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Agronomic Response of Soybeans and Soil Fertility Status under Application of Biocompost and Biochar on Entisols Lombok, Eastern Indonesia

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Abstract: A field experiment was conducted on early dry season of April to July 2014 to evaluate the effect of applying biocompost and biochar on the growth and yield of soybean and soil fertility status. The experiment was set up using a Randomized Block Design. Two factors tested were biocompost and biochar. Biocompost consist of four rates: 0, 5, 10, and 15 ton ha$^{-1}$ and biochar consist of five rates: 0, 10, 20, 30 and 40 ton ha$^{-1}$. The results of the study showed that: plant height only increased significantly at plots treated with biocompost while no significant effect was recorded at all biochar treated plots. Biocompost increased yield of soybean up to 2.25 ton ha$^{-1}$ while biochar at 10 ton ha$^{-1}$ increased the yield reached to 2.09 ton ha$^{-1}$. Combination both of biocompost and biochar improved soybean nodulation by 67.22% resulted in increased of nitrogen uptake by plants. At control, no added organic amendments, the concentration of N in plant tissues was 4.4% which was much lower compared to plots treated with biocompost and biochar. Application of biocompost and biochar improved soil fertility (i.e. organic-C and CEC).

Keywords: agronomic, biocompost, biochar, soybean

I. Introduction

Soybean (Glycine (L.) Merr.) is the second main food crops in Indonesia in which the current demand to this commodity has gradually increased along with increase the national population. Indonesian farmers cultivate soybean mostly under 60% of irrigated land following rice and 40% grown under upland or rainfed cropping system. Soybean production in Indonesia reached about 1,500,000 ton which was lower than national demand which was 2,071,011 ton in 2015.

In Lombok, soybean is also cultivated on the second largest of agricultural area where the land is dominated by sandysoils of Entisols. The soils have generally poor fertility due to low soil organic carbon (SOC), low of nutrients status particularly N, P and K, as well as low of cation exchange capacity (CEC) (Suwardji et al., 2007; Sukartono et al., 2011). The positive effect of applying organic matter (i.e. manure and biocompost) have been shown to improve soil fertility, however, the benefits usually occurs in short period probably one year due to rapid mineralization of organic matter in the tropical environment (Diels et al., 2004).

In response to improve soil fertility status, the application of biocompost as a fresh organic matter and biochar is important to be taken into account. Sudantha (2007) explained that biocompost is fermented compost produced under lignoselulotics microbiawhich has role as pest control and organic decomposer such as saprophite T. harzianum isolate SAPRO-07 and endofit T. koningii isolat ENDO-02. Sudantha (2009) reported that the use of biokompost (fermented compost from saprofit T. harzianum isolate of SAPRO-07 and endofit T. koningii isolate of ENDO-02) could improve crops tolerance to drought and withstand to patogen and improve soybean yield. As a fresh organic matter, biocompost in soil undergo mineralization easily for releasing nutrients and also releasing CO2 to atmosphere. Therefore, mixing biocompost and biocharas may have good effect for sustaining soil organic carbon.

Biochar is a rich carbon materials produced from heating of organic biomass without or limited oxygen. Biochar as a soil organic ammendments has been confirmed to improved soil fertility of sandy loam soils in the semi-arid tropical of northern Lombok, Indonesia(Sukartono, 2011). Application biochar in particular acid soils also improved soil fertility status such as soil pH, CEC and soil organic-C (Lehmann, et al., 2003), as well as biological changes in soils (Rondon et al., 2007). Improvements in plant growth and yield following biochar applicationalso has been reported for some legume crops such as common beans (Phasealus vulgaris L) Rondon et al., 2007), soybean (Glicine max (L.) Merr. (Tagoe et al., 2007). However, application of mixing biocompost and biochar under soybean cropping system on light textured soils in the semi-arid tropical region has been very limited.

Therefore, this paper addresses confirmation on effect of applying biocompost and biochar on growth and yield of soybean on Entisols Lombok, Indonesia.

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II. Materials and Methods

2.1. Location

A field trial was conducted in the early dry season (April to July 2014) on upland agricultural area in Montong Village, Kediri Sub-district, Lombok, eastern Indonesia (08°38’10.71” S, 116°10’13.31” E; altitude 30.50 m above sea level). Annual rainfall of site in 2014 was 2099 mm, distributed between November/December to April/May, mean air temperature was 30°C and atmospheric humidity about 89%. Soil type of the experimental sites was Ustipsamment (Soil Survey Staff, 1998) derived from volcanic materials. The top soil has asandy loam texture (45% sand and 15% clay) with pH of 6.10 and soil organic carbon (1.40%), 0.15% N and cation exchange capacity, CEC 18.90 cmol kg⁻¹.

