Research Article

Effect of integrated use of biochar, FYM and nitrogen fertilizer on soil organic fertility

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Abstract

The study was conducted to determine 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 at Agricultural Research Farm of Khyber Pakhtunkhwa Agricultural University Peshawar in 2010-2011. Soil samples at 0-15 cm depth were collected from maize and mungbean plots at harvest stage (May, 2011). Both maize and mungbean crops received biochar alone and in combination with FYM before sowing (November, 2010). The soil samples were analyzed for soil organic matter and mineral N. The results showed that the effect of fertilizer N and FYM on accumulation of soil organic matter (SOM) was generally inconsistent. However, the biochar exerted considerable influence on the accumulation of SOM. The residual SOM content after crop harvest were maximum in treatments receiving the highest level of biochar. The values for SOM increased with increasing level of biochar. The soil mineral nitrogen was generally greater in treatments receiving fertilizer N at 30 kg than at 15 kg ha⁻¹. However, the effect of biochar and FYM on soil mineral N was inconsistent as differences in soil mineral N between the nil and maximum biochar treatments were not remarkable. These results suggested that biochar application resulted in the accumulation of SOM. However, biochar and FYM had no considerable influence on accumulation of soil mineral N whereas fertilizer N resulted in the accumulation of mineral N in soil to some extent.

Key words: Biochar, FYM, Nitrogen fertilizer and Organic Matter, Mineral Nitrogen

Introduction

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. Biochar application (CA) has received a growing interest as a sustainable technology to improve highly weathered or degraded soils [1]. It can enhance plant growth by improving soil chemical characteristics (i.e. nutrient retention and availability) and soil physical characteristics (i.e. bulk density, water holding capacity, permeability) and soil biological properties, all contributing to an increased crop

productivity [2,3]. 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 [4]. Biochar effect the regulation and production function of the agricultural soil [5]. There are several reasons to expect that biochar might decrease the possibility of nutrient leaching in soils and enhanced nutrient cycling

has been cited in various field studies for positive impacts on yield. 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 [6]. Conceptually three main mechanisms have been proposed (described in detail below) 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 catalyse useful soil reactions, (iii.) modifying physical character of the soil in a way that benefits root growth and/or nutrient and water retention and acquisition. These actual effects of CA 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.

Recently the use of organic materials as fertilizers for crop production has received attention for sustainable crop productivity [7]. Organic matter is the life of soil and the practices that support organic matter build up also favour sustainable productivity [1]. Incorporation of plant residues is a useful means to sustain organic matter content and thereby enhance the biological activity, improve physical properties and increase nutrient availability [6]. Organic manuring by way of direct application of conventional farmyard manure, mulching, crop residue or green manuring has declined over the years due to various operational constraints. Agricultural scientists are engaged to establish an agricultural system, which can lower production

cost and conserve the natural resources. Therefore, recent interest in manuring has re-emerged because of high fertilizer prices and importance of green manure, farmyard manure and other types of manures maintaining long-term soil productivity besides meeting timely requirement of nutrients. There is also a positive interaction between the combination of organic manures and urea as nitrogen source [2].

Nitrogen fertilization plays an important role in improving soil fertility and increasing crop productivity [8]. Nitrogen fertilization increases grain yield (43-68%) and biomass (25-42%) in maize. It contributes 18-34% increase in soil residual N [7]. 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 [9]. 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 [10]

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 of biochar, FYM and chemical fertilizer N on crop yields and soil properties. This paper reports the results of the effect of biochar, alone and in combinations with FYM and fertilizer N, on soil organic matter and mineral N in selected cropping system.

Objective

To study the interactive effects of biochar application in combination with farmyard manure (FYM) and nitrogen (N) fertilizers on soil organic matter and mineral nitrogen.

