INTERACTIVE EFFECT OF BIOCHAR, FYM AND NITROGEN ON SOIL PROPERTIES AND YIELD OF BLACKGRAM

THESIS

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Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
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Enrolment Number- KK/1260 **2019**

DECLARATION OF STUDENT

I hereby declare that, the experimental work and its interpretation of the thesis entitled **"INTERACIVE EFFECT OF BIOCHAR, FYM AND NITROGEN ON SOIL PROPERTIES AND YIELD OF BLACK GRAM"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The sources of material used and all assistance received during the course of investigation have been duly acknowledged.

Place : Akola. (**KADAM YOGESH DATTATRAY)**

Date **:** / /2019 Enrolment No. KK-1260

CERTIFICATE

This is to certify that thesis entitled "**INTERACTIVE EFFECT OF BIOCHAR, FYM AND NITROGEN ON SOIL PROPERTIES AND YIELD OF BLACK GRAM"** submitted in partial fulfillment of the requirements for the degree of **"Master of Science in Agriculture (Soil Science and Agricultural Chemistry)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, is a record of bonafide research work carried out by **KADAM YOGESH DATTATRAY** under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

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Date :   /   / 2019

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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER (AFTER VIVA-VOCE)

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Abbreviations		Expanded form
%	-	Percent
@	-	At the rate
$^{-1}$ or /	-	Per
^{0}C	-	Degree Celsius
CD	-	Critical Difference
cm	-	Centimeter
CV	-	Coefficient of Variation
DAS	-	Days After Sowing
dS m^{-1}	-	Deci Siemens Per Meter
EC	-	Electrical Conductivity
et al.	-	*et alia* (and others)
etc.	-	*Et cetera*
Fe	-	Ferrous
Fig.	-	Figure
g	-	Gram
h^{-1}	-	Per Hour
ha	-	Hectare
i.e.	-	*id est* (that is)
INM	-	Integrated Nutrient Management
J	-	Journal
FYM	-	Farmyard manure
K	-	Potassium
L	-	Litre
m	-	Meter
m^2	-	Meter square
mg	-	Milligram
Mg m^{-3}	-	mega gram per cubic meter
mm	-	Millimeter
Mha	-	Million hectare
Mn	-	Manganese

MW	-	Metrological week
N	-	Nitrogen
No.	-	Number
NS	-	Non significant
OC	-	Organic Carbon
P	-	Phosphorus
ppm	-	Parts per million
PSB	-	Phosphate solubilizing bacteria
RDF	-	Recommended dose of fertilizer
q	-	Quintal
S	-	Sulphur
SE (m)±	-	Standard error of mean
SA	-	Soil Application
T	-	Tones
viz.	-	*Videlicet* (namely)
WHC	-	Water holding capacity
Wt.	-	Weight
Zn	-	Zinc

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E) Thesis Abstract

a.	Title of the Thesis	:	**INTERACTIVE EFFECT OF BIOCHAR, FYM AND NITROGEN ON SOIL PROPERTIES AND YIELD OF BLACKGRAM**
b.	Full name of Student	:	**Kadam Yogesh Dattatray**
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ABSTRACT

The present investigation was conducted during *Kharif*- 2018-19 to study the **"Interactive effect of biochar, FYM and nitrogen on soil properties and yield of blackgram"** at Research Farm, Department of Agronomy, Dr. PDKV, Akola. The experiment was laid out in Randomized Block Design with nine treatments and three replication.

On the basis of results obtained in the present investigation, highest yield and yield attributing characters of blackgram were observed with soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_7, T_5, T_3 and T_8.

Nutrient content and uptake of (NPK) by blackgram was significantly highest in treatment where soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) was applied and it was on par with treatment T_7, T_5, T_3 and T_8. The test weight was significantly highest in treatment receiving soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was found to be on par with all other treatments expect treatment T_1.

Protein content of blackgram was increased due to the application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_7, T_8, T_5 and T_3. Chemical properties like pH and EC show slightly changes but treatment differences were non-significant and organic carbon content significantly increased with application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_8, T_7 and T_5.

The available N, P, and K significantly increased with application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_8 and T_7. The lower value of available N, P and K were recorded in treatment (T_1) i.e. control. The bulk density was non- significant and WHC increased with application biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} and it was found to be on par with the treatments T_8, T_7 and T_5.

The significantly increase in soil microbial biomass carbon (SMBC) was recorded in treatment where soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} and it was found to be on par with the treatment T_7, T_8 and T_5. Whereas, the lowest soil microbial biomass carbon was reported in treatment control (T_1). The correlation matrix showed a positive and significant relationship between yield with various soil properties, available P (0.839**) was highly correlated with yield of blackgram followed by available N (0.785**), organic carbon (0.735**) and available K (0.713**) indicating their contribution in improving yield of blackgram.

CHAPTER I

INTRODUCTION

1.1 Background information

The world agriculture in the last few decades has been heavily dependent on chemical fertilizers as source of plant nutrients to meet the increasing demand for food. However, in the recent years, the environmentalists and agricultural scientists have realized that continued and unbalanced use of chemical fertilizers deteriorate the soil fertility, cause environmental pollution and affect the soil microbial activity. Thus, increasing awareness is being created on the use of organics including biochar to sustain the soil fertility and plant productivity.

In recent years, biochar has emerged as an amendment with mineral fertilizer and hold a promise to improve the yield of crops. The biochar is found to have positive impact on soil fertility, resulting in an increase in crop yield without causing hazard to soil and water environment.

Biochar is a fine grained charcoal high in organic carbon and largely resistant to decomposition. It is produced from pyrolysis of plants and waste feed stocks. It can enhance plant growth by improving soil chemical characteristics (i.e. nutrient retention and availability) and soil physical characteristics (i.e. bulk density and water holding). The net effect on the soil physical properties depends on the interaction of the biochar with the physico-chemical characteristics of the soil and other determinant factors such as the climatic conditions prevalent at the site and the management of biochar application. In addition, biochar is highly recalcitrant to microbial decomposition and thus guarantees a long term benefit for soil fertility. Biochar effect on regulation and production function in the agricultural soil. A beneficial impact of biochar on the plant-available phosphorus has been observed in soils enriched with biochar, which in contrast to ammonium, is not a characteristic generally associated with soil organic matter. Biochar also has an affinity for organic compounds.

Conceptually three main mechanisms have been proposed to explain how biochar might benefit crop production: (i) direct modification of soil chemistry through its intrinsic elemental and compositional make up, (ii) providing chemically active surfaces that modify the dynamics of soil nutrients or otherwise catalase useful soil reactions, (iii) modifying physical characters of the soil in a way that benefits root growth or nutrient and water retention and acquisition. These actual effects of biochar application, however, depend on various factors such as the soil fertility and the water balance at a given site and possibly even the cultivated genotype.

Some of the common agricultural by-products available in large quantities include bagasse, rice husk, wheat straw, groundnut shell, tea waste, casuarina leaf litter, silk cotton shell, cotton waste, oil palm fiber and shells, cashew nut shell, coconut shell, coir pith etc. (Sugumaran and Sheshadri, 2009). The chemical composition of the biochar organic carbon 38.8 %, Total P_20_5 1 g kg^{-1}, K_20 3.3 g kg^{-1}, $CaC0_3$ 5.7 g kg^{-1}, MgO 1.1 g kg^{-1} and C/N 68.2 (Yeboah. 2009). Apart from carbon sequestration, there are other environmental benefits that can be derived from the application of biochar in soils which include reduction in the emission of non-CO_2 GHGs by soils. Soil is a significant source of nitrous oxide (N_2O) and both a source and sink of methane (CH_4).

FYM is one of the components of INM as it is a very good organic source of nutrients. It is a cheap and easily available source of organic nutrients for farmer. Integrating FYM with inorganic fertilizer, scientists are getting very good response of the crop. Application of this source of organic improves physical, chemical and biological condition of the soils. FYM can supply all nutrients required by the plant, however, with low quantity. It is always advised to apply to the soil along with chemical fertilizer so that the farmers can obtain very good crop yield. FYM contains 0.5% N, 0.2% P and 0.5% K. FYM is a good source of nutrient and contributed towards build up organic matter in soil.

Nitrogen fertilization plays an important role in improving soil fertility and increasing crop productivity. Nitrogen fertilization increases grain yield and biomass in crop. It contributes 18-34% increase in soil residual N. Sole residue incorporation or in combination with N fertilizer have positive effects on plant growth and production as well as on soil physico-chemical properties. The use of organic materials in combination with inorganic fertilizers to optimize nutrient availability to plants is a difficult task as organic materials have variable and complex chemical nature. This requires the understanding and knowledge about the chemical composition, particularly the nutrient content and C quality of organic materials and its interaction with inorganic nutrient sources. Unfortunately, there has been little synthesis of the integrated effects of organic materials on net nutrient management. Numerous trials have compared the yields from a given amount of inorganic fertilizer (A), an organic material (B), and their combination (A+B), and in many situations (A+B) have produced higher yields than A or B alone. It should not be surprising that, the combination does better because more total nutrients have been added than A or B alone. Therefore, it is necessary to assess the effects of biochar and FYM on crop productivity under field conditions in relation to agronomic practices at a given site because such research is rare and is little known about possible interaction effects. For this purpose, a field experiment has been initiated on biochar, FYM and chemical fertilizer N on crop yields and soil properties.

Blackgram (*Vigna mungo* L.) is one of the important pulse crops grown in India which belong to the family "Leguminoceae". Blackgram reported as originated in the India. This crop is cultivated since ancient times and is one of the most highly prized pulses of India. It has been introduced to other tropical areas mainly by Indian immigrants. People in various regions of India use blackgram with different names like *urd* or *urid* in Hindi, Marathi and Gujarati; *Maskalai* in Bengali; *Mannipappu* in Telugu; *Ulathamparuppu* in Tamil; *Udri bale* in Kannada and *Uzhummu* in Malayalam. Blackgram is consumed in various forms as dal (whole or split, husked and unhusked). The taproot produces a branched root system with smooth, rounded root 2 nodules. The whole plant is used as fodder for cattle and is a good green manure and soil conservation crop. Many delicious food items can be prepared from black gram e.g. *dosa, idli, curry, papad, bari* (spiced balls), pudding (halva) and *imurti* (a delicious sweet). Blackgram seeds are a good source of minerals and energy. It is rich in proteins (24 %), carbohydrates (60 %), fat (1 - 5 %), amino acids, vitamins and minerals and much richer than most of grains used as concentrate.

1.2 Importance and need of study

Biochar is one of the most important organic manure which play a key role in maintain the nutrient status of soil. The nutrients removal by crops is generally more than that supplied through chemical fertilizer and this negative balance over the years led to low fertility status of soil, which resulted in decline in the soil fertility and crop yields and also the heavy use of chemical fertilizers which are increasing day by day. The indiscriminate uses of these chemical fertilizers are prone to several environmental problems like deterioration of soil heath and contamination of natural resources.

Adequate and timely application of organic and inorganic fertilizers is most essential for maintain the soil fertility and proper growth of the crop. Combination of Biochar, FYM and inorganic fertilizer result in higher addition of organic matter (Khan N. *et al.* 2013).

Application of organic sources i.e. Biochar, FYM along with NPK fertilizer is effective in alleviating the nutrient deficiency in soil, improving physical properties of soil and its organic carbon status. Managing organic source of plant nutrients with mineral fertilizer and their incorporation into the soil in a cropping system has certain favourable and augmenting effects on soil physical and biological properties for sustainability and high productivity of crops.

Sustaining soil quality is the most appropriate method to ensure sufficient food to support life. Maintenance of soil organic carbon in soil is considered essential for long-term sustainable agriculture. Soil organic matter is the most important attribute of soil quality. Soil organic matter being a storehouse of all essential plant nutrients, plays pivotal role in crop production and soil organic matter together with physical properties has been proposed as indicator of soil quality.

1.3 Objectives:

The study on "Interactive effect of biochar, FYM and nitrogen on soil properties and yield of blackgram" was planned with the following objectives:

1. To study the interactive effects of biochar with FYM and nitrogen on soil properties.
2. To assess the interactive effect of biochar with FYM and nitrogen on uptake of nutrients and yield of blackgram.

1.4 Scope and limitation

The influence of biochar on soil and yield is both indirect and direct as the biochar contain more carbon which plays multifunctional role such as buffering, restoring and supplying of soil and plant nutrients etc. It is a storehouse of all soil microorganisms inhabiting in soil; improve physical, chemical and biological properties of soil.

Many studies have found that biochar stay in soil for centuries to millennia. This is because the mass of the material is extremely resistant to decomposition of microbes. Throughout pyrolysis, the structure of molecular biomass is recognized, to a form that is extremely constant in soil. Carbon that was in the atmosphere gets combined into biomass by plant wastes, plants are pyrolyzed, and biochar placed in soil. Thus biochar can be employed as an instrument to sequester or sieze carbon in soil in safe system.

The interactive effects of biochar application in combination with farm yard manure (FYM) and nitrogen (N) fertilizer on soil organic matter (SOM) and mineral nitrogen (Khan N. *et al*. 2010), as it influences soil physical, chemical, and biological properties and processes. Besides, it is also extremely important in maintaining overall quality of environment as soil contains a significant part of global carbon stock. Hence, there is a growing interest in assessing the role of soil as a sink for carbon under different agricultural management practices and land uses.

1.5 Hypothesis

The interactive effect of Biochar, FYM and Nitrogen on soil properties and yield of blackgram experiment provides a good platform for studying the soil quality in terms of physical properties. These experiment can be used for precise monitoring of changes in soil fertility and productivity and could be of paramount help in solving the complex problems related to the soil fertility management. The biomass added to soil through biochar and organic manure which adds enough organic matter in soil, which improves physical, chemical and biological properties of soil. The soil quality attributes sensitive management practices which can be identified based on the study.

CHAPTER II

REVIEWS OF LITERATURE

In this chapter an attempt has been made to present a brief review of the important research work on “Interactive effect of biochar, FYM and nitrogen on soil properties and yield of blackgram.” The literature pertaining to the present study has been briefly reviewed under the following heads.

1.1 Effect of levels of Biochar on soil physical properties

1.2 Effect of levels of Biochar on soil chemical properties

1.3 Effect of levels of Biochar on soil biological properties

1.4 Effect of levels of Biochar on crop yield

1.5 Effect of FYM and Nitrogen on soil properties

1.6 Effect of FYM and Nitrogen on crop yield

1.1 Effect of levels of Biochar on soil physical properties

1.1.1. Bulk density

Sudarso and Pontianak (2010) conducted an experiment in glass house to study the effect of rice husk biochar on soil physical properties and concluded that the bulk density of soil decreased from 1.24 Mg m^{-3} to 1.17 Mg m^{-3} when soil amended with rice husk biochar @ 10 t ha^{-1}.

Islami *et al.* (2011b) conducted a field experiment and revealed that the bulk density of the soils amended with biochar @ 15 t ha^{-1} (1.16 Mg m^{-3}) was significantly reduced over soils with no biochar amendments (1.19 Mg m^{-3}). Application of biochar @ 20 t ha^{-1} led to reduction in bulk density by 9.1% over control (Sun *et al*. 2013).