2.2. Biocompost and biochar preparation

Composted materials used in the experiments were derived from rice straw and leaf litter. Those materials were chopped using chopping machine and subsequently air dried. Those organic materials were thoroughly mixed with cattle dung and powder rice husk and sprayed with endophit T. polysporum (isolate ENDO-04) and T. harzianum isolate (isolate SAPRO-07) contained solution. Then, the water content of those mixed materials was made to reach ranges of 30 to 40 (% w/w) (Fig 1) and after that it was wrapped for three weeks incubation to allow complete fermentation.

Fig. 1. Biocomposting process of organic materials (rice straw, leaf litter and cattle dung).

Biochars used in the study was produced from coconut shell and prepared through the auto thermal combusting in pits (1.0 m deep, 1.0 m wide, and 1.5 m long) for 10 hours until the whole feedstock changed to black coloured chars which introduced as Sukartono et al (2011). The production of the biochars was completely conducted under home industry in Lembah Village, Sub-district of Gunung Sari, Western Lombok. The biochars were crushed and sieved in laboratory to reach 1.0 mm particle size which characteristics as shown in Sukartono, et al (2011).

2.3. Experimental design and plots constructions

A field factorial trial was set up using a Randomized Block Design (RBD) in which treatments of biocompost and biochar were applied with four replications in plots of size 4 m x 4 m. Biocompost consisted of four rates: 0; 5; 10 and 15 ton ha⁻¹ and biochar tested were 0; 10; 20; 30 and 40 ton ha⁻¹. Each combination treatment had four replications in which soybean cropping system had been grown.

Plots were established after rice harvested by removing standing rice straw and ploughing the soil to 20 cm depth using a hand tractor. Plots were constructed with size of 4 m x 4 m. Each plot was separated by furrow (30 cm wide and 30 cm depth) for external drainage. Distance between block was 0.75 m.

Three seeds were sown per hole at every single plot with row spacing of 20 cm x 25 cm. One week after sowing, two plants were allowed for growing season. Fertilizers containing N, P and K (Phonska 16-16-16) was applied at 14 days after sowing (14 DAS) with rates of 200 kg ha⁻¹. Fertilizers were banded 5 cm depth in between rows of crops. Soil moisture of was controlled through watering plots on the basis of soil water content at field capacity. This was measured using tensiometer.

2.4. Measurements

Measurements were carried out for agronomics and soil parameters. Agronomic parameters measured during experiment were plant height, yields on the basis of dry seeds, number of nodules, and nitrogen uptake. Plant height was measured at 8 weeks (56 DAS). Soil variables involved pH, organic-C, CEC, N, P, and K. Soil pH was determined in 1:2.5 ratio of soil: water, organic carbon by Walkley and Black method, and total N by Kjeldhal method; available P was extracted by Bray-1 method; CEC and exchangeable K using ammonium acetate at pH 7.0. The data were analyzed using ANOVA and the significance was tested by HSD test (p=0.05) with MINITAB Version 13.
III. Results and Discussion

3.1. Plant height

There was no interaction between biocompost and biochar observed in plant height. Biocompost, fermented compost generated from endofungi and saprophyte of *Trichoderma* spp had only a significant effect on plant height as sown in Fig 2. The highest plant height (57 cm) was performed by crops grown on plots treated with 15 ton ha\(^{-1}\) of biocompost and the lowest was recorded at crops received 5 ton ha\(^{-1}\) (52 cm). This data confirmed positive contribution of biocompost in improving early growth of soybean. Biocompost mostly soluble nutrients which are readily available for crops. Herlina and Dewi (2011) reported that the application of biocompost could produce healthy crops and improve crops flowering and growth. Sudantha (2008) also explained that compost generated from fermented of *Trichoderma* spp improve crops growth as a result of better microbica activities and control external soil pathogen.