Materials And Methods

A field experiment on the effect of biochar, FYM and fertilizer-N on the soil was commenced at Agricultural Research Farm of Khyber Pakhtunkhwa Agricultural University Peshawar in 2010-2011. The experiment is comprised of three cropping patterns i.e. maize-wheat, mungbean-wheat and maize-berseem and biochar application at two levels (25 and 50 tons ha^{-1}), farm yard manure (FYM) at two levels (5 and 10 tons ha^{-1}) and nitrogen (N) at two levels (75 and 150 kg N ha^{-1} for maize, 60 and 120 kg N ha^{-1} for wheat, 15 and 30 kg N ha^{-1} for berseem, 15 and 30 kg N ha^{-1} for mungbean). Half of recommended dose i.e. 75 kg N ha^{-1} (maize), 15 kg N ha^{-1} (mungbean). Recommended dose i.e. 150 kg N ha^{-1} (maize), 30 kg N ha^{-1} (mungbean)

The experiment was laid out in randomized complete block design with split plot arrangements with four replications. Cropping pattern was allotted to main plot, while

treatment combinations of biochar, FYM and N with a control (all the three at nil level) to sub-plots. All phosphorus and half of nitrogen were applied at sowing time and remaining half dose of N was applied with second irrigation, while in mungbean all the N was applied at sowing. Urea and SSP were used as sources of N. The detail of treatments is given in Table 1 and Table 2.

The plot size of 5m by 3m with strong bunds around each plot was used. The field was ploughed twice up to the depth of 30 cm with the help of cultivator followed by planking to break the clods and level the field. Cultivars for maize and mungbean were Azam and NM-92 respectively with Seed rate were 30 kg ha^{-1} for maize and 25 kg ha^{-1} for mungbean were used. Sowing for maize and mungbean was done on 15th July 2011. Recommended cultural practices were followed throughout the growing period. At maturity, soil samples at 0-15 cm were collected from selected treatment plots for carbon and mineral nitrogen contents. The following treatments were included in soil sampling:

Soil sampling and processing

There were 3 main plots, each had 13 subplots. Six soil samples were collected at random from different positions in each subplots in the field. The samples were then mixed and kept in plastic bags. The plastic bags were labeled showing the plot number from which the sample was taken. The soil samples were brought to the lab, air dried, grounded and sieved through 2 mm sieve.

Laboratory analysis

The detailed procedure followed for the determination of soil mineral nitrogen, soil organic matter and soil organic carbon were as follows:

Table 1. The treatment combinations of the main-plot factor A

Factor A.		Main plot		
Cropping patterns		2010-2011		2011-2012
CP1		maize	Wheat	maize
CP2		mungbean	Wheat	Wheat
CP3		maize	Berseem	Berseem

Table 2. The treatment combinations of the sub-plot factor B

Factor B.		Sub-plot		
Treatments	BC (tons ha ⁻¹)	FYM (tons ha ⁻¹)	N (kg ha ⁻¹)	
T1	0	0	0	
T2	0	5	15	
T3	0	5	30	
T4	0	10	15	
T5	0	10	30	
T6	25	5	15	
T7	25	5	30	
T8	25	10	15	
T9	25	10	30	
T10	50	5	15	
T11	50	5	30	
T12	50	10	15	
T13	50	10	30	

Soil mineral Nitrogen

Soil mineral nitrogen was determined by the steam distillation procedure of Keeney and Nelson (1982).

Soil mineral nitrogen was determined by shaking 20 g soil sample with 100 ml of 1 M KCl solution for 1 hour. After filtering, 20 ml of the extract was distilled with MgO to recover NH₄-N or with MgO + deverda's alloy to recover both NH₄-N and NO₃-N. Blank was also run using the above method but without soil extract. At last the distillate was titrated against 0.005 N HCl until the end point is attained which is light pink.

Mineral nitrogen was determined by using the following formula:

$$\text{Mineral nitrogen (mg/kg)} = \frac{(S-B) \times 0.005 \times 0.014 \times 100 \times 1000000}{\text{Wt of sample} \times \text{ml of extract}}$$

Soil organic carbon

Organic C in soil was determined by the modified method of Nelson and Sommers, (1982). One gram of air dried finely ground soil sample was treated with 10 ml of 1N K₂Cr₂O₇ solution and 20 ml of concentrated H₂SO₄ for 1 minute. After cooling, 200 ml of distilled water was added and filtered. Filtrate was titrated against 0.5 N FeSO₄.7H₂O solutions after adding 5-6 drops of ortho-phenophthroline indicator, the change of colour from greenish to dark brown showed the end point. A blank reading was also run at the same time.

