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Effect Of Biochar On Availability Of Nutrition Fe (Iron) In Acid Soil

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ABSTRACT

Iron (Fe) is a micro nutrient that is absolutely fulfilled in plant metabolic reactions. Iron is needed in relatively small amounts, but the solubility of iron in acid soils is very high. The high content of soluble iron in the soil causes the growth and production of the resulting plant is not optimal. The application of soil amendments such as biochar can reduce the solubility of iron in acid soils. This study aims to examine the effect of the application of biochar as a soil enhancer on the availability of Fe nutrients in acid soils. This research is an experimental research conducted in a laboratory. This study used a completely randomized design (CRD) with 1 factor, namely the dose of biochar, consisting of 5 dose levels as treatment, namely: dose 0 g/100 g soil, dose 2.1 g/100 g soil, dose 4.4 g/100 g soil, dose 6.3 g/100 g soil, and dose 8.4 g/100 g soil, and each treatment was incubated for 8 weeks. The observed soil parameters were pH, C-Organic content, Fe-available, which were carried out at incubation times of 0, 1, 4, and 8 weeks. The results showed that the application of biochar had an effect on the availability of Fe in acid soils. The application of different doses of biochar has a different effect on significantly the availability of Fe in acid soils. In all incubation periods, the application of biochar at a dose of 2.1 g/100 g soil was able to reduce the available Fe content in the soil to 4.17, 3.59, 3.51 ppm at 1, 4, and 8 weeks of incubation, respectively

Keywords:

Biochar, soluble Fe, acid soil, soil amandment

INTRODUCTION

Iron (Fe) is an essential element whose presence is absolutely fulfilled in plant metabolism, such as the process of respiration, photosynthesis, DNA synthesis, and directing the structure of chloroplasts to form chlorophyll and activate enzymes [1]. The presence of iron is very abundant in nature, but in certain areas the availability of iron (Fe) for plants varies widely, which can be in a state of deficiency or can be in a state of poisoning. The availability of iron is related to the solubility of iron, which increases the solubility of iron, the more easily absorbed and available to plants. In acidic soils the solubility of iron is a problem because iron is a source of soil acidity where Al, Fe oxide and Al-dd will release H^+ ions into the soil solution when these elements undergo hydrolysis [2]. Iron deficiency or deficiency for plants occurs at pH > 7.5 and pH > 8.5, acute chlorosis occurs in plants [3]. The results of tissue analysis of some leaf plants obtained the level of micronutrient concentration of iron (Fe) which can be categorized as deficient, if Fe <50 µg/g,

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sufficient if Fe 50-250 µg/g, and toxic if Fe >250 µg/ g [4].

The high solubility of iron is one of the problems in the use of acid soil for the cultivation of food crops [5]. Iron will be available both to plants in the pH range of 4.6-7.4 [6], while at pH 7.5-8.5 the solubility of Fe^{2+} is very small, starting from 10-10 M [7]. To reduce the solubility of iron can be done by increasing the pH of the soil.

The use of soil enhancers such as biochar is an attempt to increase the pH of acid soils [8]. Iron ions begin to precipitate at a pH of 6.0-8.0 so that the iron content is getting smaller in that pH range. Increasing the pH from 4 to 8 causes the availability of Fe3+ to decrease with the soluble amount from 10-8 to 10-20 M [9]. Biochar is a material that has high stability in the soil so it is very well used as a soil enhancer. Biochar also has functional groups that are able to control metal ions through the formation of chelate formation by organic ligands that help control iron ions around plant roots in the soil [7].

METHOD

The study was carried out in January - July 2021. This study is an incubation experiment [10, 11, 12] conducted at the Soil Science Laboratory, using a completely randomized design (CRD) with 1 factor, namely palm shell biochar dose: 0 tons/ha, 5 tons/ha, 10 tons/ha, 15 tons/ha, and 20 tons/ha. Each treatment will be repeated 3 times to obtain 15 experimental units. The biochar used is palm shell biochar made with a pyrolysis temperature of 600 °C.

