Effectiveness of Biopelet Combination of Biochar, Chicken Manure and Fish Waste To Improvement of Chemical Properties of Sandy Soil and Soybean Plant Growth

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Abstract. Most of the activities of the use of organic fertilizers and natural additions of organic matter in agricultural intensification fields in Indonesia have not been able to compensate for the rate of decline in soil organic matter by the decomposition process. Biochar has high C levels and has the mean residence time (MRT) in long period in the soils. It was proven that biochar application may increase soil Carbon but has not been able to increase the production of plant. Therefore the use of biochar combined with organic waste rich in nutrients is important to be developed. The purpose of this study was to determine the effectiveness of some biochar compositions with sugar cane, chicken manure, fish waste in the form of biopelet fertilizer on improving the chemical properties of sandy soils and the vegetative growth of soybean plants. This study used a Randomized Completely Block Design (RCBD) with 2 factors, namely: the first factor (B): the composition of Biochar consisted of 3 levels, namely: 1) 70% biochar, 15% chicken manure, 15% fish waste (B1), 2) 50% biochar, 25% chicken manure, 25% fish waste (B2), 3) 20% biochar, 40% chicken manure, 40% fish waste and the second factor were (D): The dose of biopelet fertilizers, consists of 4 levels, namely: 1) Control (D0), 2) 2.5 tons.ha-1 (D1), 3) 5 tons.ha-1 (D2), 4) 10 tons.ha-1 (D3). The results showed that the addition of biopelet fertilizer can effectively improve soil chemical properties (pH, C-organic, and CEC) and the availability of NPK of the sandy soil. The effectiveness of increasing the N-total of soil varies by an average of 32.42 to 75.79%; followed by available P varies between 17.46 to 40.69%, and Kexch between 8.7 to 25.67%. Improvement of soil chemical properties and the availability of NPK by biopelet fertilizer applications could increase plant growth, but reduce the weight of root nodules.

1. Introduction
Many research results showed that in the wet tropics including Indonesia, agricultural lands have experienced a continuous decline in the level of organic matter [1, 2]. Whereas organic matter is one of the keys that controls the ideal physical, chemical, and biological properties, in accordance with plant growth and sustainability. Most of the activities of using organic fertilizers and natural additions in agricultural intensification fields in Indonesia have not been able to compensate for the rate of decline in organic matter by the decomposition process. Factors that influence the speed of decomposition of soil organic matter were mainly temperature [3], microorganisms [4], changes in land management [5], composition of organic matter [1] and others.
The use of biochar which has high C levels and Mean Residence Time (MRT) in long time had been shown to increase long-term C [6, 7], but were poor in nutrients [8] so as not to be able to increase crop production. Biochar enriched with NPK nutrients could improve the properties of acid soils and the availability of these nutrients [9].

Organic fertilizer is believed to be urgently needed at this time and for the foreseeable future in agricultural inputs, because it is one of the effective alternatives to reduce the role of chemical or synthetic fertilizers in agricultural activities. The use of organic fertilizer in the form of pellets had the ability to release nutrients slowly and continuously to support the uptake of wheat plants at different growth stages. Organic fertilizer in the form of pellets had several advantages over ordinary organic fertilizers, in addition to slow release of nutrients, it also had a high percentage of durability (91.73%) or low damage (8.27%) when processed through a compress pellet machine [10].

Therefore the use of biochar combined with organic waste rich in nutrients and packaged in pellets was important to be developed as a source of organic fertilizer. The purpose of this study was to determine the effectiveness of some biochar compositions of sugar cane, chicken manure, fish waste in the form of organic biopelet fertilizers on improving the chemical properties of sandy soils and the vegetative growth of soybean plants.

2. Research Method

2.1. Production of Biopelet Fertilizers and Soil Sampling

Biochar was made using the Kon Tiki method and raw materials derived from corn waste in the form of corncobs. Fish waste and chicken manure used for nutrient enrichment were dried and mashed, which were then mixed with biochar to become a homogeneous mixture. The percentage of each ingredient was adjusted according to treatments. The making of biopelet fertilizer was done by means of a mixture of these materials formed pellets using a concentration of 4% molasses adhesive. The process of molding into biopelet fertilizer using a meat grinder with a diameter of 5 mm. Biopelet fertilizers that had been printed completely were then dried in the oven for 4 hours at a temperature of 60-70°C [11]. The chemical properties of each biopelet fertilizer based on different biochar levels were presented in Table 1. Based on the results of the test, all biopelet fertilizers met the technical requirements of organic fertilizer (Decree of the Minister of Agriculture of the Republic of Indonesia No. 261/KPTS/SR.310/M/4/2019 concerning Minimum Technical Requirements of Fertilizers Organic, Biofertilizers, and Soil Enhancers, Minister of Agriculture of the Republic of Indonesia).

