IMPACT OF BIOCHAR APPLICATION AND ITS COMBINATION WITH RECOMMENDED DOSE OF FERTILIZER ON GROWTH AND YIELD OF EGGPLANT

NISHAT TARANNUM

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA- 1207, BANGLADESH

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BY

NISHAT TARANNUM

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Approved By:

Assoc. Prof. Khairul Kabir	**Assistant Prof. Banalata Das**
Supervisor	Co-Supervisor

Prof. Dr. Khaleda Khatun
Chairman
Examination Committee

Khairul Kabir
Associate Professor
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207, Bangladesh
Mobile: +8801913919663
Email. kabir@sau.edu.bd

CERTIFICATE

This is to certify that the thesis entitled, ***"IMPACT OF BIOCHAR APPLICATION AND ITS COMBINATION WITH RECOMMENDED DOSE OF FERTILIZER ON GROWTH AND YIELD OF EGGPLANT"*** *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*** *in* ***HORTICULTURE****, embodies the result of a piece of bonafide research work carried out by* ***NISHAT TARANNUM****, Registration No.* ***15-06459, Email: nishatsmrity1994@gmail.com, Cell: +8801521581329*** *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.

Dated: June, 2022
Place: Dhaka, Bangladesh

Assoc. Prof. Khairul Kabir
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

LIST OFABBREVIATIONS

FULL WORD		ABBREVIATION
Agriculture	=	Agric.
Agro-Ecological Zones	=	AEZ
Bangladesh Bureau of Statistics	=	BBS
Bangladesh Economic Review	=	BER
Biochar	=	BC
Biology	=	Biol.
Biotechnology	=	Biotechnol.
Bioenergy	=	Bioen.
Botany	=	Bot.
Carbon Exchange Cation	=	CEC
Cultivar	=	Cv.
Duncan's Multiple Range Test	=	DMRT
Dry weight	=	DW
Editors	=	Eds.
Entomology	=	Entomol.
Environments	=	Environ.
Fresh weight	=	FW
International	=	Intl.
Journal	=	J.
Liter	=	L
Triple super phosphate	=	TSP
Science	=	Sci.
Soil Resource Development Institute	=	SRDI
Technology	=	Technol.
Serial	=	Sl.

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The author

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IMPACT OF BIOCHAR APPLICATION AND ITS COMBINATION WITH RECOMMENDED DOSE OF FERTILIZER ON GROWTH AND YIELD OF EGGPLANT

ABSTRACT

An experiment was carried out in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, to investigate the impact of biochar application on growth and yield of eggplant from October 2020 to February 2021 during the Rabi season. The experiment was set up in a randomized complete block design (RCBD) with seven treatments, including *i.e.,* B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t/ha BC + 100% RDF, B_2: 2 t/ha BC + 90% RDF, B_3: 3 t/ha BC + 100% RDF, B_4: 3 t/ha BC + 80% RDF, B_5: 4 t/ha BC + 100% RDF and B_6: 4 t/ha BC + 70% RDF. Different growth and developmental parameters were collected for the purpose of the evaluating experimental outcomes. Result of the experiment revealed that different doses of biochar application had significantly influenced plant height, number of leaves plant^{-1}, leaf length plant^{-1} and leaf breadth plant^{-1} at different days after transplanting. Among the different doses of biochar application, the B_5 treatment produced the highest number of flowers plant^{-1} (51.74), number of fruits plant^{-1} (28.88), fruit length plant^{-1} (11.12 cm), fruit diameter plant^{-1} (7.74 cm), individual fruit weight plant^{-1} (170.50 g), yield plant^{-1} (4.92 kg), yield plot^{-1} (16.53 kg) and yield (49.20 t ha^{-1}). However, the second highest fruit yield (38.50 t ha^{-1}) was recorded from B_6 treatment followed by B_3 (35.40 t ha^{-1}) treatment and the minimum fruit yield (22.50 t ha^{-1}) was observed in B_0 treatment. Therefore, based on the above findings, it could be concluded that the application of biochar and its combination with recommended dose of fertilizers (4 t/ha BC + 100% RDF) showed better performance on the growth, yield, and yield attributing traits of eggplant.

CHAPTER I
INTRODUCTION

Bangladesh is one of the main horticultural crops producing countries in South Asia (Khanum *et al*., 2020). Agriculture, including horticulture, is the largest single sector of the economy, accounting for about 11.63 % of the country's GDP (BER, 2021). Brinjal (*Solanum melongena* L.) is an important vegetable for its commercial and nutritional value in the world, as well as in Bangladesh. Raw eggplant contains 92 % water, 9 % dietary fiber, 6 % carbohydrates, 2 % protein, 2.35- 3.53 g of sugar, and has negligible fat (0.18-0.20 g). It provides low amounts of essential nutrients (Ca, Fe, Mg, P, K, Zn) with only manganese having a moderate percentage 11% of the daily value (Khadka *et al*., 2022). According to Sowinska and Krygier (2013), eggplants contain low calorie and high nutrient. Gandhi and Sundari (2012) described that eggplant can also be utilized as medicine to reduce cholesterol in blood and it is suitable as diet to regulate hypertension. Due to high nutrient content of eggplant, it is presumed that the demand for eggplant will increase, so that the production should also increase (Sowinska and Krygier, 2013). "The Begoon" (Brinjal or Eggplant) is a very common and favorite vegetable in Bangladesh that has a link with the social, cultural and economic lives of rural people. Brinjal has been a staple vegetable in our diet since ancient times. It is one of the main vegetables, and its production ranks third among all vegetables in the world. It is grown all over the world, though there is a heavy concentration in Asia. China is the largest producer, followed by India. China has a 60.67 percent share of world production, while India's share stands at 25.70 percent (Rahman *et al*., 2016). Vegetables in much of Asia and the Pacific region are grown by small-scale farmers who are unorganized and scattered in different locations (Vista *et al.,* 2017). Although Bangladesh produced huge amount of brinjal it is only a fraction of the world's production. Brinjal is the second most important vegetable in Bangladesh in terms of both production area and yield, only surpassed by potatoes. In Bangladesh, more than 19940.48 hectares of cultivable land are devoted to brinjal cultivation (BBS, 2021). It is grown in the agricultural fields as a cash crop in the commercial vegetable growing areas and almost every rural household has few brinjal plants in the kitchen garden. In Bangladesh, brinjal is classified into two categories in respect of production period such as rabi brinjal and Kharif brinjal. Although it is more or less available throughout the year, its peak supply comes during December to

April. Brinjal grown in Bangladesh are of different varieties, also differing in size, shape and color. However, Bangladesh has obtained the food sufficiency but the nutritional point of view; it has far from achieved the safety and quality food production (Roy *et al*., 2019).

It is necessary to apply the optimum doses of fertilizers to obtain better growth and development of plant for higher yield. However, the excessive use of chemical fertilizers to meet crop demand has badly affected the soil health and productivity and is also adding a high economic load but at present condition it is not possible to completely eliminate the use of chemical fertilizers. On the other hand, reliance on organic fertilizers and biofertilizers alone is also not feasible because they are comparatively low in nutrient amount and can better serve as a supplement rather than substitute (Chojnacka *et al.*, 2020).

Biochar, also known as black-carbon, is a recalcitrant carbon-rich compound that when added to the soil, has the capacity to restore up to 9 to 11 Gt (Giga ton) of carbon per year (Wang *et al.,* 2013). This recalcitrance property of biochar enables its permanence in the soil 10-1000 times longer than the most in the soil of organic matter residence time (Lehmann and Joseph, 2015). Lin *et al.* (2017) investigated the potential effect of biochar on improving soil properties and reported increase in soil pH, CEC, various enzymatic activities, and available nutrients (N, P, K, Ca, Mg) in the amended soil. Nurida and Rachman (2011) investigated that biochar application in soil at doses of 5.0-7.5 t ha^{-1} was capable of improving crop productivity by enhancing soil physico-chemical properties, and improving soil microbial community and diversity. However, negative priming effects of biochar were also reported by (Hangs *et al.,* 2016). Addition of biochar in soil could result in net microbial immobilization of nutrients as biochar contains small amount of native labile carbon with high C:N ratio (Deluca *et al.,* 2009). Likewise, biochar develops reactive surfaces over time after exposure to water and oxygen in the soil solution, allowing it to adsorb nutrients (Chintala *et al.,* 2013), eventually decreasing the available mineral nutrients in the soil solution. Similarly, decreased crop yields with the sole application of biochar in soil with a low indigenous supply of nutrients have been reported, possibly as a result of adsorption of mineral nutrients and dissolved organic carbon to its surface (Dey and Mavi, 2021).

Furthermore, the combined use of inorganic and organic sources of plant nutrients is the most effective approach to managing long-term soil fertility, as well as soil productivity. Similarly, combined application of biochar with inorganic fertilizers has been shown to improve agronomic benefits in terms of crop growth and production, especially in low fertile soil, either acting as a direct source of available nutrients or increasing nutrient availability in the soil (Hameeda *et al.,* 2019). For example, it has been discovered that co-applying biochar with N fertilizer has beneficial effects on soil characteristics, crop accessible N uptake, and crop productivity (Lori *et al.,* 2013). On the other hand, it has also been observed that the addition of carbon-rich biochar immobilizes N and reduces the bioavailability of critical nutrients by their sorption onto the biochar surface (De Sousa *et al.,* 2014). According to Prayogo *et al*. (2014), using biochar at rates of 0.5% and 2% in the presence or absence of litter, respectively, had no effect or decreased net CO_2 mineralization. However, when poultry dung biochar and N-fertilizer were applied together rather than separately, it was claimed that the amount of microbial biomass carbon increased (Zhang *et al.,* 2014). Similar to this, Gandahi *et al*. (2015) discovered that adding biochar to 25% of the prescribed NPK fertilizers increased the amount of nutrients that were readily available in the soil. Vegetable crops have different nutrient requirements than cereal crops, therefore it would be fascinating to see how biochar application will affect them both with and without inorganic fertilizers. Therefore, by considering the above facts, the present study entitled, "Impact of biochar application and its combination with recommended dose of fertilizer on growth and yield of eggplant" was undertaken with the following specific objectives:

i. to evaluate the effect of biochar and inorganic fertilizer on the growth and yield of eggplant and
ii. to investigate the effect of biochar on growth and yield of eggplant.

CHAPTER II
REVIEW OF LITERATURE

Biochar a fine-grained, carbon-rich, porous product remaining after plant biomass has been subjected to thermo-chemical conversion process (pyrolysis) at low temperatures (~350-600°C) in an environment with little or no oxygen (Amonette and Joseph, 2009). Actually, biochar is not a pure carbon, but it is a mixture of carbon (C), hydrogen (H), oxygen (O), sulphur (S), nitrogen (N) and ash in varying proportions. The important property of biochar is that it is highly porous in nature, thus can retain more and more amount of water and increases the soil surface area. Apart from this, it has the ability to sequester organic carbon in the soil and thus improves aggregate stability of soil. It is also a good source of nutrients that can be released slowly into the soil and can be taken up by plants. Therefore, the literature so for available pertaining to the present study entitled "Impact of biochar application and its combination with recommended dose of fertilizer on growth and yield of eggplant" is being presented under the following headings:

2.1 Characterization of biochar

2.2 Effect of biochar on soil carbon

2.3 Effect of biochar on nutrient availability

2.4 Effects of biochar on nutrient uptake from soil

2.5 Effect of biochar on growth and yield of crop

2.1 Characterization of biochar

Younis *et al*. (2017) characterized the cotton stalk biochar and found that pH, electrical conductivity, nitrogen, phosphorus and potassium content were 8.51, 1.52 dSm^{-1}, 0.47%, 0.96% and 0.82%. The ash content in cotton stalk biochar was 62%.

Paneque *et al*. (2016) performed a field experiment to study the effect of biochar on morphology, productivity and water relation of sunflower plants under non-irrigation conditions. The results showed that addition of 1.5 t ha^{-1} biochar did not significantly change the pH of the soil, its electrical conductivity or its water holding capacity.

Amendments with 15 t ha^{-1} slightly increased the water holding capacity of the soil but showed no lasting impact on soil pH.

Jim *et al.* (2015) analyzed the biochar characteristics of agricultural crop residues and observed that charring at high temperature decreased nitrogen and sulphur contents but increased phosphorus, potassium, calcium and magnesium content.

Jindo *et al*. (2014) conducted the experiment to study physical and chemical characterization of biochars derived from different agricultural residues and confirmed that low temperature pyrolysis produced high biochar yields; in contrast, high-temperature pyrolysis led to biochars with a high carbon content, large surface area and high adsorption characteristics.

Wan *et al.* (2014) studied the pyrolysis temperature influences ameliorating effects of biochars on acidic soil and revealed that pH, carbonates content, base cation and alkalinity of biochar increased with increase in pyrolysis temperature. The high pH of biochar has been attributed to hydrolysis of salts of calcium, magnesium and potassium.

Wang *et al.* (2013) observed that for a given feedstock, increasing pyrolysis temperature from 500 ^{o}C to 700 ^{o}C increased the ash content, surface area, pH, total phosphorous and calcium contents and reduced the biochar yield, cation exchange capacity, total acid and nitrogen. Increase in residence time from 4 to 8 or 16 hour, increased the surface area and ash content of biochar but decreased the biochar yield.

