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Soil Properties and Response of Spring Onion to Different Levels of Biochar

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Biochar is the solid product of thermal decomposition of organic materials. Its benefits to crops has been shown in several studies but few have dealt with its effect on soil. This research was therefore conducted to determine the effect on soil properties and response of spring onion to different levels of biochar. An experimental research in a Randomized Complete Block Design (RCBD) with 4 replicates was used in the study. Different levels of biochar used were 0 (control), 10, 20 and 30 t-ha-1. We found out that increasing levels of biochar corresponded to decreasing values of bulk density, but increasing values of porosity, saturation point, field capacity, permanent wilting point, water holding capacity, number of plantlets per hill, computed yield per hectare and net income. No effect was found on soil temperature, weight of roots, and ROE.

Keywords: Biochar, spring onion, soil properites

Introduction

Biochar is a fine-grained and porous form of charcoal intended as soil amendment. It is produced by thermal decomposition of organic material under limited supply of oxygen.

Most biochars are alkaline or have pH near neutral (Lehmann, and Joseph, 2009). As such they are observed to increase soil pH and may be used to replace lime. Aside from liming effect, biochars provide other agricultural benefits that liming does not provide. Among the agronomic values of biochar is its ability to improve soil physical properties such as bulk density, porosity (Sparkes and Stoutjesdijk, 2011) l and water holding capacity (Mukherjee and Lal, 2013). As a soil amendment it potentially stimulates microbial activity and growth (Gomez, Denef, Stewart, Zheng and Cotrufo, 2014). It has been shown to improve soil chemical properties (Lehmann, Gaunt and Rondon, 2006).

Increases in crop yield have also been attributed to biochar application (Cornelissen *et al.*, 2013). Increased yield with rice hull biochar has been

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shown on rice (Haefele, Konboon and Wongboon, 2011) and corn (Ganotisi, Cabalar and Castro, 2005) both grown on sandy soils.

Studies on biochar focus mainly on the agronomic and environmental benefits but there is a dearth of information on the effects of biochar on soil properties (Weyers, and Spokas, 2011; Hazelton and Murphy, 2007; Yong *et.al*., (2016).

This study was therefore directed towards the effect of different levels of rice hull biochar on soil properties, and yield of spring onion.

The importance of this research study lies on the conservation of soil and water to become available in the future. In so doing it will provide a solution on the use of inorganic fertilizer, waste disposal, and it will also provide another source of livelihood to our local farmers, entrepreneurial individuals, government, and cooperatives and private sectors.

Objectives: The study aims to determine the effect of different levels of rice hull biochar on soil properties, yield and yield components of spring onion

Materials and methods

Biochar used in this study was carbonized rice hull characterized by bulk density of 0.185 g-cm-3, oH of 6.6 and water holding capcity of 294.83 %.

Experimental Research design

A field experiment was conducted in the Southern Tagalog region of the Philippines where Lipa loam soil predominates. The treatments were levels of bichar at rates 0, 10, 20 and 30 ton-ha^{-1}. Experimental plots were arranged in randomized complete block design (RCBD).

The experimental area was divided into four blocks. Each block was divided into four plots measuring 1.2 X 1.8 m to accommodate 12 hills. Biochar was incorporated with the soil (0-15 cm from the surface) after the experimental plots were made.

Ammonium phosphate (16-20-0) was applied in all treatments at the rate of 65 g-m-^{2}, based on the result of soil analysis conducted at Analytical Services Laboratory (ASC), University of the Philippines at Los Baños, and proportionally reduced to plot size requirement. Spring Onion plantlets were transplanted early in the morning. Each hill contained one plantlet.

Physicochemical properties of soil

Soil temperature was monitored using a soil thermometer inserted 15 cm below the surface. Soil Acidity was determined using a pH meter inserted

15 cm below the surface. Soil bulk density was determined by core method with soil taken from soil depth of 0-15 cm. Porosity was detemined from bulk densty and specific density of 2.65 g-cm^{-3}.