| Chemical Properties | Unit | Biochar Concentration (%) | Explanation (*) |
|---------------------|------|----------------------------|-----------------|
| pH                  |      | 7.22 | 7.41 | 7.12 | Fulfill |
| N-total             | %    | 1.65 | 3.08 | 3.85 | Fulfill |
| P-Available         | ppm  | 0.5  | 1.24 | 1.51 | Fulfill |
| Kexch               | %    | 0.75 | 0.9  | 0.83 | Fulfill |
| CEC                 | Cmol/kg | 33.2 | 30.8 | 19.6 | Fulfill |
| C-Organic           | %    | 20.8 | 24.57 | 29.4 | Fulfill |

* Based on Technical Requirements of Organic Fertilizers (2009)

The soil used as planting media and biopelet fertilizer test was sandy soils (Regosol) which had low chemical characteristics as presented in Table 2. Based on 5 variables of chemical properties namely pH H2O, Cation Exchange Capacity (CEC), N-total, and organic-C, it were showed mostly low, except Kexch (available) which was very high. Data from the initial analysis of soil chemical properties were presented in Table 2.
Table 2. Soil Chemical Properties Used as Planting Media and Biopelet Fertilizer Test

| Variable Soil Chemical Properties | Unit | Value | Status (*) |
|----------------------------------|------|-------|------------|
| pH                              | -    | 7.63  | Somewhat Alkaline |
| N-total (Kjeldahl)              | %    | 0.13  | Low        |
| P-Available (Olsen)             | ppm  | 0.19  | Very Low   |
| K-exch (NH4-As, pH 7, AAS)      | %    | 1.01  | Very High  |
| CEC (NH4-As, pH 7)              | Cmol/kg | 9.6  | Low        |
| C-Organic (Kurmis)             | %    | 1.17  | Low        |

* Based on Soil Analysis Results Assessment Criteria, Soil Research Institute (1998)

2.2. Implementation of the Experiment
This study used a randomized completely block design (RCBD) with 2 factors. The first factor (B): The composition of biopelet materials consisting of 3 levels, namely: 1) 70% biochar, 15% chicken manure, 15% fish waste (B1), 2) 50% biochar, 25% chicken manure, 25% fish waste (B2), and 3) 20% biochar, 40% chicken manure, 40% fish waste. The second factor was the dose of biopelet fertilizers (D) consisting of 4 levels, namely: 1) Control or without addition (D0), 2) 2.5 tons.ha⁻¹ (D1), 3) 5 tons.ha⁻¹ (D2), and 4) 10 tons.ha⁻¹ (D3). Plant media, sandy soil escaped 2 mm sieve as much as 8 kg in a polybag were treated by biopelet fertilizer as much as above treatments. Furthermore, the planting media were irrigated to the field capacity and incubated for 4 weeks.

Observations were made when the plant entered the final vegetative phase on the 40th day. Observations were carried out by carefully removing the plants and their roots from the polybag so that the roots and their nodules were not damaged.

Observation variables for testing the effectiveness of biopelet fertilizers on improving soil chemical properties and soybean plant growth were C-organic, N-total, P-available, K-available, Cation Exchange Capacity (CEC), plant height, number of leaves, root length, wet weight and dry weight of plants, number and weight of nodules. Effectiveness was measured based on the difference in changes in the value of the variables treated to control divided by the values of the variables treated.

3. Result and Discussion

3.1. Effectiveness of Regosol Soil Improvement and NPK Nutrient Availability
The treatment of biopelet fertilizers (a combination of biochar, fish waste, and chicken manure) in sandy soil significantly increases soil C-organic content. In general the increase was in accordance with the dose of biopelet fertilizer, except for the application of 10 tons.ha⁻¹ which seems to be decreasing (Figure 1). Differences in composition or percentage of biochar, fish waste, and chicken manure do not make a significantly difference. Based on these data, it was known that the effectiveness of increasing soil C-organic was very high, namely the addition of 2.5 tons.ha⁻¹ by an average of 33.4%; increased to 41.1% if the addition was increased to 5 tons.ha⁻¹. On the contrary, the increase in dose to 10 tons.ha⁻¹ did not increase beyond the addition of 5 tons.ha⁻¹, only slightly above the addition of a dose of 2.5 tons.ha⁻¹ which was 35.9%.
Fig 1. Average increase in soil C-organic content by the treatment of biopelet fertilizers with some biochar levels