Quirk *et al.* (2012) studied the utilization of biochar in sugarcane and sugar industry management and revealed that sugarcane trash biochar has more pH, electrical conductivity, cation exchange capacity, nitrogen, phosphorus, potassium and total carbon content than sugarcane bagasse biochar.

Rojith and Singh (2012) characterized biochar produced by slow pyrolysis of coir pith at 500 ^{0}C and reported that pH, carbon, hydrogen, nitrogen and sulphur were 6.50, 62.24 %, 4.82 %, 0.27 % and 0.13 %, respectively. When it was produced at 600^{0} C, coir pith biochar recorded pH of 7.40, carbon content of 63.14 %, hydrogen content of 3.62 %, nitrogen content of 0.64 % and sulphur content of 0.21 %.

Weixiang *et al*. (2012) studied the chemical characterization of rice straw derived biochar for soil amendment and noticed that the degree of carbonization for biochar was increased with increasing pyrolysis temperature. As the pyrolysis progressed, oxygen and hydrogen were removed, leaving the remaining carbon to form aromatic carbon bond.

Keiluweit *et al.* (2010) conducted the experiment to study the dynamic molecular structure of plant biomass derived black carbon (biochar) and showed that the low temperature pyrolysis (<550 ^{0}C), favours greater recovery of carbon and also of several nutrients (e.g., nitrogen, potassium, and sulphur) that are increasingly lost at higher temperatures.

Singh *et al*. (2010) revealed that wood biochars had higher total carbon, lower ash content, lower total nitrogen, phosphorous, potassium, sulphur, calcium, magnesium, aluminium, sodium and copper contents, and lower potential cation exchange capacity and exchangeable cations than the manure-based biochars, and the leaf biochars were generally in-between. Increase in pyrolysis temperature increased the ash content, pH, and surface basicity and decreased surface acidity.

Mcbeath and Smernik (2009) showed that aromatic condensation in biochar increased with increasing pyrolysis temperature. Activated biochar contain the most highly condensed aromatic structures, but also indicated the importance of feed stock and retention time on aromatic condensation. Further, manure-based biochar prepared at low temperature may comprise a considerable amount of aliphatic carbon and less amount of aromatic aryl carbon and thus can easily mineralized than wood based biochars.

Steinbeiss *et al.* (2009) investigated the effect of biochar amendment on soil carbon balance and soil microbial activity and confirmed that low temperature biochars were noticed to have a less condensed carbon structure and were expected to a greater reactivity in soil than high temperature biochar and gave a better contribution to soil fertility.

Brown *et al.* (2006) investigated the production and characterization of synthetic wood biochar for use as surrogates for natural sorbents and found that lower surface area (~10 m^2g^{-1}) of biochars produced at lowest (300^0C) and highest (>1000^0C) pyrolysis temperature. While, higher surface area of ~400 m^2g^{-1} was recorded at intermediate pyrolysis temperature of 650 to 850^0C.

Trompowsky *et al.* (2005) studied the characterization of humic like substances obtained by chemical oxidation of eucalyptus charcoal and showed that the final pyrolysis temperature influenced the yield of humic and fulvic acids in biochar produced from two *Eucalyptus* species.

Hamer *et al.* (2004) investigated the interactive priming of black carbon and glucose mineralization and reported that different biochar products will decompose to varying extents, depending on the physical and chemical properties of a specific biochar. They also found that (0.3 % and 0.8 %) of initial carbon is emitted as carbon dioxide for two biochars produced at different temperatures.

Antal and Gronli (2003) studied the art, science, and technology of charcoal production and suggested that low pyrolysis temperatures can create biochars that contain semi degraded cellulose and hemi-cellulose compounds because 300 to 400^0C is the critical temperature range for their structural breakdown. Compared with 500^0C, biochars created at 250^0C probably contain more carboxylic acid and aldehyde functional groups.

2.2 Effect of biochar on soil carbon

Sara and Shah (2018) conducted a field experiment to examine the residual effect of biochar on soil properties and yield of maize under different cropping systems. The results showed that soil organic carbon was significantly greater for chickpea-maize than for wheat maize cropping system.

Timilsina *et al*. (2017) conducted a field experiment to study the effects of biochar application on soil properties and production of radish (*Raphanus sativus* L.) on

loamy sand soil and investigated that highest soil organic matter content of soil were obtained from 20 mg ha^{-1} application of biochar.

Azeem *et al.* (2016) studied the effect of biochar amendment on soil microbial biomass, abundance and enzyme activity in the mash bean field and found that microbial biomass carbon and nitrogen increased by 19 % and 67 % with biochar amended at 0.5 % carbon. Urease and dehydrogenase activities significantly increased with biochar applied at 0.5 % carbon and NPK fertilization.

Agegnehu *et al*. (2015) investigated the effects of biochar and compost, applied individually or together, on soil fertility, peanut yield and greenhouse gas emissions. The results showed that soil organic carbon increased from 0.93 % to 1.25 %.

Jien *et al.* (2015) studied the stabilization of organic matter by biochar application in compost amended soils and found that biochar application reduce the carbon mineralization of the added compost through mutual interaction of biochars and compost and thus extend the efficiency of the compost application.

Mukherjee *et al*. (2014) investigated the effect of biochar and other amendments on the physical properties and greenhouse gas emissions of an artificially degraded soil. They observed that in silty loam soil, when biochar prepared from oak wood is applied at 7.5 t ha^{-1}, it increases soil carbon by 7 % and reduces soil bulk density by 13 %.

Satriawan and Handayanto (2015) investigated the effects of biochar and crop residues application on chemical properties of a degraded soil of South Malang, and phosphorus uptake by maize and found that application of maize biochar (40 t ha^{-1}) with sugarcane litter (40 t ha^{-1}) resulted in highest soil organic carbon than application of maize biochar (40 t ha^{-1}) without litter.

Venkatesh *et al*. (2015) estimated that in India, biochar from residue of maize, castor, cotton and pigeon pea can sequester about 4.6 Mt of total carbon annually in soil.

Lehmann *et al*. (2011) studied the biochar effect on soil biota and investigated that biochar production and application to soil, carbon sequestration takes place through shift from short term bio-atmospheric carbon cycle to long term geological carbon cycle.

Sukartono *et al*. (2011) reported that soil organic carbon increased from about 0.9 % (untreated soil) to about 1.20 % (biochar and cattle manure treated). Soils treated with biochar had consistently higher organic carbon contents, which also remained more stable, compared to the soils treated with cattle manure, implying the higher potential of biochar for soil carbon sequestration.

Afeng *et al*. (2010) conducted a field trial to investigate the effect of biochar at rates of 0, 10 and 40 t ha^{-1} on rice yield and methane and nitrous oxide emissions with or without nitrogenous fertilization in rice. They reported that in anthrosol, when wheat straw biochar applied at 10 and 40 t ha^{-1} soil organic carbon increased by 57% and total nitrogen percentage is enhanced by 28% in the 40t ha^{-1} without nitrogen fertilization.

Liang *et al*. (2008) investigated the stability of biomass-derived black carbon in soils. The results concludes that the biochar rich anthrosols had higher proportions (72-90 %) of carbon in the more stable organo-mineral fraction than biochar poor adjacent soils (2.70 %), suggesting some degree of physical stabilization. A low carbon mineralization indicated a lower microbial activity and lower carbon quality in biochar rich anthrosols than biochar poor adjacent soils, due to the high resistance of biochar to decomposition.

Baldock and Smernik (2002) studied the chemical composition and bioavailability of thermally altered *Pinus resinosa* (Red pine) wood and reported that if the residues are converted into biochar, 50 % of initial biomass carbon can be recovered as compared to only 3 % during open burning and less than 10 to 20 % after 5 to 10 years during biomass decomposition.

Skjemstad *et al*. (2001) investigated the changes in chemical nature of soil organic carbon in vertisols under wheat in south-eastern Queensland. They showed that the

proportion of biochar carbon relative to the total amount of soil carbon increased from (33 %) and (7 %) in two native savanna soils up to (53 %) and (27 %) in the same soils during 50 years of cropping with mainly wheat and sorghum.

Gill and Walia (2000) studied the crop residues as a source of organic manure and its effects and observed that the soil organic matter content was improved by incorporation of biochar residue in rice-wheat crop sequence from 0.43 to 0.48 %.

2.3 Effect of biochar on nutrient availability

Dume *et al*. (2016) performed the experiment on interactive effects of biochar in soil related to feedstock and pyrolysis temperature. Results indicated a significant increase in soil pH, organic matter, organic carbon, total nitrogen, available phosphorus, cation exchange capacity and basic cations when compared with control.

Zornoza *et al*. (2016) studied the stability, nutrient availability and hydrophobicity of biochars derived from manure, crop residues, and municipal solid waste for their use as soil amendments. The results concludes that low temperature provided higher availability of nutrients and cation exchange capacity and lower salinity and alkalinity.

Wang *et al*. (2016) investigated the effects of biochar and compost on mungbean growth and soil properties in a semi-arid area of north east china and reported that the application of biochar + compost (10 t ha^{-1} biochar + 20 t ha^{-1} compost) showed the highest concentration of available nitrogen, phosphorus and potassium.

Ahmed *et al*. (2015) studied the carbon mineralization and nutrient availability in calcareous sandy soils amended with woody waste biochar. It concludes that the combined addition of PM + BC increased available nitrogen, phosphorus and potassium compared with the PM or BC treatments. Also the incorporation of biochar into calcareous soils might have benefits in carbon sequestration and soil fertility improvement.

Gandahi *et al.* (2015) conducted a pot culture experiment to study the impact of rice husk biochar and macronutrient fertilizer on fodder maize and soil properties and reported that the recommended NPK levels of 130-80-40 kg ha^{-1} as well as 25 % less than recommended NPK + 10 t ha^{-1} rice husk biochar augmented nitrogen contents (2.95 and 2.94 %) of maize plants, respectively.

Purakayastha *et al*. (2015) studied the characterization, stability, and microbial effects of four biochars produced from crop residues and observed that in sandy loam soil, when biochar from different sources applied at 20 t ha^{-1}, maize biochar enhanced soil available nitrogen and phosphorus, wheat biochar increased the soil available potassium, rice biochar being relatively labile in soil fuelled the proliferation of microbial biomass.

Rogovska *et al*. (2014) hypothesized that even without a yield response, applying biochar to a midwestern mollisol could improve soil quality and plant nutrient availability because of the carbon it supplies and its conditioning effect.

Biederman and Harpole (2013) investigated the biochar and its effects on plant productivity and nutrient cycling and reported that biochar application induces changes in soil chemical properties including an increase in soil pH, cation exchange capacity, and nutrient contents.

Chen *et al.* (2013) studied the biochar soil amendment increased bacterial but decreased fungal gene abundance with shifts in community structure in a slightly acid rice paddy from South West China and reported that a reduction in soil bulk density is anticipated due to biochar low bulk density and its highly porous structure.

Xu *et al*. (2013) investigated that from direct or indirect mechanism which one is more important for enhancing nutrient bioavailability with biochar application into a sandy soil. The results suggested that biochar application, resulting in pH changes and mineral sorption, can indirectly change nutrient bioavailability especially for phosphorous apart from direct release from biochar. The long term effect of phosphorous availability with biochar application deserves further attention for large scale soil ecological restoration.

Afeng *et al.* (2012) investigated the effect of biochar amendment on maize yield and greenhouse gas emissions from a soil organic carbon poor calcareous loamy soil from Central China Plain and found that application of biochar to calcareous and infertile dry croplands poor in soil organic carbon will enhance crop productivity and reduce greenhouse gas emission.

Nigussie *et al*. (2012) studied the effect of biochar application on soil properties and nutrient uptake of lettuces grown in chromium polluted soils and reported that application of biochar is very imperative to increase soil fertility, enhance nutrient uptake, ameliorate chromium polluted soils and reduce the amount of carbon produced due to biomass burning.

Nelson *et al*. (2011) studied the nitrogen and phosphorus availability in biochar amended soils to determine biochar effects on nitrogen and phosphorus availability in the presence and absence of external nutrient inputs. Results indicate that biochar amended soils may need additional nitrogen after biochar addition to maximize crop production.

Steiner *et al*. (2008) investigated the nitrogen retention and plant uptake on a highly weathered central Amazonian Ferralsol amended with compost and charcoal and observed that for agronomic purposes biochar applied with nitrogenous fertilizer helps to counter the potentially available biochar nitrogen. The total nitrogen recovery in soil, crop residues, and grains was significantly higher in compost (16.5 %), charcoal (18.1 %), and charcoal and compost treatments (17.4 %) in comparison to only mineral-fertilized plots (10.9 %).

Steiner *et al*. (2007) studied the longterm effects of manure, charcoal and mineral fertilization on crop production and fertility and reported the beneficial impact of biochar on the plant available phosphorus has been observed in soils enriched with biochar which in contrast to ammonium is not a characteristic generally associated with soil organic matter.

