INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 12, No. 5, p. 272-277, 2018
http://www.innspub.net

RESEARCH PAPER | OPEN ACCESS

Effects of biochar on soil chemical properties in relation at different intervals

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Article published on May 30, 2018

Key words: Biochar, Wheat straw, Sugarcane bagasse, Soil properties, Nutrient availability

Abstract

A field study was conducted at research farm of Arid Agriculture University Rawalpindi, to find the relation between biochar application rates and days after its application on soil pH, EC, TOC, Nitrate-Nitrogen, extractable phosphorus and available potassium. Samples were taken from 0-15 cm depth at 0 days, 60 days, and 120 days of biochar application. Biochar were made from wheat straw and sugarcane bagasse, and applied at the rate of 5 and 10 t/ha of both type. Results showed no significant change in soil pH, Nitrate, and Nitrogen. While soil electrical conductivity, total organic carbon, phosphorus and potassium showed significant increase. Soil EC increased by 24% in treatment sugarcane bagasse at 10 t/ha after 120 days of its application. 36% increase was observed in total organic carbon in soil treated with sugarcane bagasse biochar at 10 t/ha after 60 days of its application. Soils treated with 10 t/ha wheat straw biochar and sugarcane bagasse biochar showed 27% and 26% increase in extractable phosphorus respectively after 60 days of its application. Biochar (wheat straw) applied at 10 t/ha elevated soil extractable potassium 10.7% after 120 days of its application and 10.3% increase was observed after 60 days of its application.

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Introduction

Biochar, a product of waste organic material when applied to the agricultural fields shows several benefits (Laird, 2008; Lehman and joseph, 2008). Slow and gradual nutrient release is one of the vital benefits of biochar (Liard, 2008). Biochar produced from animal manure have greater nitrogen and phosphorus content than biochar made from plants waste (Chan and Xu, 2009). Biochar provides a safe way to dump the pollution causing carbon, which will remain unchanged for several years when transformed to biochar (Sohi *et al.*, 2010).Plant nutrient availability of elements such as P, K and Ca are typically increased, while free Al is decreased in solution in biochar-amended soils (Chan *et al.,* 2007). This occurs as a function of biochar's high porosity and surface to volume ratio, together with an increase in the pH of acid soils, attributed to the basic compounds found in biochar. Effect of two biochar produced from poultry litter at two different temperatures and applied rates (0, 10, 25 and 50 t ha^{-1} for radish and soil quality of a hard setting Chromosol and observed 42% increases in yield at 10 t ha^{-1} to 96% at 50 t ha^{-1} of biochar application. They noticed significant changes in soil chemical and physical properties, including increases in C, N, pH, and available P. (Chan *et al.,* 2008). Biochar comparison of three different sources poultry litter, peanut hulls and pine chips. Results indicated that Iron and manganese are associated, and largely retained during biochar formation. The poultry litter biochar had the highest amount of Fe at 3.91mg kg^{-1}, whereas the peanut hulls and pine chips biochar were significantly lower at 0.42mg kg^{-1} and 0.13mg kg^{-1} respectively. It was concluded that poultry litter biochar was highest in iron than peanut hulls and pine chips (Gaskin *et al.,* 2010). Novak *et al.* (2009) studied the Impact of biochar Amendment on fertility of a Southeastern Coastal Plain Soil. Soil columns containing 0, 0.5, 1.0, and 2.0% (wt/wt). The biochar had a pH of 7.6, contained 834.2 and 3.41g kg^{-1} of C and N, respectively. These effects reflect the addition of elements and the higher sorption capacity of biochar for selective nutrients (especially Ca, P, Zn, and Mn). Biochar additions to the Norfolk soil caused significant fertility improvements. The pecan shell biochar study conducted by Novak *et al.* (2009) showed that extractable Zn marginally decreased from 13 to 10mg kg-1 with an increase in the addition of biochar concentration. This demonstrates that the biochar has a high sorption capacity for Zn.

In a study where three different biochar were compared against each other, it was shown that the concentration of Zn showed great variety depending on which feedstock was used. The poultry litter biochar was much higher than the pine chips and peanut hulls biochar with reported values of 414 mg kg^{-1}, 47.8 mg kg^{-1}, and 20.2 mg kg^{-1} respectively. Novak *et al.* (2009) studied on pecan shell biochar and found that the copper concentration was not significantly affected by biochar addition. Its results show that at 0.5% increments of biochar from no biochar addition to 2.0%, the Cu concentration fluctuated around 0.7mg kg^{-1} Cu. Zhang *et al.* (2012) studied effect of biochar amendment on soil quality, crop yield and greenhouse gas emission. The results showed that biochar amendment increased soil pH, soil organic carbon and total nitrogen.

