield, specific gravity, dry matter, starch, sugar content, antioxidant and polyphenol activity of potato. The experiment was consisted of two factors, *i.e.*, factor A: - Vermicompost level (Vm-4): Vm_1: 0 t ha^{-1}, Vm_2: 3 t ha^{-1}, Vm_3: 6 t ha^{-1} and Vm_4: 9 t ha^{-1}; factor B: - Tuber size (T-5): T_1: 5–10 g,

T_2: 10–20 g, T_3: 20–30 g, T_4: 30–40 g and T_5: >40 g. Among the twenty (20) treatment combinations, vermicompost at the rate of 9 t ha^{-1} with tuber size >40 g produced the maximum average tuber weight (71.66 g).

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz*., Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3 - (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz*., V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. All parameters studied in this experiment were increased with the increasing vermicompost levels. BARI Alu-28 cultivated with vermicompost 6 t ha^{-1} performed the best results and the same variety with 4 t ha^{-1} also showed the statistically similar results in terms of growth, most of the yield and quality parameters. Among the 16 treatment combinations, the maximum average tuber weight (57.18 g) was produced from BARI Alu-28 (Lady Rosetta) with 6 t ha^{-1} of vermicompost treatment (V_2Vm_4).

Ferdous (2015) conducted an experiment to evaluate the effect of variety and vermicompost on the yield, sugar and antioxidant activity of potato and their performance under ambient storage condition. The experiment was consisted of two factors, *i.e.*, Factor A: four potato varieties; V_1: BARI TPS-1, V_2: BARI Alu-28 (Lady Rosetta), V_3: BARI Alu-25 (Asterix) and V_4: BARI Alu-29 (Courage); Factor B: four vermicompost level; M_1: 0 t ha^{-1}, M_2: 2 t ha^{-1}, M_3: 4 t ha^{-1} and M_4: 6 t ha^{-1}. The study revealed that vermicompost had significant effect on most of the yield and quality contributing parameters. Results demonstrated that yield and other parameters increased with increasing vermicompost level. Among the sixteen treatment combinations, Asterix with vermicompost @ 4 t ha^{-1} produced the maximum average tuber weight (64.31 g).

Venkatasalam *et al*. (2012) conducted a study with FYM and vermicompost for different Indian potato cultivars to compare their effect on potato seed production. Uniform size (20–25 g) sprouted virus free buffer stock tubers of Indian potato cultivars *viz.,* Kufri Ashoka, Kufri Badshah, Kufri Bahar, Kufri Chandramukhi, Kufri Chipsona-1, Kufri Chipsona-2, Kufri Kanchan, Kufri Lalima, Kufri Lauvkar and Kufri Pukhraj were planted (2–3 cm depth) in pots (20 × 20 cm) which were $^{3}/_{4}$th filled with two different organic manures in the ratio of 2:1. The approximate quantity of FYM and vermicompost used per pot was about 300 and 200 g respectively. The recommended dose of NPK fertilizers (120 N:100 P_2O_5:100 K_2O kg ha^{-1}) was applied in two split doses, 50% N, 100% P and 100% K at the time of planting and remaining 50% of N 45 days after planting (DAP). In general, most of the yield attributing characters of potato was significantly augmented by farmyard manure as compared to vermicompost. Results indicated that the average tuber weight was significantly affected by organic manures and varieties.

2.7 Review on effect of vermicompost on plant yield parameter

2.7.1 Potato yield

Mostofa (2016) conducted an experiment to assess the effect of vermicompost and tuber size on the yield, specific gravity, dry matter, starch, sugar content, anti-oxidant and polyphenol activity of potato. The experiment was consisted of two factors, *i.e.,* factor A: - Vermicompost level (Vm-4): Vm_1: 0 t ha^{-1}, Vm_2: 3 t ha^{-1}, Vm_3: 6 t ha^{-1} and Vm_4: 9 t ha^{-1}; factor B: - Tuber size (T-5): T_1: 5–10 g, T_2: 10–20 g, T_3: 20–30 g, T_4: 30–40 g and T_5: >40 g. Results showed that yield and other processing quality parameters increased significantly with increasing vermicompost level irrespective of tuber size. Among the twenty treatment combinations, vermicompost @ 9 t ha^{-1} with tuber size >40 g produced maximum tuber yield (31.33 t ha^{-1}).

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz*., Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3

- (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz.*, V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. BARI Alu-28 cultivated with vermicompost 6 t ha^{-1} performed the best results and the same variety with 4 t ha^{-1} also showed the statistically similar results in terms of growth, most of the yield and quality parameters. Among the 16 treatment combinations, the variety Lady Rosetta produced the highest tuber yield (33.86 t ha^{-1}) when cultivated with 6 t ha^{-1} of vermicompost.

Ferdous (2015) conducted an experiment to evaluate the effect of variety and vermicompost on the yield, sugar and antioxidant activity of potato and their performance under ambient storage condition. The experiment was consisted of two factors, *i.e.*, Factor A: four potato varieties; V_1: BARI TPS-1, V_2: BARI Alu-28 (Lady Rosetta), V_3: BARI Alu-25 (Asterix) and V_4: BARI Alu-29 (Courage); Factor B: four vermicompost levels; M_1: 0 t ha^{-1}, M_2: 2 t ha^{-1}, M_3: 4 t ha^{-1} and M_4: 6 t ha^{-1}. The study revealed that vermicompost had significant effect on most of the yield and quality contributing parameters. Results demonstrated that yield and other parameters increased with increasing vermicompost level. Among the sixteen treatment combinations, Asterix with vermicompost @ 4 t ha^{-1} produced the maximum potato yield (36.01 t ha^{-1}).

Islam (2015) carried out an experiment to evaluate the effect of vermicompost on growth and yield of potato. The experiment was consisted of two factors *viz.*, Factor A: three varieties (V_1 = Diamant, V_2 = Cardinal and V_3 = Lady Rosetta) and Factor B: four levels of vermicompost (T_0 = Control, T_1 = Vermicompost @ 6 t ha^{-1}, T_2 = Vermicompost @ 8 t ha^{-1} and T_3 = Vermicompost @ 10 t ha^{-1}). Results revealed that variety and vermicompost individually and their interaction had significant effect on all growth parameters and yield contributing characters of potato. The results obtained in terms of the highest tuber weight (27.47 t ha^{-1}) was from V_1T_2 treatment combination (Diamant with vermicompost @ 8 t ha^{-1}).

Singh and Chauhan (2014) conducted an experiment to observe the impact of organic manures on yield of potato. On an average treatment [⅓ N-FYM + ⅓ N-Vermicompost + ⅓ N-Neem cake plus agronomic practices for weed and pest control (without chemical)] significantly maximized tuber yield of potato.

Kmetova *et al.* (2013) conducted an experiment to study the effect of different doses application of dry granulated vermicompost on yield parameters of maize (*Zea mays*) and potatoes (*Solanum tuberosum* L.). The experiment with potatoes included seven treatments of fertilization. The first treatment was a control treatment, i.e., without the appliance of dry granulated vermicompost. In treatment second to sixth, increasing doses of vermicompost were applied (3.30; 6.60; 9.90; 13.20 and 19.80 t ha^{-1}, respectively). Through the following doses of granulated vermicompost, 40, 80, 120, 160 and 240 kg ha^{-1} N were applied to the soil. In seventh treatment, not only the granular vermicompost but also the industrial NPK fertilizer (150 kg urea + 200 kg ha^{-1} NPK 15:15:15) was applied. The increasing doses of vermicompost significantly increased the yield of potato tubers.

Yourtchi *et al.* (2013) conducted an experiment to study the effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato (cv. Agria). The experimental factors included nitrogen fertilizer with three levels (50, 100 and 150 kg ha^{-1} as urea) and vermicompost with 4 levels *viz*., 0 (control), 4.5, 9, and 12 t ha^{-1}. Results illustrated that the highest value of fresh weight of tuber and total tuber weight were found from application of 150 kg N ha^{-1}. Data also demonstrated that vermicompost application @ 12 t ha^{-1} promoted fresh weight of tuber and total tuber weight in comparison to control treatment. Furthermore, the interaction effects between different nitrogen rates and vermicompost application significantly improved growth parameters, yield and NPK content of tuber compared with nitrogen and/or vermicompost alone treatments. To gain maximum yield and avoidance of environments pollution, use of 150 kg N ha^{-1} as nitrogen fertilizer and 12 t ha^{-1} of vermicompost application were suggested.

Kumar *et al*. (2012) conducted field experiments in three consecutive summer seasons of 2005 to 2007 to study the effect of integrated nutrient management on soil health and productivity of potato (*Solanum tuberosum* L.) under rainfed condition. The experiment was laid out in a split plot design with eight nutrient management practices (combinations of organic manures *viz.*, farm yard manure (FYM), poultry manure (PM), vermicompost (VC) and inorganic fertilizers in main plots and seed tuber treatment with three biofertilizers (*Azotobactor*, phosphorus solubilizing bacteria (PSB) and *Azotobactor* + PSB) in sub-plots. The results showed that 50% of the recommended dose of NPK through inorganic + 50% recommended dose of nitrogen (RDN) through organic manures (FYM, PM or VC) or 100% recommended dose of NPK through inorganic fertilizers alone favourably influenced the tuber yield of potato compared to other treatments.

Nongmaithem and Pal (2011) carried out a field experiment for two consecutive years to study the growth and yield of potato (*Solanum tuberosum* L.) during Rabi season under different sources of organic nutrients. Application of vermicompost @ 8 t ha^{-1} + biofertilizers in potato (cv. Kufri Jyoti) gave better effect in term of growth, yield as well as the biochemical parameters. There was significant increase in yield by the application of vermicompost @ 8 t ha^{-1} + biofertilizers (20.59 t ha^{-1}) over control (7.37 t ha^{-1}). Application of vermicompost @ 8 t ha^{-1} + biofertilizers showed positive effect on tuber bulking rate of the crop.

Shweta and Sharma (2011) conducted an experiment to find out the influence of vermicompost on the performance of potato in an acid alfisol. Application of organic manures along with chemical fertilizers had a significant effect on tuber and haulm yield. The highest tuber (30.46 t ha^{-1}) and haulm yield (9.04 t ha^{-1}) was recorded from application of 100% NPK + 25 t ha^{-1} vermicompost (VC) and was significantly the higher over sole use of chemical fertilizers. Tuber yield of potato recorded under 100% of recommended dose of NPK without organics (21.39 t ha^{-1}) was at par with 25 t FYM ha^{-1} or 12.50 t VC ha^{-1} applied along

with 75% of recommended dose of NPK thereby, indicating a saving of 25% in NPK.

Ansari (2008) studied the effect of vermicompost application in reclaimed sodic soils on the productivity of potato (*Solanum tuberosum*), spinach (*Spinacia oleracea*) and turnip (*Brassica campestris*). The soil quality was monitored during the experiment followed by productivity. The treatments were 4, 5 and 6 t ha^{-1} of vermicompost as soil application in plots already reclaimed by vermitechnology. The overall productivity of vegetable crops during the two years of the trial was significantly greater in plots treated with vermicompost @ 6 t ha^{-1}. The investigation showed that the requirement of vermicompost for leafy crops like spinach was lower (4 t ha^{-1}), whereas that for tuber crops like potato and turnip was higher (6 t ha^{-1}).

Alam *et al.* (2007) conducted an experiment to study the effect of vermicompost and NPKS fertilizers on growth and yield of potato (cv. Cardinal). There were 12 treatments; *viz.*, control (T_1), vermicompost (VC) 2.50 t ha^{-1} (T_2), VC 5.0 t ha^{-1} (T_3), VC 10.0 t ha^{-1} (T_4), VC 2.50 t ha^{-1} + 50% NPKS (T_5), VC 5.0 t ha^{-1} + 50% NPKS (T_6), VC 10.0 t ha^{-1} + 50% NPKS (T_7), VC 2.50 t ha^{-1} + 100% NPKS (T_8), VC 5.0 t ha^{-1} + 100% NPKS (T_9), VC 10.0 t ha^{-1} + 100% NPKS (T_{10}), 50% NPKS (T_{11}) and 100% NPKS (T_{12}). The doses of N-P-K-S were 90-40-100-18 kg ha^{-1} for potato. Application of vermicompost and NPKS significantly influenced the growth and yield of potato. The treatment T_{10} [VC 10.0 t ha^{-1} + 100% NPKS] produced the highest tuber yield (25.56 t ha^{-1}) of potato. The lowest yield and yield contributing parameters were recorded in control (T_1). Application of various amounts of vermicompost (2.50, 5.0, 10.0 t ha^{-1}) with NPKS fertilizers (50% and 100%) increased the vegetative growth and yield potato. Vermicompost at 2.50, 5.0 and 10 t ha^{-1} with 50% of NPKS increased tuber yield over control by 78.3%, 96.9% and 119.5%, respectively. Moreover, vermicompost at 2.50, 5.0 and 10.0 t ha^{-1} with 100% of NPKS increased tuber yield by 146.8%, 163.1% and 197.9%, respectively. The results indicated that vermicompost (10.0 t ha^{-1}) with NPKS (100%) produced the highest growth and

yield of potato. It was suggested that 100% inorganic fertilizers with 5–10 t ha^{-1} of vermicompost is suitable for better production of potato but 10 t ha^{-1} of vermicompost may not economically profitable.

Sood and Sharma (2001) carried out a field experiment for assessing the utility of growth promoting bacteria, *Azotobacter* and vermicompost for potato production. The results indicated that vermicompost @ 5 t ha^{-1} increased the tuber yield by 34 to 65 q ha^{-1}. The increase in yield was more when optimum NPK dose of fertilizer was applied.

2.7.2 Weight of marketable potato

Mostofa (2016) conducted an experiment to assess the effect of vermicompost and tuber size on the yield, specific gravity, dry matter, starch, sugar content, antioxidant and polyphenol activity of potato. The experiment was consisted of two factors, *i.e.*, factor A: Vermicompost level (Vm-4): Vm_1: 0 t ha^{-1}, Vm_2: 3 t ha^{-1}, Vm_3: 6 t ha^{-1} and Vm_4: 9 t ha^{-1}; factor B: Tuber size (T-5): T_1: 5–10 g, T_2: 10–20 g, T_3: 20–30 g, T_4: 30–40 g and T_5: >40 g. Results showed that yield and other processing quality parameters increased significantly with increasing vermicompost level irrespective of tuber size. Among the twenty treatment combinations, vermicompost @ 9 t ha^{-1} with tuber size >40 g produced the maximum marketable yield (27.59 t ha^{-1}).

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz*., Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3 - (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz*., V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. Among the 16 treatment combinations, the variety Lady Rosetta produced the highest marketable yield (28.78 t ha^{-1}) when cultivated with 6 t ha^{-1} of vermicompost level.

Ferdous (2015) conducted an experiment to evaluate the effect of variety and vermicompost on the yield, sugar and antioxidant activity of potato and their performance under ambient storage condition. The experiment was consisted of two factors, *i.e.*, Factor A: four potato varieties; V_1: BARI TPS-1, V_2: BARI Alu-28 (Lady Rosetta), V_3: BARI Alu-25 (Asterix) and V_4: BARI Alu-29 (Courage); Factor B: four vermicompost level; M_1: 0 t ha^{-1}, M_2: 2 t ha^{-1}, M_3: 4 t ha^{-1} and M_4: 6 t ha^{-1}. The study revealed that vermicompost had significant effect on most of the yield and quality contributing parameters. Among the sixteen treatment combinations, Lady Rosetta with vermicompost @ 6 t ha^{-1} showed the maximum marketable potato yield (30.78 t ha^{-1}).

2.7.3 Weight of non-marketable potato

Mostofa (2016) conducted an experiment to assess the effect of vermicompost and tuber size on the yield, specific gravity, dry matter, starch, sugar content, antioxidant and polyphenol activity of potato. The experiment was consisted of two factors, *i.e.*, factor A: - Vermicompost level (Vm-4): Vm_1: 0 t ha^{-1}, Vm_2: 3 t ha^{-1}, Vm_3: 6 t ha^{-1} and Vm_4: 9 t ha^{-1}; factor B: - Tuber size (T-5): T_1: 5–10 g, T_2: 10–20 g, T_3: 20–30 g, T_4: 30–40 g and T_5: >40 g. Results showed that yield and other processing quality parameters increased significantly with increasing vermicompost level irrespective of tuber size. Among the twenty (20) treatment combinations, the maximum non-marketable yield (4.88 t ha^{-1}) was recorded from Vm_1T_3 (no vermicompost with 20–30 g of tuber).

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz*., Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3 - (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz*., V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. Among the 16 treatment combinations, the maximum non-marketable yield (5.08 t ha^{-1}) was

recorded from V_2Vm_4 treatment combination (BARI Alu-28 (Lady Rosetta) with vermicompost @ 6 t ha^{-1}).