Addition of up to 10 tons.ha⁻¹ was thought to be greater in decomposition so that more C was lost from the soil through CO2 emissions. In addition, the combination of the three ingredients in an amount of 10 tons.ha⁻¹ indicates a more ideal combination for decomposition. This was as said by Ref.[12] that there was a close relationship between soil nutrients, the quality of organic matter media, and decomposition. The supply of nutrients from the soil or mix of organic matter was an important factor controlling the rate of decomposition, because important nutrients in the soil or litter affect the community and decomposer activities (soil organisms).

This also corresponds to an important variable in the decomposition of organic matter, namely the C/N ratio. Based on the calculation of the C/N ratio of biopelet fertilizer with biochar 70% was 12.61 (ideal according to the soil, so there was no concern about the impact of the immobilization process); while 50% and 20% have lower C/N, namely 7.98 and 7.64, respectively. Based on many research results showed that the lower the C/N ratio of organic matter (organic fertilizer) the higher or faster the decomposition processes. This decomposition of biopelet fertilizer will further affected the decrease in pH because it releases organic acids [2] and will open new sorption sites thereby increasing soil CEC. Based on the data from this research the soil C-organic content had a very significant correlation with soil pH that is -0.65**, which was negative i.e. the higher the level of soil C-organic will be followed by a decrease in soil pH value.

Regarding biochar decomposition, the results of the study by Ref. [13] showed that the biochar decomposition stage begins with increasing logarithmically and decreasing with time. In Addition that the mean residence time of C biochar based on unstable and recalcitrant pools was estimated to be around 108 days and 556 years with pool sizes of 3% and 97%, respectively.

3.2. Soil acidity or pH

The treatment of biopelet fertilizer containing biochar, shrimp waste, and chicken manure in sandy soils with an initial pH of 7.63 (slightly alkaline) could reduce it to near ideal values for most plant growth (pH slightly below 7). The magnitude of decrease in pH of treated soil (a combination of biochar, shrimp waste and chicken manure) varies between 1.99 to 3.43% and the greatest decrease or could be said to be the most effective in lowering the pH which was close to ideal was a combination of 70 % biochar + 15% chicken manure + 15% fish waste with a total dose of 10 tons.ha⁻¹.
The treatment of biopelet fertilizer had not achieved the ideal soil pH which was around 6-7 so that the treatment of this material needs to be continued in the next planting season. The period and duration of application were important to know so that they could maintain their ideal conditions. The ideal soil acidity would affect the availability of nutrients needed by plants, especially the nutrients P and B, whose solubility were directly controlled by soil pH.

![Fig 2. Average decrease in soil pH by the treatment of biopelet fertilizers with some biochar levels](image)

The decrease in soil pH based on increasing the dose was quadratic with a very high R² that varied from 0.89 to 0.99; which was more fully presented in Figure 2. These decreases in pH indicated the decomposition process of the added material (especially from fish waste and chicken manure) into compounds as organic acids so as to increase the amount of H⁺ ions which could reduce soil pH [2, 14, 15].

If the average effectiveness of reducing soil pH by treatment based on biochar concentrations was greatest at 3.43% in the application of 10 tons.ha⁻¹ with a concentration of 70%. Reducing the dose of application up to 2.5 tons.ha⁻¹ would reduce the effectiveness up to 3.09%; likewise a decrease in concentration of up to 20% biochar would reduce the effectiveness of reducing soil pH by only 2.48%. This proved that the decrease in soil pH by the treatment of biopelet fertilizers containing biochar, shrimp waste, and chicken manure could reduce high soil pH in accordance with the dosage or concentration of biochar.

