Research Article

EFFECTS OF BIOCHAR APPLICATON ON SOIL PROPERTIES AND PRODUCTION OF RADISH (*Raphanus sativus* L.) ON LOAMY SAND SOIL

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ABSTRACT

A field experiment was conducted to assess the effects of biochar application on soil properties and production of Radish (*Raphanus sativus* L.) on loamy sand soil. The experiment was conducted using a Randomized Complete Block Design (RCBD) with five levels of biochar (0, 5, 10, 15 and 20 Mg ha^{-1}), each replicated for four times. The application of biochar significantly increased the biomass, root and shoot yields of radish. The soil organic matter, soil bulk density, total nitrogen, available phosphorus and available potassium contents of soil also significantly increased with the addition of biochar; however, the pH of the soil did not differ significantly, but increased with increasing rates of biochar application. The highest soil organic matter, total nitrogen, available phosphorus, and available potassium contents of soil and biomass, root and shoot yields of radish were obtained from 20 Mg ha^{-1} application of biochar and the lowest soil bulk density was obtained from the same level of biochar application. Biochar application to soil would be of immense value to improve soil and plant productivity.

Key words: Pyrolysis, nutrients, soil management

INTRODUCTION

Biochar is the porous carbonaceous solid produced by thermo-chemical conversion of organic materials in an oxygen limited atmosphere that has physiochemical properties suitable for the safe and long-term storage of carbon in the environment and potentially soil improvement (Hammond et al., 2011). The agricultural use of biochar have been growing and attracting more research interest globally due to its potential benefits to crop production, soil fertility and carbon sequestration. The use of biochar enhanced crop yields, decreased the soil acidity, increased water and nutrient holding capacity; stimulates the nutrient uptake and reduced the greenhouse gas emissions from the soil (Sohi et al., 2009 and Quayle, 2010). The biochar has the high surface area and porosity as compared to other soil amendments which make the soil to retain the nutrient and water and also provide habitat to the soil microorganisms (Warnock et al., 2007). However, the benefits of biochar are influenced by the source of raw materials used for biochar preparation, amount of biochar applied and types of soil. Biochar application is based on the nitrogen content of biochar, soil type and crop requirements (Hunt et al., 2010). Soils having good structure, porosity, hydraulic conductivity, bulk density and strength provide good medium for growth to beneficial microorganisms, better nutrient and water movement into the soil profile, higher nutrient and water retention and more root growth ultimately provide higher yield as compared to degraded soil having poor physical properties (Abdallah et al., 1998).

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Biochar can be prepared from the various organic materials such as crop residues, forest litters, twigs and animal residues. In Nepal, the agricultural and forest wastes are available in surplus amount, but farmers have practice of open burning of these wastes which resulted in loss of nutrient resources from the soil. Also, Nepalese farmers have faced problem of the unavailability of quality and sufficient quantity of fertilizers on time which is the main limiting factor for the crop production. The conversion of the agriculture and forest waste into the biochar could be one of the viable options to prevent the loss of resources and use of biochar as soil amendment could solve the problem of fertilizer unavailability to the farmers. Although several researches have been conducted on the efficiency of biochar elsewhere in the world but there is a limited information available in Nepal about the efficiency of biochar to maintain the productivity of soil and crops. Hence, a field experiment at Nawalparasi district, Nepal was carried out to assess the effectiveness of biochar on soil properties and radish crop production.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at farmer's field, Daunnedevi VDC -5, Nawalparasi district, Lumbini Zone, Nepal during October, 2013 to January, 2014 to assess the effects of biochar application on soil properties, yield and yield attributing characteristics of Radish (*Raphanus sativus)*.The geographical location of the experimental site is at 27^0 48' 14.11'' north latitude and 83^0 78' 71.24'' east longitude with the elevation of 113.408 m above the mean sea level.

Crop rotation of cropping field

The experimental field was under rice cultivation before the experiment. A forty-day variety of radish was used as a test crop to conduct the experiment.

Experimental set up

The experiment was carried out using a Randomized Complete Block Design (RCBD), with four replications. There were five treatment combinations having five rates of biochar (0, 5, 10, 15 and 20 Mg ha^{-1}). Three digit random tables were used from random table and the treatments were adjusted on ascending order of the random numbers using the rules of randomization in each block. There were 20 plots each having 1.8 × 1 m^2 area with 45 plants in each plot. The distances between the replications and between the plots were maintained 1m and 0.5m, respectively. The net experimental area was 36 m^2 while the gross area was 117 m^2.