Ferdous (2015) conducted an experiment to evaluate the effect of variety and vermicompost on the yield, sugar and antioxidant activity of potato and their performance under ambient storage condition. The experiment was consisted of two factors *i.e.*, Factor A: four potato varieties; V_1: BARI TPS-1, V_2: BARI Alu-28 (Lady Rosetta), V_3: BARI Alu-25 (Asterix) and V_4: BARI Alu-29 (Courage) and Factor B: four vermicompost levels; M_1: 0 t ha^{-1}, M_2: 2 t ha^{-1}, M_3: 4 t ha^{-1} and M_4: 6 t ha^{-1}. The study revealed that vermicompost had significant effect on most of the yield and quality contributing parameters. Among the sixteen treatment combinations, Asterix with vermicompost @ 4 t ha^{-1} produced the maximum non-marketable potato yield (5.36 t ha^{-1}).

2.7.4 Grade 'A' potato yield

Singh and Chauhan (2014) conducted an experiment to observe the impact of organic manures on yield of potato. On an average treatment [⅓ N- FYM + ⅓ N-Vermicompost + ⅓ N-Neem cake plus agronomic practices for weed and pest control (without chemical)], significantly maximized 'A' grade tuber yield of potato.

2.7.5 Grade 'B' potato yield

Singh and Chauhan (2014) conducted an experiment to observe the impact of organic manures on yield of potato. On an average treatment [⅓ N- FYM + ⅓ N-Vermicompost + ⅓ N-Neem cake plus agronomic practices for weed and pest control (without chemical)], significantly maximized 'B' grade tuber yield of potato.

2.7.6 Grade 'C' potato yield

Singh and Chauhan (2014) conducted an experiment to observe the impact of organic manures on yield of potato. On an average treatment [⅓ N- FYM + ⅓ N-Vermicompost + ⅓ N-Neem cake plus agronomic practices for weed and pest

control (without chemical)], significantly maximized 'C' grade tuber yield of potato.

2.8 Review on effect of vermicompost on qualitative parameter

2.8.1 Dry matter content

Mostofa (2016) conducted an experiment to assess the effect of vermicompost and tuber size on the yield, specific gravity, dry matter, starch, sugar content, antioxidant and polyphenol activity of potato. The experiment was consisted of two factors, *i.e.,* factor A: - Vermicompost level (Vm-4): Vm_1: 0 t ha^{-1}, Vm_2: 3 t ha^{-1}, Vm_3: 6 t ha^{-1} and Vm_4: 9 t ha^{-1}; factor B: - Tuber size (T-5): T_1: 5–10 g, T_2: 10–20 g, T_3: 20–30 g, T_4: 30–40 g and T_5: >40 g. Results showed that yield and other processing quality parameters increased significantly with increasing vermicompost level irrespective of tuber size. Among the twenty (20) treatment combinations, vermicompost @ 9 t ha^{-1} with tuber size >40 g exhibited the highest percentage of dry matter content (22.77%).

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz.*, Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3 - (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz.*, V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. BARI Alu-28 cultivated with vermicompost 6 t ha^{-1} performed the best results and the same variety with 4 t ha^{-1} also showed the statistically similar results in terms of growth, most of the yield and quality parameters. In case of dry matter content, Lady Rosetta showed the best performance compared to those other varieties when 6 t ha^{-1} vermicompost was applied. Among the 16 treatment combinations, the numerically highest dry matter percentage (25.74%) was recorded from V_2Vm_1.

Ferdous (2015) conducted an experiment to evaluate the effect of variety and vermicompost on the yield, sugar and antioxidant activity of potato and their performance under ambient storage condition. The experiment was consisted of two factors, *i.e.*, Factor A: four potato varieties; V_1: BARI TPS-1, V_2: BARI Alu-28 (Lady Rosetta), V_3: BARI Alu-25 (Asterix) and V_4: BARI Alu-29 (Courage); Factor B: four vermicompost level; M_1: 0 t ha^{-1}, M_2: 2 t ha^{-1}, M_3: 4 t ha^{-1} and M_4: 6 t ha^{-1}. The study revealed that vermicompost had significant effect on most of the yield and quality contributing parameters. Among the sixteen treatment combinations, Courage with vermicompost @ 6 t ha^{-1} showed the maximum dry matter content (23.25%).

Islam (2015) carried out an experiment to evaluate the effect of vermicompost on growth and yield of potato. The experiment was consisted of two factors *viz.*, Factor A: three varieties (V_1 = Diamant, V_2 = Cardinal and V_3 = Lady Rosetta) and Factor B: four levels of vermicompost (T_0 = Control, T_1 = Vermicompost at 6 t ha^{-1}, T_2 = Vermicompost at 8 t ha^{-1} and T_3 = Vermicompost at 10 t ha^{-1}). Results revealed that variety and vermicompost individually and their interaction had significant effect on all growth parameters and yield contributing characters of potato. The highest dry weight of haulm $hill^{-1}$ at harvest (39.80 g) was achieved from V_2T_3. The results obtained in terms of highest dry weight of 100 g tuber (23.17 g) was from V_1T_2 treatment combination (Diamant with Vermicompost @ 8 t ha^{-1}).

Singh and Chauhan (2014) conducted an experiment to observe the impact of organic manures on yield of potato. The results revealed that dry matter (g) was higher in treatment (⅓ N-FYM + ⅓ N-Vermicompost + ⅓ N- Neem cake plus agronomic practices).

Kmetova *et al.* (2013) conducted an experiment to study the effect of different doses application of dry granulated vermicompost on yield parameters of maize (*Zea mays*) and potatoes (*Solanum tuberosum* L.). The experiment with potatoes included seven treatments of fertilization. The first treatment was a control

treatment, i.e., without the appliance of dry granulated vermicompost. In treatment second to sixth, increasing doses of vermicompost (3.3; 6.6; 9.9; 13.2 and 19.8 t ha^{-1}, respectively) were applied. Through the following doses of granulated vermicompost, 40, 80, 120, 160, 240 kg ha^{-1} N were applied to the soil. In seventh treatment, not only the granular vermicompost but also the industrial NPK fertilizer (150 kg urea + 200 kg ha^{-1} NPK 15:15:15 was applied. The increasing doses of vermicompost significantly increased the dry matter content in tubers.

Yourtchi *et al.* (2013) conducted an experiment to study the effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato (cv. Agria). The experimental factors included nitrogen fertilizer with three levels (50, 100 and 150 kg ha^{-1} as urea) and vermicompost with 4 levels *viz*., 0 (control), 4.50, 9, and 12 t ha^{-1}. Data demonstrated that vermicompost application @ 12 t ha^{-1} promoted leaf and stem dry weight and fresh and dry weight of tuber in comparison to control treatment. Furthermore, the interaction effects between different nitrogen rates and vermicompost application significantly improved growth parameters, yield and NPK content of tuber compared with nitrogen and/or vermicompost alone treatments.

2.8.2 Total Soluble solid (TSS)

Mostofa (2016) conducted an experiment to assess the effect of vermicompost and tuber size on the yield, specific gravity, dry matter, starch, sugar content, antioxidant and polyphenol activity of potato. The experiment was consisted of two factors, *i.e.*, factor A: - Vermicompost level (Vm-4): Vm_1: 0 t ha^{-1}, Vm_2: 3 t ha^{-1}, Vm_3: 6 t ha^{-1} and Vm_4: 9 t ha^{-1}; factor B: - Tuber size (T-5): T_1: 5–10 g, T_2: 10–20 g, T_3: 20–30 g, T_4: 30–40 g and T_5: >40 g. Results showed that yield and other processing quality parameters increased significantly with increasing vermicompost level irrespective of tuber size. Among the twenty (20) treatment combinations, the maximum total soluble solid (5.72° Brix) of tuber showed by Vm_1T_1, which was statistically similar to Vm_1T_2 and Vm_1T_3.

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz.*, Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3 - (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz.*, V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. BARI Alu-28 cultivated with vermicompost 6 t ha^{-1} performed the best results and the same variety with 4 t ha^{-1} also showed the statistically similar results in terms of growth, most of the yield and quality parameters. Among the 16 treatment combinations, the highest Total Soluble Solid (7.65° Brix) was recorded from BARI Alu-28 (Lady Rosetta) with 6 t ha^{-1} of vermicompost (V_2Vm_4).

Ferdous (2015) conducted an experiment to evaluate the effect of variety and vermicompost on the yield, sugar and antioxidant activity of potato and their performance under ambient storage condition. The experiment was consisted of two factors, *i.e.*, Factor A: four potato varieties; V_1: BARI TPS-1, V_2: BARI Alu-28 (Lady Rosetta), V_3: BARI Alu-25 (Asterix) and V_4: BARI Alu-29 (Courage); Factor B: four vermicompost level; M_1: 0 t ha^{-1}, M_2: 2 t ha^{-1}, M_3: 4 t ha^{-1} and M_4: 6 t ha^{-1}. The study revealed that vermicompost had significant effect on most of the yield and quality contributing parameters. Results demonstrated that yield and other parameters increased with increasing vermicompost level. Among the sixteen treatment combinations, BARI TPS-1 with vermicompost @ 4 t ha^{-1} showed the maximum value (7.80° Brix) for total soluble solids (TSS^o).

2.8.3 Specific Gravity

Mostofa (2016) conducted an experiment to assess the effect of vermicompost and tuber size on the yield, specific gravity, dry matter, starch, sugar content, antioxidant and polyphenol activity of potato. The experiment was consisted of two factors, *i.e.*, factor A: - Vermicompost level (Vm-4): Vm_1: 0 t ha^{-1}, Vm_2: 3 t ha^{-1}, Vm_3: 6 t ha^{-1} and Vm_4: 9 t ha^{-1}; factor B: - Tuber size (T-5): T_1: 5–10 g, T_2: 10–20 g, T_3: 20–30 g, T_4: 30–40 g and T_5: >40 g. Results showed that yield

and other processing quality parameters increased significantly with increasing vermicompost level irrespective of tuber size. Among the twenty (20) treatment combinations, vermicompost at the rate of 9 t ha^{-1} with tuber size >40 g exhibited the highest specific gravity (1.084 g cm^{-3}).

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz*., Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3 - (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz*., V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. Among the 16 treatment combinations, the highest specific gravity (1.150 g cm^{-3}) was recorded from BARI TPS-1 with 4 t ha^{-1} of vermicompost (V_1Vm_3).

Ferdous (2015) conducted an experiment to evaluate the effect of variety and vermicompost on the yield, sugar and antioxidant activity of potato and their performance under ambient storage condition. The experiment was consisted of two factors, *i.e.*, Factor A: four potato varieties; V_1: BARI TPS-1, V_2: BARI Alu-28 (Lady Rosetta), V_3: BARI Alu-25 (Asterix) and V_4: BARI Alu-29 (Courage); Factor B: four vermicompost level; M_1: 0 t ha^{-1}, M_2: 2 t ha^{-1}, M_3: 4 t ha^{-1} and M_4: 6 t ha^{-1}. The study revealed that vermicompost had significant effect on most of the yield and quality contributing parameters. Results demonstrated that yield and other parameters increased with increasing vermicompost level. Among the sixteen treatment combinations, Asterix with vermicompost @ 6 t ha^{-1} showed the highest specific gravity (1.085 g cm^{-3}).

2.8.4 Firmness

Mostofa (2016) conducted an experiment to assess the effect of vermicompost and tuber size on the yield, specific gravity, dry matter, starch, sugar content, antioxidant and polyphenol activity of potato. The experiment was consisted of two factors, *i.e.*, factor A: - Vermicompost level (Vm-4): Vm_1: 0 t ha^{-1}, Vm_2: 3

t ha^{-1}, Vm_3: 6 t ha^{-1} and Vm_4: 9 t ha^{-1}; factor B: - Tuber size (T-5): T_1: 5–10 g, T_2: 10–20 g, T_3: 20–30 g, T_4: 30–40 g and T_5: >40 g. Results showed that yield and other processing quality parameters increased significantly with increasing vermicompost level irrespective of tuber size. Among the twenty (20) treatment combinations, vermicompost at the rate of 9 t ha^{-1} with tuber size >40 g exhibited the highest firmness (44.349 N).

Chandra (2015) conducted a field experiment to find out the effect of four different vermicompost (Vm) levels *viz*., Vm_1 - (control), Vm_2 - (2 t ha^{-1}), Vm_3 - (4 t ha^{-1}) and Vm_4 - (6 t ha^{-1}) on growth, yield and quality of four potato varieties *viz*., V_1 - BARI TPS-1, V_2 - BARI Alu-28 (Lady Rosetta), V_3 - BARI Alu-29 (Courage) and V_4 - BARI Alu-25 (Asterix). The different levels of vermicompost had significant effect on most of the growth, yield and quality contributing parameters of potato irrespective of varieties. Among the 16 treatment combinations, the highest firmness value (46.77 N) was recorded from BARI Alu-28 (Lady Rosetta) with 6 t ha^{-1} of vermicompost (V_2Vm_4).

Ferdous (2015) conducted an experiment to evaluate the effect of variety and vermicompost on the yield, sugar and antioxidant activity of potato and their performance under ambient storage condition. The experiment was consisted of two factors, *i.e.*, Factor A: four potato varieties; V_1: BARI TPS-1, V_2: BARI Alu-28 (Lady Rosetta), V_3: BARI Alu-25 (Asterix) and V_4: BARI Alu-29 (Courage); Factor B: four vermicompost level; M_1: 0 t ha^{-1}, M_2: 2 t ha^{-1}, M_3: 4 t ha^{-1} and M_4: 6 t ha^{-1}. The study revealed that vermicompost had significant effect on most of the yield and quality contributing parameters. Results demonstrated that yield and other parameters increased with increasing vermicompost level. Among the sixteen treatment combinations, Asterix with vermicompost @ 6 t ha^{-1} showed the highest firmness (32.73 N).

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 during the period from 4 November, 2019 to 22 February, 2020.

3.2 Geographical location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter above the sea level.

3.3 Agro-Ecological Region

The experimental site belongs to the agro-ecological zone of "Modhupur Tract", AEZ-28. 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. The experimental site is shown in the map of AEZ of Bangladesh in Appendix I.

3.4 Climate of the experimental site

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

3.5 Soil

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

3.6 Experimental treatments

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

Factor A: Biochar levels (4)

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

ii. B_2: 5.00 t ha^{-1},

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

iv. B_4: 10.00 t ha^{-1}.

Factor B: Vermicompost levels (4)

i. V_1: 2.50 t ha^{-1},

ii. V_2: 5.00 t ha^{-1},

iii. V_3: 7.50 t ha^{-1} and

iv. V_4: 10.00 t ha^{-1}.

Treatment combinations were as B_1V_1, B_1V_2, B_1V_3, B_1V_4, B_2V_1, B_2V_2, B_2V_3, B_2V_4, B_3V_1, B_3V_2, B_3V_3, B_3V_4, B_4V_1, B_4V_2, B_4V_3 and B_4V_4.

3.7 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three (3) replications. Total 48 unit pots were made for the experiment with 16 treatments. Each pot was of required size (Appendix IV).

3.8 Planting material

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

3.9 Collection of tubers

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

3.10 Crop management

3.10.1 Preparation of tuber

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

3.10.2 Pot preparation

The experimental pots (L = 10.50 and D = 9.50 inch) were first filled at 4 November 2019 with 10 kg soil. Potted soil was brought into desirable fine tilth by hand mixing. The stubble and weeds were removed from the soil and then vermicompost was mixed. The final pot preparation was done on 8 November 2019. The soil was treated with insecticides (cinocarb 3G @ 4 kg ha^{-1}) at the time of final pot preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.10.3 Manure and fertilizer application

The 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	250
TSP	150
MoP	250
Gypsum	120
Zinc Sulphate	10
Boric Acid	10

Source: Mondal *et al.*, 2011.

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.

3.10.4 Biochar application

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

3.10.5 Planting of seed tuber

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

3.11 Intercultural operations

3.11.1 Weeding

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

3.11.2 Irrigation

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

3.11.3 Mulching

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

3.11.4 Earthing up

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

3.11.5 Plant protection measures

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

3.11.6 Haulm cutting

Haulm cutting was done at 11 February 2020 at 90 DAS, 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.

3.11.7 Harvesting of potatoes

Harvesting of potato was done on 18 February 2020 at 7 days after haulm cutting. The potatoes of each pot were separately harvested, bagged and tagged and brought to the laboratory. The yield of potato hill^{-1} was determined in gram. Harvesting was done manually by hand.

3.12 Recording of data

The following data were recorded during experimentation period:

i. Days to emergence (DAS),
ii. Plant height (cm),
iii. Number of stems plant^{-1},
iv. Number of leaves plant^{-1},
v. Number of total tuber plant^{-1},
vi. Average tuber weight plant^{-1} (g),
vii. Yield plant^{-1} (g),
viii. Weight of marketable potato plant^{-1} (g),
ix. Weight of non-marketable potato plant^{-1} (g),
x. Number of marketable tuber plant^{-1},
xi. Number of non-marketable tuber plant^{-1},
xii. Tuber dry matter (%),
xiii. Starch (%),
xiv. Reducing sugar (mg g^{-1} FW),
xv. Grading of potato (g plant^{-1}),
xvi. Specific Gravity (g cm^{-3}),
xvii. Potato firmness and
xviii. Total soluble solid content of potato.