Materials and methods

Biochar production

Sugarcane bagasse and wheat straw was collected and used for biochar production. First these were air dried and ground. After grinding, material was placed in a biochar production tank. After 3 hours biochar was collected from biochar production tank and stored in plastic bags.

Soil sampling

Soil samples were collected from surface 0-15cm at 0 days of biochar application, 60 days after biochar application and 120 days after biochar application dried, sieved through 2 mm sieve and used for analysis of pH, electrical conductivity, total organic carbon, soil texture and nutrients (nitrogen, phosphorus, potassium, zinc, iron, manganese and copper). The treatments were wheat straw biochar (WSB) at 5 t ha^{-1}, and 10 t ha^{-1}, sugarcane biochar (SCB) at 5 t ha^{-1} and 10 t ha^{-1} and a control (no biochar).

Analytical methods

Electrical conductivity (EC) and Soil reaction (pH)

Soil samples electrical conductivity and Soil reaction was determined with 1: 2.5 soil water suspension. (Rhoades, 1982; McLean, 1982).

Soil organic matter

Titration method was used for Soil organic matter (Nelson and Sommers, 1982).

Soil texture

Bouyoucos hydrometer method was used to determine soil texture. Percent sand, silt and clay were used to determine soil textural class on the USDA Soil Textural Triangle (Gee and Bauder, 1962).

Nitrate nitrogen

Salicylic acid method was used to determine nitrate nitrogen. In this method yellow color develops. Reading was recorded by using spectrophotometer at wavelength of 410 nm (Vendrell and Zupancic, 1990).

Extractable phosphorus

Color was developed from soil samples using Ascorbic acid and then the solution was run on spectrophotometer at 882 nm wavelength. Standard curve was developed using range of P standards for computing P value form reading output (Olsen, 1954).

Soil extractable potassium (K)

For potassium extraction ten gram of air dried soil was extracted with 20 mL AB-DTPA extracting reagent potassium concentration was analyzed by atomic absorption spectrophotometer (Soltanpour and work man, 1979).

Statistical analysis

The experimental design was RCBD. The data collected were analyzed statistically in means were compared at 5% level of significance (Steel *et al.,* 1997).

Results and discussion

Effect of biochar on soil chemical properties at different intervals

Soil reaction

Data on different biochar treatments on soil pH are presented in Fig. 1. The results showed that different biochar did not affect the soil pH significantly, but however a little change had on soil pH. The maximum soil pH 8.04 was observed in treatment Sugarcane bagasse biochar at 10 t/ha after 120 days of its application, which was 3% more than control. The lowest soil pH 7.78 was recorded in control treatment. Depending on material, biochar are alkaline in nature and may change the soil pH a bit (Jeffery *et al.,* 2011). On applying biochar in paddy soils in china a marginal change of 6% in soil pH was observed (Huang *et al.,* 2013).

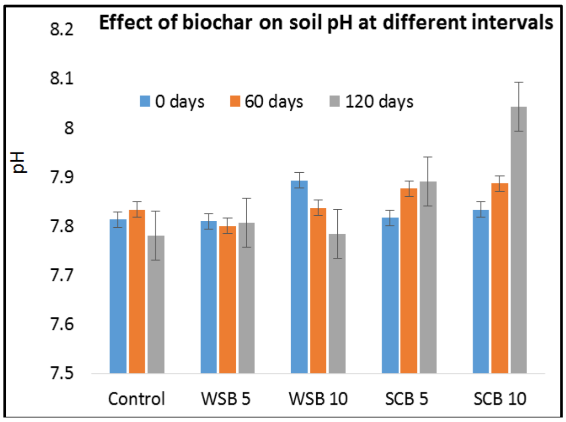

Fig. 1. Data on different biochar treatments on soil pH.

Electrical conductivity

Effect of different biochar treatments on electrical conductivity of soil is shown in Fig. 2. The maximum EC 0.72dS/m was observed in soil treated with sugarcane bagasse biochar at 10 t/ha after 120 days of its application which was 24% more than control, followed by 0.66dS/m in the soil treated with wheat straw biochar at 10 t/ha after 120 days of its application. The minimum EC0.513dS/m was observed in treatment wheat straw biochar at 5 t/ha in 0 days of its application.

