International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Response of pH, WHC and CEC due to Biochar Application in Inceptisol Soil

Dirga Sapta Sara [1)], Emma Trinurani Sofyan [1)], Ania Citraresmini [1)], Benny Joy[1)]

[1)] Universitas Padjadjaran, Address Jl. Bandung-Sumedang KM.21, West Java, Indonesia

ABSTRACT

Biochar has been identified as an effective soil amendment in improving soil quality, especially in marginal soils such as Inceptisol, which often suffer from low cation exchange capacity (CEC), water holding capacity (WHC), and high pH. This study aims to evaluate the impact of biochar application on changes in pH, CEC, and WHC in Inceptisol soil. The research was conducted at the Laboratory of Soil Chemistry and Plant Nutrition, Faculty of Agriculture, Universitas Padjadjaran, using a randomized block design (RAK) experimental design and five treatments consisting of 1 control treatment and four biochar dosage levels with five replications. The results showed that biochar application significantly increased soil pH from 4.81 to 6.34, CEC from 35.13 cmol kg^{-1} to 59.21 cmol kg^{-1}, and WHC from 48.22% to 61.74%.

Keywords: Soil acidity, Soil amandement, Soil quality

INTRODUCTION

Biochar has been widely studied as one of the potential soil amendments in an effort to improve soil quality, especially on marginal soils such as Inceptisol. Inceptisol soils, which are soils with minimal profile development and low fertility, often face problems such as low cation exchange capacity (CEC), water holding capacity (WHC), and high acidity (pH). The application of biochar to this soil is expected to provide improvements to the physical and chemical properties of the soil.

Studies conducted by Lehmann and Joseph (2015) and Bruun et al (2014) show that biochar can increase soil pH due to its alkaline nature. This is important for Inceptisol soils that are often acidic, where an increase in pH can increase nutrient availability to plants. In addition, research by Agegnehu et al. (2015) confirmed that biochar is able to increase soil CEC. This increase in CEC occurs because biochar has a large surface area and many active sites that can adsorb cations, so it can improve soil fertility.

Water holding capacity (WHC) is also an important trait that can be improved by the addition of biochar. Blanco-Canqui (2017) reported that biochar is able to increase soil WHC through improving soil pore structure. The pore structure of biochar allows for better water retention, which is very beneficial for plants especially in environmental conditions with limited water availability.

Further research by Mukherjee et al (2014) and Jeffery et al (2015) also indicated that biochar can play a role in stabilizing carbon in the soil, which has implications for improving soil quality in the long term. In addition, research by Liu et al. (2016) and Sun et al (2014) revealed that particle size and concentration of biochar also play an important role in influencing soil hydraulic conductivity and dissolved organic carbon release, which have a direct impact on soil physical properties.

Thus, this study aims to evaluate the response of Inceptisol soil to biochar application, especially in terms of changes in pH, WHC, and CEC. The results of this study are expected to provide a scientific basis for the use of biochar as a soil improvement strategy on less productive lands.

METHODS

This test was conducted at the Soil Chemistry and Plant Nutrition Laboratory Experimental Field (KTNT), Sumedang Regency, West Java, which is located at an altitude of 700 m above sea level. This test was conducted from April to August 2023. The analysis was conducted at the Laboratory of Soil Chemistry and Plant Nutrition, Faculty of Agriculture, Universitas Padjadjaran Jatinangor. The materials used in this test were planting media in the form of Inceptisol soil from Jatinangor which was brought to the test site. Biochar soil improver derived from rice husk. The experiment used a randomized group design (RAK) with five test treatments of biochar soil improver with five replications.

The test method is soil incubation for two months in random conditions with biochar treatment, then put into a 10 kg bucket. Soil samples were treated with biochar equivalent to 0, 0.5, 1.0, 1.5 and 2 times the recommended dose. The recommended dose of biochar use is 10 t/ha. Then the effect of biochar application was observed by analyzing the soil at the end of incubation. The test parameters observed were pH, CEC and WHC (*Water Holding Capacity*). Observations were made in the laboratory including observations at the beginning and at the end of incubation. The laboratory observations made include pH, CEC and WHC. Sample observations were made by taking soil samples at the end of the observation.

RESULTS AND DISCUSSION

The pH measurement refers to the analysis The incubation method for eight weeks shows changes in soil pH. Soil pH management has become one of the priorities in agricultural practices. Biochar has been proven as an effective material in increasing soil pH as shown in Table 1.

Table 1. Results of Soil pH Analysis After Incubation

Code	**Treatment**	**Soil pH**
A	Control (without biochar treatment)	4,81 a
B	0.5 Biochar dosage (5 t/ha)	5,43 b
C	1 Dose of Biochar (10 t/ha)	5,97 c
D	1.5 Biochar dosage (15 t/ha)	6,34 d
E	2 Dose of Biochar (20 t/ha)	6,42 d

Notes: Mean numbers followed by the same letter are not significantly different based on Duncan's Multiple Range Test at 5% level.

Biochar dose equivalent to 1.5 doses of Biochar can increase soil pH from 4.81 to 6.34 (treatment D) as well as the addition of Biochar at various other levels. The increase in soil pH was seen as the dose of Biochar given increased. At the end of the incubation period, the increase in soil pH treated with Biochar was still at a more effective pH, namely at a dose of Biochar equivalent to 1.5 doses with a pH of 6.34. The increase in soil pH from 4.81 to 6.34 after biochar application showed a significant effect of biochar application in reducing soil acidity. Biochar, which usually has alkaline properties, can increase soil pH through several mechanisms, which include increasing the content of basic cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+) as well as adsorption of hydrogen (H^+) and aluminum (Al^{3+}) ions responsible for soil acidity.