### 3.3. Soil Cation Exchange Capacity (CEC)

The combination or interaction of the composition and dosage of biopelet fertilizer on the ability of the soil to exchange cations in the soil was not statistically significant, but the single factor of biopelet fertilizer dosage was significantly increasing the value of soil CEC. A statistical test on a single treatment factor, namely the dose of biopelet fertilizer, could significantly increase the CEC of sandy soils which was originally low in status, which was 9.6 Cmol.kg⁻¹, which could increase to 18.27 Cmol.kg⁻¹ (application of biopelet fertilizer 5 tons.ha⁻¹) (Figure 3). The figure also showed that lower doses of biopelet fertilizer (2.5 ton.ha⁻¹) and higher biochar concentrations (70%) further increased the value of sandy soil CEC compared to lower biochar concentrations of 50 and 20%. The effectiveness of increasing sandy soil CEC was highest in combination treatment with 10 ton.ha⁻¹ dosage and 50% biochar concentration, which was effectively an increase of 37.44%.
Fig 3. Average increase in soil cation exchange capacity (CEC) by the treatment of biopelet fertilizers with some biochar levels

Similar to soil pH variables, reducing the dose of biopelet fertilizer given and / or lowering biochar levels would reduce the effectiveness of increasing soil CEC values. Decreased effectiveness by decreasing the dose of biopelet fertilizer up to 2.5 tons.ha$^{-1}$ (biochar concentration, 50%) reached up to 18.86% while decreasing by biochar concentration to 20% (biochar dose, 10 tons.ha$^{-1}$) reached up to 28.35%.

Based on a lot of literature could be explained that the CEC value of soil is influenced by the texture and content of C-organic soil. The dominant soil particle size that influences the value of CEC is clay, followed by dust and very little contribution is sand. The soil used in this study was sandy soil so that the soil texture did not contribute significantly to the value of the CEC. The CEC value of this soil is greatly influenced by organic matter [16] and its value can vary depending on pH or is said to be a variable charge. The relationships between CEC with soil pH and C-organic were categorized tight, which were represented by the equation $y = 6.87x + 6.5$ (right for CEC vs C-org) and $y = 18.24x + 145.71$ (left for CEC vs pH) or have a relationship, $r = -0.72\,*\,(n = 36)$ and $0.69\,**\,(n = 36)$, respectively; the complete one was presented in Figure 4.

Fig 4. Relationships between CEC with pH and C-organic of sandy soil treated with biopelet fertilizer with some biochar levels
Decomposition will increase the charge (carboxylate, phenolics, etc.) which are generally variable depending on pH. In conditions of relatively high pH the charge will be more negative so that it will create new sorption sites or increase the value of the soil CEC.

From the picture a very close relationship between pH and CEC was found, namely $r = -0.72**$. When soil with the sandy soil conditions, most CECs are determined by organic matter content, i.e. the higher the organic material the higher the CEC contribution. The contribution of CEC from organic matter is variable, depending on the pH. In a low pH the soil content will be positive thereby reducing CEC. Conversely, the high pH of soil, the charge will be negative or CEC will be increased. The relationship between pH and CEC of this soil was also shown in Figure that was in accordance with the equation $y = -18.24x + 145.71$.

3.4. Availability of NPK Nutrients of Soil

The combination of biochar, shrimp waste, and chicken manure was primarily intended to increase the availability of low to very low N and P nutrients in sandy soils (Table 2). The application of biopelet fertilizers from various compositions and dose as described in the methodology section had been proven to increase the availability of both N and P and even K, even though the initial status of K was very high. The effectiveness of increasing nutrient availability in the soil was highest in the N available (represented by N-Total of soil), which on average varied between 32.42 to 75.79%; followed by P-available which varied between 17.46 to 40.69%, and K-exch between 8.7 to 25.67%. This value is also often said to be the efficiency of fertilization and this efficiency was high. The high value of the effectiveness or efficiency of fertilization was caused by creation the combination materials into biopelet, which was included also as organic fertilizer. It also proved that biochar could increase the effectiveness of fertilization in the soil, especially in sandy soil which generally has very low fertilization efficiency.

Table 3. Percentage increase in the availability of NPK in the soil or its effectiveness by a combination treatment of biochar levels and biopelet fertilizer doses

| (%) | 2.5 | 5 | 10 |
|-----|-----|---|----|
|     | N   | P | K  | N  | P | K  | N  | P | K  |
| 70  | 52.73 | 24.91 | 13.19 | 48.00 | 17.46 | 12.22 | 50.94 | 21.80 | 14.59 |
| 50  | 58.18 | 22.12 | 13.02 | 75.79 | 23.58 | 8.70 | 69.74 | 40.69 | 14.53 |
| 20  | 32.43 | 20.49 | 25.67 | 54.55 | 23.15 | 20.57 | 65.69 | 19.63 | 14.72 |
| 70  | 52.73 | 24.91 | 13.19 | 48.00 | 17.46 | 12.22 | 50.94 | 21.80 | 14.59 |

Based on the average value in general, it showed that the higher the dose of biopelet fertilizer up to 10 tons.ha-1 continued to increase its effectiveness, but the increase in effectiveness was highest at the addition of 2.5 tons.ha-1, be followed by 5 tons.ha-1. It also showed that the addition of up to 10 tons.ha-1 began to have symptoms sloping. This phenomenon might be in accordance with the law of diminishing return fertilization.

