INTEGRATED EFFECT OF NITROGEN AND AKHA BIOCHAR ON SOIL PROPERTIES AND PRODUCTION OF MAIZE

MD. TADRISUL ISLAM

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENTAL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY, DHAKA-1207

JUNE, 2020

INTEGRATED EFFECT OF NITROGEN AND AKHA BIOCHAR ON SOIL PROPERTIES AND PRODUCTION OF MAIZE

BY

MD. TADRISUL ISLAM

Reg. No. 13-05423

A Thesis
Submitted to the Department of Agroforestry and Environmental Science,
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
AGROFORESTRY AND ENVIRONMENTAL SCIENCE
SEMESTER: JANUARY– JUNE, 2020

Approved by:

Tania Sultana
Assistant professor
Supervisor

Prof. Dr. Nazmun Naher
Co- supervisor

Dr. Jubayer-Al-Mahmud
Chairman
Examination Committee

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENTAL SCIENCE
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
Bangladesh

PABX: +88029144270-9
Ext. 309 (Off.)
Fax: +88029112649

Ref : **Date:**

CERTIFICATE

This is to certify that thesis entitled, **"INTREGRATED EFFECT OF NITROGEN AND AKHA BIOCHAR ON SOIL PROPERTIES AND PRODUCTION OF MAIZE"** 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 AGROFORESTRY AND ENVIRONMENTAL SCIENCE**, embodies the result of a piece of bonafide research work carried out by **MD. TADRISUL ISLAM**, Registration No. **13-05423** 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, 2020
Place: Dhaka, Bangladesh

Tania Sultana
Assistant Professor
Supervisor

Dedicated To

MY BELOVED PARENTS

MD. ATAUR RAHMAN

And

KOHINUR BEGUM

ACKNOWLEDGEMENTS

All praises are devoted to **Almighty Allah**, the most gracious, the most merciful, the beneficent, the lord of the Day of Judgment and the supreme ruler of the universe, who enabled the author to complete the thesis successfully for the degree of Master of Science (MS) in Agroforestry and Environmental Science.

The author expresses his deepest sense of gratitude, immense indebtedness and profound appreciation to his research supervisor **Tania Sultana**, Assistant Professor, Department of Agroforestry and Environmental Science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka for planning the research work, vigilant supervision, constructive suggestions, sympathetic encouragement to conduct the research work as well as preparation and for going through the manuscript of the thesis.

He also expresses his grateful appreciation and deep sense of respect to his research co-supervisor **Prof. Dr. Nazmun Naher,** Department of Agroforestry and Environmental Science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka for proper guidance, continuous advice, painstaking suggestions, kind help and worthfull encouragement during the course of research work and preparation of this manuscript.

He is immensely indebted to **Dr. Jubayer-Al-Mahmud**, Chairman, Department of Agroforestry and Environmental Science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka for providing his help, heartiest co-operation, valuable advice, facilities and supports to conduct the experiment.

He would like to express my heartiest appreciation, ever indebtedness and deep sense of gratitude to **Dr. Abdullahil Baque,** Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for allowing the author to work with his released maize variety “SAU Hybrid Bhutta 1” and helping with all the information and he also thanks to **Cristian Commission for Development in Bangladesh (CCDB)**, Mirpur, Dhaka for supplying akha biochar.

The author also express his heartfelt thanks to **Prof. Dr. Md. Forhad Hossain, Dr. Ferzana Islam, Prof. Dr. Md. Kausar Hossain** and **Md. Shariful Islam** Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka for their inspiration and constant encouragement during the period of study and preparing the manuscript.

Grateful thanks are expressed to all of his friends especially Osman Goni, Anup Roy, Mayenuddin, Sajedul Islam, Hamidur Rahman, Moon, and Nafis Bin Reza for their active encouragement, inspiration, direct and indirect help in the endeavor to complete this thesis.

At last but not the least, the author wishes to express his profound gratitude and deepest appreciation to his parents and all other maternal and paternal relatives for their ever ending prayer, encouragement, sacrifice and dedicated efforts to educate his to this level.

The Author

INTEGRATED EFFECT OF NITROGEN AND AKHA BIOCHAR ON SOIL PROPERTIES AND PRODUCTION OF MAIZE

ABSTRACT

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh, during the Robi season from October 2018 to April 2019 to study the integrated effect of nitrogen and akha biochar on soil properties and production of maize. The experiment was laid out in two factors split plot design with three replications. Factor A: T_1= Akha Biochar, T_2= Compost, T_3= Control and Factor B: Different Nitrogen doses i.e.N_0= 0%, N_1 = 50%, N_2 = 75% and N_3 = 100% Recommended doses of Nitrogen. The size of the plot was 2m × 2.5m i.e. $5m^2$. Maize seed of SAU Hybried Vutta 1 was used as planting material. Result revealed that, the highest plant height was observed in T_1 (140.77 and 204.94 cm at 60 and 90 DAS, respectively) and N_3 (68.14, 159.85 and 235.83 cm at 30, 60 and 90 DAS, respectively). Length of cob (21.60 cm and 23.83 cm), diameter of cob (15.11 cm and 15.82 cm), number of grain rows/cob (27.44 and 32.54), weight per ear (213.76 g and 293.45 g), weight of 250 grains (82.83 g and 95.77 g), grain yield (8.29 and 11.63 ton/ha), Stover yield (9.42 and 13.13 ton/ha) and total yield (17.73 and 24.76 ton/ha) were highest in T_1 and N_3 respectively. The highest plant height (70.59, 161.68 and 240.65 cm at 30, 60 and 90 DAS, respectively), diameter of cob (15.99 cm), number of grain rows/cob (32.34), weight per ear (304.71 g), weight of 250 grains (96.47 g), grain yield (12.54 ton/ha) and total yield (25.83 ton/ha) were observed N_3T_3 (100% recommended doses of Nitrogen and control) treatment which was statistically similar to N_3T_1, N_2T_1 and N_3T_2. The highest soil pH (6.35 and 6.24), OC% (0.6233 and 0.6044%), total N (0.1001 and 0.1011%), Available P (167.06 and 167.06 ppm) and exchangeable K (0.1608 and 0.1667 meq $100g^{-1}$) were observed in T_1 and N_3 treatment respectively. For the combine effect the highest soil pH (6.49), organic carbon (0.70%), total nitrogen (0.1427%), Available phosphorus (202.15 ppm) and exchangeable potassium (0.1933 meq $100g^{-1}$) were recorded in N_3T_1 from which organic carbon (0.65%) and Available phosphorus (198.35 ppm)were statistically similar with N_2T_1. From this study, it may be concluded that Akha biochar had significant positive response for the improving growth and yield of maize and also the fertility of the postharvest soil was improved apprehensively due to application of Akha biochar along with 75% recommended dose of Nitrogen.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
CV%	Percentage of coefficient of variance
DAE	Department of Agriculture Extension
DAS	Days after sowing
^{o}C	Degree Celsius
et al.	And others
g	gram(s)
ha^{-1}	Per hectare
mg	Milligram
MoP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Non-significant
%	Percent
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resource and Development Institute
TSP	Triple Super Phosphate
Wt.	Weight
meq	Milliequivalent
OC	Organic carbon
P	Phosphorus
K	Potassium
pH	Hydrogen ion concentration
cm	centimeter

Chapter I

Introduction

CHAPTER I

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops both as food for human and feed for animals in the world agricultural economy. This cereal crop belongs to the family Poaceae. It has very high yield potential so that there is no cereal on the earth which has so immense potentiality and that's why it is called as the "Queen of cereals". It ranks 1st position in respect of yield per unit area, 2nd positon in respect total production and 3rd positon after wheat and rice in respect of area of production in cereal crops. Maize grain contains 70% carbohydrate, 10% protein, 4% oil, 10.4% albumin, 2.3% crude fiber, 1.4% ash. World average yield of maize is 27.8 q ha^{-1} maize ranks first among the cereals and is followed by rice, wheat, and millets, with average grain yield of 22.5, 16.3 and 6.6 q/ha respectively (Nasim *et al*., 2012).

Maize is a long duration, quick growing crop and has the potentiality to produce high quantity grains per unit area (Majid *et al.*, 2017). In tropical, sub-tropical and temperate regions of the world Maize is cultivated for both grain as well as fodder. Maize has multiple uses as a cereal such as bread making, corn flakes, corn syrup, corn starch, textile, paper making and in other food industries (Kumar and Jhariya, 2013). Due to the presence of unsaturated fatty acids corn oil is suitable for human consumption (Khan *et al*., 2013).

Biochar is a charcoal that formed from the thermal decomposition of biomass in a low or zero oxygen presence in the environment, at moderately low temperatures (<700°C) (Lehmann and Joseph, 2009). Biochar application to the soils is presently attaining universal attention due to the potentiality of biochar to improve water holding capacity, soil nutrient retention capacity and sustainable carbon store, thus reducing greenhouse gas emissions (Downie *et al.*, 2009). Biochar's capacity to concurrently act in both soil modification and as a carbon sequestration medium afford a win-win prospect that in the near future could help to decrease the atmospheric carbon dioxide (Amonette and Joseph, 2009).

Bangladesh Biochar Initiative (BBI) was formulated to entrench the use of biochar producing stove as an environment-friendly cooking appliance. The Christian Commission for Development in Bangladesh (CCDB) took the responsibility for the invention of low-cost and agro-friendly cookstove (local name Akha) which can be used for cooking with locally available feedstock (BBI, 2015).

The Akha is a wood-burning cookstove developed by the Bangladesh Biochar Initiative. It is clean-burning, fuel-efficient and produces a constant heat without stoking. However, what really sets the Akha apart from other biomass cookstoves its ability to make char at the same time as cooking. Producing char maximizes the utility of the wood, because we can get more energy if we burn the char as charcoal, or we can increase agricultural productivity if we use the char as biochar. The stoves produce biochar that enhances the soils ability to retain nutrients and water, thereby making it more productive with less inorganic fertiliser (BBI, 2015).

Due to high population growth and low productivity of crops Bangladesh is facing a problem of malnutrition. The traditional crops of Bangladesh including rice and wheat seem quite unable to meet the nutritional requirement. Maize can be a potential crop for both nutritional support and may offer a partial solution to the problem of food shortage if its present yield level and total production can further be raised. Among the all agronomic traits which influence the growth and yield of the crops, fertilizer management is the prominent one.

In Bangladesh there is some work done by Shahi *et al.* (2018) and Islam *et al.* (2015) on effect of rice husk biochar on maize and there is no work done by the scientist on akha biochar. But the socio-economic condition of Bangladesh motivates the rural people to produce akha biochar which can produce easily by using akha stove and also use them to the field.

Therefore the experiment was undertaken to assess the integrated effect of nitrogen and akha biochar on soil properties and production of maize variety SAU BHUTTA-1 in the Research field of SAU.

OBJECTIVES

The experiment was conducted to fulfill the following objectives:

1. To determine the effect of akha biochar on maize production.
2. To assess the effect of akha biochar on soil properties.

CHAPTER II

REVIEW OF LITERATURE

Biochar is offering multiple benefits for soil health and it can constitute a viable option for sustainable agriculture due to its potential as a long-term sink for carbon in soil and beneficial for crops. The research work so far done at home and abroad regarding the integrated effect of nitrogen and akha biochar on soil properties and production of maize along with other relevant information are given below:

2.1 Biochar

Biochar has been defined in a similar way 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 limited oxygen conditions (Sohi *et al.* 2009). In fact, Biochar 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 Properties of biochar

The matrix of biochar has been determined by X-ray diffraction (Lehmann and Joseph, 2009). This work revealed as an essential amorphous structure with crystalline areas (Lehmann and Joseph, 2009) consisting of random polycyclic aromatic (graphene) layers rimmed by the functional groups (Zhu *et al.*, 2005) and mineral compounds (Lehmann and Joseph, 2009). Associated with the pyrolysis process above 330˚C is the formation of poly aromatic sheets which create turbostratic structures (Keiluweit *et al*., 2010) and increased porosity as temperature increases. Studies have demonstrated that higher temperatures lead to a decrease in particle size and the development of microporosity (< 2nm), which underpin the high surface area of biochar (Downie *et al.*, 2009). Physical properties vary depending upon the biomass feedstock used and the thermochemical conditions of char formation.

2.3 Importance of biochar

The chemical properties of Biochar Owing to different production conditions and indeed variety in feedstock materials used to produce biochar chemical attributes vary considerably. At an elemental level biochar properties can be ascribed with respect to ratios of C, H, O and N. Particularly, ratios of H/C and O/C are used to determine the degree of biochar aromaticity i.e. the lower is the ratio, the greater is the aromaticity of biochar (Kookana *et al*., 2011). H/C and O/C ratios have been reported to be higher in biochars produced at a low temperature, due to incomplete charring of the feedstock; H/C and O/C ratios decrease with increasing temperature of production (Baldock and Smernik, 2002). Thus, higher temperature chars are inherently more resistant to chemical modifications and therefore are more recalcitrant. The nutrient content in biochar also varies depending upon feedstock type and pyrolysis conditions used in the process. Higher temperatures and faster heating rates strongly influence the retention nutrients within the biochar formed: nitrogen (N) and sulphur (S) compounds, for example, volatilize at 200˚C and 375˚C respectively; while biochar becomes depleted in potassium (K) when produced above 700˚C and of phosphorous (P) above 800˚C (DeLuca *et al*., 2009). Minerals such as magnesium (Mg), calcium (Ca) and manganese (Mn) volatilize at temperature above 1000˚C; pH, electrical conductivity (EC) and extractable NO_3 tend to be higher with high temperatures (800˚C), while low temperature (350˚C) results in greater extractable amounts of P, NH4 + and phenols. Feedstock type is responsible for different ratio of C/P and C/N; in particular, wood and nut based biochars show high ratio of C/P and C/N ratios, while manure, crop and food waste biochars have lower ratios (Kookana *et al*., 2011). Biochar can improve water holding capacity of soil, reduce soil emissions of greenhouse gases, reduce nutrient leaching, reduce soil acidity, reduce irrigation and fertilizer requirements (Laird, 2008, Novak *et al*., 2009). Modest additions of biochar to soil reduce nitrous oxide (N_2O) emissions up to 80% and eliminate methane emissions (Lehmann, 2007) and used as a soil amendment to improve yield and elevated pH requiring plants. Biochar addition enhanced maize yield under different mineral fertilization of nitrogen and water conditions.

2.4 Effect of Biochar on soil organic carbon

Biochar as ecologically clean and stable form of carbon has complex of physical and chemical properties which make it a potentially powerful soil-amendment (Mutezo, 2013). Therefore, during the last decades, the biochar application as soil amendment has been a matter for a great number of investigations. For the ecological view of point the trend of decreasing of soil organic matter in European agricultural land is a major problem. The availability of different functional groups (e.g. carboxylic, phenolic, acidic, alcoholic, amine, amide) allows soil organic matter to buffer over a wide range of pH values in the soil (Krull *et al*., 2004). Therefore, the loss of soil organic matter also reduces cation exchange capacity resulting in lower nutrient retention (Kimetu *et al*., 2008).

Lehmann *et al.* (2007) reported that biochar can influence the mineralization of native soil organic carbon (SOC) through "priming effects". However, the long term direction, persistence and extent of SOC priming by biochar remain uncertain. Using natural carbon abundance and under controlled laboratory conditions, shows that biochar stimulated the mineralisation SOC ("positive priming") caused a loss of 4 to 44 mg C g^{-1} SOC over 2.3 years in a clayey, unplanted soil (0.42% OC). Positive priming was greater for manure based or 400°C biochars, plant based or 550°C biochars, but was trivial relative to recalcitrant C in biochar. From 2.3 to 5.0 years, the amount of positively primed soil CO_2 in the biochar treatments decreased by 4 to 7 mg C g^{-1} SOC. They concluded that biochar stimulates native SOC mineralisation in the low-C clayey soil but that this effect decreases with time, possibly due to depletion of labile SOC from initial positive priming, and/or stabilization of SOC caused by biochar induced organo-mineral interactions.

2.5 Effect of Biochar on 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 to 10 Gt C is sequestrated per year which is the equivalent or more than the present global emissions from the use of fossil fuel. In addition, biochar carbon added almost 40% of the carbon to the soil (Glaser *et al.* 2001; Skjemstad *et al.* 2002). Lehmann (2007) predicted that the retention time 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 secure 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 carbon has beneficial soil amendment and/or fertilizer value.

2.6 Effect on soil fertility

Biochar is a product of pyrolysis of biomass in absence of oxygen and it has a high potential to sequester carbon into more stable soil organic carbon (OC). Despite a large number of studies on biochar and soil properties, few studies have investigated the effects of biochar in contrasting soils. The current research was conducted to evaluate the effects of different biochar levels (0%, 1% and 3%) on several soil physiochemical properties and nitrate leaching in two soil types (loamy sand and clay) under greenhouse conditions and wet-dry cycles by Ghorbani *et al.* (2019) in Lahijan (loamy sand, 37°13′02.0″N 50°00′43.9″E) and Rasht (clay, 37°11′51.0″N 49°39′06.2″E) in Guilan province, North of Iran. The experiment was performed using a randomized design with three levels of biochar produced from rice husks at 500 °C in three replications. Cation exchange capacity was increased significantly, by 20% and 30% in 1% and 3% biochar-amended loamy sand soil, respectively, and increases were 9% and 19% in 1% and 3% biochar-amended clay soil, respectively. Loamy sand soil did not show any improvement in aggregate indices, including mean weight diameter, geometric mean diameter, water stable aggregates and fractal dimension, which was contrary to the results of the clay soil. Application rice husk biochar at the both rates decreased nitrate leaching in the clay soil more than in the loamy sand. The study highlights the importance of soil type in determining the value of biochar as a soil amendment to improve soil properties, particularly soil aggregation and reduced nitrate leaching. The benefits of the biochar in clay soil were greater than in loamy sand soil.

Biochar is pyrolyzed (charred) biomass 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 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, biochar can persist in the soils and sediments for many centuries (Downie *et al*., 2011), and has great potential to improve agronomic production when applied as a soil amendment.

Recent researches has included the investigation of biochar application on the performance of infertile, low cation exchange capacity (CEC), acidic soils with kaolinitic clays and deteriorating soil organic carbon contents (Chan *et al*., 2007; Chan and Xu, 2009; Novak *et al*., 2009). Generally, the addition of biochar to the soil has been reported to have a multitude of agricultural benefits. These include a high soil sorption capacity, reduced nutrient loss through surface and groundwater runoff and a gradual release of nutrients to the growing plant (Laird, 2008).

2.7 Biochar Effect on nutrient use efficiency

AlWabel *et al.* (2017) summarizes the influences of pyrolysis conditions and feedstock types on biochar properties and how biochar properties affect soil properties. They found that both pyrolytic parameters and feedstock types are the main factors controlling biochar properties such as recalcitrance, nutrient content and pH. Biochar produced at low temperatures may improve the availability of nutrient and crop yield in acidic and alkaline soils, whereas high temperature biochar may enhance the long term soil carbon sequestration. Biochar can also improve the efficiency of inorganic and organic fertilizers by enhancing the microbial functions and reducing nutrient loss, therefore making nutrients more available to plants.

Integration of biochar and chemical or organic fertilizers generally provides better nutrient management and crop yield in most types of soils.

2.8 Impact of Biochar on soil chemical properties

The effect of biochar addition on the chemical properties of acidic soil were investigated to determine the liming potential of biochars by Chintala *et al.* (2013). The study was conducted by incubating acidic soil (clayey, smectitic, acid, mesic, shallow, Aridic Ustorthent) of pH less than 4.80 with biochars for 165 days. Biochars were produced from two biomass feed stocks such as corn stover (*Zea mays L.*) and switch grass (*Panicum virgatum L.*) using microwave pyrolysis (at 650°C). Corn stover biochar, switch grass biochar and lime (calcium carbonate) were applied at four rates (0, 52, 104, and 156 Mg ha^{-1}) to acidic soil. Amendment type, application rate, and their interaction had significant effects on soil pH, EC, and CEC of acidic soil. Exchangeable acidity was significantly affected by the amendment type. The application of corn stover biochar had shown a relatively larger increase in soil pH than the switch grass biochar at all application rates. The ameliorating effect of biochars on chemical properties of acidic soil was consistent with their chemical composition.

Brandstaka *et al.* (2010) listed the general effects of biochar on the soil. It is beneficial for sequestration of carbon, improvement of cation exchange capacity, durability of soil aggregates, microbial activity, bioenergy production, water retention capacity; reduction of nitrous oxide, methane emissions from soils, leaching, soil erosion and need of fertilization and thereby enhancement of soil fertility and crop yields.

Leached sandy soils typically have low soil pH value, poor buffering capacities, low CEC, with values ranging from 2-8 c mol kg^{-1}, and can have Aluminum toxicity (Novak *et al*., 2009). The addition of biochar to highly leached soil, infertile soils has been shown to give an almost immediate increase in the availability of basic cations (Liang *et al.*, 2006), and a significant improvement in crop yields, particularly where nutrient resources are in short supply (Lehmann and Rondon, 2006). Over time, these additions continue to promote the availability of soil nutrient by giving rise to greater stabilization of organic matter and a subsequent reduction in the release of nutrients from organic matter (Glaser *et al*., 2001; Lehmann and Rondon, 2006).

Several studies comparing the application of fresh biomass and biochars of the same biomass into the soil with similar soil characteristics have found that primarily due to their recalcitrant nature (Baldock and Smernik, 2002; Steiner *et al.,* 2008), biochar , unlike fresh biomass, may persist in the soil for hundreds of years (Zimmerman 2010). A long term study involving frequent applications of fresh paper mill waste biomass on sandy soil failed to demonstrate the long term buildup of soil carbon (Curnoe *et al.*, 2006). In contrast, Van Zwieten *et al.* (2010) found that papermill biochar significantly increased the total soil carbon in the range of 0.5 – 1.0 %. Furthermore, biochar compare to the fresh biomass of the same biomass has proven to be more effective for carbon sequestration (Vaccari *et al.*, 2011), increasing soil fertility (Wang *et al*., 2009), and improving the liming potential of acid soils (Yuan *et al.*, 2011).

The pyrolysis method could play an important role in soil properties. For example, mineralization of N could be enhanced by application of biochar produced from slow pyrolysis rather than fast pyrolysis (Bruun *et al.*, 2012).

Yao *et al.* (2012) indicated that there are varied responses of soil to biochar for the leaching of nutrients and the absorption of nutrients on biochar.

Quilliam *et al.* (2012) conducted a three-year field experiment, there was no difference between biochar added and not-added soil but reapplication of biochar after three years significantly increased available P, exchangeable K and calcium, soil moisture, dissolved organic carbon and electrical conductivity.

Biochar is synonymous with the biomass derived from black carbon (Liang *et al*., 2006), and is consequently commonly referred to as black carbon (BC). Black carbon is a solid residue that forms by partial burning of plant materials, fossil fuels and other geological deposits. Formation of black carbon gives rise to two different products. In the first instance, volatiles re-condense to a soot-BC which is very high in graphite, while the solid residues produce a form of char-BC. Black carbon generally encompasses carbon forms of varying aromaticity and falls along a broad spectrum that includes charred organic materials to charcoal, soot and graphite (Schmidt and Noack, 2000).

Lehmann (2007) reported that biochar may be an alternative to renewable energy because of it's not carbon neutral, but rather carbon negative. It may serve as a long term terrestrial sink of carbon because biochar is formed by a carbon negative process,. The carbon negative process means that the feedstock parent material used to manufacture biochar initially withdraws the organic carbon from the photosynthesis and decomposition carbon cycle pathways (Lehmann, 2007). This process is then followed by storing the organic carbon in the soil, thus causing it to accumulate over time (Glaser, 2007). Relative to merely using fresh material to store carbon, because biochar decomposes over a long period of time, it is able to create a slow release of

CO_2 into the atmosphere over an extended period, and thus reduce CO_2 emissions. Therefore biochar is able to gain CO_2 from the atmosphere, it would circumvent from the contribution of climate change, and hence aid in reducing global warming (Lehmann, 2007a).

2.9 Effect of Biochar on soil pH

The effects of biochar derived from different feed stocks on soil pH, Nitrogen transformation, and pH buffering in three acid soils and the mechanisms of changes in these parameters were examined by Dai *et al.* (2013). The effects of biochar additions on pH change were determined both by the alkalinity (excess cations) of biochar and nitrification in soils. With the Psammaquent (loamy, mixed, super active, thermic Typic Psammaquent) soil, the alkalinity of biochar was the main factor affecting the soil pH increase, while with the Plinthudult and Paleudalf soil, both the alkalinity of the biochar and nitrification in the soil contributed to the soil pH changes. In addition, the alkalinity of biochar made a large contribution to the pH increase while N nitrification made a relatively small contribution to the pH decrease. A positive priming effect of biochar on soil organic N probably occurred during the incubation period. Generally, the biochar increases soil pH buffering and the incorporation of tested biochars in the study can both increase and maintain soil pH for long period of time and the swine manure biochar had the greatest effect while the reed straw biochar had little effect. The magnitude of the effects depends on soil type, biochar type and incorporation rate.

Liu *et al.* (2012) conducted an incubation experiment which was conducted to determine the effects of biochar on the pH of alkaline soils. It was found that application of alkaline biochar did not increase the soil pH but instead produced a decreasing pH trend, especially with higher biochar application rates. The decrease in soil pH was more significant at the 10 cm to 20 cm layer than in the 0 cm to 10 cm layer. The soil type (Aeolian sandy soil) which had the highest pH, showed the largest decrease in pH after 11 months of incubation. The acidic materials produced by the oxidation of biochar and organic matters may have caused the pH decrease. The high soil cation exchange capacity caused by biochar application might restrict the soil salinization process to some extent.