Moisture Retention

Four 400-g soil samples were collected from the field experimental area. Each 400-g sample was mixed with the required amount of biochar according to the design of the experiment. From these mixtures, four 100-g samples were taken to represent a trial for saturation point and field capacity determination. Each trial sample was weighed and placed in a tared disposable plastic cup. The cups were filled with water and set aside for 24 hours. The cups were sealed with cheese cloth, and allowed to drain off the excess water. After draining, the soil samples were weighed after 6, 12, 24, 48 hours. The samples were then oven dried for 24 hours at 105 ^{o}C.

One kg of soil sample was taken from each experimental plot and placed in polyethylene bags. Matured spring onions were grown in these bags. At flowering stage, watering was stopped. The spring onions were monitored daily. Soil moisture content was determined when the plants were permanently wilted. Wilting point was noted when shoots have lost turgidity. Using the computed permanent wilting point, the water holding capacity (WHC) was calculated from the difference between field capacity and permanent wilting point.

Statistical analysis

The collected data were organized and presented in textual and tabular forms. Analysis of Variance (ANOVA) was used to determine significant differences among treatments. The significant results from ANOVA were subjected to further statistical analysis with the use of Fisher's LSD Test. Minitab 16 was used to facilitate computation.

Results and Discussion

Physicochemical properties

Different levels of biochar did not affect soil temperature. The soil temperature varied from 27.75 – 28.85 ℃ which is within the range (18-29 ℃) of temperature requirements for spring onions (The International Gardener Guide, 2010).

Soil bulk density was decreased with biochar applied at 30 tons-ha^{-1}. This implies that application of biochar can increase the movement of air and water in the soil at high application rate. This confirms the same report by Masulili, Utomo and Syechfani (2010). A reduced bulk density with 25 t-ha^{-1} application rate was also reported by Eastman (2011). However, decreased bulk density was reported at a mega dose of 116.1 t-ha^{-1} application rate by Major *et al*. (2010).

Soil porosity increased with biochar application rate. However, the change was noted only at 20-30 tons-ha^{-1}. Greater porosity implies better aeration which encourages biodiversity of soil fauna and flora. It also implies higher potential to store water and allow roots to extend more readily through the soil. Water clings to the surface of the soil particles but drains out of the large pore spaces. Plant roots can draw off only the available part of the clinging water layer.

Other studies confirm the result of this present study. An increase in total soil porosity from about 40% (Control) to more than 50% in all rice hull biochar-treated soils has been reported (Masulili *et al*., 2010). Mukherjee and Lal (2013) collated and synthesized available information regarding the effect of biochar on soil physical properties. They reported decreased bulk density and increased porosity.

Biochar also affected soil pH. Without biochar (Control), soil pH was acidic (Table 1). Biochar increased soil pH, with the greatest increase at 30 ton-ha^{-1}. The 10-ton-ha^{-1} rate did not affect soil pH. This result shows that biochar increases soil acidity at levels not less than 20 ton-ha^{-1}.

Table 1. Physico-chemical properties of soil treated with different levels of biochar.

Treatment, levels of CRH application	Bulk Density (mean)	Soil Porosity (mean)	Soil pH (mean)
Control	0.789 ^{a}	70.233 ^{b}	5.975 ^{c}
10 tons	0.752 ^{a}	71.621 ^{b}	6.125 ^{c}
20 tons	0.721 ^{a}	72.791 ^{ab}	6.363 ^{b}
30 tons	0.631 ^{b}	76.203 ^{a}	6.573 ^{a}

Bulk density: F= 6.39 P= 0.008 CV= 11.84%
Soil porosity: F= 6.39 P= 0.008 CV= 11.84%
Soil pH F= 15.24 P= 0.008 CV= 5.41%
**In a column, means that do not share a letter are significantly different α=0.05.*

The liming effect is attributed to the alkalinity of biochar (Yuan, Xu, Wang and Yu Li, 2011). In line with this report, rice hull biochar has reportedly increased pH of acid sulfate soil (Masulili, Utomo, Ha and Syechfani, 2010); Laird *et al*. (2010) reported a 1.0-point pH increase compared to un-amended soil.