The amount of C was then determined by the formula:

$$\text{O.C \%} = \frac{\text{blank (N of FeSO}_4 \times \text{ml of FeSO}_4) - \text{Sample (N of FeSO}_4 \times \text{ml of FeSO}_4) \times 0.4}{\text{Wt. of soil}}$$

Soil organic matter

Soil organic matter was determined from the amount of soil organic C using the following formula:

Soil organic matter % = % O.C * 100/58

Statistical Analysis

The data were analyzed statistically using combined analysis of variance techniques appropriate for randomized complete block design with split plot arrangement. Means were compared using LSD test at 0.05 level of probability (Jan *et al*; 2009).

Results and Discussion

The analysis was aimed to study the effects of biochar application in combination with farmyard manure (FYM) and mineral nitrogen (N) fertilizer on soil organic carbon and mineral nitrogen at Agricultural Research Farm of Khyber Pakhtunkhwa Agricultural University Peshawar in 2010-2011. The results of organic matter and mineral nitrogen of the soil are shown in Table 3.

Soil organic matter

Although differences in soil organic matter (SOM) between treatments were significant, value in the control treatment was at par with values in most of the fertilizer treatments. The effect of fertilizer N and FYM on accumulation of SOM was generally inconsistent. However, the biochar exerted considerable influence on the accumulation of SOM. The residual SOM content after crop harvest were maximum in treatments receiving the highest level of biochar. The values for SOM increased with increasing level of biochar.

Soil mineral N

Differences in soil mineral N level between the control and fertilizer treatments were significant. The soil mineral N was generally

greater in treatments receiving fertilizer N at 30 kg than at 15 kg N ha⁻¹. However the effect of biochar and FYM on soil mineral N was inconsistent as differences in soil mineral N between the nil and maximum biochar treatments were not remarkable. The results showed that the residual mineral N in soil after maize or mungbean harvest was almost the same in with or without biochar or FYM treatments received before crops sowing. However, mineral N was greater in treatments receiving high than lower dose of fertilizer N. These results suggested that both biochar and FYM had no considerable influence on accumulation of soil mineral N whereas fertilizer N resulted somehow in the accumulation of soil mineral N.

Conclusion

The present study on the effect of integrated use of biochar, FYM and N fertilizer on soil organic fertility was carried out in 2010-2011 in the laboratory of Soil and Environmental Sciences, Khyber Pakhtunkhwa Agricultural University Peshawar to evaluate their interactive effect on the accumulation of soil organic matter and mineral nitrogen. 39 subplots were selected for sampling. The soil samples were collected from a depth of 0-15 cm, brought to the lab, air dried and then analyzed for organic matter and mineral N.

The results obtained from laboratory analysis showed that the effect of fertilizer N and FYM on the accumulation of soil organic matter (SOM) was inconsistent. However, the biochar exerted considerable influence on the accumulation of SOM. The residual SOM contents after crop harvest were maximum in treatments receiving the highest level of biochar. Similarly the combined effect of FYM and biochar on soil mineral N was inconsistent

Table 3. Soil mineral nitrogen (mg/kg), soil carbon (%) and soil organic matter as affected by various biochar level, farm yard manure level and mineral nitrogen application.

Treatment No.	BC(t/ha)	FYM(t/ha)	N(kg/ha)	Min N(mg/kg)	% O.C	% O.M
1	0	0	0	21.29 d	0.83 bc	1.44 cd
2	0	5	15	25.08 cd	0.75 bc	1.30 d
3	0	5	30	28.29 abcd	0.91 bc	1.58 cd
4	0	10	15	26.83 bcd	0.64 c	1.58 cd
5	0	10	30	28.87 abc	0.82 bc	1.42 cd
6	25	5	15	28.58 abc	0.80 bc	1.38 cd
7	25	5	30	34.98 a	0.80 bc	1.38 cd
8	25	10	15	32.62 ab	1.08 b	1.82 bc
9	25	10	30	34.87 a	1.08 b	1.38 cd
10	50	5	15	22.75 cd	1.00 bc	1.73 cd
11	50	5	30	23.04 cd	0.91 bc	1.57 cd
12	50	10	15	33.67 ab	1.58 a	2.23 ab
13	50	10	30	34.79 a	1.63 a	2.67 a

However fertilizer N resulted somehow in accumulation of soil mineral N.

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