EFFECT OF BIOCHAR ON GROWTH AND YIELD OF MUNGBEAN (BARIMung-6)

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CERTIFICATE

This is to certify that the thesis entitled **'EFFECT OF BIOCHAR ON GROWT AND YIELD OF BARIMung-6'** submitted to the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SOIL SCIENCE**, embodies the results of a piece of bonafide research work carried out **KAMRUNNAHER TOMA**, Registration No. **16-07565** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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TO

MY BELOVED PARENTS

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ABSTRACT

This research work was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka during the period from March, 2017 to July, 2017 to study the growth and yield of mungbean (BARI Mung-6) as influenced by different levels of biochar. The experiment comprised of the following 8 treatments as T_1= Control,T_2 = RFD (Recommended Fertilizer Dose);T_3 = RFD + Biochar @ 2 ton ha^{-1} T_4 = RFD + Biochar @ 4 ton ha^{-1};T_5 = ⅔of RFD + Biochar @ 2 tonha^{-1}; T_6 = ⅔ of RFD + Biochar @ 4 ton ha^{-1}; T_7= ½ of RFD + Biochar @ 2 ton ha^{-1};T_8 = ½ of RFD + Biochar @ 4 ton ha^{-1}. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. From the research field, the maximum plant height (44.70 cm) was recorded from T_3 treatment, which was statistically identical with other treatments whereas, the minimum plant height (37.57 cm) was recorded from T_1 treatment. The maximum number of branches plant-1, number of pods $plant^{-1}$, pod length (cm), number of seeds pod^{-1}, weight of l000-seed (g) was recorded from T_3 treatment, which was statistically identical with other treatments whereas, the minimum plant height was recorded from T_1 treatment. In addition, yield of grain ton per ha significantly varied among the different levels of biochar applications (Table 4).On the one hand the highest grain yield (1.40 t ha^{-1}) was obtained from T_3 (RFD + Biochar @ 2 ton ha^{-1}) treatment, which was followed by T_4 (1.29 t ha^{-1}) and lowest grain yield (0.83 t ha^{-1}) was obtained from T_1 (control) treatment. On the other hand, in all the cases lower values were found in the control treatment. From this study, it may be concluded that biochar had significant positive effect on growth and yield of mungbean.

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CHAPTER I

INTRODUCTION

Mungbean (*Vigna radiata* L. Wilczek) is one of the major pulse crops supplementing protein in cereal-based diet of the poor people in Bangladesh. Seed contains carbohydrate (51%), protein (26%), minerals (4%), and vitamins (3%). It is potentially useful in the predominent rice-based farming system because of its short duration (Ahmed *et al*., 1978).

Mungbean (*Vigna radiata* L.) is an important pulse crops having high nutritive value**.** It not only plays an important role in human diet but also improve the soil fertility by fixing the atmospheric nitrogen (Ather Nadeem *et al*., 2004). Its seed is more palatable, nutritive, digestible and non-flatulent than other pulses (Anjum *et al*., 2006).

Yield potential of mungbean is generally low. Various factors responsible for low yield of mungbean at the farmer's field are: lack of awareness of farmers about optimum time of sowing, using high yielding variety, improper planting patterns, insufficient plant protection measures and imbalanced use of fertilizers.

Mungbean has good digestibility and flavor. It contains 1-3% fat, 50.4% carbohydrates, 3.5-4.5% fibers and 4.5-5.5% ash, while calcium and phosphorus are 132 and 367 mg per 100 grams of seed, respectively (Frauque *et al.,* 2000).

Mungbean is highly responsive to fertilizers and manures. It has a marked response to nitrogen, phosphorus and potassium. These nutrients play a key role in plant physiological process. A balanced supply of essential nutrients is indispensable for optimum plant growth. Continuous use of large amount of N, P and K are expected to influence not only the availability of other nutrients to plants because of possible interaction between them but also the buildup of some of the nutrients creating imbalances in soils and plants leading to decrease fertilizer use efficiency (Nayyar and Chhibbam, 1992).

Biochar is the solid product of pyrolysis, which is to be used for environmental management and increase crop production. Biochar is a solid material obtained from thermochemical conversion of biomass in an oxygen limited environment. Biochar application to soils can potentially aid mitigation of climate change by sequestering carbon (C). (Yamato *et al*., 2006) revealed that biochar can lead to changes in physical and chemical properties of the soil that resulted in the increased nutrient availability in the soil and increase plant root colonization by mycorrhizal fungi. In addition, biochar may change emissions of other greenhouse gases from soil such as nitrous oxide (N_2O) methane (CH_4) (Rondon *et al.*, 2005). Biochar addition can improve plant productivity directly because of its nutrient holding capacity and release characteristics, or indirectly, through improved nutrient retention. Biochar additions to agricultural soil have been reported to reduce green house gas emission, as well as improve soil fertility and crop productivity (Lehmann *et al*., 2003).

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

Biochar enhance N availability into the soil, reduce leaching loss of N by retain water. Mineralization of N could be enhanced by application of biochar produced from slow pyrolysis rather than fast pyrolysis (Bruun *et al.*, 2012). Nitrogen is of vital importance for plant growth due to being a part of amino acid, protein and chlorophyll molecule (Gilbert *et al.,* 1949). N is beneficial for its growth, development and protein synthesis.

Several studies take places on biochar upon vegetables. The yield of tomato fruit was significantly higher in beds with charcoal than without charcoal (Yilangai *et al*., 2014). Biochar application increased vegetable yields by 4.7-25.5% as compared to farmers' practices (Vinh *et al*., 2014). Very little work has been done with biochar in mugbean production that's why this experiment was set up the study to look at the effect of biochar on soil physical properties and also effect of biochar on yield of mugbean.

OBJECTIVES OF THE RESEARCH WORK

- To observe the effect of biochar on the growth and yield of mungbean.
- To find out the optimum dose of biochar along with inorganic fertilizer for better growth and yield of mungbean.

CHAPTER II

REVIEW OF LITERATURE

Many research works on mungbean have been performed extensively in several countries especially in the South East Asian countries for its improvement of growth and yield. In Bangladesh, little attention has so far been given for the improvement of mungbean variety or its cultural management. Currently Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have started extensive research work on varietal development and improvement of this crop. Findings of various experiments related to the present study in home and abroad have been reviewed and discussed in this chapter.

2.1 Biochar

Biochar has been defined in similar ways by several authors. It is a ‘black carbon manufactured through pyrolysis of biomass’ (Lehmann *et al.* 2006); ‘the high carbon materials produced from the slow pyrolysis (heating in the absence of oxygen) of biomass’ (Chan *et al.* 2007); and ‘a fine-grained and porous substance, similar in its appearance to charcoal produced by natural burning or by the combustion of biomass under oxygen-limited conditions’ (Sohi *et al.* 2009). In fact, it is a product of biomass obtained from heating in a suitable temperature regime in the absence of oxygen (the process of fast or slow pyrolysis) or from a gasification system.