Warnock *et al.* (2007) studied the mycorrhizal responses to biochar in soil and observed that both biochar and mycorrhizal associations are potentially important in

various ecosystem services provided by soils, contributing to sustainable plant production, ecosystem restoration, and soil carbon sequestration and hence mitigation of global climate change.

Lehmann *et al*. (2003) compared the soil fertility and leaching losses of nutrients between a Fimic Anthrosol and a Xanthic Ferralsol from Central Amazonia and reported the immediate beneficial effect of biochar addition on nutrient availability are largely due to higher potassium, phosphorus, and zinc availability to a lesser extent of calcium and copper.

Glaser *et al*. (2002) conducted the experiment on ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal and observed the increasing trend of bioavailable phosphorous and base cations in the biochar. Also higher nutrient retention and nutrient availability were found after charcoal additions to soil, related to higher exchange capacity, surface area and direct nutrient additions.

2.4 Effects of biochar on nutrient uptake from soil

Sara and Shah (2018) conducted a field experiment to study the residual influence of biochar on soil properties and yield of maize under different cropping systems. The result showed that nutrient uptake of maize was significantly greater for chickpea-maize than for wheat-maize cropping system.

Joseph *et al*. (2015) carried out the pot culture experiment to determine the effects of four different BMC (Biochar-Mineral Complexes), with different formulations applied at rates of 100 and 200 kg ha^{-1}, on the mycorrhizal colonisation, wheat growth and nutrient uptake, and soil quality improvement. It was found that the phosphorus and nitrogen uptake in wheat shoots were significantly greater for a low application rate of BMC (100 kg ha^{-1}). The present formulation of BMC was effective in enhancing growth of wheat at low application rate (100 kg ha^{-1}). The increase in growth appeared due to an increase in phosphorus uptake in the plants that could be partly attributed to an increase in mycorrhizal colonisation and partly due to the properties of the BMC.

Gokila and Baskar (2015) studied the characterization of *Prosopis juliflora* biochar and its influence of soil fertility on maize in alfisols. The results showed that combined application of biochar with 100 % recommended dose of fertilizer and biofertilizer increased the nutrient use efficiency and soil fertility status of soil.

Coumaravel *et al.* (2015) conducted a field experiment with maize hybrid on an inceptisol to evaluate the effect of biochar on yield, NPK uptake and fertility status of the soil revealed that nitrogen uptake ranged from 23.34 kg ha^{-1} to 160.28 kg ha^{-1}, phosphorus uptake from 4.28 kg ha^{-1} and 34.02 kg ha^{-1} and potassium uptake ranged between 18.88 kg ha^{-1} and 109.74 kg ha^{-1}.

Xu *et al*. (2014) reported the effects of biochar application on phosphorus sorption were highly influenced by soil acidity. As the rate of biochar application increased phosphorus sorption increased in the acidic soil but slightly decreased in alkaline soil. Desorbed phosphorus significantly increased at all levels of biochar application studied soil. Inorganic phosphorus fractionation revealed that biochar addition sharply increased the calcium bounded phosphorus and slightly enhanced the aluminium retained phosphorus.

Karer *et al*. (2013) conducted a field experiment to investigate the effect of biochar on soil characteristic and nutrient uptake on crop yield on two temperate soils (Cambisol and Chernozem). The study analyzed that variable biochar application rates did not affect the total uptake of nearly all macro and micronutrients when same nitrogen supply provided.

Lentz and Ippolito (2012) studied the biochar and manure affect calcareous soil and corn silage nutrient concentration and uptake. The result represent that biochar application to calcareous soils may lead to reduced nitrogen availability, requiring additional soil nitrogen inputs to maintain yield target.

Nigussie *et al*. (2012) conducted a pot culture experiment to investigate the effect of biochar application on the selected properties of chromium polluted soils and uptake of lettuces grown in polluted soils. From the result it concludes that uptake of

nitrogen, phosphorus and potassium were significantly ($P<0.01$) increased by addition of biochar.

Sukartono *et al*. (2011) conducted a field study to evaluate the effects of biochar application on soil fertility status, nutrient uptake, and maize yield in the sandy soils of semiarid Lombok, Indonesia. It concludes that biochar application improved soil fertility status, especially soil organic carbon, cation exchange capacity, available phosphorus, exchangeable potassium, calcium, and magnesium, and increased nutrient uptake and maize yield.

Choppala *et al*. (2010) conducted the experiment to study the effect of maize stalk biochar on uptake of nutrient and reported that the highest uptake of phosphorus and potassium were observed in soils amended with 10 t ha^{-1} maize stalk biochar.

Gaskin *et al*. (2010) observed that peanut hull biochar increased the concentration of nutrients (pH, N, P, K, Mg and Ca). In the same study, the changes in corn tissue nutrient (N, P, S and Mg) status with the application of biochar, which showed little response whereas, yield of corn has significantly, respond to biochar application during the course of the two-year study.

Chan *et al*. (2007) conducted a pot culture experiment to investigate the effect of biochar produced from green waste by pyrolysis on the yield of radish and the soil quality of an alfisol and observed that biochar possess plant available potassium in highly exchangeable form which is available for plant uptake.

Rondon *et al*. (2007) studied the biological nitrogen fixation by common beans increases with biochar additions and investigated that biological nitrogen fixation by common beans was increased from 50 to 72 % of total nitrogen uptake with increasing rates of biochar addition (0, 31, 62 and 93 t ha^{-1}) to a low fertility oxisol.

Lehmann *et al*. (2006) conducted an experiment to study the biochar sequestration in terrestrial ecosystems and found that biochar application boosts up the soil fertility and improves soil quality by raising soil pH, increasing moisture holding capacity,

attracting more beneficial fungi and microbes, improving cation exchange capacity and retaining nutrients in soil.

2.5 Effect of biochar on growth and yield of crop

Kaur and Sharma (2020) evaluated the significance of mixed wood biochar application on the growth parameters of the berseem crop. Their study indicated that application of 5 % biochar increased plant height by 28-50 % and plant biomass by 30-60 % in a period of 180 days over no application of biochar.

Mollick *et al*. (2020) conducted a field experiment in Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during the period from November, 2017 to March, 2018 in rabi season to observe the effect of biochar on the yield and quality of potato tuber and to find out the optimum dose of biochar along with inorganic fertilizer for achieving the maximum yield of potato. The results indicated that biochar application significantly ($p<0.05$) increased plant height, weight of tubers, yield of tubers, tuber dry matter content, tuber specific gravity, soil organic carbon. Results suggested that biochar application had significant positive effect on plant and soil.

Adekiya *et al.* (2019) revealed that there was an increase in yield components of radish by the application of biochar and poultry manure either as sole or in a combination. The highest yield was obtained from the combine application of biochar and poultry manure.

Haque *et al*. (2019) conducted an experiment at the farmer's field in Shibalaya upazilla of Manikganj district during rabi season of 2017 to study the effectiveness of biochar on soil fertility and yields of brinjal and cauliflower. There were five treatments viz. control, recommended inorganic fertilizer (RF), biochar 1 t/ha + RF, biochar 3 t/ha + RF and biochar 5 t/ha + RF laid out in a randomized complete block design with four replications. Data revealed that biochar at the rate of 5 t/ha along with RF provided maximum yields of brinjal (67 t/ha) and cauliflower (42 t/ha). The pH, nutrients and moisture contents of the study soils increased and bulk density decreased with the higher rates of biochar application.

Khan *et al.* (2019) compared the effect of mesquite biochar (MB, 10 tons ha^{-1}), farmyard manure (FYM, 10 tons ha^{-1}), and NPK fertilizers (120:80:80 kg ha^{-1}) on soil fertility and growth of onion. The maximum bulb weight (6.13 kg per plot), leaf length (32.38 cm), total onion yield (268.55 kg ha^{-1}) were observed in the plots treated with MB as compared with FYM and NPK fertilizers.

Gamareldawla *et al.* (2017) carried out a study to analysing the influence of biochar application eg. 0 %, 2 % and 4 % w/w on the soil properties, growth, yield and water productivity of tomato plant under poor silt loam soil. To study influence of three different biochar application on the tomato performance, comprehensive experimental works was carried out using pots inside the greenhouse. A randomized complete block design with three treatments [CK (no biochar, control), T_1 (2 % w/w biochar) and T_2 (4 % w/w biochar)], under three replications for each treatment was used. The result of the experiment revealed that biochar amendments significantly increased all yield components, except fruit diameter and color index were not affected by biochar addition. T_2 and T_1 treatments recorded highest fruit number per plant, flower per plant, fruit weight, fruit water content and total yield per plant compare to those under no biochar-control treatments. This attributed to the improvement of soil properties and plant growth parameters under biochar additions.

Rageendrathas and De Silva (2017) reported that yield of onion was significantly increased by the application of paddy husk biochar. Biochar application increased the plant height compared to the fertilizer alone treatments.

Trupiano *et al*. (2017) studied the effects of biochar amendment, compost addition, and their combination on lettuce plants grown in a soil poor in nutrients. Soil microbiological, chemical, and physical characteristics were analyzed, together with plant growth and physiology. The effect of biochar and compost toxicity was also investigated using cress plants and earthworms. Results showed that compost amendment had clear and positive effects on plant growth and yield. The research also demonstrated that biochar alone stimulated lettuce leaves number, leaves length and breadth and total biomass. As per the research, combining biochar and compost, had no positive synergic and summative effect. The research demonstrated that in a soil the biochar alone could be effectively used to enhance soil fertility and plant growth

and biomass yield. The results showed that, combined application and single application biochar or compost additions increased the plant height, stem girth, and dry matter yields of maize.

Vista and Khadka (2017) reported that excessive dose of biochar is not beneficial for vegetable crops. They found that application of 30 t ha^{-1} of biochar was most satisfactory for overall improvement of yield and growth parameters of vegetable crops.

Youseef *et al.* (2017) revealed that the number of main stems and number of tubers significantly increased with increasing biochar application rates up to 12 m^3 ha^{-1}.

Akca and Namli (2015) reported that the fresh and dry weight of tomatoes, pepper, and lettuce were recorded to increase after biochar treatment than other treatments.

Vinh *et al.* (2014) investigated biochar treatment and its effects on rice and vegetable yields in mountainous areas of northern Vietnam. The result showed that in comparison with NPK treatment, rice yields were increased by 5.9-22.3% in treatments with biochar and by 26.3- 34.2% in treatments of compost mixed with 5% biochar. Application of biochar for vegetables increased the yields by 4.7-25.5%, compared with farmer practices in both sites.

Akhtar *et al*. (2014) investigated the effects of biochar on physiology, yield and quality of tomato under different irrigation regimes. The results showed that addition of biochar increased the soil moisture contents in deficit irrigation and partial root zone drying, which consequently improved physiology, yield and quality of tomato as compared with the non-biochar control.

Rahila *et al.* (2014) conducted a research to study the effect of charcoal on the growth of tomato. The application of biochar at the rate of 30 kg on super vegetable garden bed increased the stem growth and fruit yield compared to untreated beds.

Yilangai *et al.* (2014) investigated the effect of charcoal (biochar) on the growth of tomato (*Lycopersicum esculentus*). Four Super Vegetable Garden (SVG) growing

beds and four traditional vegetable beds each measuring 15 m^2 (12.5 m by 1.2 m) and 1 m gap between beds were laid out. After preparing the subsoil, 30 kg of biochar was spread on the four SVG beds as evenly as possible. Results obtained from this research showed that stem growth was significantly higher (35 %) in tomatoes grown on SVG beds treated with charcoal than traditional beds without charcoal. Number of fruits $plant^{-1}$, fruit length, fruit diameter, individual fruit weight and fruit yield in tomato plant was also significantly higher on beds with charcoal than beds without charcoal.

Carter *et al.* (2013) reported that application of rice husk biochar, showed significant change in final biomass, plant height, root biomass and no. of leaves in lettuce and cabbage in comparison to no biochar treatment.

Schulz *et al.* (2013) reported the positive impacts of application of mixture of biochar prepared from beech wood at 350-450 °C and compost prepared by 50 % sewage sludge, 25 % freshly chaffed lop and 25 % sieve leftovers of earlier composting on plant growth of Oat crop. The application of composted biochar significantly increased the plant height, above ground biomass ($p< 0.01$) and grain yield ($p<0.001$) as compared to control. This increase was only due to the addition of biochar while compost did not significantly contribute to this effect.

Varela *et al.* (2013) reported that the positive effects of capturing radiation by biochar in winter sown crop could be attributed larger canopy size and greater chlorophyll content in chick-pea with application of biochar.

Poorter *et al.* (2012) reported that application of bamboo biochar showed the significant effect on plant height and fresh weight, but it had no significant effect on the no. of leaves and oven dry weight of economic yield. Plant height, larger stem diameter, root mass fraction, and root mass increased due to nitrogen and phosphorus availability in soil because of stimulation of accumulated dry matter in vegetative parts by the application of biochar in soil.

Cui *et al*. (2011) extended a field study involving wheat production in order to study the effect of biochar (BC) amendment in paddy soil that had long-term contamination

of Cd. The BC was used as an amendment in Cd-contaminated soil for its special property. BC was amended at rates of 10 to 40 t ha^{-1} during the rice season before rice transplantation in 2009. BC amendments increased grain yield of wheat as compared to control where BC was not applied.