Mankasingh *et al.* (2011) conducted an experiment to investigate the potential of biochar on soil properties. A steady decrease in bulk density from 0.99 g cm^{-3} to 0.89 g cm^{-3} was observed when, the biochar was applied at different rates (0, 1.1, 2.2 and 4.4%).

Jien and Wang (2013) conducted an experiment and reported that during incubation duration, consistent bulk density about 1.10 Mg m^{-3} was found for the amended soils, however rapid increase of bulk density was found in the control at 21 days and then maintained a consistent value at about 1.40 Mg m^{-3} to the end of the incubation. After incubation of 105 day the bulk density of the biochar-amended soils significantly decreased from 1.42 Mg m^{-3} to <1.15 Mg m^{-3} and rate of decease increased with the biochar application rate.

Prabha S. *et al.* (2013) conducted an experiment and reported that the bulk density decreased from 0.678 g cm^{-3} in the control experiment to 0.60 g cm^{-3} in the biochar treated soil and this may be due to the formation of soil aggregation.

Aslam *et al.* (2014) reported that the bulk density steadily decreased with increase in the rates of biochar application and reached the minimum level of 0.38 g cm^{-3} at 100% biochar application.

Mukherjee *et al.* (2014) conducted a field experiment and reported that the bulk density of the soil amended with biochar @ 7.5 t ha^{-1} was significantly reduced by 24% as compared to control.

Pandian K. *et al.* (2016) reported that the higher bulk density of 1.40 g cm^{-3} and low pore space volume (41.0%) were observed in control while low bulk density of 1.36 g cm^{-3} and higher pore space (47.5%) were observed in biochar 5 t $ha^{-1.}$ Since biochar has a bulk density much lower than that of mineral soils and, therefore, application of biochar may increase the volume of unit weight soil and thereby reduce the bulk density of soil.

1.1.2. Water holding capacity

Busscher *et al.* (2010) in an incubation study, water added to the soils to maintain 10% water content as minimum, 370 g water was found recorded for the soils amended with biochar @ 5 g kg^{-1} as compared to the 400 g kg^{-1} water required for the soils with no amendment.

Uzoma *et al.* (2010) conducted an experiment to investigate the effect of lack locust (*Robinia pseudocacia* L.) biochar on soil hydraulic properties and nutrient retention in a sandy soil. It was concluded that the biochar produced at 500 ºC and applied at a rate of 20 t ha^{-1} increased the available water capacity by 97%, saturated water content by 56% when compared to unamended sandy soil.

Yaghoubi and Reddy (2011) conducted an incubation experiment and reported that the water content in the soil amended with 20% biochar was significantly superior (3.80%) to control (2.82%).

Artiola *et al.* (2012) conducted a green house experiment with the biochar amendment @ 2%, 4% and reported that the water holding capacity ranged from 185 to 200%, providing that the biochar is capable of holding water twice its weight.

Basso *et al.* (2013) conducted an experiment and observed that the effect of biochar on soils and reported that addition of biochar to sandy loam soil increased the water holding capacity.

Karer *et al.* (2013) conducted a field experiment with the application of biochar at different rates (0, 24 and 72 t ha^{-1}) and concluded that the water holding capacity of soils amended with biochar was significantly increased (51.7%) as compared to that of in soils with no biochar (47.6%).

Sun *et al.* (2013) conducted a field experiment and observed that the soil water content was slightly higher i.e. 3% with biochar application @ 20 t ha^{-1} as compared to control, but the increase was not statistically significant. Ulyett *et al.* (2014) reported the significant increased in the water holding capacity (1.3%) on application of biochar @ 60 t ha^{-1} over conventionally managed soils where increase was only 0.3%.

Youn *et al.* (2013) conducted a study to determine the effect of woody biochar on water holding capacity of loamy sand soil. Results showed doubling in water holding capacity by mass using 9% mixture of biochar (equivalent to 195 Mt ha^{-1}) which is an agriculturally relevant concentration.

Yadav N. *et al.* (2018) conducted a field experiment and reported that the physio-chemical properties were soil pH, bulk density, water holding capacity, or cation exchange capacity of soils amended with biochar. Application of biochar at 10, 15 and 20 t ha^{-1} mixing rates significantly increased water use efficiency (WUF) increased by 6, 139 and 91%, respectively as compared to control in sandy soil.

1.2 Effect of levels of Biochar on soil chemical properties

1.2.1. Soil reaction and EC

Chan *et al.* (2007) conducted a field experiment using different rates of biochar application and the results revealed the significant increase in pH values on biochar application. Application of biochar @ 100 t ha^{-1} recorded the maximum pH (5.19) over control (4.58). However, soil reaction was within the range of acidity.

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

Masulili *et al*. (2010) conducted a field experiment and reported that the pH value was significantly increased to 4.40 from 3.36 on application of biochar @ 10 t ha^{-1} in acidic soils.

Yaghoubi and Reddy (2011) conducted an incubation experiment and reported that the pH in the soils amended with 20% biochar was significantly increased from 5.3 to 7.3, which was towards the neutral state.

Nigussie *et al.* (2012) conducted a field experiment and revealed a significant increase in the EC of the soils treated with biochar @ 10 t ha^{-1} (0.27 dSm^{-1}) as compared to control (0.21 dSm^{-1}).

Shenbagavalli and Mahimairaja (2012) carried out an incubation (0, 30, 60 and 90 days) study in alkaline soils with, incorporation of biochar in soil at different rates (1, 2, 3, 4, 5%) which resulted proportionally decreased the soil pH from 8.42 to 7.92 after 90 days.

Masto *et al.* (2013) conducted a field experiment and showed significant changes in soil pH on different treatment and stages of maize growth but interaction effect was not significant. The mean pH increased from 6.09 in control to 6.58 at biochar and lignite fly ash treated soils, respectively.

Mukherjee *et al.* (2014) conducted an experiment and concluded that pH of soil amended with biochar @ 7.5 t ha^{-1} was significantly increased by 0.4 units over control

Ouyang *et al.* (2014) during incubation study, observed that the pH values significantly increased from 0.79 to 2.21 units with different biochar treatments @ 5% w/w. pH of the soils incubated with 5% biochar showed significant reduction in the pH values (0.3 to 0.4 units) that is towards the neutral pH as compared to initial soil pH 8.3 (Wu *et al.* 2014).

Wu *et al.* (2014) conducted an incubation study to evaluate the influence of furfural biochar on the physico-chemical properties of saline soils. During the incubation 5% biochar lowered the soil pH by 0.3 to 0.4 with respect to control and increased the electrical conductivity.

Mandal *et al.* (2015) reported that the application of biochar had a positive and significant effect on improvement in soil pH. Irrespective of the sources of biochar its application improved soil pH by 0.26 to 0.30 units within in two month. Maximum improvement was observed from the biochar of pine needle. All weed biomass biochar had a significant on soil pH.

1.2.2. Organic carbon

Chan *et al.* (2007) conducted a field experiment of different rates of biochar application and reported that the organic carbon values

(64.6 g kg^{-1}) were significantly increased with biochar application @ 100 t ha^{-1} as compared to no biochar application (21.2 g kg^{-1}).

Steinbeiss *et al.* (2009) noticed the build up of 27% more carbon content in the soils incubated with biochar @ 3% as compared to soil not amended with biochar.

Masulili *et al.* (2010) conducted a field experiment and reported that the organic carbon values were significantly increased (4.9%) with biochar application @ 10 t ha^{-1} as compare to control plot (0.54%).

Zwieten *et al.* (2010a) conducted a glass house experiment with five different biochar rates (0, 1.1, 2.2, 4.4 and 11.0%), reported that the total carbon content was increased significantly from 2.1 to 8.6 with increased in the biochar contents, but only minor increased in the organic carbon was detected.

Robertson *et al.* (2012) observed that significantly increased in total carbon (*i.e.,* 14.25%) on application of biochar @ 10% as compared to non biochar treatment (3.6%).

Shenbagavalli and Mahimairaja (2012) observed that the initial SOC content was 5.1 g kg^{-1}. After incubation study soil organic carbon content varied from 5.8 to 13.6 g kg^{-1} with different rates of biochar application i.e. 1, 2, 3, 4, 5%, whereas control recorded the lowest (4.5 g kg^{-1}).

Widowati *et al*. (2012) explored the use of city waste as biochar found that the organic carbon content in the soils with the integral application of N fertilizer @ 145 kg ha^{-1} and city waste biochar @ 30 t ha^{-1} was significantly higher (3.21%) than the sole use of N fertilizer @ 145 kg ha^{-1} (1.41%) and control (1.39%).

Masto *et al.* (2013) conducted a field experiment and concluded that application of biochar @ 4 t ha^{-1} has increased soil organic carbon values from 0.813 to 8.17%. Application of biochar @ 12 t ha^{-1} significantly increased soil organic carbon content (Xie *et al.* 2013). Abewa *et al.* (2014) expressed a similar view.

Mukherjee *et al.* (2014) conducted a field experiment and reported that the organic carbon of the soil was significantly increased by 26% over control on application of biochar @ 7.5 t $ha^{-1.}$

Qayyum *et al.* (2014) conducted incubation studies in three different soils. In all the soils biochar @ 12.82% showed relatively higher proportion of stabilize total carbon, 22-85% over control soils. Wu *et al.* (2014) found that organic carbon values significantly increased by 8 times over control on soil incubation with 5% biochar.

Wu *et al.* (2014) conducted a 56 days incubation study to evaluate the influence of furfural biochar on the physico-chemical properties of a saline soil. Application of biochar at a rate of 5% increased the soil organic carbon content by 8 times with respect to control.

Husien A. *et al.* (2017) showed that none of the interaction effect of the treatments was significant on soil organic carbon. Likewise, the main effect of nitrogen levels on soil organic carbon were non- significant. However, that of biochar levels on soil organic carbon was highly significant ($P < 0.001$) as well as farmyard manure levels on soil organic carbon was significant ($P < 0.05$).

1.2.3. Nitrogen

Zwieten *et al.* (2010a) conducted a glass house experiment with 5 different biochar rates (0, 1.1, 2.2, 4.4 an 11%) and observed the significant reduction in the NH_4^+ - N and significant increased in the NO_3 levels in the soils at highest rate of biochar application.

Sukartono *et al.* (2011) conducted a field study for two seasons (rainy and dry season) to evaluate the influence of biochar application on soil fertility status in sandy soils. Biochar application improved the soil fertility status especially nitrogen, phosphorus and potassium content as compared to other treatments

Nigussie *et al.* (2012) conducted a pot experiment and observed the highest total nitrogen (0.48%) in the soils treated with biochar @10 t ha^{-1} and lowest in the control (0.40%).

Robertson *et al*. (2012) conducted an experiment and reported that the application of biochar @ 10% significantly increased the total nitrogen content (0.286%) as compare to the non biochar treatment (0.178%).

Widowati *et al.* (2012) found that combined application of N fertilizer @ 145 kg ha^{-1} and city waste biochar @ 30 t ha^{-1} significantly increased the N content in soil (0.21%) over the sole use of N fertilizer @ 145 kg ha^{-1} (0.18%) and control (0.11%).

Brantley *et al.* (2014) conducted a field experiment and reported that the nitrogen use efficiency of the soils applied with same quantity of nitrogen was significantly higher on application of biochar @ 4.5 t $acre^{-1}$ (44.4%) as compared to no biochar amendment (12.2%).

Goa *et al.* (2018) the soil available nitrogen levels of different amounts of biochar treatment (including biochar treatment alone) are higher than those of the control treatment significantly, showing that the application of biochar can increase the content of available nitrogen in the soil, among all treatments the content of available nitrogen in C2 NPK was highest. There was no significant difference in the levels of available nitrogen between the individual biochar treatments (C1, C2, C3) and their corresponding biochar treatments. The possible reason was that biochar could increase the content of available nitrogen in the soil.

1.2.4. Phosphorus

Chan *et al.* (2007) conducted a field experiment using different rates of biochar and reported that the available phosphorus (40.8 mg kg^{-1}) values were significantly higher with biochar application @ 100 t ha^{-1} as compared to the non biochar application (28.6 mg kg^{-1}).

Masulili *et al.* (2010) conducted an experiment at Pancabhakti University Indonesia and suggested that application of biochar @ 10 t ha^{-1} significantly increased the total phosphorus.

Islami *et al.* (2011) reported that the soil available phosphorus (12.20 ppm) was significantly higher with application of biochar @ 15 t ha^{-1}

as compared to the soils with no biochar amendment (10.9 ppm). They also reported that application of two different types of biochar *viz.,* FYM biochar and cassava biochar @ 15 t ha^{-1} significantly increased the phosphorus level from 11.1 to 12.1, 11.6 mg kg^{-1} respectively.

Widowati *et al.* (2012) reported that the available P in soil was significantly higher (38.76 ppm) on integral application of N fertilizer @ 145 kg ha^{-1} and city waste biochar @ 30 t ha^{-1} compared to the sole use of N fertilizer @ 145 kg ha^{-1} (22.54 ppm) and control (21.56 ppm).

Masto *et al.* (2013) conducted a field experiment and concluded that application of biochar @ 4 t ha^{-1} has increased the soil phosphorus from 4.32 mg kg^{-1} to 7.76 mg kg^{-1}.

Xu *et al.* (2014) conducted an experiment to evaluate the effect of four biochars on P sorption and desorption in three soil types (Brown, Black and Fluvo - aquic soil) with different level of acidity. As the rate of biochar application increased, P sorption increased in the acidic soil but slightly decreased in the alkaline soil. Desorbed P significantly increased at all level of biochar application in the studied soils.

Zhai *et al.* (2014) conducted an incubation study in two types of soils *viz.,* iron and aluminium dominated slight acid red earth and calcium dominated alkaline fluvo-aquic soils and concluded that the available P content was significantly increased proportional to the increasing biochar rates (i.e. 0, 2, 4 and 8%). The maximum Olsen P was achieved in soil treated with biochar @ 8% which was 46 mg kg^{-1} in red earth and 137 mg kg^{-1} in fluvo-aquic soil after 42 DAI.

Bhattarai B. *et al.* (2015) conducted a field experiment and reported that the biochar application of different origin on phosphorus has least significant difference in having intermediate results, but it has been found that biochar application has slow increasing effect on soil phosphorus in all cases of application than in control condition. Among all application, poultry manure biochar has higher phosphorus contribution on soil (82.527 t ha^{-1}) and lowest (38.122 t ha^{-1}) in control condition.

Husien A. *et al.* (2017) showed that the soil available phosphorus increase with the increase of biochar (0, 5 and 10 t ha^{-1}) by 35.44 and 43.29% and farmyard manure rate (0 and 6 t ha^{-1}) by 18.70% over the control respectively. Therefore from this point of view the levels of biochar affect soil available phosphorus than the levels of farmyard manure; this is due to the effects of biochar on soil reaction than farmyard manure which increases the mobility of phosphate in the soil solution.

Gao T. *et al*. (2018) concluded that the available phosphorus content of different amounts of biochar with NPK is higher than that of the single biochar treatment, respectively are 81.8%, 81.5%, 94.3%, of which C2 NPK own highest content of treatment. It showed that the application of biochar with NPK treatment could increase soil available P content.