2.2 Biochar and carbon sequestration

The relatively stable nature of biochar allows for carbon sequestration value (Lehmann et al. 2006). Lehmann *et al.* (2006) estimated that about 5-10 Gt C is sequestrated per year which is the equivalent or more than the present global emissions from fossil fuel use. In addition, biochar carbon added almost 40% of the carbon to soil (Glaser *et al*. 2000; Skjemstad *et al.* 2002). Lehmann (2007a) predicted that the retention times of carbon in biochar would be at least hundreds, but more likely thousands of years. In addition, as a pyrolysed product, biochar is protected from rapid microbial degradation and is able to securely sequester carbon, contributing to mitigation of greenhouse gas emissions (Lehmann et al. 2006). Day *et al*. (2004) emphasized that using biochar to sequester carbon in soil to mitigate climate change could only be economical if the sequestered C has beneficial soil amendment and/or fertilizer value.

2.3 Effect of biochar

The widespread problems of an escalating global human population, diminishing food reserves and climate change (carbon abatement) are a growing concern (Lehmann and Joseph 2009). It has been predicted that over the next two decades, crop yields of primary foods such as corn (maize), rice and wheat will considerably decrease as a result of warmer and drier climatic conditions particularly in semi-arid areas (Brown and Funk 2008). In addition to this, agricultural soil degradation and soil infertility are common problems (Chan and Xu 2009). As a means of addressing these problems, the application of biochar to soils has been brought forward in an effort to sustainably amend low nutrient-holding soils (Laird 2008; *et al*. 2011).

Biochar is pyrolyzed (charred) biomass, or also commonly known as charcoal or agrichar, produced by an exothermic process called pyrolysis (Lehmann and Joseph 2009). Pyrolysis is the combustion of organic materials in the presence of little or no oxygen, leading to the formation of carbon-rich char that is highly resistant to decomposition (Thies and Rillig 2009). As a result thereof, biochar can persist in soils and sediments for many centuries (Downie *et al*., 2011), and has great potential to improve agronomic production when applied as a soil amendment.

In previous studies, soils used to investigate the agricultural properties of biochar have mostly been highly weathered soils from humid tropic regions (Verheijen *et al*., 2009). Only recently has research included the investigation of biochar application on the performance of infertile, acidic soils with kaolinitic clays, low cation exchange capacity (CEC), and deteriorating soil organic carbon contents (Chan *et al*., 2007; Chan and Xu 2009; Novak *et al*., 2009). Generally, the addition of biochar to soil has been reported to have a multitude of agricultural benefits. These include a high soil sorption capacity, reduced nutrient loss by surface and groundwater runoff, and a gradual release of nutrients to the growing plant (Laird 2008).

On the contrary, a few possible negative implications have been reported to be associated with biochar. Kookana *et al*., (2011) found that these include i) additional agronomic input costs, ii) the binding and deactivation of synthetic agrochemicals due to an interaction with herbicides and nutrients, iii) the deposit and transport of hazardous contaminants due to the release of toxicants such as heavy metals present in biochar, and iv) an immediate increase in pH and electrical conductivity (EC). Furthermore, although studies have highlighted that contaminants such as organic compounds, heavy metals, and dioxins may be present in biochar, there is limited published research that proves that these contaminants are available (Smernik 2009; Verheijen *et al*., 2009).

The dark anthropogenic soils found in Brazil, also known as Amazonian Dark Earths (ADE) refer to black fertile soils called terra preta de Indio (Woods and Denevan 2009). These rich black earths are highly fertile and produce large crop yields despite the fact that the surrounding soils are infertile (Renner 2007). Studies involving radiocarbon dating have revealed that these soils were produced up to 7000 years ago during pre-Columbian civilization. It is believed that the accumulation of charcoal in these soils is as a result of anthropogenic activities which consequently led to the formation of terra pretasoils (Glaser 2007). Although most dark earths are as a result of long-term human habitation, studies show that chemical changes in the soil are central to the darkening of these soils. These chemical changes encourage soil biotic activity and downward development, and thus resulting in melanization. While these ADE have formed over several millennia, they have not formed at a constant rate. Several studies have found that the rate of formation can fall in the range of 0.015 cm to

1.0 cm per annum. In particular, dark brown to black soils are classified as terra preta de Indio based on similarities in texture and subsoil of the underlying and immediately surrounding soil (Woods and McCann 1999).

2.4 Biochar effects on crops

There are varied responses of crops to biochar (Chan et al. 2008a).Van Zwieten *et al.* (2010a) tested two biochars produced from the slow pyrolysis of paper mill waste, in two agricultural soils in a glasshouse and found that they significantly increased biomass in wheat, soybean and radish in ferrosol soil but reduced wheat and radish biomass in calcaresol, amended with fertilizer in both soils. A significant decrease in dry matter content of radish was obtained when biochar was applied at 10 ton ha(Chan *et al*. 2008a). In a separate experiment, there was no significant effect of biochar rates (0, 7 and 15 tons ha (Brandstaka *et al*. 2010).

Asai *et al.* (2009) showed that biochar increased rice grain yields at sites with low P availability, which might be due to improved saturated hydraulic conductivity of the top soil, xylem sap flow of the plant and response to N and NP chemical fertilizer treatments. Limiting soil N content by biochar application in N deficient soils could be due to the high C/N ratio, hence it might reduce crop productivity temporarily (Lehmann et al. 2003). However, some biochars contain considerable amount of micronutrients. For example, pecan-shelled biochar contained greater amount of copper (Cu), magnesium (Mg) and zinc (Zn) than the soil (Novak *et al.* 2009). In a separate experiment, concentrations of heavy metals including Cu and Zn increased in sewage sludge biochar but those of available heavy metals decreased (Liu *et al*. 2014). Furthermore, poultry litter biochar was also rich with considerable amounts of Zn, Cu and manganese (Mn) (Inal et al. 2015). Thus, it is essential to compare its effect solely and in combination with other nutrient sources. Some authors (Verheijen *et al*. 2009; Brandstaka et al. 2010) have emphasized the need for further research on potential benefits of biochars as well as their economics. However, their interactions with other organic sources as well as microbes and release of nutrients from them are insufficiently assessed.

Biochar at the rates of 20 and 40 t ha^{-1} without N fertilization in a carbon poor calcareous soil of China increased maize yield by 15.8% and 7.3% while the rates with 300 kg ha^{-1} N fertilization enhanced the yield by 8.8% and 12.1% ,respectively (Zhang *et al*. 2012). In addition, biochar application in a nutrient-poor, slightly acidic loamy sand soil had little effect on wheat yield in the absence of mineral fertilization but when applied with the highest rate of mineral fertilization, it produced yield 20–30 % more than mineral fertilizer alone (Alburquerque *et al*. 2014).

The yield of tomato fruit was significantly higher in beds with charcoal than without charcoal (Yilangai *et al.* 2014). Biochar application increased vegetable yields by 4.7-25.5% as compared to farmers' practices (Vinh *et al.* 2014). In another work, biochar did not increase annual yield of winter wheat and summer maize but the cumulative yield over four growing season was significantly increased in a calcareous soil (Liang *et al*. 2014). Biochar of maple was tested at different concentrations for root elongation of pea and wheat but no significant difference was observed (Borsari 2011), possibly due to little effect of biochar in the short-term. The wood chip biochars produced at 290^{o}C and 700^{0} C had no effect on growth and yield of either rice or leaf beet (Lai *et al.* 2013). A biochar significantly increased growth and yield of French bean as compared to no biochar (Saxena *et al*. 2013). A rice-husk biochar tested in lettuce-cabbage-lettuce cycle increased final biomass, root biomass, plant height and number of leaves in comparison to no biochar treatments (Carter *et al*. 2013).