Soil water retention

The saturation point, field capacity, permanent wilting point and water holding capacity increased as the level of biochar application increased. This implies that biochar has the ability to improve water retention and may be used where water is limiting. This may be explained by increased porosity which implies more space for water. Study of Fischer and Glaser (2012) explain that field capacity is generally influenced by the particle size, structure and content of organic matter.

Table 2. Soil moisture status of soil treated with different levels of biochar.

Treatment, levels of CRH application	Saturation point (mean)	Field capacity (mean)	Permanent wilting point (mean)	Water holding capacity (mean)
Control	52.029 [c]	49.090 [c]	20.192 [d]	28.898 [b]
10 tons	53.753 [b]	52.550 [b]	20.962 [c]	31.587 [a]
20 tons	54.360 [ab]	52.662 [b]	21.240 [b]	31.423 [a]
30 tons	55.510 [a]	54.124 [a]	22.029 [a]	32.097 [a]

Saturation point: F= 12.04 P= 0.001 CV= 11.4%
Field capacity: F= 82.58 P= 0.000 CV= 10.2%
Permanent wilting point: F= 80.02 P= 0.000 CV= 3.0%
Water holding capacity: F= 29.94 P= 0.000 CV= 7.2%
**In a column, means that do not share a letter are significantly different α=0.05.*

The increased water holding capacity is confirmed by Dugan *et al*. (2011) that addition of 10% by weight biochar increased permanent wilting point from 2 – 8 %. The water holding capacity increased with increased levels of biochar and attests that biochar enhances the water holding capacity of the soil. The same result was observed by Artiola (2011).

Yield of spring onion

The number of plantlets per hill was increased when biochar level increased. The treatment with 30 t-ha^{-1} produced an average of 7.3 plantlets per hill. This is 70.76 % higher than control.

The yield varied from 24,479 to 33,198 kg per hectare. This conforms to the reported yield of 20,000 - 24,000 kg-ha^{-1} by the Ontario Ministry of Agriculture, Canada (2003). Yield was highest where biochar level was highest.

Table 3. Number of plantlets per hill and computed yield per hectare treated with different levels of biochar.

Treatment, levels of CRH application	Computed yield per hectare (kg/ha)	No. of plantlets per hill
Control	24,479 ^{c}	4.275 ^{d}
10 tons	28,260 ^{bc}	5.125 ^{c}
20 tons	31,302 ^{ab}	6.000 ^{b}
30 tons	33,198 ^{a}	7.300 ^{a}

No. of plantlets per hill: F= 31.50 P= 0.000 CV= 6.11%
Yield per 0.24 m^2 harvest area: F= 8.42 P= 0.003 CV= 7.51%
Computed yield per hectare (kg/ha): F= 8.42 P= 0.003 CV= 7.51%
**In a column, means that do not share a letter are significantly different α=0.05.*

Cost and return analysis

The expenses and incomes from 2 cropping seasons of spring onion are shown in Table 4. It is assumed that yield will not change within 2 consecutive cropping seasons with biochar applied only once. Total expenses for control is Php 39,606.00. Additional expenses were incurred due to labor and cost of biochar. Expenses were increased by 10.73%, 18.31%, and 25.88% for 10, 20, and 30 t-ha^{-1}, respectively. Net income was increased by 16.02%, 29.03%, and 36.80% for 10, 20, and 30 t-ha^{-1}, respectively. The return on expenses was highest with 30 t-ha$^{-1.}$

Table 4. Cost and return analysis on production of spring onion with different levels of biochar

Variable	0 tons/ha	10 tons/ha	20 tons/ha	30 tons/ha
Expenses (Php)	39,606	43,856	46,856	49,856
Net income (Php)	327,581	380,050	422,675	448,112
Return on expenses (%)	827.10	866.59	876.03	898.81

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