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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_2O), 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_2O, 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_2O, CH_4 and CO_2 emissions. The emissions of N_2O, 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 equ 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 *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 *et al*., 2007).

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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_2O) is produced during nitrification and denitrification of either organic or inorganic N. N_2O 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 (*Trichoderma* sp), nitrogen fixing bacteria (*Bacillus sp*) and phosphorus dissolving bacteria (*Azospirillium* sp), while Biosure© contains sulfur reduction bacteria (*Desulfovibrio* sp). Both biofertilizers are

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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 CO_2, CH_4 and N_2O 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 flawing 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 Sumertajaya, 2002).

Margasari varieties of rice were planted on already, nursed 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). CH_4, N_2O and CO_2 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):

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

Where: k=constant (0.536 for CO_2 and CH_4, and 1.250 for N_2O); dc/dt=changes in concentration (ppm) per unit time (hour); T=temperature (^{0}C)

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 NO_3-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 dang and R + *Bacillus brevis* + cow dang 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

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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. CH_4, N_2O and CO_2 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 CO_2, CH_4 and N_2O, 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:H_2O = 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).

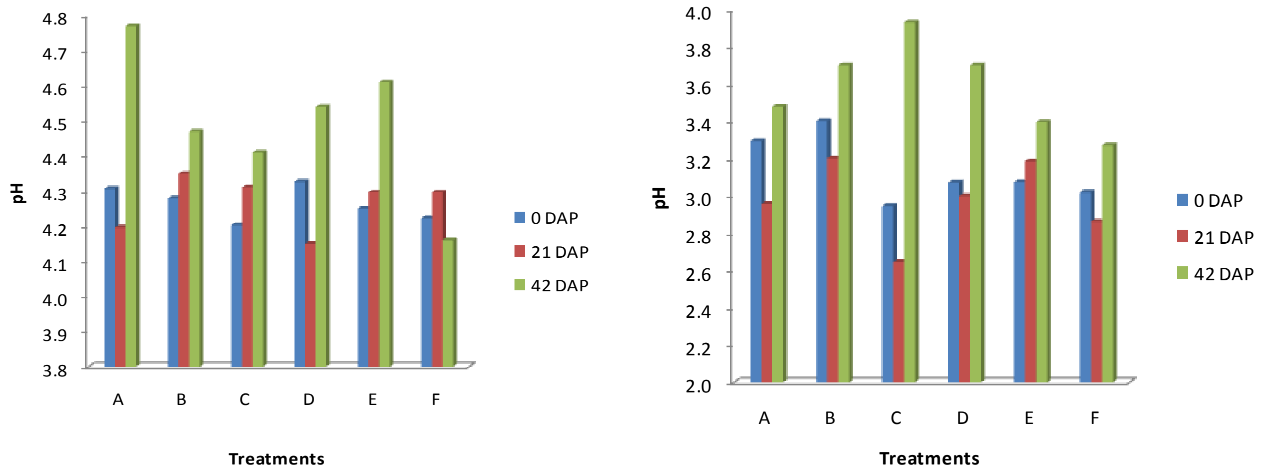

Figure 1. Changes in pH of soil extract (left) and ground water (right) as affected by different fertilizers. Note: (A) = recommended dose of N, P and K, (B) = 75% of A + 25 kg/ha of Biotara, (C) = 75% of A + 25 L of Biosure, (D) = 75 % of A + 25 kg/ha of Biotara + 25 L of Biosure, (E) = 50 % of A + 25 kg/ha of Boar + 25 L of Biosure, and (F) = no fertilizer added. DAF = days after fertilization.

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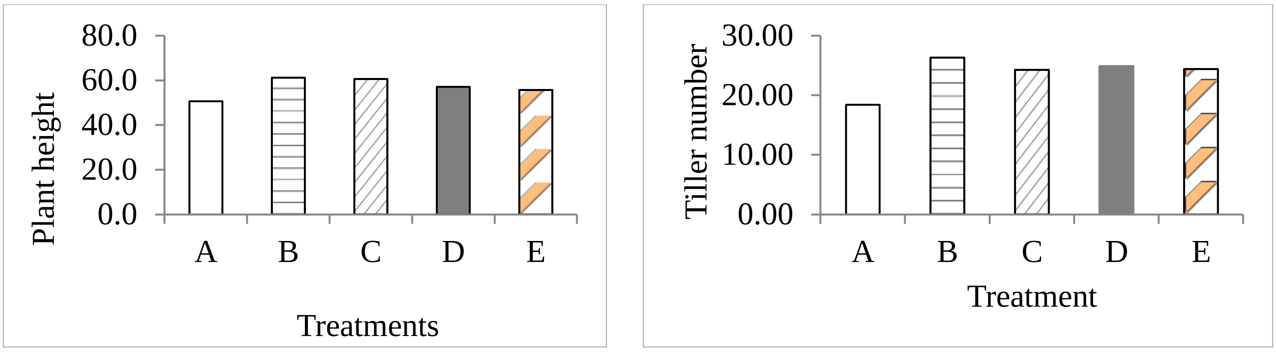

Figure 2. Changes in plant height (left) and tiller number (right) of paddy plant as affected by different fertilizers. Explanations for the symbols are the same as those in Figure 1.