Haefele *et al.* (2011) observed clear positive effect of biochar application on yield and fertilizer use efficiency only in the site where the natural soil fertility was very low. Biochar application improved the CEC and soil water holding capacity and thereby 16-35 percent improvements in grain yield over control.

Jeffery *et al.* (2011) evaluated the evidences regarding the relationship between biochar and crop productivity by conducting a meta-analysis. The greatest positive effects were seen with biochar application rates of 100 t ha^{-1} (39 %). Other positive effects were seen in acidic (14 %) and neutral pH soils (13 %) and soils with coarse (10 %) or medium (13 %). These results suggest main two mechanisms for yield improvement *viz*., liming effect and improved water holding capacity.

Clough *et al.* (2010) confirmed the direct role of biochar in nutrient supply to plants. Graber *et al.* (2010) emphasized that treating plants by biochar positively enhanced plant height of tomato crop.

Purakayastha (2010) reported that application of biochar prepared from wheat straw at 1.9 t ha^{-1} along with recommended doses of NPK (NPK:180:80:80) significantly increased the yield of maize in Inceptisol of IARI farm and this treatment was superior to either crop residue incorporation (CRI) or crop residue burning (CRB).

Asai *et al.* (2009) studied the effect of biochar application on grain yield of upland rice at ten different sites, combining different rate of biochar and fertilizer application (N and P) and two cultivars. Biochar application resulted in higher grain yields at the sites with low P availability. In the absence of N fertilizer and at highest rate of biochar application, there was reduction in leaf chlorophyll content indicating biochar application is highly dependent on soil fertility and fertilizer management.

Hossain *et al.* (2010) investigated and quantified the effects of wastewater sludge biochar on soil quality, growth, yield and bioavailability of metals in cherry tomatoes, pot experiments were carried out in a temperature-controlled environment and under four different treatments consisting of control soil, soil with biochar; soil with biochar and fertiliser, and soil with fertiliser only. The results revealed significant effect of biochar on the height of the plant, increase in fruits size & grain yield of the plant.

Chan *et al.* (2008) evaluated two biochar produced from poultry litter under different condition in a pot experiment by assessing yield of radish. The yield increase was largely due to the ability of biochar to increase nutrient availability, particularly N and other beneficial effects of biochar on soil quality. In this regard, the non-activated (450 °C) poultry litter biochar was more effective than the activated (550 °C) biochar. These results highlight the importance of feedstock and process conditions during pyrolysis in determining the soil amendment values of biochar.

Chan *et al.* (2007) conducted a pot culture study to investigate the effect of biochar produced from green waste on the yield of radish. In the absence of N fertilizer, application of biochar to the soil did not increase radish yield even at the highest rate of 100 t ha^{-1}. However, a significant interaction between biochar and N fertilizer was observed, in that yield increased with increasing rates of biochar application, highlighting the role of biochar in improving N fertilizer use efficiency of the plant.

Rondon *et al.* (2007) demonstrated the potential for increasing the N input by BNF (Biological Nitrogen Fixation) into agro-ecosystems in highly weathered and acid soils by biochar applications. Nitrogen fixation was significantly improved by moderate rates of biochar additions. The reason for the improved BNF was mostly an effect of the improved availability of B and likely of Mo and to a lesser extent, a decreased N availability and increased availability of K, Ca, and P and higher pH as well as lower Al saturation.

CHAPTER III
MATERIALS AND METHODS

This chapter describes the materials and methods used in the field experiment from October 2020 to February 2021 to conduct the experiment titled "Impact of biochar application and its combination with recommended dose of fertilizer on growth and yield of eggplant." It includes a brief overview of the experimental site, soil and environment, cultivar, crop cultivation, experiment design and treatment, and data collection under the following headings.

3.1 Experimental period

The experiment was carried out during the period from October 2020 to February 2021 in the Rabi season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh. The experimental site is geographically located at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meters above sea level.

3.2.2 Agro-Ecological Zones

The experimental field belongs to the Agro-Ecological Zones (AEZ) of “The Madhupur Tract”, AEZ-28. This was a region of complex relief and soils developed over the Madhupur clay, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain. For a better understanding of the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix I.

3.2.3 Soil

The soil texture was silty clay with pH 5.6. The morphological, physical, and chemical characteristics of the experimental soil have been presented in Appendix II.

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April, and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity, and rainfall during the experiment period was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix III.

3.3 Planting material

The BARI BEGUN 5 was used as planting material in this experiment. The BARI BEGUN 5 seeds were collected from the Joydebpur, Gazipur-based Horticulture Research Center of the Bangladesh Agricultural Research Institute (BARI).

BARI BEGUN 5

BARI BEGUN 5 was developed by Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. It was originated from local germplasm and was developed by selection method. It was released in the year of 1998. It is a high yielding variety. Plant straight early bearer and fruits are round with shiny blackish violet, color, fruit/plant 35-40, each fruit weight 120-130 g. This variety is well cultivated in all type of soil and weather of Bangladesh. First October to mid-November (Rabi) are the planting season of this variety and give a yield of 45-50 t/ha. It is tolerant to fruit stem borer and wilt disease and content high antioxidant.

3.4 Collection of biochar

Wood, wood chips and sawdust were pyrolyzed to create the biochar used in the fields (collected from sawmill). Biochar was purchased from Christian Commission for Development in Bangladesh, Mirpur, Dhaka. Nutrient content of biochar is given below:

Properties	**Values**
Moisture	37.5 %
pH	9.1
Organic Carbon	34.1 %
Nitrogen (N)	0.19 %
Phosphorus (P)	0.03 %
Potassium (k)	0.11 %
Sulphur (S)	0.03 %
Zinc (Zn)	0.00%
Copper (Cu)	0.00%
Chromium (Cr)	0.00%
Cadmium (Cd)	2 ppm
Lead (Pb)	4.12 ppm
Nickel (Ni)	0.00 ppm

3.5 Experimental treatment

There was single factor with seven treatments in this experiment namely different doses of biochar application with inorganic fertilizer in per hectare of land as mentioned below:

B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF)

B_1: 2 t BC + 100% RDF

B_2: 2 t BC + 90% RDF

B_3: 3 t BC + 100% RDF

B_4: 3 t BC + 80% RDF

B_5: 4 t BC + 100% RDF

B_6: 4 t BC + 70% RDF

3.6 Raising of seedlings

The nursery beds were prepared 1m wide, 3 m long and elevated up to 15 cm from the ground level with the help of soil mixture (1/3 well rotten FYM + 1/3 sand + 1/3 soil) at the upper level of nursery bed, creating a porous and well drained condition. BARI BAGUN 5 seeds were sown on the nursery beds in rows 5 cm apart and seed were treated with bavistin @ 2g/kg. After sowing the seeds, the rows were covered with a thin layer of sieved FYM and the nursery bed covered with paddy straw. Sprinkling of water with water cans was done immediately. This practice was repeated frequently as and when required to make the beds well moisturized till the germination. After seeds germination, the cover of dry paddy straw was removed. Weeding was done manually as and when weeds appeared in the nursery beds, without disturbing the seedlings. At the 2-4 leaf stage, irrigate seedlings with 0.1% urea solution. Application of neem cake powder @ 250 g/m^2 of nursery bed.

3.7 Experimental design and layout

The experiment was laid out in randomized complete block design with single factor and three replications. There were 7 treatments and 21 unit plots. The unit plot size was 3.36 m^2 (2.8 m × 1.2 m). The blocks and unit plots were separated by 1.0 m and 0.70 m spacing, respectively. The intra block and plot spaces were used as irrigation and drainage channels.

3.8 Land preparation and transplanting

The experimental area was ploughed and harrowed in order to bring the soil in well-pulverized condition. FYM was applied @ 20 t/ha. The plots were made according to the layout plan after leveling. Seedlings were taken off from the nursery beds and transplanted in the plots at a spacing of 70 cm row to row and 70 cm plant to plant after applied root treatment by Bavi or Manco Zeb. Five-week-old seedlings immediately followed by light irrigation were transplanted for proper establishment of the seedlings. It was done in the afternoon hours. A week after transplanting gap filling was done. All the other recommended package of practices was followed to raise a healthy crop.

3.9 Irrigation

The first irrigation was administrated immediately after transplantation to ensure proper establishment of the plant. Subsequent irrigation was given at 15 days interval up to the month of January.

3.10 Fertilizer application

The prescribed quantities of inorganic fertilizers along with biochar were applied as per the treatment requirement. Nitrogen, phosphorus, potassium, boron and zinc were applied, in the form of urea, single super phosphate, muriate of potash, boric acid and zinc sulphate, respectively. The full amount of FYM, phosphorus, boron, zinc was applied and along with one third of nitrogen and potash before transplanting the seedling. The rest of the nitrogen and potash were applied in two equal doses at 25 and 50 days after transplanting. Recommended dose of fertilizer is given below:

Treatment	Cowdung (kg)	Urea (g)	TSP (g)	MoP (g)	Gypsum (g)	Boron (g)	Biochar (g)
B_0 (100% RDF)	3.36	100.8	84	67.2	33.6	3.36	0
B_1 (2t BC+100%RDF)	3.36	100.8	84	67.2	33.6	3.36	672
B_2 (2t BC+90%RDF)	3.024	90.72	75.6	61.2	30.24	3.024	672
B_3 (3t BC+100%RDF)	3.36	100.8	84	67.2	33.6	3.36	1008
B_4 (3t BC+80%RDF)	2.688	80.64	67.2	54.4	26.88	2.688	1008
B_5 (4t BC+100%RDF)	3.36	100.8	84	67.2	33.6	33.6	1344
B_6 (4t BC+70%RDF)	2.352	70.56	58.8	47.6	23.52	2.352	1344

3.11 Intercultural operations

The experimental plots were kept weed free. Hand weeding was done as and when needed. The crop was sprayed with Capture 75 WDG @ 0.2 g/L of water and Voliam Flexi 300 SC @ 0.5 ml/L of water alternate to keep the crop free from pests and disease during the crop growth period.

3.12 Harvesting of fruits

The fruit was harvested when it reached a marketable size. Hand picking was used to select the best-sized fruits from each plot for the market. Fruit harvesting began when the fruit reached at maturity stage. At the harvesting stage, the fruits turn a deep purple color. Before harvesting the eggplant, the compactness of the fruit was determined by pressing it between the thumbs. Fruit damage was avoided by harvesting with caution. The harvest lasted until 27 February, 2021.

3.13 Sampling

The sampling was done at 30 days up to harvest for growth analysis. Four plants were randomly selected from each treatment and replication for the study in 3.36 m^2 plot.

3.14 Collection of data

Data about the following characters were recorded from four randomly selected plants from each plot. The following parameters were studied for the present experiment:

i. Plant height (cm)
ii. Number of leaves $plant^{-1}$
iii. Leaf length (cm)
iv. Leaf breadth (cm)
v. Number of flower $plant^{-1}$
vi. Number of fruits $plant^{-1}$
vii. Fruit length (cm)
viii. Fruit diameter (cm)
ix. Individual fruit weight (g)
x. Yield $plant^{-1}$
xi. Yield $plot^{-1}$
xii. Yield ha^{-1}

3.15 Data collection procedure

i. Plant height (cm)

The height of the main stem from the ground level to the apical bud (leaf apex) was measured with the meter scale at different days after transplanting.

ii. Number of leaves plant^{-1}

The number of leaves per plant counted for four randomly selected plants and average was recorded.

iii. Leaf length (cm)

The leaf length of eggplant was measured using the measuring tape and express as a centimeter (cm).

iv. Leaf breadth (cm)

The leaf breadth of eggplant was measured using a measuring tape and express as centimeter (cm).

v. Number of flower plant^{-1}

Number of flowers was counted on each selected plants and average was worked out.

vi. Number of fruits plant^{-1}

The number of fruits was counted in each picking in three randomly tagged plants from each treatment. The number of fruits per plant was calculated by dividing the total number of fruits harvested in all harvests by four.

vii. Fruit length (cm)

The length of the fruits from the calyx joint to the apex was measured in centimeters for three randomly selected fruits from each plot, at the peak fruiting stage.

viii. Fruit diameter (cm)

The diameter of the fruit was measured with the help of slide calipers and then average was recorded.

ix. Individual fruit weight (g)

The weight of five fruits (four plants/treatment) was recorded separately with the help of the weighing balance and the average was worked out for each treatment.

x. Fruit yield plot^{-1} (kg)

Fruits harvested from all plants in each plot including four observational plants were weighted at each harvest. Total yield plot^{-1} was calculated after final harvest.

xi. Fruit yield (t ha^{-1})

The total fruit yield (kg) per plot was converted in tons per hectare by multiplying with factor.

3.16 Economic Analysis

The cost of production was calculated to find out the most economic biochar application on growth and yield of eggplant. All input cost like the cost for land lease and interests on running capital were computing in the calculation. The interests were calculated @ 13% in simple rate. The market price of eggplant was considered for estimating the return.

3.16.1 Analysis for total cost of production of eggplant

All the material and non-material input cost, interest on fixed capital of land and miscellaneous cost were considered for calculating the total cost of production. Total cost of production (input cost, overhead cost), gross return, net return and BCR are presented in Appendix XV.