1.25. Potassium

Masulili *et al.* (2010) conducted a field experiment and reported that the available potassium was significantly increased (0.51 cmol (p^+) kg^{-1}) with biochar application @ 10 t ha^{-1} as compared to control plot (0.20 cmol kg^{-1}).

Islami *et al.* (2011) revealed that the application of two different biochar @ 15 t ha^{-1} significantly increased exchangeable potassium level from 1.56 to 1.64 - 1.78 cmol (p^+) kg^{-1}. They also reported that the available potassium (1.64 cmol (p^+) was significantly higher in the soils amended with biochar @ 15 t ha^{-1} as compared to the soils with no biochar amendment (1.55 cmol (p^+) kg^{-1}.

Robertson *et al.* (2012), conducted an incubation study application of biochar @ 10% significantly increased the potassium content (0.68 cmol (p^+) kg^{-1}) as compared to the non biochar treatment (0.51 cmol (p^+) kg^{-1}).

Widowati *et al.* (2012) conducted a field experiment and revealed that the integral application of N fertilizer @ 145 kg ha^{-1} and city waste biochar @ 30 t ha^{-1} was revealed in significantly higher exchangeable K (2.01 cmol (p^+) kg^{-1}) over the sole use of N fertilizer @ 145 kg ha^{-1} (0.75 cmol (p^+) kg^{-1}) and control (0.67 cmol (p^+) kg^{-1}).

Husien A. *et al.* (2017) showed that the interaction effect of biochar, farmyard manure and nitrogen levels on soil available potassium was highly significant ($P < 0.001$). As the analyzed result of mean interaction revealed that the effect of biochar, farmyard manure and nitrogen levels on soil available potassium were increases with the levels of means interaction increase.

1.3. Effect on level of biochar on Biological properties

Influences of biochar on ammonification, nitrification, denitrification and N_2-fixation, and provide potential mechanisms that may be driving these relationships. (Berglund *et al.* 2004, Deluca *et al.* 2006) biochar has been found to increase net nitrification rates in temperate and boreal forest soils that otherwise demonstrate no net nitrification.

Warnock *et al. (*2007) reviewed several mechanisms through which biochar might affect soil microorganisms, including its effect on sorption of microbial signaling compounds and the physical structure of biochar, which provides a habitat for microbes within the porous structure of charred material.

In a study in Dhanbad, India biochar produced from a water hyacinth significantly increased soil biological activity (three times in active biomass) and soil respiration by 1.9 times. An interesting observation was made by (Elad *et al.* 2010), who proposed disease and pest management in crops with biochar application.

1.4 Effect of biochar on crop yield

Chan *et al*. (2007) conducted a field experiment and observed that the application of biochar made from greenwaste did not increase the dry matter production of radish even at the highest rate (100 t ha^{-1}). Instead, at 10 t ha^{-1} of biochar, yield was slightly depressed compared with the nil biochar control. With the addition of nitrogen fertilizer (100 kg N ha^{-1}), significant increase in radish yield were observed in all the biochar treatments (including the nil biochar control), and there was a significant interaction between biochar application rates and nitrogen fertilizer addition.

Rondon *et al.* (2007) conducted a field experiment and reported that the bean yield increased by 46% and biomass production by 39% compared to control at 90 and 60 g biochar kg^{-1}, respectively.

Steiner *et al.* (2008) conducted a field experiment and showed that the charcoal amended with chicken manure amendments resulted in the highest cumulative crop yield (12.4 t ha^{-1}).

Liu (2013) found that the benefits at field application rates typically below 30 tons ha^{-1} field application and reported that increases in crop productivity varied with crop type with greater increases for legume crops (30%), vegetables (29%), and grasses (14%) compared to cereal crops corn (8%), wheat (11%), and rice (7%) resulting in improved crop yields.

Chintana and Preeda (2014) used biochar as soil amendment for improving crop yield. The results showed that the biochar application significantly improved the growth and yield of soybean with respect to control at every application rate.

Bhattarai B *et al.* (2015) conducted an experiment and reported that the number of pod $plant^{-1}$, number of seed pod^{-1} and biomass (t ha^{-1}) were highly significantly affected by application of biochar of different origin.

Partey *et al.* (2015) conducted a study to evaluate the beneficial effect of biochar in legume - crop rotation systems on crop performance. The experimental results showed that the mean grain yield for all cropping seasons was 1.8 t ha^{-1} for biochar amended plots and 1.3 t ha^{-1} for un-amended plots.

Yang *et al.* (2015) conducted a field experiment to investigate the effect of different biochars on crop yield. The results showed that the biochar amended @ 4 t ha^{-1} increased the yield (5.1 t ha^{-1}) of peanut compared to without biochar (4.2 t ha^{-1}).

Yooyen *et al.* (2015) showed higher rates of soil nutrients, growth, dry matter and yields in biochar treatments. The treatments with 20 t ha^{-1} and 30 t ha^{-1} of biochar produced seeds weight, which were 28% and 36.8% heavier, respectively in comparison to the control. Increase in growth and yield of soybean crop was observed in biochar treatments compared to the control.

Abdul Rab *et al.* (2016) conducted a pot experiment to evaluate the sole impact of biochar on yield and yield components of mungbean crop. The treatments were consisted of 5 levels of biochar (25, 50, 75, 100 t ha^{-1}) along with control. The biochar levels significantly improved pods $plant^{-1}$ (23), pods length (9.2 cm), grains pod^{-1} (11), 100 grains weight (6.8 g), biological yield (28.3 g pot^{-1}), grain yield (4.2 g pot^{-1}) and harvest index (14.87%). While days to emergence of mungbean were non-significant. Hence it was concluded from the experiment that the application of biochar at the rate of 25 t ha^{-1} is beneficial for improving mungbean grain yield in Semi-arid region.

Hussain Z. *et al.* (2017) conducted a field experiment having three replications and 13 fertilizer treatments. Biochar application at three levels (0, 25 and 50 ton ha^{-1}), farmyard manure (FYM) at two levels (5 and 10 t ha^{-1}) and nitrogen (N) at two levels were included in the experiment. Biochar application at the rate of 25 t ha^{-1} resulted in higher seed yield (639 kg ha^{-1}) as compared to control (579 kg ha^{-1}).

1.5 Effect of FYM and Nitrogen on soil properties.

Ramesh *et al.* (2006) conducted an experiment and observed that application of cattle manure resulted in higher soil organic carbon, available N and K of soil compared to chemical fertilizer applications and the control.

Bhattacharyya *et al.* (2007) conducted an experiment and observed that the decrease in bulk density of soil due to addition of FYM along with NPK fertilizer as compared to NPK and control treatment.

Bandyopadhyay *et al*. (2010) conducted a field experiment and observed that integrated use of NPK and FYM significantly improved the soil organic carbon content by 29.8 and 45.2% compared to NPK and control treatment, respectively.

Khan *et al.* (2010) observed that Farm yard manure (FYM) significantly decreases the bulk density of soil as compare to control. The higher mean value of 1.470 Mg m^{-3} in case of control followed by 1.388 Mg m^{-3} (5.57% decrease) and 1.24 Mg m^{-3} (18.5% decrease) in case of application of farm yard manure (20 Mg ha^{-1} and 40 Mg ha^{-1}), respectively.

Pathak *et al.* (2011) observed that the final soil organic carbon concentrations in both NPK and NPK + FYM treatments were higher than the control treatment. Compared to the NPK treatment also, the NPK + FYM treatment had higher soil organic carbon concentration in all the long term experiments.

Rathore D.S. *et al.* (2011) conducted a field experiment and observed that the organic carbon of soil after the harvest of black gram and wheat was higher where FYM had been applied. The highest OC content was recorded where FYM was applied @ 5 t ha^{-1} it may be due to addition of organic manure, which stimulated the growth and activity of micro organisms and also due to better root growth.

Parvathi *et al.* (2013) made observations in long-term manure and fertilizers experiment of groundnut in alfisol and revealed that the highest value of organic carbon was noticed in FYM alone treated plot from 0.21 to 0.40% as compared to other treatment.

Tadessel T. *et al.* (2013) reported that the highest organic matter being recorded for the (15 t ha^{-1}) FYM application. Soil physical characteristics after rice harvesting such as soil bulk density and available water holding capacity showed significant response only to FYM application but not to the inorganic fertilizers and their interactions with FYM. Compared to lower two rates, the 15 t ha^{-1} FYM resulted in the lowest soil bulk density. Concerning the soil available water holding capacity, statistically equivalent and higher values were recorded for 7.5 t ha^{-1} and 15 t ha^{-1} FYM. Application of 15 t ha^{-1} FYM increased the soil organic matter and available water holding capacity by about 2.16% and 17.6%, respectively, while it reduced the soil bulk density by 0.31 $g{\cdot}cm^{-3}$.

Ojha R.B. *et al.* (2014) reported that the soil pH and EC are not affected in first season by different level of FYM. However, pH in second season is significantly affected by residual FYM dose but EC does not significantly differ with the residual level of FYM. Residual FYM dose 10.5, 14 and 17.5 t ha^{-1} have similar pH which significantly differs with 0, 3.5 and 7 tons of residual FYM.

Aher *et al.* (2015) studied on the influence of organic farming practices on soil health and crop performance of soybean. The crop cultivar JS-335 was grown with 30:26.2:16.6 kg ha^{-1} (NPK) recommended dose of fertilizers under three management practices viz., organic, chemical and integrated (50:50) in randomized block design with three replications. The soil organic carbon and available N, P and K were found significantly higher i.e. soil organic carbon (11.3 g kg^{-1}), available N (125 mg kg^{-1}) and available P (49.7 mg kg^{-1}) in the plot managed organically. While, available K (320.1 mg kg^{-1}) was not significant with respect to chemical and integrated practices.

Tana T. *et al.* (2017) reported that the combined application of organic and inorganic fertilizers had significant effect on the bulk density of the soil both in Adiyo and Ghimbo. The bulk density ranged from 1.21 g cm^{-3} from the application rate of 5 t FYM ha^{-1} in combination with 25% inorganic N and P to 1.61 g cm^{-3}, from the control in Adiyo. Similarly, the lowest bulk density (1.20 g cm^{-3}) in Ghimbo was obtained from the application rate of 5 t FYM ha^{-1} in combination with 25 and 50% inorganic N and P and the highest bulk density (1.54 g cm^{-3}) was from the control.

Kumar A. *et al.* (2018) conducted an experiment and reported that the significantly higher soil organic carbon content was found in the treatment T4 [50% NPK Zn + biofertilizer (PSB+BGA) + FYM (10 t ha^{-1})] in comparison to other treatments.

Mairan (2018) reported that the highest availability of nitrogen (225 kg ha^{-1}) was recorded with treatment T_3 i.e. FYM @ 5 t ha^{-1}. There was progressive buildup of available phosphorus during both the years of experiment. Higher amount of available phosphorus (20.18 kg ha^{-1}) was recorded in treatment T_3 i.e. FYM @ 5 t ha^{-1} followed by T6, T1 and T7 treatments. There was no significant effect of cropping systems on availability of potassium though both the cropping systems as soybean + pigeonpea and sorghum + pigeon pea give the significant results. The treatment T3 i.e. FYM @ 5t ha^{-1} recorded maximum available K at 260 kg ha^{-1} followed by treatment T2 i.e. glyricidia @ 6t ha^{-1} (255 kg ha^{-1}). Thus, application of organic sources helps in improving availability of the nutrient of soil.

Meena K.B. *et al.* (2018) conducted an experiment and reported that the application of FYM either alone or in combination with NPK resulted in considerable changes of SOC in the surface (0-15 cm) soil layer than that of unfertilized control as well as NPK treated plots. The plots that received FYM (7.3 g kg^{-1}) and FYM + NPK (6.50 g kg^{-1}) had significantly higher build-up in SOC over unfertilized control (4.9 g kg^{-1}) and NPK treated plots (5.1 g kg^{-1}) in the surface soil. The increase in build-up in SOC under FYM and FYM + NPK treatments was 43.1 and 27.5% greater over treatment receiving NPK fertilizer alone and 49.0 and 32.7% greater over treatment receiving no fertilizer or manure (control).

1.6 Effect of FYM and Nitrogen on crop yield

Ghosh *et al.* (2001) conducted an experiment and reported that application of FYM 10 t ha^{-1} along with recommended dose of NPK to soybean led to record significantly higher seed yield (2.65 t ha^{-1}) as compared to NPK alone (1.45 t ha^{-1}).

Naeem *et al.* (2006) studies the effect of organic manures and inorganic fertilizer on growth and yield of green gram and reported from the result that among organic sources, grain yield was found the best with poultry manure 3.5 t ha^{-1} closely followed by FYM 5 t ha^{-1}.

Bandyopadhyay K.K. *et al*. (2010) observed that annual application of FYM @ 4 t ha^{-1} along with recommended dose of fertilizers (NPK) significantly improved the grain yield of soybean by 14.2% over NPK and by 50.3% over control treatment.

Sharma V. *et al.* (2010) conducted a field experiment on Interaction of nitrogen with zinc and farmyard manure was found to be significant with respect to seed yield. On analyzing the data it was found that application of nitrogen (20 kg ha^{-1}) with zinc (15 kg ha^{-1}) and FYM (10 t ha^{-1}) showed a significant increment in the yield, and yield attributes of blackgram over the control.

Mahetele and Kushwaha (2011) conducted an experiment during *kharif* season and observed that growth and yield attributes like nodules $plant^{-1}$, nodule dry weight $plant^{-1}$, primary branches $plant^{-1}$, test weight and seed yield of pigeonpea were found significantly higher with the application of FYM (10 t ha^{-1}) over control.

Rathore D.S. *et al.* (2011) conducted a field experiment on combined application of FYM @ 5 t ha^{-1} + 40 kg P_2O_5 ha^{-1}, 5 t ha^{-1} of FYM + dual inoculation of PSB + VAM and 40 kg P_2O_5 ha^{-1} + dual inoculation of PSB + VAM gave higher seed and stover yields of blackgram. This combination was found significantly superior over other combinations.

Jat R. *et al.* (2012). conducted the experiment and reported that the application of FYM at 5 t ha^{-1} significantly increased yield attributes as well as yield of greengram over no application of FYM. The respective increase in grain and stover yield due to FYM application was 11.24 and 11.27% over no FYM application. This perhaps was caused by favourable effects of FYM application on growth attributes, which contributed higher photosynthates for the reproductive parts of the plants.

Kokani J.M. *et al*. (2014) showed that significant differences in seed and stover yield of blackgram due to FYM. Application of FYM @ 5 t ha^{-1} produced significantly higher seed (1149 kg ha^{-1}) and stover yields (2652 kg ha^{-1}) which was to the tune of 10.16 and 19.08% higher as compared to control.

Maruthi I.B. *et al*. (2014) conducted an experiment and reported that the application of (T_{12}) 50% recommended dose of NPK (15:40:18.75 kg ha^{-1}) + 50% Recommended dose of FYM (5 t ha^{-1}) + 50% Vermicompost (2 t ha^{-1}) + Brady rhizobium (250g ha^{-1}) + PSB (250 g h^{-1}) recorded significantly highest seed yield $plant^{-1}$ (10.2 g $plant^{-1}$) and seed yield per hectare (28.65 q ha^{-1}) as compared to (T_1) RDF (30:80:37.5 kg ha^{-1}) (8 gm and 21.08 q ha^{-1} respectively).