2.10 Effect of boichar on crop

Although the composition of biochars depends upon the nature of feedstocks and the operating conditions of pyrolysis, biochars are generally expected to be rich in nutrients. These characteristics can have a direct effect on plant growth. For example, the addition of 68t C ha^{-1} increased rice biomass by 17% while the presence of 135 t C ha^{-1} of biochar enhanced the growth by 43% (Glaser *et al.*, 2002; Lehmann *et al.*, 2003). Improved crop yields have been attributed to the improvement in P, K and possibly Cu levels following the addition of biochar (Chan and Xu, 2009). Biochar has the potential to increase cation exchange capacity, surface absorption capacity and soil water holding capacity on account of its physical and chemical characteristics of biochar; specifically: its high surface-area, high porosity and variable-charge (Amonette and Joseph, 2009; Yang *et al.*, 2010). Therefore application of biochar is expected to enhance soil properties in terms of increasing or maintaining the pH of the soils (Rondon *et al*., 2007), toxin neutralization (Wardle *et al.*, 1998), and reduce soil strength (Chan *et al.*, 2007). Again these properties vary depending upon the properties of biochar and also on account of the original characteristics of soil and plant species of interest. In support of these benefits, Zwieten *et al.* (2007) reported a nearly 30 to 40% increase in wheat height when biochar produced from paper mill sludge was applied at a rate of 10 t ha^{-1} to an acidic soil. Hoshi (2001) suggested that the biomass increase of tea trees (20% in height and 40% in volume) were partly due to the ability of biochar to keep pH constant in soil. Chan *et al.* (2007) found that dry matter of radish in a pot increased by up to 26.6% when N fertilizer was applied at 100kg ha^{-1} compared to a control with the same treatment but in the absence of biochar. Another important area where biochar might contribute is the levels of soil carbon. Significantly, the modern agricultural practices have resulted in the degradation of soil carbon and as a consequence levels of carbon are much lower now than they were several decades ago (Jones *et al.,* 2011). Biochar has recently come to the fore as an additional soil amendment source of organic carbon. Of the greatest significance is the fact that biochar is inherently stable and as a consequence, offers the opportunity to replenish soil carbon reservoirs in a long lasting way. The measurements of biochar over time were taken; Preston and Schmidt (2006) determined an average half-life of biochar in coastal temperate rainforest of western Vancouver of 6623 years, while Hammes *et al.* (2008) calculated a turnover time of biochar from fires in a Russian steppe of only 293 years. There exists an uncertainty on the residence of time of biochar as the calculation could be affected by spatial variabilities (Lehmann *et al.,* 2009) and the decomposition or mineralization of biochar can be affected by several physical conditions. Nevertheless, although biochar is subjected to decomposition processes, its stability remains high over long periods of time.

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 top soil, xylem sap flow of the plant and response to N and NP chemical fertilizer treatments. Limiting soil nitrogen 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 nutrient such as copper (Cu), magnesium (Mg) and zinc (Zn) than the soil (Novak *et al.,* 2009). In a separate experiment, concentrations of heavy metals including Copper and Zinc 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 Mn (Inal *et al.,* 2015). Thus, it is essential to compare the effect of biochar solely and in combination with other nutrient sources. Some authors (Verheijen *et al*., 2009; Brandstaka *et al.*, 2010) have emphasized on the need for further research on potential benefits of biochars as well as their economics. However, biochars interactions with other organic sources as well as microbes and release of nutrients from them are insufficiently assessed.

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 to 30 % more than mineral fertilizer alone (Alburquerque *et al.,* 2014). The yield of tomato fruit was significantly higher in the beds with charcoal than without charcoal (Yilangai *et al.,* 2014). Application of Biochar increased vegetable yields by 4.7 to 25.5% as compared to farmers' practices (Vinh *et al.,* 2014). In another work, biochar did not increase the annual yield of winter wheat and summer maize but the cumulative yield over four growing season was significantly increased in the calcareous soil (Liang *et al.,* 2014). The 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 short term crops. The wood chip biochars produced at 290^{o}C and 700^{o} C had no effect on the growth and yield of either rice or leaf beet (Lai *et al*., 2013). A biochar significantly increased the 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, plant height, root biomass and number of leaves in comparison to no biochar treatments (Carter *et al*., 2013).

2.11 Effect of Biochar on Maize

Lanh *et al.* (2019) showed that the soil ameliorating qualities of biochar are linearly related with its effect on soil water retention capacity. It was therefore hypothesized that a simple measurement of the water retention capacity of the biochar itself could serve as an indicator of its capacity to enhance growth of plants in soils. Experiment aimed to produce biochar of different qualities as indicated by its water retention capacity.

The application of 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). An oak biochar derived from a slow pyrolysis process was tested on a maize-soybean rotation in an alfisol soil for four years at 0 t ha^{-1}, 5 t ha^{-1} and 25 t ha^{-1} with 100% and 50% of N fertilizer, resulting in an overall positive trend in total above ground biomass and grain yield (Hottle, 2013).

Major *et al.*, (2010) conducted a study whereby a single dolomitic lime and wood biochar application on an acidic infertile It was found that yield of maize increases were as a result of increases in pH and nutrient retention. It was found that due to the decreasing Ca and Mg soil stocks; there was a stark overall decline in yield in the fourth year of application. In another work, the application of biochar did not increase annual yield of winter wheat and summer maize but the cumulative yield of maize over four growing season was significantly increased in a calcareous soil (Liang *et al.*, 2014).

Ali *et al.* (2015) studied on wheat quality, nutrient uptake and nutrient use efficiency are significantly influenced by nutrient sources and application rate. Application of Biochar displayed a significantly increased in wheat leaf, stem, straw and grain N content; grain and total N-uptake and grain protein content by 24, 20, 24, 56, 50, 17 and 20% respectively. Similarly, application of biochar significantly increased soil total N (TN) and soil mineral N (SMN) by 63 and 40%, respectively in second year. Farmyard manure application increased grain, leaf and straw N content by 20, 19.5 and 18% respectively, and increased total N-uptake and grain protein content by 49 and 19% respectively. Farmyard manure increased soil TN and SMN by 63 and 32% in both the years of the experiment. Mineral N application increased soil TN by over a half and SMN by a third, and grain protein content increased 16%. In contrast, nitrogen use efficiency (NUE) decreased for all amendments relative to the control. However, biochar treated plots improved NUE by 38% compared to plots without biochar. The experiment has illustrated the potential of biochar to bring about short-term benefits in wheat and soil quality parameters in wheat-maize cropping systems.

Use of biochar for soil fertility improvement is gaining popularity due to its potential to improve soil quality, increase crop yield, and sequester carbon from the atmosphere biosphere pool into the soil. A 40 day pot experiment was carried out by Mensah and Frimpong (2018) to investigate the effects of corncob biochar and compost applied alone (at a rate of 2%, w/w) or in combination (1% of each, 1% compost + 1%

biochar) on soil physicochemical properties, growth, and the yield of maize on two soils of contrasting pH and texture collected from the Rainforest and Coastal Savannah agro ecological zones of Ghana. Biochar and compost applied alone or in combination significantly increased soil pH, the total organic carbon, available phosphorus, mineral nitrogen, reduced exchangeable acidity and increased effective cation exchange capacity in both soils. Additionally, combined application and single application of biochar or compost additions increased the plant height, stem girth and dry matter yields of two local and hybrid varieties of maize used in the study. The study showed that biochar applied alone or in combination with compost offers the potential to enhance the quality of soil and improve the yield of maize.

An experiment was conducted by Shashi *et.al.* (2018) to study the impact of rice husk biochar on the growth, water relations and the yield of maize (BARI Hybrid Bhutta-9) under drought (60 and 40% of FC) conditions. Results revealed that drought stress reduced the plant height, relative water content and the grain yield of maize. But rice husk biochar at different doses improved the plant height, relative water content and the grain yield of maize under drought conditions. Under 60% of FC, the highest plan height, leaf water content and yield were 196.67 cm, 79.86% and 89.75 g/plant, respectively when biochar was applied at the rate of 20 t/ha but under 40% of FC, it was 173.33 cm, 78.32% and 84.57 g/plant, respectively when biochar was applied at the same dose. It may be concluded that, rice husk biochar at the rate of 20 t/ha showed the best result to promote the growth, water relation traits and the yield of maize under drought condition.

CHAPTER III

MATERIALS AND METHODS

The experiment was undertaken during October 2018 to April 2019 to come across the integrated effect of nitrogen and akha biochar on soil properties and production of maize where SAU HYBRIED VUTTA 1 was used. The materials and methods of this experiment are presented in this chapter under the following headings-

3.1 Experimental Site

The experiment was conducted at the east-south corner of research field of Sher-e-Bangla Agricultural University (SAU). It is situated at 23°74/ North latitude and 90°35/ East longitude (Anon., 1989). The field was 8.6 m above the sea level and belongs to Madhupur Tract (AEZ 28) (Apendix II). For understanding better about experimental site it is shown in the Map of AEZ of Bangladesh in Appendix- I.

3.2 Climate

The climate of the experimental field 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 Soil

The experimental land belongs to the general soil type which was characterized by shallow red brown terrace soil. The land of the selected experimental site was medium high under the Tejgaon series. Sunshine was available there during the experimental period. Soil sample was collected from 15 cm depth of the experimental site and was sent to SRDI, Dhaka for analysis. The result of analysis was given in Appendix-II.

3.4 Materials

(a) Seeds- SAU HYBRIED VUTTA 1 was collected from Dr. Abdullahil Baque, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka 1207.

(b) Fertilizers- Akha Biochar form Christian Commission for Development in Bangladesh (CCDB), Compost form ACI, Urea, TSP, MP, Gypsum, ZnSO4, Boric Acid and Cowdung. All of the chemical fertilizers and cowdung was collected from the SAU farm. Post-harvest soil Samples were sent to Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur for analysis. The result of analysis was given in Appendix-IV.

3.5 Description of the variety

SAU Hybried Vutta 1

Identifying character: Higher yield potential, resistant to diseases and pests. Developed by Dr. Abdullahil Baque, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka 1207. Year of release: 2018.

Crop duration: 145-155 days

Yield: 10.2-13.8 t ha^{-1}

Suitable area: All over Bangladesh

Sowing time: 15 November – 15 December

Harvesting time: After attaining physiological maturity

Major diseases and Management:

Diseases: Mainly leaf blight disease occurs at vegetative stage.

Management: Clean cultivation with timely sowing and balance fertilizer application. Seed treatment with vitavax- 200 @ 2.5g kg^{-1} seed, spraying with Tilt or Folicure @ 0.5% and burning of crop residues.

3.6 Experimental design and treatments:

Design: Split-plot.

The experiment comprised as two factors.

Factor A: Organic Fertilizer (3)

1. T_1 : Akha Biochar
2. T_2 : Compost
3. T_3 : Control

Factor B: Nitrogen level (4)

1. N_0 : 0% Recommended dose of Nitrogen (Control)
2. N_1 : 50% Recommended dose of Nitrogen
3. N_2 : 75% Recommended dose of Nitrogen
4. N_3 : 100% Recommended dose of Nitrogen

Recommended dose:

Cow dung 6.0 t ha^{-1}, Akha biochar 4 t ha^{-1}, compost 4.0 t ha^{-1}, Urea, TSP, MP, Gypsum, $ZnSO_4$ and Boric acid at the rate of 500, 250, 200, 150, 10 and 5 kg ha^{-1}, respectively.

3.7 Layout of the experiment

The experiment was laid out according to the split plot design. The field was divided into 3 blocks to represent 3 replications. Each block was consisted of 12 unit plots. Thus the total number of plots was 36. The size of each unit plot was 2.5m × 2m. Row to row and plot to plot distances was 50 cm. Distance maintained between replication and line to line were 50 cm and 50 cm. The treatments were assigned in plot at random. Details layout of the experimental plot has been presented below.

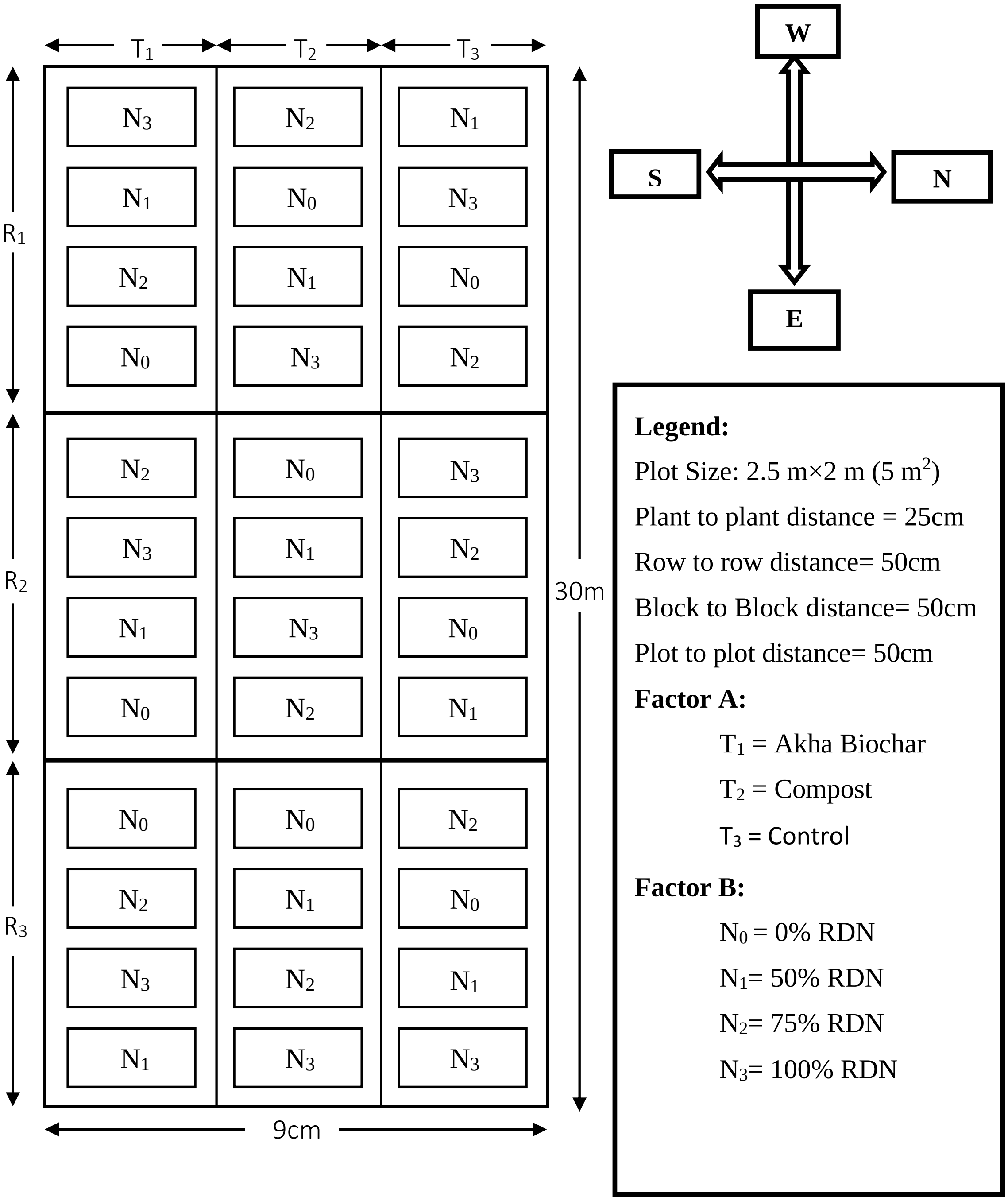


Figure 1: Layout of the experimental plot.

3.8 Detail of experimental preparation

3.8.1 Land preparation

The plot selected for the experiment was opened in the first week of October 2018 with a power tiller and was exposed to the sun for a week, after one week the land was harrowed, ploughed and cross- ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed.

3.8.2 Fertilization

Well rotten cowdung were applied @ 6.0 t ha^{-1} before final land preparation according to treatment. The recommended chemical fertilizer dose used for hybrid variety was 250, 200, 150, 10 and 5 kg ha^{-1} of TSP, MP, Gypsum, $ZnSO_4$ and Boric acid respectively. Urea was used 241 kg N ha^{-1} for N_3, 185 kg N ha^{-1} for N_2, 125 kg N ha^{-1} for N_1, 0 kg N ha^{-1} for N_0. Akha Biochar and compost were used in T_1 and T_2 treatmemt at the rate of 4 t ha^{-1}. Fertilization (basal dose) was completed on 23 October, 2018. One third of urea along with full amount of other fertilizers, Akha biochar and compost as per treatment applied during final land preparation as basal dose and the rest urea as per treatment was applied in two equal installments as side dressing. The first installment of fertilizer was given on 26 November, 2018 and the second installment of fertilizer was given on 5 January, 2019.

3.8.3 Seed Sowing

Seed of SAU Hybried Vutta 1 was sown on 7 November, 2018 in lines maintaining a row to row distance of 50 cm and plant to plant distance of 25 cm having 1 seeds $hole^{-1}$ in the well prepared plot.

3.9 Intercultural operations

3.9.1 Irrigation

First irrigation was given on 22 November, 2018 which was 15 days after sowing. Second irrigation was given on 8 December, 2018 which was 31 days after sowing. Third irrigation was given on 11 January, 2019 which was 65 days after sowing and fourth irrigation was given on 1 February, 2019 which was 85 days after sowing.

3.9.2 Fencing of Experimental field

The whole experimental area was covered by net protecting from birds and other animals.

3.9.3 Gap filling, thinning and weeding

Gap filling was done on 17 November, 2018 which was 10 days after sowing. During plant growth period one thinning and two weeding were done, thinning was done on 23 November, 2018 which was 16 days after sowing and the weeding was done on 7 December, 2018 and 6 January, 2019 which was 30 and 60 days after sowing, respectively.

3.9.4 Earthing up

Earthing up was done on 12 December, 2018 which was 35 days after sowing. It was done to protect the plant from lodging and for better nutrition uptake.

3.9.5 Plant protection measures

Insecticides Ripcord 10 EC @ 2 ml litre^{-1} water was sprayed to control caterpillar on 10 December, 2018 to protect the crop.

3.9.6 Harvesting

The crops were harvested when the husk cover was completely dried and black coloration was found in the grain base. The cobs of five randomly selected plants of each plot were separately harvested for recording yield attributes and other data. Harvesting was done on 6 April, 2019.

3.9.7 Drying

The harvested products were taken on the threshing floor and it was dried for about 3-4 days.

3. 10 Data collection

Data collection of maize was done on the basis of following parameter-

1. Plant height (cm)
2. Leaf length (cm)
3. Leaf width (cm)
4. Number of leaf
5. Leaf Area Index (LAI)
6. Tassel length (cm)
7. Cob to tassel distance (cm)
8. Length of cob (cm)
9. Diameter of cob (cm)

10. Number of grain rows cob^{-1}

11. Number of grains row^{-1}

12. Weight per ear (g)

13. 250 grain weight (g)

14. Dry weight of ear (g)

15. Grain Yield (t ha^{-1})

16. Stover yield (t ha^{-1})

17. Total yield (t ha^{-1})

18. Post-harvest soil analysis

3.10.1 Plant height at different DAS (30, 60 and 90)

At different stages of crop growth (30, 60 and 90 DAS), the height of five randomly selected plants per plot was measured from ground level to the tip of the plant portion and the mean value of plant height was recorded in cm.

3.10.2 Leaf length at different DAS (30, 60 and 90)

At different stages of crop growth (30, 60 and 90 DAS), the length third leaf of the selected plants per plot was measured from ground level to the tip of the leaf and the mean value of plant height was recorded in cm.

3.10.3 Leaf width at different DAS (30, 60 and 90)

At different stages of crop growth (30, 60 and 90 DAS), the width selected leaves of the selected plants per plot was measured and the mean value of plant height was recorded in cm.

3.10.4 Number of leaf per plant at different DAS (30, 60 and 90)

At different stages of crop growth (30, 60 and 90 DAS), number of leaf per plant of the selected plants per plot was measured and the mean value of plant height was recorded in cm.

3.10.5 Leaf Area Index (LAI)

Leaf area index were estimated manually by counting the total number of leaves per plant and measuring the length and average width of leaf and multiplying by a factor of 0.70 (Kluen and Wolf, 1986). It was done at 35 and 65 days after sowing (DAS).

3.10.6 Tassel length (cm)

Tassel length was measured in centimeter from the base of the tassel to the top portion of tassel at each of the five randomly selected plants in each plot.

3.10.7 Cob to tassel distance (cm)

It was measured in centimeter from the base of the topmost cob to the top portion of tassel at each of the five randomly selected plants in each plot.

3.10.8 Length of cob (cm)

Five matured cobs were randomly selected from each plot. Then length of cobs was measured and calculated the mean.

3.10.9 Diameter of cob (cm)

Five matured cobs were randomly selected from each plot. Then diameter of cobs was measured and calculated the mean.

3.10.10 Number of grain rows cob^{-1}

The number of row of five cobs was counted at each of the five randomly selected plants in each plot and averaged.

3.10.11 Number of grains row^{-1}

Number of seeds per rows was recorded for each row of five cobs.

3.10.12 Weight per ear (g)

Five matured ear were randomly selected from each plot. Then weight of the ears was measured and calculated the mean.

3.10.13 250 grains weight (g)

From the seeds sample from five randomly selected plants in each plot, 250 grains were taken to weigh them in gram (g).

3.10.14 Dry weight (g)

Three plants were randomly selected from each plot. Then dried in the oven for 24 hours and weight was measured and calculated the mean.

3.10.15 Grain yield (t ha^{-1})

Grain yield was calculated from cleaned and well dried grains collected from the central 1.5 m^2 area of all 2 inner rows of the each plot (leaving two boarder rows) and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.10.16 Stover yield (t ha^{-1})

Stover yield was determined from the central 1.5 m length of all 2 inner rows of the each plot. After threshing, the sub sample was oven dried to a constant weight and finally converted to t ha^{-1}.

3.10.17 Total yield (t ha^{-1})

It was the total yield including both the economic and stover yield.

3.10.18 Post harvest soil analysis

After harvest, soil was collected from the all 36 plots and then dried in the sunlight. After drying the samples were sent to Department of soil science, Bangabandhu Sheikh Mujibur Rahman Agricultural University to determine soil pH, Organic carbon (%), total nitrogen (%), available phosphorus (ppm) and exchangeable potassium (meq 100g^{-1}). The data was collected from there.

3.11 Statistical analysis

The data obtained for different parameters were statistically analyzed using Statistix 10 software. The significance of the difference among the treatments means was estimated by the Duncan's Multiple Range Test at 5% level of significance.

CHAPTER IV

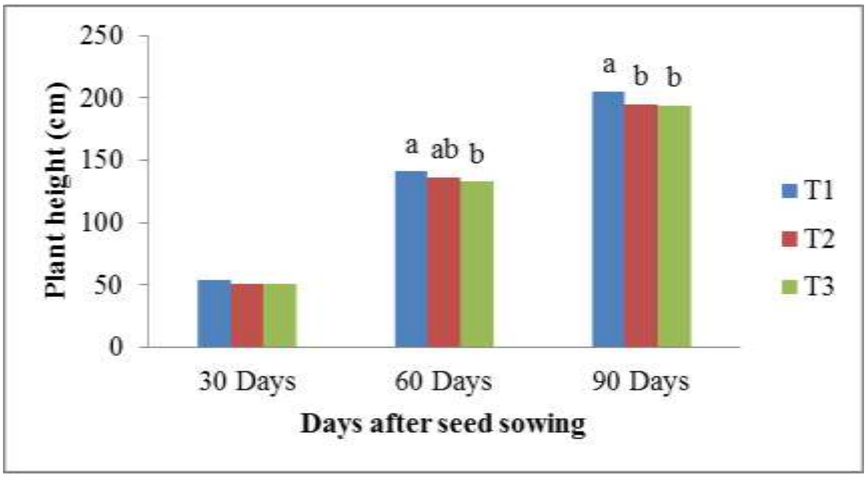
RESULTS AND DISCUSSION

The experiment was conducted to study the integrated effect of nitrogen and akha biochar on soil properties and production of maize. Data on different growth and other parameters, yield attributes and yield, soil parameters were recorded. The results have been presented with the help of graphs and table, and possible interpretations given under the following headings.

4.1 Plant height (cm)

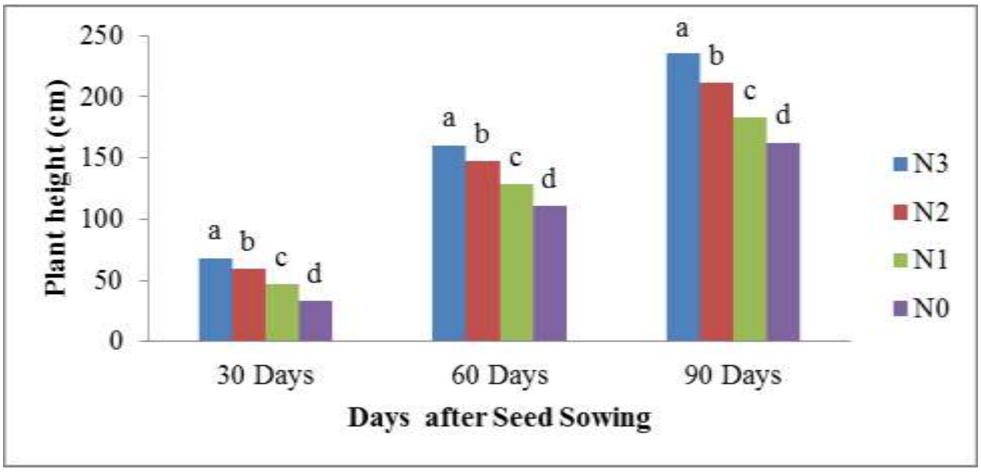
The mean effect of different organic fertilizers (Akha biochar and compost) on plant height of SAU Hybrid Vutta-1 was non significant at 30 DAS (Figure 2). The highest plant height (53.588 cm) was recorded from T_1 (Akha Biochar) treatment, which was statistically identical with other treatments whereas, the lowest plant height (50.325 cm) was recorded from T_3 (control) treated plot. The mean effect of different organic fertilizers (Akha biochar and compost) on plant height of SAU Hybrid Vutta-1 was significant at 60 and 90 DAS (Figure 2). The highest plant height (140.77 and 204.94 cm at 60 and 90 DAS, respectively) was recorded from T_1 (Akha Biochar) treatment whereas, the lowest plant height (132.59 and 194.00 cm at 60 and 90 DAS, respectively) was recorded from T_3 (control) 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. Lehmann *et al.* (2011) found that under drought conditions biochar promoted plant height of maize. Kim *et al*. (2016) showed that application of biochar can increase soil water holding capacity which increased tissue water status and ultimately increased plant height.

The mean effect of different nitrogen doses on plant height of SAU Hybrid Vutta-1 was significant at 30, 60 and 90 days after sowing (DAS) (Figure 3). At 30, 60 and 90 DAS the highest plant height (68.14, 159.85 and 235.83 cm, respectively) was recorded from N_3 (100% Recommended dose of Nitrogen) treatment, whereas, the lowest plant height (32.77, 110.44 and 162.44 cm respectively) was recorded from N_0 (0% Recommended dose of Nitrogen) treated plot. It was revealed that plant height increased with the increased days after sowing (DAS) i.e., 30, 60 and 90 DAS and also revealed that the plant height increased with the increased amount of nitrogen application as well. This may be due to the synergistic effect of N because it enhanced vegetative growth of maize.