3.13 Experimental measurements

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

3.13.1 Days to emergence

After sowing the potato tuber keenly observed the first emergence in each pot twice in a day (morning and afternoon).

3.13.2 Plant height (cm)

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

3.13.3 Number of stems plant^{-1}

Number of stems plant^{-1} was counted at an interval of 15 days starting from 30 DAS up to 60 DAS. It was done by counting total number of stems of all sampled plants then the average data were recorded.

3.13.4 Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at an interval of 15 days starting from 30 DAS up to 60 DAS. It was done by counting total number of leaves of all sampled plants then the average data were recorded.

3.13.5 Number of total tuber plant^{-1}

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

3.13.6 Average tuber weight plant^{-1} (g)

Average tuber weight was measured by using the following formula-

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

3.13.7 Yield plant^{-1} (g)

Tubers of each pot were collected separately from which yield of tuber plant^{-1} was recorded in gram.

3.13.8 Marketable tuber and non-marketable tuber (by weight and by number)

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

3.13.9 Tuber dry matter (%)

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

3.13.10 Starch (%)

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

3.13.11 Reducing sugar

3.13.11.1 Extraction of sugar

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

3.13.11.2 Reducing sugar determination (glucose)

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

3.13.12 Grading of tuber (g plant^{-1})

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

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

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

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

3.13.14 Potato firmness

Fries and crisp texture measurements were performed at room temperature by a puncture test performed in a Texture Analyzer (Sun scientific co. Ltd, Japan) equipped with a wedge probe imitating front teeth. Maximum Force (MF) was defined as the force at which the wedge penetrates the outer layer of the surface of the fried potato fries and crisps slices (Segnini *et al.*, 1999).

3.13.15 Total soluble solids (TSS)

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

3.14 Statistical Analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of biochar and vermicompost on yield and quality of export and processing potato. The results obtained from the study have been presented, discussed and compared in this chapter through tables and figures. The analysis of variance of data in respect of all the parameters has been shown in Appendix V to XII. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings. The analytical results have been presented in Table 1 through Table 15 and Figure 1 through Figure 14.

4.1 Days to emergence (DAS)

4.1.1 Effect of biochar

Days to emergence was significantly influenced by the different biochar levels (Figure 1 and Appendix V). Results revealed that the doses of biochar 2.5 t ha^{-1} (B_1) took the maximum days (11.17 days) for emergence whereas, the minimum (8.58 days) was taken by 10.00 t ha^{-1} (B_4). This result showed that 10.00 t ha^{-1} was the early to emergence dose whereas, 2.5 t ha^{-1} was the late one.

4.1.2 Effect of vermicompost

Significant variation of days to emergence was found due to different vermicompost levels (Figure 2 and Appendix V). Figure 2 showed that duration of emergence decreased with increasing vermicompost levels. The minimum days to emergence (8.58 days) was required in V_4 (10.00 t ha^{-1}) treatment and the maximum (11.42 days) was recorded in V_1 (2.50 t ha^{-1}).

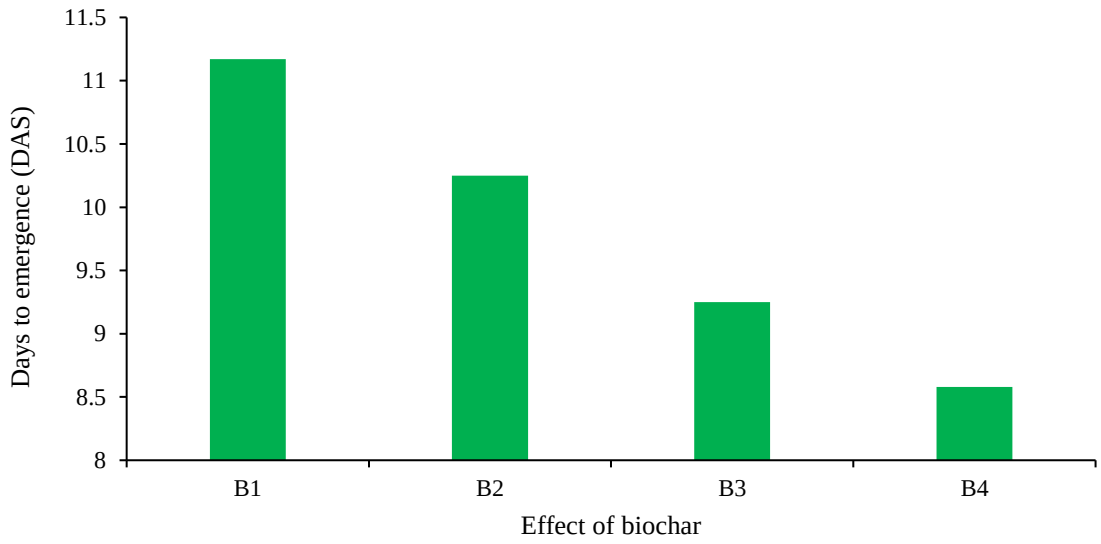

Figure 1: Effect of biochar on days to emergence of potato (LSD value = 0.42) Note: B_1 - 2.5 t ha^{-1}, B_2 - 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1}.

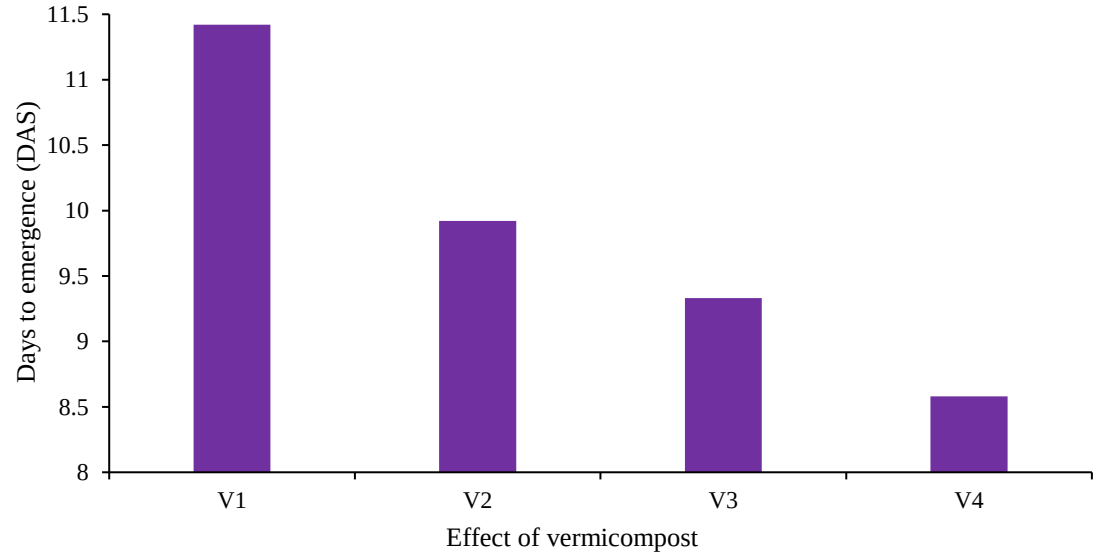

Figure 2: Effect of vermicompost on days to emergence of potato (LSD value = 0.35) Note: V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.1.3 Interaction effect of biochar and vermicompost

Interaction effect of biochar and vermicompost levels significantly influenced the days taken to emergence of potato tubers (Table 1 and Appendix V). The minimum duration for emergence (7.33 days) was recorded from the combination of B_4V_4 (biochar: 10.0 t ha^{-1} and vermicompost: 10.0 t ha^{-1})

treatment whereas, the maximum duration (12.33 days) was recorded from the combination of B_1V_1 (biochar: 2.50 t ha^{-1} and vermicompost: 2.50 t ha^{-1}).

Table 1: Interaction effects of biochar and vermicompost on days to emergence of potato

Treatment combination	Days to emergence (DAS)
B_1V_1	12.33 a
B_1V_2	11.67 b
B_1V_3	10.67 d
B_1V_4	10.00 e
B_2V_1	11.67 b
B_2V_2	10.33 de
B_2V_3	10.00 e
B_2V_4	9.00 f
B_3V_1	11.33 bc
B_3V_2	9.00 f
B_3V_3	8.67 fg
B_3V_4	8.00 h
B_4V_1	10.33 de
B_4V_2	8.67 fg
B_4V_3	8.00 h
B_4V_4	7.33 i
LSD $_{(0.05)}$	**0.35**
CV (%)	**8.34**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1} and V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.2 Plant height (cm)

4.2.1 Effect of biochar

Plant height due to different levels of biochar applications was significantly influenced at days after sowing (DAS) (Figure 3 and Appendix V). The longest plant (55.40, 64.99 and 75.28 cm at 30, 45 and 60 DAS, respectively) was recorded from B_4 (10.0 t ha^{-1}) treatment whereas, the shortest plant (43.46, 53.36 and 61.73 cm at 30, 45 and 60 DAS, respectively) was recorded from B_1 (2.50 t ha^{-1}) treatment. The results were conformity with the findings of Ali (2017).

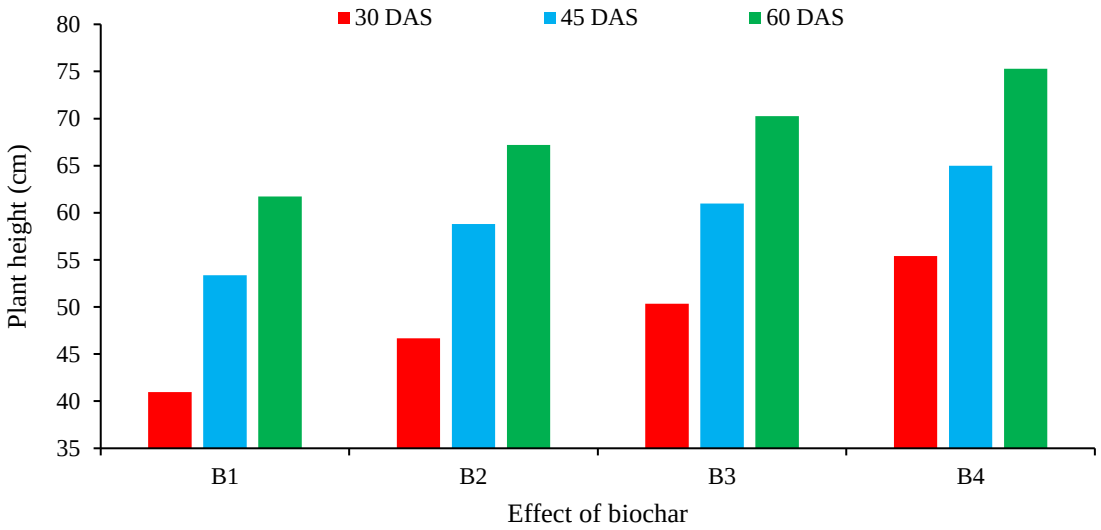

Figure 3: Effect of biochar on plant height of potato (LSD value = 2.69, 1.73 and 2.02 at 30, 45 and 60 DAS, respectively)
Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1}.

4.2.2 Effect of vermicompost

There was significant variation for using different levels of vermicompost on plant height of potato at different DAS (Figure 4 and Appendix V). Results explained that the longest plant (52.75, 63.32 and 73.21 cm at 30, 45 and 60 DAS, respectively) was achieved from V_4 (10.0 t ha^{-1}) which was statistically identical with V_3 (7.50 t ha^{-1}) at 30 DAS (50.18 cm). On the other hand, the shortest plant (45.82, 55.10 and 63.34 cm at 30, 45 and 60 DAS, respectively) was observed from V_1 (2.50 t ha^{-1}). The results were conformity with the

findings of Islam (2015), Chandra (2015), Yourtchi *et al*. (2013) and Venkatasalam *et al*. (2012).

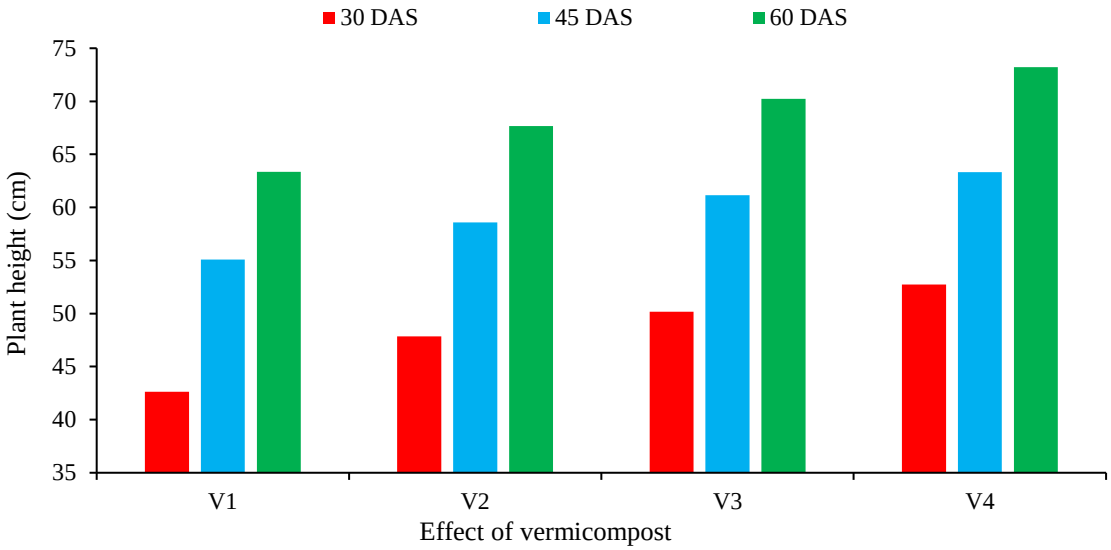

Figure 4: Effect of vermicompost on plant height of potato (LSD value = 2.37, 1.35 and 1.90 at 30, 45 and 60 DAS, respectively)
Note: V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.2.3 Interaction effect of biochar and vermicompost

Significant variation of plant height was found due to interactional effect of biochar and vermicompost levels in all the studied durations (Table 2 and Appendix V). The longest plant (60.47, 68.30 and 78.13 cm at 30, 45 and 60 DAS, respectively) was measured from B_4V_4 combination and the shortest plant (38.10, 42.77 and 50.93 at 30, 45 and 60 DAS, respectively) from B_1V_1 treatment combination.

Table 2: Interaction effects of biochar and vermicompost on plant height of potato

Treatment combination	Plant height (cm) at		
	30 DAS	**45 DAS**	**60 DAS**
B_1V_1	38.10 j	42.77 h	50.93 k
B_1V_2	41.67 i	52.07 g	59.70 j
B_1V_3	45.53 h	59.00 e	66.30 h
B_1V_4	48.53 e	59.59 e	70.00 f
B_2V_1	44.47 h	56.63 f	62.97 i
B_2V_2	46.50 f	57.90 f	67.10 gh
B_2V_3	47.10 fg	59.33 e	68.37 fg
B_2V_4	48.67 ef	61.40 d	70.33 e
B_3V_1	47.37 f	59.00 e	66.90 h
B_3V_2	49.43 e	59.50 e	68.90 fg
B_3V_3	51.27 d	61.43 d	70.90 d
B_3V_4	53.33 c	64.00 bc	74.37 c
B_4V_1	50.53 e	62.00 d	72.57 c
B_4V_2	53.80 c	64.83 b	75.03 b
B_4V_3	56.80 b	64.83 b	75.40 b
B_4V_4	60.47 a	68.30 a	78.13 a
$LSD_{(0.05)}$	**2.37**	**1.35**	**1.90**
CV (%)	**11.23**	**9.34**	**10.35**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1} and V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.3 Number of stems plant^{-1}

4.3.1 Effect of biochar

Biochar levels had significant effect on number of stems plant^{-1} throughout the growing season (Figure 5 and Appendix VI). The highest number of stems plant^{-1} (7.33, 7.58 and 7.58 at 30, 45 and 60 DAS, respectively) was obtained in B_4 (10.0 t ha^{-1}) treatment and lowest (4.00, 4.08 and 4.17 at 30, 45 and 60 DAS, respectively) was obtained in B_1 (2.50 t ha^{-1}). 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. The main reasons for increased number of stems plant^{-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 (Lehmann *et al*., 2003). The results were conformity with the findings of Das (2018) and Ali (2017).