Ojha R.B. *et al.* (2014) reported that the highest grain yield of mungbean was obtained from the residual FYM level 14 t ha^{-1} and highest biomass of mungbean was obtained from the residual FYM level 17.5 t ha^{-1}. There was a significant positive correlation exists between treatments and crop parameters. It shows that, both the initial level and residual levels of FYM have significant role in crop yields and biomass production.

Shirle *et al*. (2014) studied the effect of manures and fertilizers on yield and soil properties under soybean-safflower cropping sequence during 2006-07 to 2010-11 on Vertisol (Typic Haplusterts). The pooled mean indicated that the 100% NPK + FYM @ 10 Mg ha^{-1} was recorded highest grain yield of soybean (26.44q ha^{-1}) and safflower (18.71 q ha^{-1}).

Prasad D. *et al.* (2015) the maximum seed yield (870 kg ha-1), straw yield (1843 kg ha^{-1}), biological yield (2713 kg ha^{-1}) and harvest index (32.10%) of blackgram was recorded under 100% RDF + Zn + Fe (N:P:K- 20:30:15 kg ha^{-1} + $ZnSO_4$ 5 kg ha^{-1}+ $FeSO_4$ 5 kg ha^{-1}) which was at par with treatment 100% RDF, 50% RDF + 50% RDN through FYM and FYM 4 t ha^{-1} and significantly increased over rest of treatment and control.

Jalali M. *et al.* (2017) conducted an experiment on different nitrogen levels, application of nitrogen @ 30 kg N ha^{-1} was found to be most effective which exhibited significantly higher growth, yield attributes and productivity in terms of grain, straw and biological yield.

Singh R.K. *et al*. (2017) reported that the highest grain yield (872.96 kg ha^{-1}) was recorded in treatment T_8 (Shekhar-2 + 75% Organic + 25% Inorganic) however, treatment T_9 (Shekhar-2 + 50% Organic and Inorganic) and T_7 (Shekhar-2 + 100% Inorganic) was found to be statistically at par with treatment T_8 (Shekhar-2+75% Organic + 25% Inorganic).

Bhadu K. *et al.* (2018) reported that the seed yield significantly higher with 25% nitrogen through FYM, 25% nitrogen through vermicompost, Rhizobium inoculation and PSB spray @ 5ml/l (785.54 kg ha^{-1}) followed by 724.25 kg ha^{-1} in plots given 50% nitrogen through FYM, 50% nitrogen through vermicompost and PSB spray @ 3ml/l (NM_3). The significantly lowest seed yield (449.83 kg ha^{-1}) was recorded in control (NM_5) than other treatments.

CHAPTER III

MATERIAL AND METHODS

With a view to study "Interactive effect of biochar, FYM and nitrogen on soil properties and yield of blackgram" a field experiment was conducted during 2018-19 on the Research farm, Department of Agronomy, Dr. PDKV Akola. The details of material used and methods adopted during the course of investigation are described below under appropriate heads.

3.1 Material required

3.1.1 Climate and weather conditions

3.1.2 Experimental details

3.1.3 Treatment details

3.2 Biochar preparation

3.2.1 Application of biochar, FYM and chemical fertilizer application

3.3 Methods adopted

3.4 Collection and processing of soil samples for analysis

3.5 Biochar chemical analysis

3.6 Soil physical, chemical and biological analysis

3.7 Plant analysis

3.8 Statistical analysis

3.9 Location, duration and season of experiment

3.1 Material Required

3.1.1 Climate and weather conditions

Monthly metrological data on important parameters recorded during the course of investigation at Agro Meteorological Observatory, Dr. PDKV, Akola was used for the study. The weekly meteorological data and rainfall recorded is given in Table 1.

Table 1. Monthly Weather data for the year 2018-2019 recorded at Meteorological Observatory, Department of Agronomy, Dr PDKV., Akola

Actual 2018-19
Normal 1981-2010

Month	T MAX (°C)		T MIN (°C)		BSH (hrs)		Ws (km/hr)		RHI (%)		RHII (%)		Evap (mm)		RF (mm)		CRF (mm)	Rainy Days	
2018	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A		N	A
JANUARY	29.8	**30.2**	11.8	**10.9**	8.2	**7.9**	4.2	**1.2**	70	**63**	29	**21**	4.4	**5.8**	10.7	**0.0**	**0.0**	0.9	**0**
FEBRUARY	32.6	**33.1**	13.7	**15.8**	8.8	**7.1**	4.9	**2.2**	57	**55**	22	**22**	6.3	**7.2**	7.4	**0.7**	**0.7**	0.6	**0**
MARCH	37.0	**37.4**	18.2	**20.3**	8.9	**7.2**	6.0	**3.0**	45	**38**	18	**15**	9.1	**9.0**	15.2	**3.4**	**4.1**	1.1	**1**
APRIL	41.0	**41.8**	23.5	**25.4**	9.4	**9.1**	8.0	**3.9**	38	**33**	15	**12**	12.7	**11.7**	2.6	**0.3**	**4.4**	0.4	**0**
MAY	42.3	**43.7**	27.5	**30.3**	9.4	**8.6**	12.8	**7.5**	46	**37**	19	**15**	15.6	**14.9**	12.4	**0.5**	**4.9**	1.2	**0**
JUNE	37.5	**36.6**	25.9	**25.2**	6.7	**5.4**	13.5	**11.2**	69	**74**	41	**43**	10.7	**9.8**	142.6	**291.6**	**296.5**	6.8	**13**
JULY	32.1	**30.0**	23.9	**23.9**	4.0	**2.0**	10.6	**6.4**	83	**88**	61	**70**	5.3	**4.4**	200.7	**261.9**	**558.4**	10.8	**18**
AUGUST	30.4	**29.6**	23.1	**23.7**	3.7	**2.0**	9.9	**8.5**	87	**86**	68	**69**	4.1	**4.5**	189.7	**212.2**	**770.6**	9.9	**8**
SEPTEMBER	32.1	**32.1**	22.5	**23.0**	6.0	**5.9**	6.8	**3.9**	85	**84**	57	**52**	4.6	**4.7**	123.2	**64.4**	**835.0**	6.5	**2**
OCTOBER	33.4	**35.0**	18.6	**18.8**	7.9	**8.7**	3.7	**0.7**	78	**73**	39	**30**	4.9	**5.2**	53.9	**0.0**	**835.0**	2.9	**0**
NOVEMBER	31.5	**33.2**	14.2	**16.4**	8.2	**8.1**	3.4	**0.6**	72	**73**	32	**29**	4.5	**4.8**	18.8	**4.5**	**839.5**	1.1	**1**
DECEMBER	29.6	**28.5**	11.1	**12.0**	8.1	**7.0**	3.4	**1.1**	71	**73**	29	**33**	4.0	**4.3**	11.5	**0.0**	**839.5**	1.6	**0**
2019																			
JANUARY	29.8	**28.4**	11.8	**10.5**	8.2	**7.6**	4.2	**1.2**	70	**69**	29	**27**	4.4	**4.9**	10.7	**0.0**	**0.0**	0.9	**0.0**
FEBRUARY	32.6	**32.2**	13.7	**15.6**	8.8	**8.2**	4.9	**3.0**	57	**53**	22	**22**	6.3	**6.4**	7.4	**1.9**	**1.9**	0.6	**0.0**
MARCH	37.0	**36.7**	18.2	**16.9**	8.9	**8.9**	6.0	**2.6**	45	**44**	18	**20**	9.1	**7.9**	15.2	**0.0**	**1.9**	1.1	0.0

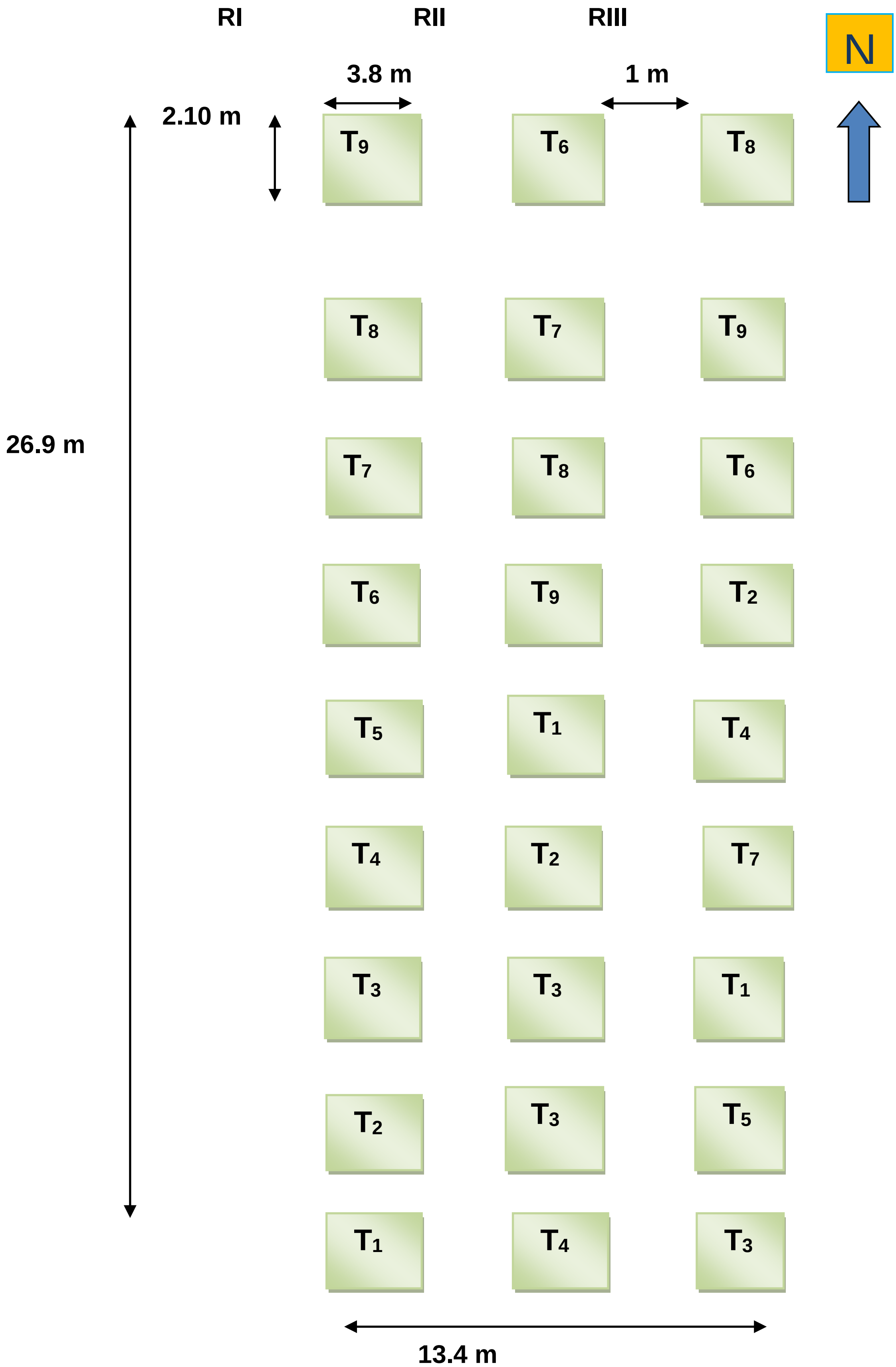

Fig. 1. Plan of layout

3.1.2 Experimental details

1. Location		: Research Farm, Department of Agronomy, Dr. PDKV Akola.
2. Year of the study		: 2018-2019
3. Season		: *Kharif*
4. Crop and Variety		: Black gram (Black Gold)
6. Design of experiment		: Randomized Block Design
7. Number of treatments		: 09
8. Number of replication		: 03
9. Spacing		: 45×10 cm
10. Plot size	Gross plot	: 3.00 × 4.00 m^2
	Net plot	: 2.10 × 3.80 m^2
11. Number of plots		: 27
12. Seed rate		: 10-12 Kg ha^{-1}
13. Method of sowing		: Drilling
14. Recommended dose of fertilizer		: 20:40:00 NPK Kg ha^{-1}

3.1.3 Treatment details

T_1- Control

T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}

T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}

T_4- FYM 10 t ha^{-1} + nitrogen 10 kg ha^{-1}

T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}

T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}

T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}

T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}

T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}

Note- 40 kg ha^{-1} P_2O_5 is common for all treatment except control T_1.

Plate 1. Overview of Experimental Field

Table 2. Physico-chemical properties of experimental site at the start of experiment

Sr. No.	Soil characteristics	Values
1.	Bulk density (Mg m^{-3})	1.47
2.	Water holding capacity (%)	38
3.	pH (1:2.5)	7.95
4.	EC (dSm^{-1})	0.28
5.	Organic carbon (g kg^{-1})	4.26
6.	Available Nitrogen (kg ha^{-1})	200.13
7.	Available Phosphorus (kg ha^{-1})	16.21
8.	Available Potassium (kg ha^{-1})	327.08

The initial soil properties at the start of experiment (*kharif*, 2018-19). The experimental soil was slightly alkaline in pH (7.95), non-saline EC (0.28 dSm^{-1}), and medium to moderate in organic carbon (4.26 g kg^{-1}). The available nitrogen was low (200.13 kg ha^{-1}), medium in available phosphorus (16.21 kg ha^{-1}) and very high in available potassium (327.08 kg ha^{-1}). While the physical properties i.e. bulk density (1.47 Mg m^{-3}) and water holding capacity of soil was (38%).

3.2 Biochar preparation

Biochar for the trial can be produced in a charring kiln. A kiln can be made from an oil drum with a simple design. It has a small holes in the bottom (it is raised up on bricks). The feedstock like sorghum residue, maize residue, sesame residue etc, which is collected from the field and burned into the drum. After that the burned material was removed from the drum and cooled by sprinkled water over burned material.

3.2.1 Application of biochar, FYM and chemical fertilizer

Application of biochar and FYM before sowing of the crop and the recommended dose of fertilizer was applied at the time of sowing. Full quantity of the recommended dose of nitrogen and phosphorus were

Plate 2. Biochar prepared from different crop residue at Agronomy Research Farm Dr. PDKV, Akola

applied at a basal dose through urea and single super phosphate respectively.

3.3. Methods Adopted

3.3.1 Methods followed for the analysis of biochar

Sr. No.	Parameter	Method	Reference
1.	pH	Glass electrode pH meter	Jackson (1973)
2.	Total C	Dry combustion method	Batjets (2005)
3.	Total N	Micro-Kjeldahl method	Keeny and Nelson (1982)
4.	Total P	Modified procedure of Change and Jackson	Peterson and Corey(1966)
5.	Total K	H_2SO_4,$HClO_4$ and HF digestion	Jackson (1973)
6.	C:N ratio	Dry Combustion method : Micro Kjeldahl method	Batjets (2005) : Keeny and Nelson (1982)

3.4 Collection and processing of soil samples for analysis

The soil samples (0-20 cm) were collected from each plot at harvesting stage. Soil sample were air dried in shade and stored in polythene bags for further analysis. The air dried sample were carefully and gently ground with wooden mortar and pestle to break soil lumps (clods) and passed through sieve of 2 mm diameter. For analysis of organic carbon the soil sample were passed through 0.5 mm sieve placed separately. The sieve sample were mixed thoroughly and stored in polythene bags, properly labeled and preserved for subsequent analysis. The samples collected during the period were analyzed and the result are presented at appropriate place in the thesis.

