INTERACTIVE EFFECT OF NITROGEN FERTILIZER, BIOCHAR AND COMPOST ON CAULIFLOWER AND SOIL FERTILITY

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CERTIFICATE

This is to certify that thesis entitled, **"INTERACTIVE EFFECT OF NITROGEN FERTILIZER, BIOCHAR AND COMPOST ON CAULIFLOWER AND SOIL FERTILITY"** 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 ENVIRRONMENTAL SCIENCE,** embodies the result of a piece of bona fide research work carried out by Nishat Tasnim, Registration No.: 18-09134 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 been fully acknowledged by her.

Dated: December, 2020
Place: Dhaka, Bangladesh

(Tania Sultana)
Assistant Professor
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DEDICATED

TO

MY BELOVED

PARENTS

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ABSTRACT

Biochar is a carbon-rich material gained from thermo-chemical conversion of biomass in an oxygen-limited environment. Biochar can improve agricultural productivity, particularly in low-fertility and degraded soil. 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 2019 to January 2020 to study the effects of nitrogen fertilizer with biochar and biochar-compost on cauliflower performance and soil fertility. The experiment was set out in two factors split plot design with three replications. The two factors were, Factor A: T_1 (Biochar), T_2 (Biochar and Compost), T_3 (Control). Factor B: Four doses of nitrogen which were N_1 (No Nitrogen), N_2 (50% Recommended dose of Nitrogen), N_3 (75% Recommended dose of Nitrogen) and N_4 (100% Recommended dose of Nitrogen). In combined effect of nitrogen with biochar-compost at 75 DAT, the maximum plant height (58.59 cm) was obtained from T_2N_3 which was statistically similar with T_2N_4 (58.12 cm) and minimum height from T_3N_1 (52.63 cm). In combined effect of nitrogen with biochar-compost, the maximum yield (40.94 ton/ha) was obtained from T_2N_3 combination which was statistically different from all other combinations and the minimum yield (16.51 ton/ha) was found from T_3N_1 combination treated plot. The maximum 1.97% organic carbon was recorded from T_2N_3 combination which was statistically similar to T_2N_4 (1.91%) and the minimum value 1.14% was recorded from T_3N_1 combination treated plot. So, combined application of biochar and compost can reduce 25% of chemical fertilizer (nitrogen fertilizer) which is environmentally friendly and increase yield.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURE (CONT.)

LIST OF APPENDICES

LIST OF PLATES

ABBREVIATIONS

Full word	Abbreviations	Full word	Abbreviations
Agro-Ecological Zone	AEZ	Milliequivalents	Meqs
Bangladesh Agricultural Research Institute	BARI	Milligram(s)	Mg
Bangladesh Bureau of Statistics	BBS	Metric ton	MT
Centimeter	cm	North	N
Percent Coefficient of Variation	CV%	Number	No.
Days After Transplanting	DAT	Meter square	m^2
And others	et al.	Master of Science	MS
Exempli gratia(L)	e.g	Negative logarithm of hydrogen ion concentration (-log[H+])	p^H
Etcetera	etc	Least Significant Difference	LSD
Degree Celsius	°C	Sher-e-Bangla Agricultural University	SAU
Percentage	%	Variety	Var
Food and Agricultural Organization	FAO	United States of America	USA
Gram	G	Department of Agricultural Extension	DAE
Id est. (L)	i.e	Geometric Mean	GM
East	E	Microgram	Mg
Editors	Eds.	Soil Resource Development Institute	SRDI

CHAPTER I

INTRODUCTION

Cauliflower (*Brassica oleracea* L. var. *botrytis* sub var *cauliflora*) is a kale belonging to the Cruciferae family. Cauliflower commonly grown in vegetable-producing countries around the world. It is a popular winter vegetable in Bangladesh. It is low in fat, high in dietary fiber, folate, water and vitamin C, possessing a very high nutritional concentration which can help to protect from a range of diseases from cancer to cataracts (Kirsh *et al*., 2007). The growth and yield of cauliflower are remarkably influenced by organic and inorganic fertilizer management, for which a combined approach benefits yield sustainability and maintains soil fertility (Noor *et al.*, 2007). The demand and price of cauliflower are higher, both in national and international markets. The rate of change of area, production and yield of cauliflower are increasing nowadays 60, 70 and 80%, respectively in Bangladesh (Mostofa *et al*., 2010). The excessive use of chemical fertilizer in vegetable and other crop production is common in Bangladesh. In Bangladesh, the yield of vegetable crops has declined due to depleted soil fertility. With consistently growing demand on shrinking land resources to feed an escalating population, it is necessary to maintain the biological health of soils at an optimum level for sustaining the productivity of agricultural soils. The application of organic resources to soil is essential to conserve soil fertility and crop productivity in agricultural systems (Karmegam and Daniel 2009). Soil Organic matter is an indicator of its fertility and thereby crop productivity. It is stated that a good and productive soil should contain as a minimum 2.5% OM, however, because of conducive climatic condition and rapid microbial decomposition of organic materials in soils of Bangladesh can't be maintained. Most of the soils have less than 1.5%, while some soils even less than 1% Organic matter (FRG, 2012). Soil fertility degradation and available nutrient depletion is common in agroecosystems with environmentally damaging amounts of modern agricultural practices, which have imbalanced the responsible abiotic and biotic soil fertility factors (Suzuki *et al.*, 2014).

Organic fertilizers are imitative from organic materials either from green plants or animals that have undergone further decomposition or undergoing in a process of decomposition (Hue and Silva, 2000; Troeh and Thompson, 2005). Materials that have been or are undergoing decomposition would be a source of energy for soil microorganisms and source of nutrients for plants through the mineralization process such as NH_4, NO_3, SO_4 and PO_4 (Hue and Silva, 2000; Brown and Cotton, 2011). Numerous studies on compost from various sources have been found to promote root formation (Arancon *et al*., 2005), increase fruit setting and yield (Atiyeh *et al*., 2002; Arancon *et al*., 2004) and also increase plant dry mass (Edwards 1995; Subler *et al*., 1998). Cow manure contains a number of nutrients that can improve physical, chemical and biological properties of soil (Suparman and Supiati, 2004). Application of Organic matter such as compost, crop residues and animal manure is a traditional practice to reestablish soil nutrient retention capacity (Rahman, 2013). The traditional organic amendments, however, are of short life span in soil and continuous application in bulk quantities diverts its attention of this practice. In this situation biochar appears as a magic solution.

Biochar is a carbon-rich material gained from thermo-chemical conversion (slow, intermediate, and fast pyrolysis or gasification) of biomass in an oxygen-limited environment. Biochar can improve agricultural productivity, particularly in low-fertility and degraded soils where it can be especially useful to the world's poorest farmers; it reduces the losses of nutrients and agricultural chemicals in run-off; it can improve the water-holding capacity of soils; and it is producible from biomass waste (Woolf *et al*., 2010). It has increased crop yield through various mechanisms including stimulation of beneficial soil microbes such as mycorrhizal fungi (Warnock *et al*., 2007), increase of soil base saturation (Major *et al*., 2010), increase in water holding capacity (Steiner *et al*., 2007) and retention of nutrients in the portion of the soil column containing roots, thus improving nutrient use efficiency (Chan *et al*., 2008; Steiner *et al*., 2008).

Biochar will be most promising technology in Bangladesh in response to soil fertility and productivity. Organic matter depletion is higher due to environmental condition of our country. Biochar will be a great solution to increase stable soil organic matter. But very limited and scattered researches have been done in Bangladesh in this regards. Considering the above fact, the present study was to explore the effects of Biochar and biochar-compost on cauliflower with the following objectives:

1. To determine the effect of nitrogen with biochar and biochar-compost on soil fertility
2. To quantify the effects of nitrogen with biochar and biochar-compost on growth and yield of cauliflower.

CHAPTER II

REVIEW OF LITERATURE

Cauliflower is one of the most important vegetables in Bangladesh, as well as in the world. Studies on various aspects of its production technology have been carried out universal. Very few numbers of works were stated on organic sources of nutrients like biochar and compost and their combination on cauliflower was studied. However, some of the researches and their findings related to the present study carried out at home and abroad are studied in this chapter under the following headings.

2.1 Effect of biochar

2.1.1 Introduction of biochar

Biochar is a black carbon manufactured through pyrolysis of biomasses, a process where organic material is heated under low oxygen conditions. One practice of biochar from crop residues is as soil modification whereas charcoal, made from wood, generally is used as fuel (Lehmann *et al*., 2006). It is the high carbon materials formed from the slow pyrolysis (heating in the absence of oxygen) of biomass (Chan *et al*., 2007). It is also defined as, a fine-grained and porous constituent, similar in its exterior to charcoal manufactured by natural burning or by the combustion of biomass under oxygen-limited conditions (Sohi *et al*., 2009). In fact, it is a product of biomass obtained from heating in a suitable temperature regime in the absence of oxygen (the process of fast or slow pyrolysis) or from a gasification system.

Biochar affects soil fertility in many ways; it can add nutrients by itself or make them more available for plant uptake by increase the decomposition of organic material or possibly, decrease decomposition rates of other organic material thereby increasing soil C concentration in the long run. Moreover, the large surface area results in increased CEC, which may check nutrient leaching and thus eutrophication (Lehmann and Joseph, 2009). A significant decrease in leaching of pragmatic fertilizers after charcoal addition. Further, enhanced plant uptake of P, K and Ca was observed (Lehmann *et al*. 2003). By increasing CEC, applied fertilizers can be adsorbed to the surface area and thereby used more proficiently by plants (Steinbeiss *et al*., 2009). Absorption of biochar may therefore give higher yield with the same amount of fertilizers. Nutrient uptake and availability can also be exaggerated by change in pH as a result of biochar addition (Lehmann and Joseph, 2009). The total nutrient concentration in biochar can be high, however the proportion of plant accessible nutrients can vary. Depending on which kind of feedstock is being used for biochar manufacture, the proportion of available nutrients differs (Lehmann *et al*., 2003). When biochar is produced from plant residues; the average carbon concentration in biochar to be 47.6 % (Wolf, 2008). However, Gaskin *et al*. (2008) showed that carbon application in biochar formed from poultry manure and pine chips can range between 40-78 %.

In general biochar has a high C/N ratio (mean value of 67) which specifies that immobilization of nitrogen can occur when applied to soil. Because of the carbon stability it cannot easily be digested by microbes and therefore N mineralization can occur. The surface area can be settled and small pores act as refugee site for microbes to avoid grazers.

The dissimilarity in pore size of biochar stimulates different habitats and thus microbe diversity (Lehmann and Joseph, 2009).

Biochars can be produced from many organic materials and under diverse conditions subsequent in products of varying properties (Baldock and Smernik, 2002; Nguyen *et al*., 2004; Guerrero *et al*., 2005). It can be produced from a wide range of biomass sources, for example, woods and barks, agricultural wastes such as olive husks, corncobs and tea waste (Demirbas, 2004), greenwaste (Chan *et al*., 2007), animal manures and other waste products (Chan *et al*., 2008; Lima *et al*., 2008). Biochar is a combination of char and ash with the major part (70 – 95%) carbon (C) (Brandstaka *et al*., 2010; Luostarinen *et al*., 2010). It can also be twisted from sewage sludge (Khan *et al*., 2013), rice-husk (Carter *et al*., 2013; Lu *et al*., 2014), wheat straw (Junna *et al*., 2014) and several other materials. Biochar solicitation in soils has positive stimuli on improving soil quality and plant growth (Chan *et al*., 2007). According to Chan *et al*. (2008), biochar produced from green waste by pyrolysis considerably increased soil pH, organic carbon, and exchangeable cations with a significant decrease in tensile strength at higher rates of biochar application (>50 t ha^{-1}) in alfisol soil

Tammeorg *et al*. (2014) evaluated 0, 5, 10, 20 and 30 t ha^{-1} of biochar with or without inorganic fertilizer or meat bone meal for two years and found biochar enriched nitrate N content, water retention capacity, soil organic carbon and K content. Biochar derived from wheat straw decreased soil bulk density and increased soil field capacity, dissolved organic carbon and available P (Alburquerque *et al*., 2014).

2.1.2 Role of biochar for crop production

There are varied reactions of crops to biochar (Chan *et al*., 2008). Van-Zwieten *et al*. (2010a) tested two biochars produced from the slow pyrolysis of paper mill waste, in two agricultural soils in a glasshouse and found that they significantly increased biomass in wheat, soybean and radish in ferrosol soil but reduced wheat and radish biomass in calcaresol, amended with fertilizer in both soils.

According to McClellan *et al*. (2007), the cases where biochar leads to decreasing plant growth can be related to short-term high pH levels, volatile or mobile matter and nutrient imbalance of fresh biochar. In their study, Alburquerque *et al*. (2013) observed that biochar with higher ash content lead to relatively higher increase in sunflower growth due to increased plant availability of nutrients. Moreover, when accumulation of biochar directly reduces a certain soil check increase in crop productivity is a likely product.

A significant decrease in dry matter contented of radish was obtained when biochar was applied at 10 ton ha^{-1} (Chan *et al*., 2008). In a distinct experiment, there was no significant effect of biochar rates (0, 7 and 15 tons ha^{-1}) on turnip, wheat, rape and faba bean yields (Brandstaka *et al*., 2010).

Asai *et al*. (2009) showed that biochar increased rice grain yields at sites with low P availability, which might be due to improved inundated hydraulic conductivity of the top soil, xylem sap flow of the plant and response to N and NP chemical fertilizer treatments. Limiting soil N content by biochar application in N deficient soils could be due to the high C/N ratio, hence it might reduce crop productivity provisionally (Lehmann *et al*., 2003). However, some biochars contain significant amount of micronutrients. For example, pecan-shelled biochar contained greater amount of copper (Cu), magnesium (Mg) and zinc (Zn) than the soil (Novak *et al.*, 2009).

In a single experiment, concentrations of heavy metals including Cu and Zn increased in sewage sludge biochar but those of available heavy metals decreased (Liu *et al.*, 2014). Furthermore, poultry litter biochar was also rich with considerable amounts of Zn, Cu and manganese (Mn) (Inal *et al.*, 2015). Thus, it is needed to compare its effect solely and in combination with other nutrient sources. Some authors (Verheijen *et al.*, 2009; Brandstaka *et al.*, 2010) have highlighted the need for further research on potential benefits of biochars as well as their economics. However, their interactions with other organic sources as well as microbes and release of nutrients from them are insufficiently measured.

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 improved the yield by 8.8% and 12.1%, respectively (Zhang *et al.*, 2012a). In addition, biochar solicitation in a nutrient poor, slightly acidic loamy sand soil had little effect on wheat yield in the absence of mineral fertilization but when pragmatic with the highest rate of mineral fertilization, it produced yield 20–30 % more than mineral fertilizer alone (Alburquerque *et al.*, 2014).

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

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

A poultry-litter biochar derived from slow pyrolysis tested in cotton showed that a higher level (3000 kg ha^{-1}) with urea produced better cotton progression than the lower rate (1500 kg ha^{-1}) which, in turn, did better than the control (Coomer *et al*., 2012).

Lehmann and Joseph (2015) reported significant crop yield benefits from biochar application to soils for various crops and plants in different environments. Uzoma *et al*. (2011) recognized a 150% and 98% increase in maize grain yield at 15 and 20 t/ha biochar application respectively to development of soil physical and chemical properties.

Crane-Droesch *et al*. (2013) reported positive crop yield response as a result of biochar submission over much of Sub-Saharan Africa, parts of South America, Southeast Asia, and southeastern North America. The observed increase in crop yields in these highly weathered and nutrient-poor soils could be explained by biochar soil changes improving soil aggregation, increasing nutrients retention, and enhancing soil water holding capacity. Despite biochar's agronomic benefits, negative effects under biochar amendment on plant productivity have also been reported in peat soils whereas moderate to negative yield response could be observed in most of the leading countries in grain production.

Liu *et al*. (2013) observed, crops grown with biochar resulted with a 10.6% increase on average on dry land soils whereas a 5.6 % increase has been reported for paddy rice. Usefulness of biochar in improving plant productivity is variable. Biochar application has been reported to increase by about 10% plant productivity (Liu *et al*., 2013) and about 25% for aboveground biomass (Biederman and Harpole, 2013). Biochar effectiveness on plant productivity fluctuated considering variations in climate, soil properties, investigated crops, and experimental conditions (Wang *et al*., 2014).

Zhang *et al*. (2012a) investigated the result of biochar on soil quality, plant yield and the emission of greenhouse gas in a rice paddy study in China and found increase in rice yield due increased soil pH, soil organic carbon, total nitrogen and decreased soil bulk density. Improvement of plant growth and crop yields with biochar application has been reported and could be attributed to modification of soil physical properties (Glaser *et al*., 2002). These changes in soil physical properties are due to enhancements on soil structure and water holding capacity (Zhang *et al*., 2012b) and improved crop nutrient availability (Atkinson *et al*., 2010) via its indirect nutrient value (Lehmann and Joseph, 2015), liming effect increased surface area (Sohi *et al*., 2009). Biochar application in combination with fertilizers sustained crop yields due to soil property improvements (Steiner *et al*., 2008). Jeffery *et al*. (2011) reported -28% to 39% changes in plant productivity (crop yield and above-ground biomass) following biochar modification to soils which are partly clarified by biochar's liming effect and superior soil moisture retention, connected with increased nutrient availability to plants. For biochar source's effects on yield response, poultry litter presented the strongest (significant) positive effect (28%), in contrast to biosolids, which were the only feedstock showing a statistically significant negative effect (-28%). Positive crop productivity occurred in acidic than in neutral soils, in sandy than in loam and silt soils.

Yamato *et al*. (2006) explored biochar effect on crop yield and reported increase in maize, cowpea and peanut yield under fertilized surroundings due to increased soil pH, cation exchange capacity, nutrient availability and reduced exchangeable Al^{3+} content.

Trupiano *et al*. (2017) conducted a study, to test the effects of biochar amendment, compost addition, and their combination on lettuce plants grown in a soil poor in nutrients. Compost alteration had clear and positive effects on plant growth and yield and on soil chemical characteristics. However, biochar alone stimulated lettuce leaves number and total biomass, improving soil total nitrogen and phosphorus contents, as well as total carbon and enhancing related microbial communities. Combining biochar and compost, no positive synergic and combined effects were observed. It was suggested that in a soil poor in nutrients the biochar alone could be effectively used to augment soil fertility and plant growth and biomass yield.

Carter *et al*. (2013) conducted a pot experiment over a three crop (lettuce-cabbage lettuce) cycle on the growth of transplanted lettuce (*Lactuca sativa*) and Chinese cabbage (*Brassica chinensis*). Biochar application rates to potting medium of 25, 50 and 150 g kg^{-1} were used with and without locally presented fertilizers (a mixture of compost, liquid compost and lake sediment). The biochar treatments were found to increase the final biomass, root biomass, plant height and number of leaves in all the cropping cycles in comparison to no biochar treatments. The greatest biomass increase due to biochar additions (903%) was found in the soils without fertilization, rather than fertilized soils (483% with the same biochar application as in the "without fertilization" case). Over the cropping cycles the impact was reduced; a 363% increase in biomass was observed in the third lettuce cycle.

2.2 Effect of compost

2.2.1 Introduction of compost

It is an organic manure prepared from the mixture of decayed or decaying organic matter. It is usually made by gathering plant material, such as leaves, small and succulent branches like grass clippings, and vegetable peels, into a pile or bin and letting it rot. Cow dung manure and other materials are often added to enrich the mixture or to speed its decomposition.

