Adding Compost to Oil Palm Planting Holes can Increase the Diversity of Soil Fungi without Significantly Affecting the Gas Emissions on Wetlands

Hasrul Satria Nur1,2*, Rindang Yuliani2, and Abdul Hadi3

1Department of Biology, Faculty of Mathematics and Natural Sciences, Lambung Mangkurat University, Banjarbaru, South Kalimantan, Indonesia
2Microbiology and Biotechnology Basic Laboratory, Faculty of Mathematics and Natural Sciences, Lambung Mangkurat University, Banjarbaru, South Kalimantan, Indonesia
3Department of Soil Science, Faculty of Agriculture, Lambung Mangkurat University Banjarbaru, South Kalimantan, Indonesia

ABSTRACT

Inorganic fertilizer has long been used in improving soil fertility and enhancing crop production in Indonesia, especially for estate crops like oil palm (Euis guenensis). However, the use of inorganic fertilizers is ought to stimulate methane formation in soil and successive greenhouse gas emissions to the atmosphere and suppress the development of particular microbes of wetlands’ soils. As the one of the alternative in oil palm cultivation is to use compost. The objectives of this study were to determine the effects of applying combined compost on gas emissions and diversity of soil fungi in oil palm field on wetlands. For these, grass compost with inorganic fertilizer (WC), oil palm empty fruit bunches compost with inorganic fertilizer (OPEPB), and the inorganic fertilizer without compost (CF) were tested. The emissions of CH4, CO2 and N2O were collected from the oil palm planting holes by closed chamber method. Soil samples were also taken and used for determination of fungi characteristic and diversity. The results of this research showed no statistical different in CH4, CO2 and N2O emissions from WC, OPEPB and CF plots. Meanwhile, the genera of soil fungi that were found on the sites after applying combining compost, viz Aspergillus, Bipolaris, Gonatobotrys, Gonatorrhodiella, Oidiodendron, Penicillium, Rhynchosporium, Rhizopus, Trichoderma, and Trichocladium. It could be concluded that the use of compost increased the diversity of soil fungi without significantly effect on gas emissions from oil palm field on wetlands.

Keywords: gas emissions, fertilizer, diversity, and soil fungi

INTRODUCTION

Inorganic fertilizer has long been used in improving soil fertility and enhancing crop production in Indonesia. However, the use of inorganic fertilizers is ought to stimulate methane formation in soil and successive greenhouse gas emissions to the atmosphere (Mambu, 2012). Li et al (2012) reported the application of nitrogen fertilizers in 210 kg ha-1 increased the CH4 emissions around 13-66% in wetland paddy field. Wihardjaka and Abdurachman (2007) also reported the addition of K fertilizers increased the CH4 emissions at non-wetland paddy field. Moreover, Hickman et al (2011) reported the use of inorganic fertilizers in plenty can stimulate N2O emission.

Oil palm plant is a plant that is cultivated widely in Indonesia thought it...
needs large amount of fertilizers. Out of seven million ha of oil palm plantations, about half are owned by farmer or so called house-hold oil palm field (Noor, 2010). Due increased price coupled with high demand competition with oil palm companies, house-hold oil palm farmers are unable to afford in inorganic fertilizer. One of the alternatives to overcome this constrain is the use of composting wastes that are largely available in oil palm field on wetlands.

Sampanpanish (2012) described that the CH₄, CO₂ and N₂O emissions from wetland paddy field that has been applied inorganic fertilizers were 1.79, 534.11, and 1.21 mg.m⁻².d, respectively. Meanwhile, the gas emissions in the field that has been applied organic fertilizers were 1.35, 377.35, and 0.88 mg.m⁻².d for CH₄, CO₂ and N₂O, respectively. The application of compost generally improves the abundant and diversity of soil microbes, such as bacteria and fungi. Pe’rez-Piques et al (2006) reported the application of compost has an affected sort of bacteria and soil fungi. However, there are few studies on the effect of waste compost on fungi diversity while keeping low greenhouse gas emissions. Thus, the objectives of this study were to determine the effect of applying combined compost on gas emissions and diversity of soil fungi in oil palm field on wetlands.

**MATERIALS AND METHODS**

**Study site**

The experiment was conducted at Gampa Asahi sub-district, Rantau Badauh district, Barito Kuala regency, South Kalimantan-Indonesia. The classification of soil on this swampy area has characterized as acid sulphate soil.

