Addition of biochar to urea and urine fertilizer for improving soil chemical properties and maize yield in acid upland, East Lampung

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Abstract. Some studies have shown the ability of biochar in nutrient retention, including N such as urea and urine. The objective was to evaluate the effect of addition of biochar to urea/urine on the soil chemical properties and maize yield in acid upland East Lampung. The study was conducted at the Research station of Indonesian Soil Research Institute, East Lampung, from February to May 2016. The study used a randomized block design 4 replications, with treatments: 1) urea, 2) biochar (BC) + urea, 3) BC + urea (dissolved), 4) BC + urine and 5) urine. The parameters measured were soil chemical properties and maize yields. The results showed that the addition of biochar on urea and urine had soil chemical properties significantly better than without biochar. Urine could be applied with biochar. The highest dry grain was obtained from BC + urea (7.49 t ha⁻¹) and dissolved BC + urea (7.15 t ha⁻¹) compared to the others treatment (5.11 to 6.05 t ha⁻¹). The application of BC + urine had a higher dry grain 12% compared to the urine without biochar treatment. Application of BC + urea, whether dissolved or not, is more effective to be applied in acid upland in East Lampung because it has soil chemical properties and yield better than BC + urine.

1. Introduction

Nitrogen is needed by plants to accelerate growth to increase plant height, number of tillers, yield and protein content. Sources of nitrogen for plants are usually from urea, NPK and urine with different concentration in each of these sources. Nitrogen in soil can reduce through volatilization, denitrification and leaching in which this process must be suppressed so that availability of nitrogen for plant can sustain. Minimizing input and loss of nitrogen is very important for agricultural production in order to increase soil fertility and maintain its sustainability [1]. Biochar is one of the ameliorants that can reduce nutrient losses through leaching and can improve the soil chemical properties as well. The meta-analysis found that the addition of biochar to the soil resulted in increasing of yield productivity, soil microbial biomass, rhizobia nodulation, plant tissue K concentration, phosphorus, potassium, nitrogen and carbon in soil compared to the conditions without biochar [2].

The function of biochar in agricultural land has been widely investigated including to increase soil fertility, water retention, and plant productivity [3-7]. Another benefit of biochar is the ability to retain nutrients [4, 8-11]. In soil given NPK fertilizer, addition of biochar is able to suppress the leaching of PO₄-P, NO₃-N, NH₄-N and K because these nutrients are retained in biochar pores [12-14] so that they are not drifted away by surface runoff. Over time, these nutrients will be released slowly and then used by plants according to plant needs [15]. Since nitrogen is an important essential nutrient for plants,
nitrogen leaching is very detrimental to plants. The plant nutrients are not fulfilled because of nutrient deficiency. As a result, the plant growth is not optimal. In addition, the use of nitrogen fertilizers becomes inefficient and even tends to be excessive due to high doses so that it increases urea demand nationally.

Biochar itself contains nutrients including NPK, in addition to its high carbon content [8, 10, 15]. Another advantage of biochar utilization is the ability for improving soil quality which is able to streamline the use of inorganic fertilizers as well by retaining nutrients in the biochar pores. The objective was to evaluate the effect of adding biochar to urea/urine on the soil chemical properties and maize yield in acid upland soil in East Lampung.

2. Materials and methods

Research was conducted at Taman Bogo Research Station of Indonesian Soil Research Institute located at Taman Bogo village, Purbolinggo Sub district, East Lampung from February to May 2016. The site coordinate is 05°00'406' S; 105°29'405' E, 300 m above sea level and it has annual rainfall around 2,000 to 2,500 mm y⁻¹. The soil type of the research location is classified as Typic Kanhapludults with a sandy clay loam texture class (at a depth of 0 to 20 cm 50 to 51% sand, 14 to 19% loam and 31 to 35% clay. Soil chemical properties are quite heterogeneous between blocks and classified as degraded soil. Based on pH, the soil is acidic and contains organic C with low level of total N and has a Cation Exchange Capacity (CEC) of about 8.56 to 9.16 cmol(+), kg⁻¹ and base saturation (BS) < 50% (table 1).