Incubation Experiment

A total of 100 g of soil was put into the incubation container, then mixed with biochar according to the treatment dose of biochar per 100 g of resistance 0 g, 2.1 g, 4.2 g, 6.3 and 8.4 g, respectively. Soil parameters were observed before and after incubation. The incubation experiment was carried out for 8 weeks. The soil properties observed before incubation were soil pH, C-Organic, CEC, and available Fe. Meanwhile, after incubation, the soil pH, C-Organic, Fe available were at 0, 1, 4, and 8 weeks after incubation. The data obtained were analyzed using the 5% F test, if there was a significant difference, it was followed by a HSD test 5%.

RESULTS AND DISCUSSION

Soil Characteristics and Biochar

Each type of soil has a different level of soil fertility. Soil that has adequate fertility will be able to provide optimal crop production results, while soil that has a low fertility level will provide less than optimal crop production results.

Table 1. Chemical properties of soil and biochar

Chemical properties	Unit	Soil[a]	Palm oil shell Biochar[b]
Soil pH	-	4.12 ac	10.67
C-bound	%	1.24 l	81.78
OC	%	-	19
Fe	ppm	41.3	-
CEC	Cmol/Kg	9.7	4.55

Source: aResults of research (2021), b[13].
Keterangan: ac: acid; l: low [14]

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Table 1 shows the characteristics of the soil and biochar used. The soil is included in the marginal soil group, with a pH of 4.35 (acidic), soil organic matter content of about 1.24% (low), soil Fe content of around 41.3 ppm classified as very high [15]. The obtained soil properties cannot support plant growth, development and production. Increasing soil fertility is done by adding soil enhancers such as palm shell biochar. The oil palm shell biochar used has a high pH which is classified as alkaline (10.67). The organic carbon (OC) content of oil palm shell biochar is high, which is more than 25% [16].

Effect of Biochar on Soil pH Changes

Changes in soil pH due to biochar administration at incubation times of 0, 1, 4, and 8 weeks are presented in Table 2. In general, increasing the dose of biochar can increase soil pH, both at incubation times of 0, 1, 4 and 8 weeks from the initial soil pH. around 4.34. The higher the dose of biochar given causes the soil pH to increase significantly. The highest pH value was obtained at a dose of 8.4 g/100 g of biochar, and the lowest was obtained without biochar. It is suspected that the influence of alkalinity of a given biochar. Palm shell biochar has a pH of 10.67 which is classified as alkaline. The increase in soil pH is higher because the amount of biochar given is increasing. The increasing amount of biochar will increase the soil pH.

Tabel 2. Changes in soil pH during the incubation period

Biochar doses	Soil pH at incubation time … (weeks)			
	0	1	4	8
0.0 g/100	4.63 a	4.37 a	4.33 a	4.87 a
2.1 g/100	5.25 b	4.55 b	5.03 b	5.27 b
4.2 g/100	5.69 c	5.04 c	5.53 c	5.78 c
6.3 g/100	5.92 d	5.36 d	5.87 d	6.10 d
8.4 g/100	6.02 e	5.61 e	5.95 e	6.44 e
HSD 5%	0.11	0.05	0.09	0.08

Note: numbers followed by the same letter are not significantly different based on the HSD test at a significance level of 5%

Increasing the dose of biochar given will increase the content of the (OH) group which causes the soil pH to increase [17, 18]. Therefore, giving a higher dose of biochar will donate a higher OH group so that the soil pH will increase. At 8 weeks incubation, the higher soil pH was suspected to be due to the addition of biochar dose where the biochar supported microbiological processes in the soil. According to [19] and [20], biochar is porosity and has a large outer surface, which is a habitat for soil microorganisms, thereby increasing their activity and population which contributes greatly to increasing soil pH.

Effect of Biochar on Soil Organic Carbon (OC) Changes

Table 3 shows that the different doses of biochar given to each sample have a different and significant effect on the OC content of the soil. The application of biochar at a dose of 8.4 g/100 g of soil into the soil was able to increase the OC content in the soil. The increase in the dose given to the soil was significant in all treatments. The administration of higher doses significantly increased the C-organic content of the soil. The

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highest soil OC content was obtained at a dose of 8.4 g/100 g soil treatment, which was 26.240%.