An oak biochar derived from a slow pyrolysis process was tested for four years at 0 t ha^{-1}, 5 t ha^{-1} and 25 t ha^{-1} with 100% and 50% of N fertilizer on a maize -soybean rotation in an alfisol soil, resulting in an overall positive trend in total above-ground biomass and grain yield (Hottle 2013). A poultry-litter biochar derived from slow pyrolysis tested in cotton showed that a higher level (3000 kg ha^{-1}) with urea produced better cotton growth than the lower rate (1500 kg ha^{-1}) which, in turn, did better than the control (Coomer *et al*. 2012).

2.5 Role of biochar on signalling process of mycorrhizae

Signalling between AMF and plants occurs in the rhizosphere (Bais *et al*. 2004; Harrison 2005; Bais *et al*. 2006; Paszkowski 2006). Plants secrete CO_2 flavonoids, sesqueterpens and strigolactones that favour AMF colonization (Bécard & Piché 1989; Nair *et al*. 1991; Xie *et al.* 1995), hyphal branching and spore germination (Gianinazzi-Pearson *et al.* 1989; Akiyama *et al.* 2005). Provided that the function of flavonoid compounds could be inhibitory or stimulatory on micro-organisms due to the change in pH (Angelini *et al.* 2003), addition of biochar increases pH which may have some stimulatory effects on AMF abundance, because biochar is a reservoir of both signalling and inhibitory compounds (allelochemicals) (Warnock *et al*. 2007). The activated carbon adsorbs AMF signalling compounds (strigolactones); after desorbing strigolactones with acetone, strigolactones stimulate hyphal branching and growth of *Gigaspora margarita* (Akiyama *et al*. 2005). Actually, water plays an important role in desorbing signalling molecules and makes them available for hyphal stimulation; if the water continues to remove these signalling compounds from biochar permanently, there will be a net decrease in the number of signal molecules resulting in decreased spore germination, hypal growth and fungal abundance (Warnock *et al*.2007). In addition, activated carbon can absorb phenolic compounds, which are toxic to AMF (Vaario *et al*.1999;Herrmann *et al*.2004).

2.6 Protection of mycorrhizae by biochar against soil predators

Biochar particles can protect AMF from soil predators (Saito 1990; Pietikäinen *et al*. 2000; Ezawa *et al*. 2002) such as mites, collembola, large protozoans and nematodes (Warnock *et al.* 2007) providing shelter for them, including in its pores (<16μm) (Kawamoto *et al*. 2005; Glaser 2007; Hockaday et al. 2007) which are of suitable size (cell diameter of bacteria 1-4 μm, hyphal size 2-64 μm but the majority <16μ) (Swift *et al*. 1979).

CHAPTER III

MATERIALS AND METHODS

This study was carried to find out the effect of biochar on growth and yield of mungbean. This chapter presents a brief description about experimental period, site description, soil and climatic condition of the experimental area, experimental details, treatments, experimental design and layout, intercultural operations, data collection and statistical analysis. The details of experiments and methods are described below-

3.1 Experimental period

The experiment was conducted during the period from March, 2017 to July, 2017 in Kharif season.

3.2 Site description

3.2.1 Geographical location

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

3.2.2 Agro-Ecological Region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1998a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1998b). The experimental site was shown in the map of AEZ of Bangladesh (Appendix I).

3.2.3 Climate characteristics

Experimental site was located in the sub-tropical monsoon climatic zone, set aparted by winter during the months from April, 2017 to September, 2017. Plenty of sunshine and moderately low temperature prevails during experimental period, which is suitable for mugbean growing in Bangladesh.

3.2.4 Soil characteristics

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were silty-clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.8 and had organic matter 1.12%. The experimental area was flat having available irrigation and drainage system and above flood level. Initial soil samples from 0-15 cm depths were collected before transplanting the rice seedling. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed for both physical and chemical properties. The properties studied included pH, organic matter, total N, available P and exchangeable K. The morphological, physical and chemical characteristics of initial soil are presented in Tables 1 and 2.

Table 1. Morphological characteristics of the experimental field

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

Table 2. Physical and chemical properties of the initial soil sample

Characteristics	Value
% Sand (2.0-0.02mm)	18.60
% Silt (0.02-0.002mm)	45.40
% Clay(<0.002mm)	36.00
Textural class	Silty-clay loam
pH	5.8
Bulk Density (g/cc)	1.45
Particle Density (g/cc)	2.52
Organic matter (%)	1.12
Total N (%)	0.06
Available P (mg kg^{-1})	19.00
Exchangeable K (meq/100g soil)	0.11
Available S (mg kg^{-1})	14.00

3.3 Experimental details

3.3.1 Treatments and factor of the experiment

Treatments:

T_1 = Control

T_2 = RFD (Recommended Fertilizer Dose)

T_3= RFD + Biochar @ 2 tonha^{-1}

T_4 = RFD + Biochar @ 4 tonha^{-1}

T_5 = ⅔of RFD + Biochar @ 2 tonha^{-1}

T_6 = ⅔ of RFD + Biochar @ 4 tonha^{-1}

T_7= ½ of RFD + Biochar @ 2 tonha^{-1}

T_8 = ½ of RFD + Biochar @ 4 tonha^{-1}

RFD (Recommended Fertilizer Dose) : $N_{15}P_{20}K_{30}S_{10}$kg ha^{-1}

Every treatment received N, P, K and S as basal doses. Blanket doses of all fertilizer were applied after final land preparation and treatment wise fertilizer dose were applied after bed preparation.

3.3.2 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each block was sub-divided into eight unit plots. The treatments were randomly distributed to the unit plots in each block. The total number of plots was 24 (8×3). The unit plot size was 3 m × 1.75 m. Block to block distance was 0.5 m and plot to plot distance was 0.25 m.

3.4 Land preparation

The plot selected for the experiment was opened by power tiller driven rotovator on the last week of March 2017; afterwards the land was ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. Finally, the land was leveled and the experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in the following section. The soil was treated with Furadan 5G @10 kg ha^{-1} when the plot was finally ploughed to protect the seed and young plant from the attack of cut worm.

3.5 Collection biochar

Biochar was collected from CCDB (Christian Commission for Development in Bangladesh), Shivaloy, Manikgonj, Bangladesh.

3.6 Seed collection and sowing

Seeds of BARIMung-6 were collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur.The Seeds of mungbean were sown on 2 April 2017. The seeds were treated with the fungicide Bavistin before sowing the seeds to control the seed borne disease. The seeds were sown in rows in the furrows having a depth of 2-3 cm. Row to Row distance was 30 cm.

3.7 Intercultural operations

3.7.1 Weeding

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

3.7.2 Watering

Frequency of watering was done upon moisture status of soil retained as requirement of plants. Excess water was not given, because it always harmful for mungbean plant.

3.8 Harvesting

The crops were harvested plot wise according to the maturity of the crops by hand picking. Maturity of crop was determined when 90% of the pod became brown to black in color. Harvesting was done in four times. The harvesting were done on 28th May, 2017; 5th June, 2017; 12th June, 2017 and 24th June, 2017. Before harvesting 10 sample plants from each plot was marked and harvested for recording data of yield and yield contributing characters. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of mungbean seed. Fresh weight of grain and stover were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. Dry weight for both grain and straw were also recorded.

