Fertilization strategy for climate change adaptation to improve nutrient availability and corn growth in ultisol soil

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Abstract. Fertilization is one of the inputs that determine growth yields, but most of the nutrients contained in fertilizers cannot be absorbed by plants due to leaching because of high rainfall. The purpose of this study was to determine the availability of nutrients and plant growth by mixing inorganic fertilizers with soil amendments consisting of biochar and coastal sediment. The experiment was a single factor experiment arranged in a completely randomized design (CRD) with five replications. Treatment consisted of treatment A: without giving fertilizer, treatment B: giving inorganic fertilizer 100% of the recommended dosage, treatment C: Inorganic fertilizer mixed with biochar and coastal sediment 50% + 50% inorganic fertilizer recommended dosage and treatment D: inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage. Improved fertilization strategies can increase nutrient availability and plant growth in Ultisol soil.

1. Introduction

The government in ensuring food needs has launched a food security program by achieving self-sufficiency in food crops for rice, corn and soybeans in 2017 [1]. However, in reality, the large food imports in recent years indicate that the food security program has not been fully successful. One of the things that have not achieved sustainable national food security is the decline in food crop production due to the reduction in the area of cultivated land due to the conversion of agricultural land to non-agricultural and food crop land to non-food crop land. According to Mariyono [2] reveals that around 200,000 hectares of agricultural land are converted to non-agricultural land every year. In addition, the decline in food crop production was also caused by climate change, which made rainfall unpredictable [3].

Efforts can be made to increase food crop production by extensification and intensification. The method of extensification is carried out by utilizing potential lands for the development of food crop cultivation. One of the land that has not been utilized and the amount is quite wide and spread evenly in the area of West Kalimantan Province is the land after mining without a permit (LMWP). LMWP has a total area of 6,613 ha spread over 267 locations in eleven districts. The land after LMWP is physically, chemically and biologically damaged and contains Hg [4]. The results of the study, Sulakhudin et al. [5] show that there is no residual Hg found in post-LMWP land in Monterado District, Bengkayang Regency, West Kalimantan, while the Hg content in post-LMWP land in Mandor District, Landak Regency, West Kalimantan is low, even post-LMWP land 11-15 years old with an average of 0.037 ppm [6]. When compared to the standard quality standard for heavy metal mercury abundance in the soil of 10 ppm [7], post-LMWP soil can be used for plant cultivation.
Cultivation of food crops in post-LMWP land requires the introduction of specific fertilization technology because the soil particles are dominated by porous sand so that many nutrients are lost through washing. Nutrient lots of washing will cause less plant roots to absorb nutrients from the fertilizer given, which will cause a low level of fertilization efficiency. One of the fertilization strategy used to reduce nutrient leaching is using slow release fertilizer. However, this technology is still quite expensive and mostly made from chemicals that can potentially pollute the environment. Solutions that can be developed to reduce costs and environmental pollution due to fertilization are used natural materials that can control the release of nutrients from the fertilizer. One of the things that can be used is to use mixing of biochar and coastal sediment that has been produced by the applicant in the Featured applied research of university Research Scheme [8]. This experiment was conducted to determine the effect of mixing inorganic fertilizers with soil amendments consisting of biochar and coastal sediment application on corn growth and yield in the land.

2. Methodology
The test was a single factor experiment arranged in a completely randomized design (CRD) with the type of fertilizer treatment. The experiment was repeated 5 times so that there were 20 experimental units. The treatment details are as follows: treatment A: without giving fertilizer (control), treatment B: giving inorganic fertilizer 100% of the recommended dosage, treatment C: Inorganic fertilizer mixed with biochar and coastal sediment 50% + 50% inorganic fertilizer recommended dosage, and treatment D: inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage.

The experimental plot used for planting maize was 3 x 4.5 m in size. The corn was planted after 1 week of fertilizing according to the treatment and by immersing three corn seeds as deep as 7 cm with a spacing of 40 x 75 cm. The number of corn plants in one experimental plot was 36 plants. Plant maintenance consists of watering, controlling pests and diseases manually. Corn plant growth parameters are plant height and stem diameter which are measured once a week until the end of vegetative growth. The parameters of nutrient availability in the soil measured are total N, available P, and exchangeable K, and soil pH. In addition, an analysis of some of the original soil properties was carried out on the land that was used as an experiment site.

The data obtained from each experiment were tested using the F test at the 5% confidence level. If the F test shows a real or very real effect, to determine the real difference between treatments, the DMRT (Duncan’s Multiple Range Test) mean difference is carried out at the 5% confidence level.