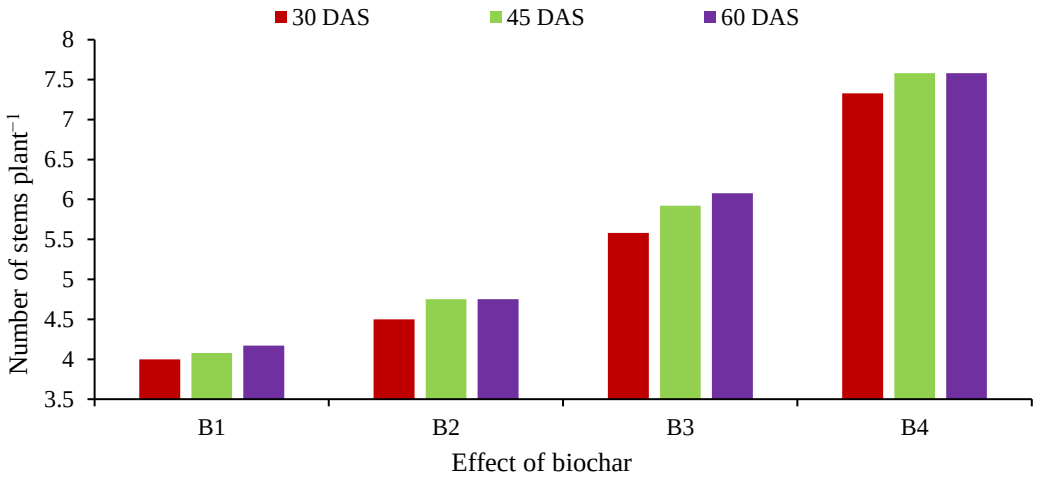

Figure 5: Effect of biochar on number of stems plant^{-1} of potato (LSD value = 0.12, 0.18 and 0.18 at 30, 45 and 60 DAS, respectively)
Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1}.

4.3.2 Effect of vermicompost

Significant influence was found by different levels of vermicompost on number of stem plant^{-1} of potato at different DAS (Figure 6 and Appendix VI). Results showed that the highest numbers of stem plant^{-1} (7.17, 7.25 and 7.25 at 30, 45 and 60 DAS, respectively) was achieved from V_4 (10.0 t ha^{-1}) which was closely followed by V_3 (7.50 t ha^{-1}). On the other hand, the lowest number of stem plant^{-1} of potato (3.67, 4.08 and 4.08 at 30, 45 and 60 DAS, respectively) were observed from V_1 (2.50 t ha^{-1}). Parallel results was observed by Venkatasalam *et al*. (2012) and they found that the number of stems was significantly influenced by the type of organic manure. However, Neher (1999) observed the maximum number of stem hill^{-1} was obtained from organic fertilizer management practices. The similar results was found by Islam (2015) and Chandra (2015).

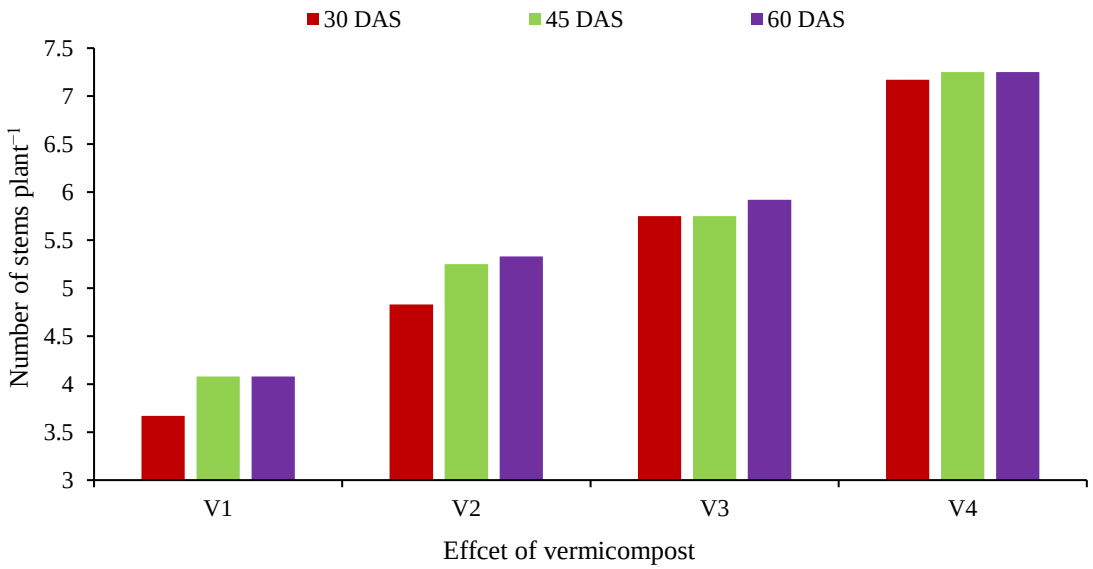

Figure 6: Effect of vermicompost on number of stems plant^{-1} of potato (LSD value = 0.09, 0.13 and 0.14 at 30, 45 and 60 DAS, respectively)
Note: V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.3.3 Interaction effect of biochar and vermicompost

Significant variation of number of stems plant^{-1} was found due to interactional effect of biochar and vermicompost levels in all the studied durations (Table 3

and Appendix VI). The highest number of stems plant^{-1} (9.33, 9.33 and 9.33 at 30, 45 and 60 DAS, respectively) was measured from B_4V_4 treatment combination whereas, the minimum (2.33, 2.67 and 2.67 at 30, 45 and 60 DAS, respectively) from B_1V_1 treatment combination.

Table 3: Interaction effects of biochar and vermicompost on number of stems plant^{-1} of potato

Treatment Combination	No. of stems plant^{-1} at		
	30 DAS	45 DAS	60 DAS
B_1V_1	2.33 k	2.67 l	2.67 l
B_1V_2	3.67 i	3.67 j	4.00 j
B_1V_3	4.00 h	4.00 i	4.00 j
B_1V_4	6.00 e	6.00 e	6.00 f
B_2V_1	3.00 j	3.00 k	3.00 i
B_2V_2	4.00 h	5.00 g	5.00 h
B_2V_3	5.00 g	5.00 g	5.00 h
B_2V_4	6.00 e	6.00 e	6.00 f
B_3V_1	4.00 h	4.67 h	4.67 i
B_3V_2	5.00 g	5.33 f	5.33 g
B_3V_3	6.00 e	6.00 e	6.67 e
B_3V_4	7.33 c	7.67 c	7.67 c
B_4V_1	5.33 f	6.00 e	6.00 f
B_4V_2	6.67 d	7.00 d	7.00 d
B_4V_3	8.00 b	8.00 b	8.00 b
B_4V_4	9.33 a	9.33 a	9.33 a
$LSD_{(0.05)}$	**0.09**	**0.13**	**0.14**
CV (%)	**5.27**	**5.83**	**5.13**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1} and V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.4 Number of leaves plant^{-1}

4.4.1 Effect of biochar

Number of leaves plant^{-1} of potato had significantly influenced by the different biochar levels at 30, 45 and 60 DAS (Figure 7 and Appendix VII). At 30, 45 and 60 DAS, the maximum number of leaves plant^{-1} (88.33, 114.17 and 131.42, respectively) was found in B_4 (10.0 t ha^{-1}) treatment while, the lowest ones (43.75, 67.17 and 85.67, respectively) was found in B_1 (2.50 t ha^{-1}) treatment. These results were also in line with the findings of Youseef *et al.* (2017) who reported that biochar application enhanced number of leaves plant^{-1}.

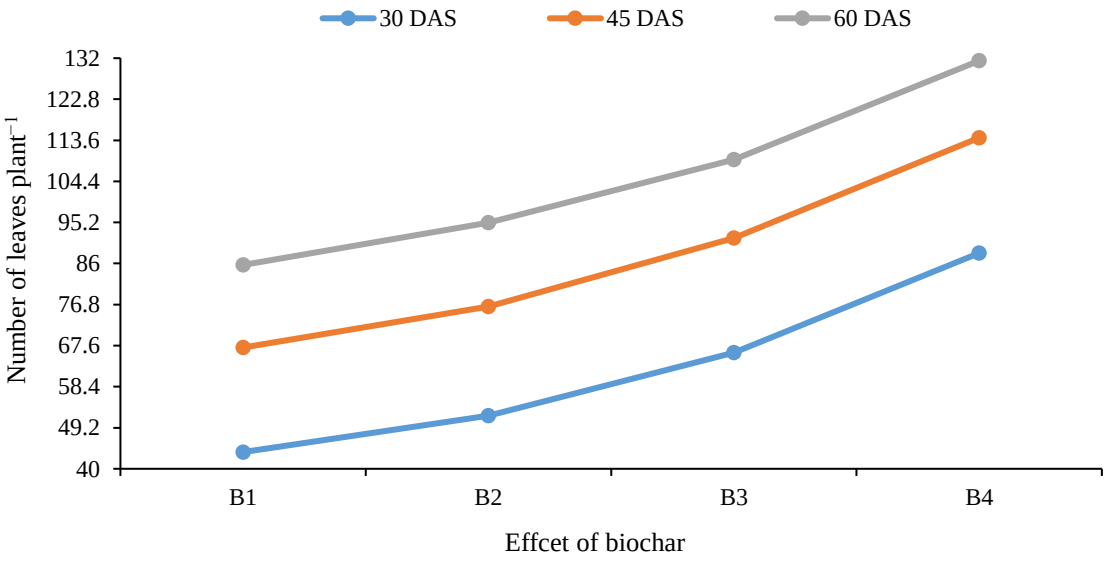

Figure 7: Effect of biochar on number of leaves plant^{-1} of potato (LSD value = 6.25, 8.52 and 10.35 at 30, 45 and 60 DAS, respectively)
Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1}.

4.4.2 Effect of vermicompost

There was highly significant difference found for different levels of vermicompost on number of leaves plant^{-1} of potato at different DAS (Figure 8 and Appendix VII). Results explained that the higher number of leaves plant^{-1} (84.08, 109.50 and 129.83 at 30, 45 and 60 DAS, respectively) were recorded from V4 (10.0 t ha^{-1}) followed by V_3 (7.50 t ha^{-1}) and V_2 (5.00 t ha^{-1}) at all growth stages. Another way the minimum number of leaves plant^{-1} (42.92, 66.42

and 83.00 at 30, 45 and 60 DAS, respectively) were observed from V_1 (2.50 t ha^{-1}). Such results under the present study were supported by Yourtchi *et al.* (2013).

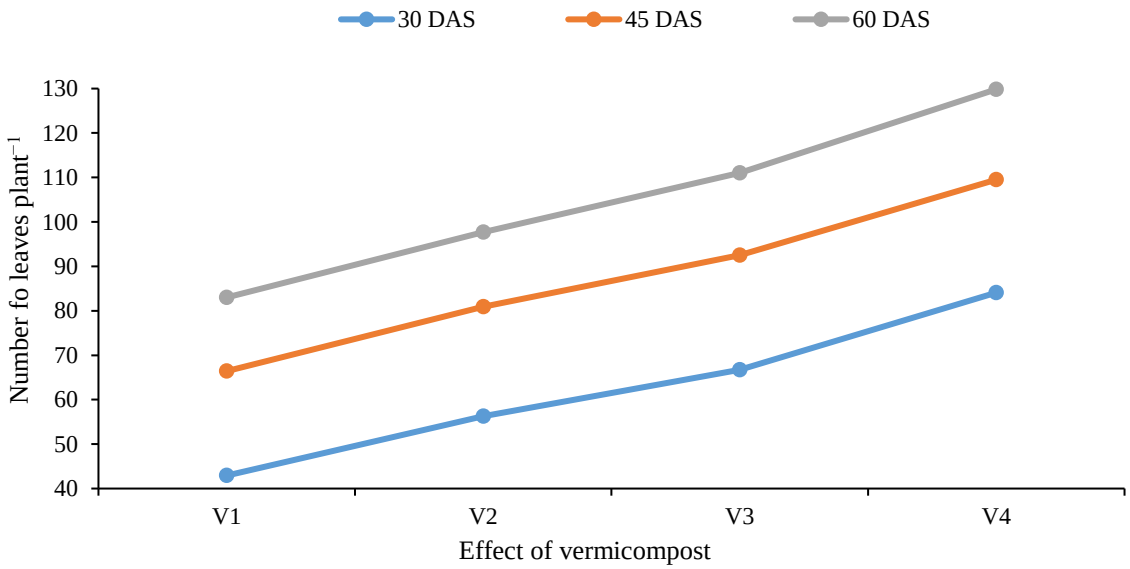

Figure 8: Effect of vermicompost on number of leaves plant^{-1} of potato (LSD value = 5.52, 7.34 and 9.26 at 30, 45 and 60 DAS, respectively)

Note: V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.4.3 Interaction effect of biochar and vermicompost

Interaction effect of different levels of biochar and vermicompost had significant influence on number of leaves plant^{-1} throughout the growing season (Table 4 and Appendix VII). The result of the investigation showed that, at 30, 45 and 60 DAS treatment combination B_4V_4 produced the maximum number of leaves plant^{-1} (117.00, 137.67 and 154.67, respectively) and treatment combination B_1V_1 produced the minimum ones (28.67, 48.67 and 66.00, respectively).

Table 4: Interaction effects of biochar and vermicompost on number of leaves plant^{-1} of potato

Treatment combination	No. of leaves plant^{-1} at		
	30 DAS	**45 DAS**	**60 DAS**
B_1V_1	28.67 k	48.67 l	66.00 j
B_1V_2	39.33 j	61.00 jk	76.00 i
B_1V_3	42.33 h	66.33 j	85.00 hi
B_1V_4	64.67 ef	92.67 f	115.67 d
B_2V_1	36.33 ij	57.67 k	72.67 ij
B_2V_2	51.33 g	74.33 hi	92.67 fgh
B_2V_3	53.33 fg	78.00 gh	95.00 fg
B_2V_4	66.67 e	95.33 ef	120.33 cd
B_3V_1	46.67 gh	69.67 ij	87.33 ghi
B_3V_2	57.00 f	84.00 g	97.67 ef
B_3V_3	72.33 d	100.67 e	123.33 cd
B_3V_4	88.00 c	112.33 c	128.67 c
B_4V_1	60.00 f	89.67 fg	106.00 e
B_4V_2	77.33 d	104.33 d	124.33 cd
B_4V_3	99.00 b	125.00 b	140.67 b
B_4V_4	117.00 a	137.67 a	154.67 a
$LSD_{(0.05)}$	**5.52**	**7.34**	**9.26**
CV (%)	**9.27**	**10.27**	**8.02**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1} and V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.5 Number of tuber plant^{-1}

4.5.1 Effect of biochar

Number of tubers plant^{-1} significantly influenced by the different levels of biochar applications (Figure 9 and Appendix VIII). The maximum (10.31) number of tubers was produced from B_4 (10.00 t ha^{-1}) treatment, whereas the minimum (8.34) was produced from B_1 (2.50 t ha^{-1}) treatment. The results were conformity with the findings of Ali (2017).

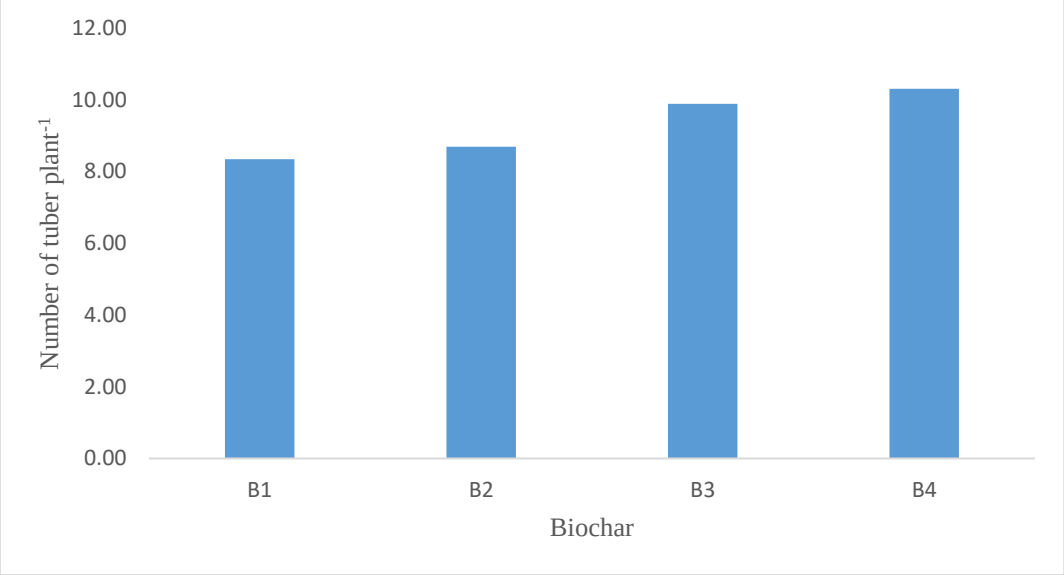

Figure 9: Effect of biochar on number of tuber plant^{-1} of potato (LSD value = NS)
Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1}.

4.5.2 Effect of vermicompost

Significant variation was found among different levels of vermicompost on number of tuber plant^{-1} (Figure 10 and Appendix VIII). The maximum (9.93) number of tuber was found from V_4 (10.0 t ha^{-1}) treatment. On the other hand, the minimum (8.69) was number of tuber found from V_1 (2.50 t ha^{-1}) treatment. Similar result was found from Venkatasalam *et al*. (2012) and they observed that the maximum number of tubers plant^{-1} was recorded in Kufri Lalima (18.2) with FYM, whereas they were minimum in Kufri Lauvkar (4.8) with vermicompost.