![Fig 2. Mean of plant height at 8 weeks (56 days after sowing)](image)

3.2. Yields.

Biocompost and biochar has a single effect on dry weight of seeds (Table 2). Table 2 show that yield of soybean increased by 25 % up to 30% at plots treated with biocompost and 10 % up to 16 at biochar treated plots. The highest yield of soybean reached 2.36 ton ha\(^{-1}\) was found at plots applied by 15 ton ha\(^{-1}\) of biocompost. The increased yield as reported here is associated with better growth as a result of improvement of soil nutrients availability (data shown in Table 3). This results was in accordance with Sudantha(2008) reported that fermented biocompost derived from endophyte of *T. polysporum*, and saprophyte of *T. harzianum* improved significantly of vegetative growth as well as yields. Crops treated by fermented biocompost tend to have better growth performance compared to control. The endophyte fungy (*T. Polysporum*) and saprophyte of *Trichoderma* spp. hosted in biocompost produced special hormone which promote growth of the crops (Sudantha, 2010).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yields (g plot(^{-1}))</th>
<th>Yields (ton ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biocompost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 ton ha(^{-1})</td>
<td>449.38 ± 0.00</td>
<td>1.8</td>
</tr>
<tr>
<td>5 ton ha(^{-1})</td>
<td>496.29 ± 0.00</td>
<td>1.99</td>
</tr>
<tr>
<td>10 ton ha(^{-1})</td>
<td>563.24 ± 0.00</td>
<td>2.25</td>
</tr>
<tr>
<td>15 ton ha(^{-1})</td>
<td>588.65 ± 0.00</td>
<td>2.36</td>
</tr>
<tr>
<td>HSD 5 %</td>
<td>31.34</td>
<td></td>
</tr>
<tr>
<td><strong>Biochar</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 ton ha(^{-1})</td>
<td>478.37 ± 0.00</td>
<td>1.91</td>
</tr>
<tr>
<td>10 ton ha(^{-1})</td>
<td>521.84 ± 0.00</td>
<td>2.09</td>
</tr>
<tr>
<td>20 ton ha(^{-1})</td>
<td>528.58 ± 0.00</td>
<td>2.11</td>
</tr>
<tr>
<td>30 ton ha(^{-1})</td>
<td>538.91 ± 0.00</td>
<td>2.16</td>
</tr>
<tr>
<td>40 ton ha(^{-1})</td>
<td>554.25 ± 0.00</td>
<td>2.22</td>
</tr>
<tr>
<td>HSD 5 %</td>
<td>37.41</td>
<td></td>
</tr>
</tbody>
</table>

*) Mean with the same superscript letters do not differ significantly at 5%.

In respect to biochar, the yields of soybean also increased by 14% to control. However, there was no significant differences of yields between rates. This suggest that application of 10 up to 40 ton ha\(^{-1}\) of biochars is likely rates for improving soil quality of Entisols. Growth performance of crops was much better under biochars and biocompost treatments compared to no added organic amendments. This result was associated
with of soil quality improvement as presented in Table 3. Previous study by Sukartono et al (2011) reported that biochar had positive contribution in improving soil properties and yields of maize.

3.3. Number of root nodules

The analysis variances show that there was a significant interaction between biocompost and biochar observed at number of root nodules. The positive interaction pattern was depicted in Fig. 3. Overall, Fig.3 shows that total number of root nodules increased along with increased amount organic amendments being added to soils. The highest number of root nodules was 119 at plots treated with 10 ton ha⁻¹ of biocompost plus 20 ton ha⁻¹ biochar (B2C2).

![Fig. 3. Number of root nodules of soybean at several combinations of biocompost and biochar](image)

The greatest number of root nodules suggest better root proliferation resulted in favorable rhizosphere environment for *Rhizobium sp.* as the bioactivator in promoting nodulation. Suharjo (2001) stated that environmental factors controlling the activities of bioactivators such as *Rhizobium* bacteria are soil pH, soil organic carbon as well as soil nutrients availability. Thus from soil fertility perspective, combination application of biocompost as fresh organic matter and biochar would likely perform suitable organic amendments to improve soil fertility of light textured soils and eventually promoting *Rhizobium* sp. activity. Tate (1995) reported that water stress under dry condition, the roots nodulation of legume crops was mostly suppressed due to very low population of *Rhizobium* bateria.

Root nodules is firstly formed through a secretion process of metabolic product into the root zone in which it stimulate the growth of bacteria. Then, bacteria performed colonization within rhizosfer of legume crops. Collino *et al.* (2000) showed that colonisation of *B. japonicum* occurred after 5 days of inoculation of bacteria through soybean roots. In white clover, however, Collino *et al.* (2000) showed that coinoculation of *A. lipoferum* T1371 and *R. leguminosarum* resulted in colonisation at secondary hair roots. Formation of root nodules of soybean is affected by essential soil nutrients (i.e. P, K, Ca, S and Mo), soil moisture and temperature. Optimum soil moisture for bacteroid formation is soil water status at a field capacity and soil temperature ranges from 20ºC to 30ºC. The effectiveness of noodle formation is mostly indicated by size of nodules formed at primary roots of soybean observed at around 42 days after sowing (Suharjo, 2001).