**Preparation and application fertilizers**

Compost that used in this experiment was prepared previously by Mawar (2014). The sort of organic fertilizers that used in this research were oil palm empty fruit bunch compost and grass (fern species Stenochlaena palustris) compost. Inorganic fertilizer was also applied as comparison and compost supplement. Twelve planting holes each sizing 60 x 60 x 60 cm were prepared two weeks prior to fertilizer application. Four holes were filled with inorganic fertilizers at the rate of 250 kg ha⁻¹ N, 250 kg ha⁻¹ SP36 and 150 kg ha⁻¹ KCl (consider as CF plot hereafter). The rest of the holes were filled with either oil palm empty fruit bunch compost (considered as OP EFB plots hereafter) or grass compost (considered as WC hereafter) at the rate of eight ton ha⁻¹. Urea, SP36 and KCl fertilizers were also applied to OPEF and WG to reach the same N, P and K doses to CF plots. Furthermore, oil palm plants that has been nursed for 18 month were planted at the same day with fertilizer applications.

**Soil and gas sample collection**

Gas collection carried out by close chamber method as described by Hadi et al. (2012). The interval of gas sampling was 2, 7, 12 minutes after the chambers closure. The sample samples were transferred to laboratory and used for determination of CH₄, N₂O and CO₂. Gas sample was collected every two weeks for 3.5 months. In addition, gas concentrations were quantified by gas chromatography of GHG 450 types Shimadzu. Then gas sample was...
calculated based on the formula below (Hadi et al 2005):

\[ F = k \cdot h \cdot \frac{\Delta c}{\Delta t} \times \frac{273}{T} \]

Whereas, the F refer to gas emissions rate \((\text{mg N}_2\text{O m}^{-2} \cdot \text{h}^{-1}) (\text{gCO}_2\text{m}^{-2} \cdot \text{h}^{-1}) (\text{gCH}_4\text{m}^{-2} \cdot \text{h}^{-1})\); k refer to constant volume gas conversion into weight \((\text{CO}_2 \text{and CH}_4 = 0.536, \text{N}_2\text{O} = 1.250)\); h = the height chambers in meter; \(\Delta c/\Delta t\) refer to changes of the gas concentration (ppm) per unit of times (hours) and T refer to the temperature in chambers \(^o\text{K}\).

Soil sampel was collected from the oil palm planting hole. The sample was collected for three times, viz the initially before applied the waste compost, the middle after applied (35 days) and the last after applied (77 days). Soil sample was composite and taken up 0-20 cm in deep (Cappucino and Sherman, 2002). All samples was analyzed for diversity of soil fungi through characterization and identification. Identification of soil fungi covered the characteristic, such as morphology and microscopy. The characteristics of morphology were shape, color, size, pigmentation, and growth rate colony (Rohilla and Salar, 2012). Besides that, the microscopy characteristics consist of shape, color, spore location, position of the septa in mycellium, septa shaped into the spore, and morphology of conidiophore. The characteristics above was analyzed by dichotomous key of fungi.

**Research Design and Data Analysis**

The reasearch design that used in this study was completely random block design in one factors, whereas the sort of compost as treatment. Types of compost were OP EFB, grass, and control. Every treatments consist of four groups. So the amount of combination every treatment i.e, 12 units design. Analysis of varians is used if the data gas emissions rate has fully assumed homogeneous and normality. Moreover, Duncan test (5%) is used if the analysis varians data showed the significantly, but the Kruskal Wallis is used if the data has not fully assumed of homogenous and normality (Mattjik and Sumertajaya, 2002).

**RESULTS AND DISCUSSION**

**Gas Emission CH\(_4\), CO\(_2\), and N\(_2\)O**

The emission of CH\(_4\), CO\(_2\), and N\(_2\)O were varied with different treatments and fluctuated from time to time (Figure 1). For example, the CH\(_4\) emissions from OP EFB + inorganic fertilizers was 0.019 gCH\(_4\)m\(^{-2}\)h\(^{-1}\) on the iniatially and become – 0.316 gCH\(_4\)m\(^{-2}\)h\(^{-1}\) at the end of measurement. Contrastly, the emissions of CH\(_4\) in the grass compost + anorganic fertilizers is showed increased from 0.012 gCH\(_4\)m\(^{-2}\)h\(^{-1}\) at day zero become to 0.711 g CH\(_4\) m\(^{-2}\) h\(^{-1}\) at day 77. The CH\(_4\) emissions from inorganic fertilizer plot without compost decreased gradually up to the end of the observation (Figure 1C).

Reducing gas CH\(_4\) on this study has correlated to the sort of microbes produced CH\(_4\). Generally, the microbes that produced CH\(_4\) is a group of methanogenic bacteria, meanwhile, the sort of waste compost that used is not ideally substrate for the bacteria. Therefore, the amount of CH\(_4\) also decreased gradually.
Figure 1. Temporal N₂O, CO₂ and CH₄ emissions from CF, OP EPB and WG plots.
On this cases, the increasing of CH\textsubscript{4} in the oil palm planting hole that received combining fertilizers, grass compost + anorganic fertilizers is due to by the properties of grass compost that easily to degraded and decomposed by microbes, mainly by methanogenic bacteria to forming gas CH\textsubscript{4}. According to Wihardjaka (2001), the emissions of plant that has recieved a straw compost is higher increased than a plant without its. The interaction of anorganic and anorganic fertilizers showed no effect of CH\textsubscript{4} emissions. In this cases, the forming of CH\textsubscript{4} depend on many factors, not only sort of fertilizers but also a redox potential, pH, temperature, kinds of plants, and anorganic matter in soil (Asri, 2010).