3.9 Collection of experimental data:

Ten (10) plants from each plot were selected as random and were tagged for the data collection. Data were collected at harvesting stage. The sample plants were cut down to ground level prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters:

1. Plant height (cm)
2. Number of branches plant^{-1}
3. Number of pods plant^{-1}
4. Pod length (cm)
5. Number of seeds pod^{-1}
6. Weight of 1000-seeds (g) plot^{-1}
7. Grain yield (t ha^{-1})

8. Straw yield (t ha^{-1})
9. Biological yield
10. Harvest index

3.9.1 Plant height

The plant height was measured from the ground level to the top. Height of 10 plants randomly from each plot were measured. It was done at the ripening stage of the crop.

3.9.2 Number of branches $plant^{-1}$

Branches were counted at the ripening stage. Branches of 10 plants randomly from each plot were counted and averaged.

3.9.3 Number of pods $plant^{-1}$

Pods were counted at the ripening stage. Pods of 10 plants randomly from each plot were counted and averaged.

3.9.4 Pod length

Length of 10 pods from each plot were measured randomly and averaged after harvesting.

3.9.5 Number of seeds pod^{-1}

It was done after harvesting. At first, number of seeds pod_{-1} was counted. Seeds of 10 pods randomly from each plot were counted and averaged.

3.9.6 Thousand seeds weight

Thousand seeds of mungbean were counted randomly and then weighed plot wise.

3.9.7 Seed yield

Seeds obtained from 1m^2 area from the center of each unit plot was dried, weighted carefully and then converted into t ha$^{-1.}$

3.9.8 Straw yield

The stover of the harvested crop in each plot was sun dried to a constant weight. Then the stovers were weighted and thus the stover yield plot-1 was determined. The yield of stover in kg plot^{-1} was converted to t ha^{-1}.

3.9.9Biological Yield (t ha^{-1})

The sum of grain yield and Stover yield is regarded as biological yield. Biological yield was determined by the using the following formula –

Biological yield = Grain yield + Stover yield.

3.9.10 Harvest index (%)

It denotes the ratio of economic yield to biological yield and was calculated with the following formula (Gardner et al., 1985).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100\%$$

Where, Economic yield = Grain yield

Biological yield= Grain yield (t ha^{-1}) + Straw yield (t ha^{-1})

3.10 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. pH, organic matter, total N, available P and Exchangeable K contents. The soil samples were analyzed by the following standard methods as follows:

3.10.1 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 as described by Page *et al*., 1982.

3.10.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method (Page *et al*., 1982). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.724 (Van Bemmelen factor) and the results were expressed in percentage.

3.10.3 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO4: CuSO4. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO4 were added. The flasks were swirled and heated 200^0c and added 3 ml H_2O_2 and then heating at 360^0c was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al*., 1982). Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100/W$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

W = Sample weight in gram

3.10.4 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.10.5 Exchangeable potassium

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

3.11 Statistical Analysis

Data recorded for yield and yield contributing characters including the nutrient content and uptake were compiled and tabulated in proper form for statistical analyses. Analysis of variance was done with the help of MSTAT-C computer package programme. The mean differences among the treatments were evaluated with DMRT test (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of biochar on growth and yield of BARIMung-6. The results obtained from the study have been presented, discussed and compared in this chapter through table(s) and figures. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings.

4.1 Plant height (cm)

Plant height due to different levels of biochar applications was significantly influenced at harvest (Figure 1). The maximum plant height (44.70 cm) was recorded from T_3 treatment, which was statistically identical with other treatments whereas, the minimum plant height (37.57 cm) was recorded from T_1 treated plot. This finding was in agreement with the findings of Carter *et al*., (2013). They found that rice-husk biochar tested in lettuce-cabbage-lettuce cycle increased final plant height in comparison to no biochar treatments.

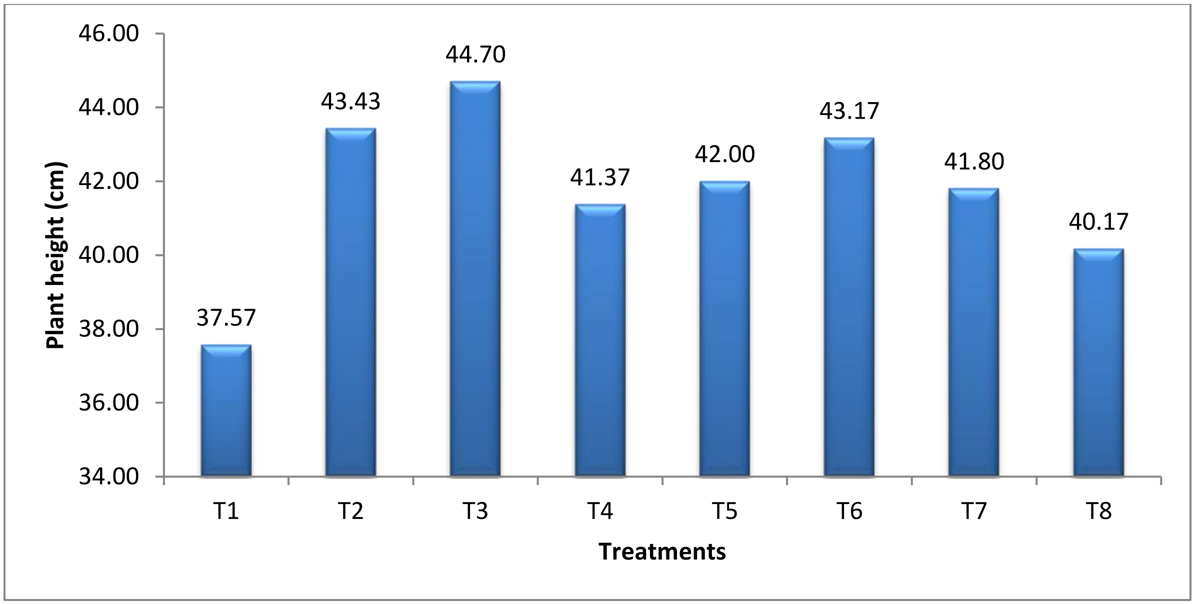

Figure 1. Effect of Biochar on Plant height at harvest of mungbean

($LSD_{0.05}$= 3.92); T_1= Control; T_2 = RFD (Recommended Fertilizer Dose); T_3= RFD + Biochar @ 2 ton ha^{-1}**;** T_4 = RFD + Biochar @ 4 ton ha^{-1}**;** T_5 = ⅔of RFD + Biochar @ 2 ton ha^{-1}**;** T_6 = ⅔ of RFD + Biochar @ 4 ton ha^{-1}**;** T_7= ½ of RFD + Biochar @ 2 ton ha^{-1}; T_8 = ½ of RFD + Biochar @ 4 ton $ha^{-1.}$

4.2 Number of branch plant^{-1}

The number of branch plant^{-1} was significantly varied among the different levels of biochar application (Figure 2). The maximum number of branch plant^{-1} (9.60) was obtained from T_3 treatment which was statistically identical with other treatments and whereas, the minimum (5.00) was obtained from T_1 treatment. Saxena *et al.*, (2013) showed that biochar significantly increased growth of french bean as compared to no biochar.