Low dose (2.5 ton.ha-1) and 50% biochar concentration appeared to have the highest increase in effectiveness compared to the others; if the dose increased to 5 tons.ha-1, the increase in effectiveness raised even smaller to 10 tons.ha-1 which tended to be relatively the same as 5 tons.ha-1.

3.5. Effectiveness of Increasing Soybean Plant Growth

3.5.1 Wet and Dry Weight of Plants

Previously it had been explained that in general the application of biopelet fertilizer containing biochar, shrimp waste, and chicken manure with various compositions could effectively improve the chemical properties of sandy soil. Improvement of soil properties could also increase the effectiveness of soybean growth as presented in Figure 5. Based on this figure it was shown that the addition of biopelet fertilizer...
up to 10 tons.ha-1 could increase wet weight and dry weight of soybean plants, especially for the composition of 50% biochar, 25% shrimp waste, and 25% chicken manure. It concluded that the composition was the most effective treatment in improving the chemical properties of sandy soil and soybean plant growth when compared to other compositions.

![Graph showing increase in wet and dry weight of soybean plants]  

**Fig 5.** Average increase in wet weight (left) and dry weight (right) soybean plants (5 weeks after planting) by the treatment of biopelet fertilizer with some biochar levels

### 3.5.2 Number and Wet Weight of Root Nodules

The increase in plant growth shown by both wet and dry weight was apparently not followed by growth of plant root nodules. Figure 6 showed that the treatment of adding biopelet fertilizer to sandy soil as a growth medium for soybean plants up to 10 tons.ha-1 actually reduced the wet weight of root nodules. The sharpest reduction occurred in the combination of 20% biochar and fish waste and chicken manure 40% each. This combination was the richest biopelet fertilizer, which was the highest levels of N and P, innate from fish waste and chicken manure (Table 1).

![Graph showing average reduction in number of root nodules]  

**Fig 6.** Average reduction in the number of soybean root nodules by biopelet fertilizer treatment with some biochar levels
Based on the statistically analysis, the relationship between wet weight of root nodules and plant growth was very small or low, but high to very high when associated with soil chemical properties (pH, $r = 0.5$ and C-organic, $r = -0.62^{**}$) and nutrient availability especially N and P ($-0.76^{**}$ and $-0.56^*$, respectively). The relationship of wet weight of root nodules with the availability of nutrients had negative correlation, namely the higher availability of nutrients actually reduced the wet weight of root nodules. Conversely the relationship of soil pH by the addition of biopelet fertilizer, was proportional or had positive correlation to the wet weight of root nodules.

4. Conclusion
Based on the results and discussion above, it could be concluded as follows:
1. Biopelet fertilizer with several biochar compositions, fish waste, and chicken manure had been proven to be effective in improving soil chemical properties (pH, C-organic, and CEC) and the availability of NPK of sandy soil.
2. The effectiveness of increasing the availability of nutrients in the soil was highest in the N available (N-total soil), which on average varied between 32.42 to 75.79%; followed by P-available which varied between 17.46 to 40.69%, and K-exch between 8.7 to 25.67%.
3. Improvement of soil chemical properties and the availability of NPK by biopelet fertilizer applications could increase plant growth. The response of soybean growth to low doses of biopelet fertilizer (2.5 tons.ha$^{-1}$) would increase wet weight of plant. This pattern occurred if the dose was increased by the addition to 5 tons.ha$^{-1}$ which showed a tendency to decline the increase in wet weight if the percentage of biochar increased, even there would be a sharp decrease in the dose of 10 tons.ha$^{-1}$.
4. The relationship between root nodules wet weight and plant growth was very small or low, while the relationship with the chemical properties of the soil was high and very high (pH, $r = 0.5$ and C-organic, $r = -0.62^{**}$) and the availability of nutrients especially N and P ($-0.76^{**}$ and $-0.56^*$, respectively).

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