At an incubation period of 8 weeks, the dose of biochar was able to increase the organic carbon content. The effect of biochar dose on increasing soil organic carbon content at 8 weeks of incubation was almost the same as the pattern shown at 4 weeks of incubation. The organic carbon content increased with increasing the dose given. During the incubation period there was a change in the organic carbon content of the soil. Soil organic carbon content did not increase, it decreased. This shows the activity of microorganisms in the soil that utilize organic carbon in the soil as energy. The use of organic carbon by microorganisms as energy is a natural process, and produces organic acids that play a role in chemical reactions in the soil. According to [21] stated that biochar is an organic compound that has a high carbon content (40-60%) and is resistant to weathering so that it is used as a soil carbon reserve that is able to function as an effective organic ameliorant to improve soil fertility.

Table 3. Changes in soil organic carbon content during the incubation period

Biochar Doses	soil organic carbon content at incubation time … (weeks)			
	0	1	4	8
0.0 g/100	14.16 ab	14.84 a	5.05 a	3.28 a
2.1 g/100	8.92 ab	17.58 ab	5.50 ab	4.98 c
4.2 g/100	8.39 a	17.22 ab	5.82 ab	5.44 d
6.3 g/100	12.33 ab	20.62 bc	7.08 b	4.28 b
8.4 g/100	26.24 c	20.24 bc	12.44 c	10.57 e
HSD 5%	4.66	10.43	0.96	0.80

Note: numbers followed by the same letter are not significantly different based on the HSD test at a significance level of 5%

Effect of Biochar on Fe- available Changes in Soil

During the incubation period, the application of biochar doses was able to reduce the available Fe content in the soil at a dose of 2.1 to 4.4 g/100 g soil, as shown in Table 4. The Fe content again increased with an increase in the dose of biochar given. Dosage of biochar 6.3 to 8.4 g/100 g soil resulted in higher soil Fe, which was significant with the previous dose. However, this increase is still lower than the control value. The lowest Fe content was obtained at a dose of biochar 4.4 g/100 g soil at 3.49 and the highest at a dose of biochar 6.3 at 5.96 ppm.

In this study, the value of Fe available in the soil was different at each treatment dose of biochar. Dosage of biochar available in soil caused Fe available in soil to increase at 1 week and 8 weeks incubation, while at a dose of 2.1 g/100 g soil biochar was able to reduce available Fe in soil. It is suspected that the increase in Fe available in the soil occurs due to reactions caused by other metals such as Al^{3+}, because Al^{3+} is more reactive in binding organic compounds in this case biochar. It is suspected that the administration of high doses of biochar causes a retention reaction of Al^{3+} to biochar which is dominant over Fe.

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Table 4. Changes in soil available Fe during the incubation period

Biochar doses	soil available Fe at incubation time … (weeks)			
	0	1	4	8
0.0 g/100	4.52 e	4.55 c	4.22 e	5.01 d
2.1 g/100	4.04 c	4.17 a	3.59 ab	3.51 a
4.2 g/100	3.49 a	4.58 d	3.99 d	4.51 b
6.3 g/100	3.91 b	4.55 c	3.64 bc	5.96 e
8.4 g/100	4.35 d	4.46 b	3.49 a	4.90 c
HSD 5%	1.48	0.94	1.56	0.23

Note: numbers followed by the same letter are not significantly different based on the HSD test at a significance level of 5%

Relationship Between Available Fe Content with pH and OC of Soil

The solubility of iron in the soil will affect the level of soil acidity, and will differ from one soil to another depending on the availability and reaction in the soil. The main factors that affect the solubility of iron such as soil organic compounds, bacteria and others.