Physico-chemical properties of soil and biochar

The characteristics of experimental soil and biochar are shown in Table 1.

Table 1. Physico-chemical Properties of Soil and Biochar

Parameters	Soil	Biochar
pH	6.8	8.4
Texture	Loamy sand	-
Organic carbon (%)	0.65	67.39
Hydrogen(%)	-	3.29
Nitrogen (%)	0.1	1.2
Phosphorous (mg/kg)*	0.43	2900
Potassium (mg/kg)**	8.70	8300

*Total phosphorus for Biochar and Available Phosphorous for soil

**Total potassium for Biochar and Available potassium for soil

Cultural operations

First ploughing was carried out on 29 October, 2013, followed by second on 30 October, 2013 and planking on 30 October, 2013 to make the soil well pulverized and friable. The weeds, stubbles and other unwanted materials were removed manually from the experimental plots. Twenty plots were well prepared according to the experimental design adopted and they were leveled uniformly. The well ground biochar passed through 1mm sieve was applied in the plots before two week of seed sowing. The radish seeds were sown in all plots at 20×20 cm plant to plant and row to row spacing on 27 November, 2013. There were all together 9 rows with 5 seeds in each row constituting 45 plants in each plot. First manual weeding at 15 days and the second at 30 days after sowing were done to make the soil pulverized for better aeration and water holding capacity. The roots of radish plants were ready for harvesting after forty-five days of sowing. All the sample plants were harvested manually at a time. Harvested plants from each plot were separated into roots and shoots and they were weighed separately.

Observations and measurement

The five plants among 45 plants were tagged for data collection leaving 40 plants from all sides of experimental unit. The bio-morphological characters such as plant height, number of leaves, root length, root diameter, leaf area, biomass, root and shoot yield and dry matter content of 5 tagged plants were recorded at different specified period.

Soil sampling, preparation and analysis

Soil was sampled before sowing and at harvest. Soil samples were collected at random points in the middle of each plot (to avoid edge effect) from top soil (0 to 20 cm depth) with the help of bucket augur. Samples were ground in mortar and pestle and passed through sieve after air drying at room temperature. The properties of soil before and after the experiment were analyzed using standard methods as described in table 2.

Table 2. Analysis methods for various soil parameters

Parameters	Analysis methods
Soil texture	Hydrometer method (Gee, Bauder&Klute, 1986).
Soil pH	Beckman electrode pH meter in 1:2 soil and water ratio (Cottenie *et al.,* 1982)
Soil Bulk Density	Core ring method
Organic matter content	Degtjareff or chromic acid titration method (Wakly& Black, 1934)
Nitrogen content	Kjeldahl distillation (Bremner&Mulvaney, 1982)
Phosphorous content	Modified Olsen's (Olsen, 1954) using spectrophotometry
Potassium content	Ammonium acetate extraction method using flame photometry (Simard, 1993).

Biochar preparation and analysis

Maize stovers, paddy husks and woody twig materials were collected from the farmer's field and dried in the sun and the dried materials were chopped into small pieces to prepare the biochar. The biochar stove consist of cylindrical drum with combustion chamber and ventilation cone and outer lid. The fuel materials were placed in the combustion chamber for lightening purpose and biowastes were kept between the combustion chamber and outer chamber, a gasifier space. The fuel materials were ignited using the kerosene. After ignition, the combustion chamber becames hotter which showed flame color yellow and after that the bio-wastes in the gasifier chamber began to burn after 30 minute. At that time, it released gases and flame was changed to blue which indicated the complete burning of fuel. After that, the cylindrical drum was covered with a lid. It consumed one and half hours to complete the whole process of conversion of bio-wastes into the biochar. After cooling the drum, the biochar was ground by grinder and passed through sieve which was used for application in the treatments of the experiment. The chemical properties of biochar were analyzed at laboratory.

Statistical analysis

The data were first tabulated in Microsoft Excel and analyzed using MSTAT-C. Means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez & Gomez, 1984).