In a broad sense the efficiency of land will be seriously decreased. Therefore it is necessary to add organic modifications in cultivation practices such as compost of green biomass and cow manure that may purpose as an alternative to substitute mineral fertilizers and to improve the physical and biological properties of soil (Hue and Silva, 2000; Golabi *et al.*, 2004; Fronning *et al.*, 2008). Compost of cow manure is mixed of solid and liquid waste from the cow's shed which is used as an organic fertilizer on crops (Hartatik and Widowati, 2013). Cow manure contains a number of nutrients that can recover physical, chemical and biological properties of soil (Suparman and Supiati, 2004). The use of cow manure can improve the growth and yield some crops such as maize, soybean, cucumber, and some vegetable crops (Mucheru-Muna and Mugendi, 2007; Ghorbani *et al.*, 2008; Jahan *et al.*, 2014).

In the last decade efforts to reduce dependency on using mineral fertilizers by developing organic fertilizers produced from natural materials are arisen in agricultural practices (Golabi *et al.*, 2004; Brown and Cotton, 2011). Organic fertilizers are resultant from organic materials either from green plants or animals that have undergone further decomposition or undergoing in a development of decomposition (Hue and Silva, 2000). Materials that have been or are undergoing decomposition would be a source of energy for soil microorganisms and source of nutrients for plants through the mineralization process such as NH_4, NO_3, SO_4, and PO_4 (Hue and Silva, 2000; Brown and Cotton, 2011). Humus is a material that has decayed completely and fertilize the soil. Humus also develop soil structure and increase water holding capacity of soil. Humus may affect plant growth by improving the drainage and absorbency as well as the penetration of plant roots (Golabi *et al.*, 2004).

The use of organic fertilizers will help to overwhelm the negative effects of extreme use of mineral fertilizers. Various types of organic material that can be used as organic fertilizer can be derived from waste of animal and residue of plants that can be used after composting process (Hue and Silva, 2000; Hartatik and Widowati, 2013). Applying organic compost on agricultural land is aimed to improve the properties of soil biology and physics, including maintaining the purpose of soil nutrients in the soil so easily used by plants, stimulate microbial activity in the soil to help plants to absorb nutrients provided by organic and inorganic fertilizers, thus paying to growth and yield (Brown and Cotton, 2005; Mucheru-Muna and Mugendi, 2007).

2.2.2 Role of compost for crop production

Trailing-daisy or Singapore-daisy or Creeping-daisy plants (*Wedelia trilobata*) is a herb weeds that can grow on land either low or high plain (Invasive Species Special Group, 2007). *Wedelia trilobata* is an hostile vegetation used to to restore soil fertility and commonly used for ground cover that can improve soil quality ecologically. It is a noxious weeds in agricultural land, but some studies reported that trailing-daisy weeds can be used as a green compost or organic fertilizer for crop production. Trailing-daisy weeds has a high potency as organic fertilizer due to the high content of nitrogen as well as availability of abundant populations around the agricultural areas or in uncultivated lands. Previous study showed that compost of trailing-daisy weeds can significantly increase the growth and yield of mustard and chilli peppers because improvement of chemical and physical properties of soil (Setyowati *et al*., 2014).

The use of cow manure can recover the growth and yield some crops such as maize, soybean, cucumber, and some vegetable crops (Mucheru-Muna and Mugendi, 2007; Ghorbani *et al*., 2008; Mahmoud *et al*., 2009; Jahan *et al*., 2014).

Jayalaxmi Devi *et al*. (2002) conducted a 2 year field trial to evaluate the response of brinjal to different source of nitrogen. The result revealed that the combined application of organic manure, biofertilizer and 50% reduction in chemical fertilizer increased the growth, yield attributes and fruit yield of brinjal as compared to individual application of chemical fertilizer or chemical fertilizer at low dose in association with biofertilizer. The treatment 50% N + 25% PM + BF noted a maximum fruit yield of 27.51 t/ha.

Kanwar *et al*. (2002) reported that with the application of NPK fertilizer (100%) alone, curd weight, diameter, plant height and curd yield increased. But when organic manure (FYM) was applied, significant increase in all these parameters was originate at 50% NPK level. Soil organic carbon content increased when organic fertilizers were supplied alone compared to NPK fertilizer alone.

Prabhakaran and James-Pitchai (2002) conducted field and pot experiments to study possibility of substitution of N with organic N source viz., FYM, fresh mud, fish meal, pig manure, poultry manure to get superior quality fruits of tomato. Urea was taken for assessment. Based on the N content of the organic N source on dry weight basis, the quantities required for the substitution of recommended dose of N at 50 and 100% level were worked out and applied. Application of organic N sources at both levels increased pH, TSS, titratable acidity, reducing and non reducing sugar, crude protein and ascorbic acid content of tomato over no manure (control). Among the diverse organic N sources, application of suggested dose of N in the form of poultry manure recorded higher pH, TSS, treatable acidity, reducing sugar, non-reducing sugar, crude protein and ascorbic acid content in tomato fruits in both the experiments.

Rafi *et al*. (2002) conducted the study on the effect of organic and inorganic fertilizers on yield and quality of tomato. Application of 50% recommended dose of FYM @ 12.5 t/ha along with reduced level of recommended dose of fertilizers (50% of the recommended dose of fertilizers of 100:50:50 NPK kg/ha) resulted in the highest yield with high quality. The study also exposed that the readymade organic manures of commercial company used in this study were inferior to traditional organic manures, viz., FYM and vermicompost.

Anez and Espinoza (2003) reported that lettuce and cabbage productivity were significantly and independently precious by the level of chemical fertilizers used for the climate and soil conditions in this study. It is suggested that an application rate of 10 t/ha of manure, compost or earthworm humus should be applied to the crops one month before transplanting. The fertilizer application rate for lettuce and cabbage is 100 and 150 kg N/ha, respectively.

Chaudhary *et al*. (2003) conducted a field study to examine the use of vermicompost in cabbage cv. S-22 and tomato cv. Golden Acre production. Vermicompost (VC) was prepared using Gliricidia leaves and Eisenia fetida and it was applied at 100 and 200 g/plant, with or without farmyard manure (FYM) at 250 and 500 g/plant. Soil bulk density decreased with the treatments and the lowest value was obtained with VC at 200 g/plant + FYM at 250 g/plant. The highest soil organic carbon was gained with VC at 100 g/plant + FYM at 500 g/plant. Hydraulic conductivity increased 7 times compare to the control in the treatment VC at 200 g/plant + FYM at 250 g/plant. The maximum available N was observed in VC at 200 g/plant + FYM at 250 g/plant, while maximum K was at VC at 100 g/plant + FYM at 500 g/plant. VC at 200 g/plant + FYM at 250 g/plant was the best treatment for obtaining maintainable yields in both crops.

Barani and Anburani (2004) studied the influence of vermicomposting on major nutrients in bhendi and stated that application of inorganic form of NPK at 40:50:30 kg/ha along with organic source like FYM and vermicompost recorded the maximum plant height. The highest stem girth and internodal length were observed in the treatment were FYM @ 25 t + 75% of the recommended inorganic fertilizers + vermicompost @ 5 t was applied (6.82 cm). Number of branches, nodes and dry matter production were expressively increased by the application of FYM along with the 75% of the recommended inorganic fertilizer and vermicompost @ 4 t/ha.

Barani and Anburani (2004) reported that application of FYM at 25t along with the recommended dose of inorganic fertilizer and 4t ha^{-1} vermicompost recorded the highest stem girth, number of branches per plant, number of nodes and dry matter production per plant and highest nutrient uptake in bhendi.

Yadav *et al*. (2004) pragmatic significant increase in plant height, number of branches per plant, leaf area and yield of okra due to various fertility treatment of combined application of organic manures and nitrogen levels. The treatment T7 (50% nitrogen through urea + 50% nitrogen through poultry manure) was originate best for growth attributes like plant height, number of branches and leaf area, yield and economics than the rest of the treatments. The net return was also highest in treatment T7 followed by treatment T8 (50% nitrogen through urea + 50% nitrogen through vermicompost) and minimum return were in unfertilized mechanism.

Bahadur *et al*. (2004) conducted field experiments to assess the effects of organic manures and biofertilizers on the growth and yield of cabbage. There were 13 treatments consisting of 4 organic manures (farmyard manure, pressmud, digested sludge and vermicompost) in combination with 3 biofertilizers (Azospirillum, vesicular arbuscular mycorrhiza (VAM) and phosphate solubilizing microorganisms (PSM)) plus the control (recommended NPK only). FYM, digested sludge and pressmud were applied at 10 t/ha, whereas vermicompost was given at 5 t/ha. Pressmud + VAM recorded the highest values for all parameters studied, i.e. number of outer leaves (13.3), fresh weight of outer leaves (476.67 g), number of inner leaves (31.7), head weight (1616.67 g), head length (16.8 cm), head diamet.er (15.5 cm) and head yield (602.67 q/ha).

Hangarge *et al*. (2004) observed that the application of vermicompost at 5 t ha^{-1} + organic boosters at 1 L m^{-2} in the form of spray, soil conditioner (Tetra care) at 2.5 t ha^{-1} + organic boosters at 1 L m^{-2} in the form of spray increased the availability of N, P, K and organic carbon content in the soil. Further they reported higher yields in chilli (105.67 q ha^{-1}) and spinach (743.03 q ha^{-1}) with the application of soil conditioner (2.5 t ha^{-1}), vermicompost (5 t ha^{-1}) along with organic booster (1 lit m^{-2}).

Rafi *et al*. (2005) reported that application of 50% recommended dose of FYM @ 12.5 t/ha along with reduced level of recommended dose of fertilizers (50% of the recommended dose of fertilizer of 100:50:50 NPK kg/ha) resulted in highest vegetative development and yield of tomato. The readymade organic manure recycled in this study were inferior to traditional organic manures, viz., FYM and vermicompost.

Singh *et al*. (2005) conducted study to assess the effect of vermicompost on cauliflower output and profitability considering soil health under small production systems. The farmers' response on the use of vermicompost was highly positive because of its simplicity and compatibility with the farming system components and with the household internal resources, as well as its cost effectiveness. Moreover, vermicompost was also accepted by the resource-rich farmers who preferred to use vermicompost in place of chemical fertilizers due to environmental respects and to combat health hazards. The impact analysis revealed that approximately 55% of the cauliflower growers adopted vermicompost in adopted villages as well as in neighbouring areas.

Shukla *et al*. (2006) found that application of recommended dose of N, P and K (100, 75 and 55 kg ha^{-1}) with farmyard manure and vermicompost (250 and 12.5 q ha^{-1}) regularly was better in increasing yield per plant, yield per ha, number of fruits per plant, number of fruits per cluster and average fruit weight in tomato.

Ghuge *et al*. (2007) conducted a field experiment to study the effect of organic and inorganic sources of nutrients on growth, yield and quality parameters of cabbage.

Combined effect of organic and inorganic sources prove to be better than effect of their individual use. Among the various mixtures studied, performance of 50% RDF + 50% vermicompost @ 2.5 t/ha was superior among the rest of the treatments followed by 50 percent RDF + 50% Terracare @ 1.25 t/ha and 50% RDF + 50 percent organic booster @ 1.0 litre/plant in 4 splits over control in respect of plant spread, head circumference, average yield head/plant, yield of head per hectare, chlorophyll content and compactness of head.

Murlee *et al*. (2007) determined the effect of organic and inorganic fertilizers on growth and yield of cauliflower. Treatment (150 kg Gromor + 96 kg urea + 32 kg MOP/acre) showed significantly higher curd length (17.00 cm), curd weight (560 g), yield per plot (7.89 kg), yield (392 q/ha) and cost benefit ratio (1:2.88), whereas maximum plant height (53.33 cm) was noted in treatment (104 kg urea + 32 kg DAP + 32 kg MOP/acre).

Dass *et al*. (2008) recorded that vermicompost seemed to be the best soil additive in both crops in terms of yield, net economic return and water practice efficiency (WUE). In bell pepper, use of VC+50% recommended rate of synthetic fertilizers (RRF) produced significantly higher yield over 100% RRF, with a net return increase of 29.8%. There was a similar effect for yield of cabbage. In the 50% RRF+VC treatment, WUE was 32.6% higher in bell pepper and 6.2% higher in cabbage over treatment with 100% RRF. Bulk density of the surface soil after 3 years was reduced; its organic carbon and available N and P status improved due to treatment with CM and VC. The data designate that 5 Mt ha^{-1} of VC can meet 50% of the fertilizer requirement of bell pepper and cabbage while providing higher productivity, income, and residual soil fertility.

Madhavi *et al*. (2008) carried out an experiment on Indian spinach to determine the effect of different levels of vermicompost, castor cake, poultry manure, biofertilizers on dry matter production, nutrient uptake and economics. Highest dry matter production and nutrient acceptance was recorded with the application of recommended dose of fertilizers (80 N: 40 P_2O_5: 50 K_2O kg/ha) and was on a par with poultry manure 8 t/ha + Azospirillum (2 kg/ha) + PSB (2 kg/ha). Economics of production revealed that the higher net returns and benefit cost ratio were obtained with poultry manure 8 t/ha + Azospirillum (2 kg/ha) + PSB (2 kg/ha).

Mamatha *et al*. (2008) reported that application of 75 and 100 per cent RDN through FYM and vermicompost recorded higher neck and bulb diameter, dry matter gathering in leaf and bulb and maximum yield of onion. These treatments also noted maximum percent TSS, lower percent weight loss and maximum nutrient uptake as compared to other treatments.

Peyvast *et al*. (2008) observed that by using organic fertilizers in tested vegetables (Chinese cabbage, parsley, spinach, broccoli, and garlic), high-risk concentration of nitrate in edible parts could be prevented, and therefore, their use as organic matter (OM) is recommended. For Chinese cabbage, there were no significant positive relationship between the nitrate accumulation and MSWC levels; however, for parsley and spinach, the highest amount of cattle manure vermicompost resulted in significantly lower nitrate accumulation. Application of MSWC at more than 25 and 50 t/ha is recommended for broccoli and garlic, respectively. At 50 t/ha, cattle manure compost can be also applied for garlic.

Supe and Marbhal (2008) found average weight of cabbage head, average weight of leaves, number of leaves per plant, girth of head and days required for harvesting significantly superior in treatment where 50% N was practical through organic sources over inorganic source @ 100:50:50 NPK kg/ha. However, treatment of 50% nitrogen was found at par with the treatment where increased dose of NPK (125:62.5:62.5 kg/ha) was applied. As regards the compactness of head, the treatment 50% N through neem cake+50% N through inorganic source @ 100:50:50 kg/ha.

Velmurugan *et al*. (2008) determined the effect of different organic manures and biofertilizers on cauliflower with reference to growth and yield attributes. Application of the recommended dose of fertilizer (T12 = farmyard manure (FYM) 15 t/ha + 50:100:50 kg NPK/ha as basal dressing and 50 kg N/ha 45 days after transplanting) recorded the maximum plant height (32.56 cm), number of leaves (26.60), length of leaves (30.55 cm), width of leaves (15.46 cm), leaf area (472.303 cm^2) and leaf area index (0.175). The control plants (T13 = without any application) exhibited the minimum plant height (21.52 cm), number of leaves (19.88), length of leaves (22.96 cm), width of leaves (13.2 cm), leaf area (303.072 cm2) and leaf area index (0.112). Application of the recommended dose of fertilizers (T12) recorded the maximum curd length (15.66 cm), curd width (17.21 cm) and curd weight (340.12 g/plant) than the control (11.23 cm, 12.32 cm and 228.85 g, respectively).

Devi and Singh (2012) conducted an experiment with varying levels of chemical fertilizers (NPK) and vermicompost. NPK and vermicompost significantly influenced the yield ascribing characters and growth and biomass production in cabbage (*Brassica oleraceae* var. *capitata*) cv. Pride of India. There were six treatments viz. T1: control i.e. without any fertilizer; T2: NPK @140:140:140 kg/ha; T3: NPK@105:105:105 kg/ha + Vermicompost @ 1 ton/ha; T4: NPK@70:70:70 kg/ha + Vermicompost @ 2tons/ha; T5: NPK@35:35:35 kg/ha + Vermicompost @ 3 tons/ha; T6: Vermicompost @ 4 tons/ha). A maximum of 58.67% increase in yield over control was pragmatic in a combined application of NPK and vermicompost in halves of their recommended doses.

Getnet and Raja (2013) conducted a study to produce vermicompost from organic solid wastes by using red earth worm (*Eisenia fetida*) and to check growth promoting and pest suppression properties on cabbage (*Brassica oleracea*). Vermicompost was applied at the rate of 25, 50, 100 and 200 gm/plant individually. Each application 10 plants were selected and vermicompost application was continued on bimonthly basis. Totally 40 plants were used for control group in which 10 plants were selected randomly. Significant modifications ($p<0.05$; LSD) were observed in the growth and development and number of plant stand height, cabbage head, leaves of cabbage compared to control. Vermicompost have significant impact on cabbage growth promotion and reduce the aphid infestation. In future using vermicompost to all kinds of crops and adopting it as commercial fertilizer may create job opportunity to small scale farming society. Also, in this ever escalating cost of chemical fertilizers, the use of vermicompost seems to be quite reasonable in agro-management and should be inclusive as one of the elements of poverty alleviation strategies.

Sajib *et al*. (2015) made an investigation on yield performance of cabbage (*Brassica oleracea* var.*capitata*) under different combinations of manures and fertilizers. The treatments were T1 = recommended doses of NPK (urea @ 350 kg ha^{-1}, TSP @ 250 kg ha^{-1}, MoP @ 300 kg ha^{-1} respectively), T2 = cowdung @ 10 t ha^{-1}, T3 = vermicompost @ 10 t ha^{-1}, T4 = Trichoderma compost @10 t ha^{-1}, T5 = 50% cowdung + 50% recommended doses of fertilizer, T6 = 50%vermicompost + 50% recommended doses of fertilizer and T7 = 50% Trichoderma compost + 50% recommended doses of fertilizer. The growth and physio-morphological characteristics, yield attributes and yield were positively and significantly influenced by the application of vermicompost with recommended dose of NPK and also cowdung compost with the recommended dose of NPK. In most cases 50% vermicompost + 50% recommended doses of fertilizer receiving treatment performed better. However, the maximum yield of cabbage (57.16 t ha^{-1}) was obtained from the treatment receiving 50% vermicompost + 50% recommended doses of fertilizers and the lowest yield of cabbage (38.48 t ha^{-1}) was obtained from the control. But considering the highest benefit cost ratio of cabbage (3.63) was well-known when applied 50% cowdung + 50% recommended doses of fertilizer was applied for sustainable crop production.

Alam *et al*. (2017) conducted a field experiment at BARI, Rangpur, Bangladesh during the Rabi season of 2014-15 and 2015-16 to evaluate the effects of vermicompost on the growth and yield of cabbage. The treatments were T1 = 100% recommended chemical fertilizer (RCF), T2 = 80% RCF, T3 = 60% RCF, T4= 100% RCF+ Vermicompost (VC) @ 1.5 t ha^{-1}, T5= 80% RCF+ VC @ 3 t ha1, T6 = 60% RCF+ VC @ 6 t ha^{-1} and T7 = Complete control. The highest head yield was recorded from T4 during 2014-15 and 2015-16 (59.21 t ha^{-1} and 72.61 t ha^{-1} respectively) where the lowest yield was obtained from T7 (27.11 t

ha^{-1} and 24.05 t ha^{-1} respectively). The total soluble solids were higher in T7 treatment. The highest gross margin was intended in T4 (203060 and 270060 Tk. ha^{-1} in 2014-15 and 2015-16, respectively) and the lowest was in T7 (74300 and 59000 Tk. ha^{-1} in 2014-15 and 2015-16, respectively).