Figure 1 is the relationship between pH and Fe available in the soil during the incubation period. During the incubation period, the available Fe content increased with increasing pH. In this study, a soil pH of about 4-6 was able to reduce the available Fe content in the soil as shown in the graph of the relationship between pH and Fe. Changes in redox potential and soil pH affect the active form of Fe in the soil solution. Under conditions of low soil pH and an oxidizing atmosphere, a balance occurs between SO_4 activity (as a source of soil acidity) and dissolved Fe (in high amounts) to produce jarosite, which is a mineral formed as a result of pH and redox balance. Changes in pH and redox will affect the balance of jarosite which results in the re-dissolving of Fe in the soil.

Figure 2 is the relationship between C-organic and Fe available in the soil, the incubation period shows that the dosage of biochar has different roles in suppressing the solubility of Fe available in the soil at each incubation time. It is concluded from the graph of the results of the research data that the dosage of biochar showed an unequal pattern so that in this study organic C did not affect the Fe content available in the soil.

Biochar is an alkaline material capable of carrying an OH- ion, and contains an alkali metal and alkaline earth oxide compounds capable of hydrolyzing water thereby releasing OH- as well. Biochar application can cause OH release and react with Fe3+ and H+ with the following reaction [13]:

$$Fe^{3+} + 3\ OH^- \longrightarrow Fe(OH)_3$$
$$H^+ + OH^- \longrightarrow H_2O$$

The formation of $Fe(OH)_3$ and H_2O that occurs in the soil causes the levels of Fe^{3+} and H^+ in acid soil to decrease. Biochar and compost are able to chelate Fe and Al so that P is released and becomes available to plants [22, 23]. The use of biochar as a soil enhancer, biochar is widely used to overcome problems in the soil. According to [24] that the application of biochar can increase the pH of acid soils. In addition, biochar is able to increase soil CEC, availability of nutrients N, P, and K, can reduce the toxicity of heavy metals (Pb, Cu, Cd and Ni) and can increase nutrient.

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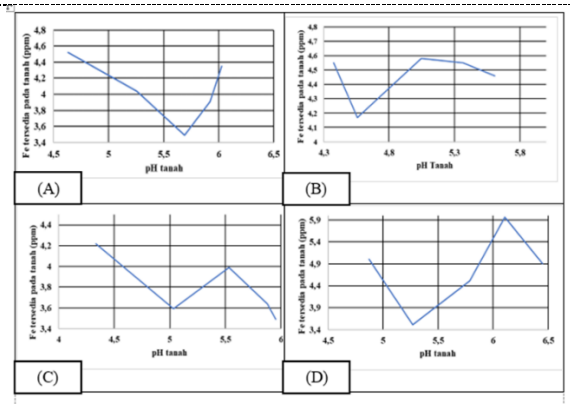

Figure 1. The relationship between soil pH and available Fe at incubation times of 0 (A), 1 (B), 4 (C), and 8 weeks (D) (Source: Mansyur and Ayni, 2021)

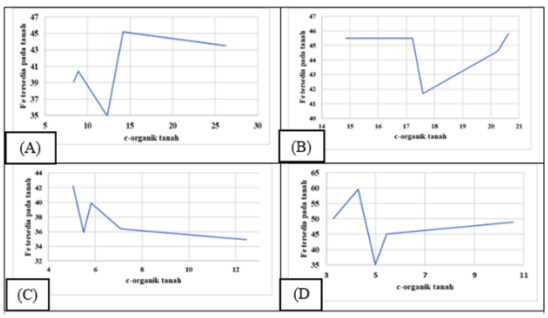

Figure 2: The relationship between OC and available Fe in the soil at incubation times of 0 (A), 1 (B), 4 (C), and 8 weeks (D) (Source: Mansyur and Ayni, 2021)

CONCLUSION

Biochar application has a different effect on soil pH, C-organic and Fe content available in the soil. During the incubation period, the pH value increased with increasing doses of biochar given. Administration of biochar at a dose of 2.1 g/100 g soil is the best dose to reduce the available Fe content in the soil. The available Fe content in the soil at incubation times of 0, 1, 4, and 8 weeks was 4.04, 4.17, 3.59, and 3.51 ppm, which were classified as low-medium based on the criteria for the solubility of Fe in the soil.

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