T_1: Biochar, T_2: Compost, T_3: Control

Figure 2. Effect of organic fertilizers on plant height (cm) of maize at different days after sowing (DAS). CV (%) 11.59, 6.72 and 7.88; and LSD $_{(0.05)}$ NS, 6.83 and 9.79, at 30, 60 and 90 DAS, respectively



N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 3. Effect of different nitrogen doses on plant height (cm) of maize at different days after sowing (DAS). CV (%) 8.39, 4.42 and 8.60; and LSD $_{(0.05)}$ 4.99, 6.95 and 19.63, at 30, 60 and 90 DAS, respectively

The interaction effect of different organic fertilizer and nitrogen doses on plant height of SAU Hybrid Vutta-1 was significant at 30 and 90 DAS (Table 1). The rate of increase was much higher in the early stages of growth 30 DAS and 90 DAS. At 30 DAS, N_3T_3 combination showed the tallest plant (70.59 cm) which was statistically similar with N_3T_2; whereas N_0T_3 combination showed the shortest plant (29.65 cm) which was statistically similar with N_0T_1 and N_0T_2. At 60 DAS, N_3T_2 combination showed the tallest plant (161.68 cm); whereas N_0T_3combination showed the shortest plant (107.26 cm). At 90 DAS, N_3T_3 combination showed the tallest plant (240.65 cm) which was statistically similar with N_3T_1 and N_3T_2; whereas N_0T_3 combination showed the shortest plant (160.45 cm) which was statistically similar with $N_0T_1$and N_0T_2. Application of Akha biochar with the synergistic effect of N can increase soil water holding capacity and which increased tissue water status and ultimately increased vegetative growth and plant height.

Table 1. Interaction effect of different nitrogen doses and organic fertilizers (Akha biochar and compost) on plant height (cm) of maize at different days after sowing (DAS).

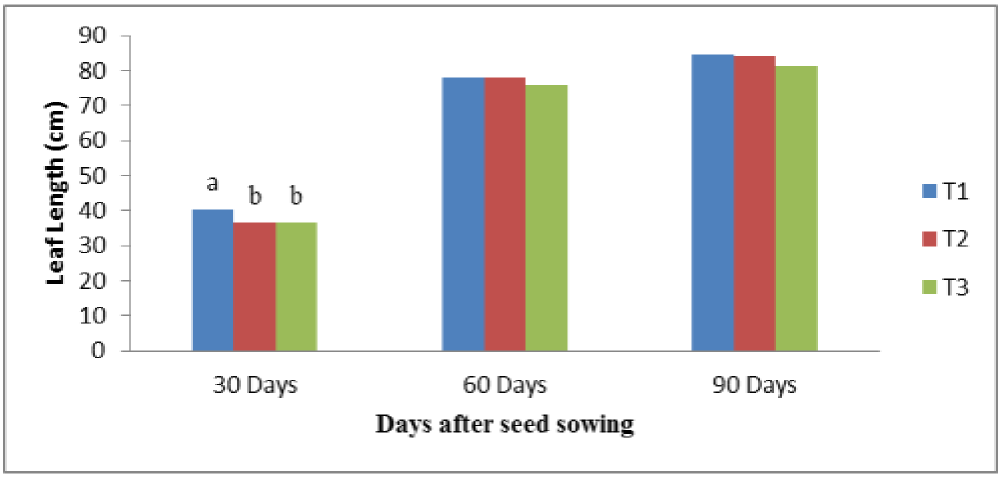
Treatment	30 DAS	60 DAS	90 DAS
N_0T_1	34.08 e	114.95	165.21 c
N_0T_2	34.59 e	109.12	161.68 c
N_0T_3	29.65 e	107.26	160.45 c
N_IT_I	47.74 d	130.69	185.27 bc
N_IT_2	46.71 d	128.82	182.95 bc
N_IT_3	44.81 d	125.09	179.81 bc
N_2T_1	68.46 a	159.08	239.73 a
N_2T_2	52.40 cd	143.90	198.30 b
N_2T_3	56.25 bc	138.49	195.11 b
N_3T_1	64.07 ab	158.35	229.54 a
N_3T_2	69.75 a	161.68	237.29 a
N_3T_3	70.59 a	159.53	240.65 a
LSD $_{(0.05)}$	8.40	NS	25.264
CV (%)	9.31	5.79	5.72

N_0: 0%, N_1: 50%, N_2: 75%, N_3: 100% Recommended dose of Nitrogen, T_1: Biochar, T_2: Compost and T_3: Control.

4.2 Leaf length (cm)

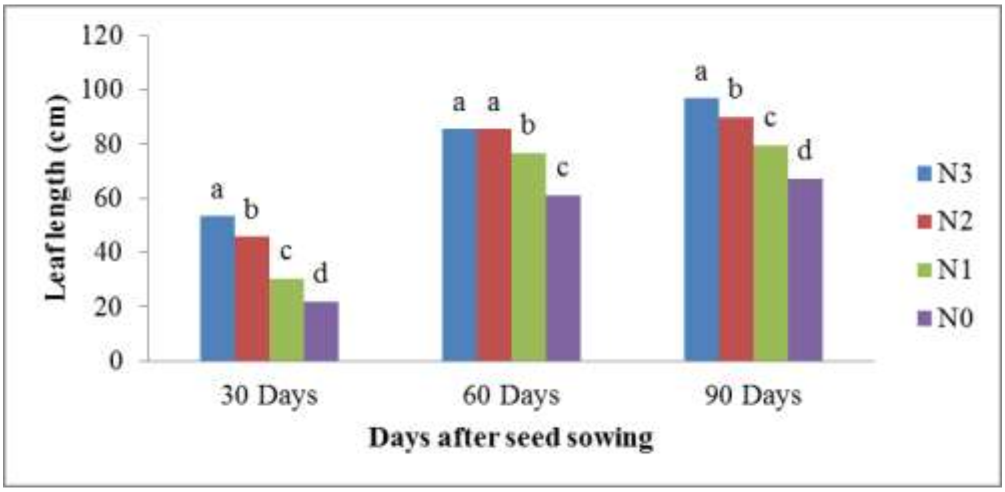
The mean effect of different organic fertilizers (Akha biochar and compost) on leaf length of SAU Hybrid Vutta-1 was significant at 30 DAS (Figure 4). The highest leaf length (40.208 cm) was recorded from T_1 (Akha Biochar) treatment whereas, the lowest leaf length (36.695 cm) was recorded from T_3 (control) treated plot which was statistically similar with T_2. The mean effect of different organic fertilizers (Akha biochar and compost) on leaf length of SAU Hybrid Vutta-1 was non significant at 60 and 90 DAS. At 60 DAS the highest leaf length (78.038 cm) was recorded from T_2 (compost) treatment whereas, the lowest leaf length (75.637 cm) was recorded from T_3 (control) treated plot. At 90 DAS the highest leaf length (84.725 cm) was recorded from T_1 (Akha Biochar) treatment whereas, the lowest leaf length (81.122 cm) was recorded from T_3 (control) treated plot. The results specified that Akha biochar as organic fertilizer helped to increase the leaf length by ensuring maximum release of essential nutrients. Graber *et al.* (2010) emphasized that treating tomato plants by biochar positively enhanced leaf size.

The mean effect of different nitrogen doses on plant height of SAU Hybrid Vutta-1 was significant at 30, 60 and 90 days after sowing (DAS) (Figure 5). At 30, 60 and 90 DAS the maximum leaf length (53.30, 85.47 and 96.70 cm, respectively) was recorded from N_3 (100% Recommended dose of Nitrogen) treatment, whereas, the minimum leaf length (21.82, 21.82 and 67.30 cm respectively) was recorded from N_0 (0% Recommended dose of Nitrogen) treated plot. It was revealed that leaf length increased with the increased days after sowing (DAS) i.e., 30, 60 and 90 DAS and also revealed that the leaf length increased with the increased amount of nitrogen application as well. This could be due to the synergistic effect of N because it enhanced vegetative growth of maize.



T_1: Biochar, T_2: Compost, T_3: Control

Figure 4. Effect of different organic fertilizers on leaf length (cm) of maize at different days after sowing (DAS). CV (%) 7.32, 6.87and 7.36; and LSD $_{(0.05)}$ 2.90, NS and NS, at 30, 60 and 90 DAS, respectively



N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 5. Effect of nitrogen doses on leaf length (cm) of maize at different days after sowing (DAS). CV (%) 5.72, 7.72 and 5.27; and LSD $_{(0.05)}$ 2.49, 6.88 and 5.07, at 30, 60 and 90 DAS, respectively

The interaction effect of different organic fertilizer and nitrogen doses on leaf length of SAU Hybrid Vutta-1 was significant at 30 and 90 DAS (Table 2). At 30 DAS, N_3T_3 combination showed the highest leaf length (54.11 cm) which was statistically similar with N_2T_1, N_3T_2 and N_3T_1; whereas N_0T_3 combination showed the shortest leaf length (20.60 cm) which was statistically similar with N_0T_1 and N_0T_2. At 60 DAS, it was non significant and N_2T_2 combination showed the highest leaf length (87.71 cm); whereas N_0T_3combination showed the shortest leaf length (58.41 cm). At 90 DAS, N_3T_3 combination showed the highest leaf length (97.79 cm) which was statistically similar with N_2T_2 N_2T_1, N_3T_1 and N_3T_2; whereas N_0T_3 combination showed the shortest leaf length (66.33 cm) which was statistically similar with N_0T_1 and N_0T_2.organic fertilizers with different doses of nitrogen increased the water holding capacity of soil and ensured the availability of nutrients which helped to increase the leaf length.

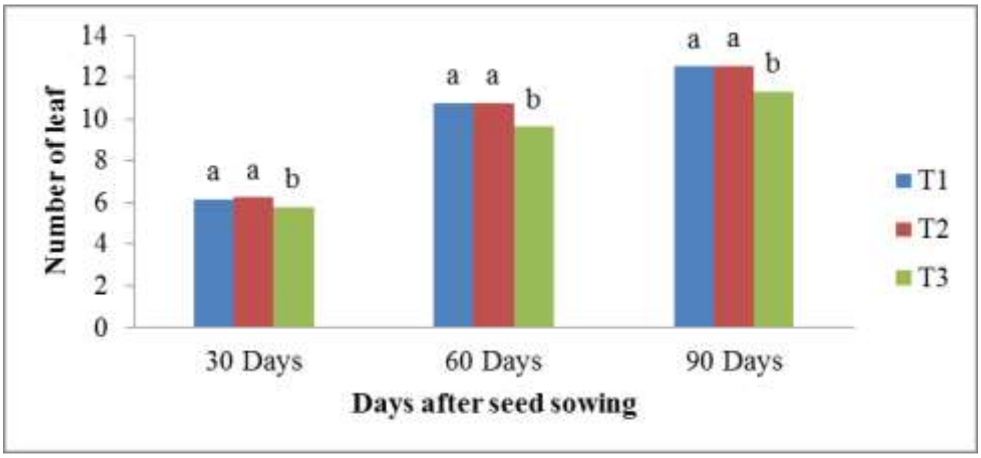
Table 2. Interaction effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) on leaf length (cm) of maize at different days after sowing (DAS).

Treatment	30 DAS	60 DAS	90 DAS
N_0T_1	22.89 d	63.74	68.30 c
N_0T_2	21.96 d	61.73	67.28 c
N_0T_3	20.60 d	58.41	66.33 c
N_IT_I	31.03 c	78.57	80.19 b
N_IT_2	30.76 c	76.51	79.53 b
N_IT_3	29.77 c	75.13	78.76 b
N_2T_1	53.81 a	87.70	93.80 a
N_2T_2	41.09 b	87.71	94.67 a
N_2T_3	42.29 b	81.01	81.61 b
N_3T_1	53.11 a	82.08	96.61 a
N_3T_2	52.68 a	86.21	95.71 a
N_3T_3	54.11 a	88.00	97.79 a
LSD (0.05)	5.35	NS	8.05
CV (%)	8.87	6.64	5.33

N_0: 0%, N_1: 50%, N_2: 75%, N_3: 100% Recommended dose of Nitrogen, T_1: Biochar, T_2: Compost and T_3: Control.

4.3 Number of leaf

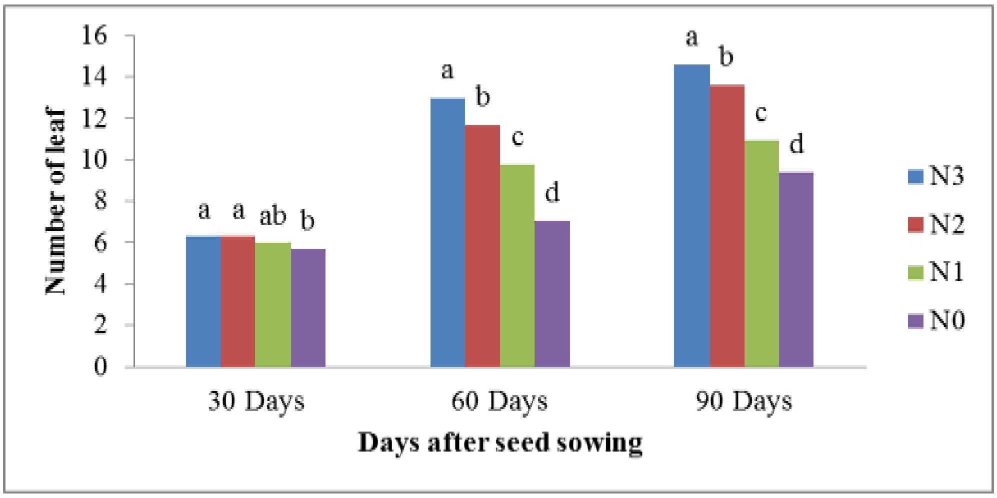
The mean effect of different organic fertilizers (Akha biochar and compost) on number of leaf of SAU Hybrid Vutta-1 was non significant at 30 DAS and significant at 60 and 90 DAS (Figure 6). At 30 DAS the highest number of leaf (6.23) was recorded from T_2 (compost) treatment whereas, the lowest number of leaf (5.79) was recorded from T_3 (control) treated. At 60 and 90 DAS, the highest number of leaf (10.775 and 12.54 respectively) was recorded from T_1 (Akha Biochar) treatment which was statistically similar with T_2; whereas, the lowest number of leaf (9.617 and 11.32 respectively) was recorded from T_3 (control) treated plot. The results indicated that biochar; organic manure created favorable condition for growth and development for increase of number of leaves plant^{-1} than control. Biochar amendment on different soils has led to increased availability and uptake of nutrients by plants which facilitated proliferate leaf production of potato (Hass *et al.*, 2012 and Uzoma *et al.*, 2011). Carter *et al*. (2013) confirmed that the biochar treatments were increased the leaf number of lettuce and cabbage.



T_1: Biochar, T_2: Compost, T_3: Control

Figure 6. Effect of different organic fertilizers on number of leaf of maize at different days after sowing (DAS). CV (%) 4.03, 8.17 and 4.39; and LSD $_{(0.05)}$ 0.27, 0.96 and 0.60, at 30, 60 and 90 DAS, respectively

The mean effect of different nitrogen doses on number of leaf of SAU Hybrid Vutta-1 was significant at 30, 60 and 90 days after sowing (DAS) (Figure 7). At 30 DAS the highest number of leaf (6.29) was recorded from N_3 (100% Recommended dose of Nitrogen) treatment which was statistically similar with N_2; whereas, the lowest number of leaf (5.70) was recorded from N_0 (0% Recommended dose of Nitrogen) treated plot which was statistically similar with N_1. At 60 DAS the highest number of leaf (12.98) was recorded from N_3 treatment whereas, the lowest number of leaf (7.07) was recorded from N_0 treated plot. At 90 DAS the highest number of leaf (14.58) was recorded from N_3 treatment which was statistically similar with N_2; whereas, the lowest number of leaf (9.39) was recorded from N_0 treated plot.



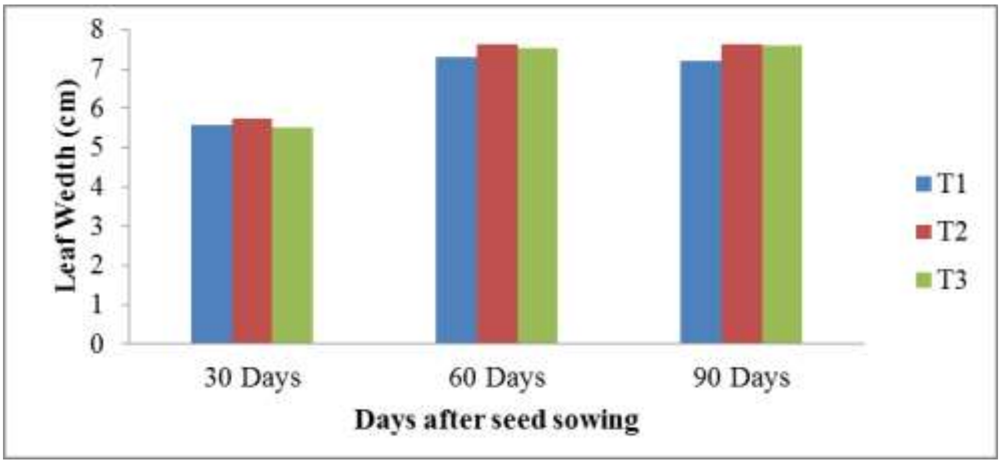
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 7. Effect of different nitrogen doses on number of leaf of maize at different days after sowing (DAS). CV (%) 4.95, 8.96 and 7.37; and LSD $_{(0.05)}$ 0.34, 1.07 and 1.03, at 30, 60 and 90 DAS, respectively

Combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) showed an increasing trend with advances of growth period in respect of number of leaf (Table 3). It exhibits non significant influence on number of leaf of maize at 30, 60 and 90 DAS. At 30 DAS, N_3T_3 combination showed the highest number of leaf (6.57); whereas N_0T_3 combination showed the lowest number of leaf (5.67). At 60 DAS, N_3T_2 combination showed the highest number of leaf (13.53); whereas N_0T_3 combination showed the lowest number of leaf (6.73). At 90 DAS, N_3T_2 combination showed the highest number of leaf (14.63); whereas N_0T_3 combination showed the lowest number of leaf (9.03).

4.4 Leaf width (cm)

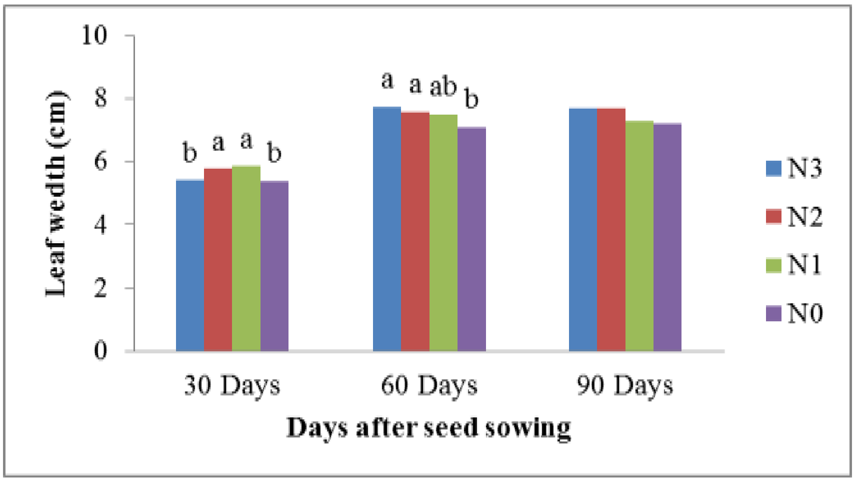
The mean effect of different organic fertilizers (Akha biochar and compost) on number of leaf of SAU Hybrid Vutta-1 was non significant (Figure 8). At 30 DAS the highest leaf width (5.73 cm) was recorded from T_2 (compost) treatment whereas, the lowest leaf width (5.49 cm) was recorded from T_3 (control) treated. At 60 and 90 DAS, the highest leaf width (7.61 and 7.62 cm, respectively) was recorded from T_2 (compost) treatment whereas, the lowest leaf width (7.3 and 7.21 cm, respectively) was recorded from T_1 (Akha biochar) treated plot.



T_1: Biochar, T_2: Compost, T_3: Control

Figure 8. Effect of different organic fertilizers on Leaf width (cm) of maize at different days after sowing (DAS). CV (%) 11.34, 7.74 and 8.32; and LSD $_{(0.05)}$ NS, NS and NS, at 30, 60 and 90 DAS, respectively

Significant variation was observed on leaf width (cm) due to different doses of nitrogen (Figure 9) at 30 DAS and non significant at 60 and 90 DAS. At 30 DAS, the highest leaf width (5.84 cm) was recorded from N_1 treatment which was statistically similar with N_2; whereas, the lowest leaf width (5.39 cm) was recorded from N_0 treated plot which was statistically similar with N_3. At 60 DAS the largest leaf width (7.75 cm) was recorded from N_3 treatment, the minimum leaf width (7.09 cm) was recorded from N_0 treated plot. At 90 DAS, the largest leaf width (7.71 cm) was recorded from N_3 treatment whereas; the lowest leaf width (7.21 cm) was recorded from N_0 treated plot.



N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 9. Effect of different nitrogen doses on Leaf width (cm) of maize at different days after sowing (DAS). CV (%) 4.91, 5.71 and 7.81; and LSD $_{(0.05)}$ 0.31, 0.49 and NS at 30, 60 and 90 DAS, respectively

Significant variation was observed on leaf width (cm) due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) at 30 DAS (Table 3). The highest leaf width (6.15 cm) was recorded from N_IT_3 treatment which was statistically similar except N_3T_3, N_3T_1, N_0T_3 and N_0T_1; whereas, the lowest leaf width (4.87 cm) was recorded from N_0T_3 treated plot. At 60 and 90 DAS the variation was non significant. The highest leaf width (8.04 cm) was recorded from N_3T_2 treatment whereas the lowest leaf width (7.00 cm) was recorded from N_0T_2 treated plot. The highest leaf width (8.24 cm) was recorded from N_3T_3 treatment; whereas, the lowest leaf width (6.91 cm) was recorded from N_IT_I treated plot.

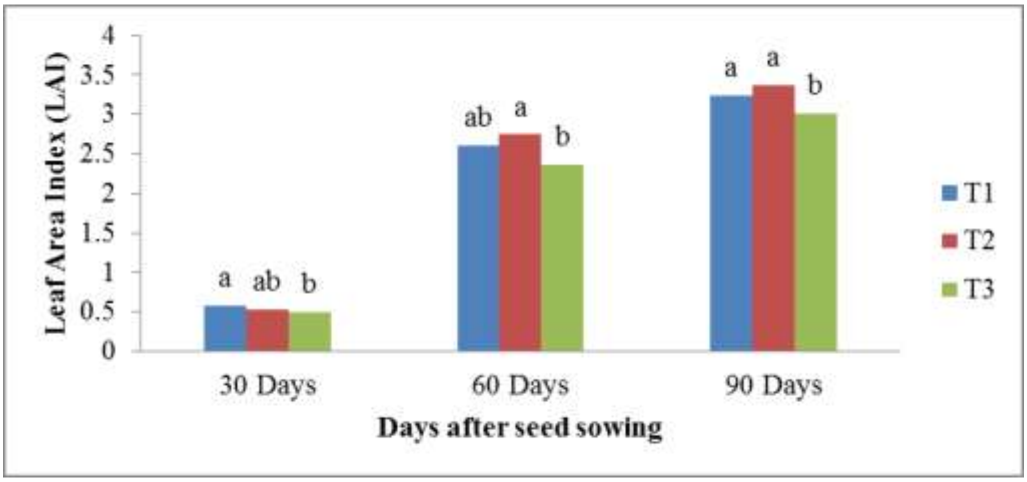
Table 3. Interaction effect of different nitrogen doses and organic fertilizers (Akha biochar and compost) on number of leaf and leaf width (cm) of maize at different days after sowing (DAS).

Treatment	Number of leaf			leaf wedth (cm)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
N_0T_1	5.67	7.37	9.40	5.33 bc	7.24	7.03
N_0T_2	6.20	7.10	9.73	5.97 ab	7.00	7.61
N_0T_3	5.23	6.73	9.03	4.87 c	7.25	7.00
N_IT_I	6.00	10.23	11.60	5.53 abc	7.85	6.91
N_IT_2	6.53	10.00	11.73	5.87 ab	7.38	7.85
N_IT_3	5.37	9.07	9.50	6.15 a	7.33	7.05
N_2T_1	6.50	12.53	14.53	6.05 ab	7.75	7.33
N_2T_2	6.33	12.40	14.07	5.61 abc	7.69	7.75
N_2T_3	6.00	10.20	12.17	5.65 ab	7.59	8.02
N_3T_1	6.43	12.97	14.50	5.39 bc	7.61	7.59
N_3T_2	5.87	13.53	14.63	5.49 abc	8.04	7.24
N_3T_3	6.57	12.47	14.60	5.31 bc	7.24	8.24
LSD (0.05)	NS	NS	NS	0.75	NS	NS
CV (%)	9.31	1.39	7.41	8.62	8.69	8.97

N_0: 0%, N_1: 50%, N_2: 75%, N_3: 100% Recommended dose of Nitrogen, T_1: Biochar, T_2: Compost and T_3: Control.

4.5 Leaf area index

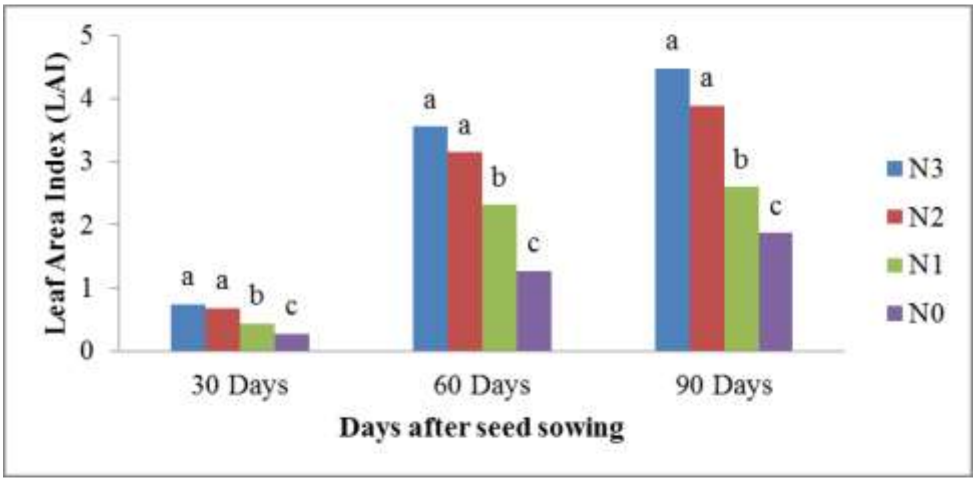
Significant variation was recorded on leaf area index due to organic fertilizers (Akha biochar and compost) (Figure 10). At 30 DAS, the highest leaf area index was recorded from T_1 (0.5823), which was statistically at similar with T_2 (0.5293) while the lowest value was recorded from T_3 (0.4950). At 60 and 90 DAS, the highest leaf area index was recorded from T_2 (2.7466 and 3.3766 respectively), which was statistically at similar with T_1 while the lowest value was recorded from T_3 (2.6303 and 3.0103 respectively). Application of Akha biochar had increased the leaf area index by availing the nutrient to the plant. Njoku *et al.* (2015) showed that biochar amended plots had significantly higher leaf area index than control. Lashari *et al.* (2015) reported that there were great increases in leaf area index of maize when grown in biochar amendments. Ahmad *et al.* (2015) found that application of biochar significantly improved soil fertility, leaf area plant^{-1} and leaf area index.