A.	**Soil Analysis**		
a)	**Physical properties**		
1.	Bulk density	Clod coating method	Blacke and Hartage (1986)
2.	Water holding capacity	By using Keen Reckzonski boxes	Gupta & Dakshinamoorthi, 1980
b)	**Chemical properties**		
1.	pH	By using glass electrode pH meter	Jackson (1973)
2.	EC	By using conductivity meter	Jackson (1973)
3.	Organic carbon	Wet oxidation	Nelson & Sommers (1982)
4.	Available N	Alkaline potassium permagnate method	Subbiah and Asija (1956)
5.	Available P	Olsen method $NaHCO_3$ (0.5M) pH 8.5 colorimetric	Watanable and Olsen (1965)
6.	Available K	Neutral normal ammonium acetate using Flame photometer	Jackson (1973)
c)	**Biological properties**		
1.	SMBC	Chloroform Fumigation Extraction method	Jenkinson and Powlson (1976)
B.	**Plant Analysis**		
1.	Total N	Micro Kjeldhals method	Piper (1966)
2.	Total P	Vanadomolybdade yellow colour method using diacid extract Spectrophotometer	Jackson (1973)
3.	Total K	Flame photometrically from diacid extract	Piper (1966)

3.5 Chemical properties of biochar

3.5.1 pH

Biochar pH was determined in 1:2.5 soil : water suspension using digital pH meter (Systronics make digital pH meter) having glass electrode as described by Jackson (1973).

3.5.2 Total Carbon

A known weight of finely powdered biochar sample which passed through 0.5 mm sieve was weighed into a previously weighed silica crucible and kept in a muffle furnace at 600 to 800 °C for 3 hours and after the ashing of sample the weight was recorded and then total carbon was calculated as percentage.

3.5.3 Total Nitrogen

Total nitrogen in biochar was determined by Micro-Kjeldahl method as described by Keeny and Nelson (1982).

3.5.4 Total Phosphorus

Total phosphorus in biochar was determined by Modified procedure of Change and Jackson as described by Peterson and Corey (1966).

3.5.5 Total Potassium

Total potassium in biochar was determined by H_2SO_4,$HClO_4$ and HF digestion as described by Jackson (1973).

3.5.6 C:N ratio

C:N ratio in biochar was determined by Dry Combustion method **:** Micro Kjeldahl method described by Batjets (2005) **:** Keeny and Nelson (1982).

3.6 Soil properties

3.6.1. Bulk density

Bulk density of the disturbed soil samples was determined using glass vial method (Blacke and Hartage 1986).

3.6.2 Water holding capacity

The maximum water holding capacity of soil was determined using Keen's cup as described by Gupta and Dakshinamoorthi (1980).

3.6.3 SMBC

The SMBC of soil was determined by Chloroform Fumigation Extraction method as described by Jenkinson and Powlson (1976).

3.6.4 Soil pH

Soil pH was determined in 1:2.5 soil: water suspension using digital pH meter having glass electrode as described by Jackson (1973).

3.6.5 Electrical conductivity

The clear water supernatant obtained from the suspension used for pH was utilized for the EC measurement using conductivity meter (Jackson, 1973).

3.6.6 Organic carbon

Approximately one gram of 2 mm sieved soil sample was powdered using agate pestle and mortar so that entire amount passed through a 0.5 mm sieve. A known weight of finely powdered sample was treated with known excess volume of standard $K_2Cr_2O_7$ and concentrated H_2SO_4. The unused $K_2Cr_2O_7$ was quantified by back titration with standard ferrous ammonium sulphate using ferroin as an indicator (Nelson & Sommers 1982).

3.6.7 Available nitrogen

Available nitrogen in soil was determined by alkaline potassium permanganate distillation method as described by Subbiah and Asija (1956).

3.6.8 Available phosphorus

Available phosphorus in soil was determined by Olsen method $NaHCO_3$ (0.5M) pH 8.5 colorimetric method as described by Watanable and Olsen (1965).

3.6.9 Available potassium

Available potassium was extracted from soils using neutral *N* ammonium acetate at 1:5 soil to extractant ratio and the concentration of potassium in the extract was determined using Flame photometer (Jackson 1973).

3.7 Plant analysis

Five randomly selected plants from each net plot at different stages were oven dried and used for chemical analysis after grinding.

3.7.1 Digestion of plant samples with di-acid mixture

Di-acid extract was prepared as per method outlined by (Jackson, 1973). It is carried out using 9:4 mixture of HNO_3:$HCLO_4$. The pre-digestion of sample were done by using 10 ml HNO_3 in samples for P and K.

3.7.2 Total Nitrogen

Nitrogen in plant samples was determined by Kjeldahl digestion distillation method as described by Piper (1966).

3.7.3 Total Phosphorus

To a known volume of the di-acid digested extract, vanadomolybdate was added to develop yellow color of vanadomolybdo phosphoric acid in nitric acid medium. The color intensity was measured at 420 nm wavelength (Piper, 1966).

3.7.4 Total Potassium

Five ml of the di-acid digested extract was diluted to 25 ml with distilled water and fed to a calibrated flame photometer. By comparing the flame photometer a reading of the sample with the calibration curve of potassium, per cent potassium in the plant sample was calculated (Piper, 1966).

3.8. Statistical analysis

The level of statistical significance to the experimental data was carried out as per procedure described by Gomez and Gomez (1984).

3.9. Location, duration and season of experiment

The experiment on “Interactive effect of biochar, FYM and nitrogen on soil properties and yield of blackgram" was conducted at Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *Kharif* 2018.

CHAPTER IV

RESULT AND DISCUSSION

Result pertaining to study entitled "Interactive effect of biochar, FYM and nitrogen on soil properties and yield of blackgram" conducted during *kharif* 2018-19 and the results obtained during the course of present investigation are presented, tabulated, interpreted and discussed in this chapter under appropriate headings.

4.1 Chemical properties of biochar

4.2 Yield of blackgram

4.3 Yield attributing character of blackgram

4.4 Number of root nodules and dry weight of root nodules plant^{-1}

4.5 Content and uptake of nutrients by blackgram

4.6 Quality parameter of blackgram

4.7 Chemical properties of soil after harvest of blackgram

4.8 Fertility status of soil after harvest of blackgram

4.9 Physical properties of soil after harvest of blackgram

4.10 Biological properties of soil

4.11 Pearson's Correlation coefficient of yield with various soil properties.

4.1 Chemical properties of biochar

The data pertaining to chemical properties of biochar prepared from different crop residue are presented in Table 3.

The chemical properties of biochar i.e. pH, EC and total carbon content of various crop residue mixture was 8.72, 0.59 dSm^{-1} and 73.0 % respectively. While, the total nitrogen, phosphorus and potassium content were 0.36 %, 0.17 % and 1.12 % respectively and C:N ratio content was 202.77 %.

The biochar obtained from different crop residue was alkaline in nature. Similar properties were observed by Pandian *et al.* (2016).

Table 3. Chemical properties of biochar

Sr. No.	Chemical properties	
1.	pH (1:2.5)	8.72
2.	EC (dSm^{-1})	0.59
3.	Total carbon (%)	73.0
4.	Total N (%)	0.36
5.	Total P (%)	0.17
6.	Total K (%)	1.12
7.	C:N ratio	202.77

4.2 Yield of blackgram

The data pertaining to the yield of blackgram was significantly influenced by various treatments over control is presented in Table 4 and graphically represented in Fig 2.

The significantly higher seed yield (788 kg ha^{-1}) of blackgram was found with soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_7, T_5, T_3 and T_8. The lowest seed yield of blackgram (392 kg ha^{-1}) was recorded in treatment T_1 i.e. control.

The significantly higher straw yield (994 kg ha^{-1}) of blackgram was found with soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_7, T_5, T_3 and T_8. The lowest straw yield of blackgram (610 kg ha^{-1}) was recorded in treatment T_1 i.e. control.

From above data, it was observed that increase in the yield of crop due to blackgram is being a leguminous crop, fix atmospheric nitrogen and biochar enhanced the nitrogen amount thus lead to greater grain yield and reproductive efficiency of crop. Also the blackgram has the ability to fix atmospheric nitrogen, however, microorganisms initially need energy for fixation and therefore N application improves efficiency of microorganisms. Timely and slowly release of nutrients from FYM throughout the growing season might be possible reason for improving seed yield in FYM amended plots. Similar results were observed by Sharma *et al.* (2010), Cornelissen *et al*. (2013) and Rab *et al.* (2016). Hussain *et al*. (2017), also noticed, grain yield and yield attributes of crop increased significantly with various levels of biochar, FYM and nitrogen.

Table 4. Yield of blackgram as influenced by various treatment

Treatment	**Yield of blackgram ($kg\ ha^{-1}$)**	
	Seed	**Straw**
T_1- Control	392	610
T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	518	733
T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	769	972
T_4- FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	641	832
T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	771	975
T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	762	954
T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	778	984
T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	767	966
T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	788	994
SE (m)±	7.5	10.1
CD at 5%	22.6	30.4

4.3. Yield attributing characters of blackgram

The data pertaining to yield attributing characters of blackgram i.e. number of pods $plant^{-1}$, number of branches $plant^{-1}$ and height of plant is reported in Table 5.

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

The data in relation to the number of pods $plant^{-1}$ of blackgram was significantly influenced by various treatments over control. The significantly highest number of pods $plant^{-1}$ (18.85) was observed with soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @

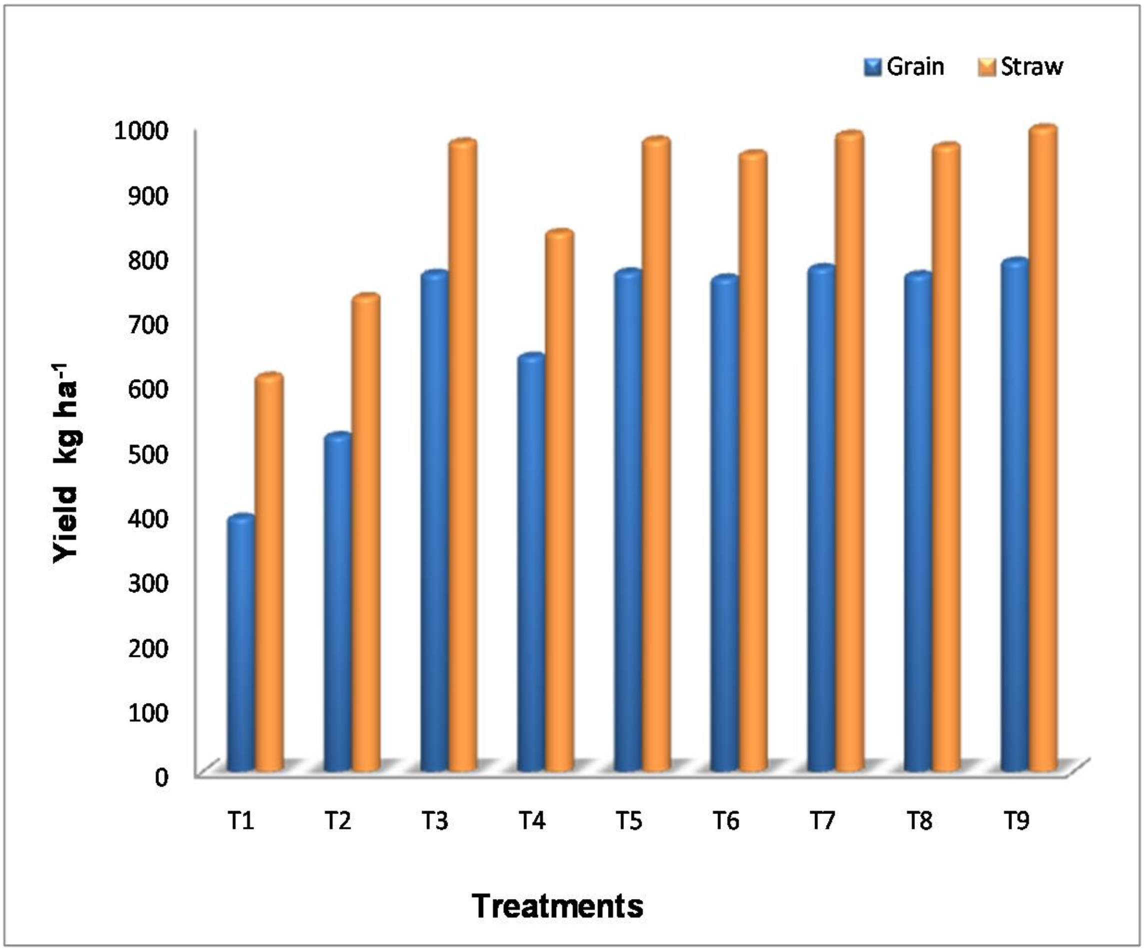

Fig 2. Yield of black gram as influenced by various treatments

20 kg ha^{-1} and it was found to be on par with the treatments T_7, T_5, T_3 and T_8. The lowest number of pods plant^{-1} (10.03) was recorded in control treatment i.e. T_1.

Table 5. Yield attributing characters of blackgram as Influenced by various treatments

Treatment	No. of Pod plant^{-1}	No. of braches plant^{-1}	Plant height (cm)
T_1- Control	10.03	6.70	36.20
T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	12.16	8.13	38.73
T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	16.86	11.06	43.48
T_4- FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	13.40	9.60	40.33
T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	17.28	11.16	44.26
T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	13.96	9.96	42.37
T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	18.19	11.03	45.30
T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	16.46	10.93	43.37
T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	18.85	11.50	46.63
SE (m)±	0.83	0.19	1.13
CD at 5%	2.51	0.60	3.42

Biochar application was resulted in higher pods plant^{-1}, it might due to the biochar application which increase the C:N ratio and reproductive growth of crop. These results are confirmed with Saxena *et al.* (2013), who reported that the number pods plant^{-1} increased with application of biochar.

4.3.2 Number of branches plant^{-1}

The significantly higher number of branches plant^{-1} (11.50) of blackgram was observed with soil application of biochar @ 10 t ha^{-1} + FYM @10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} and it was found to be on par with the treatments T_7, T_5, T_3 and T_8. The lowest number of branches (6.70) plant^{-1} was recorded in treatment T_1 i.e. control. The treatment T_9 i.e. soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} was increased 71.64 % number of branches plant^{-1} over control.