Ali and Kashem (2018) showed a field experiment to evaluate the effect of different levels of fertilizers, cowdung and vermicompost on the growth and yield of cabbage. The experiments were T1= 392-330-150-133-8-5 kg ha-1 of urea-TSP MoP-Gypsum-Zinc sulphate-Solubor boron (BFRG-2012), T2= T1 + Cowdung (5 t ha-1), T3= T1 + Vermicompost (5 t ha^{-1}) and T4 = Vermicompost (10 t ha^{-1}).

Significant variation was observed in different growth and yield contributing characters with treatments except spreading area of plant. The tallest plant (14.03 cm) was observed in T3 at 30 DAT whereas the undeviating plant (9.01 cm) was observed in T4. At 45 DAT, the highest leaf length and leaf breadth (11.40 cm and 7.73 cm, respectively) found in T3 treatment. The highest length and weight of root (25.75 cm and 30.97 g) were indicated with the treatment of T3. The highest fresh weight of stem (14.17 g) was indicated with the treatment of T3. The highest head yield was detailed from T3 (42.12 t ha^{-1}). The result revealed that vermicompost was gave the better enactment with recommended doses of chemical fertilizers than applying chemical fertilizers alone.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2019 to January 2020 to study the effect of biochar and compost on cauliflower performance and soil fertility. The materials and methods that were used for conducting the experiment are presented under the following headings:

3.1 Experimental Site

The experiment was lead out at the east-south corner of research field of Sher-e-Bangla Agricultural University (SAU). It is placed 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) (Appendix III). For better understanding about experimental site it is exposed 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). Climatological data related to the temperature, relative humidity and rainfall during the experiment period was composed from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix- II.

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 particular 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 outcome of analysis was given in Appendix-III.

3.4 Materials

(a) Used Cauliflower

The variety, Snow White was considered for the experiment.

(b) Fertilizers- Biochar, Compost, Urea, TSP, MP, Gypsum, Boric Acid, Ammonium Molibdate. Biochar from Biochar Bangladesh Initiative (BBI) and other fertilizers were collected from the SAU farm. Sample of Biochar were sent to Soil Resources Development Institute (SRDI) for analysis. The result of analysis was given in Appendix-IV.

3.5 Factors and treatments of the experiment

The experiment consist of as two factors.

Factor A:

1. T_1: Biochar

2. T_2: Biochar and Compost

3. T_3: Control

Factor B:

1. N_1: No Nitrogen

2. N_2: 50% Recommended dose of Nitrogen

3. N_3: 75% Recommended dose of Nitrogen

4. N_4: 100% Recommended dose of Nitrogen

Recommended dose:

Biochar 5 t ha^{-1},compost 10.0 t ha^{-1}, Urea, TSP, MP, Gypsum, $ZnSO_4$, $(NH_4)_2MoO_4$ and Boric acid at the rate of 150, 150, 120, 100 ,1 and 3 kg ha^{-1}, respectively.

3.6 Collection of seedlings, biochar and compost

Cauliflower seedling: The cauliflower variety; Snow White was used for the study. The seedlings of this variety were collected from Mithapukur, Rangpur.

Biochar: The field used biochar was derived from pyrolysis of wood, wood chips and sawdust (collected from sawmill) and it was produced by Biochar Bangladesh Initiative Dhaka, Bangladesh.

Compost: Compost was collected from SAU farm.

3.7 Preparation of the main field

The plot was nominated by SAU farm for the experiment in the last week of October, 2019 with a power tiller and was exposed to the sun for a few days, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to get a good tilth. Weeds and stubble were detached and finally obtained a desired tilth of soil for transplanting. The individual plots were made by making ridges (20 cm high) around each plot to check lateral runoff of irrigation water.

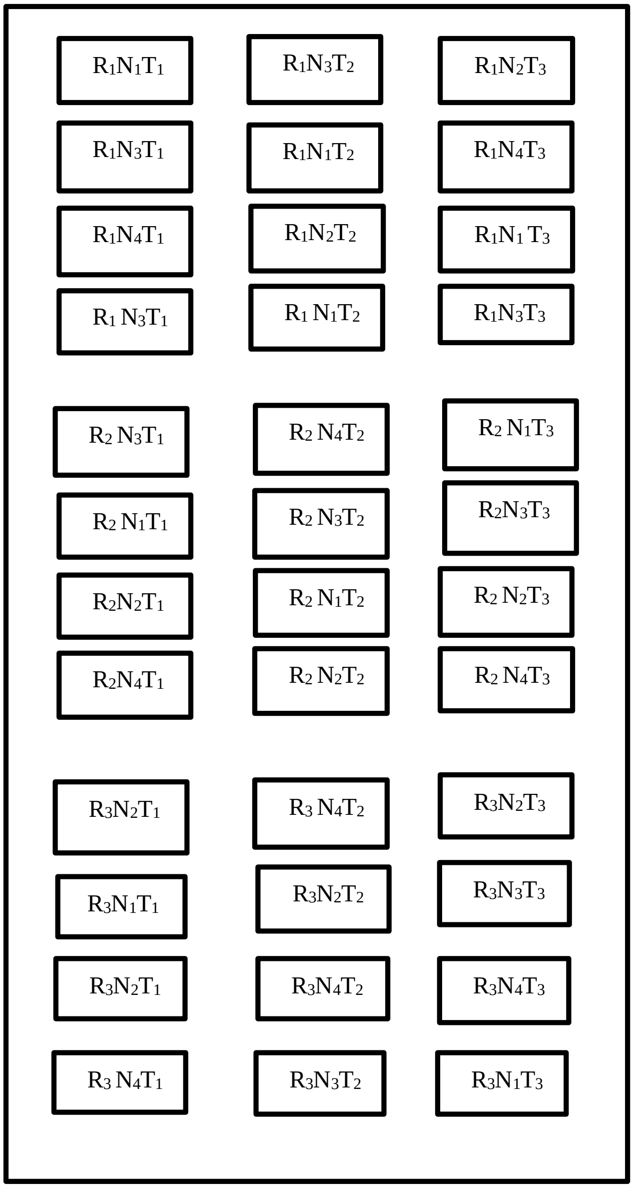
3.8 Application of biochar, compost and other fertilizers

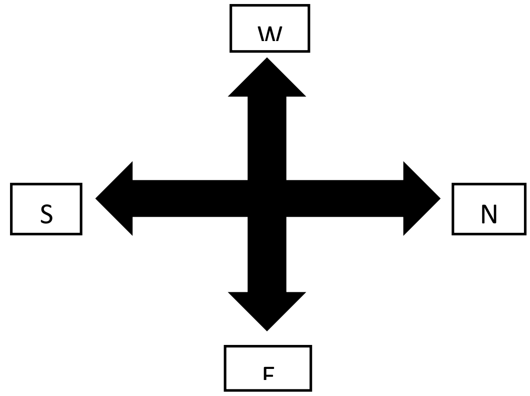
Under the present study, collected biochar was applied to the field. Only Biochar used in T_1 treatment at the rate of 5 t ha^{-1}. The biochar and compost were used T_2 treatment. In T_2 treatment, biochar used as same dose of T_1 treatment and compost used at the rate of 10 The recommended chemical fertilizer dose used for this variety was Urea, TSP, MP, Gypsum, $ZnSO_4$, $(NH_4)_2MoO_4$ and Boric acid at the rate of 150, 150, 120, 100 ,1 and 3 kg ha^{-1}, respectively. Urea was used 150 kg N ha^{-1} for N_4, 112.5 kg N ha^{-1} for N_3, 75 kg N ha^{-1} for N_2, 0 kg N ha^{-1} for N_1. Fertilization (basal dose) was finished on 20 October, 2019.

One third of urea along with full amount of other fertilizers, biochar and compost as per treatment applied during final land preparation as basal dose and the rest urea as per treatment was applied in three equal installments as side dressing. The first installment of fertilizer was 10 DAT, the second installment of fertilizer was 30 DAT and the third installment of fertilizer was given on 45 DAT.

3.9 Layout of the experiment

The experiment was set 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 2.4m × 1.8m. Row to row and plot to plot distances was 50 cm. Distance maintained between replication was75 cm. The treatments were assigned in plot at random. Details layout of the experimental plot has been presented below.





Legend:

Plot size: 2.4m ×1.8m

Plot to plot distance: 50cm

Line to line distance: 60cm

Plant to plant distance:45cm

Factor A:

T_1=Biochar

T_2=Biochar +Compost

T_3=Control

Factor B:

N_1= 0% RDN N_2=50% RDN

N_3=75% RDN N_4=100% RDN

Figure1. Layout of the experiment plot

3.10 Transplanting of seedlings

Healthy and uniform sized 28 days old seedlings were transplanted in the experimental field on 6 November, 2019 maintaining a spacing of 60 cm × 45 cm. The seedlings were watered after transplanting. A strip of the same crop was established around the experimental field as border crop to do gap filling and to check the border effect.

3.11 Intercultural Operation

After establishment of seedlings, various intercultural operations were performed for better growth and development of the cauliflower.

3.11.1 Gap filling and weeding

When the seedlings were established in the soil, the soil around the base of each seedling was crushed. A few gaps filling were done by healthy plants from the border whenever it was required. During plant growth period 3 times weeding were done, first weeding was done on 25 November, 2019, second was on 15 December 2019 and the final weeding was 4 January 2020. Different types of weeds were controlled manually when it was need.

3.11.2 Earthing up

Earthing up was done on 15 December, 2019 which was 39 days after transplanting. It was done to protect the plant from lodging and for better nutrition uptake.

3.11.3 Irrigation

Light over-head irrigation was supplied to the field with a watering can to the plots immediately after transplanting and it was continued for a week for rapid and well establishment of the transplanted seedlings. Irrigation was also applied to the field when it was necessary as cauliflower is a water loving vegetables but over irrigation may cause the death of plant. That's why moderate irrigation was provided to the field.

3.11.4 Plant protection

The crop was protected from the attack of insect-pest by spraying Ripcord at the rate of 2 ml/L water on 3 times, first spraying was done on 11 November 2019.The application of fungicide was also done 2 times and the first application was done on 6 December 2019 .

3.12 Crop Harvesting

The crop was harvested in two times depending upon the maturity of the cauliflower. Before harvesting of the cauliflower curd, compactness of the curd was tested by pressing with thumbs. Harvesting was done manually. Proper care was taken during harvesting period to prevent damage of cauliflower curd. First harvesting was in 26 January, 2020 and final harvesting was done in 31 January, 2020.

3.13 Data Collection and Recording

Five plants were selected randomly from each unit plot for data collection. The parameters were recorded from each of the selected plant of each plot. The following parameters were recorded during the study:

3.13.1 Growth parameters

1. Plant height (cm)

2. Number of leaves plant^{-1}

3. Leaf length (cm)

4. Leaf breadth (cm)

3.13.2 Yield contributing parameters

1. Curd initiation time (DAT)

2. Number of harvested curd

3. Curd diameter (cm)

4. Individual curd weight (gm)

5. Total yield (ton/ha)

3.13.3 Soil related parameters:

1. P^H
2. Organic carbon
3. Nitrogen percentage
4. Phosphorus (ppm) and
5. Sulfur(ppm)

3.14 Procedure of recording data

3.14.1 Growth parameters

3.14.1.1 Plant height (cm)

Plant height was recorded at 15, 30, 45, 60 and 75 days after transplanting (DAT) of crop duration. Data were recorded as the average of 5 plants selected at random from the 3 rows of each plot. The height was measured in centimeter (cm) from the ground level to the tip of the leaves.

3.14.1.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was calculated at different days after transplanting (DAT) of crop duration. Leaves number plant^{-1}was recorded from pre-selected 5 plants by counting all leaves from each plot and mean was calculated. It was recorded at days 15, 30, 45, 60 and 75 days after transplanting (DAT).

3.14.1.3 Leaf length (cm)

Leaf length was measured by using a meter scale. The measurement was taken from base of leaf to tip of the petiole. Average length of leaves was taken from five random selected plants from 3 rows of each plot. Data was recorded from15, 30, 45, 60 and 75 days of transplanting. Mean was expressed in centimeter (cm).

3.14.1.4 Leaf breadth (cm)

Leaf breadth was recorded as the average of five leaves selected at random from the plant of 3 rows of each plot starting from15 to 75 days at 15 days interval. Thus mean was recorded and expressed in centimeter (cm).

3.14.2 Yield contributing parameters

3.14.2.1 Curd Initiation time

Curd initiation time was recorded by investigating of the cauliflower field at the initiation time of cauliflower.

3.14.2.2 Total number of curd harvested

Harvesting was done in two times by picking up the curd by hand with the help of a sickle to separate the curd from the plant.

3.14.2.3 Diameter of curd (cm)

Diameter of curd was measured from five plants when it was harvested and then mean was recorded and expressed in centimeter (cm).

3.14.2.4 Individual weight curd (g)

Weight was taken after separating the curd from five selected plants and then mean was recorded and expressed in gram (g).

3.14.2.5 Total Yield of (t ha^{-1})

Total curd weight was taken gradually from each plot and then converted into tone per hectare.

3.14.3 Soil related parameters

After harvest, soil was collected from the all 36 plots and then dried in the sunlight. After drying the samples were sent Soil Resource Institute located in farmgate, Dhaka.

3.14.3.1 Soil p^H

There are two methods for measuring p^H: colorimetric methods using indicator solutions or papers, and the more accurate electrochemical methods using electrodes and a milli voltmeter (p^H meter). The Soil Resource Institute was measured soil p^H by using p^H meter.

3.14.3.2 Organic carbon

The soil organic carbon was recorded by Wet Oxidation method.

3.14.3.3 Total Nitrogen percentage

Total Nitrogen percentage was measured by Kjeldhal systems.

3.14.3.4 Available Phosphorus

Available Phosphorus was measured by Olsen's method.

3.14.3.5 Sulfur (ppm)

The amount of sulfur was recorded in Turbidimetric method.

3.15 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the Statistix 10 software. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

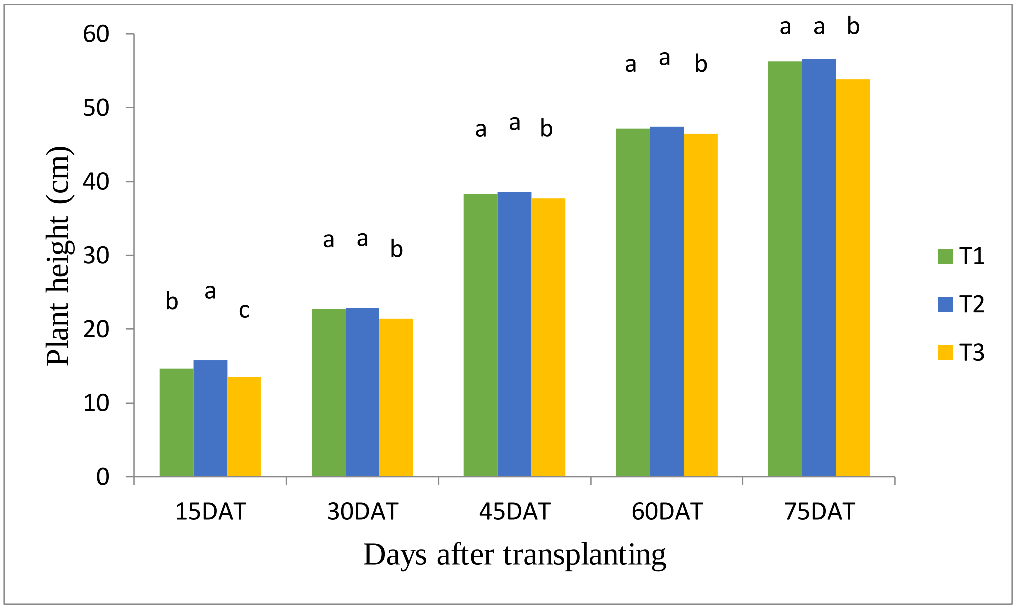
RESULTS AND DISCUSSION

The research work was done to know the the effect of biochar and biochar-compost on the Cauliflower performance and soil fertility. Data such as vegetative, yield and soil related parameters which were recorded from the experiment, have been presented in tables and figures for easy discussion, assessment and understanding. The results of each parameters have been discussed under the following headings.

4.1 Growth Parameters:

4.1.1 Plant height (cm)

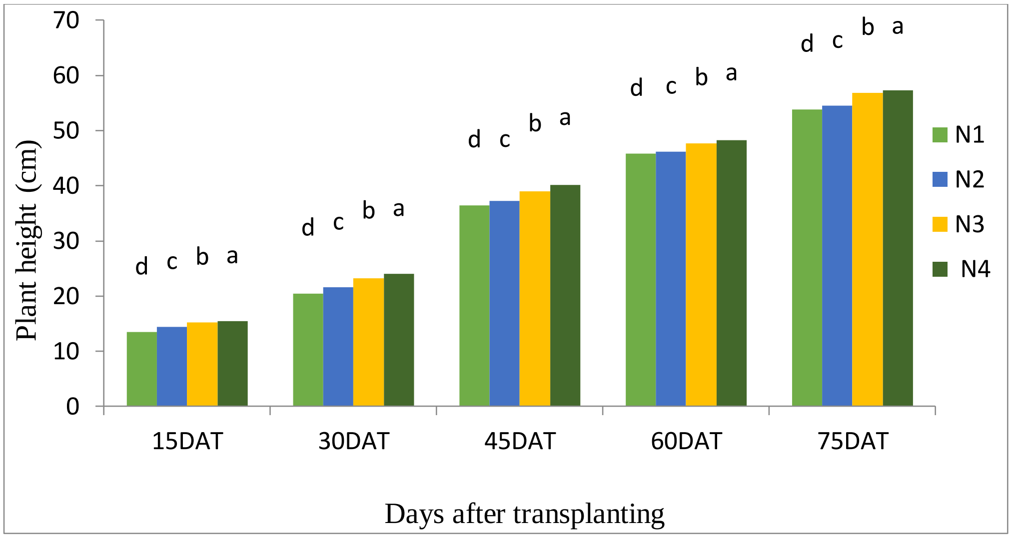
There was a non significant variation on plant height of cauliflower at different growth stages influenced by biochar and compost (Figure 2 and Appendix V). At 15DAT, the maximum plant height was (15.76 cm) found from T_2 (biochar + compost) treatment and minimum plant height was (13.50 cm) obtained from T_3 (control) treated plot. Result revealed that the highest plant height (22.89 cm, 38.61 cm, 47.39 cm and 56.61 cm at 30 DAT ,45 DAT,60DAT and 75DAT,respectively) was obtained from the treatment T_2 which was statistically identical with T_1 (biochar) at all growth stages. The lowest plant height (21.39 cm, 37.73 cm, 46.48 cm, 53.88 cm at 30 DAT, 45 DAT, 60 DAT, 75 DAT, respectively) was obtained from the treatment T_3 (control) which was inferior than other treatment. A experiment was also conducted by Cartel *et al.* (2013) where they observed a rice-husk biochar increased the plant height compared to no biochar treatment.



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure 2: Effects of biochar, biochar-compost on plant height of cauliflower at different days after transplanting

Plant height of cauliflower at different growth stages was significantly influenced by different doses of nitrogen application (Figure 3 and Appendix V). At 15, 30, 45, 60 and 75 DAT, the maximum plant height (15.47 cm, 24.04 cm, 40.19 cm, 48.28 cm, 57.29 cm) was obtained from N_4 (100% recommended dose of nitrogen) which was superior from other doses of nitrogen and the minimum plant height (13.44 cm, 20.48 cm, 36.47 cm, 45.81 cm, 53.78 cm) was obtained from N_1 (no nitrogen) which was inferior from other doses. Kanwar *et al*. (2002) reported that the plant height was increased when 100% NPK fertilizer was applied to the field.