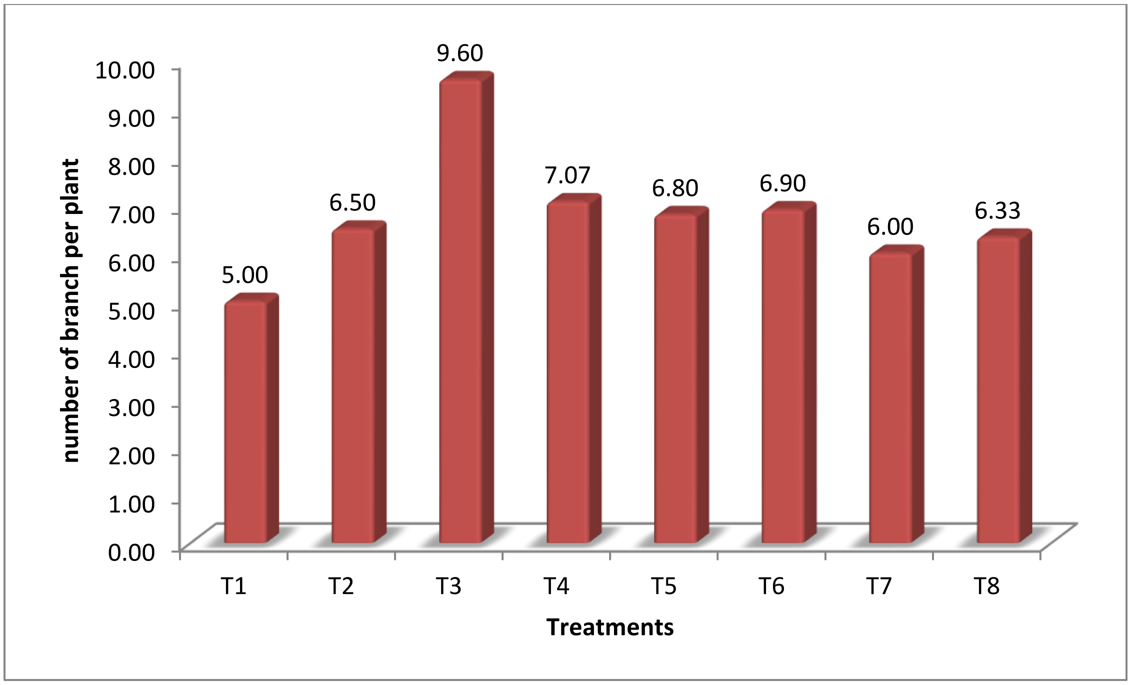

Figure 2. Effect of Biochar on number of branch plant^{-1} of mungbean

($LSD_{0.05}$= 0.72)
T_1= Control; T_2 = RFD (Recommended Fertilizer Dose); T_3= RFD + Biochar @ 2 ton ha^{-1}; T_4 = RFD + Biochar @ 4 ton ha^{-1}; T_5 = ⅔of RFD + Biochar @ 2 ton ha^{-1}; T_6 = ⅔ of RFD + Biochar @ 4 ton ha^{-1}; T_7= ½ of RFD + Biochar @ 2 ton ha^{-1};T_8 = ½ of RFD + Biochar @ 4 ton ha^{-1}

4.3 Number of pod plant^{-1}

Number of pod plant^{-1} significantly influenced by the different levels of biochar applications (Table 3 and fig. 3). The maximum number of pod plant^{-1} (13.40) was produced from T_3 (RFD + Biochar @ 2 ton ha^{-1}) treatment, whereas the minimum number of pod plant^{-1} (8.00) was produced from control. Saxena *et al*., (2013) showed that biochar significantly increased growth and yield of french bean as compared to no biochar.

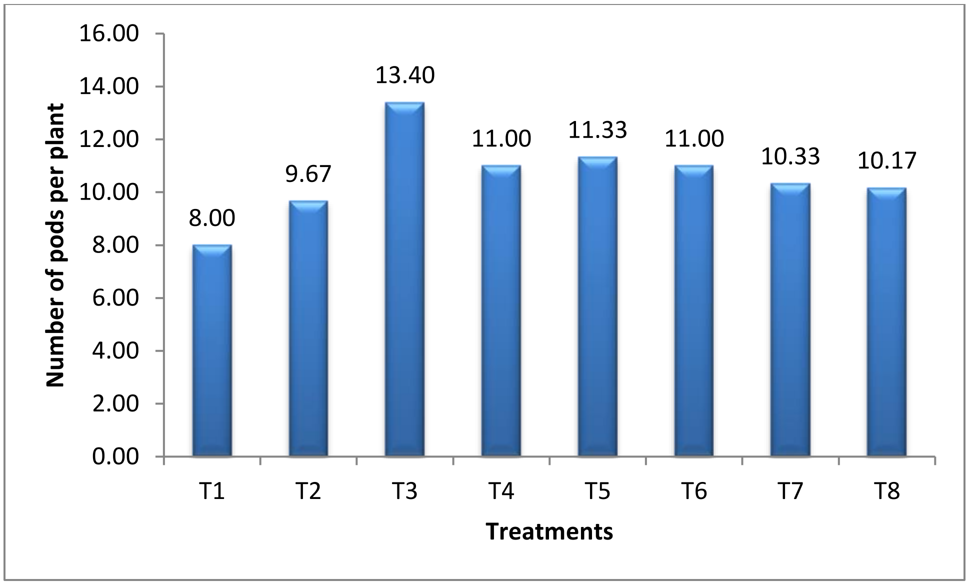

Figure 3. Effect of Biochar on Number of pods plant^{-1} of mungbean

4.4 Length of pod (cm)

Length of pod was significantly varied among the different levels of biochar applications (Table 3 and Fig. 4). The highest length of pod (9.80 cm) was observed from T_3(RFD + biochar @ 2 ton ha^{-1}) while the lowest length of pod (6.40 cm) was observed from T_1 (Control) treatment .

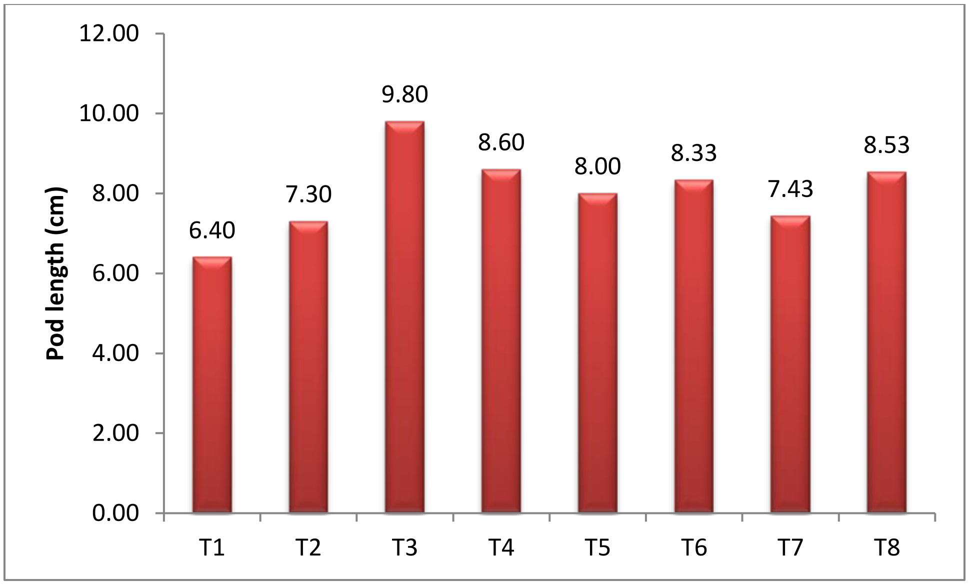

Figure 4. Effect of Biochar on pod length of mungbean

4.5 Number of seed per pod

Application of biochar had significant effect on the number of seed per pod (Table 3 and Fig. 5). The highest number of seed per pod (10.67) was obtained from T_3 (RFD + Biochar @ 2 ton ha^{-1}) treatment, which was statistically similar with other and lowest number of seed per pod (6.67) was obtained from T_1 treatment.