Nitrogen is a integral part of chlorophyll and thus play a key role in the process of photosynthesis and plant vegetative growth which resulted in more branches plant^{-1} (Khan *et al.* 2008). Similarly improvement in branches plant^{-1} of crop due to biochar + FYM amended plots could be high in content of carbon and other nutrient and also the timely and slowly release of nutrient throughout the growing season. (Hussain *et al.* 2017). Also Kokani *et al.* (2014) reported that increase in the number of branches plant^{-1} due to addition of FYM in soil which improved physical, chemical and biological properties of soil and these lead to improve the root growth and development and thereby uptake of nutrients and water from greater soil volume resulting in highest number of branches plant^{-1}.

4.3.3 Plant height

The significantly highest plant height (46.63 cm) was observed with soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was found to be on par with the treatments T_7, T_5, T_3 and T_8. The lowest plant height (36.20 cm) was recorded in control (T_1). The treatment T_9 i.e. soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} was increased upto 28.81% plant height over control.

Plant height was significantly increased by the imposed treatments in all stages of crop growth. It might be attributed due to the biochar providing better growing conditions to crop by continuous supply of nutrients and improvement in soil properties. The variation in plant height was observed due to variation in the availability of major nutrients. Inoculation of effective microorganism in the soils increase the growth parameter of the crop. This was supported by Bandara *et al.* (2015). Similarly Babaji *et al.* (2011) reported that increase in plant height due to residual effect of FYM application on soil increased crop growth might be the result of adequate nutrition release by FYM.

4.4 Number of root nodules and dry weight of root nodules plant^{-1}

The data pertaining root nodule and dry weight of root nodule plant^{-1} is reported in Table 6.

4.4.1 Number of root nodule plant^{-1}

The significantly higher number of root nodules plant^{-1} (22.47) was noticed with the soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was found to be on par with the treatments T_8, T_5 and T_7. The lowest (15.87) number of root nodule plant^{-1} was recorded in treatment T_1. i.e. control.

Table 6. Number of root nodule and dry weight of root nodule plant^{-1} of blackgram as Influenced various treatments

Treatment	No. of nodule plant^{-1}	Dry wt. of nodule plant^{-1} (g)
T_1- Control	15.87	0.21
T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	16.73	0.25
T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	18.13	0.27
T_4- FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	20.60	0.29
T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	21.20	0.30
T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	19.67	0.29
T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	20.76	0.31
T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	21.80	0.32
T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	22.47	0.33
SE (m)±	0.61	0.01
CD at 5%	1.80	0.03

This increased in number of root nodules plant^{-1} was due to favourable physical environment of biochar-amended soil. The positive changes of root biomass was mainly due to the highest addition of biochar, which influenced the soil moisture, nutrient dynamics and improved the soil physicochemical properties and thus increased the root nodules of crop (Pandian *et al.* 2016).

4.4.2 Dry weight of root nodule plant^{-1}

The significantly higher dry weight of root nodules plant^{-1} (0.33 gm) was recorded with the soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was found to be on par with the treatments T_8, T_7, and T_5. The lowest (0.21 gm) dry weight of root nodules plant^{-1} was recorded in control i.e. T_1.

Increasing dry weight of root nodules plant^{-1} could be increased root allocation proportion due to addition of biochar which increase the number of bacteria and also the soil physico-chemical properties and hence more root nodule plant^{-1} were produced. Similar results finding with the observation made by Zhu *et al*. (2018).

4.5 Content and uptake of nutrients by blackgram.

4.5.1 Content and uptake of nitrogen

The results in relation to content and uptake of nitrogen by blackgram is reported in Table 7 and graphically represented in Fig 3.

The content of nitrogen was found to vary from 3.54 to 3.64% in grain and 1.07 to 1.34% in straw. The highest content of nitrogen in grain (3.64%) was recorded in treatment T_9 i.e. soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} and it was on par with treatment T_7, T_5, T_3 and T_8. The lowest nitrogen content in grain (3.54%) was recorded in control treatment i.e. T_1.

The highest nitrogen content in straw (1.34%) was recorded in treatment T_9 i.e. soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} and it was on par with treatment T_7, T_5, T_3 and T_8. The lowest content nitrogen in straw (1.07%) was recorded in treatment T_1 i.e. control.

Table 7. Content and uptake of nitrogen by blackgram as influenced by various treatment

Treatment	Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
T_1- Control	3.54	1.07	13.88	6.52	20.40
T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	3.58	1.11	18.54	8.13	26.67
T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	3.62	1.29	27.84	12.53	40.37
T_4- FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	3.60	1.13	23.07	9.40	32.47
T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	3.63	1.28	27.99	12.68	40.67
T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	3.60	1.18	27.43	11.25	38.68
T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	3.63	1.31	28.24	12.89	41.13
T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	3.62	1.26	27.76	12.17	40.30
T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	3.64	1.34	28.68	13.31	41.99
SE (m)±	0.01	0.03	0.66	0.64	1.05
CD at 5%	0.03	0.09	1.97	1.94	3.16

Comparison between various treatments, higher N content was observed in soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} than other treatment. It was also noticed that the content of nitrogen is higher in grain than straw. The soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} increased by 2.82% and 25.23% nitrogen content in grain and straw respectively over control.

The data indicated that the significantly higher uptake of nitrogen (28.68 kg ha^{-1}) by grain of blackgram was observed with the soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg

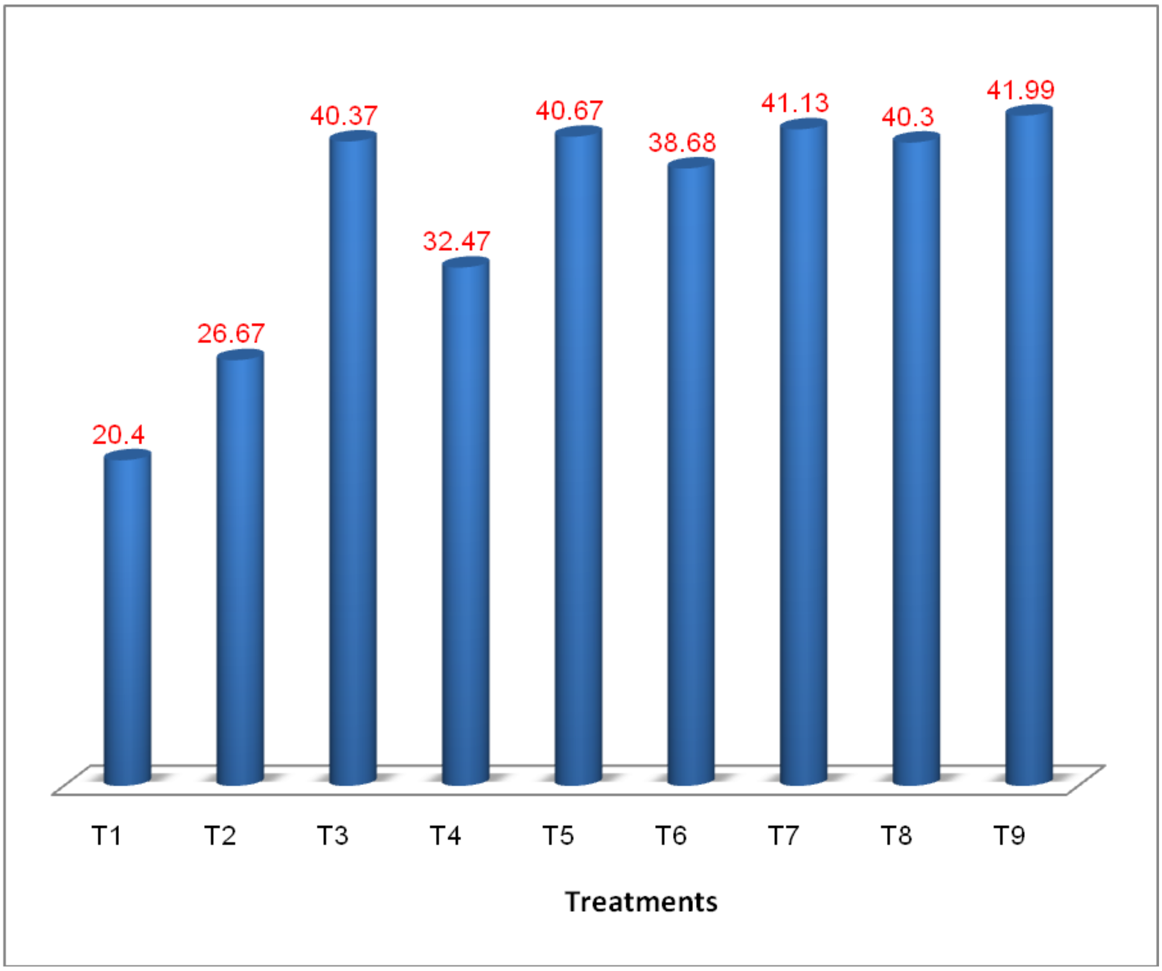

Fig.3 Total nitrogen uptake (kg ha^{-1}) by blackgram as influenced by various treatment

ha^{-1} (T_9) and it was found to be on par with treatment $T_{7,}$ $T_{5,}$ T_3 and $T_{8.}$ The lowest N uptake by blackgram seed (13.88 kg ha^{-1}) was recorded in treatment T_1 i.e. control.

The significantly higher N uptake (13.31 kg ha^{-1}) by blackgram straw was observed with the application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was also found to be on par with treatment $T_{7,}$ $T_{5,}$ T_3 and $T_{8.}$ The lowest N uptake by blackgram straw (6.52 kg ha^{-1}) was recorded in treatment T_1 i.e. control.

The significantly highest total N uptake (41.99 kg ha^{-1}) by blackgram was recorded in treatment (T_9) which was found to be on par with $T_{7,}$ $T_{5,}$ T_3 and T_8. The lowest total N uptake by blackgram seed (20.40 kg ha^{-1}) was recorded in treatment (T_1) i.e. control.

From above discussion, it can be observed that biochar act as a habitat for soil microorganism involved in N, P and S transformation and also has the capacity to support the presence of adsorbed bacteria from which the organism may influence soil process. FYM provide half of the N, third part of P and full of K availability and further increase microbial population that assimilates N from atmosphere thus N uptake along with other nutrient are significantly increase in seeds of crop. Similar result were observed by Pietikainen *et al.* (2000), and). Ranpariya *et al.* (2017). Nigussie *et al*. (2012), also recorded nutrient content and uptake of crop increased significantly with various levels of biochar, FYM and nitrogen.

4.5.2 Content and uptake of phosphorus

The data in respect of content and uptake of phosphorus by blackgram were significantly influenced by various treatments and presented in Table 8 and graphically represented in Fig 4.

The content of phosphorus was found to vary from 0.45 to 0.65% in grain and 0.20 to 0.34% in straw. Content of phosphorus in grain (0.65%) of blackgram was highest in treatment of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_7, T_5, T_3 and T_8. The lowest phosphorus content (0.45%) in grain was recorded in treatment T_1 i.e. control.

Content of phosphorus in straw (0.34%) of blackgram was highest in treatment where soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) which was on par with treatment T_7, T_5, T_3 and T_8. The lowest phosphorus content (0.20%) in straw was recorded in treatment T_1 i.e. control.

Table 8. Content and uptake of phosphorus by blackgram as influenced by various treatment

Treatment	Phosphorus content (%)		Phosphorus uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
T_1- Control	0.45	0.20	1.76	1.22	2.98
T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	0.48	0.22	2.48	1.61	4.09
T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	0.61	0.32	4.69	3.11	7.80
T_4- FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	0.50	0.23	3.20	1.91	5.11
T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	0.62	0.32	4.77	3.12	7.89
T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	0.52	0.27	3.96	2.57	6.53
T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	0.63	0.33	4.90	3.24	8.14
T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	0.60	0.31	4.60	2.99	7.59
T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	0.65	0.34	5.12	3.37	8.49
SE (m)±	0.02	0.01	0.18	0.23	0.35
CD at 5%	0.06	0.03	0.55	0.70	1.08

The soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} increased by 44.44% and 70.00% phosphorus content in grain and straw respectively over control.

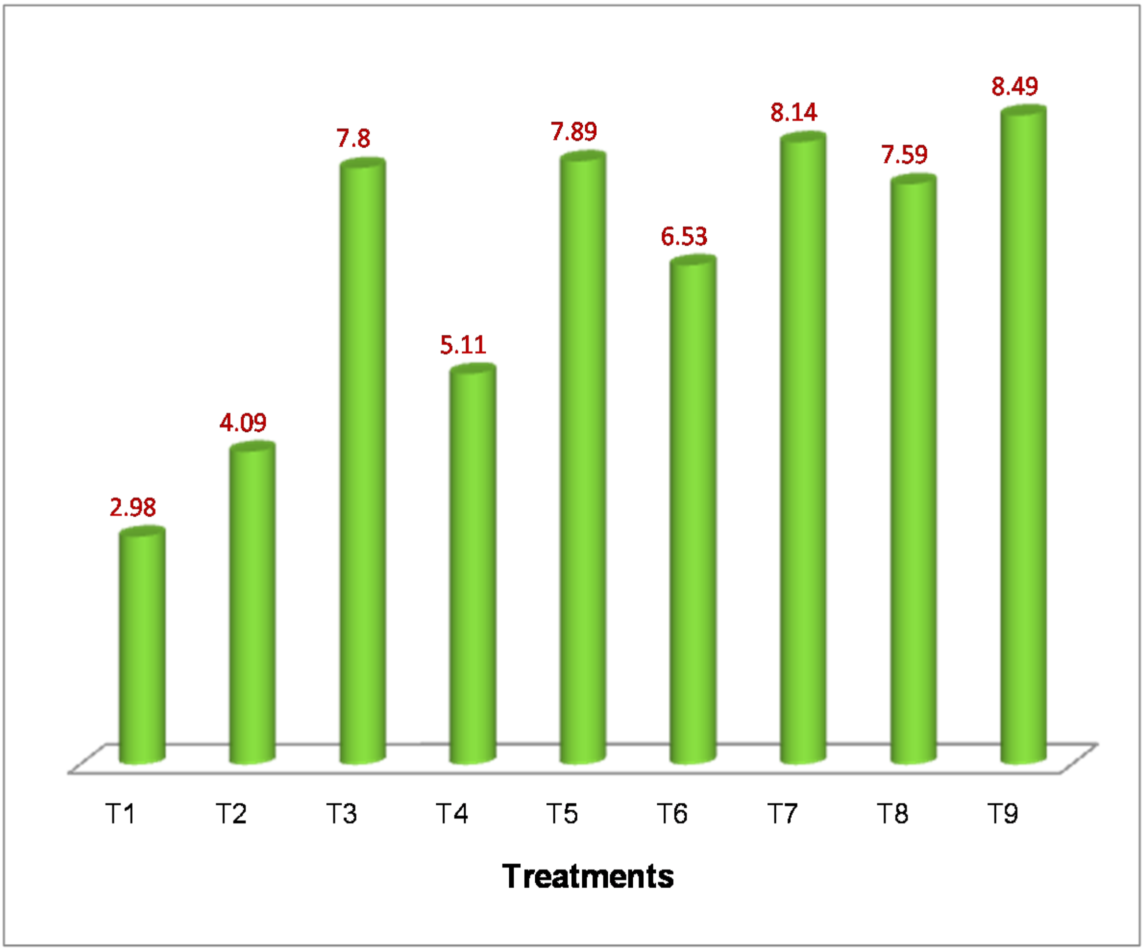

Fig.4 Total phosphorus uptake (kg ha^{-1}) by blackgram as influenced by various treatment

The significantly higher P uptake (5.12 kg ha^{-1}) by blackgram grain was observed with application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par (4.90 kg ha^{-1}) with the treatment T_7, T_5, T_3 and T_8. The lowest P uptake by blackgram (1.76 kg ha^{-1}) was observed in treatment T_1 i.e. control.