(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure 3: Effects of different nitrogen doses on plant height of cauliflower at different days after transplanting

The combination of different doses of nitrogen with biochar and biochar-compost shown in table 1 with increasing days in respect of plant height. At 15 DAT, the maximum plant height was found in T_2N_3 (16.79 cm) combination treated plot which was statistically similar to T_2N_4 (16.56 cm) combination and the minimum plant height was found from T_3N_1 (12.28 cm) combination which was significantly dissimilar from all other combination. The tallest plant found from 30 DAT was 24.31 cm in T_2N_3 combination which was statistically similar to T_1N_4 (24.29) and T_2N_4 (24.15), whereas the minimum height (19.7 cm) was found from T_3N_1 combination which was statistically dissimilar from all other combination. At 45 DAT, the maximum plant height was obtained from T_2N_3 (40.73cm) which was statistically identical with T_2N_4 (40.02 cm) and T_1N_4 (40.03 cm) combination and the minimum height was obtained from T_3N_1 (35.89 cm) plot which was different from all other combination. The maximum plant height at 60 DAT was obtained from T_2N_3 (48.71 cm) which was identically similar with T_1N_4 (48.59 cm) and T_2N_4 (48.32 cm) combination and minimum was obtained from T_3N_1 (45.44 cm) which was identically similar with T_1N_1 (45.84). At 75 DAT, the maximum plant height (58.59 cm) obtained from T_2N_3 which was statistically similar with T_2N_4 (58.12 cm) and minimum height from T_3N_1 (52.63 cm) which was inferior from other combination. The combined application was also observed by Jayalaxmi Devi *et al.* (2002) to evaluate the response of brinjal.

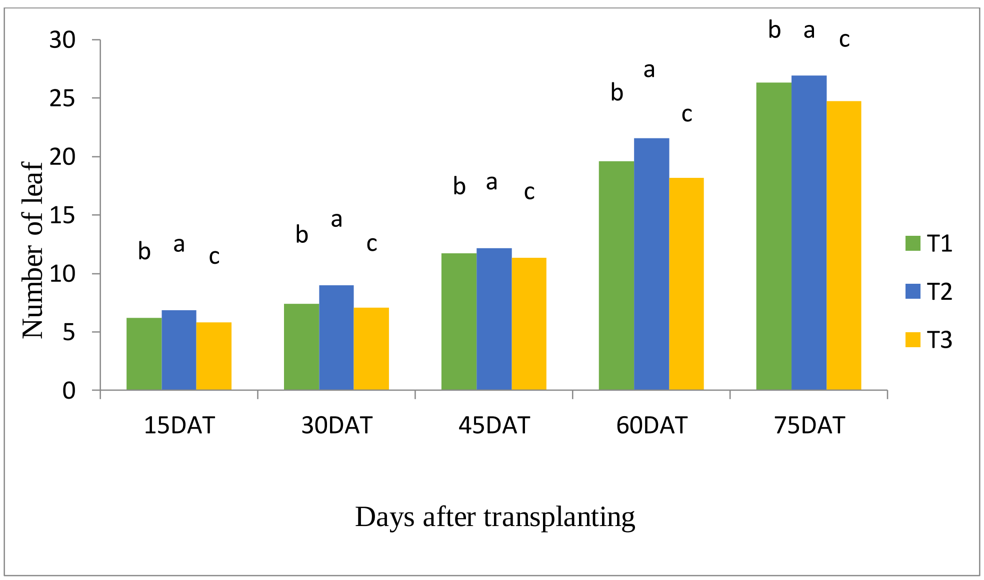
Table 1: Combined effects of different doses of nitrogen with biochar and biochar-compost plant height (cm) of cauliflower at different days after transplanting (DAT)

Treatments	Plant Height (cm)				
	15 DAT	30 DAT	45DAT	60 DAT	75 DAT
T_1N_1	13.63e	20.58ef	36.37ef	45.84de	54.19d
T_1N_2	14.63d	22.64bc	37.14e	46.23cd	55.13c
T_1N_3	15.00c	23.38ab	38.91c	47.91b	57.37b
T_1N_4	15.28b	24.24a	40.03ab	48.59a	58.59a
T_2N_1	14.41d	21.18de	36.88e	46.15cd	54.54cd
T_2N_2	15.31b	21.91cd	37.51de	46.41c	55.21c
T_2N_3	16.79a	24.31a	40.72a	48.7a	58.59a
T_2N_4	16.56a	24.15a	40.02ab	48.32ab	58.12a
T_3N_1	12.28g	19.70f	35.89f	45.44e	52.63e
T_3N_2	13.32f	20.15ef	37.04e	45.96d	53.15e
T_3N_3	13.84e	22.03cd	38.14d	46.59c	54.56cd
T_3N_4	14.58d	23.69ab	39.83bc	47.94b	55.19c
CV (%)	1.11	2.44	1.13	0.55	0.70

(Where, T_1: Biochar, T_2: Biochar and Compost, T_3: Control
N_1: No Nitrogen
N_2:50% Recommended dose of Nitrogen
N_3: 75% Recommended dose of Nitrogen
N_4: 100% Recommended dose of Nitrogen)

4.1.2 Leaf Number:

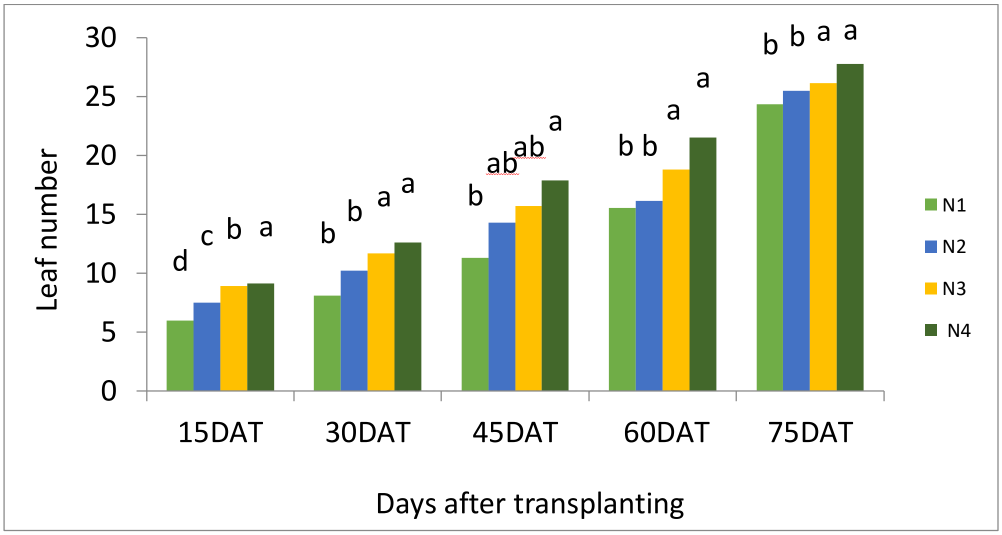
Leaf number was significantly varied at different growth stages of cauliflower due to application of biochar and compost (Figure3 and Appendix VI). The highest leaf number (6.85, 8.98, 12.17, 21 and 26.92 at 15, 30, 45, 60 and 75 DAT respectively)) was obtained from treatment T_2 (biochar and compost) which was statistically different from all other treatments and the lowest leaf number (5.81, 7.1, 11.33, 18.16 and 24.75 at 15, 30, 45, 60 and 75 DAT, respectively) was obtained from treatment T_3 (control) treated plot which was inferior than all other treatments. The leaf number was also observed by Cartel *et al*. (2013). They observed that the leaf number was increased in biochar applied treatment compare to no biochar treatment.



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure 4: Effects of biochar, biochar-compost on leaf number of cauliflower at differen days after transplanting

There was a significant modification on leaf number of cauliflower because of application of different doses of nitrogen at different growth stages (Figure5 and Appendix VI). Maximum leaf number (9.11, 12.59, 17.87, 21.53 and 27.76 at 15, 30, 45, 60 and 75 DAT, respectively) was recorded from N_4 (100% Recommended doses of Nitrogen) which was superior than all other doses of nitrogen. Minimum leaf number (5.97, 8.11, 11.33, 15.54 and 24.34 at 15, 30, 45, 60 and 75 DAT, respectively) was found from N_1 (No Nitrogen) which was inferior than all other doses of nitrogen.



(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure5: Effects of different doses of nitrogen on leaf number of cauliflower at different growth stage

The combined effect of different doses of nitrogen with biochar and compost was observed on leaf number at different growth stages of cauliflower (Table 2). The highest leaf number (7, 9, 12.67, 24 and 28.33 at 15, 30, 45, 60 and 75 DAT, respectively) was recorded from T_2N_3 combination treated plot which was significantly different from all other combination. The lowest leaf number (5, 6, 10.67, 17, 23.33 at 30, 45, 60 and 75 DAT, respectively) was recorded from T_3N_1 combination which was inferior than other combination. The combining effect of biochar and compost with nitrogen was also observed by Trupiano *et al*. (2017 where they observed that the leaf number was increased compare to the control condition.

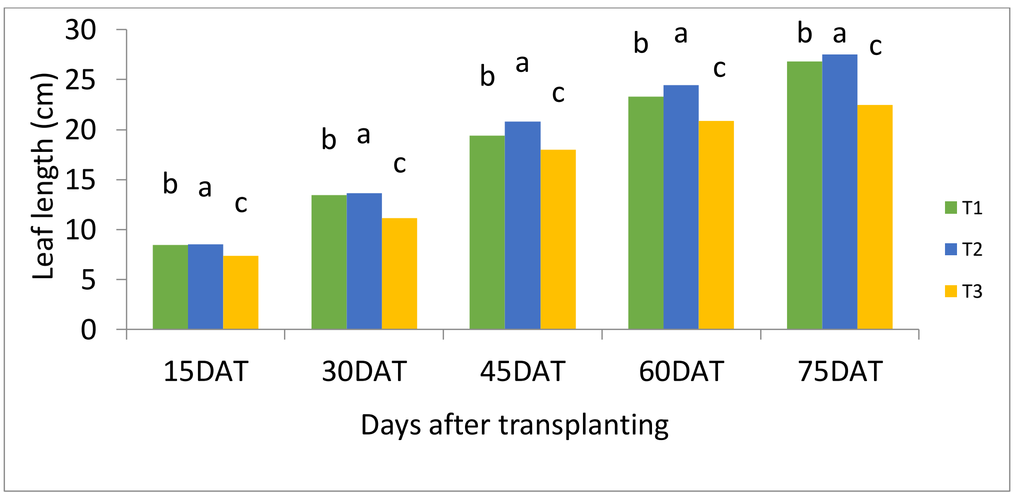
Table2: Combined effect of different doses of nitrogen with biochar and biochar-compost on leaf number of cauliflower at different days after transplanting (DAT)

Treatment	Leaf Number Per Plant				
	15 DAT	30 DAT	45DAT	60 DAT	75 DAT
T_1N_1	5.00c	7.00bc	11.33ab	18.33efg	25.00cde
T_1N_2	6.00b	8.00b	11.33ab	19.00def	26.00bcd
T_1N_3	6.00b	800b	12.33ab	19.67cde	26.67abc
T_1N_4	6.00b	8.00b	12.33ab	21.33bc	27.67ab
T_2N_1	5.00c	7.00b	11.33ab	19.00def	25.33cd
T_2N_2	6.00b	8.00b	12.33ab	20.33cd	26.33bc
T_2N_3	7.00a	9.00a	12.67a	24.00a	28.33a
T_2N_4	7.00a	9.00a	12.33ab	23.00ab	27.67ab
T_3N_1	5.00c	6.00c	10.67b	17.00g	23.33e
T_3N_2	6.00b	6.00c	11.00ab	17.33fg	24.33de
T_3N_3	6.00b	7.00b	12.33ab	18.67defg	25.33cd
T_3N_4	6.00b	8.00b	11.33ab	19.67cde	26.00bcd
CV (%)	5.95	6.38	8.02	5.84	3.90

(Where, T_1: Biochar, T_2: Biochar and Compost, T_3: Control
N_1: No Nitrogen
N_2:50% Recommended dose of Nitrogen
N_3: 75% Recommended dose of Nitrogen
N_4: 100% Recommended dose of Nitrogen)

4.1.3 Leaf Length:

Leaf length was significantly varied at different growth stages of cauliflower due to application of biochar and compost (Figure 6 and Appendix VII). The highest leaf length (8.53, 13.64, 20.79, 24.44 and 27.52 cm at 15, 30, 45, 60 and 75 DAT respectively)) was obtained from treatment T_2 (biochar and compost) which was statistically different from all other treatments and the lowest leaf length (7.36, 11.12, 17.98, 20.89 and 22.49 at 15, 30, 45, 60 and 75 DAT, respectively) was obtained from treatment T_3 (control) treated plot which was inferior than all other treatments. So the combined application of biochar and compost helps to increase leaf length by ensuring maximum release of essential nutrients.

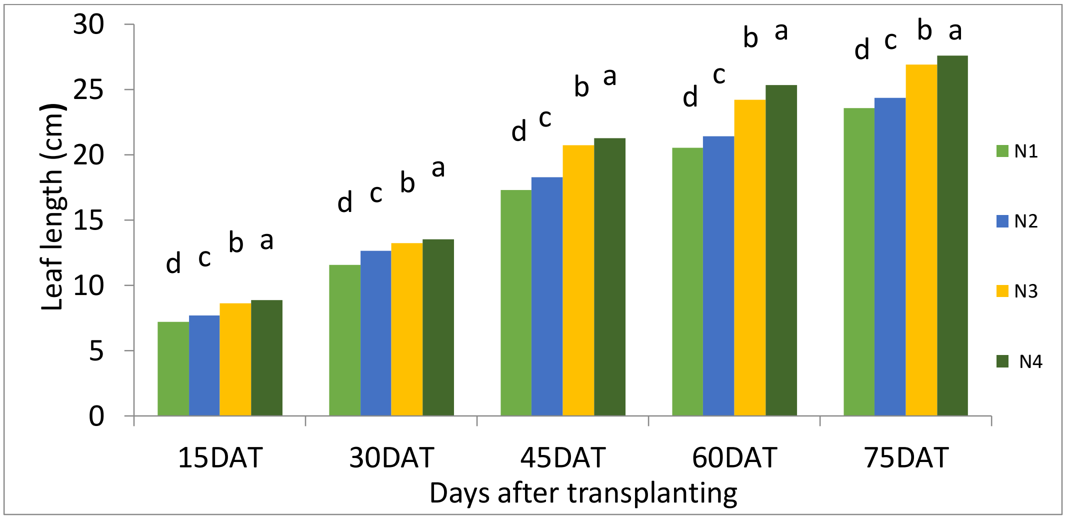


(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure 6: Effects of different organic fertilizers on leaf length of cauliflower at different days after transplanting

There was a significant difference on leaf length of cauliflower because of application of different doses of nitrogen at different growth stages (Figure7 and Appendix VII). Maximum leaf length (8.86, 13.55, 21.29, 25.34 and 27.58 cm at 15, 30, 45, 60 and 75 DAT, respectively) was found from N_4 (100% Recommended doses of Nitrogen) which was superior from other doses of nitrogen. Minimum leaf length (7.2, 11.58, 17.31, 20.55

and 23.58 cm) was found from N_1 (No Nitrogen) which was inferior from other doses of nitrogen. The leaf length was significantly increased in Yadav *et al.* (2004) experiment where they applied different doses of nitrogen.



(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure 7: Effects of different doses of nitrogen on leaf length of cauliflower at different date after transplanting

The combined effect of different doses of nitrogen with biochar and compost was observed on leaf length at different growth stages of cauliflower (Table 3). At 15DAT, the highest leaf length 9.96 cm was recorded from T_2N_3 combination which was statistically identical with T_1N_4 (9.92) combination and the lowest length 6.93 cm was recorded from T_3N_1 combination which was inferior than other combinations. Similarly the highest leaf length (14.54, 23.86, 27.45 and 30.76 cm at 30, 45, 60 and 75 DAT, respectively) was recorded from T_2N_3 combination which was significantly superior from other combinations and also the lowest leaf length (6.93, 10.24, 16.5, 18.22 and 20.86 cm at 15, 30, 45, 60 and 75 DAT, respectively) was recorded from T_3N_1 combination which was inferior from other combination treated plot. The combined application of organic and inorganic fertilizer was increased the leaf length of cabbage in Ghuge *et al.* (2007) experiment.

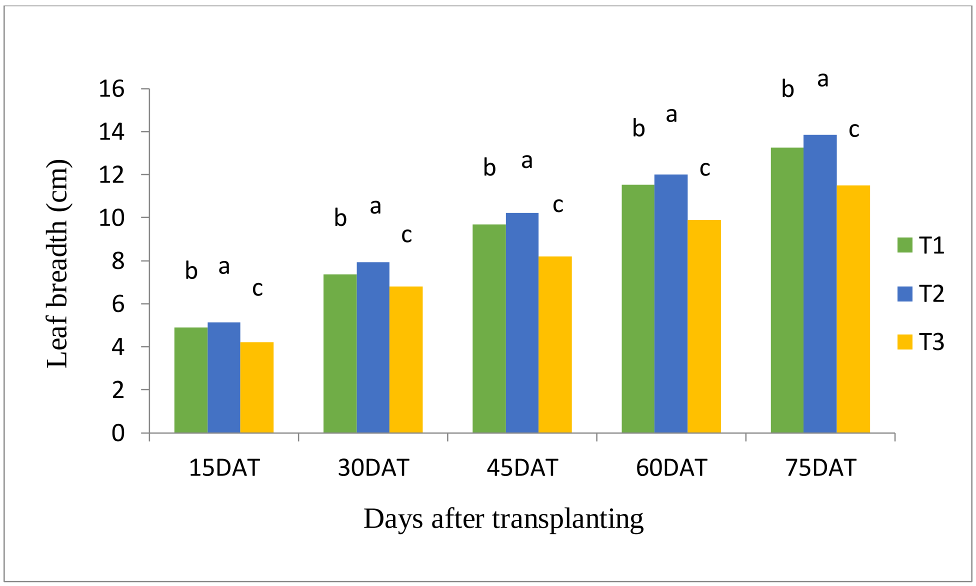
Table3: Combined effects of different doses of nitrogen with biochar and biochar-compost on leaf length (cm) of cauliflower at different days after transplanting (DAT)

Treatment	Leaf Length(cm)				
	15 DAT	30 DAT	45DAT	60 DAT	75 DAT
T_1N_1	7.29ef	12.17e	17.12i	21.51gh	24.72g
T_1N_2	7.90d	13.51d	18.23h	22.37f	25.11f
T_1N_3	8.67b	13.95c	19.78d	24.98e	27.45d
T_1N_4	9.92a	14.25b	22.51a	25.32c	29.91b
T_2N_1	7.38e	12.32e	18.32g	21.92fg	25.12f
T_2N_2	8.06c	13.63d	19.43e	22.46f	26.53e
T_2N_3	9.96a	14.54a	23.86a	27.45a	30.76a
T_2N_4	8.73b	14.10b	21.56c	25.92b	27.68c
T_3N_1	6.93g	10.24h	16.50j	18.22j	20.86j
T_3N_2	7.19f	10.75g	17.12i	19.45i	21.38i
T_3N_3	7.32e	11.21f	18.52f	21.13h	22.57h
T_3N_4	8.013c	12.31e	19.81d	24.77c	25.16f
CV (%)	0.80	0.75	0.23	1.33	0.22

(Where, T_1: Biochar, T_2: Biochar and Compost, T_3: Control
N_1: No Nitrogen N_2:50% Recommended dose of Nitrogen
N_3: 75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

4.1.4 Leaf Breadth:

Leaf breadth was significantly varied at different growth stages of cauliflower because of application of biochar and compost (Figure 8 and Appendix VIII). At 15, 30, 45, 60, 75 DAT the maximum leaf breadth 5.14, 7.94, 10.24, 12 and 13.84 cm was recorded at treatment T_2 (biochar and compost) and T_2 (biochar and compost) was significantly different from other treatments. Minimum 4.21, 6.79, 8.19, 9.88 and 11.49 cm were observed at treatment T_3 (control) and T_3 (control) was inferior than other treatments. The leaf breadth was also increased in Velmurugan *et al*. (2008) experiment.