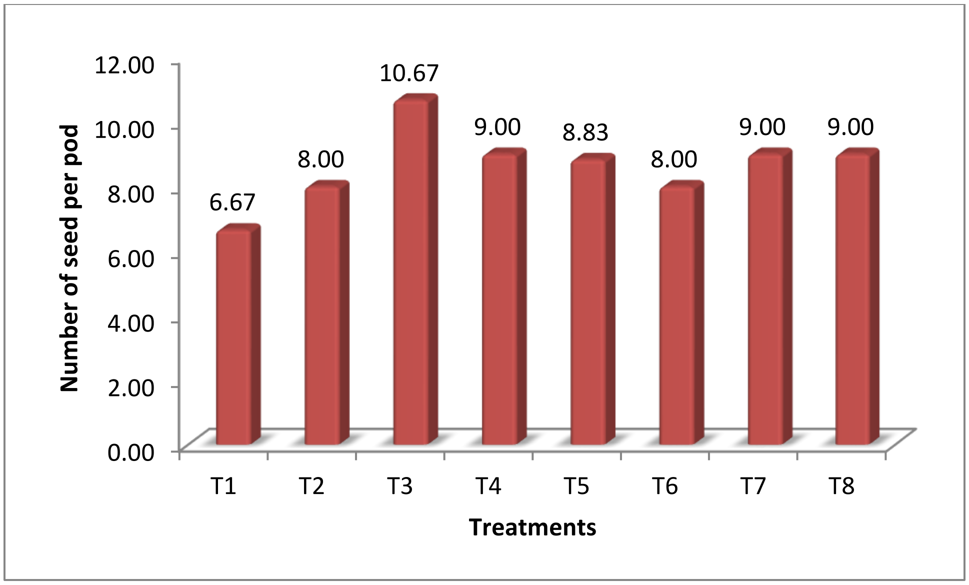

Figure 5. Effect of Biochar on number of seed pod^{-1} of mungbean

4.6 1000 seeds weight (g)

A insignificant variation was observed on thousand seed weight due to application a different doses of biochar. Maximum thousand seed weight (51.43) was found under T_3 treatment and minimum was (48.27) found under T_1 treatment (Table 3).

Table 3: Effect of Biochar on Number of pods per plant, Pod length, Number of seed per pod, Thousand seed weight of mungbean

Treatments	Number of pods per plant	Pod length (cm)	Number of seed per pod	Thousand seed weight (g)
T_1	8.00 c	6.40 e	6.67 c	48.27
T_2	9.67 bc	7.30 de	8.00 bc	48.50
T_3	13.40 a	9.80 a	10.67 a	51.43
T_4	11.00 b	8.60 b	9.00 b	50.80
T_5	11.33 b	8.00 bcd	8.83 b	48.80
T_6	11.00 b	8.33 bcd	8.00 bc	49.27
T_7	10.33 b	7.43 cde	9.00 b	49.17
T_8	10.17 b	8.53 bc	9.00 b	49.90
LSD (0.05)	1.80	1.02	1.28	NS
CV (%)	9.67	7.23	8.45	5.11

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

T_1= Control; T_2 = RFD (Recommended Fertilizer Dose); T_3= RFD + Biochar @ 2 ton ha^{-1}; T_4 = RFD + Biochar @ 4 ton ha^{-1}; T_5 = ⅔of RFD + Biochar @ 2 ton ha^{-1}; T_6 = ⅔ of RFD + Biochar @ 4 ton ha^{-1}; T_7= ½ of RFD + Biochar @ 2 ton ha^{-1};T_8 = ½ of RFD + Biochar @ 4 ton ha^{-1}

4.7 Grain yield (ton ha^{-1})

Yield of grain ton significantly varied among the different levels of biochar applications (Table 4 and Fig. 6) The highest grain yield of mungbean (1.40 t ha^{-1}) was obtained from T_3 (RFD + Biochar @ 2 ton ha^{-1}) treatment, which was followed by T_4 (1.29 t ha^{-1}) and the lowest grain yield (0.83 t ha^{-1}) was recorded in T_1 (control) treatment.