RESULTS

Effects of biochar application on yields of radish

The effects of biochar application on biomass, root and shoot yields of radish is presented in Table 3. With increasing application of biochar, biomass, root and shoot yields significantly increased ($p<0.05$). The highest biomass yield (63.2 Mg ha^{-1}) was obtained from 20 Mg ha^{-1} biochar application which was similar to 15 Mg ha^{-1} application, but was significantly higher than other treatments. Treatments receiving no biochar had the lowest (36.94 Mg ha^{-1}) yield which was significantly ($p<0.05$) lower than 15 and 20 Mg ha^{-1} biochar application, but was at par with 5 and

10 Mg ha^{-1} application. The highest root yield (46.83 Mg ha^{-1}) was obtained from 20 Mg ha^{-1} biochar application which was significantly higher as compared to 0, 5 and 10 Mg ha^{-1}application. The highest (16.38 Mg ha^{-1}) and the lowest (11.44 Mg ha^{-1}) shoot yields were recorded from 20 Mg ha^{-1} and 0 Mg ha^{-1} biochar rates, respectively. The shoot yield from 20 Mg ha^{-1} was significantly higher than 0 and 5 Mg ha^{-1} but it was at par with 10 and 15 Mg ha^{-1} biochar application (Table 3).

Table 3. Effects of Biochar application on yields of radish at harvest at Daunnedevi, Nawalparasi, Nepal (2014)

Biochar rate (Mg ha^{-1})	Yields (Mg ha^{-1})		
	Biomass	Root	Shoot
0	36.94^{c}	25.50^{b}	11.44^{b}
5	42.36^{bc}	30.25^{b}	12.11^{b}
10	44.08^{bc}	30.97^{b}	13.10^{ab}
15	54.05^{ab}	38.95^{ab}	15.10^{ab}
20	63.20^{a}	46.83^{a}	16.38^{a}
Grand Mean	48.12	13.01	13.62
SEM (±)	4.78	4.22	1.28
$LSD_{0.05}$	14.76*	13.01*	3.95*
CV (%)	19.90	24.47	18.83

Means followed by the same letter (s) in a column are not significantly different at 5% level of significance as determined by DMRT

Effects of biochar application on soil properties

Soil pH: The effect of biochar application on soil pH at harvest of radish has been presented in figure (1). The effect of biochar application on soil pH was not significant among the treatments but it was increased with higher rates of biochar application.

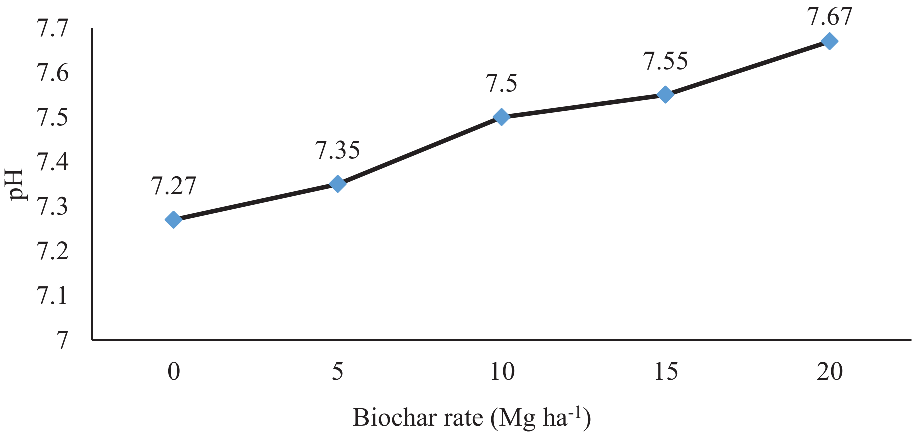

Figure 1: Soil pH as influenced by different rate of biochar application at Daunnedevi, Nawalparasi, Nepal (2014)

Soil organic matter: The effect of biochar application on soil organic matter was highly significant (Table 4). The highest (2.915%) soil organic matter was obtained from 20 Mg ha^{-1} biochar application which was significantly higher ($p<0.001$) than other treatments, and it was the lowest (1.165%) from no biochar application, but was at par with 5 Mg ha^{-1} biochar amended soil. Soil treated with 10 and 15 Mg ha^{-1} biochar applications had similar organic matter content ($p>0.01$)but significantly higher ($p<0.001$) than 5 Mg ha^{-1} and soil without biochar applications (Table 4).