Table 1 showed the annual CH\textsubscript{4}, N\textsubscript{2}O and CO\textsubscript{2} emissions from OP EFB, GW and CF plots, respectively.

Table 1. Annual CH\textsubscript{4}, N\textsubscript{2}O and CO\textsubscript{2} emissions and their global warming potential

|                | WG   | OP EFB | CF    |
|----------------|------|--------|-------|
| CH\textsubscript{4} (kg m\textsuperscript{-2} year\textsuperscript{-1}) | -91.91 | -43.46 | 53.42 |
| CO\textsubscript{2} (kg m\textsuperscript{-2} year\textsuperscript{-1}) | -75.41 | -723.27 | 640.90 |
| N\textsubscript{2}O (kg m\textsuperscript{-2} year\textsuperscript{-1}) | 0.08  | 0.15   | 0.29  |
| GWP\textsuperscript{*}) (kg CO\textsubscript{2} equ m\textsuperscript{-2} year\textsuperscript{-1}) | -4.94 | -5.20  | 5.60  |

\textsuperscript{*}): Global warming potential = 23 x CH\textsubscript{4} emission + 296 x N\textsubscript{2}O emission + CO\textsubscript{2} emissions

According to the ANOVA, there were no significant different in global warming potential from either WG, OP EFB or CF. This suggested that the replacement of inorganic fertilizer with waste compost on wetland did not have negative impact on environment, especially in viewpoint of greenhouse gas emissions.

**Diversity of Oil Fungi in Oil Palm Planting Hole**

Sixteen isolates of soil fungi were characterized and identified. The amount of the genere are distributed in soil samples. Five isolates were characterized as genera of *Penicillium* and *Trichoderma* from the soil sample in previously. There are seven isolates were also characterized as genera of *Penicillium*, *Rhynchosporium*, *Trichocladium*, *Bipolaris*, *Trichoderma*, and *Oidiodendron* from the soil sample in the middle period. And than, four isolates were characterized as *Gonatorrhodiella*, *Gonatobotrys*, *Rhizopus*, and *Aspergillus* from the soil sample which was collected on the end of period. Distribution of the soil fungi described in Table 2.

Addition of the waste compost is significantly increased the diversity of soil fungi. In this cases are demonstrated in Table 2 and 3. Especially in the combining fertilizers (OP EPB + anorganic fertilizers) was higly than the other treatments, meanwhile the diversity of soil fungi on the soil sample that was given anorganic fertilizers without compost are lowest than two types of combining fertilizers. Although that the diversity of soil fungi in this study is no correlation with the dynamics of gas emission. The phenomena are due to no specific fungi that has
capacity to stimulate the gas emission production. The result is differently with the Jebaraj and Raghukumar (2010) explained the activity of fungi can affected the gas emission production.

CONCLUSION & RECOMMENDATION

It could be concluded that the use of compost increased the diversity of soil fungi without significantly effect on gas emissions from oil palm field on wetlands. Therefore, the use of compost with combining chemical fertilizers are potentially to apply into the oil palm field on wetlands.

ACKNOWLEDGMENTS

We are gratefully thanks Directorate of Higher Education, Republic of Indonesia, for giving funding support through the MP3EI research grant (grant No.216/SP2H/PL/Dit.Litabmas/V/2012).

| No | Soil sample sources              | Isolates code | Genera       |
|----|----------------------------------|---------------|--------------|
| 1  | Initially (0-7 days)             | FA            | Penicillium  |
| 2  |                                 | FI            | Penicillium  |
| 3  |                                 | FK            | Penicillium  |
| 4  |                                 | FL            | Trichoderma  |
| 5  |                                 | FN            | Penicillium  |
| 6  | The middle (7-43 days)           | FCt           | Penicillium  |
| 7  |                                 | FGt           | Rhynchosporium|
| 8  |                                 | FIt           | Trichocladium|
| 9  |                                 | FKt           | Bipolaris    |
| 10 |                                 | FMt           | Trichoderma  |
| 11 |                                 | FOr           | Trichoderma  |
| 12 |                                 | FSt           | Oidiodendron |
| 13 | The end (63-77 days)             | FGa           | Gonatorrhodiella|
| 14 |                                 | FPa           | Gonatobotrys |
| 15 |                                 | FUa           | Rhizopus     |
| 16 |                                 | FXa           | Aspergillus  |