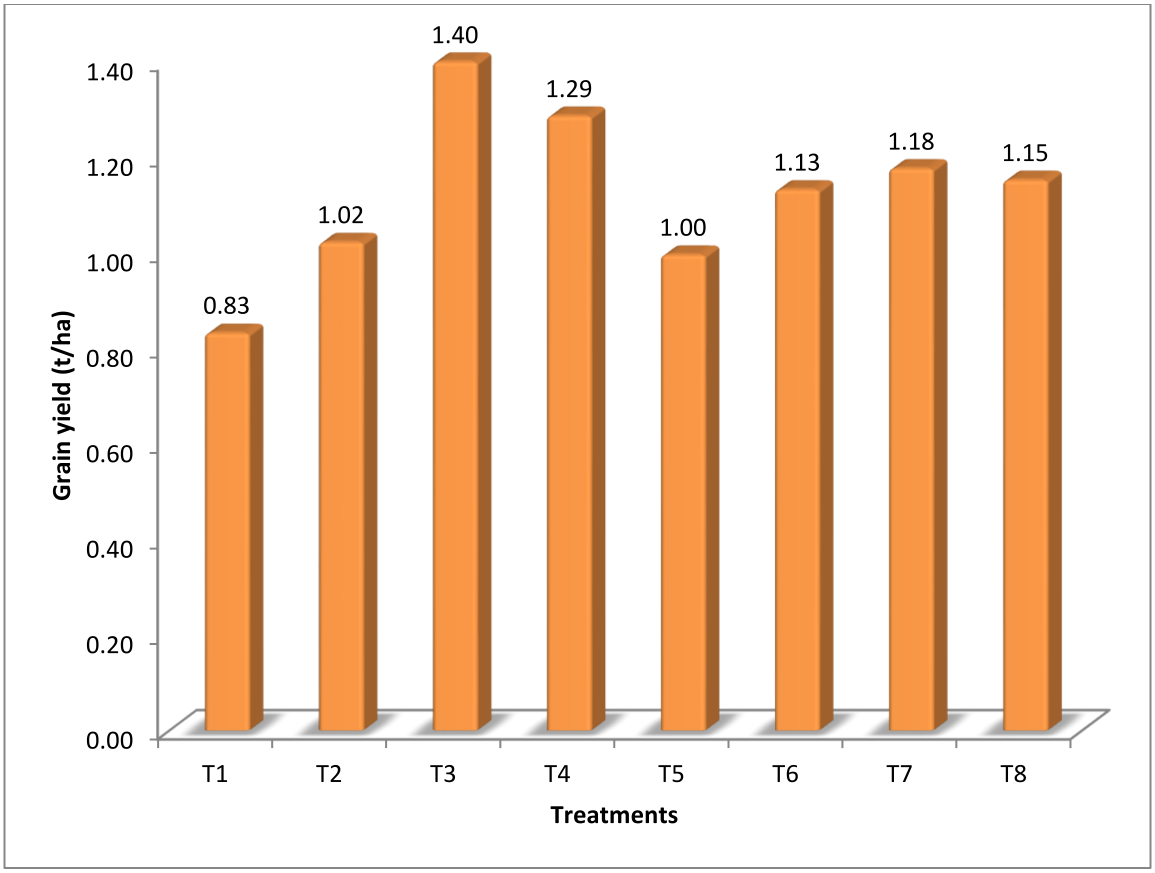

Figure 7. Effect of Biochar on grain yield of mungbean

4.8 Stover yield

Stover yield of mungbean significantly influenced different levels of biochar application. The highest stover yield (2.10 t ha^{-1}) was recorded from T_6 (2/3 of RFD + Biochar @ 4 ton ha^{-1}) treatment and the lowest stover yield (1.25) was recorded from T_3 (RFD + Biochar @ 2 ton ha^{-1}) treatment (Table 4).

4.9. Biological yield (t ha^{-1})

Applied eight types of biochar have significant variation on biological yield (t ha^{-1}) (Table 4). The maximum biological yield (3.23 t ha^{-1}) was recorded in T_6 treatment, which was statistically similar to T_4 and T_7. The T_1 treatment was given the lowest biological yield (2.42 t ha^{-1}), which was statistically similar to T_2, T_3, T_5 and T_8.

4.10. Harvest index (%)

The Application of biochar has significant variation on harvest index (%) (Table 4). The maximum harvest index (53.09 %) was obtained from T_3 treatment, which was statistically identical with other treatment. The T_1 treatment exhilited the lowest harvest index (34.48 %).

Table 4 : Effect of Biochar on yield and yield contributing characters of Mungbean

Treatments	Grain yield (tha^{-1})		Stover yield (tha^{-1})		Biological yield(tha^{-1})		Harvest index (%)	
T_1	0.83	e	1.58	cde	2.42	b	34.48	e
T_2	1.02	cd	1.51	cde	2.53	b	40.36	bcd
T_3	1.40	a	1.25	e	2.65	b	53.09	a
T_4	1.29	ab	1.83	abc	3.12	a	41.71	bc
T_5	1.00	d	1.67	bcd	2.66	b	37.29	cde
T_6	1.13	bcd	2.10	a	3.23	a	35.04	de
T_7	1.18	bc	1.93	ab	3.11	a	37.86	cde
T_8	1.15	bcd	1.42	de	2.58	b	44.80	b
LSD (0.05)	0.15		0.32		0.39		5.13	
CV (%)	7.21		11.15		8.03		7.22	

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

T_1= Control; T_2 = RFD (Recommended Fertilizer Dose); T_3= RFD + Biochar @ 2 ton ha^{-1}; T_4 = RFD + Biochar @ 4 ton ha^{-1}; T_5 = ⅔of RFD + Biochar @ 2 ton ha^{-1}; T_6 = ⅔ of RFD + Biochar @ 4 ton ha^{-1}; T_7= ½ of RFD + Biochar @ 2 ton ha^{-1};T_8 = ½ of RFD + Biochar @ 4 ton ha^{-1}.

4.11 Soil pH

An insignificant variation in the soil pH was found from biochar. The maximum soil pH (5.98) was recorded in T_3 (RFD + Biochar @ 2 ton ha^{-1}) while the lowest soil pH (5.52) was recorded in T_1(control) treatment (Table 5).

4.12 Organic matter

There was not significantly influenced by biochar on the organic carbon (Table 5). The highest organic carbon (1.52) was recorded in T_4 treatment, while the lowest organic carbon (1.33) was recorded from T_1 treatment.

4.13 Total Nitrogen

Total nitrogen was not significantly influenced by different treatment. The highest total nitrogen (0.09) was recorded in T_3 treatment while the lowest value (0.05) was noted in T_1 treatments (Table 5).

4.14 Available phosphorus

The different treatments showed significant variation in the available phosphorus**.** The highest available phosphorus (23.5 ppm**)** was recorded in T_3 while the lowest available phosphorus (11.25 ppm) was found in T_1 treatment, which was statistically similar to T_2 treatment (Table 5).

4.15 Exchangeable potassium

Exchangeable potassium was significantly influenced by different treatment. The highest exchangeable potassium (0.42 meq/100g) was recorded in T_3 treatment which was statistically identical with other treatments and the lowest exchangeable potassium (0.16 meq/100g) was recorded in T_1 treatment. (Table 5)

Table 5 : Effect of Biochar on pH, Organic matter, Total N, Available P, and Available K of Post harvest Soil

Treatments	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Available K (meq/ 100 g soil)
T_1	5.52	1.33b	0.050	11.25 d	0.16 e
T_2	5.57	1.34b	0.055	12.25 d	0.17 e
T_3	5.98	1.50a	0.090	23.50 a	0.42 a
T_4	5.96	1.52ab	0.070	20.66 b	0.36 b
T_5	5.76	1.40ab	0.060	19.32 bc	0.25 d
T_6	5.89	1.38ab	0.060	17.00 c	0.26 cd
T_7	5.70	1.43ab	0.056	18.50 bc	0.27 c
T_8	5.88	1.46a	0.058	19.50 bc	0.25 d
LSD (0.05)	NS	NS	NS	2.47	0.02
CV (%)	10.26	10.77	8.04	7.96	6.14

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

T_1= Control; T_2 = RFD (Recommended Fertilizer Dose); T_3= RFD + Biochar @ 2 ton ha^{-1}**;** T_4 = RFD + Biochar @ 4 ton ha^{-1}**;** T_5 = ⅔of RFD + Biochar @ 2 ton ha^{-1}**;** T_6 = ⅔ of RFD + Biochar @ 4 ton ha^{-1}**;** T_7= ½ of RFD + Biochar @ 2 ton ha^{-1};T_8 = ½ of RFD + Biochar @ 4 ton ha^{-1}.