3.4. Concentration of N in plant

Plants analysis for nitrogen content was conducted for assessing nitrogen uptake by plant during growth period. The nitrogen uptake for this experiment was measured for only treatments of B0C0, B2C2 and B3C4, in order to simplify differentiate between nutrient uptake of soybean at plots control and added-organic amendment plots (Fig.4).
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**Fig 4.** Concentration of N in plant under application of organic amendments. It is clearly shown in Fig 4 that N content in plant tissue increased as a result of addition of organic amendments (biocompost and biochar). Nitrogen concentration in plant was 4.4%, 4.45% and 4.65% at control, B0C0, B2C2 and B3C4 respectively. This suggests that application of organic amendments under those combination could provide better soil nitrogen availability. Biocompost improved natural soil biodiversity and nutrient cycling which resulted in increasing soil productivity and crops performance. A biocompost fermented from *Trichoderma* spp. has several advantages as nutrients and energy sources for soil microbia, promote soil aggregation, increase soil-water holding capacity, allow favourable soil aeration as well as provide better root proliferation for crops (Sudantha, 2010).

**3.5. Soil properties**

The application of a fermented *Trichoderma* - biocompost and biochar under soybean cropping system improved soil properties. This was indicated by soil chemical measurements (Table 3) after the end of cropping system.

**Table 3.** Soil chemical properties following biocompost and biochar application on soybean cropping system.

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Before experiment</th>
<th>Treatments</th>
<th>HSD 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B0C0</td>
<td>B2C2</td>
<td>B3C4</td>
</tr>
<tr>
<td>pH</td>
<td>6.2</td>
<td>6.1a</td>
<td>6.3a*</td>
</tr>
<tr>
<td>Organic-C</td>
<td>1.48</td>
<td>1.40</td>
<td>1.73a</td>
</tr>
<tr>
<td>Total-N</td>
<td>0.14</td>
<td>0.15a</td>
<td>0.17</td>
</tr>
<tr>
<td>CEC</td>
<td>18.89</td>
<td>18.91*</td>
<td>22.39</td>
</tr>
</tbody>
</table>

*B0C0 = no added biocompost and biochar, B2C2 = biocompost 10 ton ha⁻¹ and biochar 20 ton ha⁻¹; B3C4 = biocompost of 15 ton ha⁻¹ and biochar of 40 ton ha⁻¹. *Mean with the same superscript letters within rows do not differ significantly at 5%.

Data presented in Table 3 show that the application of biocompost and biochar had significant effect on changing soil properties including soil pH, organic-C, total-N and CEC. In respect to improve soil fertility status, the total soil organic-C(SOC) increased significantly after application of organic amendments. SOC was actually 1.40% at control and it reached to 1.73 and 2.26% at B2C2 and B3C4 respectively. In addition, other than SOC as key soil variables, the CEC also increased significantly higher (22.39 me% and 22.67me%) at organic amendments treated soils compared to control. This suggests that under short cropping system periods, those organic amendments could improve soil fertility status. As soil have high value of soil organic-C (SOC) and CEC means that the soil would provide better condition for water and soil nutrient availability to crop production. Similar results have been reported by Sukartono *et al.* (2011) that application of biochar and cattle manure on sandy loam soils under maize cropping system increased soil organic-S (SOC) and soil-water holding capacity.

**IV. Conclusion**

Application of organic amendments (biocompost and biochar) improved growth and yield of soybean. Both biocompost and biochar at rates of 10 ton ha⁻¹ contributed 25 and 10% respectively increased of soybean yield compared to control. The yields were reached to 2.25ton ha⁻¹ and 2.09 ton ha⁻¹. Combination of biocompost and biochar improved nodulation and nitrogen uptake by plants. The highest content of N in plant tissue was 4.65% at combination treatment of 15 ton ha⁻¹ biocompost and 40 ton ha⁻¹ biochar. So, this study was likely confirms that both biocompost and biochar are valuable amendments for improving soil fertility of sandy loam soils and soybean crop production. Although applying biocompost produced relatively higher yields, in term of

DOI: 10.9790/2402-1011040611 www.iosrjournals.org 10 | Page
maintaining stability of soil organic-C for long term basis, the application biochar mixed with biocompost would be more promising.

Acknowledgements

The research was partly funded by the University of Mataram under The University Grant of 2014. Therefore, thanks to the Rector and Head of Research Board of The University of Mataram for providing funding for the research.

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Journal Papers


