THE USE OF BIOFERTILIZERS INCREASED PLANT GROWTH WITH NO TRADE-OFF EFFECT ON GREENHOUSE GAS EMISSIONS

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ABSTRACT

Several experiments have been carried out to elucidate the reduction in greenhouse gas emissions as effect of replacement of chemical fertilizer by biofertilizers on alluvial soils in Indonesia. Biofertilizers “Biotara” and “Biosure” were applied along with NPK fertilizer on alluvial soil cultivated with rice. Emissions of nitrous oxide (N\(_2\)O), methane (CH\(_4\)) and carbon dioxide (CO\(_2\)) were monitored in biweekly basis up to the maximum vegetative growth of the rice plant. Oil palm empty fruit bunch (OP EFB) as well as grasses were composted with Bacillus brevis and Bacillus megaterium as activator. The composts were incorporated into alluvial soils cultivated to oil palm and the emissions of N\(_2\)O, CH\(_4\) and CO\(_2\) were monitored in biweekly basis. The results showed that biofertilizer “Biotara” or “Biosure” combined with NPK fertilizer (¾ recommendation dose) could increase paddy growth with no significant effect on N\(_2\)O, CH\(_4\) and CO\(_2\) emissions. The emissions of N\(_2\)O, CH\(_4\) and CO\(_2\) exhibited seasonal changes as affected by inclusion of either OP EFB and weed compost along with NPK fertilizer. Global warming potentials of each treatment for NPK, OP EFB compost and weed compost were 5.6, -5.2 and -4.9 ton CO\(_2\) eq m\(^{-2}\) year\(^{-1}\), respectively. It could be concluded that the replacements of synthetic fertilizer with biofertilizer or compost did not have negative impact on the environment which could be promoted.

Keywords: Agricultural waste, Compost, Greenhouse gases, Oil palm

INTRODUCTION

Rice and oil palm are the two most widely cultivated farm produces in Indonesia with areas of 7.4 and 7.3 million ha, respectively. It has been estimated that paddy field country wide produces as much as 12 million tons of waste annually (Hadi \textit{et al.}, 2014). Oil palm fields produce waste in the form of oil palm leaf, fruit and weeds amounting nearly 8 ton ha\(^{-1}\) annually. The wastes in the field cause diseases and give way for pest and can also become fuel for fire during dry season. The natural decomposition of oil palm waste is low and produces greenhouse gases like methane (CH\(_4\)) (Inubushi \textit{et al.}, 2007).

Carbon dioxide (CO\(_2\)) is released by all living cells involved in the decomposition of organic matter, while CH\(_4\) is produced by a group of microbes during the anaerobic decomposition of organic matter. Nitrous oxide (N\(_2\)O) is produced during nitrification and denitrification of either organic or inorganic N. N\(_2\)O can be released from the aerobic environment as well as from the anaerobic environment (Bouwman, 1990).

Organic wastes from agricultural filed ought to can be the important sources of nutrients for crops if they are managed properly. “Biotara” and “Biosure” are the established bio-fertilizers made by combining microbes with rice-husk charcoal. Biotara\© contains plant growth promoting fungi (\textit{Trichoderma} sp), nitrogen fixing bacteria (\textit{Bacillus} sp) and phosphorus dissolving bacteria (\textit{Azospirillium} sp), while Biosure\© contains sulfur reduction bacteria (\textit{Desulfovibrio} sp). Both biofertilizers are
combined with rice husk charcoal as a carrier. The use of the two bio-fertilizers improves soil quality and plant productivity (Mukhlis, 2012). However, greenhouse gas emissions as affected by these fertilizers are unknown.

The objective of this research is to elucidate the effect of synthetic fertilizers replacement by biofertilizer and compost on CO₂, CH₄ and N₂O emissions from paddy and oil palm fields in Indonesia.

**MATERIALS AND METHODS**

**Effect of replacement of chemical fertilizers by Biotara and Biosure on paddy growth and gas emissions**

Biofertilizers Biotara and Biosure were prepared according to procedures described by Mukhlis (2012). Chemical fertilizers in the form of Urea, SP-36 and KCl as sources of N, P and K, respectively, were obtained at the local market. The field trial was carried out in farmer field in the *Gampa Asahi* village, *Barito Kuala* District, *South Kalimantan*, Indonesia. Land clearing was done by using a dozer, while flaying was done manually using tools commonly used by local farmers.

Twelve plots measuring 4 m x 5 m each were established by digging a 0.5 m wide canal in between the plots and dumping the excavated soil surrounding the plots. The treatments were: (A) = recommended dose of N, P and K, (B) = 75% of A + 25 kg/ha of Biotara, (C) = 75% of A + 25 L of Biosure, (D) = 75% of A + 25 kg/ha of Biotara + 25 L of Biosure, (E) = 50% of A + 25 kg/ha of Boar + 25 L of Biosure, and (F) = no fertilizer added. Four basements made of PVC pipe were set in each plot beneath 5 cm into the soil and 50 cm apart from one to another. The treatments with three replications were arranged according to randomized block design (Mattjik and Sunertajaya, 2002).