3.16.2 Gross income

Gross income was calculated on the basis of sale of eggplant. The price of eggplant was determined on the basis of current market value of Kawran Bazar, Dhaka at the time of harvesting.

3.16.3 Net return

Net returns were arrived after deducting the cost of cultivation from the gross returns of the marketable produce on hectare basis and expressed in taka per hectare Net returns = Gross returns – Cost of production.

3.16.4 Benefit cost ratio (BCR)

It was obtained by dividing gross returns with cost of cultivation per hectare.

$$\text{Benefit Cost Ratio} = \frac{\text{Gross returns (Tk/ha)}}{\text{Total cost of production}}$$

3.17 Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10. Data analysis software and the mean differences were adjusted by Duncan Multiple Range Test (DMRT) test at 5% level of probability (Gomez and Gomez, 1984).

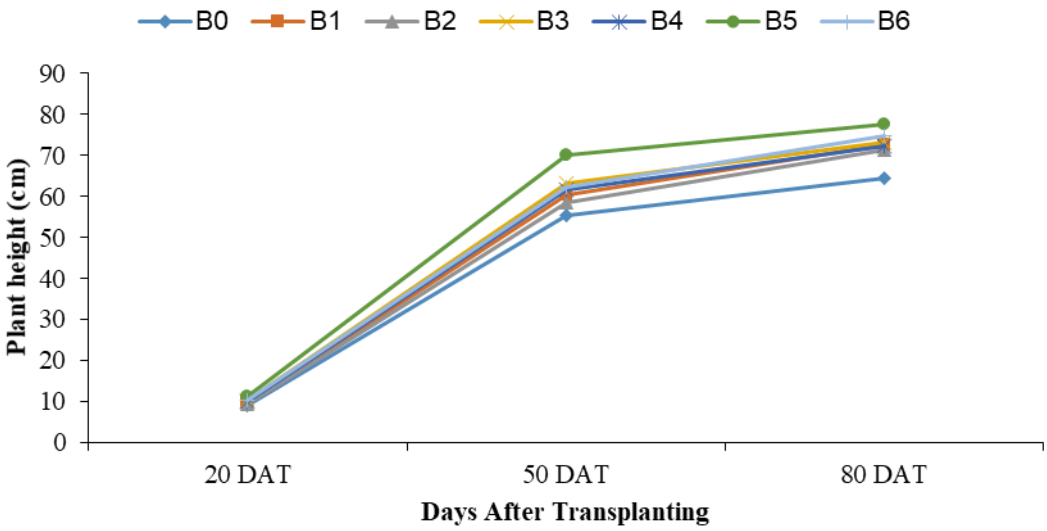
CHAPTER IV
RESULTS AND DISCUSSION

The results of the present experiment were presented in tables 1, 2 and figures 1 to 8 on the impact of biochar and its combination with recommended dose of fertilizer on growth and yield of eggplant. The analysis of variance (ANOVA) of the data on different plant characters obtained from present investigation were presented in Appendices IV to XV. The tabulated results and graphical presentation have been discussed below under the following headings. The findings have been discussed, and possible interpretations are provided under the headings listed below.

4.1 Plant height (cm)

Plant height is an important aspect of the vegetative stage of the eggplant and has an indirect impact on yield. Plant height was measured 20 days, 50 days, and 80 days after transplanting (DAT). The experimental results revealed that different doses of biochar application had a significant influence on eggplant plant height at various days after transplanting (Figure 1 and Appendix IV, V). At 20 DAT, the highest plant height (11.12 cm) was observed in B_5 (4 t BC + 100% RDF) treatment followed by B_6 (10.34 cm) and B_3 (10.17 cm). However, the lowest plant height (8.90 cm) was observed in B_0 [No BC (Biochar) + 100% recommended dose of fertilizer; RDF] treatment. At 50 DAT, the B_5 treatment had the highest plant height (70.25 cm) while the lowest plant height (55.50 cm) was observed in B_0 treatment. At 80 DAT, the highest plant height (77.58 cm) was observed in B_5 (4 t BC + 100% RDF) treatment followed by B_6 (74.67 cm), B_3 (73.25 cm), B_4 (72.33 cm) and B_1 (72.75 cm) treatment. However, the lowest plant height (64.58 cm) was observed in B_0 treatment. The increase in the plant height might be due the biochar's ability to reduce leaching of nutrients, increase water and nutrient retention, increase microbial activity and aeration in the soil and there by slow, steady and balanced nutrients were supplied. This result was in support with the findings of Kaur and Sharma (2020) reported that in berseem crop, application of 5% biochar increased plant height by 28-50%. Rageendrathas and De Silva (2017) reported that biochar application increased the plant height of onion compared to the fertilizer alone treatments. Graber *et al.* (2010)

emphasized that treating plants by biochar positively enhanced plant height of tomato crop.



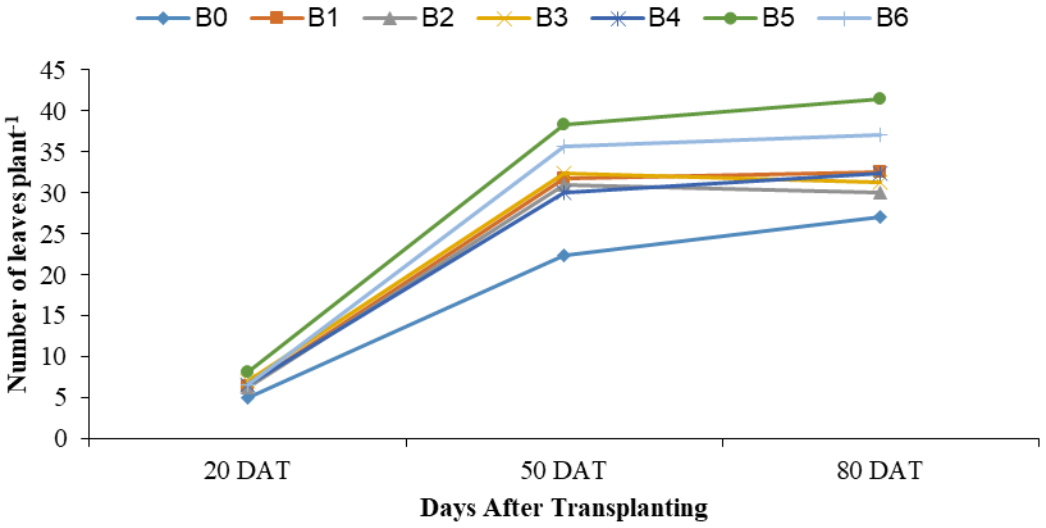
[Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF]

Figure 1. Effect of different doses of biochar application on plant height of eggplant at different days after transplanting (DAT)

4.2 Number of leaves plant^{-1}

A leaf is the principal lateral appendage of the vascular plant stem, usually borne above ground and specialized for photosynthesis. Different concentration of biochar application had shown significant effect on number of leaves plant^{-1} of eggplant at different DAT (Figure 2 and Appendix V, VII). According to the experimental findings, the B_0 treatment had the lowest number of leaves plant^{-1} (5.00, 22.42 and 27.00) at 20, 50 and 80 DAT. While application of biochar increased uptake of nutrients in the plants leading to enhanced chlorophyll content and carbohydrate synthesis that led to the increase cell division and enlargement of the cell size which helped in increased number of leaves comparable to control treatment. The highest number of leaves plant^{-1} (8.17, 38.33 and 41.50) at 20, 50 and 80 DAT was observed in B_5 treatment. Similar results were discovered by Trupiano *et al.* (2017) supporting the current finding, and reported that application of biochar alone stimulated lettuce leaves number. Carter *et al.* (2013) also concluded that application of rice husk

biochar, showed significant change in final biomass, plant height, root biomass and no. of leaves in lettuce and cabbage in comparison to no biochar treatment.



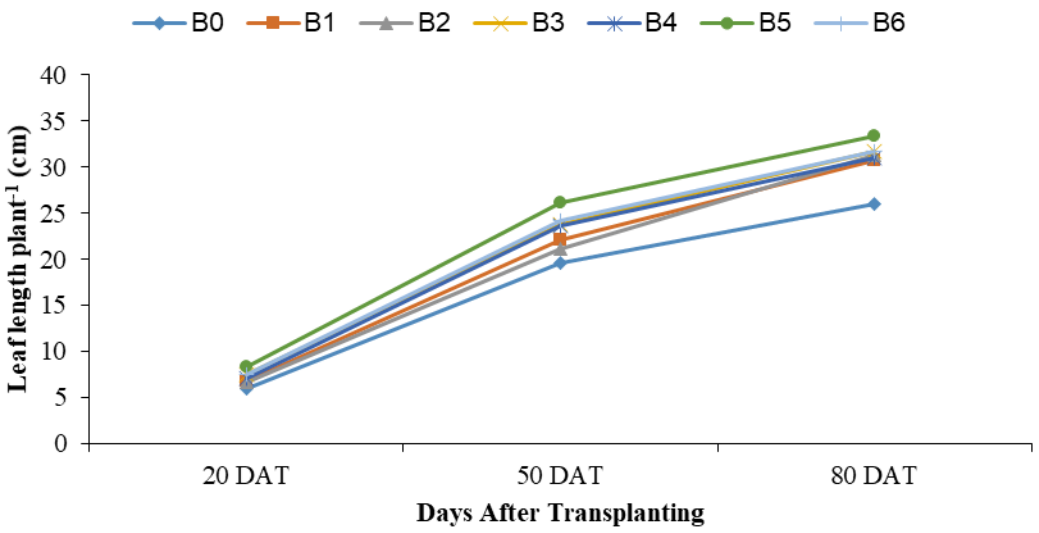
[Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF]

Figure 2. Effect of different doses of biochar application on number of leaves plant^{-1} of eggplant at different days after transplanting (DAT)

4.3 Leaf length plant^{-1} (cm)

The results of the experiment showed that different doses of biochar application had shown significant effect on leaf length plant^{-1} of eggplant at different DAT (Figure 3 and Appendix VIII, IX). The experimental result revealed that at 20 DAT the highest leaf length plant^{-1} (8.38 cm) was observed in B_5 treatment. On the other hand, the lowest leaf length plant^{-1} (6.02 cm) was observed in B_0. At 50 DAT, the B_5 treatment had the highest leaf length plant^{-1} (26.08 cm) while the lowest leaf length plant^{-1} (19.59 cm) was observed in B_0 treatment. At 80 DAT, the highest leaf length plant^{-1} (33.42 cm) was observed in B_5 (4 t BC + 100% RDF) treatment. However, the lowest leaf length plant^{-1} (26.00 cm) was observed in B_0 treatment. The variation of leaf length plant^{-1} might be due to combined application of biochar and inorganic fertilizers which increased vegetative growth that could be attributed to higher metabolic activities because of optimum nitrogen supplies and production of phytohormones which were manifested in the form of enhanced growth and higher carbohydrates production. The result was similar with the findings of Khan *et al.*

(2019) who reported that the maximum leaf length (32.38 cm) of onion was observed in the plots treated with mesquite biochar as compared with FYM and NPK fertilizers.



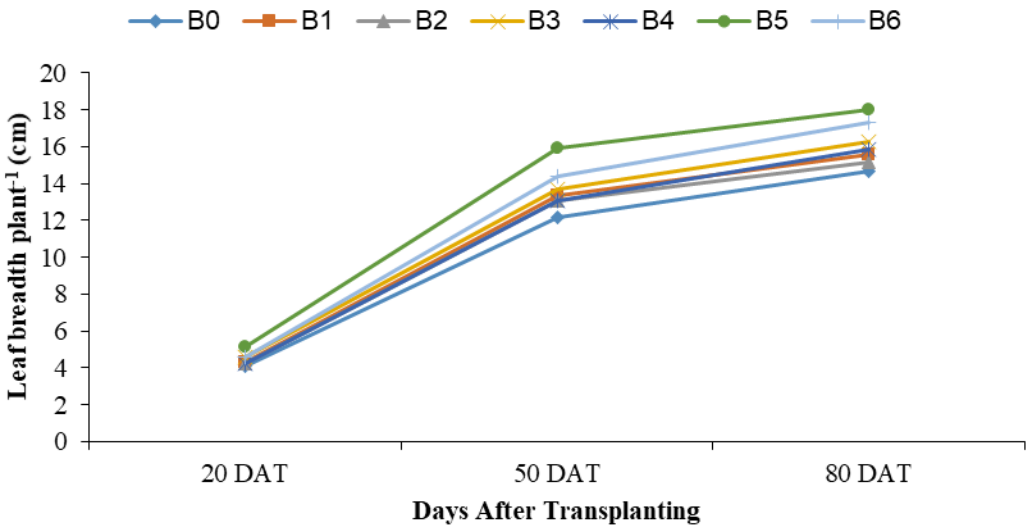
[Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF]

Figure 3. Effect of different doses of biochar application on leaf length plant^{-1} of eggplant at different days after transplanting (DAT)

4.4 Leaf breadth plant^{-1} (cm)

The leaf breadth plant^{-1} of eggplant at various DAT was significantly affected by the application of biochar at various doses (Figure 4 and Appendix X, XI). According to the experimental findings the highest leaf breadth plant^{-1} (5.14, 15.92 and 18.00 cm) at 20, 50 and 80 DAT was observed in B_5 treatment which was statistically similar with B_6 (17.33) treatment at 80 DAT. On the other hand, the lowest leaf breadth plant^{-1} (4.08, 12.17 and 14.67 cm) at 20, 50 and 80 DAT was observed in B_o treatment which was statistically similar with B_2 (4.22 cm) and B_4 (4.21 cm) treatment at 20 DAT and with B_2 (15.17 cm) treatment at 80 DAT. Biochar act as a slow nutrient releasing amendment that helps in fulfilling crop need for longer period of time. Considering the high stability of most of the biochar's over a longer period of time, a little portion may remain mineralizable over a short duration of time and can induce microbial population growth which helps to release nutrients in soil solution and thus improves plant growth and leaf breadth. Trupiano *et al.* (2017) found that applying

biochar alone increased the breadth of lettuce leaves and had a clear and positive effect on plant growth and yield.