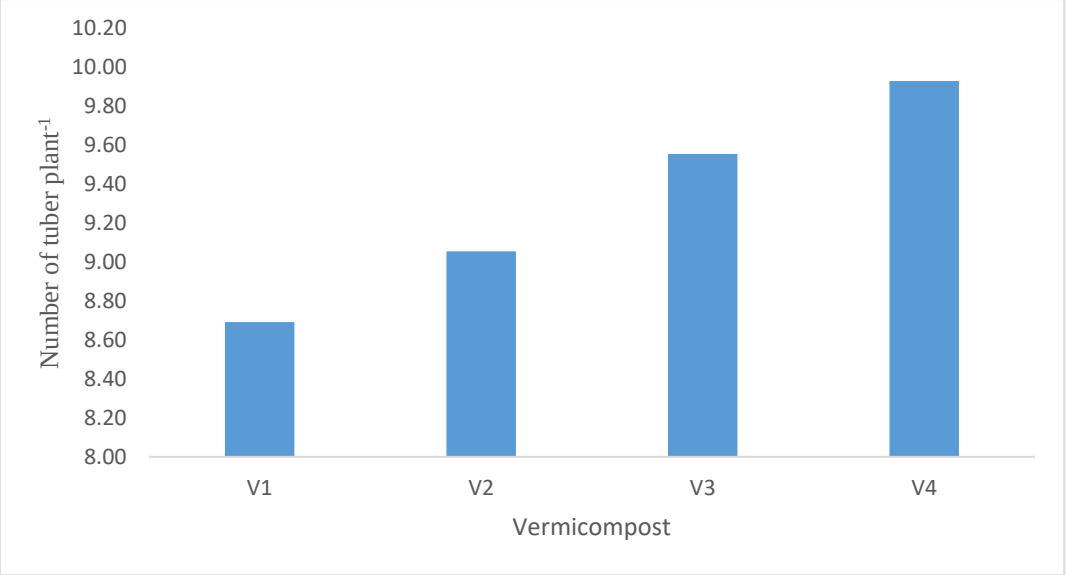

Figure 10: Effect of vermicompost on number of tuber plant^{-1} of potato (LSD value =NS)

Note: V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.5.3 Interaction effect of biochar and vermicompost

In respect of tuber number plant^{-1} due to different biochar and vermicompost levels was found statistically significant (Table 5 and Appendix VIII). The maximum (11.00) number of tuber was found from B_3V_4 and B_4V_4. On the other hand, the minimum (8.00) number of tuber was from B_1V_1 and B_1V_2.

4.6 Average tuber weight plant^{-1} (g)

4.6.1 Effect of biochar

Average tuber weight plant^{-1} significantly varied among the different levels of biochar applications (Figure 11 and Appendix VIII). The maximum weight of tubers plant^{-1} (24.20 g) was observed from B_3 (7.50 t ha^{-1}) which was statistically identical with B_4 (24.02 g) treatments while the minimum weight of tubers plant^{-1} (20.09 g) was observed from B_1 (2.50 t ha^{-1}) treatment. The result obtained from the present study was similar with Ali (2017).

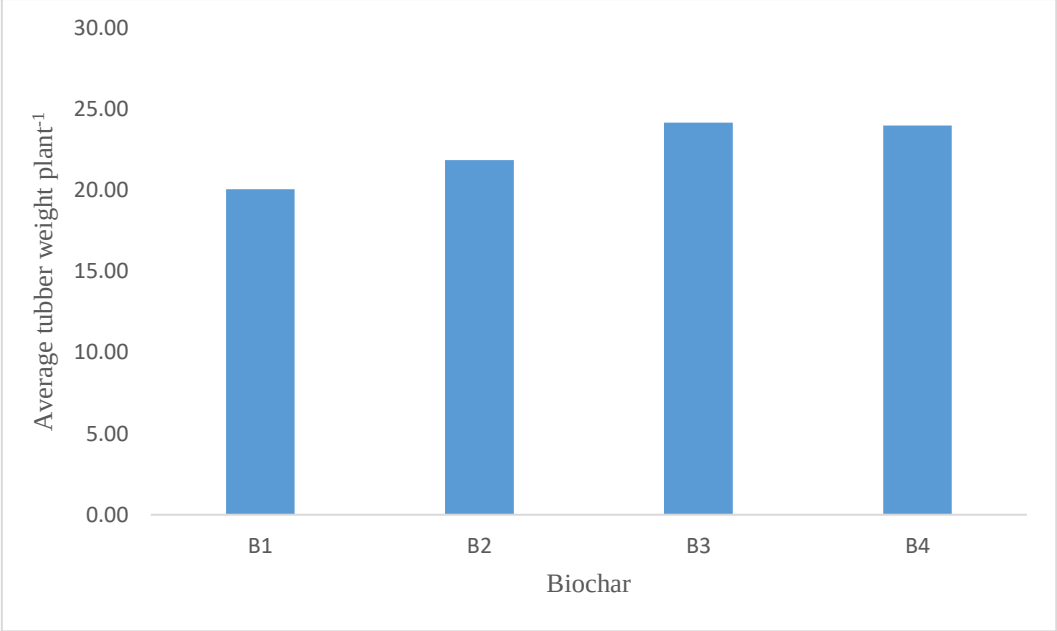

Figure 11: Effect of biochar on average tuber weight plant^{-1} of potato (LSD value = 0.18)

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1}.

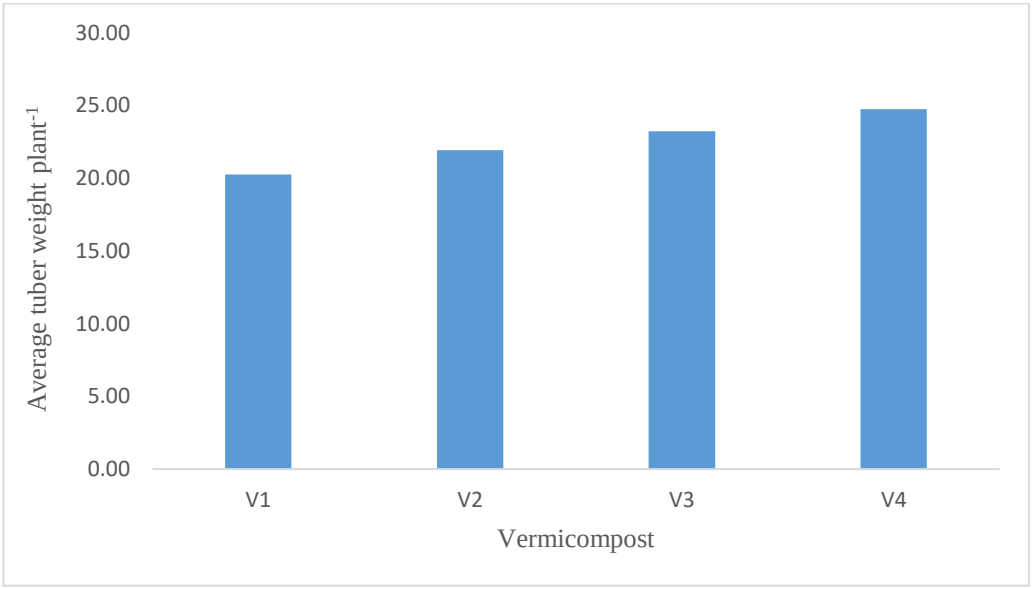

Figure 12: Effect of vermicompost on average tuber weight plant^{-1} of potato (LSD value = 0.18)
Note: V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.6.2 Effect of vermicompost

Average tuber weight plant^{-1} was significantly differed by different levels of vermicompost (Figure 12 and Appendix VIII). Results revealed that the maximum weight of tuber plant^{-1} (24.76 g) was achieved from V_4 (10.00 t ha^{-1}) where the minimum weight of tuber plant^{-1} (20.26 g) was found in V_1 (2.50 t ha^{-1}). The result obtained from the present study was similar with Yourtchi *et al*. (2013).

4.6.3 Interaction effect of biochar and vermicompost

Interaction of biochar and vermicompost levels had significant effect on average tuber weight (Table 5 and Appendix VIII). The maximum average tuber weight (26.60 g) was recorded in B_3V_4 treatment. On the other hand, the minimum average tuber weight (17.36 g) was observed in B_1V_1 treatment.

4.7 Yield plant^{-1}

4.7.1 Effect of biochar

Biochar levels had significant effect on the potato yield plant^{-1} (Figure 13 and Appendix VIII). Results revealed that, treatment B_4 produced highest potato (270.92 g) whereas, the lowest one was obtained from B_1 (217.33 g). 28.45 % more potato yield was obtained from the pot treated with 10 t ha^{-1} biochar (B_4) than the pot treated with2.50 t ha^{-1} biochar (B_1). The higher yield might be attributed to vigorous plant growth, more tuber plant^{-1} and large tuber size. Indawan *et al.* (2018) reported that tobacco biochar application increased storage root weight, storage root dry weight and storage root yield. Gautam *et al.* (2017) indicated that the application of biochar along with FYM in fertile soils in hill farming systems of small holder farmers generally increased the crop yields in biochar and compost amended soils (Getachew, 2016 and Claudia, 2014). This might be due to biochar amendment being more effective in enhancing the vegetative growth of plants (Vaccari, 2015). Yang *et al.* (2015) reported that, the yield of the corn on the control soils without biochar weighed 0.5 t ha^{-1}. Study

conducted by Olmo *et al.* (2014) revealed that biochar increased the yield by about 20%. Yilangai *et al*. (2014) reported that application of biochar together with nitrogen fertilizer enhanced biochar effect on crop growth and yield. This may be because biochar serves as a carrier substrate for nitrogen (N) which increases the effectiveness of biochar by retaining and preventing the leaching of N beyond the reach of plants. Biochar has also a potential to significantly improve durability of soil aggregates (Sun and Lu, 2014; Hale, 2013; Jeffery *et al*., 2011; Jha *et al*., 2010 and Lehmann *et al*., 2009). Another study on maize reported by Major *et al*. (2010) showed that maize increased to about 140% during the fourth year of biochar application and this was attributed to increased pH and nutrient retention in soil. Chan *et al*. (2008) reported 96% increase in radish yields from application of biochar in a greenhouse experiment and suggested that this increased yield was largely due to the ability of biochar to increase N availability. In addition, Yamato *et al.* (2006) revealed that with 2 t ha^{-1} 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}.

Table 5: Interaction effects of biochar and vermicompost on number of tuber plant^{-1}, average tuber weight plant^{-1} and yield plant^{-1} of potato

Treatment combination	Number of tuber plant^{-1}	Average tuber weight plant^{-1} (g)	Yield plant^{-1} (g)
B_1V_1	8.00	17.36 m	201.33 e
B_1V_2	8.00	18.68 l	204.00 e
B_1V_3	8.67	21.76 i	224.00 d
B_1V_4	8.70	22.54 h	240.00 cd
B_2V_1	8.32	19.95 k	210.33 d
B_2V_2	8.56	21.27 j	239.33 d
B_2V_3	8.88	22.77 g	262.00 bc
B_2V_4	9.02	23.50 f	276.00 ab
B_3V_1	9.12	22.40 h	251.00 c
B_3V_2	9.43	23.67 e	267.00 b
B_3V_3	10.00	24.11 c	273.66 ab
B_3V_4	11.00	26.60 a	292.00 a
B_4V_1	9.33	21.31 j	231.00 d
B_4V_2	10.23	24.08 cd	234.00 d
B_4V_3	10.67	24.29 c	265.00 bc
B_4V_4	11.00	26.38 b	272.00 ab
LSD $_{(0.05)}$	**NS**	**0.18**	**22.38**
CV (%)	**4.92**	**4.82**	**15.46**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1} and V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

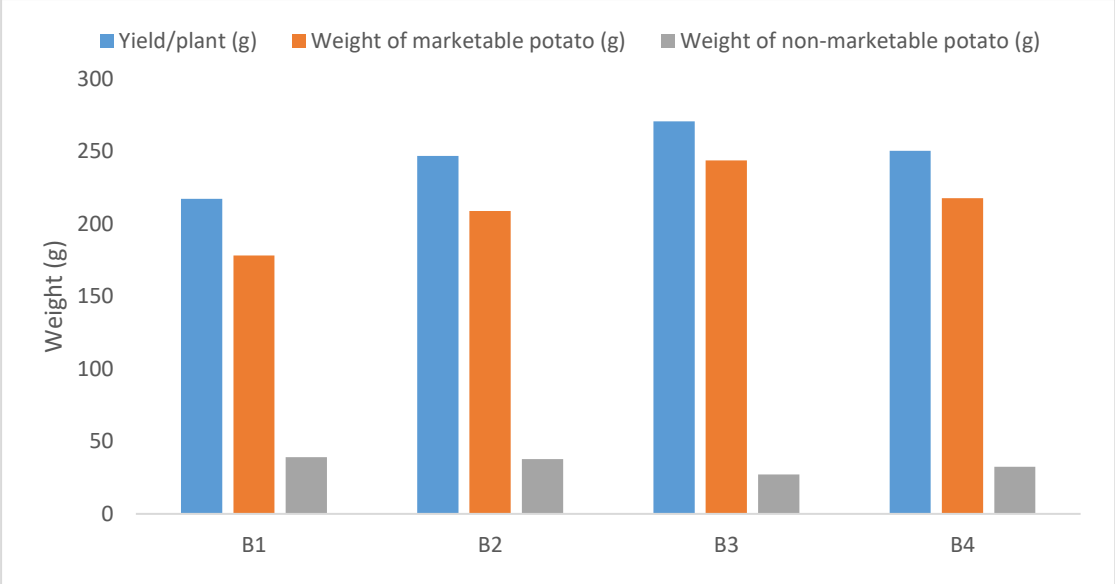

Figure 13: Effect of biochar on yield plant^{-1}, weight of marketable potato plant^{-1} and weight of non-marketable potato plant^{-1} of potato (LSD value = 22.38, 19.28 and NS, respectively)
Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1}.

4.7.2 Effect of vermicompost

There was significant variation found for different levels of vermicompost on yield plant^{-1} (g) (Figure 14 and Appendix VIII). Results examined that the highest yield plant^{-1} (270.00 g) was achieved from V_4 (10.0 t ha^{-1}) whereas, the lowest yield plant^{-1} (223.42 g) was found in V_1 (2.50 t ha^{-1}). 27.65 % more potato yield was obtained from the pot treated with 10 t ha^{-1} vermicompost (V_4) than the pot treated with 2.50 t ha^{-1} vermicompost (V_1). Similar results were also observed from the findings of Islam (2015), Chandra (2015), Yourtchi *et al*. (2013), Venkatasalam *et al*. (2012), Ansari (2008) and Alam *et al*. (2007). They observed that application of vermicompost or other organic manure with or without inorganic fertilizer increased tuber yield.

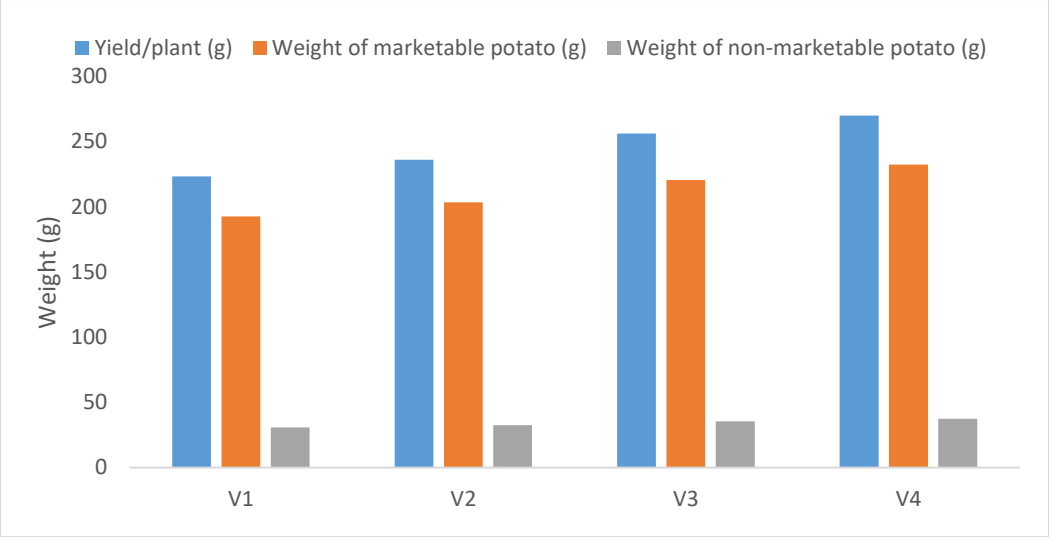

Figure 14: Effect of vermicompost on yield plant^{-1}, weight of marketable potato plant^{-1} and weight of non-marketable potato plant^{-1} of potato (LSD value = 22.38, 19.28 and NS, respectively)

Note: V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.7.3 Interaction effect of biochar and vermicompost

Interaction of biochar and vermicompost levels had significant effect on tuber yield plant^{-1} (g) (Table 5 and Appendix VIII). The highest tuber yield (292.00 g) was recorded in B_3V_4 treatment combination whereas statistically similar B_2V_4 (276.00 g), B_3V_3 (273.66 g) and B_4V_4 (272.00 g). On the other hand, the lowest tuber yield (201.33 g) was observed in B_1V_1 treatment combination whereas statistically similar B_1V_2 (204.00 g).