T_1: Biochar, T_2: Compost, T_3: Control

Figure 10. Effect of different organic fertilizers on leaf area index (LAI) of maize at different days after sowing (DAS). CV (%) 14.21, 10.82 and 6.25; LSD $_{(0.05)}$ 0.08, 0.31and 0.22, at 30, 60 and 90 DAS, respectively

Application of different doses of nitrogen showed significant influence on leaf area index of maize at 30, 60 and 99 DAS (Figure 11). At 30, 60 and 90 DAS, the highest leaf area index was recorded from N_3 (0.74, 3.56 and 4.48 respectively), which was statistically at similar with N_2 while the lowest value was recorded from N_0 (0.28, 1.27 and 1.87 respectively).



N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 11. Effect of different nitrogen doses on leaf area index (LAI) of maize at different days after sowing (DAS). CV (%) 9.65, 10.52 and 13.66; LSD $_{(0.05)}$ 0.05, 0.44 and 0.62, at 30, 60 and 90 DAS, respectively.

Significant variation was observed on leaf area index due to combined effect of different doses of nitrogen and organic fertilizers (akha biochar and compost) at 30, 60 and 90 DAS (Table 4). At 30 DAS, the highest leaf area index was recorded from N_2T_1 (0.86) treatment which was statistically similar with N_3T_1 and N_3T_3; whereas, the lowest value was recorded from N_0T_3 (0.21) treated plot which was statistically similar with N_0T_2 and N_0T_1. At 60 DAS, the highest leaf area index was recorded from N_3T_2 (3.70) treatment which was statistically similar with N_2T_2, N_2T_1, N_3T_1 and N_3T_3 whereas the lowest value was recorded from N_0T_2 (1.13) treated plot which was statistically similar with N_0T_3 and N_0T_1. At 90 DAS, the highest leaf area index was recorded from N_3T_3 (4.86) treatment which was statistically similar with N_2T_I, N_2T_2, N_3T_2 and N_3T_1; whereas, the lowest value was recorded from N_0T_3 (1.71) treated plot which was statistically similar with N_IT_3, N_0T_2 and N_0T_1.

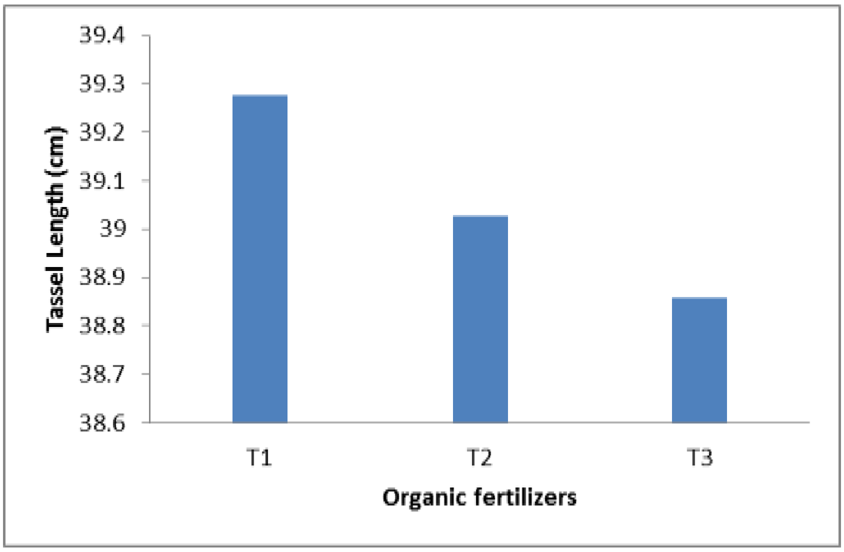
Table 4. Interaction effect of different nitrogen doses and organic fertilizers on leaf area index of maize at days after sowing (DAS).

Treatment	30 DAS	60 DAS	90 DAS
N_0T_1	0.28 g	1.36 c	1.85 cd
N_0T_2	0.33 fg	1.31 c	2.04 cd
N_0T_3	0.21 g	1.13 c	1.71 d
N_IT_I	0.42 ef	2.40 b	2.63 bc
N_IT_2	0.48 de	2.48 b	3.01 b
N_IT_3	0.41 ef	2.06 b	2.17 cd
N_2T_1	0.86 a	3.33 a	4.12 a
N_2T_2	0.60 c	3.50 a	4.25 a
N_2T_3	0.59 cd	2.62 b	3.30 b
N_3T_1	0.76 ab	3.33 a	4.38 a
N_3T_2	0.70 bc	3.70 a	4.20 a
N_3T_3	0.77 ab	3.63 a	4.86 a
LSD (0.05)	0.12	0.57	0.88
CV (%)	13.60	10.52	13.89

N_0: 0%, N_1: 50%, N_2: 75%, N_3: 100% Recommended dose of Nitrogen, T_1: Biochar, T_2: Compost and T_3: Control

4.6 Tassel length (cm)

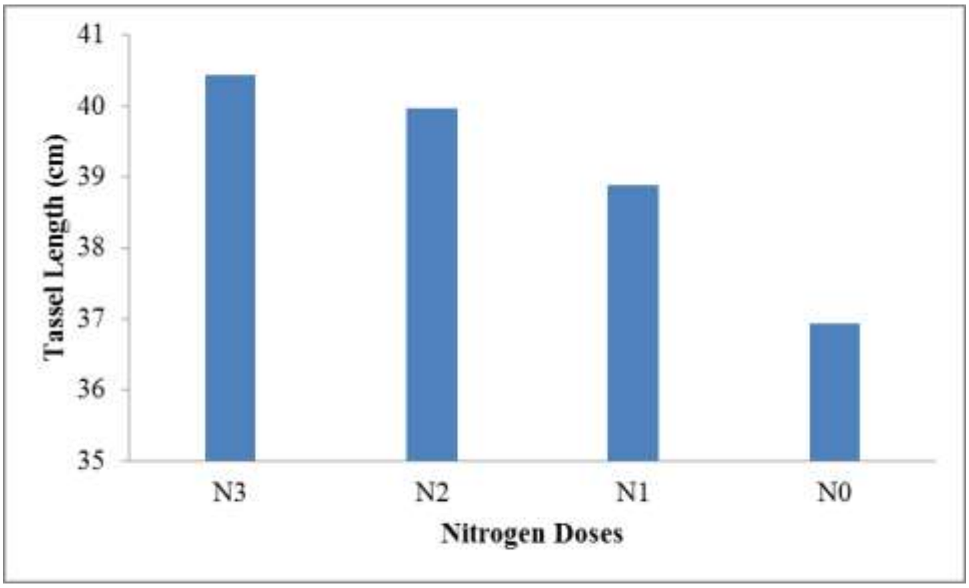
Non significant variation was recorded on tassel length due to organic fertilizers (Akha biochar and compost) (Figure 12). The highest tassel length was recorded from T_1 (39.28 cm) while the lowest value was recorded from T_3 (38.85 cm).



T_1: Biochar, T_2: Compost, T_3: Control

Figure 12. Effect of different organic fertilizers on tassel length (cm) of maize at different days after sowing (DAS). CV (%) 6.83 and LSD $_{(0.05)}$ NS.

Non significant variation was recorded on tassel length due to different level of nitrogen (Figure 13). The highest tassel length was recorded from N_3 (40.44 cm) while the lowest value was recorded from N_0 (36.93 cm).



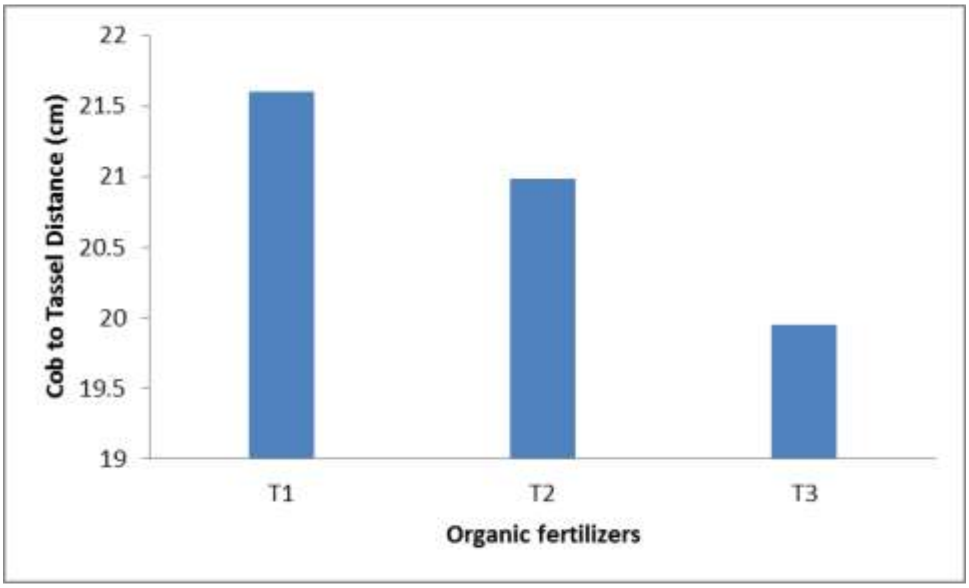
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 13. Effect of different nitrogen doses on tassel length (cm) of maize at different days after sowing (DAS). CV (%) 7.84 and LSD $_{(0.05)}$ NS.

Non significant variation was observed on tassel length due to combined effect of treatments and fertilizer doses (Table 5). The highest tassel length was recorded from N_3T_3 (41.24 cm) while the lowest value was recorded from N_2T_3 (36.17 cm).

4.7 Cob to tassel distance (cm)

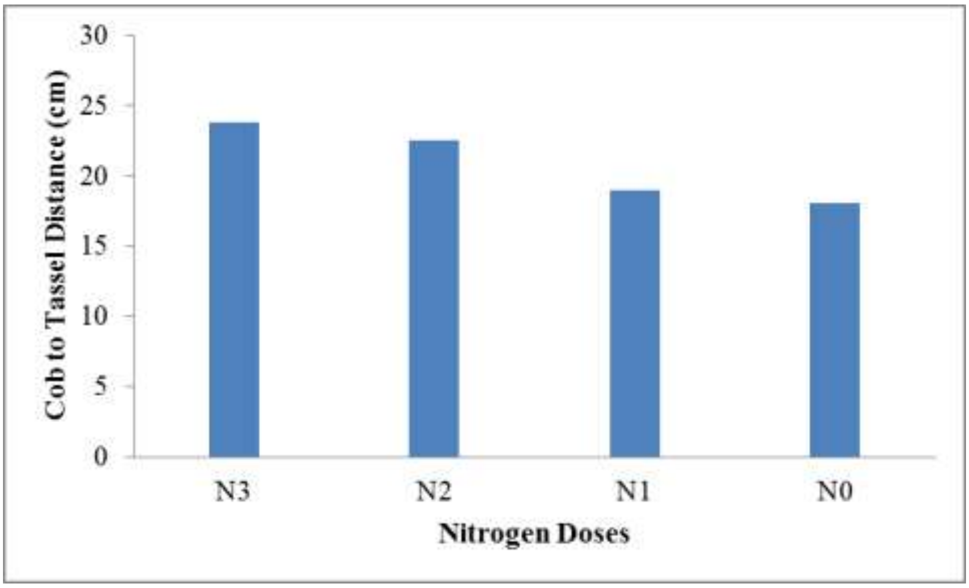
The variation was significant on cob to tassel distance due to organic fertilizers (Akha biochar and compost) (Figure 14). The highest value was recorded from T_1 (39.28 cm) while the lowest value was recorded from T_3 (80.96 cm).



T_1: Biochar, T_2: Compost, T_3: Control

Figure 14. Effect of different organic fertilizers on cob to tassel distance (cm) of maize. CV (%) 10.48 and LSD $_{(0.05)}$ 3.7.

Application of different doses of nitrogen exhibited significant influence on cob to tassel distance of maize (Figure 15). The highest value was recorded from N_3 (87.24 cm) which was statistically at similar with N_2 while the lowest value was recorded from N_0 (77.54 cm) which was statistically at similar with N_1.



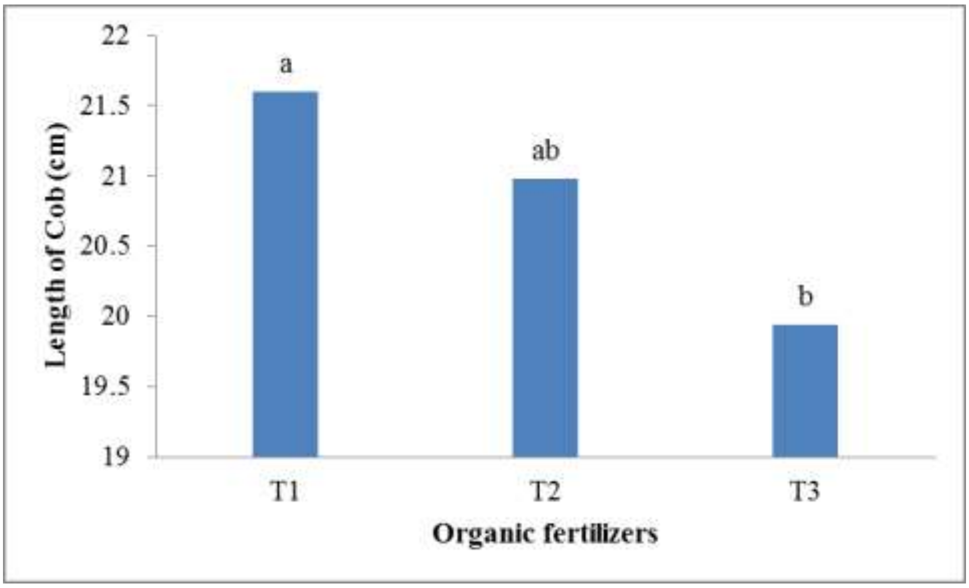
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 15. Effect of different nitrogen doses on cob to tassel distance (cm) of maize. Here, CV (%) 6.01 and LSD $_{(0.05)}$ 5.71

Interaction effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) showed significant differences on cob to tassel distance of maize (Table 5). The highest value was recorded from N_2T_2 (89.25 cm) which was statistically at similar with all except N_IT_2, N_2T_3 and N_0T_1 while the lowest value was recorded from N_2T_3 (76.87 cm) which was statistically at similar with N_IT_2 and N_0T_1.

4.8 Length of cob (cm)

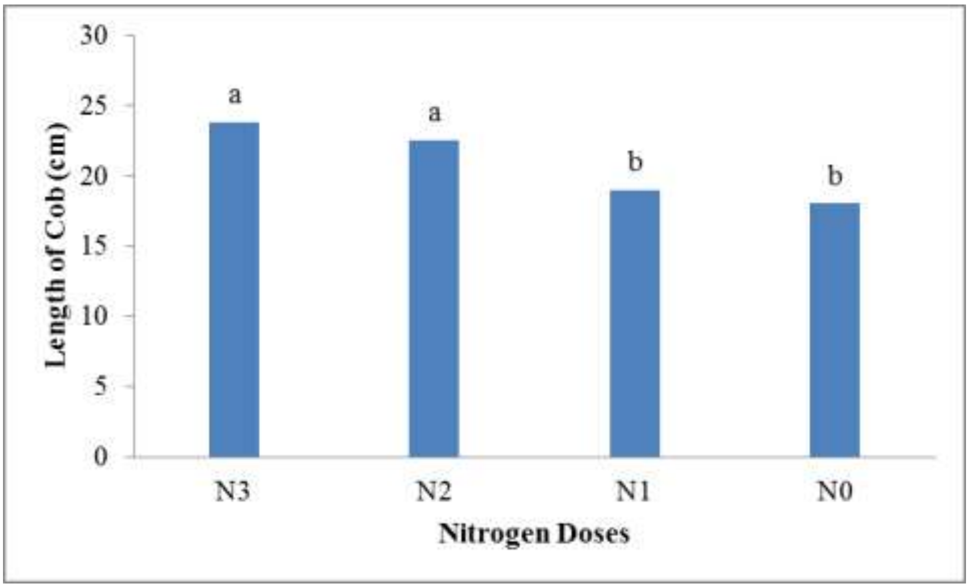
Length of cob was recorded statistically significant due to organic fertilizers (Akha biochar and compost) of maize (Figure 16). The highest value was recorded from T_1 (21.60 cm) which was statistically at similar with T_2 while the lowest value was recorded from T_3 (19.95 cm).



T_1: Biochar, T_2: Compost, T_3: Control

Figure 16. Effect of different organic fertilizers on length of cob (cm) of maize, CV (%) 6.88 and LSD $_{(0.05)}$ 1.24

Length of cob was recorded statistically significant due to different doses of nitrogen on maize (Figure 17). The highest value was recorded from N_3 (23.83 cm) which was statistically at similar with N_2 while the lowest value was recorded from N_0 (18.03 cm) which was statistically at similar with N_1.



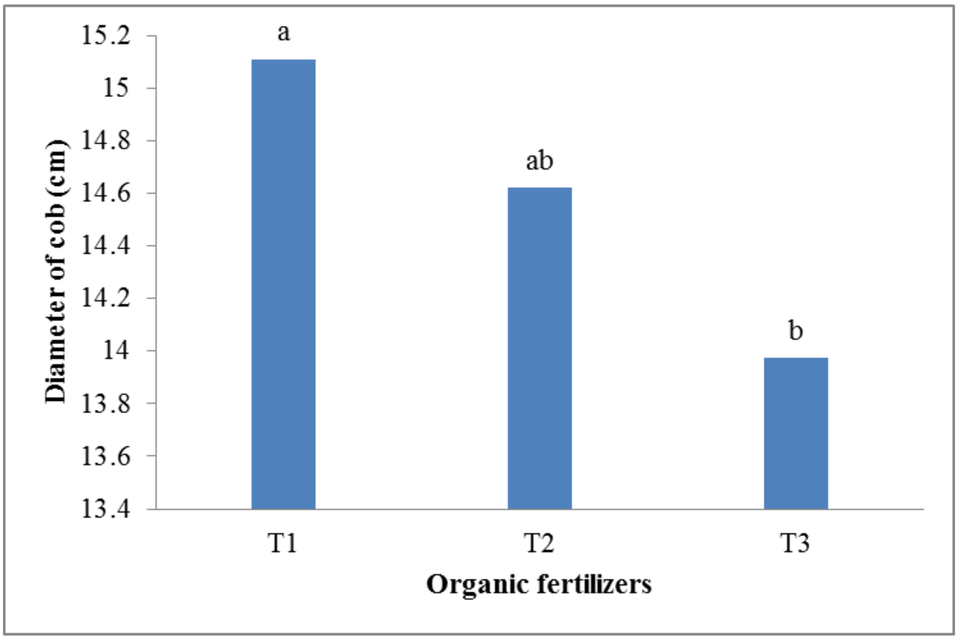
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 17. Effect of different nitrogen doses on length of cob (cm) of maize. CV (%) 8.91 and LSD $_{(0.05)}$ 1.52

Significant variation was observed on length of cob due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) of maize (Table 5). The highest value was recorded from N_2T_1 (24.14 cm) which was statistically at similar with N_3T_1, N_3T_2, N_3T_3 and N_2T_2 while the lowest value was recorded from N_0T_3 (17.20 cm) which was statistically at similar with N_0T_1, N_0T_2, N_IT_2 and N_IT_3.

4.9 Diameter of cob (cm)

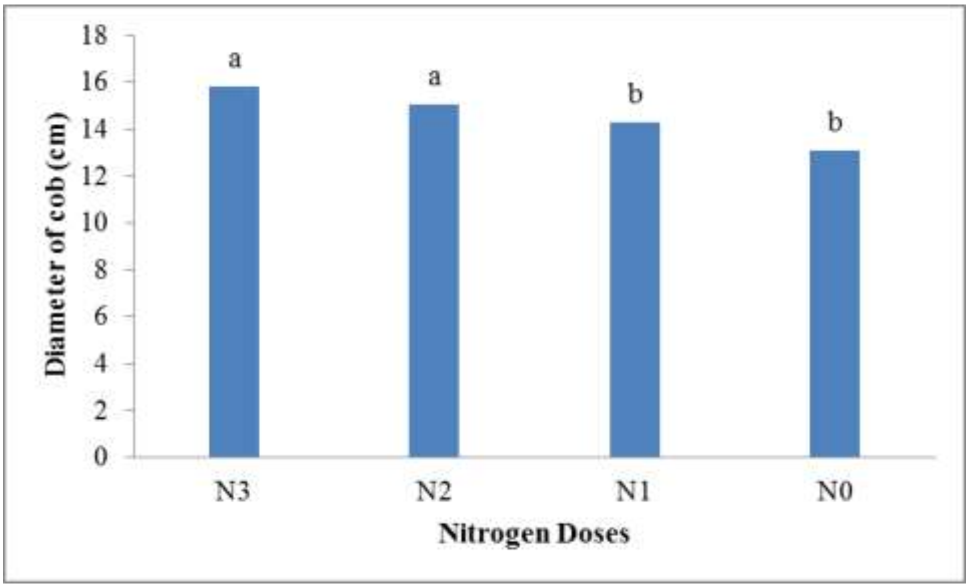
Diameter of cob was recorded statistically significant due to organic fertilizers (Akha biochar and compost) of maize (Figure 18). The highest value was recorded from T_1 (15.11 cm) which was statistically at similar with T_2 while the lowest value was recorded from T_3 (13.97 cm).



T_1: Biochar, T_2: Compost, T_3: Control

Figure 18. Effect of different organic fertilizers on diameter of cob (cm) of maize. CV (%) 4.81 and LSD $_{(0.05)}$ 0.75

Diameter of cob was recorded statistically significant due to different doses of nitrogen of maize (Figure 19). The highest value was recorded from N_3 (15.82 cm) which was statistically at similar with N_2 while the lowest value was recorded from N_0 (13.09 cm).



N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 19. Effect of different nitrogen doses on diameter of cob (cm) of maize.
Here, CV (%) 5.91 and LSD $_{(0.05)}$ 1.03

Significant variation was observed on diameter of cob due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) of maize (Table 5). The highest value was recorded from N_3T_3 (15.99 cm) which was statistically at similar with N_3T_1, N_3T_2, N_2T_1 and N_2T_2 while the lowest value was recorded from N_0T_3 (12.23 cm) which was statistically at similar with N_0T_2.

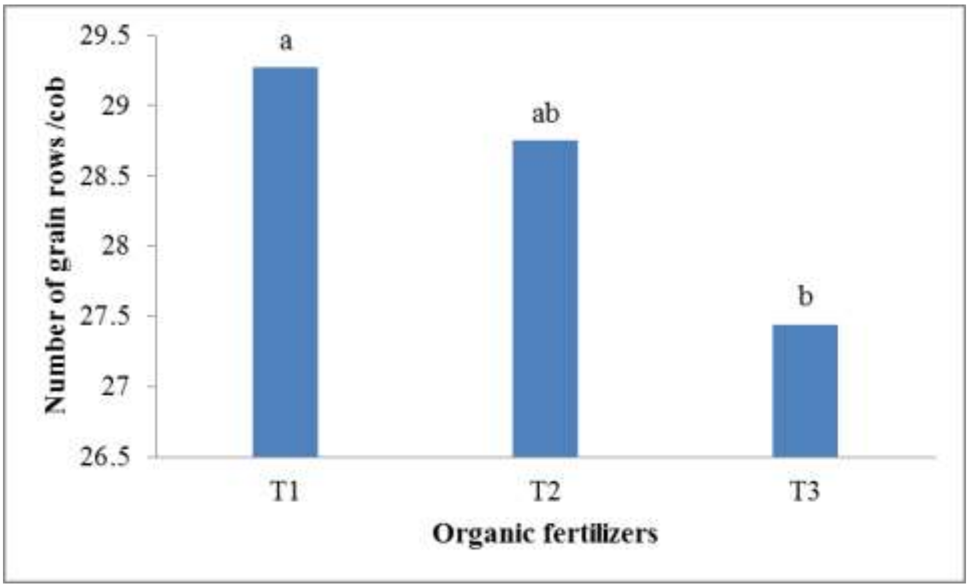
Table 5. Combine effect of different nitrogen doses and organic fertilizers on tassel length, cob to tassel distance, cob length, cob diameter of maize.

Treatment	Tassel Length (cm)	Cob to Tassel distance(cm)	Length of Cob (cm)	Diameter of Cob (cm)
N_0T_1	36.99	78.69 bc	18.37 cd	13.90 cd
N_0T_2	39.47	80.29 abc	18.52 cd	13.15 de
N_0T_3	40.91	86.27 abc	17.20 d	12.23 e
N_IT_I	39.73	84.99 abc	20.23 c	14.87 abc
N_IT_2	37.63	77.05 c	18.89 cd	14.35 bcd
N_IT_3	38.11	85.13 abc	17.74 d	13.64 cde
N_2T_1	39.35	82.77 abc	24.14 a	15.97 a
N_2T_2	40.35	89.25 a	22.73 ab	15.21 abc
N_2T_3	36.17	76.87 c	20.72 bc	14.03 cd
N_3T_1	39.07	79.01 abc	23.67 a	15.70 ab
N_3T_2	39.63	80.50 abc	23.70 a	15.78 ab
N_3T_3	41.24	87.48 ab	24.11 a	15.99 a
$LSD_{(0.05)}$	NS	10.24	2.47	1.59
CV (%)	6.83	7.32	6.89	5.91

N_0: 0%, N_1: 50%, N_2: 75%, N_3: 100% Recommended dose of Nitrogen, T_1: Biochar, T_2: Compost and T_3: Control

4.10 Number of grain rows in each cob

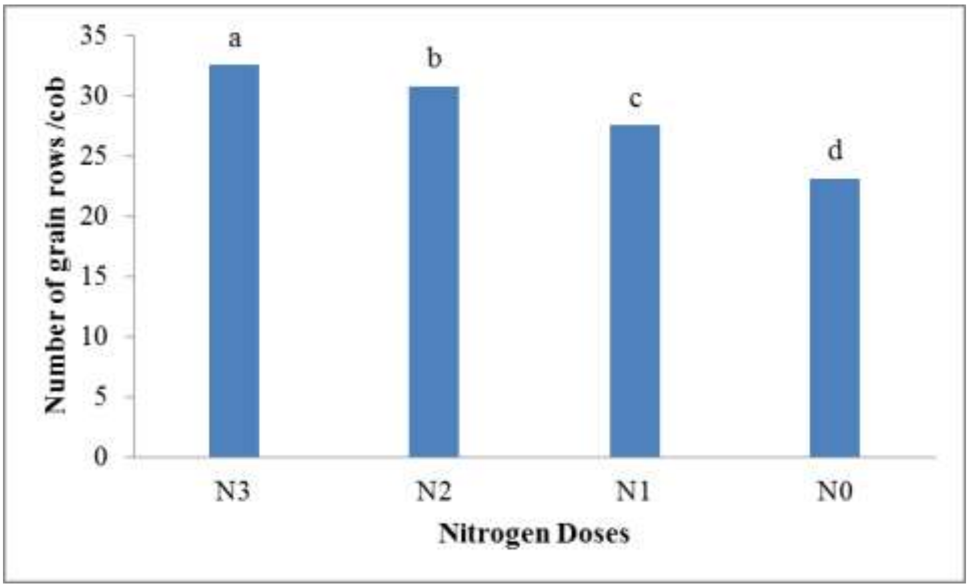
Significant variation was recorded on number of grain rows per cob due to organic fertilizers (Akha biochar and compost) (Figure 20). The highest value was recorded from T_1 (29.27) which were statistically at similar with T_2 while the lowest value was recorded from T_3 (27.44).