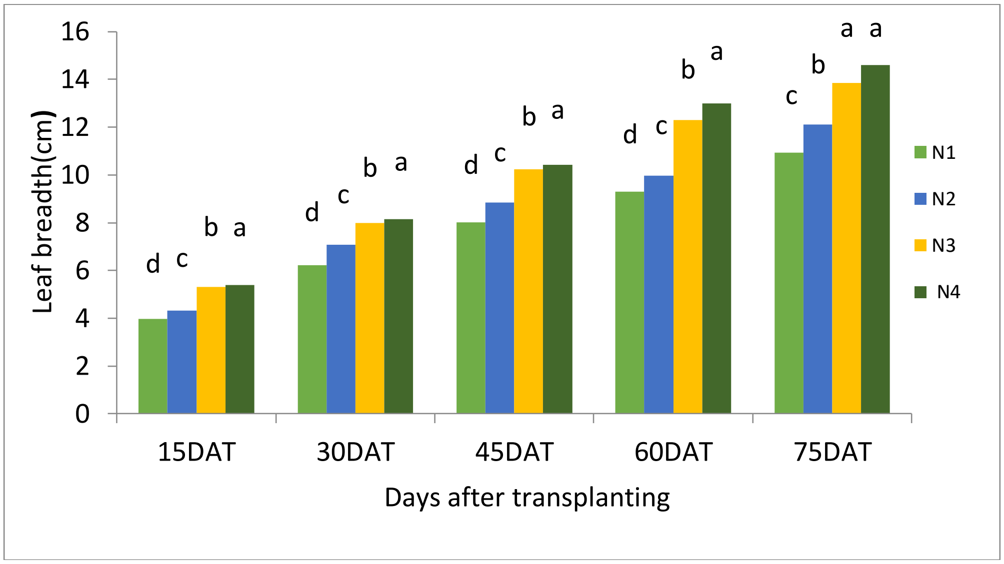


(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure 8: Effects of different organic fertilizers on leaf breadth of cauliflower at different days after transplanting

Significant variation on leaf breadth at different growth stages of cauliflower influenced by different doses of nitrogen (Figure9 and Appendix VIII). The maximum leaf breadth (5.39, 8.14, 10.42, 12.98 and 14.58 cm at 15, 30, 45, 60 and 75 DAT, respectively) was recorded from N_4 (100% Recommended dose of Nitrogen) which was superior from other doses of nitrogen and minimum (3.97, 6.23, 8.01, 9.29 and 10.93 cm at 15, 30, 45, 60 and

75 DAT, respectively) was recorded from N_1 (No Nitrogen) which was inferior than other doses of nitrogen.



(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure 9: Effects of different doses of nitrogen on leaf breadth of cauliflower different Days after transplanting

Distinguished variation was observed on leaf breadth at different growth stages of cauliflower by the combined application of different doses of nitrogen with biochar, compost (Table4). At 15DAT, the highest leaf breadth (5.88 cm) was found at T_2N_3 combination which was significantly different from other combinations whereas lowest leaf breadth (3.37 cm) was found at T_3N_1 combination treated plot which was inferior than other combination. The maximum breadth (8.96, 11.82, 14.43 and 15.29 cm at 30, 45, 60 and 75 DAT, respectively) was recorded from T_2N_3 combination which was superior than other combinations and minimum breadth (3.37, 5.99, 6.91, 8.18 and 9.81 cm at 15, 30 ,45, 60 and 75 DAT, respectively) was recorded from T_3N_1 combination which was inferior than other combinations. Trupiano *et al*. (2017) observed a little difference on leaf breadth of lettuce leaf by applying combined effect of biochar and compost.

Table 4: Combined effect of different doses of nitrogen with biochar and compost on leaf breadth (cm) of cauliflower at different days after transplanting (DAT)

Treatment	Leaf Breadth				
	15 DAT	30 DAT	45DAT	60 DAT	75 DAT
T_1N_1	4.17j	6.12h	8.18j	9.72i	11.21fg
T_1N_2	4.52h	7.21e	9.32g	10.11g	12.76cde
T_1N_3	5.37d	7.92d	10.13d	12.33d	13.87bc
T_1N_4	5.55b	8.18c	11.16b	13.92b	15.18a
T_2N_1	4.39i	6.58g	8.93h	9.95h	11.76ef
T_2N_2	4.817f	7.89d	9.67e	10.56f	13.41cd
T_2N_3	5.88a	8.96a	11.82a	14.43a	15.29a
T_2N_4	5.46c	8.31b	10.52c	13.09c	14.90ab
T_3N_1	3.37l	5.99i	6.91l	8.19k	9.81h
T_3N_2	3.62k	6.15h	7.51k	9.25j	10.15gh
T_3N_3	4.67g	7.09f	8.76i	10.15g	12.35def
T_3N_4	5.18e	7.93d	9.51f	11.93e	13.68c
CV (%)	0.62	0.54	0.42	0.47	0.52

(Where, T_1: Biochar, T_2: Biochar and Compost, T_3: Control

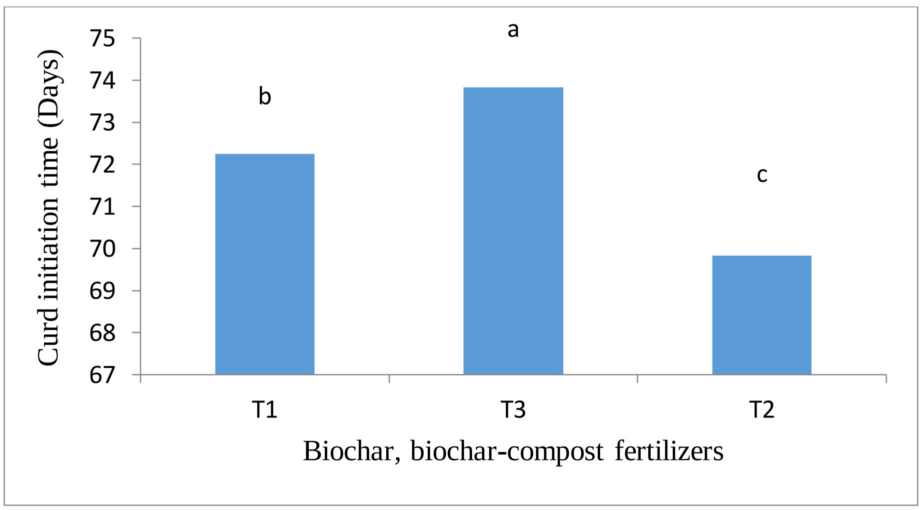
N_1: No Nitrogen N_2:50% Recommended dose of Nitrogen

N_3: 75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

4.2 Yield Parameters:

4.2.1 Curd initiation time:

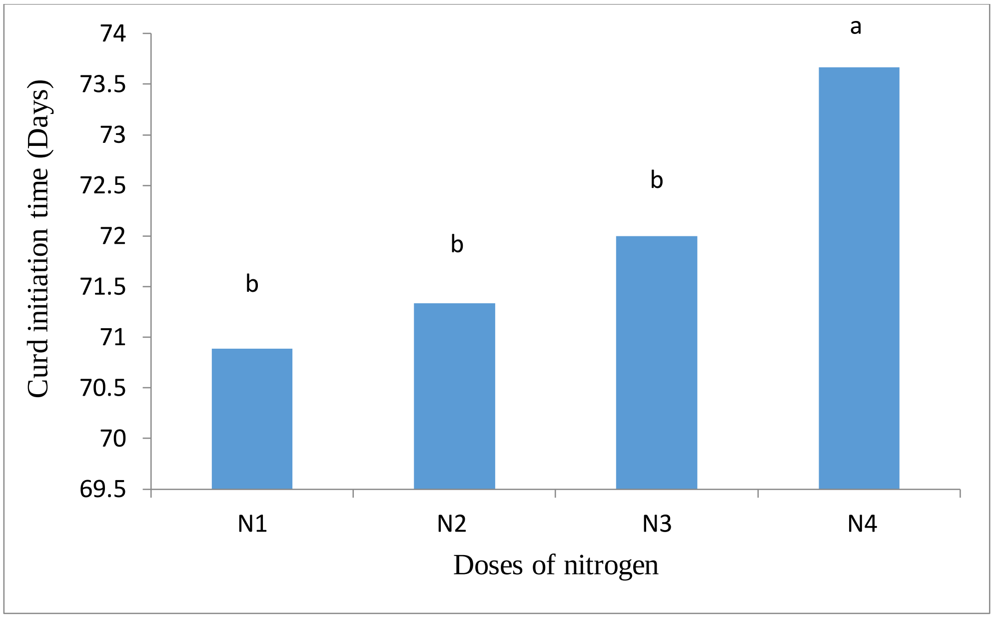
Curd initiation time was influenced by application of biochar and compost (Figure10 and Appendix IX). Maximum time (73.67 days) was needed for curd initiation at treatment T_3 (control) and minimum time (69.83 days) was needed for treatment T_2 (biochar and compost). When the combined application of biochar and compost was done, the variety gave an early production because of the organic fertilizer ensures the maximum availability of nutrients.



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure10: Effects of biochar, biochar-compost on curd initiation time of cauliflower

Different doses of nitrogen was applied to the cauliflower field at different growth stages (Figure11 and Appendix IX). When 100% recommended dose of nitrogen (N_4) was applied, it took maximum time (73.67 days) for curd initiation compare to the other doses. When no nitrogen was applied to the field it took the minimum time (70.89 days) for curd initiation which was statistically similar with N_1 (71.33 days) (50% recommended dose of nitrogen) and N_2 (72days) (75%recommended dose of nitrogen).



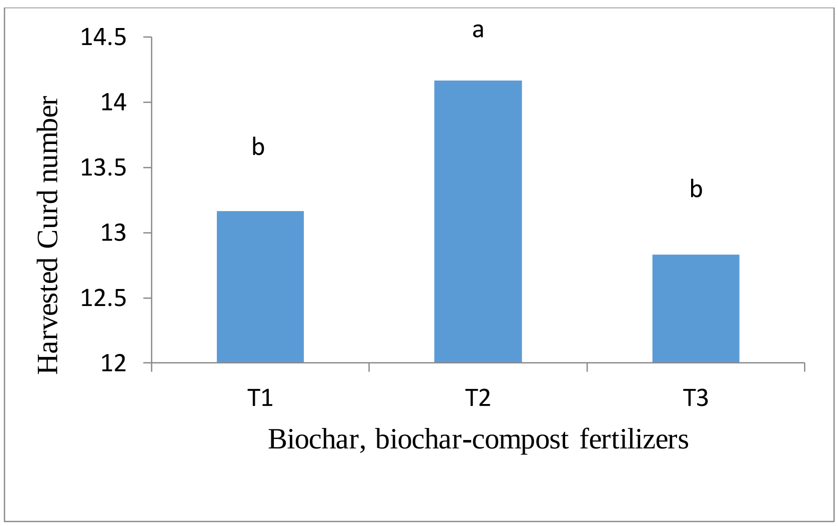
(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure11: Effects of different doses of nitrogen on curd initiation time of cauliflower

Combined effects of different doses of nitrogen and organic fertilizers on curd initiation time (days) was observed (Table 5). The highest number of days (75.33 days) was required at T_3N_1 combination which was statistically identical with T_1N_1 (74 days) and T_3N_2 (74 days) combination treated plot. The lowest number of days (68.33 days) required for T_2N_3 combination which was statistically identical with T_2N_4 (69 days) combination treated plot. When the combined application of biochar and compost with nitrogen was done it took lower days for curd initiation than the other combinations.

4.2.2 Total number of harvested curd:

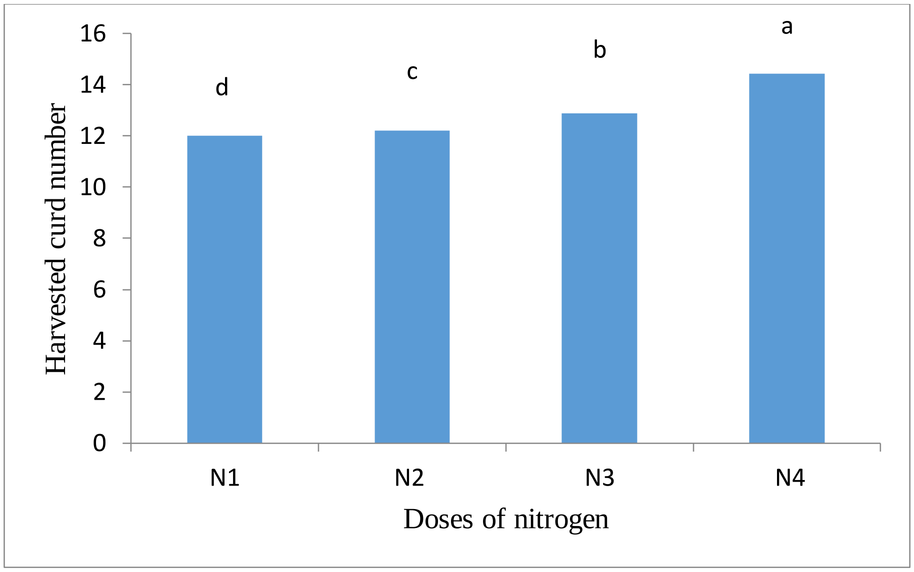
Remarkable variation was found on total number of harvested curd of cauliflower due to application of biochar and compost (Figure 12 and Appendix IX). The highest number of curd (14.17) was collected from treatment T_2 (biochar and compost) treated plot whereas the lowest number (12.83) was collected from treatment T_3 (control) treated plot. The results showed that the combined effect of biochar and compost assisted to increase the curd number by ensuring maximum release of essential nutrients.



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control

Figure12: Effects of biochar, biochar-compost on curd number of cauliflower

There was a significant variation on total number of harvested curd influenced by application of different doses of nitrogen (Figure13 and Appendix IX). The highest number (14.44) and the lowest number (12) of curd were harvested from N_4 (100% Recommended dose of Nitrogen) and N_1 (No Nitrogen) treated plot, respectively.



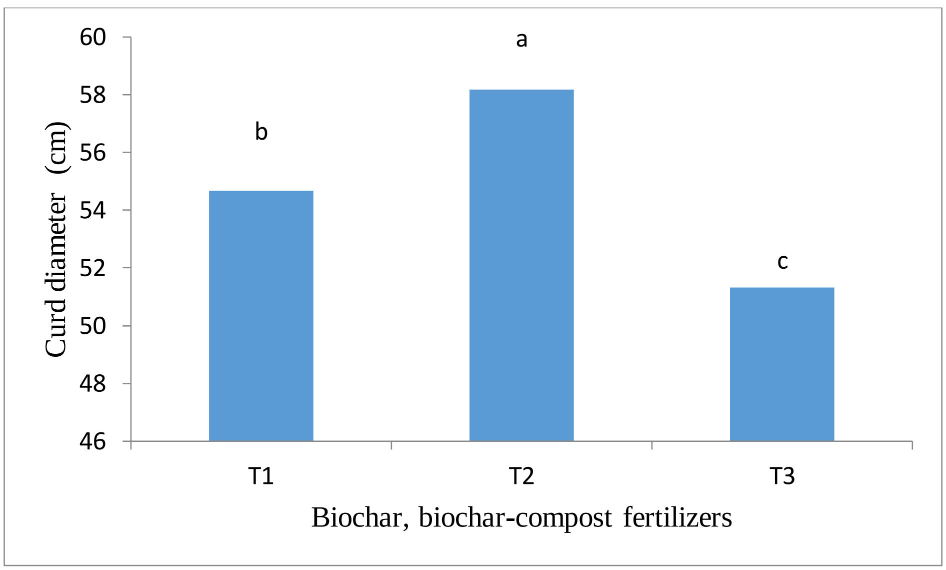
(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure 13: Effects of different doses of nitrogen on curd number of cauliflower

There was a significant variation observed on total number of harvested curd per plot from the combined application of different doses of nitrogen with organic fertilizer (biochar and compost) (Table 5).The maximum number of curd (15.00) was harvested from T2N3 combination which was statistically similar to T_2N_4 (15.00) and T_1N_4 (14.33) combination whereas minimum number of curd (11.67) was harvested from T_3N_1 combination which was statistically similar toT_1N_1 (12.00) combination treated plot. Lehmann *et al*. (2003) showed that the biochar application in nitrogen deficient soils could be due to high carbon, nitrogen ratio, hence it might reduce crop productivity provisionally. On the other hand, Murlee *et al*. (2007) determined that the combined effect of organic and inorganic fertilizer gave the significant number of curd.

4.2.3 Curd diameter:

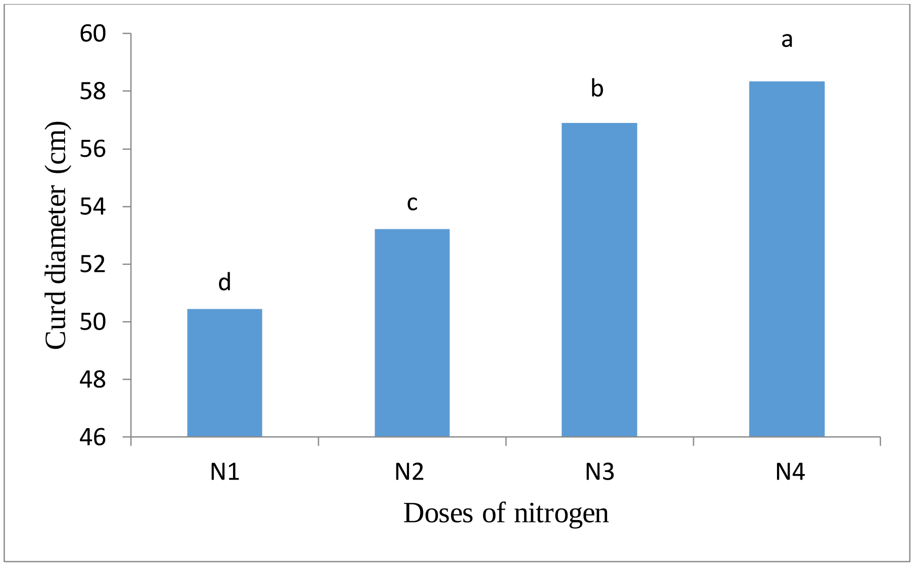
Significant variation was observed on curd diameter of cauliflower by applying different organic fertilizer such as biochar and compost (Figure14 and Appendix IX). Maximum 58.17 cm from T_2 (biochar and compost) and minimum 51.33 cm from T_3 (control) was observed. Head diameter of cabbage was also increased in Bahadur *et al.* (2004) experiment where they compared organic manure with bio fertilizer treatments with control.



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control

Figure14: Effects of organic fertilizers on curd diameter of cauliflower

The recorded data on curd diameter was statistically significant due to different doses of nitrogen application (Figure15 and Appendix IX). The highest curd diameter (58.33 cm) was observed at N_4 (100% Recommended dose of Nitrogen) and the lowest diameter (50.44 cm) was observed at N_1 No Nitrogen).