4.8 Weight of marketable potato plant^{-1} (g)

4.8.1 Effect of biochar

Different levels of biochar had significant influenced on the weight of marketable potato plant^{-1} (Figure 13 and Appendix IX). Results revealed that, treatment B_3 (7.50 t ha^{-1}) produced maximum marketable potato (243.82 g) and the minimum (178.21 g) one was obtained from B_1 (2.50 t ha^{-1}). 40.41 % more marketable potato plant^{-1} was obtained from the pot treated with 10.0 t ha^{-1} biochar (B_4) than the pot treated with 2.50 t ha^{-1} biochar (B_1). 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 because of biochar addition, which also could be the reason for better production of marketable potato. Timilsina *et al*. (2017) and Collins *et al*. (2013) also reported that increased biochar application had increased quality potato tuber. Youseef *et al.* (2017) reported that marketable yield was significantly increased with increasing biochar application rates up to 5 $m^3 fed^{-1}$. Ding *et al.* (2016) reported that organic matter and inorganic salt, such as humic-like and fluvic-like substances and available N, P, and K, can serve as fertilizer and be assimilated by plants and microorganisms. Chan *et al*. (2008) reported significant increase in radish yields from application of biochar and this increased yield was due to the biochar's ability to increase N availability to plants.

4.8.2 Effect of vermicompost

Weight of marketable potato $plant^{-1}$ was significantly influenced by different levels of vermicompost (Figure 14 and Appendix IX). The maximum (232.48 g) marketable potato was found from V_4 (10.0 t ha^{-1}) treatment and the minimum (192.52 g) was found from V_1 (2.50 t ha^{-1}). This variation might be due to change in tuber size under different vermicompost levels. Similar results was also observed from the findings of Islam (2015), Chandra (2015) and Jannatul (2015).

4.8.3 Interaction effect of biochar and vermicompost

Interaction of biochar and Vermicompost levels had significant effect on weight of marketable potato $plant^{-1}$ (Table 6 and Appendix IX). The maximum marketable potato (262.80 g) was recorded in B_3V_4 combination treatment whereas, statistically similar with B_3V_3 (246.29 g), B_3V_2 (240.30 g) and B_4V_4 (236.64 g). On the other hand, the minimum marketable potato (165.09 g) was observed in B_1V_1 combination treatment whereas, statistically similar with B_1V_2 (167.28 g), B_2V_1 (178.09 g) and B_1V_3 (183.68 g).

4.9 Weight of non-marketable potato plant^{-1} (g)

4.9.1 Effect of biochar

Biochar levels had significant influenced on the non-marketable potato plant^{-1} (Figure 13 and Appendix IX). Results exposed that, treatment B_2 (5.00 t ha^{-1}) produced maximum non-marketable potato (37.85 g) and the minimum (27.09 g) one was obtained from B_3 (7.50 t ha^{-1}).

4.9.2 Effect of vermicompost

Significant variation was found among different vermicompost levels to non-marketable potato plant^{-1} (Figure 14 and Appendix IX). The maximum (37.51 g) non-marketable potato was found from V_4 (10.00 t ha^{-1}) whereas, the minimum (30.90 g) was found from V_1 (2.50 t ha^{-1}). This variation might be due to change in tuber size under different vermicompost level. Present experiment showed that amount of non-marketable tuber number increases with increasing vermicompost levels.

4.9.3 Interaction effect of biochar and vermicompost

Interaction of biochar and vermicompost levels had no significant effect on weight of non-marketable potato plant^{-1} (Table 6 and Appendix IX). The numerically maximum non-marketable potato (43.20 g) was recorded in B_1V_4 combination treatment. On the other hand, the numerically minimum non-marketable potato (25.10 g) was observed in B_3V_1 combination treatment.

Table 6: Interaction effects of biochar and vermicompost on weight of marketable Potato plant^{-1} and weight of non-marketable potato plant^{-1}

Treatment combination	Weight of marketable potato plant^{-1} (g)	Weight of non-marketable potato plant^{-1} (g)
B_1V_1	165.09 f	36.24
B_1V_2	167.28 f	36.72
B_1V_3	183.68 ef	40.32
B_1V_4	196.80 e	43.20
B_2V_1	178.09 ef	32.24
B_2V_2	202.64 de	36.69
B_2V_3	221.84 cd	40.16
B_2V_4	233.69 bc	42.31
B_3V_1	225.90 cd	25.10
B_3V_2	240.30 ab	26.70
B_3V_3	246.29 a	27.37
B_3V_4	262.80 a	29.20
B_4V_1	200.97 de	30.03
B_4V_2	203.58 c	30.42
B_4V_3	230.55 bc	34.45
B_4V_4	236.64 ab	35.36
LSD $_{(0.05)}$	**19.28**	**NS**
CV (%)	**11.73**	**5.39**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1} and V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.10 Tuber dry matter (%)

4.10.1 Effect of biochar

Tuber dry matter (%) of potato significantly influenced different levels of biochar application (Table 7 and Appendix X). The maximum tuber dry matter (21.30 %) was recorded from B_3 (7.50 t ha^{-1}) treatment and the lower tuber dry matter (19.50 %) was recorded from B_1 (2.50 t ha^{-1}) treatment. This result had agreements with the findings of Ali (2017) and Youseef *et al.* (2017) who reported that the increases of potato dry matter may be attributed to that fertilizing with biochar positively increased number of main stems, leaves and tubers, as well as leaf area $plant^{-1}$.

4.10.2 Effect of vermicompost

Significant variation was observed by different levels of vermicompost on tuber dry matter (Table 8 and Appendix X). Results revealed that the maximum tuber dry matter (21.38 %) was achieved from V_3 (7.50 t ha^{-1}) whereas V_1 (2.50 t ha^{-1}) resulted the minimum tuber dry matter (19.50 %). Yourtchi *et al*. (2013) observed application of vermicompost with inorganic fertilizer had positive effect on dry matter content of tuber.

4.10.3 Interaction effect of biochar and vermicompost

Interaction of biochar and Vermicompost application had significant effect of tuber dry matter (%) of potato (Table 9 and Appendix X). The maximum tuber dry matter (22.17 %) was recorded in B_4V_4 which was statistically similar to B_4V_3 (22.00 %) whereas, the minimum value of potato (18.83 %) was observed in B_1V_1 which was statistically similar to B_1V_2 (19.00 %) and B_2V_1 (19.00 %).

Table 7: Effect of biochar on tuber dry matter, starch and reducing sugar of potato

Treatments	Tuber dry matter (%)	Starch (%)	Reducing sugar (mg g^{-1} FW)
B_1	19.50 d	14.48 d	0.44 a
B_2	19.88 c	15.43 c	0.40 ab
B_3	21.30 a	17.03 b	0.30 ab
B_4	20.99 b	17.33 a	0.26 b
LSD (0.05)	**0.26**	**0.23**	**0.15**
CV (%)	**3.19**	**3.82**	**1.82**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1}.

4.11 Starch (%)

4.11.1 Effect of biochar

Significant variation was found on starch content on potato due to different biochar levels (Table 7 and Appendix X). The highest starch content on potato (17.33 %) was attained by B_4 (10.0 t ha^{-1}). On the other hand, the lowest starch content on potato (14.48 %) was attained by B_1 (2.50 t ha^{-1}). Similar findings were also reported by Das (2018) and 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.

4.11.2 Effect of vermicompost

Significant variation was found among different levels of vermicompost on starch content of tuber (Table 8 and Appendix X). The highest (17.35 %) starch of tuber was contained by V_4 (10.0 t ha^{-1}). On the other hand, the lowest (14.85 %) was contained by V_1 (2.50 t ha^{-1}). Similar findings were also reported by Jannatul (2015).

Table 8: Effect of vermicompost on tuber dry matter, starch and reducing sugar of potato

Treatments	Tuber dry matter (%)	Starch (%)	Reducing sugar (mg g^{-1} FW)
V_1	19.50 d	14.85 d	0.45 a
V_2	20.00 c	15.10 c	0.38 ab
V_3	21.38 a	17.35 a	0.32 ab
V_4	20.78 b	16.95 b	0.25 b
LSD (0.05)	**0.26**	**0.23**	**0.15**
CV (%)	**3.19**	**3.82**	**1.82**

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

Note: V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.11.3 Interaction effect of biochar and vermicompost

Significant variation was found on starch content on potato due to interaction effect of different levels of biochar and vermicompost application (Table 9 and Appendix X). The highest starch content on potato (18.70 %) was attained by B_3V_4 treatment combination. On the other hand, the lowest starch content on potato (13.70 %) was attained by B_1V_1 which was statistically identical with B_1V_2 (13.80 %) and B_1V_3 (14.10 %) and which was statistically similar with B_2V_1 (14.20 %) and B_2V_2 (14.60 %).

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

4.12.1 Effect of biochar

Reducing sugar (mg g^{-1} FW) has significantly influenced different levels of biochar application (Table 7 and Appendix X). The highest reducing sugar value (0.44 mg g^{-1} FW) was recorded from the "biochar 2.50 t ha^{-1}" (B_1) which was statistically similar with B_2 (0.40 mg g^{-1} FW) and B_3 (0.30 mg g^{-1} FW) whereas,

the lowest (0.26 mg g^{-1} FW) was found from the "biochar 10.0 t ha^{-1} (B_4). Reducing sugar content decreased with the increasing biochar levels.

4.12.2 Effect of vermicompost

Reducing sugar (mg g^{-1} FW) has significantly influenced different levels of vermicompost application (Table 8 and Appendix X). The highest reducing sugar value (0.45 mg g^{-1} FW) was recorded from the "vermicompost 2.50 t ha^{-1}" (V_1) which was statistically similar with V_2 (0.38 mg g^{-1} FW) and V_3 (0.32 mg g^{-1} FW) whereas, the lowest (0.25 mg g^{-1} FW) was found from the "Vermicompost 10.0 t ha^{-1} (V_4). Reducing sugar content decrease with the increasing vermicompost levels. There is a positive correlation between the amount of nitrogen available for crops and nitrate concentration in leaves (Drews *et al.*, 1996). In addition, there is an inverse correlation between the nitrates and reducing sugar concentration. This happening could be related to the conservation of osmotic potential in plants because when photosynthetic activity decreases therefore the sugar concentration in the tissues increases, the presence of nitrates would compensate the decline of the potential (Leon *et al.*, 2012).

4.12.3 Interaction effect of biochar and vermicompost

Interaction of biochar and Vermicompost levels had significant effect of reducing sugar content (mg g^{-1} FW) of potato (Table 9 and Appendix X). The highest reducing sugar content (0.51 mg g^{-1} FW) was recorded in B_1V_1 which was statistically similar with B_1V_2 (0.49 mg g^{-1} FW), B_2V_1 (0.49 mg g^{-1} FW), B_1V_3 (0.42 mg g^{-1} FW), B_2V_2 (0.41 mg g^{-1} FW), B_3V_1 (0.41 mg g^{-1} FW) and B_4V_1 (0.39 mg g^{-1} FW) whereas, the lowest value of potato (0.15 mg g^{-1} FW) was observed in B_4V_4.

Table 9: Interaction effects of biochar and vermicompost on tuber dry matter, starch and reducing sugar of potato

Treatment combination	Tuber dry matter (%)	Starch (%)	Reducing sugar (mg g^{-1} FW)
B_1V_1	18.83 d	13.70 ed	0.51 a
B_1V_2	19.00 d	13.80 ed	0.49 ab
B_1V_3	20.84 c	16.30 b	0.42 abc
B_1V_4	19.33 c	14.10 ed	0.35 cd
B_2V_1	19.00 cd	14.20 ed	0.49 abc
B_2V_2	19.50 d	14.60 d	0.41 abc
B_2V_3	21.00 bc	16.50 b	0.38 bc
B_2V_4	20.00 c	16.40 b	0.31 cd
B_3V_1	20.50 bc	15.10 d	0.41 abc
B_3V_2	21.41 b	15.80 c	0.32cd
B_3V_3	21.67 ab	18.50 a	0.25 d
B_3V_4	21.63 b	18.70 a	0.20 d
B_4V_1	19.67 cd	16.40 b	0.39 abc
B_4V_2	20.10 bc	16.20 b	0.30 cd
B_4V_3	22.00 a	18.10 a	0.21 d
B_4V_4	22.17 a	18.60 a	0.15 e
LSD $_{(0.05)}$	**0.70**	**0.6**	**0.12**
CV (%)	**3.19**	**3.82**	**1.82**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1} and V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.13 Grading of potato (g plant^{-1})

4.13.1 Yields of potato for flakes production (25–45 mm)

4.13.1.1 Effect of biochar

The yields of potato for flakes production was significantly influenced by the different biochar levels (Table 10 and Appendix XI). The highest flakes production (129.00 g) was obtained from B_1 treatment and the lowest ones (72.25 g) was obtained from B_4 treatment. This result had agreements with the findings of Youseef *et al.* (2017) who reported that potato yield for flakes production was significantly increased with increasing biochar application rates up to 5 $m^3 fed^{-1}$.

4.13.1.2 Effect of vermicompost

The yields of potato for flakes production was significantly affected by the different levels of vermicompost application (Table 11 and Appendix XI). The highest flakes production (144.83 g) was obtained from V_2 (5.00 t ha^{-1}) treatment and the lowest ones (70.42 g) was obtained from V_3 (7.50 t ha^{-1}) treatment.

4.13.1.3 Interaction effect of biochar and vermicompost

The yields of potato for flakes production due to different levels of biochar and vermicompost application was found statistically significant (Table 12 and Appendix XI). The highest (179.33 g) flakes production exhibited by B_3V_2 whereas, the lowest (46.67 g) was exhibited by B_2V_3.

4.13.2 Yields of potato for chips production (45–75 mm)

4.13.2.1 Effect of biochar

The yields of potato for chips production was significantly affected by the different biochar levels (Table 10 and Appendix XI). The highest chips production (145.69 g) was obtained from B_4 treatment and the lowest ones (49.21 g) was obtained from B_1. This result had agreements with the findings of Youseef

et al. (2017) who reported that chips production was significantly increased with increasing biochar application rates up to 5 m^3 fed^{-1}.

Table 10: Effect of biochar on grading of potato

Treatments	Grading of potato (g $plant^{-1}$)		
	Yields of potato for flakes production (25–45 mm)	**Yields of potato for chips production (45–75 mm)**	**Yields of potato for French fry production (>75 mm)**
B_1	129.00 a	49.21 d	NF
B_2	104.75 b	109.31 c	NF
B_3	114.67 b	129.16 b	NF
B_4	72.25 c	145.69 a	NF
LSD $_{(0.05)}$	**11.23**	**9.63**	**NS**
CV (%)	**14.73**	**10.69**	**0.00**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1}.
NF = Not Found

4.13.2.2 Effect of vermicompost

The yields of potato for chips production was significantly affected by the different levels of vermicompost application (Table 11 and Appendix XI). The highest chips production (137.48 g) was obtained from V_3 (7.50 t ha^{-1}) treatment and the lowest ones (58.62 g) was obtained from V_2 (5.00 t ha^{-1}) treatment.

Table 11: Effect of vermicompost on grading of potato

Treatments	Grading of potato (g plant^{-1})		
	Yields of potato for flakes production (25–45 mm)	**Yields of potato for chips production (45–75 mm)**	**Yields of potato for French fry production (>75 mm)**
V_1	105.42 b	87.10 c	NF
V_2	144.83 a	58.62 d	NF
V_3	70.42 c	150.17 a	NF
V_4	100.00 b	137.48 b	NF
LSD $_{(0.05)}$	**11.23**	**9.63**	**NS**
CV (%)	**14.73**	**10.69**	**0.00**

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

Note: V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.
NF = Not Found

4.13.2.3 Interaction effect of biochar and vermicompost

The yields of potato for chips production due to different levels of biochar and vermicompost application was found statistically significant (Table 12 and Appendix XI). The highest (182.80 g) chips production exhibited by B_3V_4 which was statistically identical with B_4V_4 (181.31 g) whereas, the lowest (9.28 g) was exhibited by B_1V_2 combination treatment.