T_1: Biochar, T_2: Compost, T_3: Control

Figure 20. Effect of different organic fertilizers on number of grain rows per cob of maize. CV (%) 4.44 and LSD $_{(0.05)}$ 1.33

Number of grain rows per cob was recorded statistically significant due to different doses of nitrogen of maize (Figure 21). The highest value was recorded from N_3 (32.54) while the lowest value was recorded from N_0 (23.09).



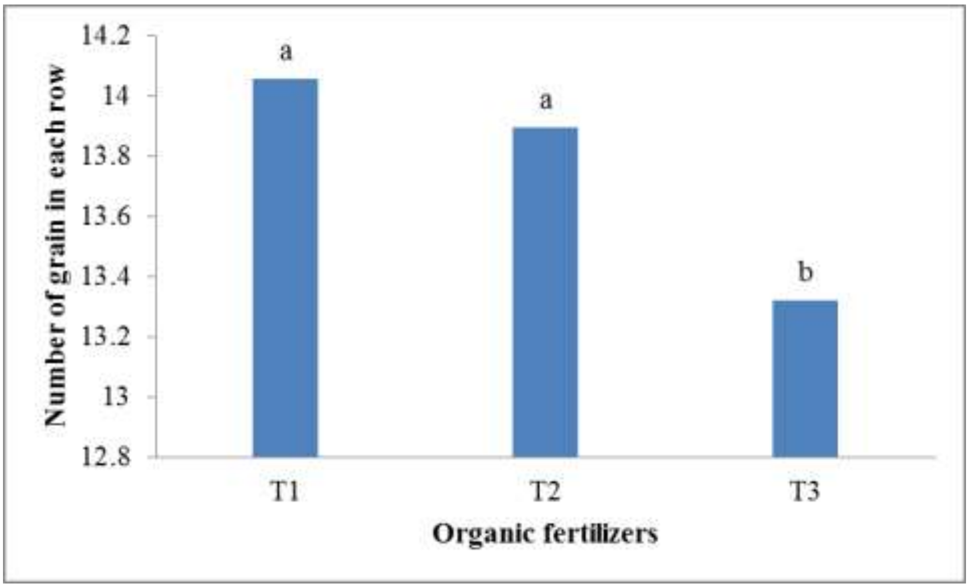
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 21. Effect of different nitrogen doses on Number of grain rows/cob of maize. CV (%) 3.84 and LSD $_{(0.05)}$ 1.26

Non significant variation was observed on number of grain rows per cob due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) of maize (Table 6). The highest value was recorded from N_3T_1 (33.02) which was statistically at similar with N_3T_3, N_3T_2, N_2T_1 and N_2T_2 while the lowest value was recorded from N_0T_3 (22.53) which was statistically at similar with N_0T_1 and N_0T_2.

4.11 Number of grain in each row

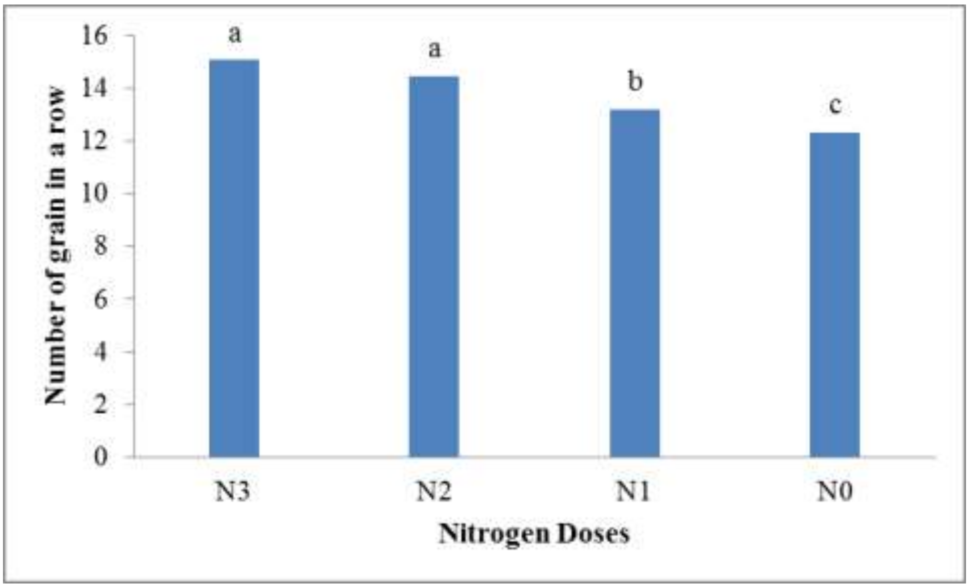
Number of grain in each row was recorded statistically significant due to different organic fertilizers (Akha biochar and compost) of maize (Figure 22). The highest value was recorded from T_1 (14.06) which was statistically at similar with T_2 while the lowest value was recorded from T_3 (13.32).



T_1: Biochar, T_2: Compost, T_3: Control

Figure 22. Effect of different organic fertilizers on number of grains in a row of maize.CV (%) 5.15 and LSD $_{(0.05)}$ 0.41

Number of grain in each row was recorded statistically significant due to different doses of nitrogen of maize (Figure 23). The highest value was recorded from N_3 (15.06) which was statistically at similar with N_2 while the lowest value was recorded from N_0 (12.33).



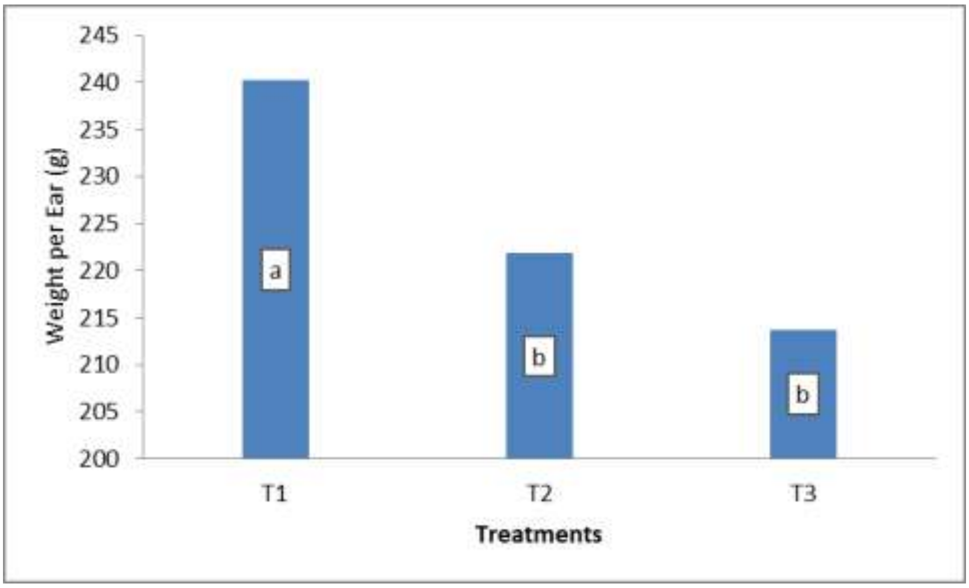
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 23. Effect of different nitrogen doses on Number of grains in a row of maize. CV (%) 4.17 and LSD $_{(0.05)}$ 0.66

Significant variation was observed on number of grain in each row due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) on maize (Table 6). The highest value was recorded from N_2T_1 (15.20) which was statistically at similar with N_3T_3, N_3T_2, N_3T_1 and N_2T_2 while the lowest value was recorded from N_0T_3 (12.26) which was statistically at similar with N_0T_1 and N_0T_2.

4.12 Weight per ear (g)

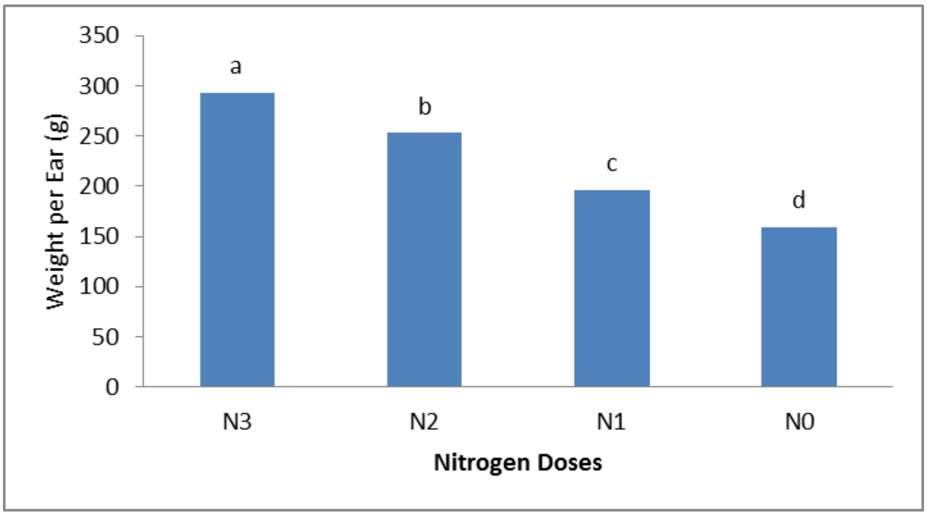
Significant variation was recorded on weight per ear due to different organic fertilizers (Akha biochar and compost) (Figure 24). The highest weight per ear was recorded from T_1 (240.19 g) while the lowest value was recorded from T_3 (213.76 g) which was statistically similar with T_2.



T_1: Biochar, T_2: Compost, T_3: Control

Figure 24. Effect of different organic fertilizers on weight per ear (g) of maize. CV (%) 10.65 and LSD $_{(0.05)}$ 20.97

Weight per ear was recorded statistically significant due to different doses of nitrogen on maize (Figure 25). The highest value was recorded from N_3 (293.45 g) while the lowest value was recorded from N_0 (159.04 g).



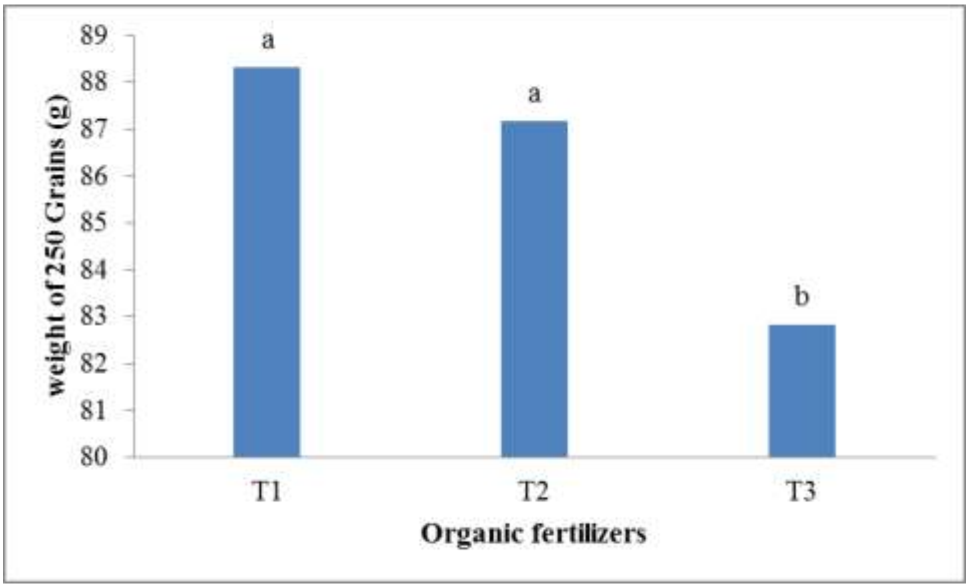
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 25. Effect of different nitrogen doses on weight per ear (g) of maize.
CV (%) 5.56 and LSD $_{(0.05)}$ 17.78

Significant variation was observed on weight per ear due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) on maize (Table 6). The highest value was recorded from N_3T_3 (304.71 g) which was statistically similar with N_3T_2, N_3T_1 and N_2T_1 while the lowest value was recorded from N_0T_3 (154.07 g) which was statistically at similar with N_0T_1 and N_0T_2.

5.13 Weight of 250 grains (g)

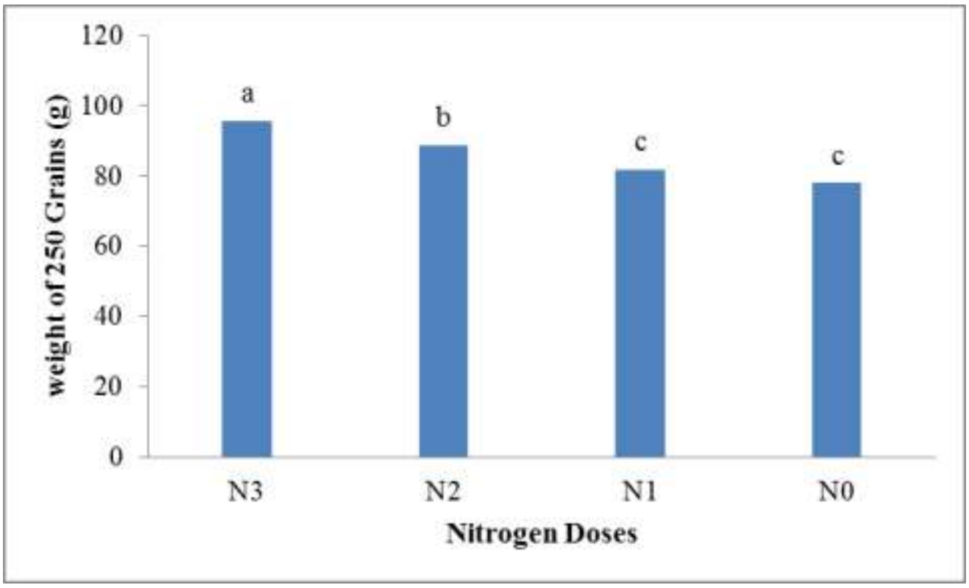
Weight of 250 grains due to different organic fertilizers (Akha biochar and compost) was significantly influenced (Figure 26). The highest value was recorded from T_1 (88.33 g) which was statistically at similar with T_2 while the lowest value was recorded from T_3 (82.83 g). Wacal *et al.* (2016) found that 1000-seed weight was all significantly influenced by biochar application.



T_1: Biochar, T_2: Compost, T_3: Control

Figure 26. Effect of different organic fertilizers on weight of 250 grains (g) of maize. CV (%) 2.63 and LSD $_{(0.05)}$ 2.82

Weight of 250 grains was recorded statistically significant due to different doses of nitrogen (Figure 26). The highest value was recorded from N_3 (95.77 g) while the lowest value was recorded from N_0 (78.02 g) which was statistically at similar with N_2. It was revealed that there was the increase of 250-grain weight with the increase in nitrogen application. Such effect of nitrogen was due to the fact that nitrogen was mainly responsible for increasing metabolic activities of maize plant (Ahmad *et al*. 2015).



N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 27. Effect of different nitrogen doses on weight of 250 grains (g) of maize. CV (%) 5.84 and LSD $_{(0.05)}$ 5.80

Significant variation was observed on weight of 250 grains due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) (Table 6). The highest value was recorded from N_3T_3 (96.47 g) which was statistically at similar with N_3T_2, N_2T_2, N_3T_1 and N_2T_1 while the lowest value was recorded from N_0T_3 (71.44 g). Application of organic fertilizers (biochar and compost) with different doses of nitrogen increases the nutrient and water availability for plant which increases the grain weight.

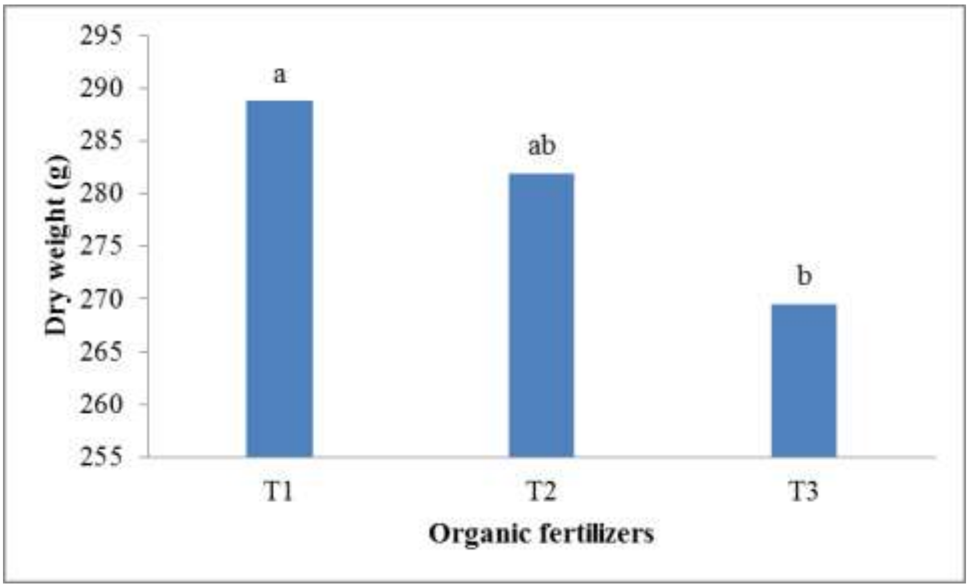
Table 6. Combine effect of different nitrogen doses and organic fertilizers on number of grain rows/cob, number of grains in a row, Weight per Ear (g) and weight of 250 Grains (g) of maize.

Treatment	**Number OF grain rows/cob**	**Number of grain in each row**	**Weight per Ear (g)**	**weight of 250 Grains (g)**
N_0T_1	23.53	12.33 c	163.33 e	81.75 b
N_0T_2	23.20	12.38 c	159.73 e	80.88 b
N_0T_3	22.53	12.26 c	154.07 e	71.44 c
N_IT_I	28.40	13.63 b	216.67 cd	82.76 b
N_IT_2	27.49	13.53 b	189.94 de	82.04 b
N_IT_3	26.67	12.37 c	181.00 de	81.03 b
N_2T_1	32.12	15.20 a	300.99 a	92.66 a
N_2T_2	32.04	14.67 a	241.83 bc	91.04 a
N_2T_3	28.23	13.53 b	215.24 cd	82.39 b
N_3T_1	33.02	15.06 a	279.77 ab	96.15 a
N_3T_2	32.26	15.00 a	295.87 a	94.71 a
N_3T_3	32.34	15.12 a	304.71 a	96.47 a
LSD (0.05)	NS	0.94	38.53	7.39
CV (%)	5.41	3.34	10.76	3.78

N_0: 0%, N_1: 50%, N_2: 75%, N_3: 100% Recommended dose of Nitrogen, T_1: Biochar, T_2: Compost and T_3: Control

4.14 Dry weight (g)

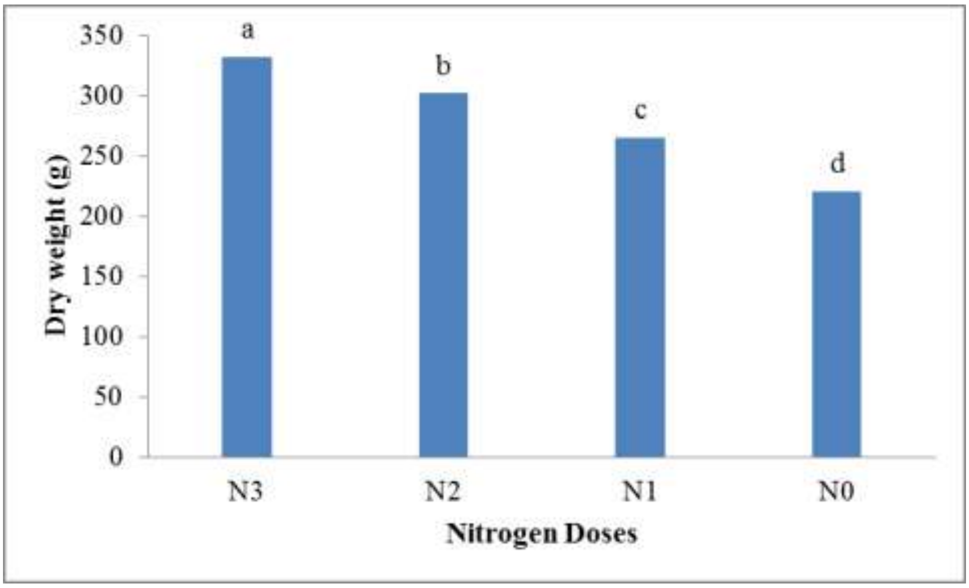
Significant variation was recorded on dry weight due to different level of treatments (Figure 28). The highest value was recorded from T_1 (288.76 g) which was statistically at similar with T_2 while the lowest value was recorded from T_3 (269.56 g). The effects of corncob biochar and compost applied in combined application and single application of biochar or compost additions increased the plant height, stem girth and dry matter yields (Jia *et al*. 2015).



T_1: Biochar, T_2: Compost, T_3: Control

Figure 28. Effect of different organic fertilizers on dry weight (g) of maize. CV (%) 4.62 and LSD $_{(0.05)}$ 14.89

Dry weight was recorded statistically significant due to different doses of nitrogen (Figure 29). The highest value was recorded from N_3 (332.18 g) while the lowest value was recorded from N_0 (220.83 g).



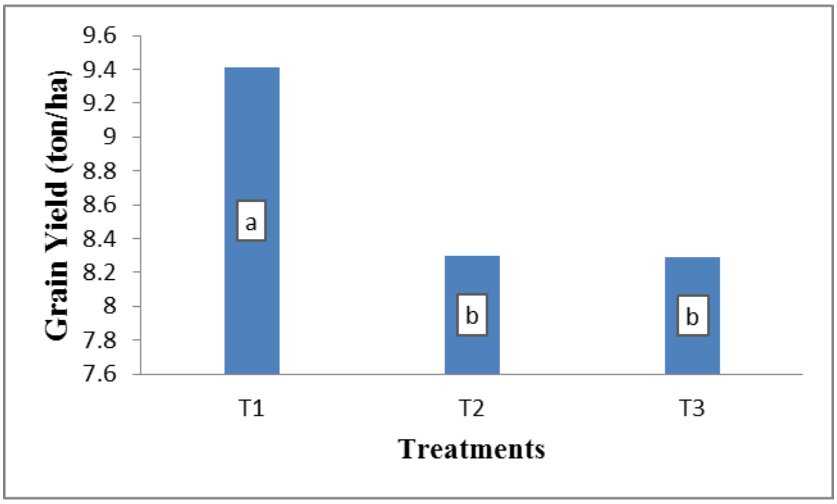
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 29. Effect of different nitrogen doses on dry weight (g) of maize. CV (%) 4.27 and LSD $_{(0.05)}$ 13.79

Non significant variation was observed on dry weight due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) (Table 7). The highest value was recorded from N_3T_3 (337.91 g) while the lowest value was recorded from N_0T_3 (214.59 g). Chan *et al.* (2007) found that dry matter of radish in a pot increased by up to 26.6% when N fertilizer was applied compared to a control with the same treatment but in the absence of biochar.

1.15 Grain yield (t ha^{-1})

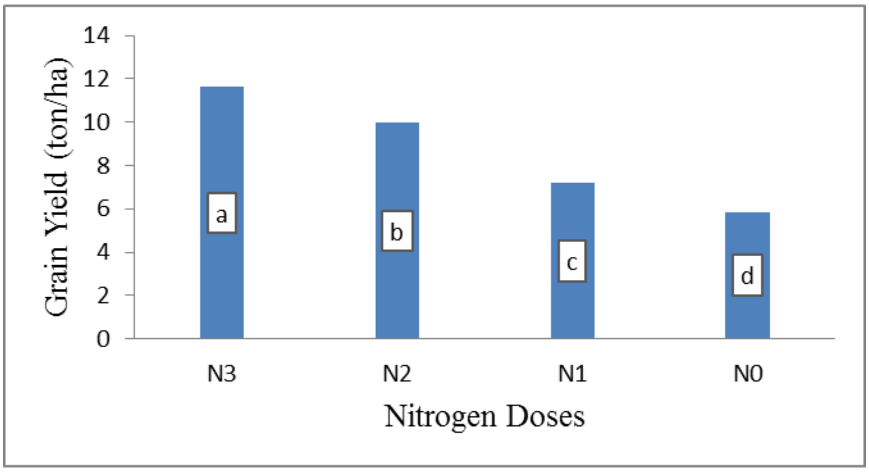
Significant variation was recorded in grain yield (t ha^{-1}) of maize for different organic fertilizers (Akha biochar and compost) (Figure 30). The highest grain yield (t ha^{-1}) was found in T_1 (9.41 ton/ha) while the lowest value was recorded from T_3 (8.29 ton/ha) which was statistically at similar with T_2. Yilangai *et al*. (2014) reported that application of biochar together with nitrogen fertilizer enhanced biochar effect on crop growth and yield. Major *et al*. (2010) showed that maize increased to about 140% during the fourth year of biochar application and this was attributed to increased pH and nutrient retention in soil.



T_1: Biochar, T_2: Compost, T_3: Control

Figure 30. Effect of different organic fertilizers on grain yield (t ha^{-1}) of maize. CV (%) 2.24 and LSD $_{(0.05)}$ 0.33

Grain yield (t ha^{-1}) was recorded statistically significant due to different doses of nitrogen (Figure 31). The highest value was recorded from N_3 (11.63 t ha^{-1}) while the lowest value was recorded from N_0 (5.87 ton/ha). It was revealed that there was the increase of grain yield with the increase in nitrogen application. Such effect of nitrogen was due to its role in photosynthesis, energy storage, cell division and cell enlargement and metabolic activities Lashari *et al*. 2015).