The significantly higher P uptake (3.37 kg ha^{-1}) by blackgram straw was observed with application biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with the treatment T_7, T_5, T_3 and T_8. The lowest P uptake by blackgram (1.22 kg ha^{-1}) straw was observed in control.

The significantly higher total P uptake (8.49 kg ha^{-1}) by blackgram was observed with application biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with the treatment T_7, T_5, T_3 and T_8. The lowest total P uptake by blackgram (2.98 kg ha^{-1}) was observed in treatment T_1 i.e. control.

From above discussion, it can be noticed that increase in uptake of P due to biochar being a highly porous with high specific surface area was attributable to the release of more nutrient in soil. The high availability of nutrients in soil might have enhanced nutrient uptake of crop. High dose of biochar addition in the tropical environment have been associated with increased plant uptake of P, K, Ca, Zn and Cu as reported by Lehmann and Rondon (2006).

4.5.3 Content and uptake of potassium

The data pertaining to content and uptake of potassium by blackgram is presented in Table 9 and graphically represented in Fig 5.

The content of potassium was found to vary from 0.83 to 0.99% in grain and 0.85 to 1.16% in straw. Potassium content in grain of blackgram was noticed highest in treatment, application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (0.99%) which was on par with treatment T_7, T_5, T_3 and T_8. The lowest potassium content (0.83%) in grain was recorded in treatment T_1 i.e. control.

Potassium content in straw of blackgram (1.16%) was highest in treatment, soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) which was on par with treatment T_8, T_7, T_5 and T_3. The lowest potassium content (0.85%) in straw was recorded in treatment T_1 i.e. control.

Table 9. Content and uptake of potassium by blackgram as influenced by various treatment

Treatment	Potassium content (%)		Potassium uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
T_1- Control	0.83	0.85	3.25	5.18	8.43
T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	0.85	0.98	4.40	7.18	11.58
T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	0.95	1.11	7.30	10.78	18.08
T_4- FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	0.86	1.03	5.51	8.56	14.07
T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	0.96	1.14	7.39	11.11	18.50
T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	0.90	1.05	6.85	10.01	16.86
T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	0.97	1.15	7.54	11.31	18.85
T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	0.94	1.09	7.20	10.52	17.92
T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	0.99	1.16	7.80	11.53	19.33
SE (m)±	0.02	0.03	0.20	0.55	0.48
CD at 5%	0.06	0.09	0.61	1.68	1.43

The soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} increased 19.27% and 36.47% potassium content in grain and straw respectively over control.

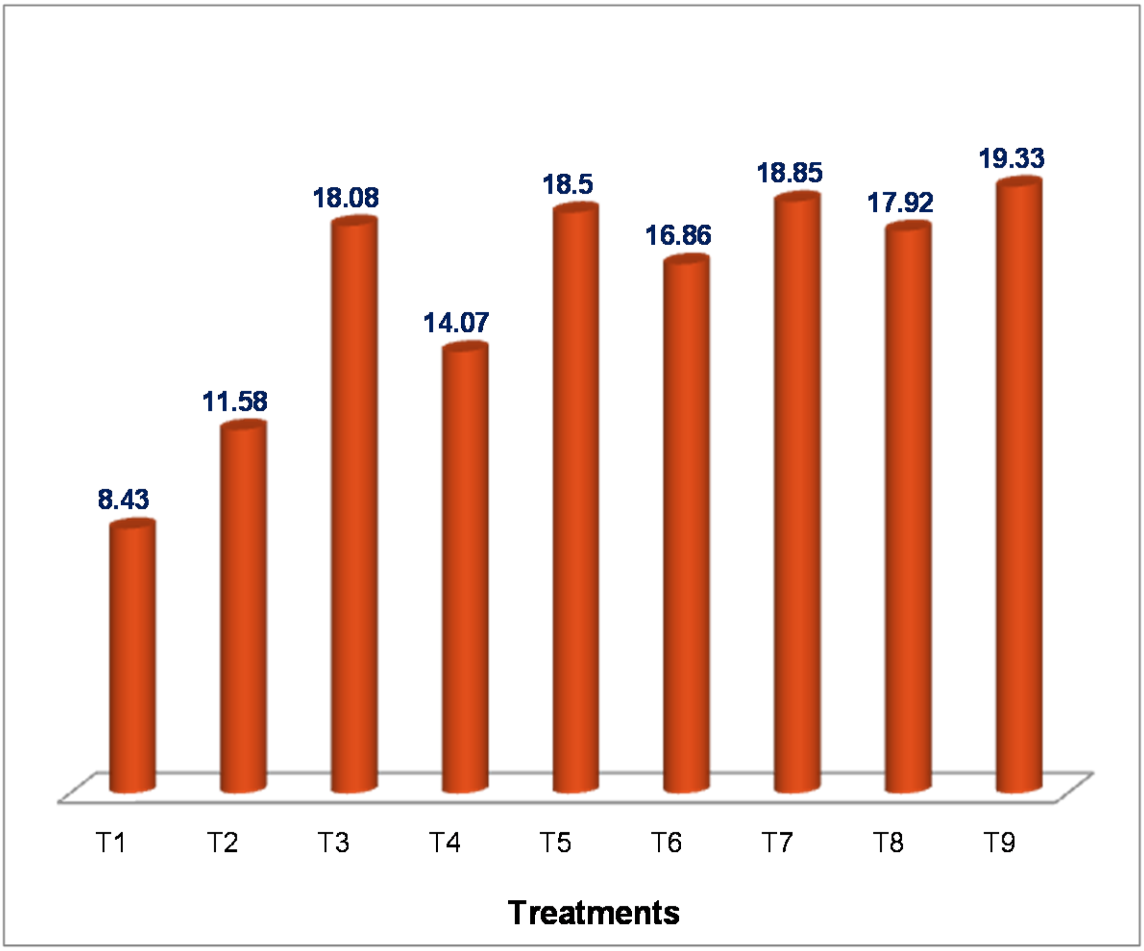

Fig.5 Total potassium uptake (kg ha^{-1}) by blackgram as influenced by various treatment

The data indicated that the significantly higher K uptake (7.80 kg ha^{-1}) by blackgram grain was observed with application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_7, T_5, T_3 and T_8. The lowest K uptake by blackgram (3.25 kg ha^{-1}) was recorded in T_1 i.e. control.

The significantly higher K uptake (11.53 kg ha^{-1}) by blackgram straw was observed with application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_7, T_5, T_3 and T_8. The lowest K uptake by blackgram (5.18 kg ha^{-1}) straw was recorded in T_1 i.e. control.

The significantly highest total K uptake (19.33 kg ha^{-1}) by blackgram was observed in the treatment of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_7, T_5, T_3 and T_8. The lowest total K uptake by blackgram (8.43 kg ha^{-1}) was recorded in T_1 i.e. control. It was noticed that the content and uptake of potassium may be increased due to the increasing amount of charcoal also increased above and below ground biomass production and the uptake of K in biochar amended soils might also be attributed to the presence of K rich ash in the biochar. Similar result reported by Lehmann and Rondon (2006). NIgussie *et al*. (2012). Uzoma *et al.* (2011) also found that increase in microbial activity due to application of biochar could also be the reason for the highest nutrient uptake in biochar treated soil.

4.6 Quality parameters of blackgram

The data in relation to quality parameters i.e. test weight and protein content by blackgram are presented in Table 10.

Table 10. Test weight and protein content in blackgram as influenced by various treatment

Treatment	Test weight (g)	Protein content (%)
T_1- Control	33.76	22.15
T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	34.15	22.43
T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	34.68	22.64
T_4- FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	34.27	22.50
T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	34.73	22.67
T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	34.45	22.56
T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	34.92	22.68
T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	34.64	22.63
T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	34.95	22.75
SE (m)±	0.36	0.04
CD at 5%	1.09	0.13

4.6.1 Test weight

The data revealed that the test weight of blackgram grain was found to vary from 33.76 to 34.95 g. Test weight was increased due to various treatments over control. Significantly highest test weight (34.95 g) was recorded in treatment soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was found to be on par with all other treatments expect treatment T_1.

The soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} increased by 3.52 % test weight over control.

Increasing the rate of biochar resulted in greater grain size, the possible reason for this may be that biochar provide the necessary minerals which improved content in grains as a result grain size is increased. Our results are in line with Arif M.*et al.* (2012) who found that grain weight increase with the application of biochar.

4.6.2 Protein content

The data revealed that the protein content in grain of blackgram was found to vary from 22.15 to 22.75%. Protein content was increased due to application of various treatment. Highest protein content (22.75%) was recorded in treatment of soil application of biochar 10 t ha^{-1} + FYM 10 t ha^{-1} and nitrogen 20 kg ha^{-1} and it was found to be on par with the treatments T_7, T_5, T_8 and T_3. The lowest weight was recorded in treatment control i.e. T_1.

The soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} increased upto 2.70% protein content over control.

Increase protein content has been observed with the application of biochar in the soil. Since the presence of organic amendments (like biochar) in the soil help the soil to retain more nutrients and water (due to negatively charged surface area and small particle size increasing its fertility status). And these nutrient and water is ultimately extracted easily by plant roots and are used to regulate its metabolism (Karhu *et al.* 2011 and Scott *et al.* 2014). The significant increase in protein content in seed of black gram was due to increased nitrogen content in seed and nitrogen which is an integral part of protein. It may also be attributed due to increased availability of phosphorus, as it is structural element of certain co-enzyme involved in protein synthesis. The present result is in accordance with the finding of Vasanthi and Subramanian (2004).

4.7 Chemical properties of soil after harvest of blackgram

The results pertaining to chemical properties of soil i.e. pH, EC, organic carbon and available nutrients of soil after harvest of blackgram were influenced by various treatments are presented in Table 11 and 12 and graphically represented in Fig 6.

Table 11. Chemical properties of soil after harvest of blackgram

Treatments	pH	EC (dSm^{-1})	OC ($g\ kg^{-1}$)
T_1- Control	7.95	0.28	4.26
T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	7.94	0.26	4.63
T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	7.93	0.26	4.71
T_4- FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	7.94	0.25	4.73
T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	7.93	0.25	4.91
T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	7.94	0.29	4.75
T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	7.94	0.29	4.92
T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	7.93	0.30	4.88
T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	7.92	0.30	4.95
SE (m)±	0.03	0.02	0.06
CD at 5%	NS	NS	0.19

4.7.1 Soil pH

The data presented in table 11 indicated that pH of soil ranges from 7.93 to 7.95 indicating that soil was slightly alkaline in reaction. The higher value of pH was recorded in control treatment T_1. The lowest pH was recorded with the soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} i.e. T_9.

Biochar contains carbonate and soluble base cations, such as calcium and magnesium. The combination of cations and carbonate in the soil will form slightly soluble carbonates and restrict the hydrolyzation of carbonate, while decreasing content of hydroxyl in the soil. Thus, the soil pH was decreased to some extent after the addition of biochar (Yuan *et al.* 2011).

4.7.2 Electrical conductivity

The electrical conductivity (EC) is a measure of soluble salt concentration in soil. Higher amount of salt in the soil restrict the nutrient uptake and thus affect the plant growth. The changes in EC due to the application of various sources were non-significant. The data in respect of electrical conductivity ranged from 0.25 to 0.30 dSm^{-1} and highest value of EC were recorded in treatment T_8 and T_9.

The increase in soil EC due to application of biochar might be attributed that ash accretion. The ash residues are generally dominated by carbonates of alkali and alkaline earth metals. Similar results were found by Bandara *et al.* (2015).

4.7.3 Organic carbon

The data pertaining to organic carbon of soil after harvest of blackgram was significantly influenced by various treatments over control. The organic carbon in soil varied from 4.26 to 4.95 g kg^{-1} indicating that the soil was medium to moderate in organic carbon content.

The significantly highest organic carbon (4.95 g kg^{-1}) in soil after harvest of blackgram was observed with the soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_8. T_7 and T_5. The lowest value (4.26 g kg^{-1}) of organic carbon was found in control plot.

The superiority of biochar with respect to the organic carbon content might be due to the huge surface area of biochar, which in turn provides micropores for beneficial microorganisms habitat thereby increasing a soil organic carbon content. High amount of organic carbon in the added biochar might have resulted in increased organic carbon content of soil at harvest. This was in corroboration with the finding of Nigussie *et al.* (2012). Similarly increase the organic carbon content in the surface of soil was mainly due to the accumulation of organic residue over a period of time. This was in accordance with the finding of several workers (Tiwari *et al.* 1995, Singh *et al*. 1999 and Alok Tiwari *et al.* 2002). The increase in soil organic carbon content might be attributed to the oxidation of soil organic carbon content (Muneshwar Singh *et al.*2008).

4.8 Fertility status of soil after harvest of blackgram

4.8.1 Available nitrogen

The result pertaining to available nitrogen in soil after harvest of blackgram was significantly influenced by various treatments. The available nitrogen in soil varied from 202.79 to 231.52 kg ha^{-1} indicating that the soil was low in available nitrogen.