The analysis of variance showed that there was no statistically different effect of the treatments on either CO_2, CH_4 or N_2O 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_2O 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_2O 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_2O emissions was on 29 September, 2013 (at 14 the day of NPK application). The peaks N_2O 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_2O emissions from weed compost plot were negligible or negative for the entire observation periods (Figure 2).

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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 equ m^2 $year^{-1}$, respectively.

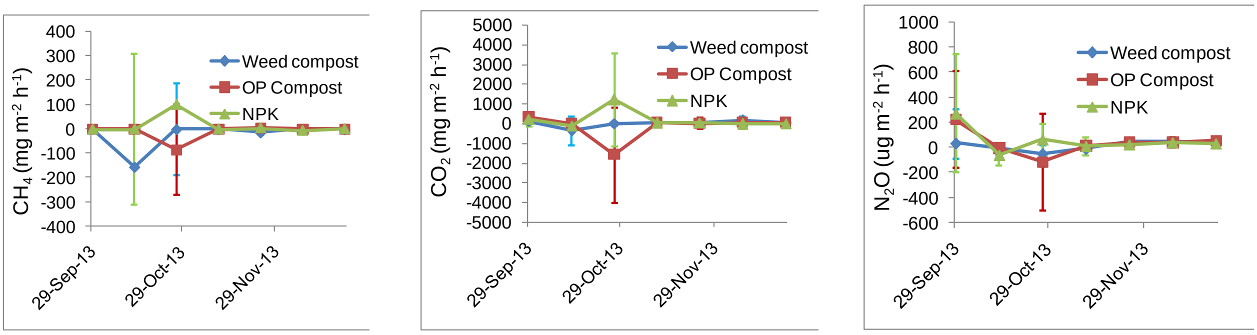

Figure 2. Gas emissions from oil palm fields provided with 100 % NPK, 80% NPK + OP compost and 80% NPK + weed compost. Bars indicate standard error from four replicates.

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). 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).

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. 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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REFERENCES

Bouwman AF. 1990. Introduction. In: Bourman AF (1990): *Soils and the Greenhouse Effect*, pp. 25-35. John Wiley & Sons, New York.

Chan YC, Sinha RK, Wang WJ. 2009. Emission of Greenhouse Gases from Home Aerobic Composting, Anaerobic Digestion and Vermicomposting of Household Wastes in Brisbane (Australia).Griffith University, Australia.

Darnoko, Sutarta AS. 2006. *Compost Factory at Oil Palm Plantation.* PPKS (LRPI). Tabloid Sinar Tani, 9 Agustus 2006 (in Indonesia).

Hadi A., Ghafur A, Farida A, Subekti T, Nursyamsi D. 2014. Gas emissions from production and use of biochar in the peatland of Kalimantan. In: K. Hayashi (2014): *Biochar for Future Food Security*, pp. 47-53. International Rice Research Institute, Philippine.

Hadi A, Fatah L, Syaifuddin, Abdullah, Affandi DN, Bakar RA, Inubushi K. 2012. Greenhouse gas emissions from paddy field, oil palm and vegetable in Kalimantan, Indonesia. *Journal of Tropical Soil*. 17: 105-114.

Inubushi K, Hashitani H, Pranoto. 2007. Green house gas emissions from oil palm waste. In: Melling *et al*. (2007): *Proceedings of Malaysian Soil Science Society Annual Meeting, Malaysia*.

Mattjik AA, Sumertajaya M. 2002. *Experimental Design with SAS and Minitab Applications.* IPB Press, Bogor (in Indonesian)

Mawar S. 2013. *CH_4 and CO_2 Emissions, and C-organic Changes during Composting of Agriculture Wastes using Cellulolytic Bacteria Indigenous to Tidal Swam.* Skripsi Program Studi Biologi FMIPA, Universitas Lambung Mangkurat, Banjarbaru (in Indonesian).

Mukhlis. 2012. *Effectivities of Biotara and Biosure in Reducing Chemical Fertilizer Use and Increasing Rice Production in Tidal Swamp Lands. Agroscientiae* 19 (3): 170-177 (in Indonesian).

Nur HS, Krisdianto. 2009. *Isolation and Selection of Cellulose Bacteria Original to Tidal Swamp to Explore Bio activator of Agricultural Waste Degradation.* (in Indonesian; unpublished).

Page AL, Miller RH, Keeny DR. 1982. *Method of Soil Analysis*. American Agronomy, Inc., Wisconsin.

Sumarto WR. 2010. *How to Establish Sustainable and Eco-friendly Oil Palm Estate*. Pustaka Khatulistiwa, Jakarta (in Indonesian).

Yagi K. 1997. Greenhouse gas emission and absorption. In: Konno, T *et al*. (1997): *Methods of Soil Environment Analysis*, pp 129-138, Hakuyusha, Tokyo (in Japanese).