This shows that the biochar application at higher rate can increase the soil electrical conductivity. The results showed a significant increase in soil EC with greater biochar application rates. Shenbagavalli and Mahimairaja (2012) when assessing the EC of various biochar, found that the EC of biochar vary with the source. They found that it may vary from 0.39dS/m to 4.18dS/m.

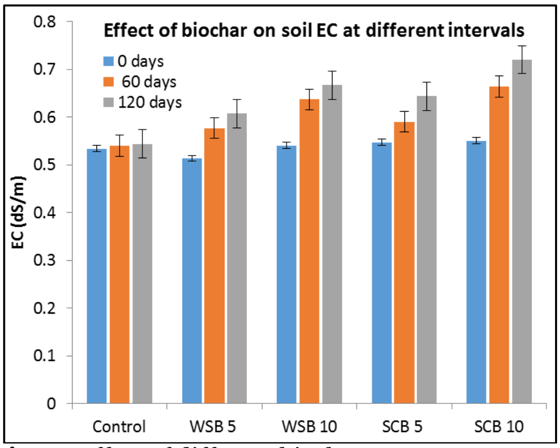

Fig. 2. Effect of different biochar treatments on EC of soil.

Effect of biochar on nutrient availability in soil at different intervals

Total organic carbon

In the present study, effect of wheat straw biochar and sugarcane bagasse biochar in different levels were observed against TOC in soil at different intervals of time (Fig. 3). Data shows that maximum Total organic carbon in soil was observed in treatment Sugarcane bagasse at 10t/ha after 60 days of its application which was significantly higher than all the other treatments which was 36% higher than observed in control. Second highest TOC was 3.19g/kg in wheat straw biochar at 10 t/ha after 60 days of its application. The lowest TOC was observed in control. Carbon (C) being the major part, biochar obtained from different plant and animal region varies in carbon concentration biochars from different source showed a range of carbon content between 40-78% (Gaskin *et al.,* 2010).

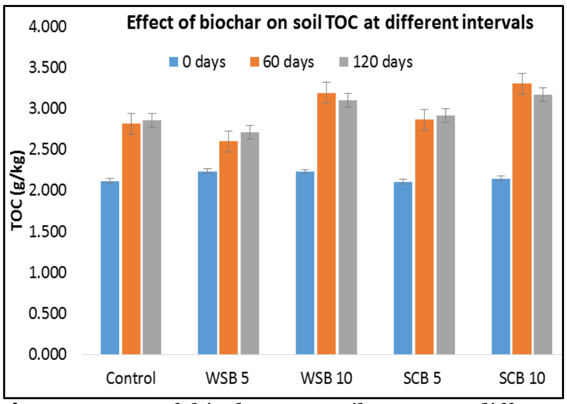

Fig. 3. Data of biochar on soil TOC at different intervals.

Nitrate-Nitrogen

Data in Fig. 4 shows the effect of different biochar treatments on nitrate nitrogen in soil. It shows that all the treatments are non-significant to each other. Data shows that maximum nitrate nitrogen 6.67mg/kg in soil was observed in treatment wheat straw biochar at 10t/ha after 120 days of its application. The lowest nitrate N was 6.26mg/kg that was observed in control after 120 days of its application. Nitrogen in biochar does not come to plant available form, because they are mostly in heterocyclic compounds (Knicker, 2007). When Biochar applied to the soils increases total nitrogen content of soil but may not significantly alter mineral nitrogen contents in soil (Zhang *et al.,* 2012).

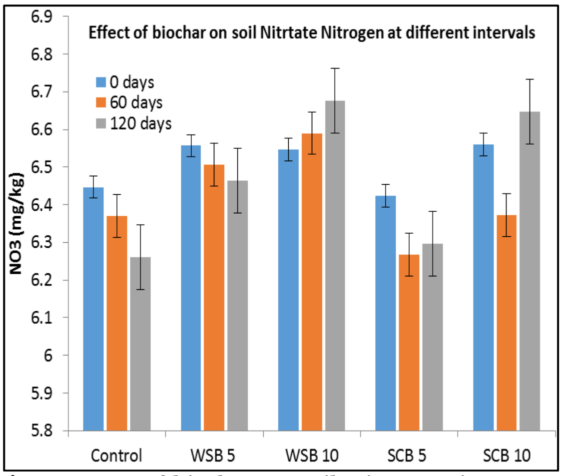

Fig. 4. Data of biochar on soil Nitrtate Nitrogen at different intervals.