Biochar is rich in base cations that can replace H^+ and Al^{3+} ions in cation exchange complexes in soil. When biochar is applied to the soil, these basic ions are released into the soil solution and neutralize the H^+ ions causing acidity. This process causes an increase in soil pH, from acidic conditions (pH 4.81) to more neutral conditions (pH 6.34). According to research by Agegnehu et al. (2015), the addition of a certain dose of biochar can significantly increase soil pH, especially in soils that were previously very acidic.

The physical and chemical properties of biochar, including large surface area and the presence of basic functional groups, enable biochar to adsorb H^+ and Al^{3+} ions from soil solution. Al^{3+} ions, which are highly toxic to plants at low pH, are precipitated as insoluble $Al(OH)_3$ at higher pH, thus reducing soil acidity. This is supported by the study of Lehmann and Joseph (2015) which showed that biochar can reduce the concentration of Al^{3+} ions in the soil, thereby increasing soil pH.

Biochar affects the chemical properties of soil, able to: (a) increasing the cation exchange capacity (CEC) will increase the ability of the soil to retain nutrients. Biochar forms complexes with micro elements, thus protecting these elements from leaching by rainwater.

(b) bind heavy metals (forming chelate compounds), then precipitate them so as to reduce soil poisoning; (c) increase the pH of acidic soils due to the continuous use of chemical fertilizers.

Table 2. CEC Analysis Result after Incubation

Code	**Treatment**	**CEC (cmol kg)-1**
A	Control (without biochar treatment)	35,13 a
B	0.5 Biochar dosage (5 t/ha)	41,72 b
C	1 Dose of Biochar (10 t/ha)	51,12 c
D	1.5 Biochar Dose (15 t/ha)	59,21 d
E	2 Dose of Biochar (20 t/ha)	60,54 d

Notes: Mean numbers followed by the same letter are not significantly different based on Duncan's Multiple Range Test at 5% level.

Data Table 2 shows that the provision of biochar increases the soil CEC. In the 8th week of treatment with the addition of biochar increased the exchangeable CEC almost close to two times more than the control or without biochar treatment. This shows that the provision of biochar on acidic soil has a positive impact on CEC. Giving Biochar 1 ½ doses and 2 doses at week 8 increased the CEC to almost twice that of the control treatment. Giving Biochar at doses greater than 1 ½ doses did not show a large increase in CEC. the increase in the CEC of inceptisol soil because Biochar is a soil improver that can increase CEC. biochar has a high CEC so that it can increase soil CEC.

The increase in soil CEC from 35.13 cmol kg^{-1} to 59.21 cmol kg^{-1} after biochar application shows the significant impact of biochar in improving soil chemical fertility. CEC is a measure of the ability of soil to hold cations on the surface of soil particles and is an important indicator of soil fertility. Increased CEC is usually associated with increased nutrient availability to plants and improved soil structure, which contributes to increased agricultural productivity.

Biochar has a highly complex pore structure and large surface area, which provides many active sites for adsorbing cations. This high surface area of biochar provides more places for cation ions to bind, thus increasing the soil CEC significantly. According to a study by Lehmann and Joseph (2015), the physical properties of biochar, including its surface area, are one of the main factors that contribute to the increase in CEC when biochar is added to soil. Biochar also contributes to the increase of organic matter in the soil, which directly affects CEC. Organic matter, including biochar, has a higher ability to hold cations compared to soil mineral particles, especially in organic matter-poor soils such as Inceptisols. Mukherjee et al (2014) stated that the addition of biochar can significantly improve soil CEC through increased organic matter content, which provides more space for cations to bind.

Table 3. WHC Analysis Results After Incubation

Code	**Treatment**	**WHC (%)**
A	Control (without biochar treatment)	48,22 a
B	0.5 Biochar dosage (5 t/ha)	53,41 b
C	1 Dose of Biochar (10 t/ha)	55,66 b
D	1.5 Biochar Dose (15 t/ha)	61,74 c
E	2 Dose of Biochar (20 t/ha)	62,48 c

Notes: Mean numbers followed by the same letter are not significantly different based on Duncan's Multiple Range Test at 5% level.

Based on the test results that can be seen in Table 3 shows that the treatment of various doses of biochar has a real effect on the WHC content in the soil compared to the control. Giving biochar with 0.5 gives a real effect compared to the control, as well as with other Biochar doses, this shows that Biochar can provide an increase in WHC in Inceptisol soil.

The increase in soil WHC from 48.22% to 61.74% after biochar application indicates that biochar has a significant effect in improving the soil's ability to store water. Biochar has a very diverse pore structure, which includes macro, meso, and micro pores. This structure allows biochar to store water within its pores. Macro pores in biochar allow water to be absorbed quickly, while micro pores can hold water longer and release it slowly. Blanco-Canqui (2017) and Yang et al (2016) reported that biochar can increase WHC by providing more pore space for water storage, thereby increasing the soil's ability to retain water beneficial to plants.

Biochar interacts with soil particles, especially fine-textured soils such as clays and sandy loams, to form stable aggregates. These aggregates increase soil porosity, allowing water to be better stored within the soil profile. With the formation of larger aggregates, biochar helps to reduce soil compaction, which also contributes to increased WHC. Agegnehu et al. (2015) and Uzoma et al (2011) showed that biochar can improve soil structure by increasing aggregation, which in turn increases the soil's capacity to hold water.

CONCLUSION

1. Biochar affects the process of increasing pH, CEC and PHC. Giving a dose of Biochar test equivalent to 1.5 doses of Biochar can increase pH, CEC and WHC compared to the control.
2. Biochar dose of 1.5 doses or 15 t/ha gave the best results on pH, CEC and PHC in Inceptisol soil.

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