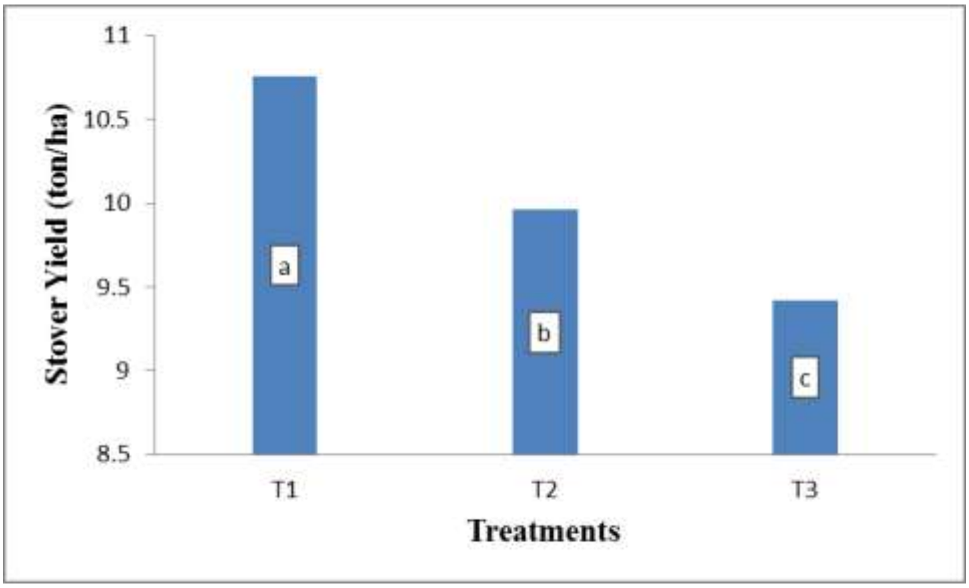
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 31. Effect of different nitrogen doses on grain weight (t ha^{-1}) of maize.
CV (%) 3.93 and LSD $_{(0.05)}$ 0.39

Significant variation was observed on grain yield (t ha^{-1}) due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) (Table 7). The highest value was recorded from N_3T_3 (12.54 t ha^{-1}) which was statistically at similar with N_2T_1 while the lowest value was recorded from N_0T_2 (5.65 t ha^{-1}) which was statistically at similar with N_0T_1 and N_0T_3. Yilangai *et al*. (2014) reported that application of biochar together with nitrogen fertilizer enhanced biochar effect on crop growth and yield. 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 top soil, xylem sap flow of the plant and response to N and NP chemical fertilizer treatments.

4.16 Stover yield (t ha^{-1})

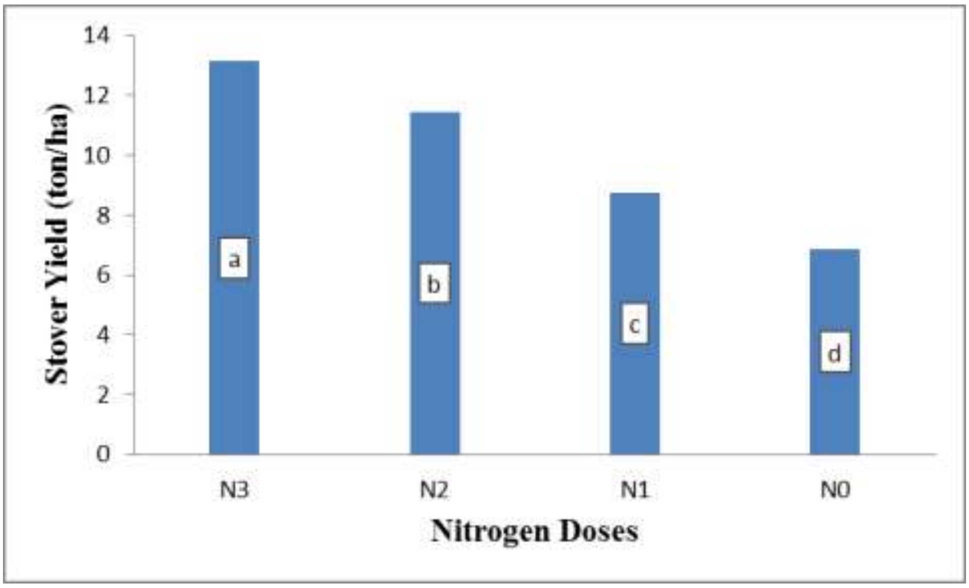
Significant variation was recorded in stover yield (t ha^{-1}) of Maize for different organic fertilizers (Akha biochar and compost) (Figure 32). The highest stover yield (t ha^{-1}) was found in T_1 (10.76 ton/ha) while the lowest value was recorded from T_3 (9.42 ton/ha). Biochar added nutrient to the soil and made the nutrient available for crops for which stover yield was increased.



T_1: Biochar, T_2: Compost, T_3: Control

Figure 32. Effect of different organic fertilizers on stover yield (t ha^{-1}) of maize. CV (%) 5.29 and LSD $_{(0.05)}$ 0.41

Stover yield (t ha^{-1}) was recorded statistically significant due to different doses of nitrogen (Figure 33). The highest value was recorded from N_3 (13.13 t ha^{-1}) while the lowest value was recorded from N_0 (6.85 t ha^{-1}). It was revealed that there was the increase of stover yield with the increase in nitrogen application. Such effect of nitrogen was due to its role in photosynthesis, energy storage, cell division and cell enlargement and metabolic activities (Uzoma *et al*. 2011).



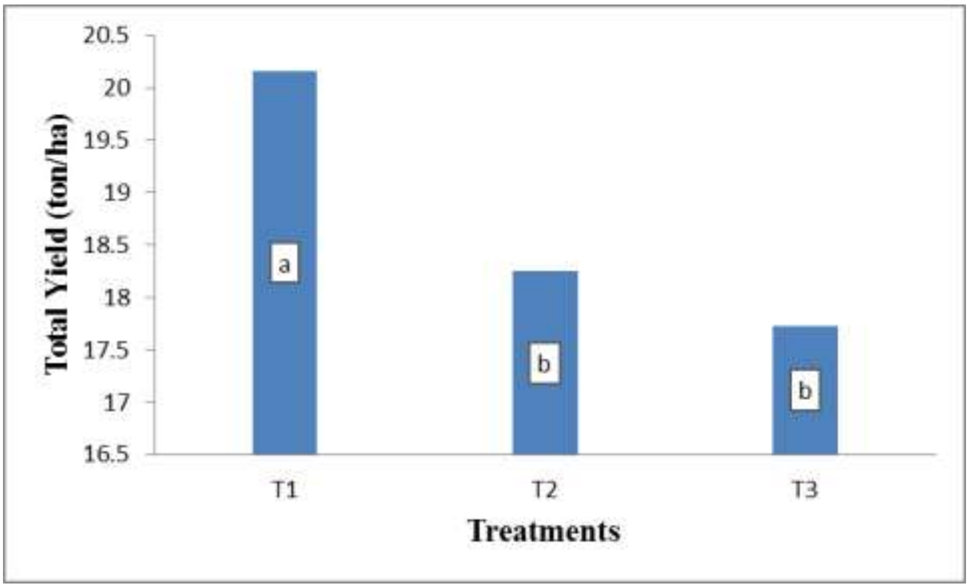
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 33. Effect of different nitrogen doses on stover yield (t ha^{-1}) of maize. CV (%) 3.45 and LSD $_{(0.05)}$ 0.39

Significant variation was observed on stover yield (t ha^{-1}) due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) (Table 7). The highest value was recorded from N_3T_1 (13.44 ton/ha) which was statistically at similar with N_3T_3, N_2T_1 and N_3T_2 while the lowest value was recorded from N_0T_3 (6.59 ton/ha) which was statistically at similar with N_0T_1 and N_0T_2. Sole fertilizer and biochar application increased stover yield of maize but in combination of biochar and nitrogen doses the result was significantly higher because in combination availability of the nutrient was higher which helped to increase the amount stover yield (Asai *et al.* 2009).

4.17 Total yield (t ha^{-1})

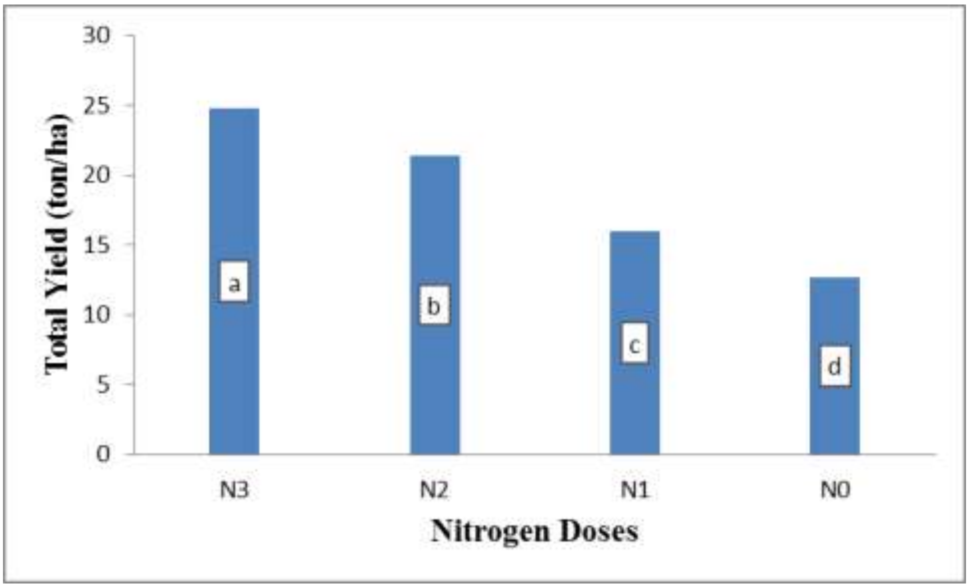
Significant variation was recorded in total yield (t ha^{-1}) of maize for different organic fertilizers (Akha biochar and compost) (Figure 34). The highest total yield (t ha^{-1}) was found in T_1 (20.16 ton/ha) while the lowest value was recorded from T_3 (17.73 ton/ha) which was statistically at similar with T_2. The application of 68 t C ha^{-1} increased rice biomass by 17 per cent while the presence of 135t C ha^{-1} of biochar enhanced the growth by 43 per cent (Glaser *et al*., 2001; Lehmann *et al*., 2003).



T_1: Biochar, T_2: Compost, T_3: Control

Figure 34. Effect of different organic fertilizers on total yield (t ha^{-1}) of maize. CV (%) 2.45 and LSD $_{(0.05)}$ 0.53

Total yield (t ha^{-1}) was recorded statistically significant due to different doses of nitrogen (Figure 35). The highest value was recorded from N_3 (24.76 t ha^{-1}) while the lowest value was recorded from N_0 (12.72 t ha^{-1}).



N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 35. Effect of different nitrogen doses on total yield (t ha^{-1}) of maize.
CV (%) 0.86 and LSD $_{(0.05)}$ 0.18

Significant variation was observed on total yield (t ha^{-1}) due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) (Table 7). The highest value was recorded from N_3T_3 (25.83 t ha^{-1}) which was statistically at similar with N_3T_1 and N_2T_1 while the lowest value was recorded from N_0T_3 (12.32 t ha^{-1}) which was statistically at similar with N_0T_1 and N_0T_2. The application of 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).

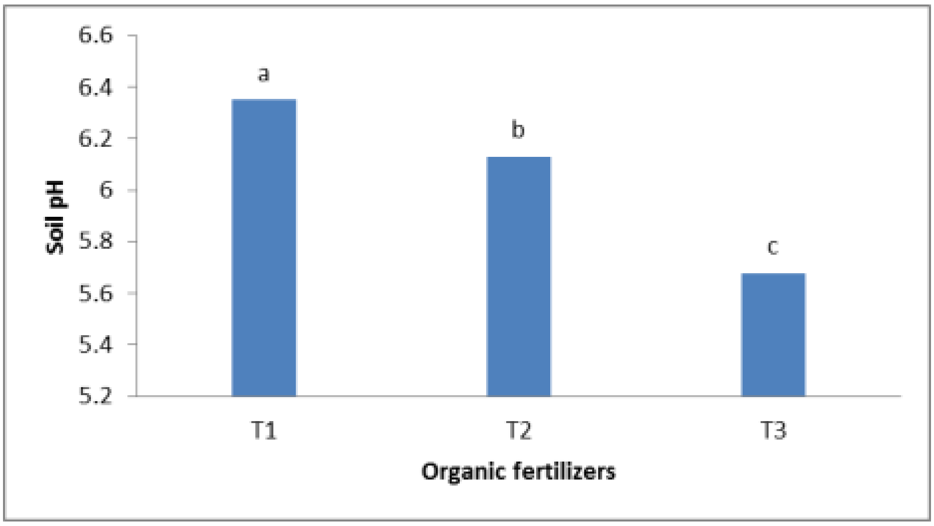
Table 7. Combine effect of different nitrogen doses and organic fertilizers on dry weight, grain yield, Stover yield and total yield of maize.

Treatment	Dry weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Total yield (t ha^{-1})
N_0T_1	225.14	6.23 gh	6.83 ef	13.06 h
N_0T_2	222.75	5.65 h	7.13 f	12.78 h
N_0T_3	214.59	5.74 h	6.59 f	12.32 h
N_IT_I	270.01	7.78 de	9.55 cd	17.33 e
N_IT_2	268.27	7.24 ef	8.85 d	16.09 f
N_IT_3	257.81	6.60 fg	7.88 e	14.48 g
N_2T_1	321.97	12.28 a	13.22 a	25.49 a
N_2T_2	312.20	9.28 c	11.20 b	20.48 c
N_2T_3	271.72	8.34 d	9.93 c	18.27 d
N_3T_1	337.91	11.34 b	13.44 a	24.77 a
N_3T_2	324.53	11.01 b	12.66 a	23.67 b
N_3T_3	334.11	12.54 a	13.29 a	25.83 a
LSD $_{(0.05)}$	NS	0.67	0.8363	0.89
CV (%)	9.73	4.45	4.81	3.30

N_0: 0%, N_1: 50%, N_2: 75%, N_3: 100% Recommended dose of Nitrogen, T_1: Biochar, T_2: Compost and T_3: Control

4.18 Soil pH

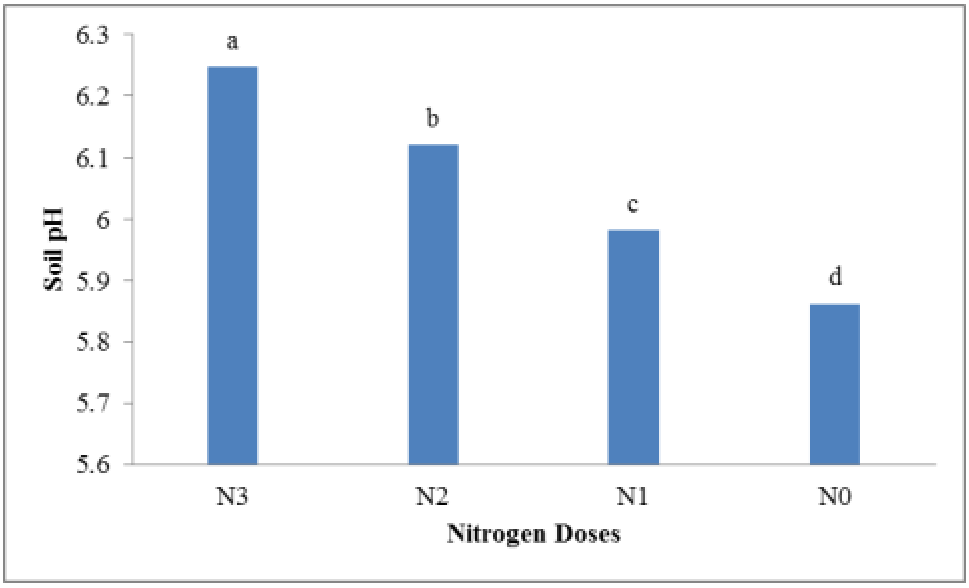
Significant variation was recorded in Soil pH of maize for different organic fertilizers (Akha biochar and compost) (Figure 36). The highest soil pH was found in T_1 (6.3508) which was Akha biochar while the lowest value was recorded from T_3 (5.6767). Nutrient availability can be affected by increasing cation exchange capacity, altering soil pH, or direct nutrient contributions from biochar (Lehmann *et al*., 2003). Therefore the application of biochar is expected to enhance soil properties in terms of increasing or maintaining the pH of the soils (Rondon *et al*., 2007), toxin neutralization (Wardle *et al*., 1998), and reduce soil strength (Chan *et al*., 2007).



T_1: Biochar, T_2: Compost, T_3: Control

Figure 36. Effect of different organic fertilizers on soil pH of soil after harvest.
CV (%) 1.16 and LSD $_{(0.05)}$ 0.039

Soil pH was recorded statistically significant due to different doses of nitrogen (Figure 37). The highest value was recorded from N_3 (6.2467) while the lowest value was recorded from N_0 (5.8622).



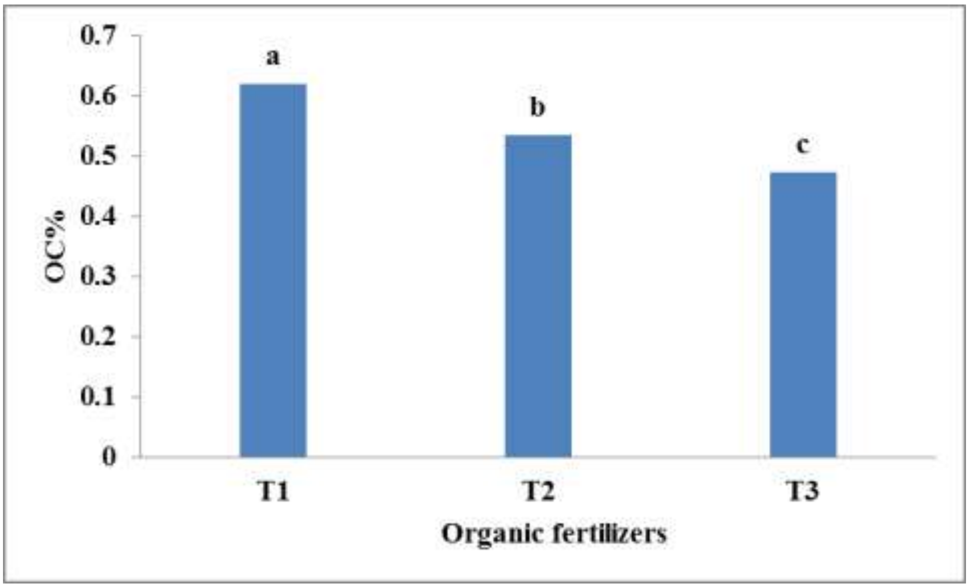
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 37. Effect of different nitrogen doses on soil pH of soil after harvest. CV (%) 0.49 and LSD $_{(0.05)}$ 0.03

Significant variation was observed on soil pH due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) (Table 8). The highest highest value was recorded from N_3T_1 (6.49) while the lowest value was recorded from N_0T_3 (5.34).

4.19 Soil organic carbon (%)

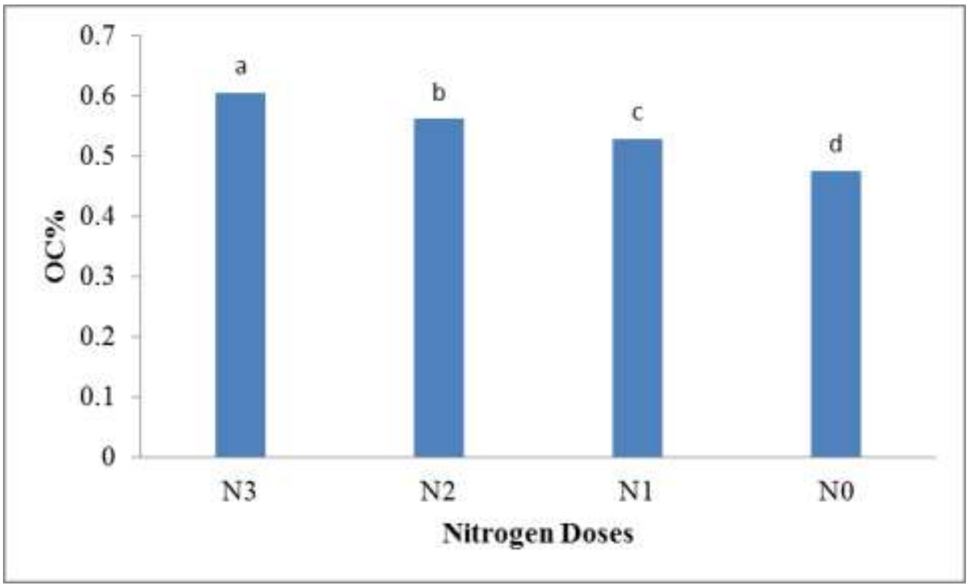
Significant variation was recorded in Soil organic carbon of maize for different organic fertilizers (Akha biochar and compost) (Figure 38). The highest soil organic carbon was found in T_1 (0.6192%) which is Akha biochar while the lowest value was recorded from T_3 (0.4725%). Biochar and compost applied alone or in combination significantly increased soil pH, the total organic carbon, available phosphorus, mineral nitrogen, reduced exchangeable acidity and increased effective cation exchange capacity in soil (Mensah and Frimpong, 2018).



T_1: Biochar, T_2: Compost, T_3: Control

Figure 38. Effect of different organic fertilizers on percentage of organic carbon (OC %) of soil after harvest.CV (%) 5.36 and LSD $_{(0.05)}$ 0.018

Soil organic carbon was recorded statistically significant due to different doses of nitrogen (Figure 39). The highest value was recorded from N_3 (0.6044%) while the lowest value was recorded from N_0 (0.4756%). Quilliam *et al.*, (2012) conducted a three-year field experiment, there was no difference between biochar added and not-added soil but reapplication of biochar after three years significantly increased available P, exchangeable K and calcium, soil moisture, dissolved organic carbon and electrical conductivity. Chemical fertilizers promote biomass production, consequently a higher amount of plant residues, roots and also root exudates which contribute to the soil organic matter pool.



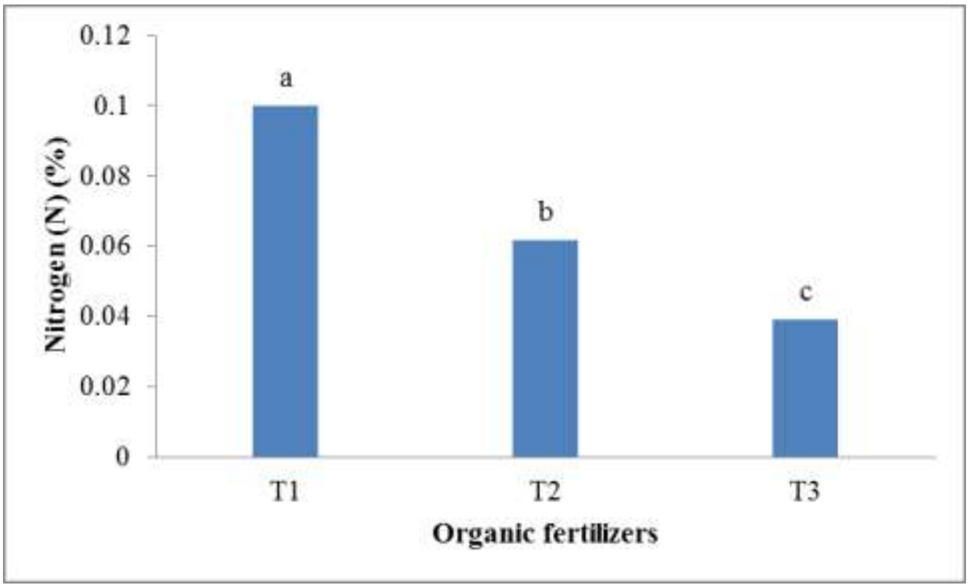
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 39. Effect of different nitrogen doses on Percentage of organic carbon (OC %) of soil after harvest. CV (%) 5.39 and LSD $_{(0.05)}$ 0.033

Significant variation was observed on soil organic carbon due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) (Table 8). The highest value was recorded from N_3T_1 (0.70%) which is statistically similar with N_2T_1 while the lowest value was recorded from N_0T_3 (0.42%). Soil organic carbon was increased with the increasing amount of nitrogen with organic fertilizers (biochar and compost) because they promoted biomass production, consequently a higher amount of plant residues, roots and also root exudates which contribute to the soil organic matter (Diacono and Montemurro, 2011).

4.20 Total nitrogen (%)

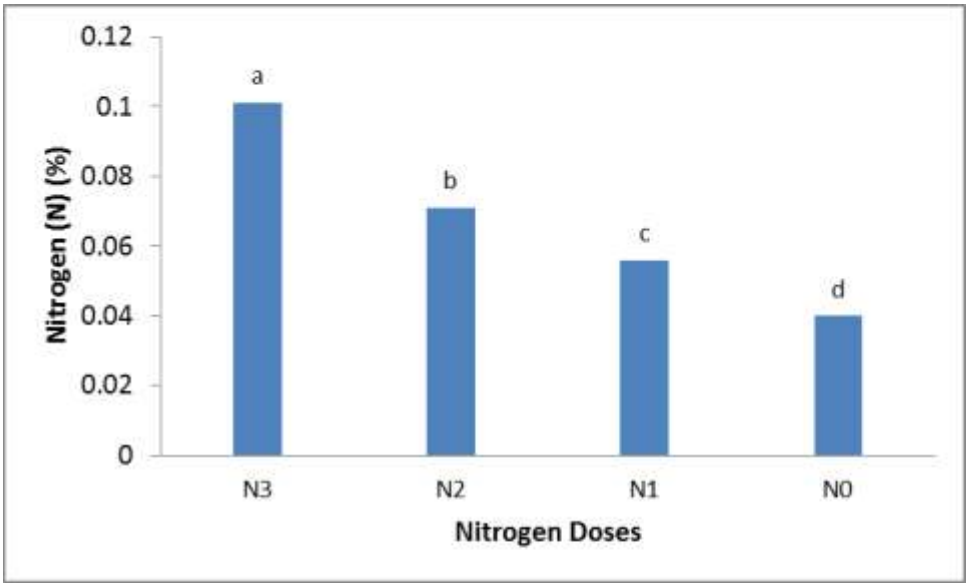
Significant variation was recorded in total nitrogen (%) of maize for different treatments (Figure 40). The highest total nitrogen (%) was found in T_1 (0.1001%) which is Akha biochar while the lowest value was recorded from T_3 (0.0392%). Ali *et al.,* (2015) studied on wheat that application of biochar significantly increased soil total N and soil mineral N by 63 and 40% respectively.



T_1: Biochar, T_2: Compost, T_3: Control

Figure 40. Effect of different organic fertilizers on total nitrogen (%) of soil after harvest.CV (%) 5.50 and LSD $_{(0.05)}$ 0.002

Total nitrogen (%) was recorded statistically significant due to different doses of nitrogen (Figure 41). The highest value was recorded from N_3 (0.1011%) while the lowest value was recorded from N_0 (0.0399%).