Margasari varieties of rice were planted on already, nurser lands for 21 days. On each plot, a hill containing three seedlings was transplanted at a spacing of 25 cm x 25 cm. At the same time, porous cups were inserted into the soil in each site to the depth of 15 cm, on the same day with fertilizer application. Polycarbonate chamber with 50 cm long, 50 cm wide and 50 cm or 100 cm height were prepared. The chamber was open at one edge and closed at another edge. A capillary plastic tube was inserted into the closed edge of the chamber through a rubber septum, in order to collect air inside the chamber. The chambers were placed with the open edge facing the basement at every gas sampling time. Air samples were taken four times at 2, 7 and 12 min, after the closure of the chamber (0, 21, 42 and 63 days after rice planting). CH₄, N₂O and CO₂ concentrations were determined by a gas chromatograph with the working conditions as explained by Hadi *et al.* (2010).

The fluxes of each gases were calculated by integrating the increase of concentrations per time unit (Yagi, 1997):

\[
\text{Flux (g C or N/m}^2$/text{h}) = k \cdot \frac{dc}{dt} \cdot \left(\frac{273}{273+T}\right)
\]

Where: \(k=\)constant (0.536 for CO₂ and CH₄, and 1.250 for N₂O); \(\frac{dc}{dt}=\)changes in concentration (ppm) per unit time (hour); \(T=\)temperature (⁰C)

Total gas emissions were calculated by integrating the emissions with duration of measurement (Yagi 1997). Soil samples were taken from 0-15 cm soil depth at 0, 21 and 42 days after rice planting and analyzed for pH, Fe, organic C and NO₃-N by the procedure described by Page *et al.* (1982).

**Effect of fertilizer replacement by compost on gas emissions from oil palm fields**

To study the effect of NPK replacement by Oil palm empty fruit bunch (OP EFB) and weed (R) composts on emissions of greenhouse gases, 12 oil palm trees in their sixth year (owned by farmers) were selected in *JajangkitPasar* Village, *Barito Kuala* District, *South Kalimantan*, Indonesia.

Four trees were given the recommended dose of NPK and were considered as control treatment. According to Mawar (2013), OP EFB + *Bacillus brevis* + cow dung and R + *Bacillus brevis* + cow dung which is referred to as “EFB compost” and “weed compost” were prepared. The compost was then applied on the soil surface within two meters apart
from the oil palm trunk at the rate of 2 ton ha⁻¹ (equal to 20% of N needs of oil palm). Inorganic fertilizers were added to the compost plots to achieve the recommended dose of N, P and K needed by mature oil palm (based on Sumarto, 2010). All experimental units were arranged following Randomized Block Design (Mattjik and Sumertajaya, 2002).

A basement made of PVC pipe with about 8 inches inner diameter was set at each site beneath 5 cm into the soil under the canopy of oil palm trees. Cylindrical PVC chamber with 8 inches in diameter and about 25 cm height were prepared. The chamber was open at one edge and closed at another edge. A capillary plastic tube was inserted into the closed edge of the chamber through a rubber septum in order to collect air inside the chamber. The chambers were placed with the open edge facing the basement at every gas sampling time. Air samples were taken at 2, 7 and 12 min after the closure of the chamber at biweekly basis until 98 days after compost application. CH₄, N₂O and CO₂ concentrations were determined by a gas chromatograph with working conditions (Hadi et al., 2012). The fluxes and total emissions of each gas were calculated according to the procedures earlier described.

The global warming potential of the three gases was calculated by multiplying the annual emissions with the mol warming potential of the gases (that is, 1, 23 and 296 for CO₂, CH₄ and N₂O, respectively) (Bouwman, 1990). Soil samples were taken from 0-15 cm soil depth at 0, 56 and 98 days after fertilizer applications and analyzed for pH, total N, and organic C by the procedure described by Page et al. (1982).

RESULT AND DISCUSSION

Effect of replacement of chemical fertilizers by biotara and biosure on soil characteristics, gas emissions, and plant growth

Changes in pH of soil extract (soil:H₂O = 1:2.5) and ground water as affected by different fertilizers are shown in Figure 1.

Although statistical analysis at 95% confidence level could not recognize the effect of treatment on the soil pH, the inclusion of Biotara and/or Biosure tended to increase the pH of ground water (Figure 1). Similarly, the inclusion of Biotara and/or Biosure tended to increase the height and tiller number of rice plant (Figure 2).