Table 4. Effects of biochar application on different soil properties at radish harvest at Daunnedevi, Nawalparasi, Nepal (2014)

Biochar rate (Mg ha^{-1})	Soil organic matter (%)	Soil bulk density (g cm^{-3})	Total nitrogen (g kg^{-1})	Available phosphorus (mg kg^{-1})	Available potassium (mg kg^{-1})
0	1.165^{c}	1.415^{a}	0.70^{b}	2.2^{b}	7.7^{c}
5	1.288^{c}	1.340^{ab}	0.80^{b}	2.7^{ab}	9.9^{b}
10	1.845^{b}	1.303^{bc}	0.86^{b}	3.0^{ab}	10.5^{b}
15	1.985^{b}	1.243^{bc}	0.90^{b}	3.3^{ab}	11.2^{ab}
20	2.915^{a}	1.235^{c}	1.20^{a}	4.0^{a}	12.3^{a}
Grand Mean	1.839	1.307	0.89	3.0	10.0
SEM (±)	0.118	0.032	0.072	0.5	0.5
$LSD_{0.05}$	0.364**	0.097*	0.223**	1.5*	1.5**
CV (%)	12.90%	4.92%	16.25	8.31	9.44

Means followed by the same letter (s) in a column are not significantly different at 5% level of significance as determined by DMRT

Soil bulk density: The bulk densities of soil were significant ($p<0.05$) among the rates of biochar application (Table 4). The lowest soil bulk density was obtained from 20 Mg ha^{-1} biochar application, and it was significantly lower ($p<0.05$) than 0, and 5 Mg/ha biochar applied soil, but was at par with 10 and 15 Mg/ha biochar applied soil. The lowest (1.235) and the highest (1.415) soil bulk density were recorded from 20 Mg ha^{-1} and without biochar applied soil, respectively (Table 4).

Nitrogen content in soils: The effects of biochar application on nitrogen content in soil were highly significant (Table 4). Addition of different doses of biochar had higher nitrogen contents of soil compared with without addition of biochar. The highest nitrogen content (1.2 g kg^{-1}) was found from 20 Mg ha^{-1} biochar application which was significantly higher ($p<0.001$) from other treatments. The lowest (0.7 g kg^{-1}) nitrogen content was obtained from without biochar amended soil but it was at par with 5, 10 and 15 Mg ha^{-1} biochar applications (Table 4).

Available phosphorus contents in soil: The phosphorus content in soil was significant ($p<0.05$) among the various rates of biochar application (Table 4). The phosphorus content in soil was increased with increased rates of biochar application. The highest phosphorus content (4.0 mg kg^{-1}) was found from 20 Mg ha^{-1} biochar application and it was similar to 5, 10 and 15 Mg ha^{-1}, but was significantly higher than no biochar (2.2 mg kg^{-1}) amended soil.

Available potassium content in soil: The effects of biochar application on available potassium contents in soil was highly significant ($p<0.001$) (Table 4). The increased rates of biochar application increased the available potassium content in soil. The highest available potassium content (12.3 mg kg^{-1}) in soil was found from 20 Mg ha^{-1} biochar application which was consistent with 15 Mg ha^{-1} but significantly higher ($p<0.001$) than other treatments. The lowest available potassium content (7.7 g kg^{-1}) was found from without biochar amended soil and it was significantly ($p<0.001$) lower than other treatments.

DISCUSSION

The biochar had capacity to increase nutrients availability in soil which increased the uptake of nutrients by plants resulting in the increase in yield of radish. Chan et al. (2008) reported significant increase in radish yields from application of biochar and this increased yield was due to the biochar's ability to increase N availability to plants. Collins et al. (2013) also reported that increased biochar application had increased biomass of potatoes.

The increase in soil pH due to biochar application was generally attributed to ash residues which contain carbonates of alkali and alkaline earth metals, silica, heavy metals, sesquioxides, phosphates and organic and inorganic nitrogen (Raison, 1979). The increase in soil organic matter in our study was due to increase in organic carbon as biochar application rate increased. Lehmann (2007) and Van Zwieten et al. (2010) reported high organic carbon in soil treated with biochar. Biochar application to soil decreased the soil bulk density because porosity of biochar was very high and when it was used in soil it significantly decreased bulk density by increasing the pore volume (Mukherjee & Zimmerman, 2013). The observed increase in N, P and K contents of soil due to application of biochar could be due to the presence of high contents of N, P and K in biochar. Chan et al. (2008) also reported the addition of biochar to soil increased total N, available P and available K of soil. Lehmann et al. (2003) reported that the application of biochar into soil increased the availability of nitrogen in soil.

CONCLUSION

The application of biochar increased soil pH, soil organic matter, total nitrogen, available phosphorus and available potassium contents of soil and decreased soil bulk density. The biomass, root and shoot yields of radish were also increased with increased rate of biochar application. It can be thus concluded that addition of biochar to soil would be of immense value to increase soil fertility and yield of radish. Thus, biochar application provides an innovative method for handling excess organic waste to sequester carbon and potentially improve soil and plant productivity which ultimately leads to the sustainable soil management.

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