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Methane Emissions and Rice Yield in Rainfed Bed System (*Surjan*) as Affected by Manure and Zeolite Treatment

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ABSTRACT

Rainfed area as one of rice production areas is facing drought due to climate change. Management of rainfed area is needed due to its contribution, in addition to the production of rice, in producing methane as a contributor to greenhouse gas emission. This research aimed to investigate the methane emission status and yield from rainfed rice system with manure and zeolite treatment on the bed system (surjan). The doses of manure were 5, 15 and 30 tons/ha and the zeolite was 1 and 2.5 tons/ha. The result showed that all treatment had no significant effect on daily methane fluxe and grain yield in surjan system. However, the combination of manure at 15 tons/ha with zeolite at 1 ton/ha promoted higher methane emissions (63.43 kg CH_4/ha/season). In addition, the combination treatment of manure at 5 tons/ha with zeolite at 2.5 tons/ha contributed to obtain higher grain yield (6.9 tons/ha).

Keywords: Methane emission; Rainfed; Surjan

ABSTRAK

Sebagai salah satu areal produksi padi, lahan tadah hujan menghadapi cekaman kekeringan karena perubahan iklim. Manajemen lahan tadah hujan diperlukan karena selain sebagai lokasi produksi padi namun juga sebagai lokasi yang menghasilkan emisi gas rumah kaca khususnya metana. Penelitian ini bertujuan untuk menginvestigasi emisi metana dan hasil gabah padi dari sistem pertanaman surjan dengan perlakuan pupuk kandang (pukan) dan zeolit. Dosis pukan yang digunakan yaitu 5, 15 dan 30 ton/ha sedangkan dosis zeolit yang digunakan yaitu 1 dan 2.5 ton/ha. Hasil penelitian menunjukkan bahwa semua perlakuan tidak berpengaruh terhadap fluks metana harian dan gabah kering panen dari lahan surjan. Kombinasi perlakuan pukan dosis 15 ton/ha dengan zeolit 1 ton/ha mengemisikan metana lebih tinggi dibandingkan kombinasi perlakuan lain sebesar 63.43 kg CH_4/ha/musim. Gabah kering panen (GKP) maksimum didapatkan pada kombinasi perlakuan pukan 5 ton/ha dengan zeolit 2.5 ton/ha seberat 6.9 ton/ha.

Kata Kunci: Emisi metana; Tadah hujan; Surjan

INTRODUCTION

Rainfed is one of the rice production systems that contribute to provide rice yield. However, rainfed known as a suboptimal area facing drought. The characteristics of rainfed area are low soil fertility level and unpredictable rainfall pattern that promotes risk under drought condition (Mulyadi and Wihardjaka, 2014). Regarding the climate change issue, the rainfed area is getting marginalized. Concerning on this issue, farmers from rainfed area adopt bed farming system (*surjan*) to develop soil productivity and obtain the diverse crop yield while as an adaptation action to climate change.

Bed farming system is common local wisdom in the coastal area that manages the rice field due to the bad drainage system. The bad drainage system is caused by the geomorphology rainfed area that is a fluviomarine plain and a former of a black swamp (Marwasta and Priyono, 2007). According to Aminatun et al. (2014), the bed farming system is called *surjan* since the rice field pattern looks like the lines pattern on the traditional clothes of Javanese (*surjan*). These lines are formed from terrestrial at high level and aquatic grooves at a low level. The terrestrial parts are planted with secondary crops or horticulture, while the aquatic grooves are planted with rice. Therefore, the *surjan* ecosystem is different from the general rice field. The great function of *surjan* is to store water from rainfall and runoff for water supply system during rice growth.