3. Result and discussion

3.1. Some initial soil properties
The results of the research that had been obtained until this progress report were made in the form of preliminary soil analysis results obtained from study site. The research site is located in Toho, Mempawah Regency. The results of the analysis of soil samples from the UNTAN research plantation which were used as research sites can be seen in Table 1.

The soil in study site reacted very acid, it can be seen from the soil pH value of 4.16. The pH value of the soil at the study site is lower than the results of Subekti [9] which shows the soil pH in the around of study site is 4.5, which includes the acid criteria. Soil that reacts very acid causes the content of several nutrients in the soil to be classified as very low, for example the nutrients Ca, K, Mg and Na. Some of the soil properties at the study site are as listed in Table 1, according to the criteria presented by Suharta et al. [10] then the soil in the study area is included in the type of ultisol soil. Furthermore, Cahyana et al. [11] stated that the requirement for a soil to enter into the ultisol order is that its base saturation value is less than 35%. In addition, the soil has a low and very low CEC value and base saturation. Base saturation values of 7.10% and CEC of 13.37 cmol(+)kg⁻¹ are included in very low and low criteria, respectively. This shows that this soil has a fairly high level of weathering and low nutrient retention, so that some soil properties need to be improved by adding ameliorant.
Table 1. Soil characteristics at study site.

| Soil properties       | Value | Criteria   |
|-----------------------|-------|------------|
| pH H₂O                | 4.16  | Very acid  |
| C-organik (%)         | 3.98  | High       |
| N Total (%)           | 0.57  | Very low   |
| C/N                   | 6.98  | low        |
| P₂O₅ Bray (ppm P)     | 68.37 | Very High  |
| CEC (cmol (+) kg⁻¹)   | 13.95 | Low        |
| Ca (cmol(+)kg⁻¹)      | 0.46  | Very Low   |
| Mg (cmol(+)kg⁻¹)      | 0.16  | Very Low   |
| K (cmol(+)kg⁻¹)       | 0.14  | Low        |
| Na (cmol(+)kg⁻¹)      | 0.23  | Low        |
| Base saturation (%)   | 7.10  | Very low   |
| Texture               |       |            |
| Sand (%)              | 9.98  | Clay Loam  |
| Silt (%)              | 57.48 | Silty      |
| Clay (%)              | 32.54 |            |

Table 2. Effect of kinds of fertilizer on soil pH value after incubation.

| Treatment                                      | pH value |
|------------------------------------------------|----------|
| Control (without fertilizer)                   | 5.17 a   |
| inorganic fertilizer 100% of the recommended dosage | 5.32 a   |
| Inorganic fertilizer mixed with biochar and coastal sediment 50% + 50% | 5.33 a   |
| inorganic fertilizer recommended dosage        |          |
| Inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage | 5.69 b   |

Note: different letters in the same column indicate a significant difference.

3.2. Effect of treatment on nutrient availability

Soil is a material that is not soft and will experience various reactions due to additional materials into the soil. The application of several kinds of fertilizers according to the treatment can result in differences in soil properties, either different from the original soil or different due to differences in treatment.

Table 2 shows that the treatment has a significant effect on the pH value of the soil. The results of the variance test showed that different types of fertilizers significantly affected the pH value of the soil. Giving a mixture of biochar and marine mud can increase soil pH. The results of the research by Zhang et al. [12] showed that the application of biochar can increase the pH of acidic soil by 0.5-1 unit, while the increase in soil pH due to the application of coastal sediment at a dose of 14 Mg ha⁻¹ has been reported by Suswati et al. [13]. The results of the variance test, showed that the soil used in the study had quite high diversity. This is thought to be due to the sloping location so that in some locations there is nutrient leaching especially basic cations, so that in the soil it is dominated by acid-causing cations.

The DMRT test results in Table 2 showed that there was an increase in the pH value of the soil due to the addition of mixing biochar and coastal sediment. The Table 2 shows that giving inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage was able to increase the highest pH compared to the initial soil and other treatments. This is because biochar and coastal sediment contains more basic cations that it can increase the soil pH value. Sulakhudin and Suswati [14] showed that the provision of coastal sediment as much as 30 tonnes ha⁻¹ and biochar 4 tonnes ha⁻¹ could increase soil pH in post-LMWP land.
Table 3. Effect of kinds of fertilizer on N-total value after incubation.

| Treatment | N-total value |
|-----------|---------------|
| Control (without fertilizer) | 0.69 a |
| inorganic fertilizer 100% of the recommended dosage | 0.76 a |
| Inorganic fertilizer mixed with biochar and coastal sediment 50% + 50% | 1.07 a |
| Inorganic fertilizer recommended dosage | |
| Inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage | 1.13 a |

Note: different letters in the same column indicate a significant difference.