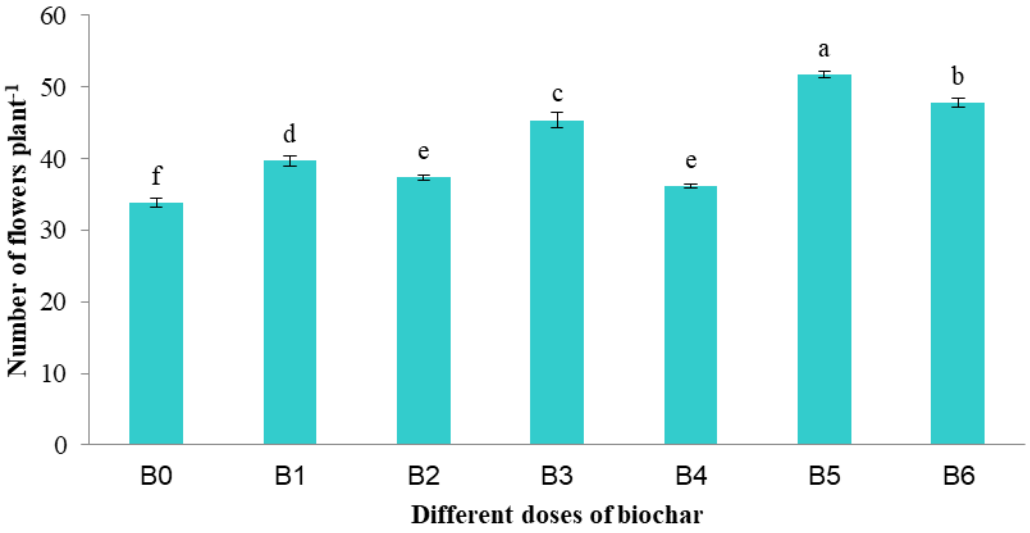


[Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF]

Figure 4. Effect of different doses of biochar application on leaf breadth plant^{-1} of eggplant at different days after transplanting (DAT)

4.5 Number of flowers plant^{-1}

The experimental results showed that biochar had a significant positive effect on the number of flowers plant^{-1} in eggplant, and with an incremental increase observed in proportion to the rate of addition (Figure 5 and Appendix XII, XIII). According to the experimental finding the highest number of flowers plant^{-1} (51.74) was observed in B_5 treatment followed by B_6 (47.84 cm) and B_3 (45.34 cm) treatment. This could be attributed to responses to the biochar application's improved physical character of the soil, which benefits root growth and/or nutrient and water retention and acquisition. While the lowest number of flowers plant^{-1} (33.84) was observed in B_0 treatment. Gamareldawla *et al.* (2017) reported that biochar amendments significantly increased flower per plant of tomato compare to those under no biochar- control treatments. This attributed to the improvement of soil properties and plant growth parameters under biochar additions. Akhtar *et al.* (2014) also showed that addition of biochar increased the soil moisture contents in deficit irrigation and partial root zone drying, which consequently improved physiology, yield and quality of tomato as compared with the non-biochar control.

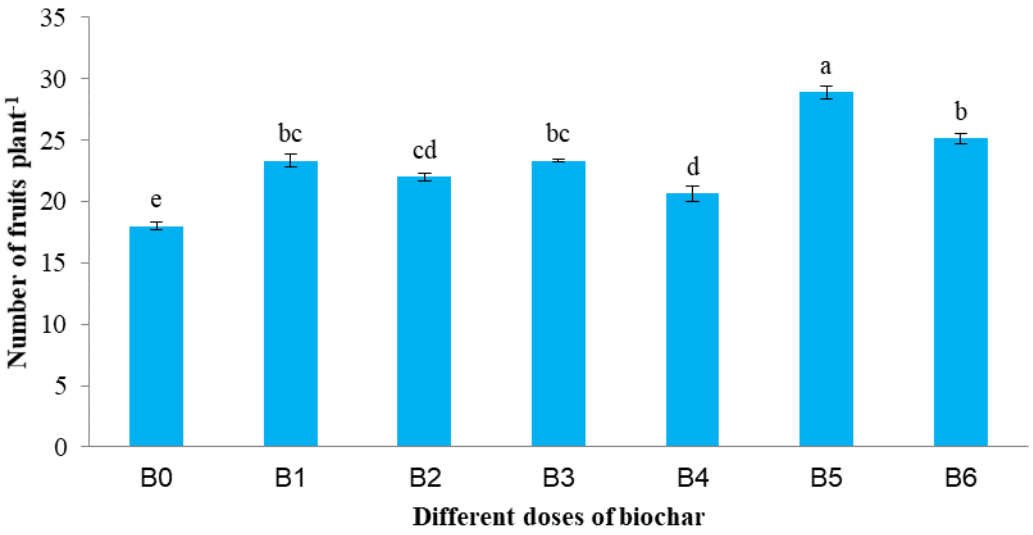


[In bar graphs, similar letter(s) are statistically similar, while dissimilar letter(s) differ significantly at the 0.05 level of probability. Vertical bars at the top of the shaded bars indicate the standard error. Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF]

Figure 5. Effect of different doses of biochar application on number of flowers plant^{-1} of eggplant

4.6 Number of fruits plant^{-1}

The number of fruits plant^{-1} of eggplant was significantly influenced by the treatment of various doses of biochar application (Figure 6 and Appendix XII, XIII). The results of the experiment showed that the highest number of fruits plant^{-1} (28.88) was found in B_5 treatment. While the B_0 treatment had the lowest number fruits plant^{-1} (18.00). The variation of number of fruits plant^{-1} of eggplant was due to biochar application could be attributed to improved physical and biological properties of the soil resulting in better supply of nutrients to the plants. Yilangai *et al.* (2014) found similar results which supported the present finding and reported that the number of fruits plant^{-1} of tomato plant was significantly higher on beds with charcoal than beds without charcoal (biochar) application. Biederman and Harpole (2013) reported that biochar application induces changes in soil chemical properties including an increase in soil pH, cation exchange capacity, and nutrient contents.

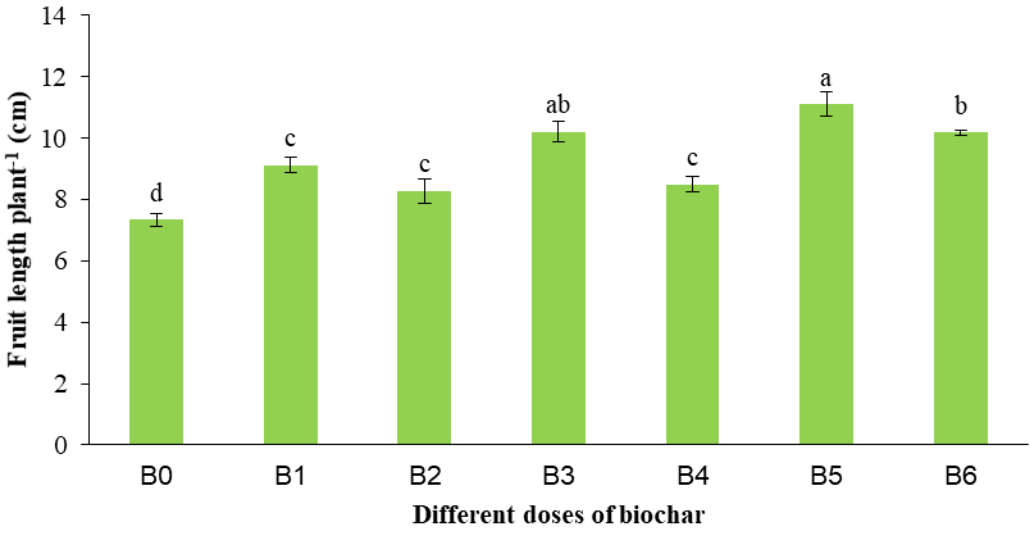


[In bar graphs, similar letter(s) are statistically similar, while dissimilar letter(s) differ significantly at the 0.05 level of probability. Vertical bars at the top of the shaded bars indicate the standard error. Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF]

Figure 6. Effect of different doses of biochar application on number of fruits plant^{-1} of eggplant

4.7 Fruit length plant^{-1} (cm)

The data obtained for fruit length plant^{-1} of eggplant was significantly affected by different doses of biochar application, as shown in figure 7 and appendix XII, XIII. The results of the experiment revealed that the highest fruit length plant^{-1} of eggplant (11.12 cm) was observed in B_5 (4 t BC + 100% RDF) treatment which was at par with B_3 (10.21 cm) treatment. However, the lowest fruit length plant^{-1} of eggplant (7.34 cm) was observed in B_0 treatment. Increase in fruit length due to combined application of biochar and inorganic fertilizers might be due to gradual and steady nutrient release during the growth period along with enhanced biological activity and balanced nutrient availability to the crop. Hossain *et al.* (2010) discovered similar results that supported the current finding and reported a significant effect of biochar on the increase in fruit size of cherry tomatoes.

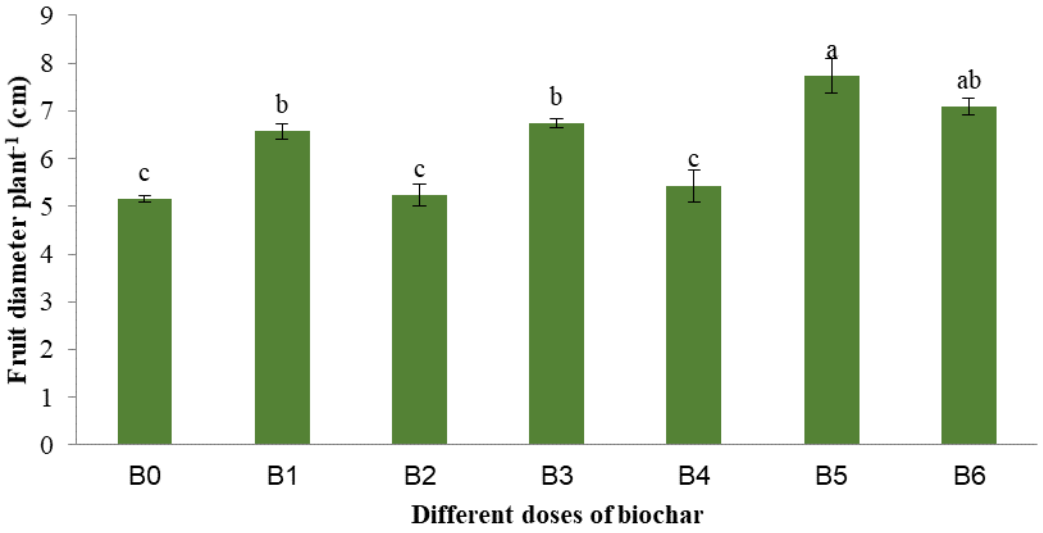


[In bar graphs, similar letter(s) are statistically similar, while dissimilar letter(s) differ significantly at the 0.05 level of probability. Vertical bars at the top of the shaded bars indicate the standard error. Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF]

Figure 7. Effect of different doses of biochar application on fruit length plant^{-1} of eggplant

4.8 Fruit diameter plant^{-1} (cm)

As shown in the figure 8 and appendix XII, XIII, the data obtained for fruit diameter plant^{-1} of eggplant was significantly affected by different doses of biochar application. The results of the experiment revealed that the B_5 (4 t BC + 100% RDF) treatment had the highest fruit diameter plant^{-1} of eggplant (7.74 cm), which was statistically similar to the B_6 (7.09 cm) treatment. On the other hand, the B_0 treatment had the lowest fruit diameter plant^{-1} of eggplant (5.15 cm) which was statistically similar with B_2 (5.24 cm) and B_4 (5.43 cm) treatment. Increase in fruit diameter might be due to application of biochar and inorganic fertilizers can provide better mobilization of plant nutrients particularly N and P during later stage of plant growth which might have thus improved fruit size and ultimately diameter. Gamareldawla *et al.* (2017) reported that biochar application had a significant effect on tomato fruit diameter due to increased nitrogen and phosphorus availability in soil due to stimulation of accumulated dry matter in vegetative parts by biochar application in soil.