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

The research work was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka (Tejgaon soil series under AEZ No. 28) during the kharif season of March, 2017 to July, 2017 to study the growth and yield of mungbean (BARI Mung-6) as influenced by different levels of biochar. The experiment comprised of the following 8 treatments as

T_1= Control, T_2 = RFD (Recommended Fertilizer Dose);T_3 = RFD + Biochar @ 2 ton ha^{-1} T_4 = RFD + Biochar @ 4 ton ha^{-1}; T_5 = ⅔of RFD + Biochar @ 2 $tonha^{-1}$; T_6 = ⅔ of RFD + Biochar @ 4 ton ha^{-1}; T_7= ½ of RFD + Biochar @ 2 ton ha^{-1}; T_8 = ½ of RFD + Biochar @ 4 ton ha^{-1}.The size of unit plot was 5.25 m^2 (3 m × 1.75 m) while block to block and plot to plot distances were 0.5 m and 0.25 m, respectively. The total number of plots were 30 (treatment combinations: 10 × replication: 3). The row to row and plant to plant distances were also 0.5 and 0.25 cm, respectively. The experiment was laid out in Randomized Completely Block Design (RCBD) method with three replications and analysis was done by the MSTAT-C package program whereas means were adjudged by DMRT at 5% level of probability.The individual application of biochar showed positive effect on the plant height, number of branches $plant^{-1}$, number of pods plant-1, pod length (cm), number of seeds pod^{-1}, weight of l000-seed (g), seed yield (t ha-1) and stover yield (t ha^{-1}).

Plant height due to different levels of biochar applications was significantly influenced at harvest (Figure 1). The maximum plant height (44.70 cm) was recorded from T_3 treatment, which was statistically identical from other treatments whereas, the minimum plant height (37.57 cm) was recorded from T_1 treatment.The maximum number of branches plant-1, number of pods plant-1, pod length (cm), number of seeds pod^{-1}, weight of l000-seed (g) was recorded from T_3 treatment, which was statistically identical from other treatments whereas, the minimum plant height was recorded from T_1 treatment. Yield of grain ton per ha significantly varied among the different levels of biochar applications (Table 4) The highest grain yield (1.40 t ha^{-1}) was obtained from T_3 (RFD + Biochar @ 2 ton ha^{-1}) treatment, which was followed by T_4 (1.29 t ha^{-1}) and lowest grain yield (0.83 t ha^{-1}) was obtained from T_1 (control) treatment. Biochar had some significant effect soil properties. The maximum soil pH (5.98) was recorded in T_3 treatment. The highest organic carbon (1.52) was recorded in T_4 treatment. The maximum total nitrogen (0.19) was recorded in T_3 treatment. The maximum available phosphorus (23.50ppm**)** was recorded from T_3 treatment. The highest exchangeable potassium (me%) (o.42%) was recorded in T_3 treatment.

5.2 Conclusion

From the present study it may be concluded that application of recommended fertilizer dose along with Biochar @ 2 ton ha^{-1} can be a promissing soil management practice for good yield of BARIMung-6 at Tejgaon series soil of SAU farm.

Based on the results of the present study, the following recommendations may be drawn

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performance.

2. Another experiment may be carried out with different doses of biochar for specific biochar effect.

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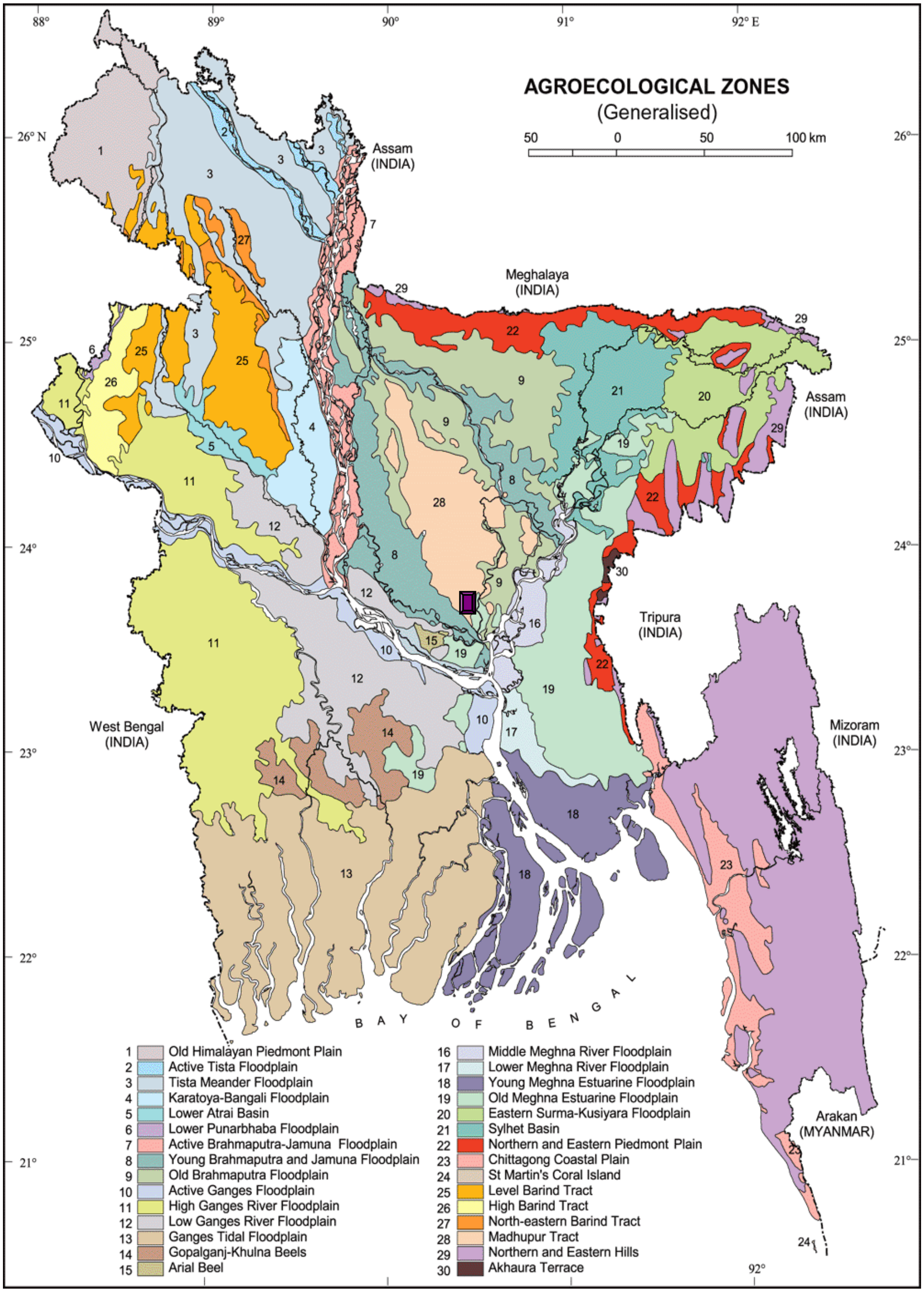
APPENDICES

Appendix I. The Map of the experimental site



Appendix. 2. Commonly used symbols and abbreviations

Abbreviations	Full word
%	Percent
@	At the rate
AEZ	Agro-Ecological Zone
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
BINA	Bangladesh Institute of Nuclear Agriculture
CEC	Cation Exchange Capacity
cm	Centi-meter
CV%	Percentage of coefficient of variation
df	Degrees of Freedom
LSD	Least Significant Difference
et al	and others
etc	Etcetera
FAO	Food and Agricultural Organization
g	Gram
H	Hours
J.	Journal
kg ha-1	Kilograms per hector
t ha-1	Ton per hectare
Kg	kilogram
m	Meter
m2	square meter
MOA	Ministry of Agriculture
MSE	Mean square of the error
No.	Number
ppm	parts per million
RCBD	Randomized Complete Block Design
Sci.	Science
SE	Standard Error
var.	variety