The DMRT test results in Table 3 show that the application of mixing biochar and coastal sediment on inorganic fertilizer has not significant effect on the N-total soil. Table 3 shows that giving Inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage can increase the N-total soil higher than the initial soil and other treatments. The application of the treatment increased the availability of soil N-total nutrient by 1.13%. These results are in line with the research of Sulakhudin et al. [5] which showed that the application of biochar and coastal sediment increased the total N- soil of the soil, but the effect was not significantly different. Further Yu et al. [15] explained that the dominant form of nitrogen in dry land is nitrate which has a negative charge so that it cannot be bound by soil particles. As a result, many nitrates are washed away due to rainwater.

Table 4. Effect of kinds of fertilizer on P-available value after incubation.

| Treatment | P-available value |
|-----------|-------------------|
| Control (without fertilizer) | 13.08 a |
| inorganic fertilizer 100% of the recommended dosage | 54.73 b |
| Inorganic fertilizer mixed with biochar and coastal sediment 50% + 50% | 46.08 b |
| Inorganic fertilizer recommended dosage | |
| Inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage | 120.26 c |

Note: different letters in the same column indicate a significant difference.

Table 4 shows that the application of various fertilizers has a very significant effect on the available P-soil. The results of the variance test showed a significant effect on the application of fertilizer in the treatment compared to the control. The application of Inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage was able to increase the available-P value higher than the control with a value of 120.26 ppm. The increase in available P was thought to be due to the effect of biochar in binding P nutrients in the soil. According Glaser and Lehr [16], application of biochar to acid soils (pH < 6.5) can significantly increase available P. Furthermore Chintala et al.[17] explained that the availability of P in the soil is influenced by Al³⁺ and Fe³⁺ elements by forming Al- and Fe-phosphates. The addition of biochar into acidic soil will increase the pH so that the solubility of Al and Fe elements decreases and the P binding by Al and Fe elements will decline. As a result, the availability of P in the soil is increasing.

Table 5. Effect of kinds of fertilizer on K-exch. value after incubation.

| Treatment | K-exch. value |
|-----------|---------------|
| Control (without fertilizer) | 0.24 a |
| inorganic fertilizer 100% of the recommended dosage | 0.47 b |
| Inorganic fertilizer mixed with biochar and coastal sediment 50% + 50% inorganic fertilizer recommended dosage | 0.67 c |
| Inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage | 0.76 c |

Note: different letters in the same column indicate a significant difference.
Table 5 shows that application of mixing biochar and coastal sediment on the $K_{\text{exch}}$ value have a very significant effect. Inorganic fertilizer mixed with biochar and coastal sediment 50% + 50% inorganic fertilizer recommended dosage was not significantly different from that of the Inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage, but the provision of various kinds of fertilizers was significantly different compared to that without applying fertilizer. The $K_{\text{exch}}$ value in the control was only 0.24, while the inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage was 0.76%. Increased availability of soil K nutrients due to the giving of biochar caused by the addition of K from biochar ash and reduced leaching caused by erosion or run off [18-19].

3.3. Effect of treatment on growth of corn plants

Plant growth measured was plant height and stem diameter. Plant height data at the age of two weeks after planting. It shows that treatment B, C and D are higher than treatment A (control). Figure 1 shows the height of the corn plant due to treatment application.

Figure 2 shows the effect of treatment on the diameter of corn plants. Preliminary results until the 3rd week of measurement show that the application of mixing biochar and coastal sediment provides the highest stem diameter value since the 2nd week of measurement.
Note: Treatment A = Control (without fertilizer); treatment B = inorganic fertilizer 100% of the recommended dosage; treatment C = Inorganic fertilizer mixed with biochar and coastal sediment 50% + 50% inorganic fertilizer recommended dosage; and treatment D = Inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage).

4. Conclusion
The application of inorganic fertilizer mixed with biochar and coastal sediment 100% recommended dosage was able to increase the availability of nutrients and growth of corn plants in Ultisol. The increase in nutrient availability was caused by a rise in soil pH due to the addition of a mixture of biochar and marine mud in inorganic fertilizers.

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