[In bar graphs, similar letter(s) are statistically similar, while dissimilar letter(s) differ significantly at the 0.05 level of probability. Vertical bars at the top of the shaded bars indicate the standard error. Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF]

Figure 8. Effect of different doses of biochar application on fruit diameter plant^{-1} of eggplant

4.9 Individual fruit weight (g)

Different levels of biochar application significantly influenced individual fruit weight of eggplant (Table 1 and Appendix XIV). The experimental result revealed that the lowest individual fruit weight (124.89 g) was observed in B_0 treatment. While application of biochar along with inorganic fertilizer influenced individual fruit weight of eggplant and the highest individual fruit weight (170.50 g) was observed in B_5 treatment. Increase in number of fruits might be due to positive effects of inorganic fertilizers with organic manures (biochar) which could have induced higher vegetative growth ultimately helped in the synthesis of greater amount of food material which were later translocated into the developing fruits, resulting in an increase in number of fruits. Similar result also observed by Youseef *et al.* (2017) revealed that the number of tubers significantly increased with increasing biochar application rates up to 12 m^3 ha^{-1}.

4.10 Yield plant^{-1} (kg)

The data obtained for eggplant yield plant^{-1} was significantly affected by different doses of biochar application (Table 1 and Appendix XIV). According to the

experimental findings the highest yield plant^{-1} (4.92 kg) was observed in B_5 treatment followed by B_6 (3.85 kg) and B_3 (3.54 kg) treatment. However, the lowest yield plant^{-1} (2.25 kg) was observed in B_0 treatment. Increase in fruit yield plant^{-1} might be due to favorable effect of biochar and inorganic fertilizers which supply the essential nutrients in balanced ratio and thus improved physical chemical and biological properties of soil which helps in better nutrients absorption and utilization by the plants resulting higher yield. Rageendrathas and De Silva (2017) reported that yield of onion was significantly increased by the application of paddy husk biochar. Vista and Khadka. (2017) reported that application of 30 t ha^{-1} of biochar was most satisfactory for overall improvement of yield and growth parameters of vegetable crops.

4.11 Yield plot^{-1} (kg)

Yield plot^{-1} of eggplant was significantly influenced by different levels of biochar application (Table 1 and Appendix XIV). The experimental results revealed that the B_0 treatment had the lowest yield plot^{-1} of eggplant (7.56 kg). While the application of biochar in conjunction with inorganic fertilizer influenced eggplant yield and the highest yield plot^{-1} of eggplant (16.53 kg) was observed in B_5 treatment followed by B_6 (12.94 kg) treatment. Increased fruit yield plot^{-1} could be attributed to the combined application of inorganic and biochar as organic fertilizers, which could have resulted in vigorous plant growth, resulting in more branches and fruits, and thus a higher yield. Vista and Khadka (2017) reported that application of 30 t ha^{-1} of biochar was most satisfactory for overall improvement of yield and growth parameters of vegetable crops. Vinh *et al.* (2014) reported that yield of rice increased by 4.7-25.5% with biochar as compared to unamended control plot. Akhtar *et al.* (2014) showed that addition of biochar increased the soil moisture contents in deficit irrigation and partial root zone drying, which consequently improved physiology, yield and quality of tomato as compared with the non-biochar control.

4.12 Yield (t ha^{-1})

Yield ha^{-1} was found to be highly significant among the different levels of biochar application (Table 1 and Appendix XIV). The experimental result revealed that the B_0 treatment had the lowest eggplant yield (22.50 t ha^{-1}). While the B_5 treatment had the highest eggplant yield (49.20 t ha^{-1}). The reason for increased fruit yield could be attributed to solubilization effect of plant nutrients by the addition of biochar leading

to increased uptake of NPK. Further biochar would have helped the soil to improve the nutrients status and water holding capacity. Rageendrathas and De Silva (2017) reported that yield of onion was significantly increased by the application of paddy husk biochar. Gaskin *et al*. (2010) observed that peanut hull biochar increased the concentration of nutrients (pH, N, P, K, Mg and Ca). In the same study, the changes in corn tissue nutrient (N, P, S and Mg) status with the application of biochar, which showed little response whereas yield of corn has significantly, respond to biochar application. Haefele *et al.* (2011) reported that biochar application improved the CEC and soil water holding capacity and thereby 16-35 percent improvements in grain yield over control.

Table 1. Effect of different levels of biochar application on individual fruit weight and yield of eggplant

Treatments	Individual fruit weight (g)	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)	Yield (t ha^{-1})
B_0	124.89 d	2.25 e	7.56 e	22.50 e
B_1	146.83 b	3.43 b-d	11.52 c	34.30 c
B_2	133.68 c	2.94 d	9.88 d	29.40 d
B_3	151.83 b	3.54 bc	11.89 c	35.40 c
B_4	148.28 b	3.06 cd	10.28 d	30.60 d
B_5	170.50 a	4.92 a	16.53 a	49.20 a
B_6	153.33 b	3.85 b	12.94 b	38.50 b
DMRT $_{(0.05)}$	6.61	0.51	0.86	2.81
CV (%)	2.53	8.47	4.20	4.61

[In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF]

4.13 Economic analysis

Economics was the major criteria to evaluate the best treatments which were economically sound and that can be accepted by farming community. The cost of cultivation, gross and net returns in addition to benefit cost ratio of different treatment combinations studied in the present investigation was presented in (Table 2 and Appendix XV).

4.14 Cost of production

The total expenditure was observed to range from Tk. 2,35,770/- (B_0) to 3,30,570/- (B_6). Among all the inputs used in the present investigation, labor contributes more to the cost of cultivation (Table 2 and Appendix XV).

4.15 Gross returns

Gross returns for different treatment combinations in the present investigation ranged from Tk. 4,50,000/- (B_0) to Tk. 9,84,000/- (B_3). Among all the treatment combinations studied, B_5 gave highest gross returns of Tk. 9,84,000/- followed by 7,70,000/- (B_6) (Table 2).

Table 2. Economic analysis of eggplant as influenced by different levels of biochar application

Treatments	Fruit yield (t ha^{-1})	Total cost of production (Tk)	Gross return/ha (Tk)	Net return/ha (Tk)	Benefit Cost Ratio (BCR)
B_0	22.50	235770	450000	214230	1.90
B_1	34.30	283170	686000	402830	2.42
B_2	29.40	274756	588000	313244	2.14
B_3	35.40	306870	708000	401130	2.31
B_4	30.60	290043	612000	321957	2.11
B_5	49.20	330570	984000	653430	2.98
B_6	38.50	305329	770000	464671	2.52

[Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF]

4.16 Net returns

Highest net returns per hectare of Tk. 6,53,430/- in eggplant cultivation under different treatment combinations of biochar and inorganic fertilizer studied was obtained with the B_5 (Tk. 6,53,430/-) followed by B_6 (TK. 4,64,671/-) whereas lowest net returns of Tk. 2,14,230/- was observed with B_0 (Table 2).

4.17 Benefit cost ratio

Among all the treatment combinations studied in the present investigation, B_5 resulted in highest benefit cost ratio of 2.98 followed by B_6 (2.52). Further, lowest benefit cost ratio of 1.90 was obtained from B_0 (Table 2).

CHAPTER V
SUMMARY AND CONCLUSION

An experiment was carried out in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, to investigate the impact of biochar application and its combination with recommended dose of fertilizer on growth and yield of eggplant from October 2020 to February 2021 during the Rabi season. The experiment was set up in a randomized complete block design (RCBD) with seven treatments, which were different doses of biochar applied with inorganic fertilizer *i.e.,* B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF. For the purpose of evaluating the experimental outcomes, data on various parameters were statistically analyzed for evaluation of the different treatment effects. The summary of the results has been described in this chapter.

Different doses of biochar application resulted in significant variations in eggplant growth, yield contributing characters, and yield. The main effect of biochar application demonstrated that, biochar application had a significant influence on eggplant plant height at various days after transplanting. At 20, 50 and 80 DAT, respectively application of biochar @: 4 t BC + 100% RDF (B_5) produced the tallest plant (11.12, 70.25 and 77.58 cm). However, the lowest plant height (8.90, 55.50 and 64.58 cm) was observed in B_0 (No BC (Biochar) + 100% recommended dose of fertilizer; RDF) treatment. The use of biochar caused a significant change in the number of leaves plant^{-1} of eggplant. The B_0 treatment had the lowest number of leaves plant^{-1} (5.00, 22.42 and 27.00) at 20, 50 and 80 DAT. While the highest number of leaves plant^{-1} (8.17, 38.33 and 41.50) at 20, 50 and 80 DAT was observed in B_5 treatment. The influence of different doses of biochar application on leaf length plant^{-1} and leaf breadth plant^{-1} was also significant. The number of flowers plant^{-1} varied significantly due to different doses of biochar application. The highest number of flowers plant^{-1} (51.74) was observed in B_5 treatment followed by B_6 (47.84 cm) and B_3 (45.34 cm) treatment. While the lowest number of flowers plant^{-1} (33.84) was observed in B_0 treatment. The effect of different doses of biochar application on the number of fruit plant^{-1}, fruit length and fruit diameter of eggplant was significant. The

highest number of fruits plant^{-1} (28.88), fruit length plant^{-1} (11.12 cm) and fruit diameter plant^{-1} of eggplant (7.74 cm) was observed in B_5 treatment. On the other hand, the B_0 treatment had the lowest number of fruits plant^{-1} (18.00), fruit length plant^{-1} (7.34 cm) and fruit diameter plant^{-1} of eggplant (5.15 cm). The weight of individual fruit weight was significantly influenced by different treatment of biochar application. The lowest individual fruit weight plant^{-1} (124.89 g) was observed in B_0 treatment. While application of biochar along with inorganic fertilizer influenced individual fruit weight plant^{-1} of eggplant and the highest individual fruit weight plant^{-1} (170.50 g) was observed in B_5 treatment. The different biochar application doses on eggplant had a significant impact on the individual fruit weight plant^{-1}, yield plant^{-1}, yield plot^{-1} and yield. The lowest yield plant^{-1} (2.25 kg), yield plot^{-1} (7.56 kg) and yield (22.50 t ha^{-1}) was observed in B_0 treatment. While the application of biochar in conjunction with inorganic fertilizer influenced yield contributing characteristics and yield of eggplant, and recorded the highest yield plant^{-1} (4.92 kg), yield plot^{-1} (16.53 kg) and yield (49.20 t ha^{-1}) in B_5 treatment.

The highest gross return (Tk. 9,84,000/-), net return (Tk. 6,53,430/-) and BCR (2.98) were obtained from B_5 where the lowest gross return (Tk. 4,50,000/-), net return (Tk. 2,14,230/-) and BCR (1.90) were found from B_0 treatment combination.

Conclusion

Based on the above findings, our experimental results revealed that, different doses of biochar application resulted in significant variations in respect of growth, yield contributing characteristics, and yield of eggplant.

The influence of different doses of biochar application on plant height, number of leaves plant^{-1}, leaf length plant^{-1} and leaf breadth plant^{-1} was significant at different days after transplanting.

Among different doses of biochar application, the B_5 treatment produced the highest number of flowers plant^{-1} (51.74), number of fruits plant^{-1} (28.88), fruit length plant^{-1} (11.12 cm), fruit diameter plant^{-1} (7.74 cm), individual fruit weight plant^{-1} (170.50 g), yield plant^{-1} (4.92 kg), yield plot^{-1} (16.53 kg) and yield (49.20 t ha^{-1}). However, the second highest fruit yield (38.50 t ha^{-1}) was recorded from B_6 treatment followed by

B_3 (35.40 t ha^{-1}) treatment and the minimum fruit yield (22.50 t ha^{-1}) was observed in B_0 treatment.

Therefore, based on the findings, it could be concluded that the use of biochar and its combinations with recommended dose of fertilizer (4 t BC + 100% RDF) influenced the growth, yield, and yield attributing characteristics of eggplant.