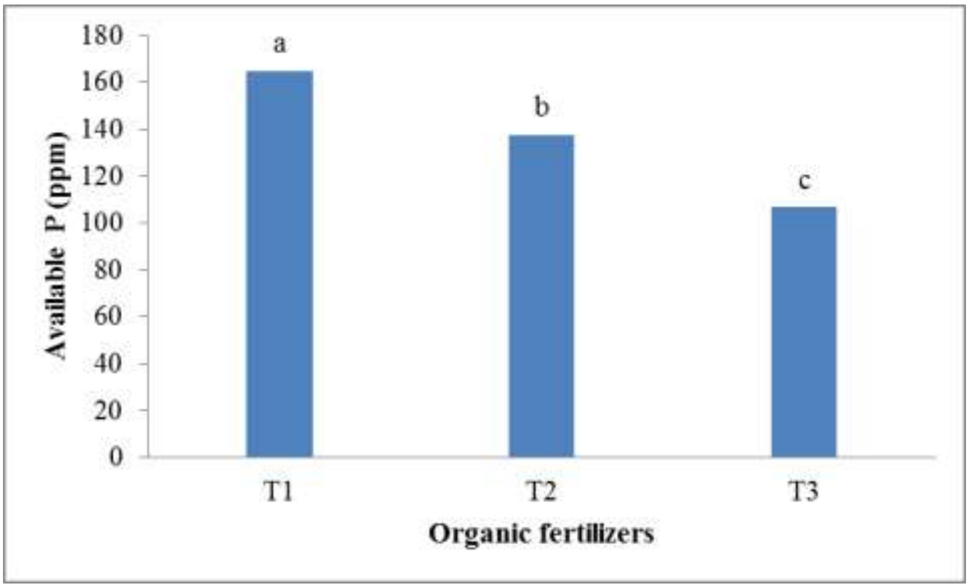
N_0: 0%, N_1: 50%, N_2: 75%, N_3: 100% Recommended dose of Nitrogen

Figure 41. Effect of different nitrogen doses on total nitrogen (%) of soil after harvest. CV (%) 3.5 and LSD $_{(0.05)}$ 0.002

Significant variation was observed on total nitrogen (%) due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) (Table 8). The highest value was recorded from N_3T_1 (0.1427%) while the lowest value was recorded from N_0T_3 (0.0308%). Biochar with different doses of nitrogen helped bacteria to perform nitrogen cycle which the amount of nitrogen was increased (Diacono and Montemurro, 2011).

4.21 Available phosphorus (ppm)

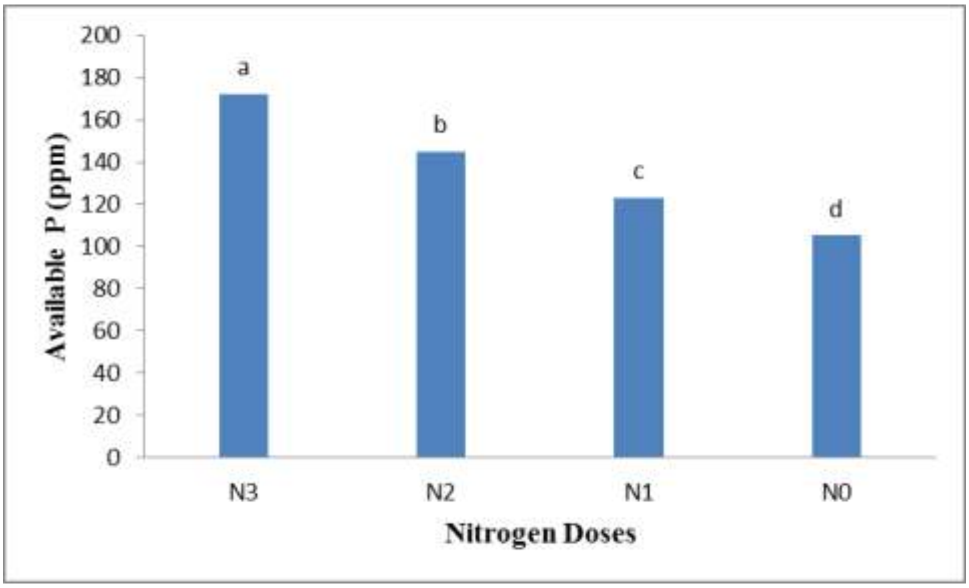
Significant variation was recorded in available phosphorus (ppm) of maize for different organic fertilizers (Akha biochar and compost) (Figure 42). The highest available phosphorus (ppm) was found in T_1 (164.87 ppm) which is Akha biochar while the lowest value was recorded from T_3 (106.61 ppm). The effects of corncob biochar and compost applied alone (at a rate of 2%, w/w) or in combination and found that Biochar and compost applied alone or in combination significantly increased soil pH, the total organic carbon, available phosphorus and increased effective cation exchange capacity (Mensah and Frimpong, 2018).



T_1: Biochar, T_2: Compost, T_3: Control

Figure 42. Effect of different organic fertilizers on available phosphorus (ppm) of soil after harvest. CV (%) 5.52 and LSD $_{(0.05)}$ 3.95

Available phosphorus (ppm) was recorded statistically significant due to different doses of nitrogen (Figure 43). The highest value was recorded from N_3 (172.01 ppm) while the lowest value was recorded from N_0 (105.25 ppm).



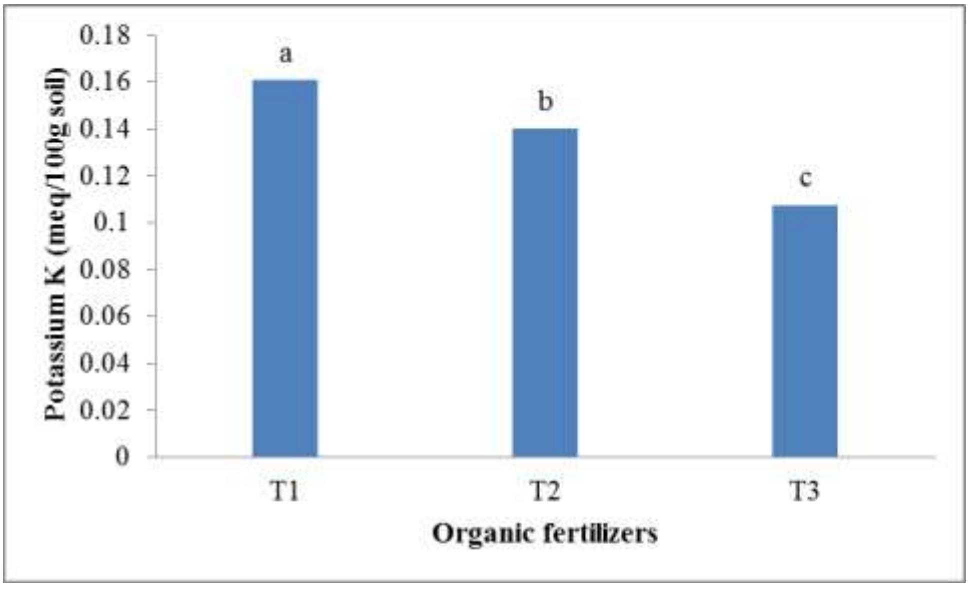
N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 43. Effect of nitrogen doses on available phosphorus (ppm) of soil after harvest. CV (%) 2.89 and LSD $_{(0.05)}$ 4.54

Significant variation was observed on available phosphorus (ppm) due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) (Table 8). The highest value was recorded from N_3T_1 (202.15 ppm) which was statistically similar with N_2T_1 while the lowest value was recorded from N_0T_3 (95.29 ppm). Biochar as reported by Jia *et al.* (2015) can absorb leachate which can help to absorb organic matter, total soluble N, plant available P and K, thereby increasing the nutrient retention capacity of the soil. For that application of biochar with different nitrogen doses helped to increase the amount of phosphorus.

4.22 Exchangeable potassium (meq 100g^{-1})

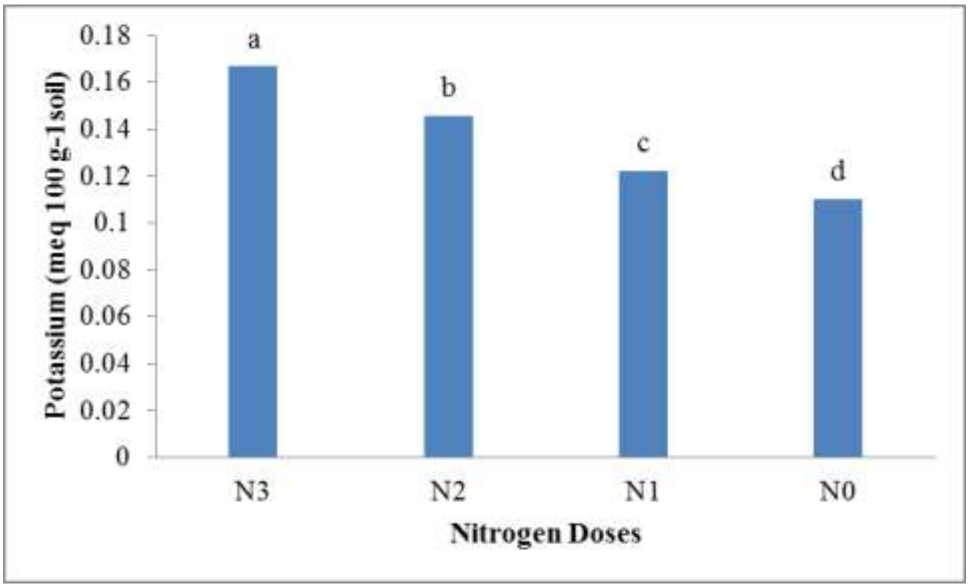
Significant variation was recorded in exchangeable K (meq 100g^{-1}) of maize for different organic fertilizers (Akha biochar and compost) (Figure 44). The highest exchangeable K (meq 100g^{-1}) was found in T_1 (0.1608 meq 100g^{-1}) which is Akha biochar while the lowest value was recorded from T_3 (0.1075 meq 100g^{-1}). Quilliam *et al.* (2012) reported that biochar significantly increased available P, exchangeable K and calcium, soil moisture, dissolved organic carbon and electrical conductivity.



T_1: Biochar, T_2: Compost, T_3: Control

Figure 44. Effect of different organic fertilizers on exchangeable potassium (K) of soil after harvest. CV (%) 8.57 and LSD $_{(0.05)}$ 0.0066

Exchangeable K (meq 100g^{-1}) was recorded statistically significant due to different doses of nitrogen (Figure 45). The highest value was recorded from N_3 (0.1667 meq 100g^{-1}) while the lowest value was recorded from N_0 (0.1100 meq 100g^{-1}).



N_0: 0%, N_1: 50%, N_2: 75% and N_3: 100% Recommended dose of Nitrogen

Figure 45. Effect of different nitrogen doses on soil exchangeable potassium (K) of soil after harvest. CV (%) 4.64 and LSD $_{(0.05)}$ 0.0072

Non significant variation was observed on exchangeable K (meq $100g^{-1}$) due to combined effect of different doses of nitrogen and organic fertilizers (Akha biochar and compost) (Table 8). The highest value was recorded from N_3T_1 (0.1933 meq $100g^{-1}$) while the lowest value was recorded from N_0T_3 (0.0900 meq $100g^{-1}$). Biochar as reported by Jia *et al.* (2015) can absorb leachate which can help to absorb organic matter, total soluble N, plant available P and K, thereby increasing the nutrient retention capacity of the soil. For that application of biochar with different nitrogen doses helped to increase the amount of potassium.

Table 8. Combine effect of different organic fertilizers and nitrogen doses on soil pH, OC%, total N (%), available P and exchangeable K of soil after harvest.

Treatment	pH	OC%	Total N (%)	Available P (ppm)	Exchangeable K (meq 100g-1)
N_0T_1	6.23 c	0.55 bc	0.0570 d	121.42 d	0.1300
N_0T_2	6.02 de	0.45 de	0.0320 f	99.02 f	0.1100
N_0T_3	5.34 h	0.42 e	0.0308 f	95.29 f	0.0900
N_IT_I	6.32 b	0.59 b	0.0860 c	146.21 c	0.1500
N_IT_2	6.09 d	0.53 c	0.0457 e	124.93 d	0.1233
N_IT_3	5.54 g	0.47 de	0.0363 f	98.65 f	0.0933
N_2T_1	6.36 b	0.65 a	0.1147 b	198.35 a	0.1700
N_2T_2	6.18 c	0.57 bc	0.0563 d	148.20 c	0.1533
N_2T_3	5.82 f	0.47 d	0.0423 e	109.63 e	0.1133
N_3T_1	6.49 a	0.70 a	0.1427 a	202.15 a	0.1933
N_3T_2	6.24 c	0.59 b	0.1133 b	177.98 b	0.1733
N_3T_3	6.01 e	0.53 c	0.0473 e	122.86 d	0.1333
LSD (0.05)	0.0734	0.0448	0.00546	7.8744	NS
CV (%)	0.76	3.87	4.99	3.35	5.68

N_0: 0%, N_1: 50%, N_2: 75%, N_3: 100% Recommended dose of Nitrogen, T_1: Biochar, T_2: Compost and T_3: Control

CHAPTER V

SUMMARY, CONCLUSION AND ROCOMMENDATION

SUMMARY

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the Robi season from October 2018 to April 2019 to study the integrated effect of nitrogen and akha biochar on soil properties and production of maize. The experiment was laid out in two factors split plot design with three replications. The experiment comprised of two factors, factor a: T_1= Akha Biochar, T_2= Compost, T_3= Control and Factor B: Different Nitrogen doses i.e. N_0= 0% recommended doses of Nitrogen, N_1 = 50% recommended doses of Nitrogen, N_2 = 75% recommended doses of Nitrogen**,** N_3 = 100% Recommended doses of Nitrogen. There were 36 unit plots and the size of the plot was 2m × 2.5m i.e. 5m^2. There were 12 treatments combination. Maize seed of SAU HYBRIED VUTTA 1 was sown as planting material. Data on different plant growth, yield and yield contributing parameters were recorded and analyzed statistically.

Application of different organic fertilizers (Akha biochar and compost) had statistically significant effect on different parameters of maize. The highest plant height (140.77 and 204.94 cm at 60 and 90 DAS, respectively), length of cob (21.60 cm), diameter of cob (15.11 cm), number of grain rows/cob (29.27), number of grains in a row (14.06), weight per ear (240.19 g), weight of 250 grains (88.33 g), dry weight (288.76 g), grain yield (9.41 ton/ha), stover yield (10.76 ton/ha) and total yield (20.16 ton/ha) was recorded in T_1 (Akha Biochar) treatment. The lowest plant height (132.59 and 194.00 cm at 60 and 90 DAS, respectively), length of cob (19.95 cm), diameter of cob (13.97 cm), number of grain rows/cob (27.44), number of grains in a row (13.32), weight per ear (213.76 g), weight of 250 grains (82.83 g), dry weight (269.56 g), grain yield (8.29 ton/ha), stover yield (9.42 ton/ha) and total yield (17.73 ton/ha) was recorded in T_3 (control).

Effect of different levels of nitrogen had statistically significant influence on different parameters of maize. The highest plant height (68.14, 159.85 and 235.83 cm at 30, 60 and 90 DAS, respectively), number of leaf (6.29, 12.98 and 14.58 at 30, 60 and 90 DAS, respectively), leaf area index (0.74, 3.56 and 4.48 at 30, 60 and 90 DAS, respectively), length of cob (23.83 cm), diameter of cob (15.82 cm), number of grain rows/cob (32.54), number of grains in a row (15.06), weight per ear (293.45 g), weight of 250 grains (95.77 g), dry weight (332.18 g), grain yield (11.63 ton/ha), stover yield (13.13 ton/ha) and total yield (24.76 ton/ha) was recorded in N_3 (100% recommended doses of Nitrogen) treatment. The lowest plant height (32.77, 110.44 and 162.44 cm at 30, 60 and 90 DAS, respectively), number of leaf (5.70, 7.07 and 9.39 at 30, 60 and 90 DAS, respectively), leaf area index (0.28, 1.27 and 1.87 at 30, 60 and 90 DAS, respectively), length of cob (18.03 cm), diameter of cob (13.09 cm), number of grain rows/cob (23.09), number of grains in a row (12.33), weight per ear (159.04 g), weight of 250 grains (78.02 g), dry weight (220.83 g), grain yield (5.87 ton/ha), stover yield (6.85 ton/ha) and total yield (12.72 ton/ha) was recorded in N_0 (control).

Combine effect of different levels of nitrogen and organic fertilizers (Akha biochar and compost) had statistically significant influence on different parameters of maize. The highest plant height (70.59, 161.68 and 240.65 cm at 30, 60 and 90 DAS, respectively), diameter of cob (15.99 cm), number of grain rows/cob (32.34), weight per ear (304.71 g), weight of 250 grains (96.47 g), grain yield (12.54 ton/ha) and total yield (25.83 ton/ha) was recorded in N_3T_3 treatment which was statistically similar to N_3T_1, N_2T_1 and N_3T_2. The lowest plant height (29.65, 107.26 and 160.45 cm at 30, 60 and 90 DAS, respectively), diameter of cob (12.23 cm), number of grain rows/cob (22.53), weight per ear (154.07 g), weight of 250 grains (71.44 g), grain yield (5.74 ton/ha) and total yield (12.32 ton/ha) was recorded in N_0 T_3 treatment.

Application of organic fertilizers (Akha biochar and compost) had statistically significant effect on soil pH, OC%, total N (%), Available P and exchangeable K of post-harvest soil. The highest soil pH (6.35), OC (0.6233%), total N (0.1001%), Available P (167.06 ppm) and exchangeable K (0.1608 meq $100g^{-1}$) was observed in T_1. The lowest soil pH (5.67), OC (0.4725%), total N (0.0392%), Available P (106.61 ppm) and exchangeable K (0.1075 meq $100g^{-1}$) was observed in T_3.

Effect of different levels of nitrogen doses had statistically significant impact on soil pH, OC%, total N (%), Available P and exchangeable K of post-harvest soil. The highest soil pH (6.24), OC (0.6044%), total N (0.1011%), Available P (167.06 ppm) and exchangeable K (0.1667 meq $100g^{-1}$) was observed in N_3. The lowest soil pH (5.86), OC (0.4756%), total N (0.0399%), Available P (105.25 ppm) and exchangeable K (0.1100 meq $100g^{-1}$) was observed in N_0.

Combine effect of different levels of nitrogen and organic fertilizers (Akha biochar and compost) had statistically significant influence on soil pH, OC%, total N (%), Available P and exchangeable K of post-harvest soil. The highest soil pH (6.49), OC (0.70%), total N (0.1427%), Available P (202.15 ppm) and exchangeable K (0.1933 meq $100g^{-1}$) was recorded in N_3T_1 from which OC (0.65 %) and Available P (198.35 ppm) were statistically similar with N_2T_1. The lowest soil pH (5.34), OC (0.42%), total N (0.0308%), Available P (95.29 ppm) and exchangeable K (0.09 meq $100g^{-1}$) was recorded in N_0T_3.

CONCLUSION

From the above information it may be concluded that

1. 100% recommended doses of nitrogen showed the better performance on growth and yield contributing characters of maize which was statistically similar to 75% recommended doses of nitrogen combine with Akha biochar.
2. For post-harvest soil properties Akha biochar combine with 100% and 75% recommended doses of nitrogen showed the better performance.

So, considering the above observation 75% recommended doses of nitrogen combine with Akha biochar may be possible to use in replacing chemical fertilizer which will reduce production cost without significant yield reduction and also improve soil properties.

RECOMMENDATION

1. Such study is needed in different conditions to find out the effect of biochar on those condition.
2. Another experiment may be carried out with different types of biochar for specific biochar effect.
3. Long duration experimentation with biochar is suggested to know its residual values and also to find out the nutrient composition of biochar derived from different sources of organic manures.
4. It is needed to study the effect of biochar on water holding capacity and other soil properties.

REFERENCES

Ahmad, M., Akbar, H., Jan, M. T., Khattak, M. J. K. and Bari, A. (2015). Effect of seeding depth, nitrogen placement method and biochar on the growth, yield and its related parameters of sugar beet. *Sarhad J. Agri*. **31**(4): 224-231.

AIS (Agriculture Information Service) (2017) Krishi Diary (In Bangla). Agriculture Information Service. Ministry of Agriculture, Government of the Peoples Republic of Bangladesh, Khamarbari, Dhaka-1215. p. 18.

Alburquerque, J. A., Calero, J. M., Barrón, V., Torrent, J., del Campillo, M. C., Gallardo, A and Villar, R., 2014, 'Effects of biochars produced from different feedstocks on soil properties and sunflower growth', *J. Plant Nut. Soil Sci.*, **177** (1): Pp. 16-25.

Ali, K., Arif, M., Jan, M. T., Khan, M. J. and Jones, D. L. (2015). Integrated use of biochar: A tool for improving soil and wheat quality of degraded soil under wheat-maize cropping pattern. *Pak. J. Bot*., **47**(1): 233-240.

AlWabel, M. I., Hussain, Q., Adel, R. A., Mahtab, U., Adel, A., Abdulazeem, A., Sallam, S. and Ok, Y. S. (2017). Impact of biochar properties on soil conditions and agricultural sustainability: A review. Land degradation and Development.

Amonette, J. E. and Joseph, S. (2009). Characteristics of biochar: microchemical properties. Chapter 3. In: Lehmann, J. and Joseph, S. (Eds.), Biochar for Environmental Management – Science and Technology, Earthscan, London: 33 – 52.

Amonette, J. E. and Joseph, S. (2009). Characteristics of Biochar: microchemical properties, in: Johannes, L., Joseph, S. (Eds.), Biochar for environmental management - Science and Technology. Earthscan publisher, UK and USA.

Anonymous. (1989). Annual Weather Report, meteorological Station, Dhaka. Bangladesh.

Anthony, A. O. (2014). Physical features of some selected Nigerian maize cultivars. *American J. Plant Sci.,* **5**(09): 1352-1358.

Asai, H., Samson, B. K., Stephan, H. M., Songyikhangsuthor, K., Homma, K., Kiyono, Y., Inoue, Y., Shiraiwa, T and Horie, T. (2009). 'Biochar amendment techniques for upland rice production in Northern Laos: 1. Soil physical properties, leaf SPAD and grain yield', Field Crops Research, **111**(1-2): Pp. 81-4.

Baldock, J. A. and Smernik, R. J. (2002). Chemical composition and bioavailability of thermally altered Pinus restnosa (red pine) wood. *Organic Geochem*. **33**: 1093-1109.

BBI (Bangladesh Biochar Initiative). (2015). Sponsored by the Christian Commission for Development in Bangladesh.

Brandstaka, T., Helenius, J., Hovi, J., Kivelä, J., Koppelmäki, K., Simojoki, A., Soinne, H. and Tammeorg, P. (2010). Biochar filter: use of biochar in agriculture as soil conditioner, University of Helsinki, Helsinki, Finland.

Bruun, E. W., Ambus, P., Egsgaard, H. and Hauggaard-Nielsen, H. (2012). 'Effects of slow and fast pyrolysis biochar on soil C and N turnover dynamics', *Soil Biol. Biochem.,* **46**: Pp. 73-9.

Bukhsh, M., Ahmad, R., Iqbal, J., Hussain. S., Rehman. A. and Ishaque, M. (2011). Potassium application reduces bareness in different maize hybrids under crowding stress conditions. *Pakistan J. Agric. Sci*. **48**(1): 41-48.

Carter, S., Shackley, S., Sohi, S., Suy, T. B. and Haefele, S. (2013). 'The impact of biochar application on soil properties and plant growth of pot grown lettuce (*Lactuca sativa*) and cabbage (*Brassica chinensis*)', *Agron.*, **3**(2): Pp. 404-18.

Chan, K. Y., Van Zwieten, L., Meszaros, I., Downie, A. and Joseph, S. (2007). Agronomic values of greenwaste biochar as a soil amendment. *Australian J. Soil Res.* **45**: 629-634.

Chan, K., Dorahy, C. and Tyler, S. (2007). 'Determining the agronomic value of composts produced from garden organics from metropolitan areas of New South Wales, Australia', *Australian J. Exp. Agril.*, **47**(11): p. 1377.

Chan, K. Y. and Xu, Z. (2009). Biochar: Nutrient properties and their enhancement. In Biochar for environmental management: science and technology. Eds. J Lehmann and S Joseph. Pp 67-84.

Chintala, R., Mollinedo, J., Schumacher, T. E., Douglas, D., Malo, D. D. and Julson, J. L. (2013). Effect of biochar on chemical properties of acidic soil. *Archives of Agronomy and Soil Science*, **60** (3):393-404.

Curnoe, W. E.., Irving, D. C., Dow, C. B., Velema, G. and Une, A. (2006). Effect of spring application of a paper mill soil conditioner on corn yield. *Agron. J.* **98**: 423-429.

Dai, Z., Wang, Y., Muhammad, N., Yu, X., Xiao, K., Meng, J., Liu, X., Xu, J. and Brookes, P. C. (2013). The Effects and Mechanisms of Soil Acidity Changes, following Incorporation of Biochars in Three Soils Differing in Initial pH. *Soil Sci. Soc. America J.*

Day, D., Evans, R. J., Lee, J. W. and Reicosky, D. (2004). 'Valuable and stable carbon co-product from fossil fuel exhaust scrubbing', *American Chem. Soc*, **49**(1): p. 352.

DeLuca, T. H., MacKenzie, M. D. and Gundale, M. J. (2009). ‘Biochar effects on soil nutrient transformations’, in Lehmann, J. and Joseph, S. Biochar for environmental management: science and technology, Earthscan, United Kingdom: 251–70.

Diacono, M. and Montemurro, F. (2011). “Long-term effects of organic amendments on soil fertility,” *J. Sustainable Agric*. **2**; Pp. 761–786.

Downie, A. E., Van Zwieten, L., Smernik, R. J., Morris, S. and Munroe, P. R. (2011). Terra Preta Australis: Reassessing the carbon storage capacity of temperate soils. Agriculture,Ecosystems and Environment.

Downie, A., Crosky, A. and Munroe, P. (2009). ‘Physical properties of biochar’, in Lehmann, J and Joseph, S, Biochar for environmental management: science and technology, Earthscan, United Kingdom: 13–32.

Downie, A., Crosky, A. and Munroe, P. (2009). Physical Properties of Biochar, in: Lehmann, J., Joseph, S. (Eds.), Biochar for environmental management – Science and Technology. Earthscan publisher, UK and USA.

Edris, K. M., Islam, A. M. T., Chowdhury, M. S. and Haque, A. K. M. M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, BAU and Govt. Peoples Republic of Bangladesh. p.118.

FAOSTAT (2016). Statistical Database. Food and Agriculture Organization of United Nations, Rome, Italy.

Ghorbani, M., Hossein, A. and Abrishamkesh, S. (2019). Effects of rice husk biochar on selected soil properties and nitrate leaching in loamy sand and clay soil, *Intl. Soil Water Conservation Res*., **7**. Pp. 258-265.

Glaser, B., Haumaier, L., Guggenberger, G. and Zech, W. (2001). The 'Terra Preta' phenomenon: a model for sustainable agriculture in the humid tropics. Naturwissenschaften **88**: 37-41.

Graber, E. R., Harel, Y. M., Kolton, M., Cytryn, E., Silber, A., David, D. R., Tsechansky, L., Borenshtein, M. and Elad, Y. (2010). Biochar impact on development and productivity of pepper and tomato grown in fertigated soilless media. *Plant Soil.* **337**: 481- 496.