Table 12: Interaction effects of biochar and vermicompost on grading of potato

Treatment combination	Grading of potato (g plant^{-1})		
	Yields of potato for flakes production (25–45 mm)	**Yields of potato for chips production (45–75 mm)**	**Yields of potato for French fry production (>75 mm)**
B_1V_1	117.33 d	47.76 g	NF
B_1V_2	158.00 b	9.28 h	NF
B_1V_3	96.67 e	87.01 e	NF
B_1V_4	144.00 c	52.80 g	NF
B_2V_1	113.00 d	65.09 f	NF
B_2V_2	138.67 c	63.97 f	NF
B_2V_3	46.67 h	175.17 b	NF
B_2V_4	120.67 d	133.02 c	NF
B_3V_1	119.33 d	106.57 d	NF
B_3V_2	179.33 a	60.97 f	NF
B_3V_3	80.00 f	166.29 b	NF
B_3V_4	80.00 f	182.80 a	NF
B_4V_1	72.00 f	128.97 c	NF
B_4V_2	103.33 e	100.25 d	NF
B_4V_3	58.33 g	172.22 b	NF
B_4V_4	55.33 g	181.31 a	NF
LSD $_{(0.05)}$	**8.45**	**7.48**	**NS**
CV (%)	**14.73**	**10.69**	**00.00**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1} and V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.
NF = Not Found

4.14 Specific gravity

4.14.1 Effect of biochar

Specific gravity of tuber varied significantly with different levels of biochar application (Table 13 and Appendix XII). The highest specific gravity of tuber was recorded (1.067 g cm^{-3}) from B_4 (10 t ha^{-1}) treatment while, the lowest (1.040 g cm^{-3}) was found from B_1 (2.5 t ha^{-1}) treatment. Similar findings were also reported by Das (2018) and Ali (2017) who reported that biochar at 10.0 t ha^{-1} increased specific gravity in potato.

4.14.2 Effect of vermicompost

Specific gravity has significantly influenced vermicompost levels (Table 14 and Appendix XII). The highest specific gravity (1.070 g cm^{-3}) was recorded from the "vermicompost 10.0 t ha^{-1}" while, the lowest (1.040 g cm^{-3}) was found from the "Vermicompost 2.50 t ha^{-1}". Similar findings were also reported by Chandra (2015) and Jannatul (2015) who reported that biochar at 10.0 t ha^{-1} increased specific gravity in potato.

4.14.3 Interaction effect of biochar and vermicompost

The specific gravity of tuber due to different levels of biochar and vermicompost application was found statistically significant (Table 15 and Appendix XII). The highest (1.084 g cm^{-3}) specific gravity of tuber exhibited by B_4V_4. On the other hand, the lowest (1.026 g cm^{-3}) specific gravity of tuber was exhibited by B_1V_1.

Table 13: Effect of biochar on specific gravity, potato firmness and total soluble solid of potato

Treatments	Specific gravity ($g\ cm^{-3}$)	Potato firmness	Total soluble solid
B_1	1.040 d	33.31 d	5.65 a
B_2	1.050 c	35.24 c	5.47 b
B_3	1.060 b	36.35 b	5.38 b
B_4	1.067 a	36.97 a	5.16 c
LSD $_{(0.05)}$	**0.04**	**0.34**	**0.09**
CV (%)	**1.29**	**5.38**	**1.28**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1}.

Table 14: Effect of vermicompost on specific gravity, potato firmness and total soluble solid of potato

Treatments	Specific gravity ($g\ cm^{-3}$)	Potato firmness	Total soluble solid
V_1	1.040 d	33.11 d	5.19 d
V_2	1.045 c	34.42 c	5.33 c
V_3	1.062 b	36.51 b	5.52 b
V_4	1.070 a	37.83 a	5.62 a
LSD $_{(0.05)}$	**0.04**	**0.34**	**0.09**
CV (%)	**1.29**	**5.38**	**1.28**

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

Note: V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.15 Potato firmness

4.15.1 Effect of biochar

Different biochar levels exerted significant difference on potato firmness (Table 13 and Appendix XII). The maximum potato firmness (36.97) was scored by the B_4 and the minimum potato firmness (33.31) was scored by the treatment B_1. Similar findings were also reported by Das (2018) and Ali (2017) who reported that biochar at 10.0 t ha^{-1} increased firmness in potato.

4.15.2 Effect of vermicompost

Potato firmness value has significantly influenced vermicompost levels (Table 14 and Appendix XII). The maximum firmness value (37.83) was recorded from the "vermicompost 10.0 t ha^{-1}" and the minimum (33.11) was found from the "Vermicompost 2.50 t ha^{-1}". Similar findings were also reported by Chandra (2015) and Jannatul (2015) who reported that biochar at 10.0 t ha^{-1} increased firmness in potato.

4.15.3 Interaction effect of biochar and vermicompost

In case of firmness of tuber flesh due to different biochar and vermicompost levels was found statistically significant (Table 15 and Appendix XII). The maximum (38.85) firmness of tuber flesh taken by B_4V_4 treatment combination and the minimum (31.88) was taken by B_1V_1 treatment combination.

4.16 Total soluble solid content of potato

4.16.1 Effect of biochar

Biochar levels had significant influenced on the total soluble solid (Table 13 and Appendix XII). Results exposed that, treatment B_1 (2.50 t ha^{-1}) produced the highest total soluble solid (5.65) and the lowest one (5.16) from B_4 (10 t ha^{-1}). Similar findings were reported by Youseef *et al.* (2017) who reported that

biochar at 2.50 m^3 fed^{-1} decreased the total soluble solid content in potato. Akhtar *et al*. (2014) found that biochar addition improved quality of tomato fruits.

Table 15: Interaction effects of biochar and vermicompost on specific gravity, potato firmness and total soluble solid of potato

Treatment combination	Specific gravity (g cm^{-3})	Potato firmness	Total soluble solid
B_1V_1	1.026 j	31.88 m	5.41 e
B_1V_2	1.031 i	32.23 l	5.59 c
B_1V_3	1.042 h	32.37 kl	5.80 a
B_1V_4	1.062 e	36.76 f	5.81 a
B_2V_1	1.033 i	32.59 k	5.18 h
B_2V_2	1.043 h	33.40 j	5.33 f
B_2V_3	1.062 e	37.44 e	5.63 c
B_2V_4	1.064 e	37.51 e	5.73 b
B_3V_1	1.049 g	33.65 j	5.25 g
B_3V_2	1.052 f	35.67 h	5.32 f
B_3V_3	1.067 d	37.90 d	5.43 e
B_3V_4	1.072 c	38.20 c	5.52 d
B_4V_1	1.052 f	34.34 i	4.93 j
B_4V_2	1.053 f	36.37 g	5.09 i
B_4V_3	1.078 b	38.32 b	5.21 gh
B_4V_4	1.084 a	38.85 a	5.42 e
LSD (0.05)	**0.03**	**0.28**	**0.06**
CV (%)	**1.29**	**5.38**	**1.28**

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

Note: B_1 - 2.5 t ha^{-1}, B_2 – 5.0 t ha^{-1}, B_3 - 7.5 t ha^{-1} and B_4 - 10.0 t ha^{-1} and V_1 - 2.5 t ha^{-1}, V_2 – 5.0 t ha^{-1}, V_3 - 7.5 t ha^{-1} and V_4 - 10.0 t ha^{-1}.

4.16.2 Effect of vermicompost

Total soluble solids (TSS) has significantly influenced vermicompost levels (table 14 and Appendix XII). The highest TSS value (5.62) was recorded from the "vermicompost 10.0 t ha^{-1}" and the lowest (5.19) was found from the "Vermicompost 2.50 t ha^{-1}".

4.16.3 Interaction effect of biochar and vermicompost

Significant variation was found among different biochar and vermicompost levels on total soluble solid of tuber (Table 15 and Appendix XII). The highest (5.81) total soluble solid of tuber exhibited by B_1V_4 which was statistically identical to B_1V_2 (5.80). On the other hand, the lowest (4.93) total soluble solid was exhibited by B_4V_1.

CHAPTER V

SUMMARY AND CONCLUSIONS

The field experiment was conducted at Sher-e-Bangla Agricultural University during the period from November 2019 to February 2020 in Rabi season to find out the effect of biochar and vermicompost on yield and quality of export and processing potato. The experiment had two factors. Factor A: Biochar: 4 levels; B_1: 2.50 t ha^{-1}, B_2: 5.00 t ha^{-1}, B_3: 7.50 t ha^{-1} and B_4: 10.00 t ha^{-1} and Factor B: Vermicompost: 4 levels; V_1: 2.50 t ha^{-1}, V_2: 5.00 t ha^{-1}, V_3: 7.50 t ha^{-1} and V_4: 10.00 t ha^{-1}. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three (3) replications. Total 48 unit pots were made for the experiment with 16 treatments. Each pot was of required size. The variety was BARI Alu-29 (Courage). Data on different growth parameter, yield and qualitative parameter of potato were recorded and significant variation was recorded for different treatment.

In case of biochar, the doses of biochar 2.50 t ha^{-1} took the maximum days (11.17 days) for emergence whereas, the minimum (8.58 days) was taken by 10.00 t ha^{-1}. The tallest plant (55.40, 64.99 and 75.28 cm at 30, 45 and 60 DAS, respectively) was recorded from 10.0 t ha^{-1} treatment whereas, the shortest plant (43.46, 53.36 and 61.73 cm at 30, 45 and 60 DAS, respectively) was recorded from 2.50 t ha^{-1} treatment. The highest number of stems plant^{-1} (7.33, 7.58 and 7.58 at 30, 45 and 60 DAS, respectively) was obtained in 10.0 t ha^{-1} treatment and the lowest (4.00, 4.08 and 4.17 at 30, 45 and 60 DAS, respectively) was obtained from 2.50 t ha^{-1}. At 30, 45 and 60 DAS, the maximum number of leaves plant^{-1} (88.33, 114.17 and 131.42, respectively) was found in 10.0 t ha^{-1} treatment while, the lowest ones (43.75, 67.17 and 85.67, respectively) was found from 2.50 t ha^{-1} treatment. The maximum (12.42) number of tubers was produced from 10.0 t ha^{-1} treatment, whereas the minimum (7.33) was produced from 2.50 t ha^{-1} treatment. The maximum average weight of tubers plant^{-1} (24.19 g) was observed from 2.50 t ha^{-1} while the minimum average weight of tubers

plant^{-1} (20.08 g) was observed from 10.0 t ha^{-1} treatment. Treatment 10.0 t ha^{-1} produced the highest potato yield per plant (244.25 g) whereas, the lowest one was obtained from 2.50 t ha^{-1} (174.75 g). 10.0 t ha^{-1} of biochar produced the maximum marketable potato (206.00 g) and the minimum (122.75 g) one was obtained from 2.50 t ha^{-1}. Treatment 2.50 t ha^{-1} produced the maximum non-marketable potato (52.00 g) and the minimum (38.25 g) one was obtained from 10.0 t ha^{-1}. The highest (5.75) number of marketable potatoes was produced from 10.0 t ha^{-1} treatment, whereas the lowest (3.25) was produced from 2.50 t ha^{-1} treatment. The highest (6.67) number of non-marketable potato was produced from 10.0 t ha^{-1} treatment, whereas the lowest (4.00) was produced from 5.00 t ha^{-1} treatment which was statistically similar (4.08) to 2.50 t ha^{-1}. The maximum tuber dry matter (22.52 %) was recorded from 10.0 t ha^{-1} treatment and the lower tuber dry matter (20.50 %) was recorded from 2.50 t ha^{-1} treatment. The highest starch content on potato (17.65 %) was attained by 10.0 t ha^{-1}. On the other hand, the lowest starch content on potato (14.48 %) was attained by 2.50 t ha^{-1}. The highest reducing sugar value (0.44 mg g^{-1} FW) was recorded from the "biochar 2.50 t ha^{-1}" whereas, the lowest (0.26 mg g^{-1} FW) was found from the "biochar 10.0 t ha^{-1}. The highest flakes production (129.00 g) was obtained from 2.50 t ha^{-1} treatment and the lowest ones (72.25 g) was obtained from 10.0 t ha^{-1} treatment. The highest chips production (130.67 g) was obtained from 10.0 t ha^{-1} treatment and the lowest ones (84.83 g) was obtained from 2.50 t ha^{-1}. The highest French fry production (5.00 g) was obtained from 5.00 t ha^{-1} treatment and the lowest (0.00 g) was obtained from other three treatment. The highest specific gravity of tuber was recorded (1.067 g cm^{-3}) from 10 t ha^{-1} treatment while, the lowest (1.040 g cm^{-3}) was found from 10 t ha^{-1} treatment. The maximum potato firmness (36.97) was scored by the 10.0 t ha^{-1} and the minimum potato firmness (33.31) was scored by the treatment 2.50 t ha^{-1}. Treatment 2.50 t ha^{-1} produced the highest total soluble solid (5.65) and the lowest one (5.16) from 10 t ha^{-1}.

In case of vermicompost doses, the minimum days to emergence (8.58 days) was required in 10.00 t ha^{-1} treatment and the maximum (11.42 days) was recorded from 2.50 t ha^{-1}. The tallest plant (52.75, 63.32 and 73.21 cm at 30, 45 and 60 DAS, respectively) was achieved from 10.0 t ha^{-1} which was statistically identical with 7.50 t ha^{-1} at 30 DAS (50.18 cm). On the other hand, the shortest plant (45.82, 55.10 and 63.34 cm at 30, 45 and 60 DAS, respectively) was observed from 2.50 t ha^{-1}. The highest numbers of stem $plant^{-1}$ (7.17, 7.25 and 7.25 at 30, 45 and 60 DAS, respectively) was achieved from 10.0 t ha^{-1} which was closely followed by 7.50 t ha^{-1}. On the other hand, the lowest number of stem $plant^{-1}$ of potato (3.67, 4.08 and 4.08 at 30, 45 and 60 DAS, respectively) were observed from 2.50 t ha^{-1}. The maximum number of leaves $plant^{-1}$ (84.08, 109.50 and 129.83 at 30, 45 and 60 DAS, respectively) were recorded from 10.0 t ha^{-1} followed by 7.50 t ha^{-1} and 5.00 t ha^{-1} at all growth stages. On the other hand, the minimum number of leaves $plant^{-1}$ (42.92, 66.42 and 83.00 at 30, 45 and 60 DAS, respectively) were observed from 2.50 t ha^{-1}. The maximum (12.17) number of tubers was found from 10.0 t ha^{-1} treatment. On the other hand, the minimum (7.33) was number of tubers found from 2.50 t ha^{-1} treatment. The maximum weight of tuber $plant^{-1}$ (24.23 g) was achieved from 2.50 t ha^{-1} where the minimum weight of tuber $plant^{-1}$ (20.26 g) was found in 10.0 t ha^{-1}. The highest yield $plant^{-1}$ (242.33 g) was achieved from 10.0 t ha^{-1} whereas, the lowest yield $plant^{-1}$ (175.33 g) was found in 2.50 t ha^{-1}. The maximum (199.67 g) marketable potato was found from 10.0 t ha^{-1} treatment and the minimum (125.83 g) was found from 2.50 t ha^{-1}. The maximum (49.50 g) non-marketable potato was found from 2.50 t ha^{-1}, which was statistically similar (46.75 g) to 5.00 t ha^{-1} whereas, the minimum (42.67 g) was found from 10.0 t ha^{-1}. The highest (5.67) number of marketable potatoes was found from 10.0 t ha^{-1} treatment. On the other hand, the minimum (3.33) was number of marketable potatoes found from 2.50 t ha^{-1} treatment. The highest (6.50) number of non-marketable potato was found from 10.0 t ha^{-1} treatment whereas, the lowest (4.00) found from 2.50 t ha^{-1} treatment. The maximum tuber dry matter

(22.42 %) was achieved from 10.0 t ha^{-1} whereas 2.50 t ha^{-1} resulted the minimum tuber dry matter (20.50 %).

The highest starch of tuber (17.23 %) was contained by 10.0 t ha^{-1}. On the other hand, the lowest (14.85 %) was contained by 2.50 t ha^{-1}. The highest reducing sugar value (0.45 mg g^{-1} FW) was recorded from the "vermicompost 2.50 t ha^{-1}" which was statistically similar with V_2 (0.38 mg g^{-1} FW) and V_3 (0.32 mg g^{-1} FW) whereas, the lowest (0.25 mg g^{-1} FW) was found from the "Vermicompost 10.0 t ha^{-1}. The highest flakes production (144.83 g) was obtained from 5.00 t ha^{-1} treatment and the lowest ones (70.42 g) was obtained from 7.50 t ha^{-1} treatment. The highest chips production (133.17 g) was obtained from 7.50 t ha^{-1} treatment and the lowest ones (76.50 g) was obtained from 5.00 t ha^{-1} treatment. The highest French fry production (5.00 g) was obtained from V_1 treatment and the lowest (0.00 g) was obtained from V_2, V_3 and V_4 treatment. The highest specific gravity (1.070 g cm^{-3}) was recorded from the "vermicompost 10.0 t ha^{-1}" while, the lowest (1.040 g cm^{-3}) was found from the "Vermicompost 2.50 t ha^{-1}". The maximum firmness value (37.83) was recorded from the "vermicompost 10.0 t ha^{-1}" and the minimum (33.11) was found from the "Vermicompost 2.50 t ha^{-1}". The highest TSS value (5.62) was recorded from the "vermicompost 10.0 t ha^{-1}" and the lowest (5.19) was found from the "Vermicompost 2.50 t ha^{-1}".

