The priming effect in compost amelioration of tropical peat soil

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Abstract. Utilization of peat land for agriculture in Indonesia is increasing and some efforts in improving the peat soil fertility is being highly concerned. In addition to fertilizers, farmers add some fresher organic matter as the ameliorants, such as compost to support better microbial growth in the soil for increasing the decomposition process. Theoretically the addition of compost onto peat soil would lead to priming effect, hence it would accelerate the decomposition of peat organic matter. This study was to observe the impact of decomposition process due to adding compost to respiratory CO₂ of peat soil. Peat soil from Central Kalimantan was used for experiment, incubated with KOH and then the respiratory CO₂ was measured with titration method. Two different sizes of peat soil materials obtained from sieving peat soils, i.e. 5 mm and > the 5 mm. Each peat soil materials were mixed with 10%, 25%, and 50% compost to the total 100 grams. Post the compost addition, the samples were incubated for 20 days, and the respiratory CO₂ was gauged for 4 times at 5 days interval during the incubation. It was showed that the more compost mixed to the peat soil materials, the more CO₂ produced. The highest CO₂ was 912.00 mg/g/day from compost incubation and a mixture of 50 gram of compost and coarse peat soil material produced 460.8 mg/g/day.

1. Introduction

Besides containing high organic matter, peat soil is poor in nutrients so that amelioration is needed. Amelioration on peat soil are applied by adding nutrients in form of fertilizer or compost for increasing soil fertility. Increasing peat soil fertility can cause Priming Effect (PE) which theoretically, is positive for the decomposition of soil organic matter. It was indicated that the utilization of peatland for agriculture promotes the decomposition of peat soil organic matter [1]. A research by Ye et al. [2] showed that the addition of rice straw to the soil resulted in a slightly positive PE. The addition of organic matter ignites root exudates lead to positive PE in peat soil, although the effect is negligible [3]. Positive PE in peat soils may reduce peat soil through the decomposition of organic matter by microbes. In addition, positive PE can change the potential of C reserves and the release of CO₂ from respiration of microbial decomposition into the air.

Soil microorganisms are responsible for most of the PE [4]. Positive PE occurred if microbial activity increases due to the addition of materials which support the activity in the soil. Soil microbial activity can be observed from the respiration of soil microbes. Measurement of soil respiration shows increasing CO₂ produced from reactions or activities in the soil, thus increasing soil respiration
indicates an increase in soil microbial activity. The activity of soil microbes of a nutrient-poor environment differs from microbial activity in nutrient-rich conditions. The spike of measured CO\(_2\) indicates a positive PE. Measurement of soil CO\(_2\) can be done in the field or in the laboratory. The laboratory approach is conducted by incubating the soil with a solution of KOH and aqua, followed by titration of the KOH to the solution of incubated soil.

Positive PE in peat soil that is activated by the addition of compost can increase CO\(_2\) while reduces the peat soil layer due to decomposition of soil organic matter. It is necessary to observe the type of PE occurring in peat soil due to the addition of a rich nutrient organic matter and microbes in the form of compost. The incidence of PE could be observed by measuring CO\(_2\) produced from the respiration process during the incubation of a mixture of peat soil and compost.

2. Methodology

2.1. Experimental design
The research was conducted from August to September 2021 at the Laboratory of Soil Science and Land resources, Bogor Agricultural University. The peat soil was taken from Central Kalimantan while compost was from the market. The peat soil from the field was air-dried and sieved using a 5 mm grids. Peat soil material that passed the sieve was separated from the bigger sizes and stored for the experiment.

| Table 1. Mixture composition. |
|-------------------------------|
| Treatment                  | Peat soil material (g/100g) | Compost (g/100g) |
| Compost (C\(_0\))          | 0                          | 100               |
| Coarser Peat (K\(_0\))     | 100                        | 0                 |
| Finer Peat (F\(_0\))       | 100                        | 0                 |
| Mixture KC\(_1\)           | 90                         | 10                |
| Mixture KC\(_2\)           | 75                         | 25                |
| Mixture KC\(_3\)           | 50                         | 50                |
| Mixture FK\(_1\)           | 90                         | 10                |
| Mixture FK\(_2\)           | 75                         | 25                |
| Mixture FK\(_3\)           | 50                         | 50                |

Sieved peat soil material was mixed with compost with various mixture composition (Table 1). The doses of compost in this experiment were 10%, 25%, and 50% of the total weight, which was 100 grams. One hundred grams of total mixture was placed in a jar along with a vial of 20 ml of 1 N KOH. Incubation was also carried out on each pure material, namely 5 mm sieved peat soil material (F\(_0\)), coarse peat soil material (K\(_0\)), and compost (C\(_0\)) so that nine treatments were obtained. The experiment was repeated 5 times plus a blank, accounting for a total of 46 experimental units.

2.2. Laboratory analysis
In this study, laboratory analysis was divided into several stages, namely initial chemical analysis for peat and compost and measurements of CO\(_2\) respiration of every 5 days. Chemical analysis in the laboratory for peat and compost included pH, C-org, ash content, dissolved C content, water content, P-available, K, Mg, Ca, as well as micronutrients Fe, Mn, Zn and Cu, and peat soil color. The
respiratory CO$_2$ was measured by titration method. The trapped alkali were titrated every 5 days for 45 days, unreacted alkali in the KOH traps was back-titrated with 1 N HCl to determine CO$_2$-C.

2.3. Data analysis
The CO$_2$ level during the incubation were observed and analyzed descriptively to show the fluctuations. The amount of CO$_2$ from each treatment were compared and correlated to understand the linear comparison between the amounts of added compost and produced CO$_2$. No linear relationship indicates the decomposition of peat soil by the soil microbes produces a higher CO$_2$ leading to the occurrence of positive PE.