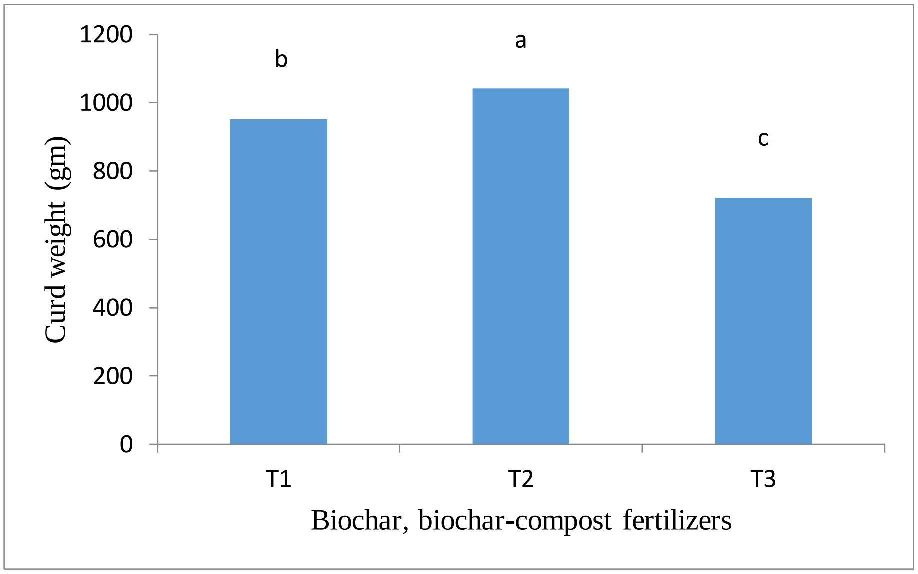
(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure15: Effects of different doses of nitrogen on curd diameter of cauliflower

Curd diameter was influenced by the combined application of different doses of nitrogen with organic fertilizer (Table 5). T_2N_3 combination was revealed the highest (62.33cm) diameter of cauliflower curd which was statistically identical with T_2N_4 (62.33cm) combination. On the other hand, the lowest diameter (48.67cm) was revealed at T_3N_1 combination plot which was statistically similar with T_3N_2 (50.33cm) combination treated plot. Kanwaret *et al.* (2002) reported that the 50% of NPK fertilizer with organic manure gave significant curd diameter compared to 100% of NPK fertilizer.

4.2.4 Individual Curd weight:

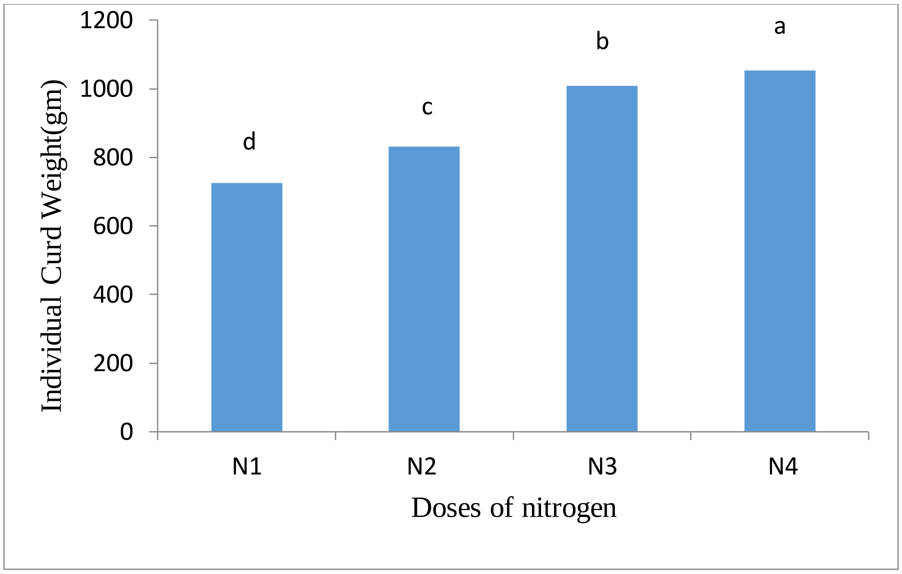
Weight of individual curd of cauliflower was significantly varied by application of biochar and compost (Figure16 and Appendix IX). The maximum individual weight (1041.9 gm) of cauliflower curd was observed from treatment T_2 (biochar and compost) which was different from all other treatment and minimum weight (722.2 gm) was obtained from treatment T_3 (control) treated plot. The maximum head weight of cabbage was observed by Bahadur *et al.* (2004) when the combined application of organic manures and bio fertilizer was done.



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure 16: Effects of biochar, biochar-compost fertilizer on weight of cauliflower

The weight of individual curd of cauliflower was influenced by application of different doses of nitrogen at different growth stages of cauliflower (Figure17 and Appendix IX) The highest curd weight (1053.6 gm) was recorded from N_4(100% Recommended dose of Nitrogen) and the lowest weight (725.8 gm) was recorded from N_1 (No Nitrogen).



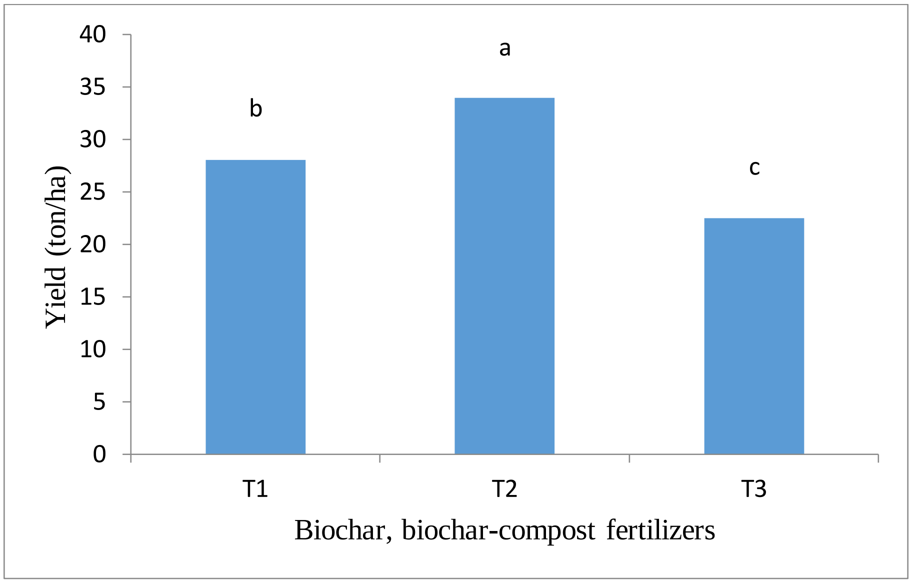
(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure17: Effects of different doses of nitrogen on curd weight of cauliflower

There was a significant variation was occurred on individual curd weight of cauliflower by using the combination of different doses of nitrogen with organic fertilizer (Table 5). The maximum curd weight 1233.0 gm from T_2N_3 and the minimum 549.0 gm from T_3N_1 combination were recorded. The combined effect of 75% recommended doses of nitrogen with biochar and compost gave the best result. On the other hand, Kanwar *et al*. (2002) found the maximum curd weight at 50% NPK level with organic manure compare to 100% NPK level with manure.

4.2.5 Total yield (ton/ha):

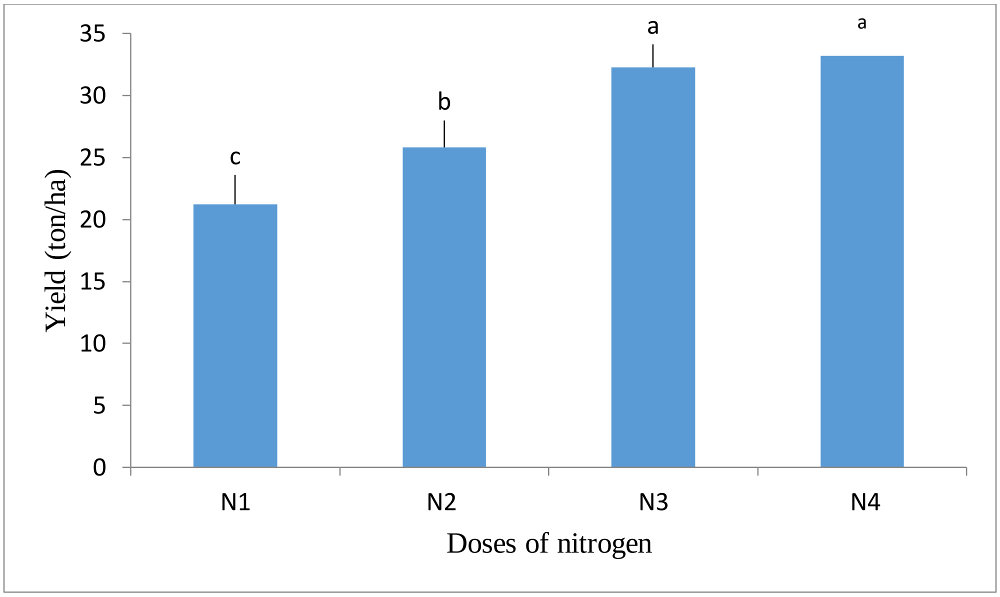
Yield of cauliflower was significantly varied from each other due to application of biochar and compost (Figure18 and Appendix IX). The highest yield (33.94 ton/ha) was observed from treatment T_2 (biochar and compost). The lowest yield (22.46 ton/ha) was observed from treatment T_3 (control) treated plot. The best observation found in treatment T_2 treated plot where both biochar and compost were present by ensuring maximum amount of available nutrient. The effect of biochar on yield of maize, cowpea, peanut was observed by Yamato *et al*. (2006). They observed that the yield was increased due to biochar application.



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure18: Effects of organic fertilizer on yield of cauliflower

Application of different doses of nitrogen at different growth stages showed an efficient result on yield of cauliflower (Figure19 and Appendix IX). The highest yield (33.20 ton/ha) was observed from treatment N_4 (100% Recommended dose of Nitrogen) which was significantly identical with treatment N_3 (75% Recommended dose of Nitrogen) .The lowest yield (21.22 ton/ha) was observed from N_1 (No Nitrogen) treated plot.



(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure19: Effects of different doses of nitrogen on yield of cauliflower

The combined application of different doses of nitrogen with biochar and compost was observed on the yield of cauliflower (Table 5). The highest yield (40.94 ton/ha) was obtained from T_2N_3 combination which was statistically different from all other combinations and the minimum yield (16.51 ton/ha) was found from T_3N_1 combination treated plot. The combined application of biochar, compost and 75% recommended dose of nitrogen was showed the best result. This observation was also recorded by Sen et al. (2018).They recorded that the biochar and compost had the significant effect on plant height, number of fruits, length and breadth of fruit, individual fruit weight and fresh yield of tomato.

Table5: Combined effects of different doses of nitrogen with biochar, biochar-compost on curd initiation time (days), curd diameter (cm), curd weight (gm), total number curd harvested per plot and total yield (ton/ha)

Treatments	Curd initiation time (days)	Curd diameter (cm)	Curd weight (gm)	Total number of curd harvested(per plot)	Total yield (ton/ha)
T_1N_1	74.00ab	51.00e	803.7f	12.00ef	21.71h
T_1N_2	71.67cde	53.00d	940.7cd	12.67de	28.31ef
T_1N_3	71.67cde	57.00b	1071.7b	13.67bc	32.25c
T_1N_4	71.67de	57.67b	990.3c	14.33ab	29.77cde
T_2N_1	71.67cde	51.67de	824.7f	13.00cd	25.44g
T_2N_2	70.33ef	56.33bc	984.0c	13.67bc	31.14cd
T_2N_3	68.33g	62.33a	1233.0a	15.00a	40.94a
T_2N_4	69.00fg	62.33a	1126.0b	15.00a	38.22b
T_3N_1	75.33a	48.67f	549.0g	11.67f	16.51i
T_3N_2	74.00ab	50.33ef	571.7g	12.67de	18.07i
T_3N_3	72.67bcd	51.33de	856.0ef	13.00cd	26.42fg
T_3N_4	73.33bc	55.00c	912.0de	14.00b	28.86def
CV(%)	1.26	1.71	2.82	3.41	5.65

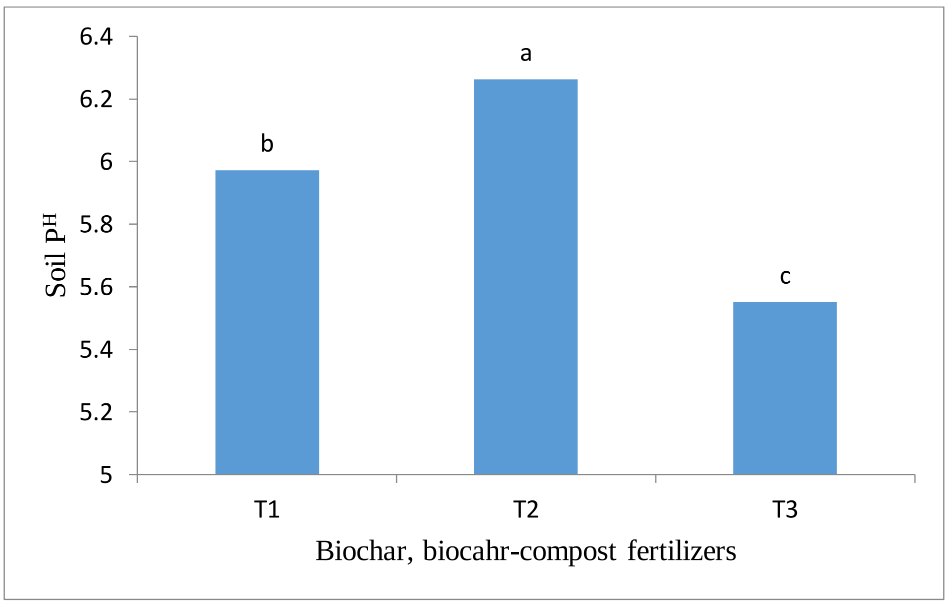
(Where, T_1: Biochar, T_2: Biochar and Compost, T_3: Control
N_1: No Nitrogen N_2:50% Recommended dose of Nitrogen
N_3: 75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

4.3 Soil parameters

Soil parameters were compared among T_1 (biochar), T_2 (biochar-compost) and T_3 (control) treatments treated plot to observe their changes in soil.

4.3.1 Soil P^H :

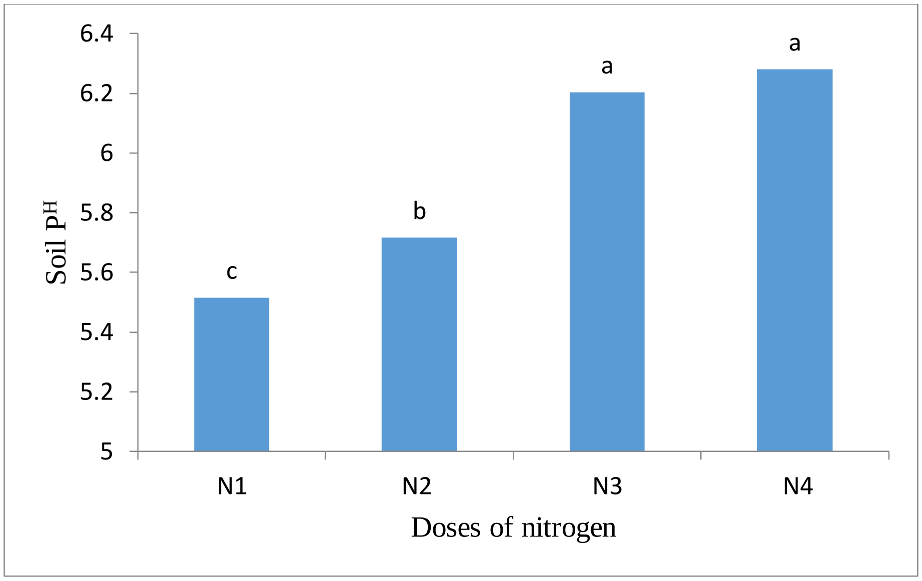
There was a significant variation was observed on soil P^H due to application of biochar and compost (Figure 20 and Appendix X). The maximum (6.25) soil P^H was found at treatment T_2 and minimum (5.55) was at treatment T_3. Zhang *et al*. (2012a) observed that the soil p^H was increased when biochar was applied to the field. Yamato *et al*. (2006) was also found that after applying biochar the soil pH was increased.



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure 20: Effects of biochar, biochar-compost on soil P^H after harvesting

Non significant variation was observed in soil P^H because of different doses of nitrogen application (Figure 21 and Appendix X). The maximum P^H 6.28 was recorded at N_4 (100% recommended dose of nitrogen) which was statistically similar to N_3 (6.20) (75% recommended dose of nitrogen). The minimum P^H 5.52 was recorded at N_1 (no nitrogen).



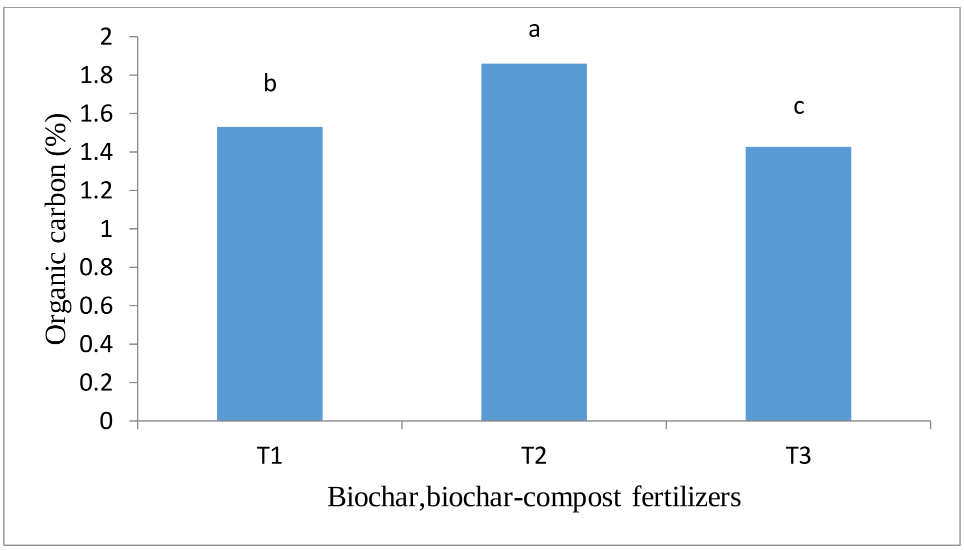
(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure21: Effects of different doses of nitrogen on soil P^H after harvesting

The combined application of different doses of nitrogen with biocar and compost on soil P^H was recorded (Table 6). The maximum soil P^H (6.70) was observed at T_2N_3 combination which was statistically identical with T_1N_4 (6.47) combination and the minimum P^H was recorded from T_3N_1 (5.19) combination which one was also statistically identical with T_3N_2 (5.38) and T_1N_1 (5.43) combination.