Extractable phosphorus

Data in Fig. 5 represents about soil extractable phosphorus. The minimum soil extractable phosphorus concentration 4.06mg kg^{-1} was observed in treatment having sugarcane biochar at 10t/ha at 0 days of char. The maximum concentration of soil available phosphorus 5.60mg kg^{-1} was observed in soil treated with wheat straw biochar at 10 t ha^{-1} after 60 days of its application followed by the treatment treated with sugarcane biochar at 10 t/ha having 5.54mgkg^{-1} after 60 days of its application showing 27% and 26% higher P respectively than control. Biochar varies with P contents from different feedstock's from 160 to 1560mg/kg of which a little portion is water soluble which changes the concentration of P in soils. (Miller *et al.,* 2013).

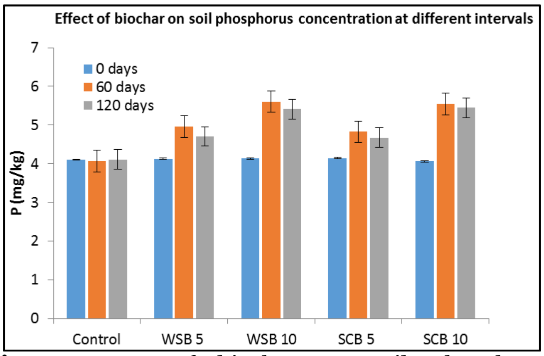

Fig. 5. Data of biochar on soil phosphorus concentration at different intervals.

Extractable potassium

Effect of different biochar treatments on extractable potassium of soil is shown in Fig. 6. The maximum extractable potassium concentration was observed in soil treated with wheat straw biochar at 10 t/ha after 120 days of its application having 149mg kg^{-1}, followed by 148.33mg kg^{-1} in the soil treated with wheat straw biocharat 10 t/ha after 60 days of its application increasing the soil extractable potassium by 10.7% and 10.3% respectively than the control. The minimum potassium concentration 133.33mg kg^{-1} was observed in control after 120 days of biochar application. Different biochar varies with K contents from different feedstocks from 0.039% to 1.83% due to which concentration of K in soils vary with the type and rate of biochar applied. (Miller *et al.,* 2013).

Table 1. Basic characteristics of soil and biochar.

Parameters	Soil
Texture	Sandy loam
pH	7.79
EC (dS m^{-1})	0.54
N (mg kg^{-1})	6.34
P (mg kg^{-1})	4.09
K (mg kg^{-1})	134
Zn(mg kg^{-1})	0.74
Fe(mg kg^{-1})	2.24
Mn(mg kg^{-1})	1.82
Cu(mg kg^{-1})	0.16

Table 2. Basic characteristics of biochar.

Parameters	Wheat straw biochar	Sugarcane bagasse biochar
pH	8.80	7.66
EC (dS m^{-1})	1.78	1.69
N (%)	1.38	0.92
P (%)	0.26	0.24
K (%)	3.00	3.30
Zn(mg kg^{-1})	47	41
Fe(mg kg^{-1})	47	84
Mn(mg kg^{-1})	106	77
Cu(mg kg^{-1})	13	11

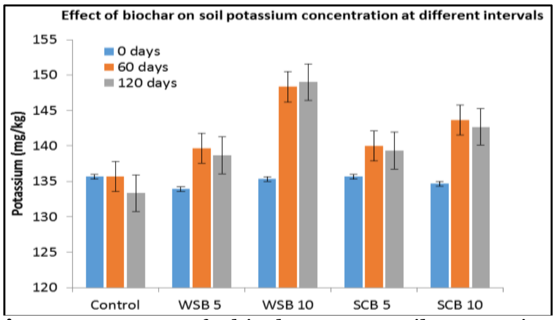

Fig. 6. Data of biochar on soil potassium concentration at different intervals.

Conclusion

From above study it is concluded that Biochar effect chemical properties of soil, at different time interval. Soil pH and Nitrate-Nitrogen did not change significantly, at different time intervals i.e. 0 days, 60 days, and 120 days. While, soil TOC, EC, extractable phosphorus and potassium changes with rate of Biochar application and time.

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