Figure 1. Changes in pH of soil extract (left) and ground water (right) as affected by different fertilizers. Note: (A) = recommended dose of N, P and K, (B) = 75% of A + 25 kg/ha of Biotara, (C) = 75% of A + 25 L of Biosure, (D) = 75% of A + 25 kg/ha of Biotara + 25 L of Biosure, (E) = 50% of A + 25 kg/ha of Boar + 25 L of Biosure, and (F) = no fertilizer added. DAF = days after fertilization.
The analysis of variance showed that there was no statistically different effect of the treatments on either CO$_2$, CH$_4$ or N$_2$O emissions (Table 1). This suggested that the replacement of synthetic fertilizer with biofertilizer does not have a negative impact on the environment and since the replacement of synthetic fertilizer with Biotara and/or Biosure improved the growth of paddy, the use of Biotara and Biosure can be recommended.

Table 1. Calculated F values in comparison with F-table for CO$_2$, CH$_4$ or N$_2$O emissions from respective treatments

| Source of variances | df | Calculated F | F-Table |
|---------------------|----|--------------|---------|
|                     |    | 0 DAP        | 21 DAP  | 42 DAP | 5% | 1% |
| Methane             |    |              |         |        |    |    |
| Group               | 2  | 1,018578     | 0,537628| 4,6731*| 4,1028| 7,5594|
| Treatments          | 5  | 1,00999      | 0,947877| 0,8311 | 3,3258| 5,6363|
| Error               | 10 |              |         |        |    |    |
| Total               | 17 |              |         |        |    |    |
| Carbon dioxide      |    |              |         |        |    |    |
| Group               | 2  | 0,4836       | 0,1443  | 5,8335 | 4,1028| 7,5594|
| Treatments          | 5  | 1,3666       | 1,1578  | 0,9358 | 3,3258| 5,6363|
| Error               | 10 |              |         |        |    |    |
| Total               | 17 |              |         |        |    |    |
| Nitrous oxide       |    |              |         |        |    |    |
| Group               | 2  | 5,4151*      | 3,1503  | 1,4515 | 4,1028| 7,5594|
| Treatments          | 5  | 0,1344       | 0,3211  | 2,3322 | 3,3258| 5,6363|
| Error               | 10 |              |         |        |    |    |
| Total               | 17 |              |         |        |    |    |

Note: *significant at 95% confidence level

The effect of chemical fertilizer replacements by compost on soil characteristics and gas emissions from oil palm fields

The emissions of CH$_4$, CO$_2$ and N$_2$O exhibited seasonal changes. The peaks of emissions CH$_4$ and CO$_2$ emissions from NPK plot were on 29 October, 2013 (42 days after fertilizer application), while the peak of N$_2$O emissions was on 29 September, 2013 (at the day of NPK application). The peaks N$_2$O and CO$_2$ emissions from OP EFB compost were on 29 September, 2013. The CH$_4$ emissions from OP EFB compost plot were negligible of a negative for the entire observation periods. Similarly, the CH$_4$, CO$_2$ and N$_2$O emissions from weed compost plot were negligible or negative for the entire observation periods (Figure 2).
Global warming potentials of each treatment were for NPK, OP EFB compost and weed compost were 5.6, -5.2 and -4.9 ton CO$_2$ eq year$^{-1}$, respectively.

Figure 2. Gas emissions from oil palm fields provided with 100 % NPK, 80% NPK + OP compost and 80% NPK + weed compost. Bars indicate standard error from four replicates.

Soil pH tends to increase from time to time with more changes in recommended NPK plots. The contents of N and C also increase from time to time, with more changes in compost treated plots (Table 2).

Table 2. Soil pH, contents of C and N before treatment, at 56 days after treatment, and at 98 days after treatment

| Treatment       | Days after treatment application |          |          |          |
|-----------------|----------------------------------|----------|----------|----------|
|                 | 0 | 56 | 98 | 98 - 0 |
| pH ($H_2O$)     |   |   |   |         |
| +Weed compost   | 3.87 | 4.76 | 4.77 | 0.90 |
| +OP Compost     | 4.34 | 5.03 | 4.87 | 0.53 |
| NPK Only        | 3.75 | 5.13 | 5.50 | 1.85 |
| Total N (%)     |   |   |   |         |
| + Weed compost  | 0.50 | 0.65 | 0.99 | 0.49 |
| + OP Compost    | 0.44 | 0.69 | 0.89 | 0.45 |
| NPK Only        | 0.59 | 0.76 | 0.92 | 0.33 |
| Organic C (%)   |   |   |   |         |
| +Weed compost   | 6.02 | 9.24 | 10.98 | 4.96 |
| +OP Compost     | 4.14 | 9.60 | 12.51 | 8.37 |
| NPK Only        | 5.12 | 9.69 | 9.86 | 4.74 |

Converting wastes to compost may be the best solution to overcoming the waste problem faced by many oil palm plantations, while sequestering atmospheric C and N. This indicated that the compost retained more C and N as compared with synthetic fertilizers. This was also reported by other researchers (Chan et al., 2009; Darnoko and Sutarta, 2006).

Replacement 20 % synthetic fertilizers with compost, will also help the planters to reduce the dependency on synthetic fertilizers which some time, are not available in the market.
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