Hammes, K., Torn, M.S., Lapenas, A.G. and Schmidt, M.W.I. (2008). Centennial black carbon turn over observed in a Russian steppe soil. Biogeosciences Discussion., **5**: 661- 683.

Hass, A., Gonzalez, J. M., Lima, I. M., Godwin, H. W., Halvorson, J. J. and Boyer, D. G. (2012). Chicken manure biochar as liming and nutrient source for acid Appalachian soil. *J. Environ. Qual.* **41**(4): 1096-1106.

Hoshi, T. (2001). Growth promotion of tea trees by putting bamboo charcoal in soil, Proceedings of 2001 International Conference on O-cha (Tea) Culture and Science, Pp. 336-345.

Inal, A., Gunes, A., Sahin, O., Taskin, M. B. and Kaya, E. C. (2015). 'Impacts of biochar and processed poultry manure applied to a calcareous soil on the growth of bean and maize', Soil Use and Management. **31**(1). Pp. 106-13.

Islam, S. J. M., Mannan, M. A., Khaliq, Q. A. and Rahman, M. M. (2015). Growth and yield response of maize to rice husk biochar [online]. *Australian J. Crop Sci*. **12**(12); Pp. 1813-1819.

Islam, T. M. T. and Kaul, A. K. (1986). Prospect of maize in Bangladesh. *FAOUNDP Publication*, Dhaka.

Jia, X., Yuan, W. and Ju, X. (2015) "Short report: effects of biochar addition on manure composting and associated N_2O emissions," *J. Sustainable Bioenergy Systems*. **5**(2); Pp. 56–61.

Jones, D. L., Edwards-Jones, G. and Murphy, D. V. (2011). Biochar mediated alterations in herbicide breakdown and leaching in soil. *Soil Biol. Biochem.,* **43**: 804-813.

Kaul, A. K. and Rahman M. M. (1983). Crop diversification for intensive cropping paper presented at first Workshop on National Cropping System Research. BARI, Joydebpur, Gazipur. 10-13:16p.

Keiluweit, M., Nico, P. S., Johnson, M. G. and Kleber, M. (2010). Dynamic molecular structure of plant biomass-derived black carbon (biochar). *Environ. Sci. Technol.*, **44**: 1247-1253.

Khan, S., Awan, I. U. and Baloch, M. S. (2013). Performance of maize varieties under irrigated conditions of Dera Ismail Khan. *Gomal Univer. J. Res.* **29**(2): 26-31.

Kim, H. S., Kim, K. R., Yang, J. E., Ok, Y. S., Owens, G., Nehls, T., Wessolek, G. and Kim, K. H. (2016). Effect of biochar on reclaimed tidal land, soil properties and maize response. *Chemosphere.* **142**: 153-159.

Kimetu, J. M., Lehmann, J., Ngoze, S. O., Mugendi, D. N., Kinyangi, J., Riha, S. J., Verchot, L., Recha, J. W. and Pell, A. N. (2008). Reversibility of Soil Productivity Decline with Organic Matter of Differing Quality Along a Degradation Gradient. Ecosystems, **11**:726-739.

Kluen, H. and Wolf, J. (1986). Modeling of Agricultural production: Weathering, *Soils Crops Prod.* Wageningen. p.23

Kookana, R. S., Sarmah, A. K., Van Zwieten, L., Krull, E. and Singh, B. (2011). Biochar Application to Soil: Agronomic and Environmental Benefits and Unintended Consequences. *Advances Agron*, **112**: 103.

Krull, E. S., Skjemstad, J. O., Baldock, J. A. (2004). Functions of Soil Organic Matter and the Effect on Soil Properties. GRDC report. Project CSO 00029.

Kumar, D. and Jhariya, A. N. (2013). Nutritional, medicinal and economical importance of corn: A mini review. *Res. J. Pharmaceutl. Sci.* **2***: 7-8.*

Lai, W. Y., Lai, C. M., Ke, G. R., Chung, R. S., Chen, C. T., Cheng, C. H., Pai, C. W., Chen, S. Y. and Chen, C. C. (2013). 'The effects of woodchip Biochar application on crop yield, carbon sequestration and greenhouse gas emissions from soils planted with rice or leaf beet', *J. Taiwan Ins. Chem. Eng*. **44**(6) Pp. 1039-44.

Laird, D. A. (2008). The charcoal vision: A win–win–win scenario for simultaneously producing bioenergy, permanently sequestering carbon, while improving soil and water quality. *Agron J.* **100** (1): 178–181.

Lanh, N. V., Bich, N. H., Hung, B. N., Quyen, N. N. and Preston, T. R. (2019). Water retention capacity of biochar and its effect on growth of maize. *Livestock Research for Rural Development.* **31:** Article #95.

Lashari, M. S., Ye, Y., Ji, H., Li, L., Kibue, G. W., Lu and H., Pan, G. (2015). Biochar manure compost in conjunction with pyroligneous solution alleviated salt stress and improved leaf bioactivity of maize in a saline soil from central China: a 2- year field experiment. *J. Sci. Food Agric*. **95**(6): 1321-1327.

Lehmann, J. and Joseph, S. (2009). Biochar for environmental management: an introduction. In Biochar for Environmental Management: Science and Technology. Eds. Lehmann, J. and Joseph, S. Pp 1-12. Earthscan, London, UK.

Lehmann, J. and Rondon, M. (2006). Bio-char soil management in highly weathered soils in the humid tropics. In Biological approaches to sustainable soil systems. Pp 517-530. CRC Press Taylor & Francis Group, Boca Raton.

Lehmann, J. (2007). 'Bio-energy in the black', Frontiers in Ecology and the Environment, **5**(7): Pp. 381-7.

Lehmann, J. and Joseph, S. (2009). Biochar for Environmental Management: Science and Technology. Earthscan, London & Sterling, VA. 416p.

Lehmann, J., Da Silva Jr., J. P.; Steiner, C., Nehls, T., Zech, W. And Glaser, B. (2003): Nutrient Availability and Leaching in an Archaeological Anthrosol and Ferralsol of the Central Amazon Basin: Fertilizer, Manure and Charcoal Amendments. *Plant Soil.* **249**: 343-357.

Lehmann, J., Solomon, D., Kinyangi, J., Dathe, L., Wirick, S. and Jacobsen, C. (2008). Spatial complexity of soil organic matter forms at nanometre scales. Nature Geosci. **1**: 238-242.

Liang, B., Lehmann, J., Solomon, D., Kinyangi, J., Grossman, J., O'Neill, B., Skjemstad, J. O., Thies, J., LuizÃ£o, F. J., Petersen, J. and Neves, E. G. (2006). Black Carbon Increases Cation Exchange Capacity in Soils. *Soil Sci. Soc. American J* .**70**: 1719-1730.

Liang, F. Li, G., Lin, Q. and Zhao, X. (2014). 'Crop Yield and Soil Properties in the First 3 Years after Biochar Application to a Calcareous Soil', *J. Integrative Agril*. **13**(3): Pp. 525-32.

Liu, T., Liu, B. and Zheng, W. (2014). 'Nutrients and heavy metals in biochar produced by sewage sludge pyrolysis: Its application in soil amendment', Polish *J. Env. Studies*. **23**(1): Pp. 271-75.

Liu, X. H. and Zhang, X. C. (2012). Effect of biochar on pH of alkaline soils in the loess plateau: results from incubation experiments. *Int. J. Agric. Biol*., **14**: 745–750.

Majid, M. A., Islam, M. S., El Sabagh, A., Hasan, M. K., Saddam, M. O., Barutcular, C. and Islam, M. S. (2017). Influence of varying nitrogen 48 levels on growth, yield and nitrogen use efficiency of hybrid maize (*Zea mays*). *J. Expt. Biol. Agril. Sci.* **5**(2): 134-142.

Major, J., Rondon, M., Molina, D., Riha, S. and Lehmann, J. (2010). Maize yield and nutrition during 4 years after biochar application to a Colombian savanna oxisol. Plant and Soil.

Major, J., J. Lehmann., M, Rondon and Goodale, C. (2010). Fate of Soil-Applied Black Carbon: Downward Migration, Leaching and Soil Respiration. *Global Change Biol*., **16**:1366-1379.

Mensah, A, K. and Frimpong, K. A. (2018). Biochar and/or Compost Applications Improve Soil Properties, Growth, and Yield of Maize Grown in Acidic Rainforest and Coastal Savannah Soils in Ghana, *Intl. J. Agron*., Pp. 8.

Mutezo, W. T. (2013). Early crop growth and yield responses of maize (*Zea mays*) to biochar applied on soil. International Working Paper Series, **13**(3): 50.

Nasim, W., Ahmad, A., Khaliq, T., Wajid, A., Munis, M. F. H., Chaudhry, H. J., and Hammad, H. M. (2012). Effect of organic and inorganic fertilizer on maize hybrids under agro-environmental conditions of Faisalabad-Pakistan. *African J. Agric. Res***.** **7**(17): 2713-2719.

Njoku, C., Uguru, B. N., Chibuike, C. C. (2015). Use of Biochar to improve selected soil chemical properties, carbon storage and maize yield in an ultisol in Abakaliki Ebonyi State, Nigeria.

Novak, J. M., Busscher, W. J., Laird, D. L., Ahmedna, M., Watts, D. W. and Niandou, M. A. S. (2009). Impact of biochar amendment on fertility of a southeastern Coastal Plain soil. Soil Sci. **174**: 105-112.

Preston, C. M. and Schmidt, M. W. I. (2006). Black (pyrogenic) carbon: A synthesis of current knowledge and uncertainties with special consideration of boreal regions. *Biogeosci*., **3**: 397-420.

Oguntunde, P. G., Fosu, M, Ajayi, A. E., van de Giesen, N. (2004). Effect of charcoal production on maize yield, chemical properties and texture of soil. Biol Fertil Soils. **39**: Pp. 295-299.

Quilliam, R. S., Marsden, K. A., Gertler, C., Rousk, J., DeLuca, T. H. and Jones, D. L. (2012). 'Nutrient dynamics, microbial growth and weed emergence in biochar amended soil are influenced by time since application and reapplication rate', *Agril. Eco. Env*, **158**, Pp. 192-9.

Rondon, M., Lehmann, J., Ramirez, J. and Hurtado, M. (2007). Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions. Biol. Fertility Soils, **43**: 699-708.

Saxena, J., Rana, G. and Pandey, M. (2013), 'Impact of addition of biochar along with Bacillus sp. on growth and yield of French beans', *Sci. Hort*., **162**, Pp. 351-6.

Shashi1, M. A., Mannan1, M. A., Islam, M. M. and Rahman, M. M. (2018). The Agriculturists **16**(2): 93-101.

Skjemstad, J. O., Reicosky, D. C., Wilts, A. R. and McGowan, J. A. (2002). 'Charcoal carbon in US agricultural soils', *Soil Sci. Soc. America J*., **66,** Pp. 1249-55.

Sohi, S., Lopez-Capel, E., Krull, E. and Bol, R. (2009). 'Biochar, climate change and soil: A review to guide future research', CSIRO Land and Water Science Report, **5**(09), Pp. 17-31.

Steiner, C., Glaser, B., Teixeira, W. G., Lehmann, J., Blum, W. E. H. and Zech, W. (2008). Nitrogen retention and plant uptake on a highly weathered central Amazonian Ferralsol amended with compost and charcoal. *J. Plant Nut. Soil Sci*. **171**: 893-899.

Thakur, C. (1980). Scientific Crop Production. Vol 1, food crops. *Metropolitan Book Co.* New Delhi. Pp. 145- 185.

Thies, J. E. and Rillig, M. C. (2009). Characteristics of biochar: Biological properties. In Biochar for environmental management: science and technology. Eds. Lehmann, J and Joseph, S. Earthscan.. Pp 85-126.

Uzoma, K. C., Inoue, M., Andry, H., Fujimaki, H., Zahoor, A and Nishihara, E. (2011). Effect of cow manure biochar on maize productivity under sandy soil condition. *Soil Use Manage.* **27**(2): 205-212.

Vaccari, F. P., Baronti, S., Lugata, E., Genesio, L., Castaldi, S., Fornasier, F. and Miglietta, F. (2011). Biochar as a strategy to sequester carbon and increase yield in durum wheat. *European J. Agron*. **34**: 231-238.

Van Zwieten, L., Kimber, S., Morris, S., Downie, A., Berger, E., Rust, J. and Scheer, C. (2010b). 'Influence of biochars on flux of N_2O and CO_2 from Ferrosol', *Soil Res.* **48**(7): Pp. 555-68.

Verheijen, F., Jeffery, S., Bastos, A., van der Velde, M. and Diafas, I. (2009). Biochar application to soils: A critical scientific review of effects on soil properties, processes, and functions, EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg.

Vinh, N., Hien, N., Anh, M., Lehmann, J. and Joseph, S. (2014). 'Biochar treatment and its effects on rice and vegetable yields in mountainous areas of northern Vietnam', *Intl. J. Agril. Soil Sci.*, **2**: Pp. 5-13.

Wacal, C., Sasagawa, D., Basalirwa, D., Acidri, R. and Nishihara, E. (2016). Effect of Biochar on Continuously Cropped Sesame (*Sesamum indicum* L.). Conference: The 241st Meeting of CSSJ (Crop Science Society of Japan), At Ibaraki University-Japan.

Wardle, D. A., Zackrisson, O. and Nilsson, M. C. (1998). The charcoal effect in Boreal forests: Mechanisms and ecological consequences. Oecologia **115**: 419-426.

Yang, X. B., Ying, G. G., Peng, P. A., Wang, L., Zhao, J. L., Zhang, L. J., Yuan, P. and He, H. P. (2010). Influence of biochars on plant uptake and dissipation of two pesticides in an agricultural soil. *J. Agril. Food Chem*., **58**: 7915-7921.

Yao, Y., Gao, B., Zhang, M., Inyang, M. and Zimmerman, A. R. (2012). 'Effect of biochar amendment on sorption and leaching of nitrate, ammonium, and phosphate in a sandy soil', Chemosphere, **89**(11): Pp. 1467-71.

Yilangai, R. M., Manu, A., Pineau, W., Mailumo, S. and Okeke-Agulu, K. (2014). 'The effect of biochar and crop veil on growth and yield of Tomato (Lycopersicum esculentus Mill) in Jos, North central Nigeria', *Current Agril. Res. J.*, **2**(1): Pp. 37-42.

Yu, C., Tang, Y., Fang, M., Luo, Z. and Cen, K. (2005): Experimental Study on Alkali Emission during Rice Straw Pyrolysis. *J. Zhejiang University (Engineering Science),* **39:** 1435-1444.

Yuan, J. H., Xu, R. K., Wang, N. and Li, J. Y. (2011). Amendment of acid sols with crop residues and biochars. Pedosphere **21**: 302-308.

Zhang, A., Liu, Y., Pan, G., Hussain, Q., Li, L., Zheng, J. and Zhang, X. (2012). 'Effect of biochar amendment on maize yield and greenhouse gas emissions from a soil organic carbon poor calcareous loamy soil from Central China Plain', Plant and Soil, **351**(1-2): Pp. 263-7

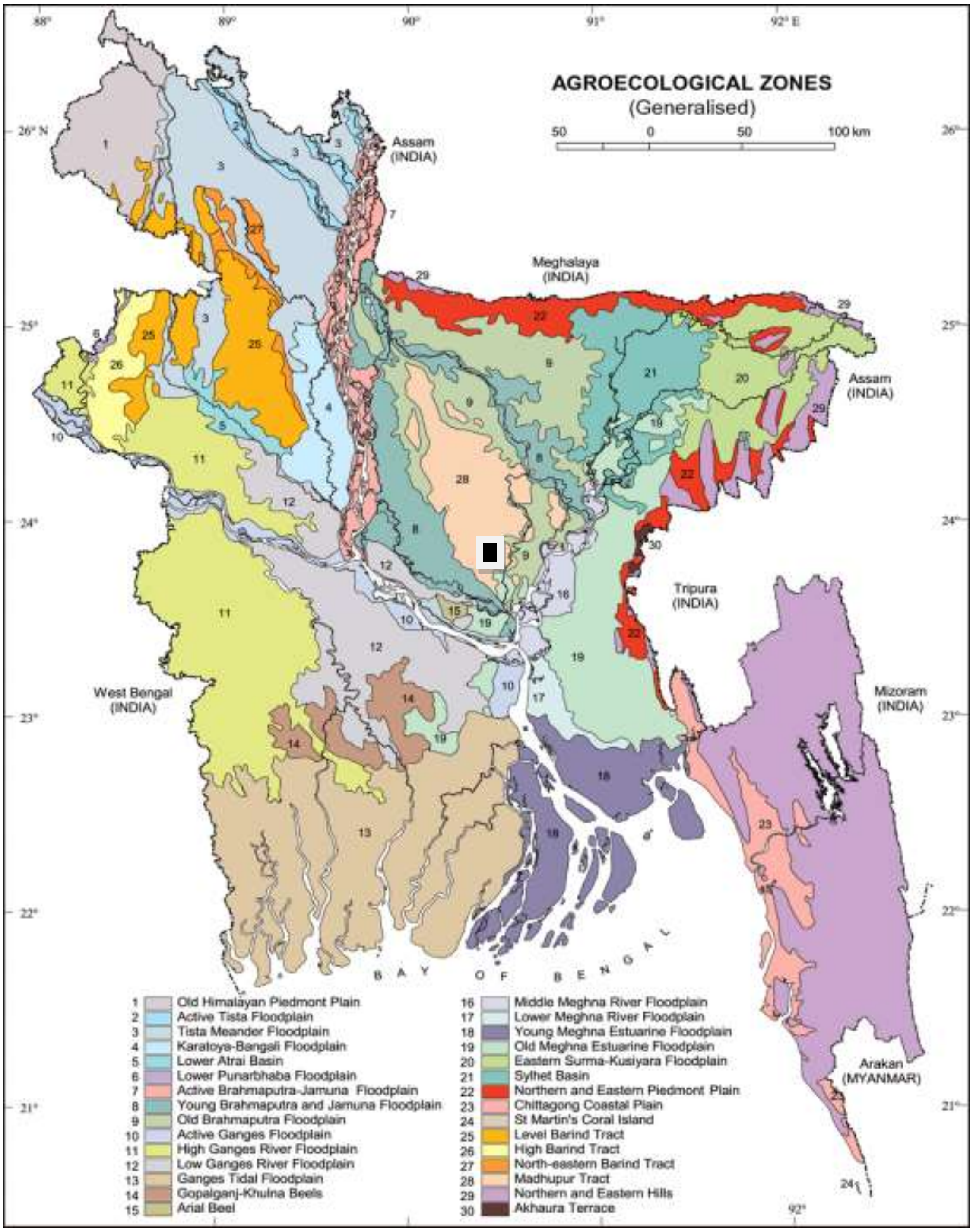
Zhu, D., Kwon, S. and Pignatello, J. J. (2005). Adsorption of single-ring organic compounds to wood charcoals prepared under different thermochemical conditions. *Environ. Sci. Technol.*, **39**: 3990-3998.

Zimmerman, A. R. (2010) Abiotic and Microbial Oxidation of Laboratory- Produced Black Carbon (Biochar). *Environl. Sci. Tech*. **44**: 1295-1301.

Zwieten, L. V., Kimber, S., Downie, A., Chan, K. Y., Cowie, A., Wainberg, R. and Morris, S. (2007). Papermill char: Benefits to soil health and plant production, Proceedings of the Conference of the Interational Agrichar Initiative, Terrigal, NSW, Australia.

APPENDICES

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



■ The experimental site under study

Appendix II: Characteristics of Agronomy Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features Characteristics	Morphological features Characteristics
Location	Horticulture farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics Value	Characteristics Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10

Source: Soil Resource Development Institute (SRDI)

Appendices III: Monthly record of air temperature, rainfall, relative humidity, Sunshine of the experimental site during the period from October 2018 to May 2019

Month (2018-2019)	*Air temperature (ºc)		*Relative Humidity (%)	*Rain Fall (mm) (total)	*Sunshine (hrs)
	Maximum	Minimum			
October, 2018	32	26	72	175	6
November, 2018	30	19	66	35	8
December, 2018	26	14	63	15	9
January, 2019	25	13	54	7	9
February, 2019	28	16	49	25	8
March, 2019	32	20	45	155	7
April, 2019	34	24	55	340	6
May, 2019	33	25	72	335	3

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka –1207.

Appendix IV: Name of fertilizers, manure Biochar used in MAIZE production and their nutrient composition (%)

A. Properties of fertilizer and manure

Fertilizer	Nutrient	Nutrient
Urea	N	46
TSP	P_2O_5	48
	P	21.12
MOP	K_2O	60
	K	49.8
Cow dung	N	0.5-1.5
	P	0.4-0.8
	K	0.5-1.9
H_3BO_3	B	17
MnO_2	Mn	55.8

Source: Fertilizer Recommendation Guide, BARC

B. properties of Biochar

Characteristics	Value
pH	8.87
Organic carbon (%)	45.6
Total N (%)	2.12
Available P (%)	0.49
Exchangeable K (%)	0.59

Source: Soil Resource Development Institute (SRDI

Appendix V: Analysis of variance of the data on plant height (cm) of maize at days after sowing (DAS)

Source of variance	Degrees of Freedom	Mean square of plant height (cm) at different days after sowing (DAS)		
		30 DAS	60 DAS	90 DAS
Replication	2	12.01	298.21	465.94
Factor A	2	36.73	203.30*	436.66*
Error REPL*A	4	35.77	84.02	243.27
Factor B	3	2129.99**	4220.01**	9300.15**
AB	6	80.21*	73.31	520.08*
Error REPL*A*B	18	18.81	48.82	156.44

******indicates 1% level of significance and * indicates 5% level of significance

Appendix VI: Analysis of variance of the data on leaf length (cm) of maize at days after sowing (DAS)

Source of variance	Degrees of Freedom	Mean square of leaf length (cm) at different days after sowing (DAS)		
		30 DAS	**60 DAS**	**90 DAS**
Replication	2	9.78	44.86	66.61
Factor A	2	50.43*	22.91	46.51
Error REPL*A	4	7.68	28.17	37.66
Factor B	3	1835.04**	1168.19**	1485.73**
AB	6	34.79*	26.77	40.34*
Error REPL*A*B	18	11.27	28.98	15.62

******indicates 1% level of significance and * indicates 5% level of significance

Appendix VII: Analysis of variance of the data on Number of leaf and leaf width (cm) of maize at days after sowing (DAS)

Source of variance	Degrees of Freedom	Mean square of Number of leaf at different DAS			Mean square of leaf width (cm) at different DAS		
		30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
Replication	2	0.152	0.55	1.24	0.075	0.776	0.669
Factor A	2	0.66	5.29*	5.76**	0.177	0.311	0.573
Error REPL*A	4	0.05958	0.7196	0.2833	0.40371	0.33508	0.38630
Factor B	3	0.714*	59.79**	51.11**	0.517*	0.701	0.618
AB	6	0.558	0.72	1.34	0.411*	0.13	0.562
Error REPL*A*B	18	0.29944	0.4889	0.9207	0.14295	0.36148	0.42644

******indicates 1% level of significance and * indicates 5% level of significance

Appendix VIII: Analysis of variance of the data on leaf area index of maize at days after sowing (DAS)

Source of variance	Degrees of Freedom	Mean square of leaf area index at different days after sowing (DAS)		
		30 DAS	**60 DAS**	**90 DAS**
Replication	2	0.002	0.075	0.876
Factor A	2	0.023*	0.458*	0.413*
Error REPL*A	4	0.00579	0.07738	0.0403
Factor B	3	0.425**	9.185**	12.718**
AB	6	0.023**	0.166*	0.446*
Error REPL*A*B	18	0.00432	0.09552	0.2632

******indicates 1% level of significance and * indicates 5% level of significance

Appendix IX: Analysis of variance of the data on tassel length, cob to tassel distance, cob length, cob diameter of maize.

Source of variance	Degrees of Freedom	Mean square			
		Tassel Length (cm)	**Cob to Tassel distance (cm)**	**Length of Cob (cm)**	**Diameter of Cob (cm)**
Replication	2	7.4915	0.6085	0.6085	1.1446
Factor A	2	0.5267	8.4113*	8.4113*	3.8957*
Error REPL*A	4	11.3396	2.0538	2.0538	0.4908
Factor B	3	21.8658	69.3764**	69.3764**	12.2498**
AB	6	2.1330	2.2835*	2.2835*	0.7547*
Error REPL*A*B	18	6.9337	1.8844	1.8844	0.8193

******indicates 1% level of significance and * indicates 5% level of significance

Appendix X: Analysis of variance of the data on number of grain rows/cob, number of grains in a row, Weight per Ear (g) and weight of 250 Grains (g) of maize.

Source of variance	Degrees of Freedom	Mean square			
		Number OF grain rows/cob	Number of grain in each row	Weight per Ear (g)	weight of 250 Grains (g)
Replication	2	8.401	0.1582	1019	0.891
Factor A	2	10.61*	1.7862**	77432**	100.700**
Error REPL*A	4	1.598	0.5012	822	5.135
Factor B	3	155.67**	13.7464**	1022753**	548.427**
AB	6	2.58	0.6317*	40859**	31.207*
Error REPL*A*B	18	2.157	0.1970	1176	16.765

******indicates 1% level of significance and * indicates 5% level of significance

Appendix XI: Analysis of variance of the data on dry weight, grain yield, Stover yield and total yield of maize.

Source of variance	Degrees of Freedom	Mean square			
		DRY Weight (g)	Grain Yield (Ton/ha)	Stover Yield (Ton/ha)	Biological Yield (Ton/ha)
Replication	2	175.1	0.1192	0.0280	0.261
Factor A	2	1136.6*	4.9111**	5.4590**	19.823**
Error REPL*A	4	167.7	0.0378	0.2824	0.211
Factor B	3	20763.2**	61.1871**	70.0564**	261.825**
AB	6	452.5	3.6960**	1.8794**	10.460**
Error REPL*A*B	18	273.8	0.1625	0.1848	0.301

******indicates 1% level of significance and * indicates 5% level of significance

Appendix XII: Analysis of variance of the data on pH, OC%, total N (%), Available P and exchangeable K of soil after harvest.

Source of variance	Degrees of Freedom	Mean square				
		pH	OC%	Total N (%)	Available P (ppm)	Exchangeable K (meq $100g^{-1}$)
Replication	2	0.001	0.001	0.00001	36.8	1.336E-03
Factor A	2	1.418**	0.068**	0.01059**	10964.9**	8.669E-03**
Error REPL*A	4	0.00497	0.00096	0.00001	79.7	1.361E-04
Factor B	3	0.250**	0.027**	0.00564**	7098.4**	5.693E-03**
AB	6	0.038**	0.001*	0.00089**	746.6**	9.537E-05
Error REP*A*B	18	0.00107	0.00043	0.00001	17.7	3.611E-05

Plate 1. Land preparation for the experiment

Plate 2. Seed sowing in experiment field

Plate 3. Weeding in the experiment field

Plate 4. Supervisor and Co-supervisor sir visiting the experiment field

Plate 5. Collecting data