In the case of interaction effects of biochar and vermicompost, the minimum duration for emergence (7.33 days) was recorded from the combination of B_4V_4 (biochar: 10.0 t ha^{-1} and vermicompost: 10.0 t ha^{-1}) treatment whereas, the maximum duration (12.33 days) was recorded from the combination of B_1V_1 (biochar: 2.50 t ha^{-1} and vermicompost: 2.50 t ha^{-1}). The tallest plant (60.47, 68.30 and 78.13 cm at 30, 45 and 60 DAS, respectively) was measured from B_4V_4 combination and the shortest plant (38.10, 42.77 and 50.93 at 30, 45 and 60 DAS, respectively) from B_1V_1 treatment combination. The highest number of stems $plant^{-1}$ (9.33, 9.33 and 9.33 at 30, 45 and 60 DAS, respectively) was measured from B_4V_4 treatment combination whereas, the minimum (2.33, 2.67 and 2.67 at 30, 45 and 60 DAS, respectively) from B_1V_1 treatment combination.

At 30, 45 and 60 DAS, treatment combination B_4V_4 produced the maximum number of leaves plant^{-1} (117.00, 137.67 and 154.67, respectively) and treatment combination B_1V_1 produced the minimum ones (28.67, 48.67 and 66.00, respectively). The maximum number of tuber (15.67) was found from B_4V_4 and the minimum (5.00) was from B_1V_1. The maximum Average tuber weight (26.60 g) was recorded from B_1V_1 treatment. On the other hand, the minimum Average tuber weight (17.36 g) was observed in B_4V_4 treatment. The highest tuber yield (272.00 g) was recorded in B_4V_4 treatment combination. On the other hand, the lowest tuber yield (133.00 g) was observed in B_1V_1 treatment combination. The maximum marketable potato (236.67 g) was recorded in B_4V_4 combination treatment. On the other hand, the minimum marketable potato (74.00 g) was observed in B_1V_1 treatment combination. The maximum non-marketable potato (59.00 g) was recorded in B_1V_1 combination treatment. On the other hand, the minimum non-marketable potato (35.00 g) was observed in B_4V_1 combination treatment. The highest number of marketable potatoes was found from B_4V_4 (7.00) combination treatment whereas, the lowest ones (1.00) was from B_1V_1 combination treatment. The highest number of non-marketable potato was found from B_4V_4 (8.67) combination treatment whereas, the lowest ones (3.00) was from B_2V_2 combination treatment. The maximum tuber dry matter (23.17 %) was recorded in B_4V_4 whereas, the minimum value of potato (19.83 %) was observed in B_1V_1. The highest starch content on potato (18.60 %) was attained by B_4V_4 treatment combination. On the other hand, the lowest starch content on potato (13.70 %) was attained by B_1V_1. The highest reducing sugar content (0.51 mg g^{-1} FW) was recorded in B_1V_1, whereas, the lowest value of potato (0.15 mg g^{-1} FW) was observed in B_4V_4. The highest flakes production (179.33 g) exhibited by B_3V_2 whereas; the lowest (46.67 g) was exhibited by B_2V_3. The highest chips production (155.33 g) was exhibited by B_4V_3, whereas, the lowest (60.67 g) was exhibited by B_2V_2. The highest (1.084 g cm^{-3}) specific gravity of tuber exhibited by B_4V_4. On the other hand, the lowest (1.026 g cm^{-3}) specific gravity of tuber was exhibited by B_1V_1. The maximum firmness of tuber flesh (38.85) taken by B_4V_4 treatment combination and the minimum (31.88) was

taken by B_1V_1 treatment combination. The highest total soluble solid of tuber (5.81) exhibited by B_1V_4 while the lowest total soluble solid (4.93) was exhibited by B_4V_1.

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

i) The effect of biochar and vermicompost had positive effect on morphological and growth characters, yield and qualitative attributes of potato.

ii) Application of 7.5 t ha^{-1} biochar with 7.5 t ha^{-1} of vermicompost combination seemed to be more suitable for getting higher tuber yield and quality and economically profitable for the farmer as this combination was statistically similar to the highest treatment combination of 10 t ha^{-1} biochar with 10 t ha^{-1} of vermicompost.

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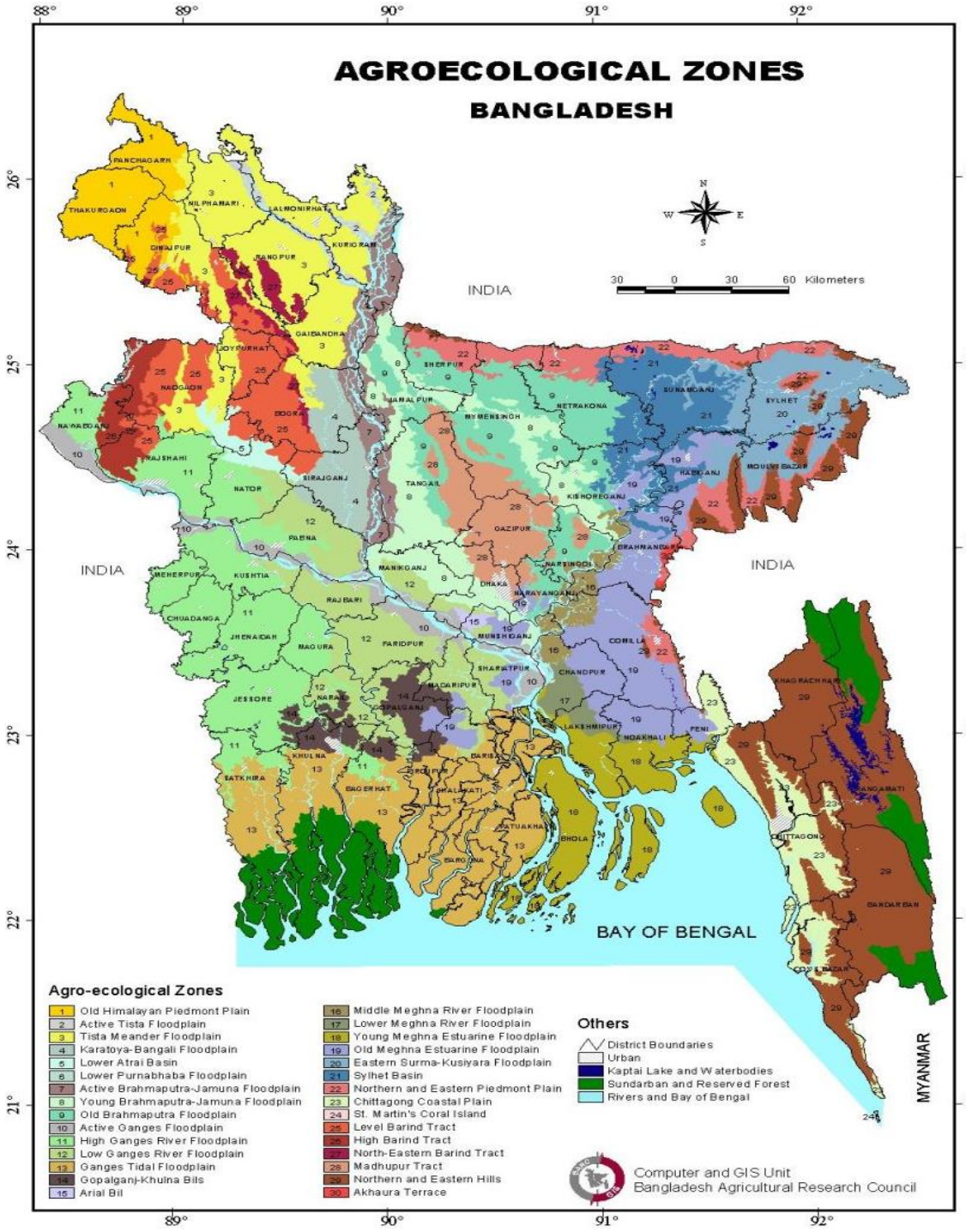
APPENDICES

Appendix I: Map showing the experimental sites under study



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

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

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

Appendix III: Characteristics of experimental field's soil

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Boro rice-Fallow-Aman rice

B. Physical properties of the initial soil

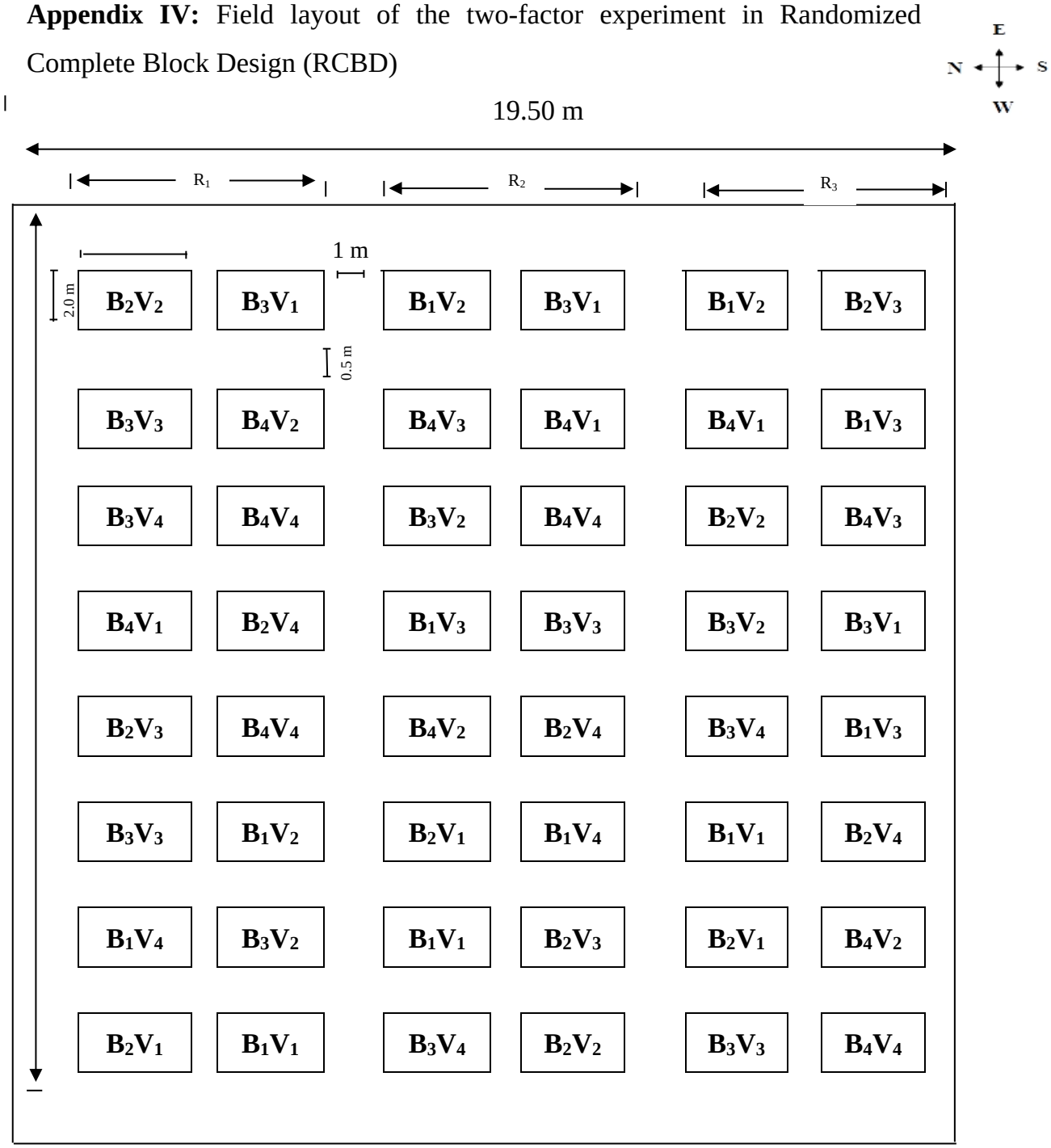
Characteristics	Value
% Sand	27
% Silt	43
% Clay	30

C. Chemical properties of the initial soil

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

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

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



Number of treatment combinations = 16
Pot spacing: = 0.5 m
Between replication = 1.0 m

Factor A: Biochar levels
B_1 = 2.50 t ha^{-1}
B_2 = 5.00 t ha^{-1}
B_3 = 7.50 t ha^{-1}
B_4 = 10.0 t ha^{-1}

Factor B: Vermicompost levels
V_1 = 2.50 t ha^{-1}
V_2 = 5.00 t ha^{-1}
V_3 = 7.50 t ha^{-1}
V_4 = 10.0 t ha^{-1}

Appendix V: Analysis of variance (mean square) of days to emergence and plant height at different DAS

Source of variation	Degrees of freedom	Days to emergence	Plant height		
			30 DAS	45 DAS	60 DAS
Replication	2	183.570	2.340	0.970	6.088
Biochar (A)	3	60.590*	134.650*	103.460*	272.727*
Vermicompost (B)	3	248.030*	84.550*	23.800*	531.024*
A × B	6	60.950*	2.460**	6.505**	175.501*
Error	33	12.680	0.093	0.031	1.158

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

Appendix VI: Analysis of variance (mean square) of number of stems plant^{-1} at different DAS

Source of variation	Degrees of freedom	Number of stems plant^{-1}		
		30 DAS	45 DAS	60 DAS
Replication	2	4.190	2.950	0.736
Biochar (A)	3	264.825*	171.764*	111.897*
Vermicompost (B)	3	54.053**	40.943**	28.359*
A× B	6	5.933**	5.342**	5.011**
Error	33	0.279	0.055	0.010

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

Appendix VII: Analysis of variance (mean square) of number of leaves plant^{-1} at different DAS

Source of variation	Degrees of freedom	Number of leaves plant^{-1}		
		30 DAS	45 DAS	60 DAS
Replication	2	0.335	0.221	1.098
Biochar (A)	3	4.323**	6.394*	0.600**
Vermicompost (B)	3	2.298**	3.199**	0.138**
A× B	6	0.247**	0.383**	0.432**
Error	33	0.003	0.013	0.015

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

Appendix VIII: Analysis of variance (mean square) of number of tuber plant^{-1}, average tuber weight plant^{-1} and yield plant^{-1}

Source of variation	Degrees of freedom	Number of tuber plant^{-1}	Average tuber weight plant^{-1}	Yield plant^{-1}
Replication	2	2.061	8.971	0.048
Biochar (A)	3	895.129*	178.432*	23.696*
Vermicompost (B)	3	363.859*	98.432*	9.651*
A× B	6	11.135*	1.792**	0.295**
Error	33	0.611	1.365	0.018

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

Appendix IX: Analysis of variance (mean square) of weight of marketable potato plant^{-1}, weight of non-marketable potato plant^{-1}, number of marketable tuber plant^{-1} and number of non-marketable tuber plant^{-1}

Source of variation	Degrees of freedom	Weight of marketable potato plant^{-1}	Weight of non-marketable potato plant^{-1}	No. of marketable tuber plant^{-1}	No. of non-marketable tuber plant^{-1}
Replication	2	4.704	0.527	0.353	12.460
Biochar (A)	3	657.152*	49.126*	6.821*	1211.430*
Vermicompost (B)	3	284.544*	16.613*	2.372**	488.588*
A × B	6	13.664*	1.543**	1.081**	14.964*
Error	33	0.755	0.068	0.067	1.816

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

Appendix X: Analysis of variance (mean square) of tuber dry matter, starch and reducing sugar

Source of variation	Degrees of	Tuber dry matter	Starch	Reducing sugar
Replication	2	0.523	0.985	1142.511
Biochar (A)	3	3.132**	157.201*	44475.739*
Vermicompost (B)	3	5.408*	125.868*	43699.940*
A × B	6	0.318**	1.171**	297.227*
Error	33	0.083	0.516	191.744

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

Appendix XI: Analysis of variance (mean square) of grading of potato

Source of variation	Degrees of freedom	Yields of potato for flakes production (30–45 mm)	Yields of potato for chips production (45–75 mm)	Yields of potato for French fry production (>75 mm)
Replication	2	0.444	0.394	2.739
Biochar (A)	3	12.845*	3.905**	8.556*
Vermicompost (B)	3	5.584*	130.150*	5.631^{NS}
A × B	6	0.264**	0.204**	3.359**
Error	33	0.047	0.034	1.245

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix XII: Analysis of variance (mean square) of specific gravity, potato firmness and total soluble solid of potato

Source of variation	Degrees of freedom	Specific gravity	Potato firmness	Total soluble solid
Replication	2	0.527	0.353	12.460
Biochar (A)	3	49.126*	6.821*	1211.430*
Vermicompost (B)	3	16.613*	2.372**	488.588*
A × B	6	1.543**	1.081**	14.964*
Error	33	0.068	0.067	1.816

*Significant at 5% level of probability

** Significant at 1% level of probability