Table 12. Fertility status of soil after harvest of blackgram as Influenced various treatments

Treatment	Available Nutrients (kg ha^{-1})		
	N	P	K
T_1- Control	202.79	16.62	330.2
T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	204.88	18.58	334.2
T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	217.42	20.50	335.8
T_4- FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	208.22	19.80	336.3
T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	223.27	20.70	338.1
T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	210.73	20.29	339.3
T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	227.87	21.04	341.2
T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	225.70	21.73	344.0
T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	231.52	22.19	348.2
SE (m)±	1.98	0.37	2.76
CD at 5%	5.96	1.34	8.32

The highest available nitrogen (231.52 kg ha^{-1}) was observed in soil after harvest of blackgram with soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with

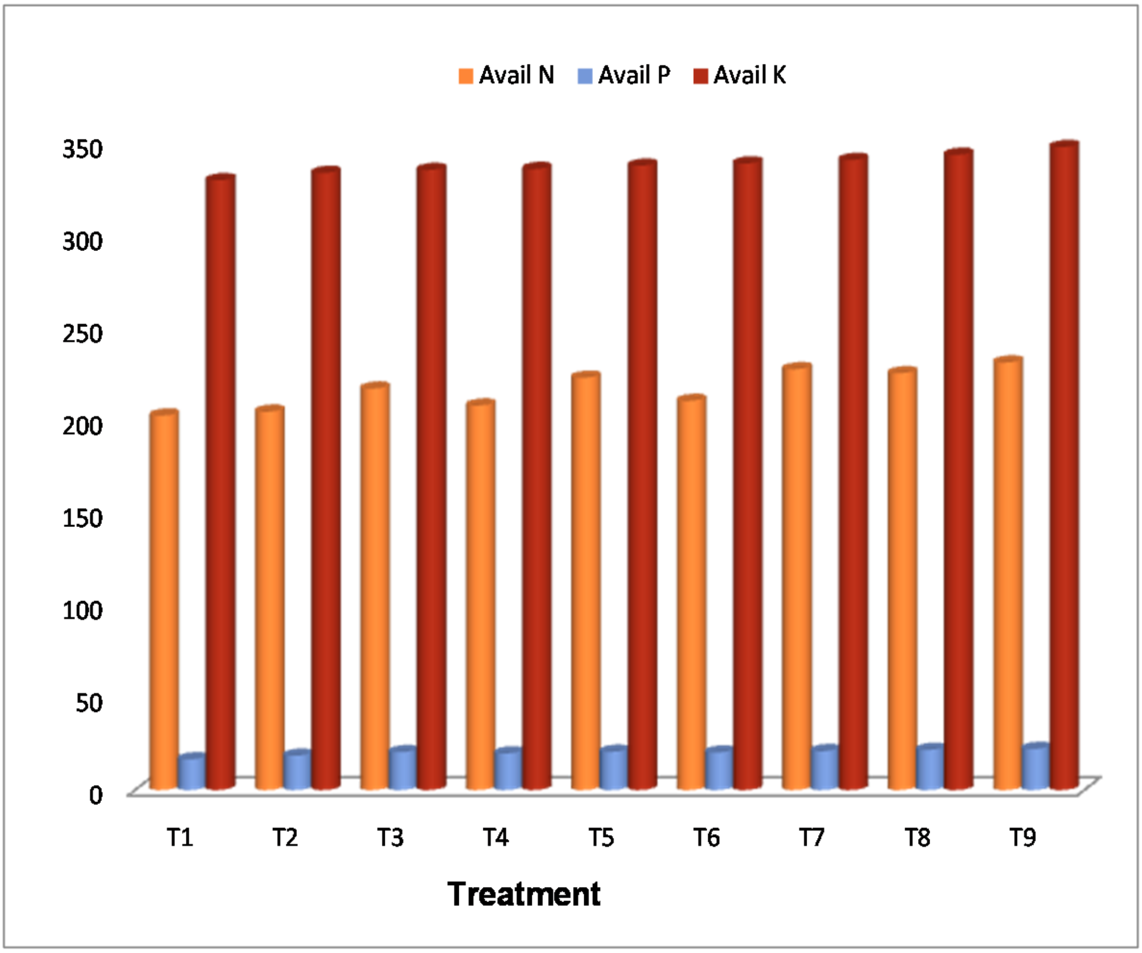

Fig 6. Available N, P, and K kg ha^{-1} as influenced by various treatment after harvest of blackgram

treatment T_8 and T_7. The lowest value of available nitrogen (202.79 kg ha^{-1}) was recorded in treatment control i.e.T_1.

The available nitrogen was increased in soil due to the biochar, it can play an essential role in nutrient cycle and thus affecting N retention in soil. Biochar efficiently absorb ammonia (NH_3) and act as a binder for ammonia in soil, therefore have the potential to decrease ammonia volatilization from soil surfaces. Similar result noticed by Asai *et al.* (2009) application of biochar modify the physical environment of soil and dynamics of soil nutrients. Similarly the highest of value of available N was due to incorporation of FYM once in 3 years over a period of time might be attributed to enhanced mineralization and accumulation of N in surface soil layer. These finding were in accordance with Kaleemulla Sharif *et al.* 1984, Bharadwaj and Omanwar, (1994) and Alok Tiwari *et al.* 2002).

4.8.2 Available phosphorus

It is evident from the data, available phosphorus content in soil varied significantly and it ranged from 16.62 to 22.19 kg ha^{-1} indicating that the soil was medium in available phosphorus content.

The highest available phosphorus (22.19 kg ha^{-1}) was observed with the soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_8 and T_7. The lower value (16.62 kg ha^{-1}) available phosphorus was found in treatment control i.e. (T_1).

The increase in phosphorus in soils treated with biochar might be due to increased microbial population, which solubilize insoluble phosphorus thereby, increase its availability. Similar result observed by (Blackwell *et al.* 2010). The increase in availability of phosphorus in biochar treated soils might be due to the direct addition of phosphorus by the biochar and also changes in soil micro dynamics. Similarly the incorporation of FYM along with inorganic P increased the availability of P and this may be due to reduction in fixation of water soluble P, increased mineralization of organic P due to microbial action and enhanced the availability of phosphorus.

4.8.3 Available potassium

The data (Table 12) on available potassium in soil after harvest of blackgram varied significantly from 330.20 to 348.20 kg ha^{-1} indicating that soil was very high in available potassium. The highest available potassium (348.20 kg ha^{-1}) was observed with the application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9)) and it was on par with treatment T_8 and T_7. The lowest value (330.20 kg ha^{-1}) of available potassium in soil was found in treatment control i.e. (T_1).

The increase in available K in soils treated with biochar might be due to the increase in surface charge of soils which hold positively charged ions and minimizes the leaching losses. (Sukartono *et al.* 2011). Similar result reported by (Bandara *et al.* 2015) that biochar release bases, such as K^+, Ca^+, and Mg^{2+} thereby, increasing the availability of nutrients. Similarly the higher value of potassium due to FYM may be ascribed to the reduction of K fixation and release of K due to interaction of organic matter with clay (Tandon,1987). Similar result were reported by Jagadeeshwari and Kumaraswamy (2000).

4.9 Physical properties of soil after harvest of blackgram

The data pertaining to physical properties of soil i.e. bulk density and water holding capacity at harvest of blackgram is reported in Table 13.

4.9.1 Bulk density (BD)

The data presented in Table 13 indicated that the bulk density of soil at harvest of crop was found non-significant by various treatment, there was a numerical reduction in bulk density in the treatment T_8 and T_9.

Mukherjee *et al.* (2013), attributed the decrease in bulk density due to biochar application to its high porosity, which when applied to soil increase the total pore volume. Similarly Babhulkar *et al*. (2000) reported that the improvement in the soil physical properties might due to increased organic matter and improved soil structure due to addition of FYM.

Table 13. Bulk density and water holding capacity of soil as Influenced by various treatments

Treatments	Bulk Density ($Mg\ m^{-3}$)	Water holding capacity (%)
T_1- Control	1.47	38.33
T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	1.46	40.33
T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	1.46	42.66
T_4- FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	1.45	42.33
T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	1.45	44.00
T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	1.46	42.66
T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	1.45	44.66
T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	1.44	44.66
T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	1.44	47.33
SE (m)±	0.01	1.23
CD at 5%	NS	3.70

4.9.2 Water holding capacity (WHC)

The experimental result pertaining to water holding capacity at harvest are presented in table 13. Data indicated that there was significant influence in water holding capacity by a various treatments. However, there was a increasing water holding capacity was recorded in soil treated with biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} and it was found to be on par with the treatments T_8, T_7 and T_5. Whereas the lowest water holding capacity was observed in control i.e. T_1.

The increasing water holding capacity of soil due to biochar because it has high specific surface area, extensive pore structure and more total porosity (micro and macro pores). Similar interpretation was made by Sun *et al.* (2013). Similarly Hearth *et al.* (2013) reported that biochar application increased the water retention capacity of the soil because it increase soil porosity and also due to adsorptive nature of biochar.

4.10 Biological properties of soil

4.10.1 Soil Microbial Biomass Carbon (SMBC)

The data pertaining to Soil Microbial Biomass Carbon (SMBC) at flowering stage of blackgram is reported in Table 14.

Table 14. Soil Microbial Biomass Carbon in soil as influenced of various treatments at flowering stage

Treatment	SMBC (mg kg^{-1})
T_1- Control	174.33
T_2- FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	185.27
T_3- FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	194.34
T_4- FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	188.01
T_5- FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	196.52
T_6- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 10 kg ha^{-1}	190.04
T_7- Biochar 5 t ha^{-1} + FYM 5 t ha^{-1} + Nitrogen 20 kg ha^{-1}	201.34
T_8- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 10 kg ha^{-1}	200.09
T_9- Biochar 10 t ha^{-1} + FYM 10 t ha^{-1} + Nitrogen 20 kg ha^{-1}	204.46
SE (m)±	2.91
CD at 5%	8.78

The significantly increase in soil microbial biomass carbon was recorded in the treatment soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} and it was found to be on par with the treatment T_7, T_8, and T_5. Whereas the lowest soil microbial biomass carbon was reported in treatment control (T_1).

Microbial biomass carbon is a measure of the carbon (C) contained within the living components of soil organic matter (i.e. bacteria and fungi). Microbes decompose soil organic matter releasing carbon dioxide and plant available nutrients. The biochar, FYM and nitrogen maximize the organic matter return to soil and minimize soil disturbance tend to increase the microbial biomass. Soil properties such as pH , clay and the availability of organic carbon all influence the size of the microbial biomass.

Positive effect of biochar was observed mainly due to a wide range of compounds on its surface immediately after pyrolysis (Painter 2001). These include compounds that are easily metabolized by microbes, such as sugars and aldehydes. Similarly Chakraborty *et al.* (2011) reported that urea along with FYM increased soil microbial biomass carbon as FYM supplied readily available organic matter in addition to increasing root biomass and root exudates due to greater crop growth. The result similar with the finding of Goyal *et al*. (1993) who reported that soil microbial biomass carbon respond to number of management practices, e.g.,addition of animal manure, synthetic fertilizers, and residue incorporation.

4.12 Pearson's correlation coefficient of yield with various soil properties

The data on correlation coefficient of yield with various soil properties are presented in Table 15.

Table 15. Pearson's correlation coefficient of yield with various soil properties

	Yield	OC	Avail N	Avail P	Avail K	Bulk density	WHC	SMBC
Yield	1							
OC	0.735**	1						
Avail N	0.785**	0.784**	1					
Avail P	0.839**	0.839**	0.736**	1				
Avail K	0.713**	0.628**	0.745**	0.699**	1			
Bulk density	-0.441*	-0.547**	-0.532**	0.347	0.275	1		
WHC	0.562**	0.831**	0.592**	0.701**	0.666**	-0.317	1	
SMBC	0.781**	0.581**	0.735**	0.663**	0.518**	-0.425*	0.426*	1

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

The correlation matrix (Table 15) showed a positive and significant relationship between yield with various soil properties. The available P (0.839**) was highly correlated with yield of blackgram followed by available N (0.785**), organic carbon (0.735**) and available K (0.713**) indicating their contribution in improving yield of blackgram.

Among other soil properties, organic carbon negatively correlated with bulk density (r=0.547**) and positively correlated with water holding capacity (r=0.831**) followed by soil microbial biomass carbon (SMBC) (r=0.581**). Similarly Chan *et al.* (2008) and Zwieten *et al.* (2010) also reported the increase in available phosphorus after the application of biochar.

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

The field experiment was conducted to study the "Interactive effect of biochar FYM and nitrogen on soil properties and yield of blackgram" in randomized block design with nine treatment and three replication. A field experiment was conducted during 2018-19 on the Research farm, Department of Agronomy, Dr. PDKV Akola.

The composite soil sample was collected initially at start of experiment and plot wise soil sample were collected after harvesting of black gram to study the effect of biochar, FYM and nitrogen on soil properties. The plant samples were also collected after harvest of crop to estimate the nutrient concentration and uptake of total nutrients.

The salient findings emanated during the course of investigation are summarized and conclusion emerged are briefly presented in this chapter.

5.1.1 Yield of blackgram

The significantly higher seed yield (788 kg ha^{-1}) and straw yield (944 kg ha^{-1}) of blackgram were recorded with soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_7, T_5, T_3 and T_8.

The increasing level of biochar with FYM and nitrogen was found beneficial for improving yield of blackgram as compared to other treatments.

5.1.2 Yield attributing characters of blackgram

The yield attributing characters *viz.*, number pods $plant^{-1}$ (18.85), number of branches $plant^{-1}$ (11.50) and plant height (46.63 cm) were significantly increased with soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} and it was found to be on par with the treatments T_7, T_5, T_3 and T_8.

5.1.3 Content and uptake of nutrients by blackgram.

The highest content and uptake of N, P and K were observed with soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} and it was found to be on par with the treatments T_7, T_5, T_3 and T_8. The nutrient uptake by blackgram was found to be reduced in treatment T_1 i.e. control.

5.1.4 Quality parameter of blackgram

The test weight was significantly highest in treatment soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was found to be on par with all other treatments expect treatment T_1.

The protein content of blackgram has been increased due to the application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_7, T_8, T_5 and T_3.

5.1.5 Fertility status after harvest of blackgram

The effect of different levels of biochar, FYM and nitrogen was found non-significant on soil pH and EC, however significant effect were recorded on soil organic carbon and available N, P and K in soil after harvest of blackgram.

The pH of soil ranges from 7.93 to 7.95 indicating that soil was slightly alkaline in reaction. The higher value of pH was recorded in control over other treatments. The lowest pH was noticed in treatment T_9 i. e soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1}. In case of EC, the treatment difference was found statistically non-significant and numerically lowest EC (0.25 dSm^{-1}) was observed in the treatment T_4 and T_5.

The highest organic carbon (4.95 g kg^{-1}) was observed with the soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_8, T_7 and T_5. The lower value (4.26 g kg^{-1}) of organic carbon was observed in control i.e. (T_1).

Available N, P and K status in soil after harvest of blackgram were significantly increased with the application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and it was on par with treatment T_8, T_7. Whereas, the lower value of available N, P and K in soil were recorded in treatment (T_1) i.e. control.

5.1.6 Bulk density and water holding capacity of soil.

The bulk density of soil at harvest of crop was found non-significantly by various treatments. There was a numerical reduction in bulk density in the treatment T_8 and T_9.

The water holding capacity of soil was found significant at harvest as influenced by various treatments. However, the increasing water holding capacity of soil was recorded in soil application with biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} and it was found to be on par with the treatments T_8, T_7 and T_5.

5.1.7 Soil Microbial Biomass carbon (SMBC)

The significantly increase the soil microbial biomass carbon (SMBC) was recorded in the treatment soil application with biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} and it was found to be on par with the treatment T_7, T8 and T_5. Whereas, the lowest soil microbial biomass carbon was reported in treatment control (T_1).

5.1.8 Pearson's correlation coefficient of yield with various soil properties

The correlation matrix showed a positive and significant relationship between yield with various soil properties. The available P (0.839**) was highly correlated with yield of blackgram followed by available N (0.785**), organic carbon (0.735**) and available K (0.713**) indicating their contribution in improving yield of blackgram.

5.2 Conclusion

1. Soil properties like bulk density, water holding capacity, organic carbon, available nutrients and soil microbial biomass carbon in soil after harvest of blackgram were significantly highest with the application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and was on par with treatment T_8, T_7, T_5 and T_3.
2. Yield, uptake of nutrients and quality of blackgram were significantly highest with the application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 20 kg ha^{-1} (T_9) and was on par with treatment T_8, T_7, T_5 and T_3.

It is concluded that, the soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} and nitrogen @ 10 kg ha^{-1} were favourably influenced the yield, uptake of nutrients and quality of blackgram as well as slightly improvement were observed in soil properties.

CHAPTER VI

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