| Table 1. Soil Characteristic before treatment application at Research Station of Taman Bogo, East Lampung, 2016. |
|-----------------|----------|--------|--------|--------|
| Parameter       | Unit     | Block I| Block II| Block III| Block IV|
| pH H₂O          |          | 5.2    | 5.0    | 5.1    | 4.7     |
| Organic C       | %        | 1.01   | 1.09   | 1.19   | 1.04    |
| Total N         | %        | 0.09   | 0.08   | 0.11   | 0.09    |
| C/N             |          | 11     | 14     | 11     | 12      |
| P₂O₅            | mg10⁻² g | 46     | 35     | 48     | 36      |
| K₂O             | mg10⁻² g | 4      | 4      | 3      | 4       |
| P₂O₅            | ppm      | 50.7   | 31.0   | 58.4   | 37.8    |
| Ca              | cmol(+), kg⁻¹ | 3.71 | 3.44   | 3.64   | 2.54    |
| Mg              | cmol(+), kg⁻¹ | 0.32 | 0.29   | 0.27   | 0.26    |
| K               | cmol(+), kg⁻¹ | 0.07 | 0.07   | 0.05   | 0.07    |
| Cation Exchange Capacity | cmol(+), kg⁻¹ | 9.16 | 8.95   | 8.87   | 8.56    |
| Base Saturation | cmol(+), kg⁻¹ | 45   | 43     | 45     | 34      |
| Al³⁺            | cmol(+), kg⁻¹ | 0.25 | 0.28   | 0.16   | 0.65    |

The research used a randomized completely block design with four replications. The treatments were tested: 1) urea, 2) Biochar (BC) + urea, 3) BC + urea (dissolved), 4) BC + urine, and 5) urine. Before the treatments were applied, laboratory analyses were conducted to determine the quality of material used. The parameters to be measured were: pH H₂O, organic C (ashing methods), total N (Kjeldahl), P₂O₅, K₂O, CaO and MgO (wet ashing with HNO₃ and HClO₄).

The plot size was 10 m² (2.5 m x 4 m) and there are 20 plots. The doze of material used were (cocoa shell) 15 t ha⁻¹ biochar, 300 kg ha⁻¹ urea, 15 m³ ha⁻¹ urine of cow and 200 kg ha⁻¹ Ponska. The crop indicator was maize, variety used is P27, and planted at a spacing of 25 cm x 75 cm. BC + urea (dissolved) was carried out by dissolving urea with water as much as 15 m³ ha⁻¹ (15 L 10 m²), then mixed with biochar 15 t ha⁻¹ and incubated for 48 hours. The mixture of biochar and urine was obtained by dissolving 15 m³ ha⁻¹ (15 L 10 m²) urine with biochar 15 t ha⁻¹ then incubated for 48 hours. BC + urea and BC + urine were spread evenly on each plot before the maize was planted, mixed evenly with soil at a depth of 15 to 20 cm using a hoe.
Urea without biochar was applied gradually, namely 20% at planting and 40% aged 21 and 42 days after planting by dibbling. Application of BC + urea and BC + urine was done all at once by spreading, while urine was also given initially by spraying it to the soil. Urea and Ponska fertilizers were applied at a distance of 5 cm from the seeds, then covered with soil.

Before applying the treatment, 10 subs composite soil samples were taken from each replication, mixed evenly in a plastic bucket, then taken about 1 kg for soil chemical analysis at harvest time in each treatment. About 6 subs composite soil samples were taken for soil chemical analysis in the laboratory. About 1 kg were taken for soil chemical analysis in the laboratory. The parameters of soil chemical properties analyzed were pH (H₂O and KCl), C-organic (Walkley and Black), N-total (Kjeldahl), K (HCl 25%), available P (Bray 2), extractable cations (Ca, Mg and K), cation exchange capacity (CEC), base saturation and exchangeable Al (NH₄OAc 1N pH 7).

The maize growth and productivity parameters observed were the plant height and yield. Plant height was measured from the soil surface to the leaf tip every week since the maize crop was 2 weeks after planting (WAP) until the time of harvesting (8 WAP). The dry grain yield of maize was weighed in each treatment. The data were analyzed using the SAS System for Linear Models. The treatment showed a significant effect followed by Duncan Multiple Range Test (DMRT) analysis to determine the differences between treatments.

3. Results and discussion

3.1. Chemical characteristics of materials used on the research

Table 2 showed that the pH of research material used are 7.8 to 10.2 and it is potential to increase pH. The mixture of biochar and urea without being dissolved has better chemical properties that was seen from the total C content and macro nutrients (N, P, K, Ca and Mg) and soil CEC. The addition of biochar, which functions as an ameliorant with urine, was also able to improve the quality of the chemical properties of the materials. BC + urea had better chemical properties than BC + urine, it can be seen from all the chemical properties analyzed. The content of C-organic and nutrients from biochar enrich the quality of the BC + Urine. Without biochar, urine only contains 1.01% total C and 0.47% total N which was classified as very low. Additional of biochar could contribute to increase of total C and other nutrients content in soil. Based on the chemical characteristic of biochar, adding biochar to both source of N fertilizer (urea and urine) could be very useful for plant because their chemical properties were better.