4.3.2 Organic Carbon (%):

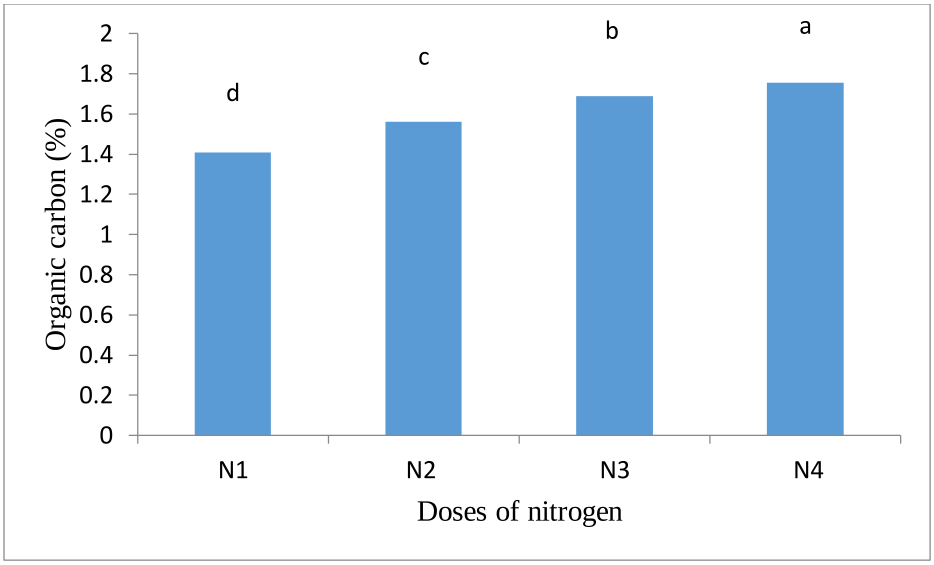
There was a significant variation was recorded in soil organic carbon for different fertilizers such as biochar, compost after harvesting cauliflower (Figure 22 and Appendix X).The maximum(1.86%) soil organic carbon was recorded from T_2 (biochar and compost) and minimum (1.43%) from T_3(control). Most incredible changes were observed in the total organic carbon contents in soils where carbon contents were increased by 25–33% from the initial levels (Haque et al. 2018). This finding is similar to the recorded value where organic carbon was increased.



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure22: Effects of biochar, biochar-compost on organic carbon after harvesting

Soil organic carbon was recorded from different doses of nitrogen after harvesting (Figure 23 and Appendix X). The maximum organic carbon 1.76% was recorded from N_4 (100% recommended dose of nitrogen) and minimum 1.41% was recorded from N_1 (no nitrogen). Rice husk and eucalyptus biochars along with optimum N fertilizer needs to be ensured in crop production which could limit mineralization and supply stable carbon in soil (Hasnat et al. 2018).



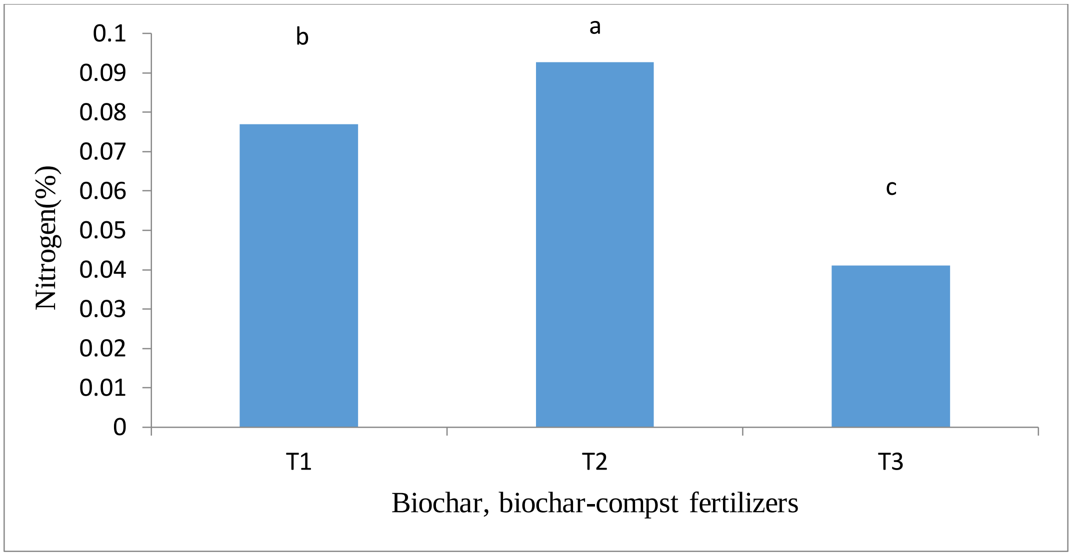
(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure23: Effects of different doses of nitrogen on organic matter after harvesting

The combined effects of different doses of nitrogen with biochar and compost was significantly observed on organic carbon after harvesting (Table6). The maximum 1.97% organic carbon was recorded from T_2N_3 combination which was statistically similar to T_2N_4 (1.91%) and the minimum value 1.14% was recorded from T_3N_1 combination.

4.3.3 Total Nitrogen (%):

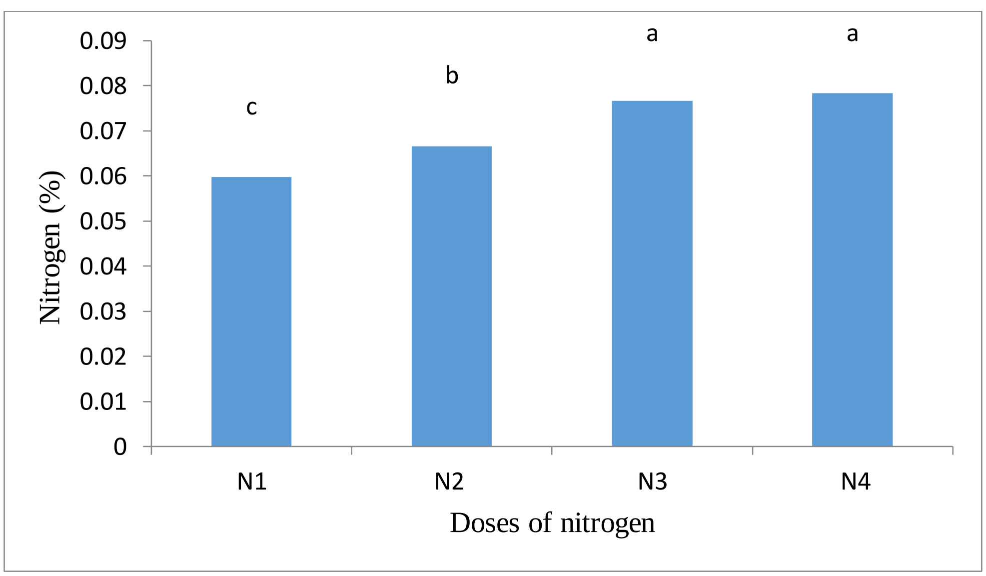
Nitrogen percentage was recorded from different fertilizer such as biochar, compost treated plot (Figure24 and Appendix X). The maximum nitrogen percentage 0.093% was recorded from treatment T_2 (biochar and compost) and minimum 0.04% was recorded from treatment T_3 (control) treated plot. Biochar with compost addition in soil increases the mineral N retention due to $NH4^+$ capture at cation exchange sites and NO_3 adsorption in the base functional group at high pH. Microbial immobilization is also responsible for N recycling and retention (Mia et al. 2018).



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure 24: Effects of biochar, biochar-compost on nitrogen percentage after harvesting

After harvesting the nitrogen percentage was observed from the different doses of nitrogen (Figure25 and Appendix X) which was applied to the field. The maximum nitrogen percentage (0.78%) was recorded from N4 (100% recommended dose of nitrogen) which was statistically similar to N_3 (0.77%) (75% recommended dose of nitrogen) and minimum (0.059%) from N_1 (No nitrogen).



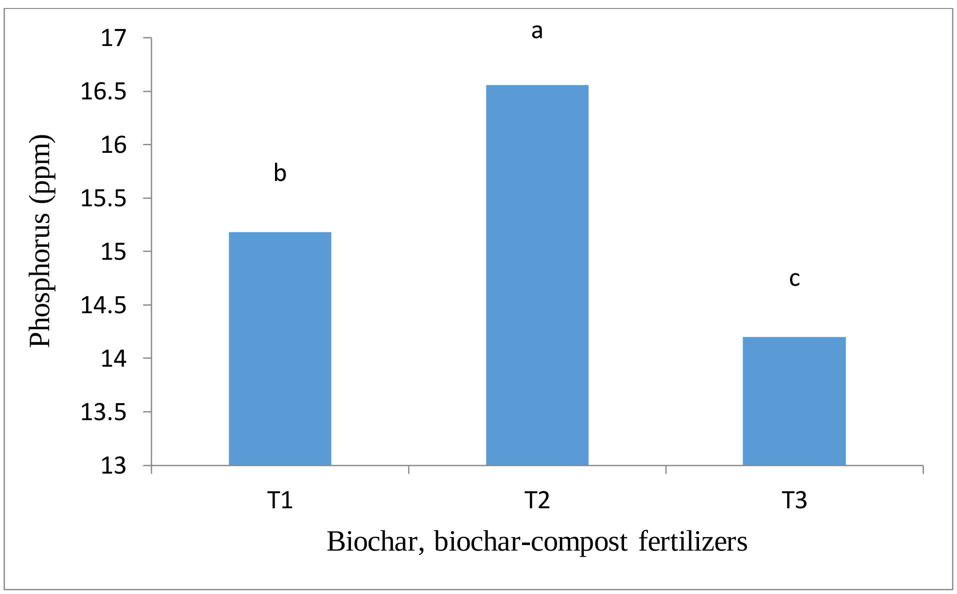
(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure 25: Effects of different doses of nitrogen on nitrogen percentage after harvesting

The combined effect of different doses of nitrogen with biochar and compost was recorded (Table 6). The highest percentage of nitrogen (0.1%) was recorded from T_2N_3 and the lowest percentage (0.03%) was recorded from T_3N_1 combination treated plot.

4.3.4 Phosphorus:

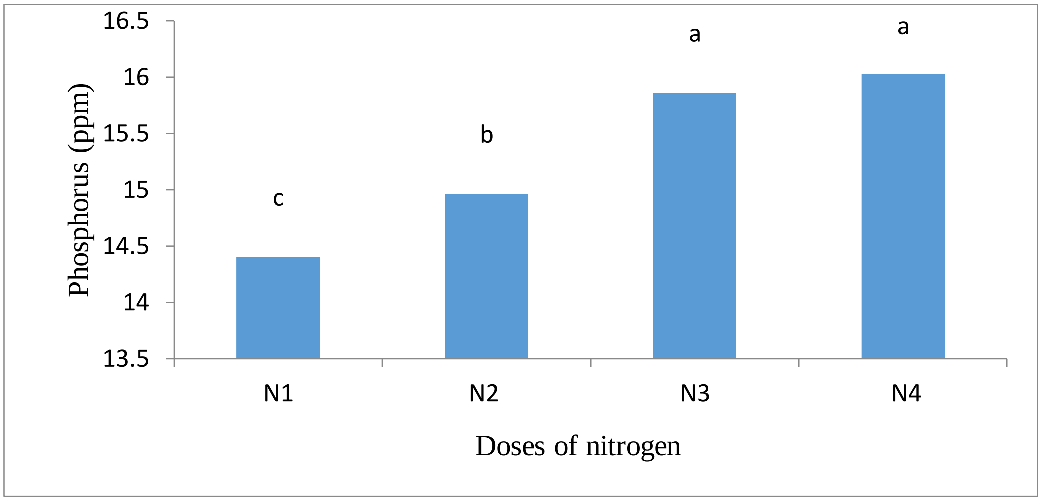
After harvesting the amount of phosphorus was recorded from different organic fertilizers treatment treated plot (Figure26 and Appendix X). The maximum (16.56 ppm) and minimum (14.2 ppm) amount of phosphorus were recorded from treatment T_2 (biochar and compost) and T_3 (control), respectively. Phosphorous availability increases after biochar amendment as it increases soil pH and releases high charged small molecule humic acids (Mia et al. 2018). Also the conducted experiment gave the higher amount of phosphorus where biochar and compost's combined application was done.



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure26: Effects of biochar, biochar-compost on phosphorus after harvesting

Amount of phosphorus was observed from different doses of nitrogen which was applied to the plot (Figure 27 and Appendix X). The maximum amount (16.03 ppm) of phosphorus was recorded from N_4 (100% recommended dose of nitrogen) which was statistically identical with N_3 (15.86 ppm) (75% recommended dose of nitrogen).The minimum amount (14.4 ppm) was recorded from N_1 (No nitrogen).



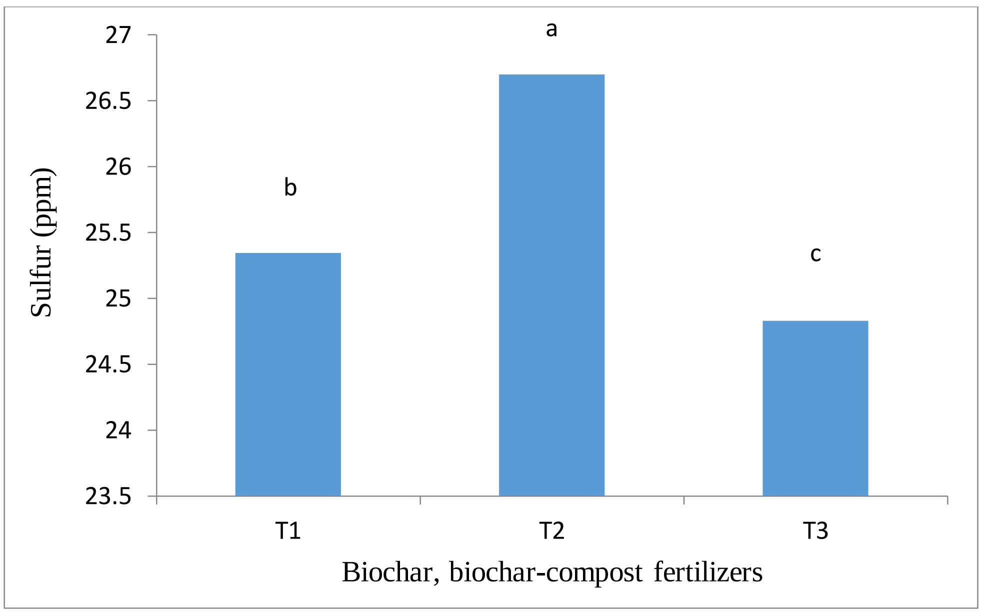
(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure27: Effects of different doses of nitrogen on phosphorus after harvesting

Significant observation was found on phosphorus when the combined application of different doses of nitrogen with organic fertilizer was done (Table 6).The maximum amount (17.78 ppm)of phosphorus was recorded from T_2N_3 combination and minimum amount (12.91 ppm) from T_3N_1 combination treated plot.

4.3.5 Sulfur:

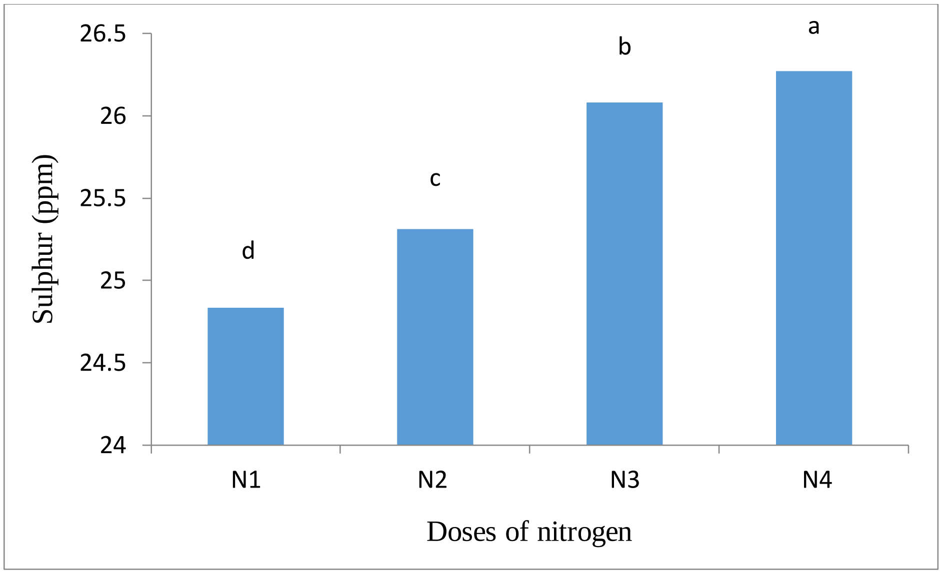
The effect of biochar, biochar-compost on sulfur after harvesting was significantly calculated (Figure 27 and Appendix X). The maximum (26.7 ppm) sulfur was found at treatment T_2 (biochar and compost) and minimum (24.83 ppm) was found at treatment T_3 (control). Trupiano *et al.* (2017) was observed that after applying biochar and compost to the lettuce field, the concentration of sulfur was increased in the soil of the experimental field.



(Here, T_1: Biochar T_2: Biochar and Compost T_3: Control)

Figure 28: Effects of biochar, biochar-compost on sulfur after harvesting

After harvesting the amount of sulfur was recoded from the different doses of nitrogen applied to the field (Figure 28 and Appendix X). The highest amount (26.27 ppm) of sulfur was recorded from N_4 (100% recommended dose of nitrogen) and the lowest amount (24.84 ppm) was from N_1 (No nitrogen).



(Here, N_1: No Nitrogen N_2: 50% Recommended dose of Nitrogen
N_3:75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

Figure 28: Effects of different doses of nitrogen on sulfur after harvesting

The combined effect of different doses of nitrogen with biochar and biochar-compost was revealed a significant result (Table 6). The maximum sulfur content combination was T_2N_3 and it was 27.72 ppm. The minimum sulfur content combination was T_1N_1 and it was 24.55 ppm. The combining effect of biochar, compost with nitrogen was observed by Trupiano *et al.* (2017). They observed that the total nitrogen and phosphorus was improved the soil. The available N, P and K were substantially higher in the biochar and compost treated soils compared to the compost treated soils (Khan et al. 2014). Soil amendments with biochar could recover similar to 46%, 54%, 54% and 61% of total C, N, P and K content as additive, respectively. So, significant amount of nutrients could be recycled to soil while biochar was applied for crop production (Mia et al. 2018).

Table 6: Combined effects of different doses of nitrogen with biochar, biochar-compost on soil $P^{H,}$ Organic carbon (%), Nitrogen (%), Phosphorus (ppm), Potassium (meq/100gm soil), Sulfur (ppm)

Treatment	PH	OC (%)	N (%)	P (ppm)	S (ppm)
T_1N_1	5.43gh	1.34f	0.06e	14.70f	24.57h
T_1N_2	5.73ef	1.54e	0.07d	15.02ef	25.05f
T_1N_3	6.26bc	1.58de	0.08c	15.19def	25.70d
T_1N_4	6.47ab	1.66cd	0.09bc	15.81cd	26.07c
T_2N_1	5.92de	1.74bc	0.08bc	15.59cde	25.39e
T_2N_2	6.04cd	1.81b	0.08bc	16.00c	26.23c
T_2N_3	6.70a	1.97a	0.01a	17.78a	27.72a
T_2N_4	6.38b	1.90a	0.09b	16.85b	27.46b
T_3N_1	5.19h	1.14g	0.03h	12.91h	24.56h
T_3N_2	5.38h	1.33f	0.03gh	13.86g	24.65gh
T_3N_3	5.65fg	1.52e	0.04g	14.61f	24.82g
T_3N_4	5.99d	1.70c	0.05f	15.43cde	25.28e
CV (%)	2.37	3.44	7.46	2.95	0.58

(Where, T_1: Biochar, T_2: Biochar and Compost, T_3: Control

N_1: No Nitrogen N_2:50% Recommended dose of Nitrogen

N_3: 75% Recommended dose of Nitrogen N_4: 100% Recommended dose of Nitrogen)

CHAPTER V

SUMMARY, CONCLUSION, RECOMMENDATIONS

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 2019 to January 2020 to study the effects of biochar, biochar-compost on cauliflower performance and soil fertility. The experiment was set out in two factors split plot design with three replications. The two factors, Factor A: Four doses of nitrogen such as N_1 (No Nitrogen), N_2 (50% Recommended doses of Nitrogen), N_3 (75% Recommended doses of Nitrogen) and N_4 (100% Recommended doses of Nitrogen). Factor B: T_1 (Biochar), T_2 (Biochar and Compost), T_3 (Control). After initial land preparation, the land was divided into 36 small plot and size of each small plot was 2.4m × 1.8m. Among 36 plot, 3 replication and each replication had 12 combinations. The variety, Snow White which was collected from Rangpur. Vegetative parameters on different growth stages, yield parameters of cauliflower and soil data was recorded after harvesting.