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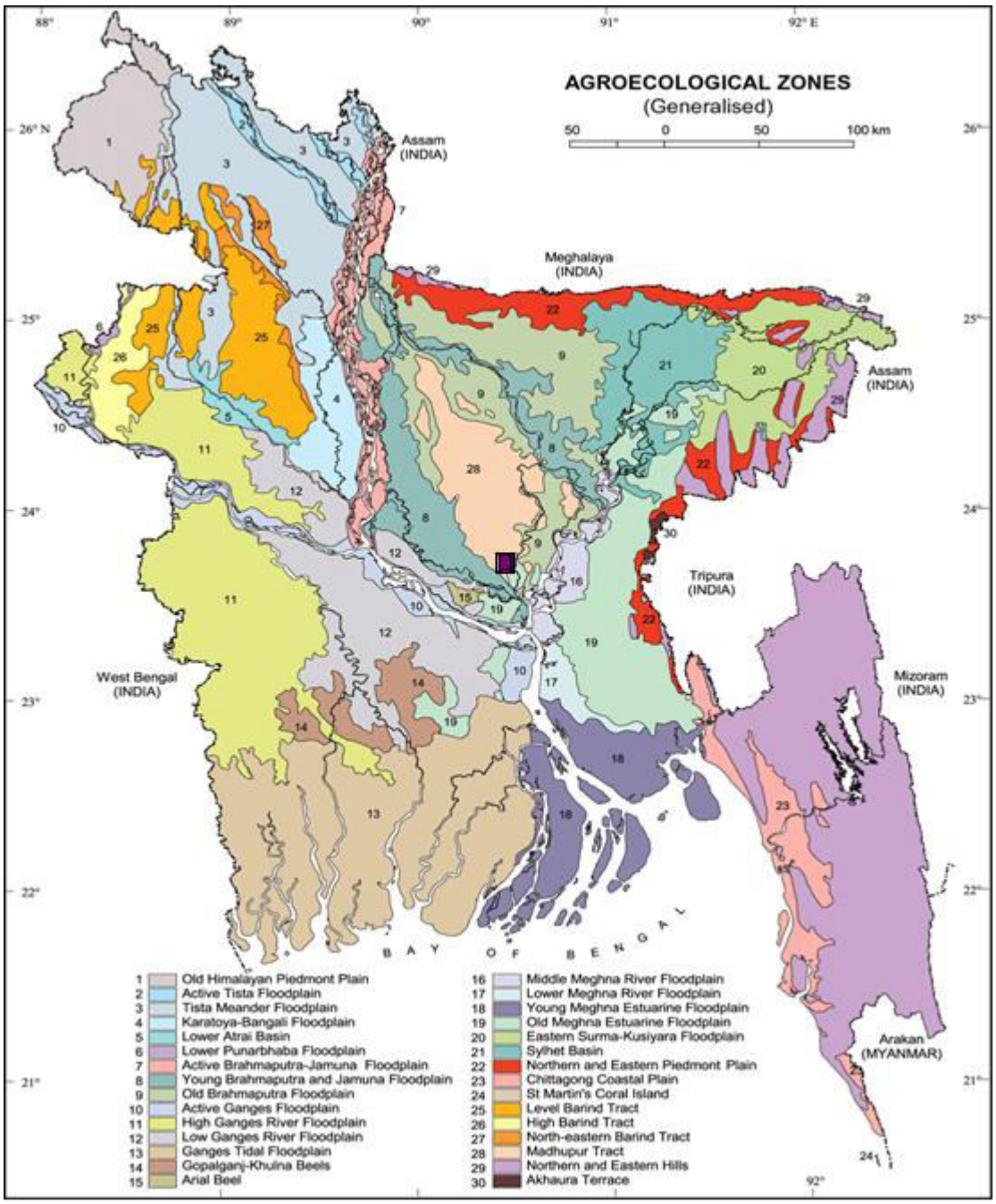
APPENDICES

Appendix I. Map showing the experimental location under study



The Experimental site under study

Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

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

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

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay

Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

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

Appendix III. Monthly meteorological information during the period from September, 2020 to February, 2021

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Average rainfall (mm)
		Maximum	Minimum		
2020	September	32.4°C	25.7°C	80%.	86 mm
	October	31.2°C	23.9°C	76%.	52 mm
	October	31.2	23.9	76	52 mm
	November	29.6	19.8	53	00 mm
	December	28.8	19.1	47	00 mm
2021	January	25.5	13.1	41	00 mm
	February	25.9	14	34	7.7 m

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

Appendix IV. Effect of biochar on plant height of eggplant at different days after transplanting (DAT)

Treatments	Plant height (cm)		
	20 DAT	50 DAT	80 DAT
B_0	8.90 e	55.50 d	64.58 d
B_1	9.54 cd	60.25 bc	72.75 bc
B_2	9.40 de	58.42 cd	71.50 c
B_3	10.17 bc	63.33 b	73.25 bc
B_4	10.02 b-d	61.58 bc	72.33 bc
B_5	11.12 a	70.25 a	77.58 a
B_6	10.34 b	62.33 bc	74.67 b
DMRT $_{(0.05)}$	0.63	4.21	2.79
CV (%)	3.58	3.84	4.17

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF.

Appendix V. Analysis of variance of the data on plant height of eggplant as influenced by different doses of biochar application

Source	Degrees of freedom (df)	Mean square of plant height at		
		20 DAT	50 DAT	80 DAT
Replication (R)	2	1.08204	7.2758	2.9471
Treatment (B)	6	1.57187*	63.7317*	47.3974*
Error	12	0.12599	5.6059	2.4642

NS: Non significant

*: Significant at 0.05 level of probability

Appendix VI. Effect of biochar on number of leaves plant^{-1} of eggplant at different days after transplanting (DAT)

Treatments	Number of leaves plant^{-1}		
	20 DAT	50 DAT	80 DAT
B_0	5.00 d	22.42 e	27.00 d
B_1	6.33 c	31.75 cd	32.50 c
B_2	6.25 c	31.00 cd	30.00 cd
B_3	7.08 b	32.42 c	31.25 c
B_4	6.58 bc	30.00 d	32.42 c
B_5	8.17 a	38.33 a	41.50 a
B_6	6.58 bc	35.75 b	37.08 b
DMRT $_{(0.05)}$	0.65	2.37	3.09
CV (%)	5.65	4.21	5.26

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF.

Appendix VII. Analysis of variance of the data on number of leaves plant^{-1} of eggplant as influenced by different doses of biochar application

Source	Degrees of freedom (df)	Mean square of number of leaves plant^{-1} at		
		20 DAT	50 DAT	80 DAT
Replication (R)	2	0.44502	82.7275	127.002
Treatment (B)	6	2.72260*	75.1856*	68.712*
Error	12	0.13755	1.7769	3.031

NS: Non significant

*: Significant at 0.05 level of probability

Appendix VIII. Effect of biochar on leaf length plant^{-1} of eggplant at different days after transplanting (DAT)

Treatments	Leaf length plant^{-1}		
	20 DAT	50 DAT	80 DAT
B_0	6.02 e	19.59 e	26.00 c
B_1	6.78 d	22.16 cd	30.67 b
B_2	6.70 d	21.17 d	31.25 b
B_3	7.46 b	23.83 b	31.75 b
B_4	7.13 c	23.60 bc	31.00 b
B_5	8.38 a	26.08 a	33.42 a
B_6	7.50 b	24.17 b	31.75 b
DMRT $_{(0.05)}$	0.30	1.54	1.57
CV (%)	2.42	6.23	4.88

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF.

Appendix IX. Analysis of variance of the data on leaf length plant^{-1} of eggplant as influenced by different doses of biochar application

Source	Degrees of freedom (df)	Mean square of leaf length plant^{-1} at		
		20 DAT	50 DAT	80 DAT
Replication (R)	2	0.65583	3.3100	3.2546
Treatment (B)	6	1.67368*	13.8010*	15.9717*
Error	12	0.02995	2.0408	0.7880

NS: Non significant

*: Significant at 0.05 level of probability

Appendix X. Effect of biochar on leaf breadth plant^{-1} of eggplant at different days after transplanting (DAT)

Treatments	Leaf breadth plant^{-1}		
	20 DAT	50 DAT	80 DAT
B_0	4.08 d	12.17 d	14.67 d
B_1	4.31 c	13.33 c	15.58 bc
B_2	4.22 cd	13.08 c	15.17 cd
B_3	4.60 b	13.67 c	16.25 b
B_4	4.21 cd	13.08 c	15.83 bc
B_5	5.14 a	15.92 a	18.00 a
B_6	4.60 b	14.42 b	17.33 a
DMRT $_{(0.05)}$	0.21	0.69	0.72
CV (%)	2.77	2.86	2.52

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF.

Appendix XI. Analysis of variance of the data on leaf breadth plant^{-1} of eggplant as influenced by different doses of biochar application

Source	Degrees of freedom (df)	Mean square of leaf breadth plant^{-1} at		
		20 DAT	50 DAT	80 DAT
Replication (R)	2	0.35155	2.69607	2.01839
Treatment (B)	6	0.39404*	4.34337*	4.20915*
Error	12	0.01522	0.15240	0.16514

NS: Non significant

*: Significant at 0.05 level of probability

Appendix XII. Effect of biochar on number of flowers plant^{-1}, number of fruits plant^{-1}, fruit length and fruit diameter of eggplant

Treatments	Number of flowers plant^{-1}	Number of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)
B_0	33.84 f	18.00 e	7.34 d	5.15 c
B_1	39.66 d	23.34 bc	9.12 c	6.57 b
B_2	37.34 e	22.00 cd	8.28 c	5.24 c
B_3	45.34 c	23.34 bc	10.21 ab	6.74 b
B_4	36.16 e	20.66 d	8.50 c	5.43 c
B_5	51.74 a	28.88 a	11.12 a	7.74 a
B_6	47.84 b	25.12 b	10.19 b	7.09 ab
DMRT $_{(0.05)}$	2.26	2.10	0.93	0.71
CV (%)	3.06	5.14	5.66	6.43

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF.

Appendix XIII. Analysis of variance of the data on number of flowers plant^{-1}, number of fruits plant^{-1}, fruit length and fruit diameter of eggplant as influenced by different doses of biochar application

Source	Degrees of freedom (df)	Mean square of			
		Number of flowers plant^{-1}	Number of fruits plant^{-1}	Fruit length	Fruit diameter
Replication (R)	2	5.068	0.5055	0.19076	2.07638
Treatment (B)	6	133.697*	35.3795*	5.25410*	3.08707*
Error	12	1.625	1.4010	0.27449	0.16292

NS: Non significant

*: Significant at 0.05 level of probability

Appendix XIV. Analysis of variance of the data on individual fruit weight and yield of eggplant as influenced by different doses of biochar application

Source	Degrees of freedom (df)	Mean square of			
		Individual fruit weight	Yield plant^{-1}	Yield plot^{-1}	Yield
Replication (R)	2	20.108	1.79441	1.4241	7.110
Treatment (B)	6	641.787*	2.08897*	23.5810*	208.897*
Error	12	13.819	0.08419	0.2343	2.500

NS: Non significant

*: Significant at 0.05 level of probability

Appendix XV. Per hectare production cost of eggplant

A. Input cost per hectare

Treatments	Labor cost (Tk.)	Ploughing cost (Tk.)	Seed cost (Tk.)	Irrigation cost (Tk.)	Pesticides cost (Tk.)	Sticking cost (Tk.)	Manure and fertilizer cost (Tk.)		Subtotal Cost (Tk.) (A)
							RDF	Biochar	
B_0	30000	12000	5000	10000	9000	5000	71000	0	142000
B_1	30000	12000	5000	10000	9000	5000	71000	40000	182000
B_2	30000	12000	5000	10000	9000	5000	63900	40000	174900
B_3	30000	12000	5000	10000	9000	5000	71000	60000	202000
B_4	30000	12000	5000	10000	9000	5000	56800	60000	187800
B_5	30000	12000	5000	10000	9000	5000	71000	80000	222000
B_6	30000	12000	5000	10000	9000	5000	49700	80000	200700

Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF.

B. Overhead cost (Tk./ha)

Treatments	Cost of lease of land for 6 months (13.5%of value of landTk.1000,000/year)	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (Tk. 13.5% of cost/year)	Subtotal (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
B_0	67500	7100	19170	93770	235770
B_1	67500	9100	24570	101170	283170
B_2	67500	8745	23611	99856	274756
B_3	67500	10100	27270	104870	306870
B_4	67500	9390	25353	102243	290043
B_5	67500	11100	29970	108570	330570
B_6	67500	10035	27094	104629	305329

Here, B_0: No BC (Biochar) + 100% recommended dose of fertilizer (RDF), B_1: 2 t BC + 100% RDF, B_2: 2 t BC + 90% RDF, B_3: 3 t BC + 100% RDF, B_4: 3 t BC + 80% RDF, B_5: 4 t BC + 100% RDF and B_6: 4 t BC + 70% RDF.

PLATES

Plate 1. Biochar in prepared land

Plate 2. Germination of eggplant seed

Plate 3. Layout of the experimental field

Plate 4. Irrigation given before transplanting of eggplant seedling

Plate 5. Transplanting of eggplant seedling

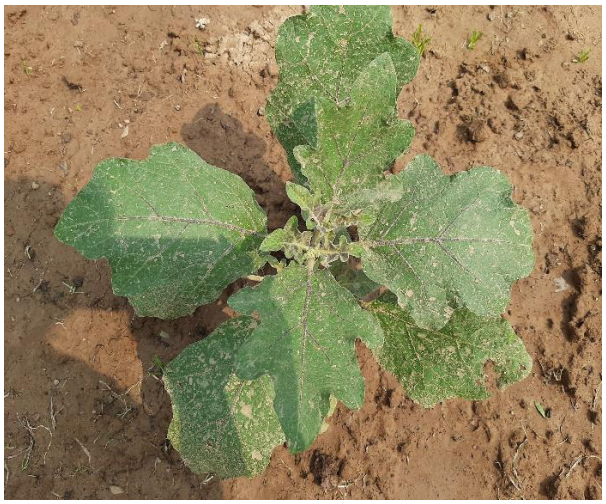


Plate 6. Growth stage of seedling of eggplant

Plate 7. Flower initiation of eggplant

Plate 8. Fruit in eggplant

Plate 9. Data collection of harvested fruits of eggplant