Table 2. Chemical properties of material used in this study at Research Station of Taman Bogo, East Lampung in 2016.

| No | Parameter     | Unit | Biochar + urea | Biochar +urea (dissolved) | Biochar + urine | Urine |
|----|---------------|------|----------------|---------------------------|----------------|-------|
| 1  | pH H₂O        | -    | 10.2           | 9.7                       | 9.7            | 7.8   |
| 2  | Water content | %    | 10.46          | 46.68                     | 61.29          | -     |
| 3  | Total C       | %    | 36.76          | 23.76                     | 6.61           | 1.01  |
| 4  | Total N       | %    | 1.71           | 1.40                      | 1.01           | 0.47  |
| 5  | Ration C/N    | -    | 22             | 17                        | 7              | -     |
| 6  | Total P₂O₅    | %    | 0.59           | 0.40                      | 0.43           | -     |
| 7  | Total K₂O     | %    | 4.05           | 2.56                      | 3.36           | -     |
| 8  | Total Ca/CaO  | %    | 2.92           | 1.58                      | 1.67           | -     |
| 9  | Mg/MgO        | %    | 1.47           | 0.90                      | 0.97           | -     |
| 10 | CEC           | c mol/1 kg⁻¹ | 29.74       | 23.61                     | 18.18          | -     |

CEC: Cation Exchange Capacity
3.2. Soil chemical properties

Tables 3a and 3b showed that the soil chemical properties after treatment application. The addition of biochar to urea and urine significantly improves soil chemical properties compared to the application of urea or urine alone. The addition of biochar did not have a significant effect on soil CEC even though it was seen that the value was higher. The addition of biochar with urea (solid) or dissolved has the soil chemical properties that was not statistically significant. The highest of the total N content was achieved by BC + urea dissolved treatment. This data shows that the cavities or pores of biochar were able to retain N from urea dissolved and not lost through leaching. Various previous studies have proven that the pores of biochar is able to retain nutrients [10, 11, 16] and nitrogen in particular [8].

**Table 3a.** Soil chemical properties, after maize harvested, with the addition of biochar to urea and urine fertilizers at acid upland, East Lampung in 2016.

| Treatments          | pH   | Organic C % | Total N mg 100 g⁻¹ | Total P ppm | Total K ppm |
|---------------------|------|-------------|---------------------|-------------|-------------|
| Urea                | 4.93 b | 1.15 c | 0.108 b            | 44.50 ab    | 4.75 b      | 27.93 ab    |
| BC + urea           | 6.18 a | 1.39 ab | 0.125 ab           | 48.50 ab    | 35.00 a     | 30.05 a     |
| BC + urea dissolved | 6.43 a | 1.55 a  | 0.140 a            | 52.00 a     | 36.00 a     | 30.20 a     |
| BC + urine          | 6.43 a | 1.23 bc | 0.128 ab           | 52.25 a     | 47.25 a     | 32.75 a     |
| Urine               | 4.98 b | 1.14 c  | 0.110 b            | 40.25 b     | 7.50 b      | 21.58 b     |

Urea 300 kg ha⁻¹, BC 15 t ha⁻¹, urea dissolved (300 kg ha⁻¹ in 15 m³ water), urine 15 m³ ha⁻¹

The numbers followed by the same letter in the same columns are not significantly different based on the DMRT test at 0.05 level.

**Table 3b.** Soil chemical properties, after maize harvested, with the addition biochar to urea and urine fertilizers at acid upland, East Lampung in 2016.

| Treatments          | Ca²⁺ cmol(+), kg⁻¹ | Mg²⁺ cmol(+), kg⁻¹ | K⁺ cmol(+), kg⁻¹ | CEC | BS % | Al³⁺ cmol(+), kg⁻¹ |
|---------------------|-------------------|-------------------|------------------|-----|------|-------------------|
| Urea                | 2.82 b            | 0.28 b            | 0.09 b           | 7.26 a | 45.25 b | 0.680 a          |
| BC + urea           | 3.92 a            | 1.13 a            | 0.70 a           | 8.40 a | 72.50 a | 0.020 b          |
| BC + urea dissolved | 4.12 a            | 1.32 a            | 0.72 a           | 8.41 a | 74.50 a | 0.001 b          |
| BC + urine          | 4.22 a            | 1.19 a            | 0.94 a           | 8.66 a | 75.00 a | 0.001 b          |
| Urine               | 3.80 b            | 0.34 b            | 0.14 b           | 7.54 a | 44.00 b | 0.440 a          |

Urea 300 kg ha⁻¹, BC 15 t ha⁻¹, urea dissolved (300 kg ha⁻¹ in 15 m³ water), urine 15 m³ ha⁻¹

The numbers followed by the same letter in the same columns are not significantly different based on the DMRT test at 0.05 level. CEC = Cation exchange capacity, BS=Base Saturation.