Biochar with compost showed significant difference on vegetative and yield parameters. Growth parameters: The highest plant height (15.76, 22.89, 38.61, 47.39 and 56.61 cm at 15, 30, 45, 60, 75 DAT, respectively), leaf number per plant (6.85, 8.98, 12.17, 21.58 and 26.92 at 15, 30, 45, 60 and 75 DAT, respectively), leaf length (8.53, 13.65, 20.79, 24.44 and 27.53 at 15, 30, 45, 60 and 75 DAT, respectively), leaf breadth (5.14, 7.94, 10.24, 12.01 and 13.84 cm at 15, 30, 45, 60, 75 DAT, respectively), curd initiation time (73.67 days), number of curd per plot (14.17), curd diameter (58.17 cm), individual curd weight

(1041.9 gm) and total yield (33.94 ton/ha) was obtained from the treatment T_2 (biochar, compost) and it was superior from other treatments. The lowest plant height (13.50, 21.39, 37.73, 46.48 and 53.88 cm at 15, 30, 45, 60 and 75 DAT, respectively), leaf number per plant (5.81, 7.1, 11.33, 18.17 and 24.75 at 15, 30, 45, 60 and 75 DAT, respectively), leaf length (7.36, 11.13, 17.98, 20.89 and 22.49 at 15, 30, 45, 60 and 75 DAT, respectively), leaf breadth (4.21, 6.79, 8.19, 9.89 and 11.49 cm at 15, 30, 45, 60 and 75 DAT, respectively), curd initiation time (69.83 days), harvested curd number (12.83), curd diameter (51.33 cm), individual curd weight (722.2 gm) and total yield (22.46 ton/ha) were obtained from the treatment T_3 (control) and it was inferior than other treatments.

Application of different doses of nitrogen, most of the vegetative and yield parameters were significantly influenced. The highest plant height (15.47 cm, 24.04 cm, 40.19 cm, 48.29 cm, 57.29 cm at 15, 30, 45, 60 and 75 DAT, respectively), number of leaf per plant (9.11, 12.59, 17.87, 21.53 and 27.76 at 15, 30, 45, 60 and 75 DAT, respectively), leaf length (8.89, 13.55, 21.29, 25.34 and 27.58 cm at 15, 30, 45, 60 and 75 DAT, respectively), leaf breadth 5.39, 8.14, 10.42, 12.98 and 14.58 cm at 15, 30, 45, 60 and 75 DAT, respectively), curd initiation time (73.67 days), harvested number of curd (14.44), curd diameter (58.33cm), curd weight (1053.6 gm) and yield (33.20 ton/ha) was obtained from N_4 (100% recommended dose of nitrogen) and it was superior than other doses of nitrogen. The lowest plant height (13.44, 20.48, 36.47, 45.80, 53.79 cm at 15, 30, 45, 60 and 75 DAT, respectively), number of leaf per plant (5.27, 8.11, 11.31, 15.54 and 24.34 at 15, 30, 45, 60 and 75 DAT, respectively), leaf length (7.20, 11.58, 17.31, 20.55 and 23.59 cm at 15, 30, 45, 60 and 75 DAT, respectively) leaf breadth (3.97, 6.23, 8.00, 9.29 and 10.93 cm at 15 , 30, 45, 60 and 75 DAT, curd initiation time (70.89 days), harvested curd number (12), curd diameter (50.44 cm), curd weight (725.8 gm) and total yield (21.22 ton/ha) was recorded from N_1 (No Nitrogen) and it was inferior than other doses of nitrogen.

Regarding combined effects of different doses of nitrogen with organic fertilizers on vegetative and yield parameters of cauliflower were influenced. The highest plant height (16.79, 24.31, 40.73, 48.70 and 58.59 cm at 15, 30, 45, 60 and 75 DAT, respectively), number of leaf per plant (8.53, 13.65, 20.79, 24.44 and 27.53 cm at 15, 30, 45, 60 and 75 DAT respectively)), leaf length (9.96, 14.54, 23.86, 27.45 and 30.76 cm at 15, 30, 45, 60 and 75 DAT, respectively), leaf breadth (5.88, 8.96, 11.82, 14.43 and 15.29 cm at 15, 30, 45, 60 and 75 DAT, respectively), curd initiation time (75.33 days), number of harvested curd (15), curd diameter (62.33 cm), individual curd weight (1233.00 gm) and total yield (40.94 ton/ha) were recorded from T_2N_3 combination treated plot and T_2N_3 combination was significantly superior than other combinations. The minimum plant height (12.27, 19.70, 35.89, 45.44 and 52.63 cm at 15, 30, 45, 60 and 75 DAT, respectively), number of leaf per plant (5.00, 6.00, 10.67, 17.00 and 23.33 at 15, 30, 45, 60 and 75 DAT, respectively), leaf length (6.93, 10.24, 16.50, 18.22 and 20.86 cm at 15, 30, 45, 60 and 75 DAT, respectively), leaf breadth (3.37, 5.99, 6.91, 8.19 and 9.81 cm at 15, 30, 45, 60 and 75 DAT, respectively), curd initiation time (68.33 days), number of harvested curd (11.67), curd diameter (48.67 cm), curd weight (549.0 gm) and total yield (16.51 ton/ha) were found from T_3N_1 combination and T_3N_1 was inferior than other combinations.

The effects of biochar and compost on soil P^H, organic carbon (%), nitrogen (%), phosphorus (ppm), potassium (meq/100g soil), sulfur (ppm) was statistically significant. The highest soil P^H (6.26), organic carbon (1.86%), nitrogen (0.09%), phosphorus (16.56ppm), potassium (0.49 meq/100g soil) and sulfur (26.70 ppm) were recorded from treatment T2 (biochar and compost) which was significantly superior than treatments. The lowest soil P^H (5.55), organic carbon (1.43%), nitrogen (0.04%), phosphorus (14.20 ppm), potassium (0.22 meq/100g soil) and sulfur (24.83 ppm) were recorded from treatment T_3 (control) which was inferior than other treatments.

The effects of different doses of nitrogen on soil P^H, organic carbon (%), nitrogen (%), phosphorus (ppm), potassium (meq/100g soil), sulfur (ppm) was recorded from the cauliflower cultivated plot. The highest soil P^H (6.28), organic carbon (1.76%), nitrogen (0.08%), phosphorus (16.03 ppm), potassium (0.56 meq/100g soil) and sulfur (24.84 ppm) were observed from N_4 (100% Recommended doses of Nitrogen) treated plot which was significantly superior than other doses of nitrogen. The lowest soil P^H (5.52), organic carbon (1.41%), nitrogen (0.06%), phosphorus (14.40 ppm), potassium (0.22 meq/100g soil) and sulfur (26.27 ppm) were observed from N_1 (No Nitrogen) which was inferior than other doses of nitrogen.

The combined effects of different doses of nitrogen with biochar and compost on soil P^H, organic carbon (%), nitrogen (%), phosphorus (ppm), potassium (meq/100g soil), sulfur (ppm) was observed on post-harvest cauliflower soil. The highest soil P^H (6.70), organic carbon (1.97%), nitrogen (0.01%), phosphorus (17.78 ppm), potassium (1.14 meq/100g soil) and sulfur (27.72 ppm) were observed from T_2N_3 combination which were significantly superior than other combinations. The lowest soil P^H (5.19), organic carbon (1.14%), nitrogen (0.03%), phosphorus (12.91 ppm), potassium (0.18 meq/100g soil) and sulfur (24.57 ppm) were observed from T_3N_1 combination which was significantly inferior than other combinations.

CONCLUSION

From the above result, it can be concluded that when organic fertilizers were applied, the combination of biochar with compost (T_2) gave the best result compared to the control (T_3) and only biocahr (T_1) applied plot.

Among the all doses of nitrogen, 100% recommended dose showed the best outcome compare to the other doses of nitrogen. But when the combined application of different doses of nitrogen with biochar and compost was done, 75% recommended dose of nitrogen with biochar and compost gave the maximum vegetative growth and highest yield.

After post-harvest soil analysis, the outcome showed that the available nutrient was maximum at 75% recommended doses of nitrogen with biochar and compost treated soil.

So overall consideration of cauliflower production under different treatments, 75% recommended dose of nitrogen with biochar and compost consider as the best treatment combination because it gives maximum yield and helps to improve soil health by using 25% less chemical fertilizers and thus it minimize production cost.

RECOMMENDATIONS

1. Further more systematic studies needed to determine the effect of biochar on soil health and productivity for more specific results.

2. This type of experiment is needed for those soil which are not suitable for crop production such as drought or coastal belt area to know the performance of crop after applying biochar and compost.

3. Specific biochar can contain specific nutrients. So before applying to the crop it is needed to know which crop is need for which kind of biochar.

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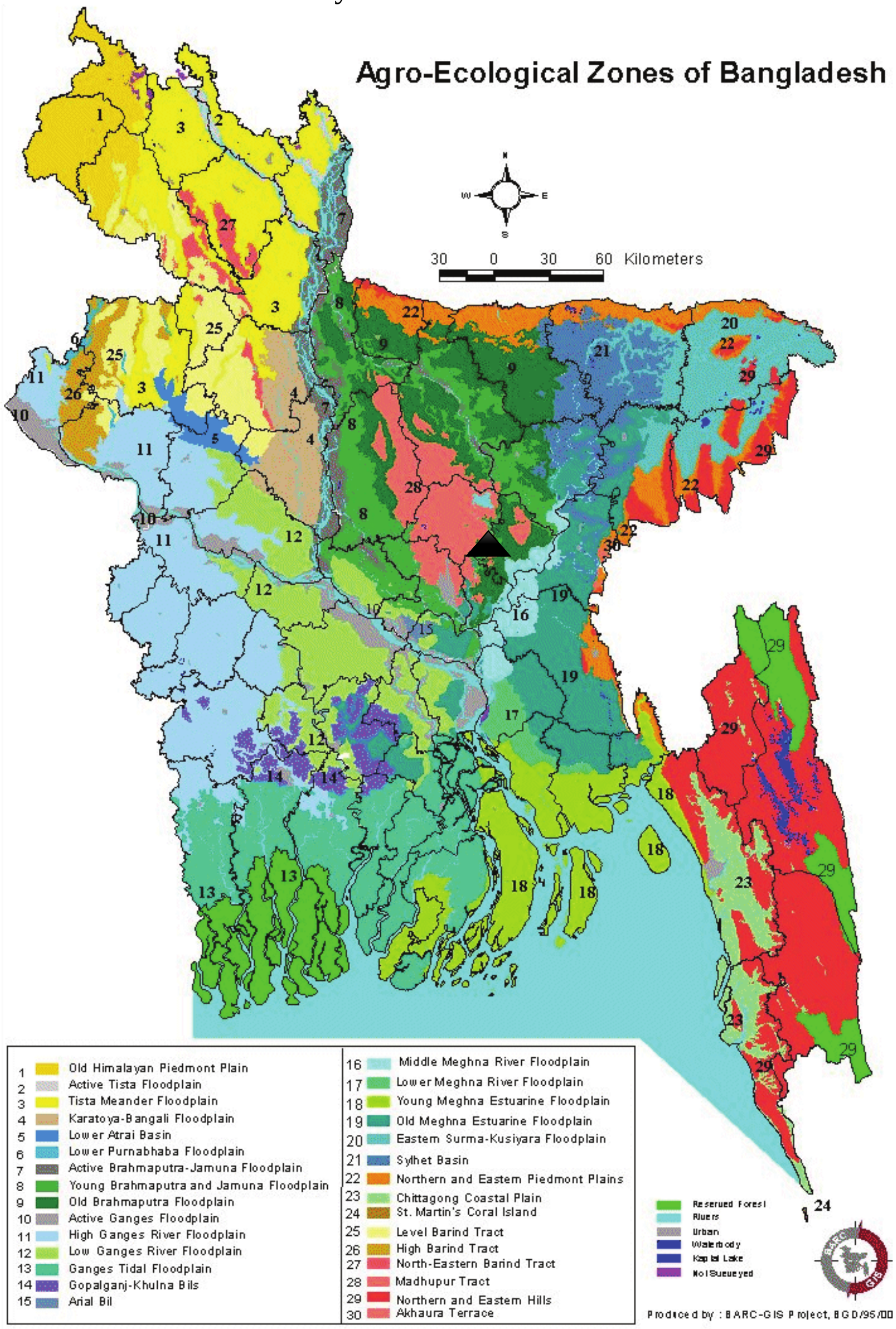
APPENDICES

Appendix I: The map of agro ecological zone of Bangladesh showing the experimental location under the study



Appendix II: Monthly records of air temperature, relative humidity and rainfall during the period from October 2019 to January 2020

Month	Year	Monthly average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Oct.	2019	36	21	28	69	Trace	219
Nov.	2019	31	18	24	63	5	231
Dec.	2019	28	16	22	61	4	212
Jan.	2020	27	13	20	57	Trace	198

Source: Bangladesh Meteorological Department (Climate division), Agargaon Dhaka 1212.

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

A. Morphological characteristics of the experimental field

Morphological Features	Characteristics
Location	Agronomy farm, SAU ,Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land Type	High land
Soil Series	Tejgaon
Topography	Fairy leveled
Flood Level	Above flood level
Drainage	Well drained

Source: Soil Resource Development Institute (SRDI)

B. Physical properties of soil

Particle size	Constitution
Texture	Silty Clay Loam
Sand (%)	26
Silt (%)	44
Clay (%)	30

Source: Soil Resource Development Institute (SRDI)

C. Chemical properties of soil

Soil characters	Value
P^H	5.8
Organic carbon (%)	1.44
Total nitrogen (%)	0.05
Phosphorus (ppm)	21
Potassium (meq/100gm soil)	0.11
Sulphur (ppm)	30

Source: Soil Resource Development Institute (SRDI)

Appendix IV: The nutrient composition of fertilizers, manure and biochar which are used in cauliflower cultivation

A. Nutrients composition of fertilizers and manures

Fertilizers	Nutrients (%)	Amount
Urea	N	46
TSP	P_2O_5	48
	P	20.12
MOP	K_2O	58
	K	50
Gypsum	S	17.7
H_3BO_3	B	16.7
Cow dung	N	0.5-1.5
	P	0.4-0.8
	K	0.5-1.9

Source: Fertilizer Recommendation Guide, BARC

B. Composition of Biochar

Characteristics	Values
P^H	8.82
Organic Carbon (%)	44.8
Total Nitrogen (%)	2.21
Phosphorus (%)	0.48
Potassium (%)	0.55

Source: Soil Resource Development Institute (SRDI)

Appendix V: Analysis of variance of plant height of cauliflower

Sources of variation	Degree of Freedom	Mean square of plant height (cm)				
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication(A)	2	0.011	0.0557	0.703	0.0012	0.460
Nitrogen (B)	3	7.5256	23.2804	25.7283	12.7544	26.7725
Error A*B	6	0.0062	0.4968	0.4223	0.0799	0.1567
Treatment(C)	2	15.3907	0.0380	2.4726	2.6691	26.9341
B*C	6	0.2857	0.9064	0.6201	0.5330	1.0728
Error A*B*C	16	0.0263	0.2981	0.1865	0.0674	0.1518

At 5%level of significance

Appendix VI: Analysis of variance of leaf number per plant of cauliflower

Sources of variation	Degree of Freedom	Mean square of leaf number				
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication(A)	2	1.591	0.25000	2.25000	3.6944	3.0833
Nitrogen (B)	3	1.333	2.55556	3.43519	20.9630	12.3704
Error A*B	6	4.383	0.13889	0.99074	0.3241	0.5648
Treatment(C)	2	3.000	4.08333	2.08333	35.3611	15.0833
B*C	6	0.3333	0.30556	0.26852	2.3241	0.4537
Error A*B*C	16	6.574	0.25000	0.88889	1.333	1.0278

At5%level of significance

Appendix VII: Analysis of variance of leaf length of cauliflower

Sources of variation	Degree of Freedom	Mean square of leaf length				
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication(A)	2	0.00119	0.0194	0.0032	0.0978	0.0037
Nitrogen (B)	3	5.61792	6.8150	32.9425	45.8855	34.2117
Error A*B	6	0.00279	0.0017	0.0015	0.0925	0.0001
Treatment(C)	2	5.06919	23.7529	23.5773	39.3482	88.8389
B*C	6	1.24293	0.4116	4.0102	4.2925	5.6726
Error A*B*C	16	0.00418	0.0091	0.0019	0.0928	0.0031

At5%level of significance

Appendix VIII: Analysis of variance of leaf breadth of cauliflower

Sources of variation	Degree of Freedom	Mean square of leaf breadth				
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication(A)	2	0.01737	0.01931	0.0075	0.0073	0.0045
Nitrogen (B)	3	4.55051	7.06265	11.9719	28.5858	24.7250
Error A*B	6	0.00111	0.00070	0.0030	0.0014	0.5746
Treatment(C)	2	2.77777	3.95032	13.5161	14.8994	17.8797
B*C	6	0.15828	0.46482	0.9742	1.9655	0.8414
Error A*B*C	16	0.00087	0.00159	0.0016	0.0027	0.4446

At5%level of significance

Appendix IX: Analysis of variance of yield contributing parameters of cauliflower

Sources of variation	Degree of Freedom	Mean square of yield contributing parameters				
		Curd initiation time	Curd diameter(cm)	Individual curd weight (gm)	Total number of harvested curd	Total yield (ton/ha)
Replication(A)	2	1.6944	2.111	2534	0.86111	6.749
Nitrogen (B)	3	13.3611	114.852	211232	8.62963	288.019
Error A*B	6	1.2500	0.852	1458	0.15741	0.902
Treatment (C)	2	48.6944	140.111	326064	5.77778	394.886
B*C	6	0.5833	8.852	13704	0.18519	15.816
Error A*B*C	16	0.8194	0.875	654	0.20833	2.531

At 5%level of significance

X: Analysis of variance soil parameters after harvesting of cauliflower

Sources of variation	Degree of Freedom	Mean square of soil parameters					
		P^H	Organic carbon (%)	Total Nitrogen (%)	Phosphorus (ppm)	Potassium (meq/100gm soil)	Sulphur (ppm)
Replication(A)	2	0.00039	0.00448	3.536	0.1866	0.19148	0.0136
Nitrogen(B)	3	1.24486	0.21155	6.923	5.2867	0.22188	4.0460
Error A*B	6	0.01631	0.00267	1.295	0.0797	0.19045	0.0046
Treatment(C)	2	1.53674	0.61650	8.415	16.8065	0.25434	11.2319
B*C	6	0.08399	0.2264	1.053	0.8159	0.17663	0.5927
A*B*C	16	0.01966	0.00304	2.751	0.2039	0.19786	0.0225

At 5%level of significance

Plate 1. Initial land preparation for the experiment

Plate 2. Initial use of inorganic fertilizer

Plate 3. Layout preparation for the experiment

Plate 4. Application of biochar to the experimental plot

Plate 5: Vegetative growth stage of experimental Field

Plate 6. Data collection

Plate 7: Supervisor sir visiting the experimental plot

Plate 8: First curd initiation

Plate 9: Harvested cauliflower