Table 2. Diversity of soil fungi in oil palm planting hole during the application of fertilizers (combined compost)
Table 3. The representative in correlation between types of fertilizers (combined compost), gas emissions, and diversity of soil fungi

| Type of fertilizers | Time of sampling | CO₂ (g m⁻² h⁻¹) | Gas emissions | N₂O (mg m⁻² h⁻¹) | Genera               |
|---------------------|------------------|-----------------|---------------|------------------|---------------------|
| The combined fertilizers (grass compost + inorganic fertilizers) | Initially (0-7 days) | 8665.706 | 364.202 | -1382.37 | Penicillium          |
|                     | The middle (7-63 days) | 1160.221 | 241.128 | 1411.279 | Penicillium, Rhynchosporium, Trichoderma |
|                     | The end (63-77 days) | 3682.497 | 65.625 | 14483.55 | Penicillium, Rhynchosporium, Trichoderma, Aspergillus |
|                     | Initially (0-7 days) | 64898.13 | -7.46069 | 2966.411 | Trichoderma          |
|                     | The middle (7-63 days) | 4486.408 | -3.18719 | 12675.92 | Trichoderma, Penicillum, Trichocladium, Bipolaris, Oidiodendron |
|                     | The end (63-77 days) | -846.629 | -31.2936 | 19769.03 | Trichoderma, Penicillum, Trichocladium, Bipolaris, Oidiodendron, Gonatorrhodiella, Rhizopus |
| Inorganic fertilizers without compost | Initially (0-7 days) | 2888.06 | 2.105592 | 4348.57 | Penicillium          |
|                     | The middle (7-63 days) | 630.493 | -14.98 | 9593.292 | Penicillium          |
|                     | The end (63-77 days) | 2965.174 | -13.266 | 20104.2 | Penicillium, Gonatoboytryss |

REFERENCES

Asri F. 2010. The effect of organic fertilizer and anorganic in methan gas at wet rice field. Thesis, Dept of soil science, Faculty of Agriculture, University of Sebelas Maret, Surakarta.

Cappucino JG and N Sherman. 2002. Microbiology, a laboratory manual. Sixth edition. The Benjamin Cummings Publishing Company, San Francisco.

Hadi A, K Inubushi, Y Furukawa, E Purnomo, M Rasmadi, and H Tsurata. 2005. Greenhouse gas emission from tropical peatland of Kalimantan. Natural cycling in agroecosystems, 71:73-80.

Hadi A, Lutfi F, Syaifuddin, Abdullah, Affandi DN, Bakar RA and Inubushi K. 2012. Greenhouse gas emissions from peat soils cultivated to rice field,
oil palm and vegetable. *J. Tropical Soil*, 16: 105-114

Jebaraj CS and C Raghukumar. 2010. Nitrate reduction by fungi in marine oxygen-depleted laboratory microcosms. *Botanica Marina*, 53: 469-474.

Mambu SM. 2012. Estimation of methan emission on rice plant controlling system at Minahasa regency. *J Bioslogos*, 2:37-44

Mawar S. 2014. The emission gas CH$_4$ and CO$_2$ then the organic changes in decomposting of agricultural by cellulolytic indegenous bacteria tidal land. Thesis, Dept of Biology, Faculty of Mathematics and Natural Sciences, Lambung Mangkurat University. Banjarbaru-Indonesia.

Mattjik AA and IM Sumertajaya. 2002. Research design by SAS and Mintab Application. IPB Press, Bogor.

Noor. 2010. Peatland: depelovment, conservation and climate changes. Gadjah Mada University Press. 212 p.

Paul E and F Clark. 1996. Soil microbiology and biochemistry. Academic Press, New York.

Pe’rez-Piques A, V Edel-Hermann, C Alabouvette, and C Steinberg. 2006. Response of soil microbial communities to compost amendments. *Soil Biology and Biochemistry*, 38: 460-470.

Rohilla SK and RK Salar. 2012. Isolation and characterization of various fungal strain from agricultural soil contaminated with pesticides. *Research journal of recent sciences*, 1:297-303.

Sampanpanish P. 2012. Effect of organic fertilizer use in rice paddy to reduce greenhouse gases. *IPCBEE*, 37: 79-85

Sumarto WR 2010. How to grow in oil palm plantation that sustainable and eco-friendly. Pustaka Khatulistiwa, Jakarta.

Suprhati. 2007. Micorobes population and methan fluxs then nitous oxides at wet rice field: effect of water controlling, organic matter, and nitrogen fertilizer. Disertation, Postgraduate of IPB, Bogor.

Wihardjaka A and S Abdurachman. 2007. The effect of fertilizers in long-term for rice plant in wet rice field on methan gas emission. *J Penelitian Pertanian Tanaman Pangan*, 26 : 199-205.

Wihardjaka A. 2001. Methan gas emission in rice field irrigation by adding of organic matters. *Agrivita*, 23: 43-51.