Biochar itself contains essential nutrients [10, 15, 17] and this study also found the same thing (see Table 2). These nutrients can slowly be released over time and then utilized by plants [15]. Various previous studies have informed that the binding mechanism of N and other elements occurs due to a large enough biochar surface area to store nutrients [18-20]. The reduction in N leaching with the application of biochar may also be caused by the physical properties of biochar which are able to retain water so water losing will decrease [21, 22]. Furthermore, in the long term, the effect of biochar on soil nutrient content occurs through complex physiochemical reactions with soil particles [23]. The data in Table 3 also shows that urine as an alternative source of N fertilizer can be applied, but it needs to be added with biochar to increase its effectiveness.

3.3. The growth and yields of maize

The effect of treatment on the growth of maize appears in the fourth week after planting (WAP). The addition of biochar was able to promote plant growth. During plant growth, the best plant height was consistently obtained from the application of BC + urea without being dissolved. Gradual application of
urea at 21 and 42 days after planting (DAP) was able to supply N when it is needed. Application of urine without biochar resulted in the lowest maize growth. The content of N of urine tested was only around 0.47%. It was not sufficient for plant needs to support the maize growth optimally. This fact indicates that direct application of urine at the beginning of planting may not be effective in meeting nitrogen needs of maize. The addition of biochar to urine increased the concentration of nitrogen to 1.01% and better effect to maize growth. The additional of biochar can increase the availability of N and P nutrients in soil so that it could support on increasing plant productivity [24-26].

Figure 1. Crop (maize) height with the addition of biochar to urea and urine fertilizers at acid upland, East Lampung in 2016.

Figure 2 shows that BC + urea yielded the highest dry grain (7.49 t ha⁻¹), followed by dissolved BC + urea (7.15 t ha⁻¹). In the field, BC + urea dissolved was applied all at once before planting time thus nitrogen was absorbed directly into the biochar pores and slowly released and utilized by plants [27]. The binding nitrogen (NH₄ or NO₃) by biochar physically (stored in the biochar pores) caused nitrogen...
to be more available for plants fitting its needed. Similarly, in terms of dry biomass yield, about 6.3 t ha\(^{-1}\) of biomass weight, the highest compared to other treatments, was produced by BC + urea treatment (figure 3). The addition of biochar to urine can increase the yield of dry shelled corn by 12% compared to the one without biochar. In addition, the function of biochar as an ameliorant can improve soil chemistry so that it better supports plant growth. A mutually beneficial interaction has occurred when biochar is applied together with N fertilizers [28, 29].

**Figure 4.** Maize yields (dry grain and biomass) of maize among treatments in the addition of biochar to Urea and Urine fertilizers at acid upland. Data is shown in) for BC + urea compared to BC + urea dissolved b) for BC + urea compared to BC + urine, c) for BC + urea dissolved compared to BC + urine d) for urea compared to urine, e) for urea compared to BC + urea and f) for BC + urine compared to urine, in addition to statistical differences. Statistically significant differences are at the 0.05 level. Different letters indicate a difference between the treatments BC + urea and BC + urine, BC + urea dissolved and BC + urine, urea and urine, urea and BC + urea, BC + urine and urine (letters a and b).

Figure 4 showed that the difference in the application of urea mixed with biochar (dissolved and not) did not affect the dry maize yield, but it significantly affected the dry biomass yield (figure 4a). Different types of N fertilizer sources (urea and urine), whether mixed with biochar or not, show that urea is more effective than urine as it is shown by the results of pulverized and dry biomass (figures 4b and 4d). Application of BC + urea (dissolved) shown in figure 4c, was able to produce higher dry grain than BC + urine, but not in the dry biomass.

The application of BC + urea (figure 4e) and BC + urine (figure 4f) significantly increased the dry grain of maize by 7.49 t ha\(^{-1}\) and 6.05 t ha\(^{-1}\) respectively compared to the without biochar which is approximately 5.11 t ha\(^{-1}\) (urea) and 4.24 t ha\(^{-1}\) (urine). The effect of the treatments on dry biomass is quite varied. The dry biomass resulting from urea and BC + urea treatments were not significantly different but both treatments provides higher dry biomass than others treatments. The results of this study found that the dry grain of maize was responsive to the addition of biochar in BC + urea (dissolved
or not) and BC + urine. The response of dry biomass is quite varied, but the finding indicated that the addition of urea was more effective than the addition of urine for increasing dry biomass.

4. Conclusions
The addition of 15 t ha⁻¹ biochar to urea and urine resulted the soil chemical properties significantly better than without biochar treatments. Urine as source of N fertilizers could be applied with biochar addition. BC + urea (dissolved) has the highest total N (0.140 %) than other treatments (0.108 to 0.128 %). The highest dry grain was obtained from BC + urea (7.49 t ha⁻¹) and dissolved BC + urea (7.15 t ha⁻¹) compared to other treatments (5.11 to 6.05 t ha⁻¹). Dry grain of maize produced by the application of BC + urine is 12% higher compared to the urine without biochar treatment. BC + urea application, whether dissolved or not, is more effective to be applied in acid upland soil in East Lampung than BC + urine application.

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