3. Results and discussion

3.1. Chemical characteristic of peat and compost used on the experiment
The peat has a pH of 3.35, like a normal Indonesian peat soils, classified as very acidic (pH < 4.0). The acidity affected by organic acids, i.e. humic acid and fulvic acid [5]. Naturally, peat soil has a low content of both macro- and micro- nutrients as showed on this experiment. Table 2 describes initial chemical analysis of the peat soil and compost. Several chemical parameters were low, such as ash at 3.17% and available P at 58.95 ppm. This applied for other parameters including K, Mg, and Ca, and micronutrient such as Fe, Zn, Cu, and Na. The organic matter of the peat was considered high as commonly found in organic soils. The humic color was observed to indicate the decomposition stage of the peat soil. The humic color was 7.5 YR/4, interpreted as dark brown, indicating hemist decomposition stage. Hemist organic material indicates intermediate decomposition between fibric and sapric. Bulk density was normal between 0.1 and 0.2 g/cm$^3$.

| Parameter                  | Result         |
|----------------------------|----------------|
| pH (1:5)                   | 3.35           |
| Water Content              | 465.26         |
| Ash Content                | 3.17           |
| Organic matter (%)         | 56             |
| Humic Color                | 7.5 YR 3/4     |
| P- Available (ppm)         | 57.89          |
| K (ppm)                    | 58.86          |
| Mg (ppm)                   | 46.80          |
| Ca (ppm)                   | 178.11         |
| Fe (ppm)                   | 244.37         |
| Mn (ppm)                   | 1.42           |
| Zn (ppm)                   | 13.37          |
| Cu (ppm)                   | 3.38           |
| Na (ppm)                   | 148.59         |

The compost was characterized by pH at 6.30 and an ash content at 30.94%. These indicate high nutrients content. Compost had an available P at 3853.06 ppm or around 0.39%. This high available P was due to a lot of plants leaves as source of P. Besides rich of macro nutrients, the compost was also rich in micro nutrients.
3.2. Respiration on fine and coarse peat soil material

Respiration in compost, coarse peat soil material, and fine peat soil material were clearly different. Respiration in compost was higher compared to in peat soils. Figure 1 shows that the compost produced the highest CO$_2$ indicating high microbial activity. In contrast, both fine and coarse peat soil produced very low CO$_2$ particularly the fine size one. The low CO$_2$ suggested low microbial activity. Low nutrient content could be the cause of low microbial activity. According to Kononen et al. [6] P was the limiting factor of microbial activity on peat soil. Meanwhile, the trend of CO$_2$ during the incubation was somewhat stable at low level. It represents low microbial activity of peat soil. Many factors possibly caused the low microbial activities, such as low nutrient content and lack of organic compounds such as carbohydrates.

Composting finer size of peat soil increased the respiratory CO$_2$. The highest CO$_2$ was generated by adding 50% compost. Figure 2 illustrated that the more compost added to the finer peat soil, the more CO$_2$ produced. Increasing CO$_2$ by composting was short lasted, getting lower by the time and stagnated after day 40. This could be due to the limitation of oxygen for soil microbes. During the incubation, there was no additional oxygen supply for soil microbial respiration which inhibited their activities. Moreover, finer size of peat is hard to decompose since higher humus fraction is existed comparing to simpler organic compounds such as carbohydrates and lignin. The higher concentration of recalcitrant lignin decreases soil respiration [8]. Therefore, adding compost to hemic peat soil with finer size does not affect the decomposition process.

Meanwhile, composting coarse peat soil clearly increased the CO$_2$. It can be seen on Figure 3 that the coarse peat soil material produces high CO$_2$, generated increasing trend by the time and by the dosages. Adding 50% compost produced the highest amount of CO$_2$. Unlike the finer material, the coarser peat soil produced high CO$_2$ and kept increasing after 45 days of incubation. The decomposing material and the presence of active soil fauna influence the rate of C release and the composition of CO$_2$ and dissolved organic compounds being generated in different molecular size [9]. The coarse peat soil material has sufficient carbohydrate or lignin compounds that can straightforwardly be decomposed by soil microbes. The availability of materials that can be overhauled by soil microbes may affect soil microbial activity in addition to nutrients and other factors. Thus, the addition of compost to coarse peat soil material has a positive effect in increasing the decomposition process.
Figure 2. The CO$_2$-C on the compost and mixture of coarse (K) peat soils materials.

Figure 3. The CO$_2$-C on the compost and mixture of coarse (K), fine (F) peat soils materials.

Coarser peat soil materials produced higher CO$_2$ compares to the finer ones. Composting any size of peat soil has proven increasing CO$_2$ from soil respiration, and the greater the amount of compost added, the higher the respiratory CO$_2$ produced. Since linear correlation between the amount of compost and the amount CO$_2$ was unobserved, positive PE possibly occurred. The capacity of the PE to reduce the C storage on soils is not linear and only partially controlled by the amount of FOM amendment [10]. The positive PE responds when the native available nutrients in the soils could not satisfy the growth of microorganisms at the high input [11], which in this experiment is compost. Since priming effects may occur due to the activity of specific groups of soil microorganisms [12], further studies is needed to find the group of organisms that works on the PE process in the peat soil and compost mixture.
Figure 4. Comparison between FK3 and KC3

4. Conclusion
Adding compost to peat soil has increased carbon dioxide that can be used to indicate increasing microbial activity. CO2 level produced from coarser peat with compost was somewhat higher than from the finer one. It was shown that microbial activity on coarser peat was greater and faster than on the finer one. The finer peat material consisted of more humus fraction than simpler organic compound such as carbohydrates and lignin. It was shown that positive PE occurred by adding compost to coarse peat soil.

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