Zeolite is a naturally crystalized aluminosilicate used as ameliorant in the rice field to develop cation exchange capacity that promotes yield and support nutrient efficiency (Ramesh and Reddy, 2011). Moreover, zeolite treatment is able to increase protein quality of rice, develop nitrogen efficiency and, in the long-term application, promote recovery of soil nitrogen level (Sepaskhah and Barzegar, 2010). The application of manure as organic fertilizer is an effort to develop the carbon sequestration for climate change mitigation scenario, to increase fertility, chemical, physical, and biological properties of the soil, to develop agronomic performance and to increase the yield as well as to enhance the soil organic nitrogen content (Diacono and Montemurro, 2011; Mulyadi and Wihardjaka, 2014). However, manure and other organic material as a soil amendment in rice field contributes to the increase in methane emissions (Dendooven et al., 2012).

Agriculture sector is one of the sources of greenhouse gas (GHG) emissions especially methane (CH_4), dinitro oxide (N_2O) and carbon dioxide (CO_2), in which each gas contributes 15%, 6% and 55% of the total emissions, respectively (Mosier et al., 1994). Rainfed as part of agriculture ecosystem also plays a role as a source of emission releasing the GHG to the atmosphere. Appropriate technology is needed to reduce GHG emissions from rainfed rice system. This study aimed to determine the level of CH_4 gas emissions from rainfed rice field in the *surjan* system treated with manure and zeolite.

MATERIALS AND METHODS

The research was conducted in the Indonesian Agricultural Environment Research Institute field trial during the rainy season in 2012. The experiment was carried out on a plot trial with the plot size of 6 m x 46.5 m using rice cv. Ciherang grown at the aquatic grooves of *surjan*. Meanwhile, the terrestrial area of *surjan* with a size of 2 m x 46.5 m was used to grow mango (Figure 1). The *surjan* cross-section consisted of the aquatic grooves as a subsoil (*tabukan part*) in a high bulk density, planted with rice, and the terrestrial part/topsoil (guludan part), planted with mango (Wihardjaka dan Indratin, 2002).

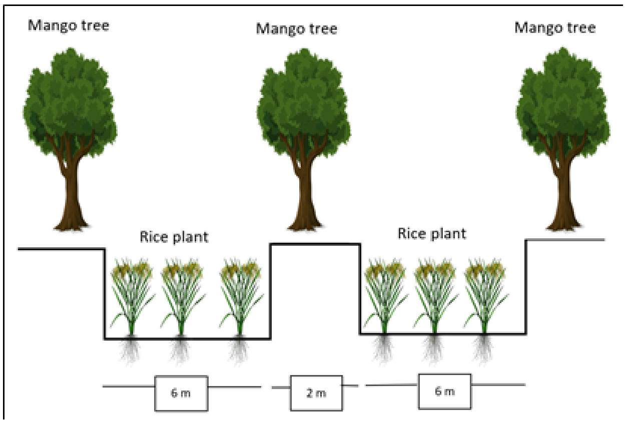

Figure 1. Agricultural Plan of the Surjan System of Rice with Mango Trees in Rainfed Areas

There were combination treatments between manure and zeolite. The manure application rates were 5, 15, 30 tons/ha, while the zeolite treatment rates were 1 and 2.5 tons/ha. Manure and zeolite were applied at the beginning of planting time. The basalt fertilizer, such as urea was applied at a dose of 250 kg/ha in each plot with leaf color chart as guidance. The dose of. P_2O_5 was 36 kg/ha applied at the beginning of planting along with the application of manure and zeolite. Meanwhile, K_2O was applied at a dose of 60 kg/ha, twice in one planting season. The first application of K2O fertilizer was 30 kg/ha at the beginning of planting along with P_2O_5, manure and zeolite application, while the second application was at 39 Days After Transplanting (DAT). The variables observed were grain yield ((*gabah kering panen (GKP)*) at 14% water content and methane emissions from *surjan* in the rainfed system. The grain yield was obtained by using harvest sampling area with a size of 2.5 x 2.5 m.

The sampling of CH_4 emissions was performed by capturing the air samples using a closed chamber method with a dimension of 50 cm × 50 cm × 103 cm. The three-time interval for gas sampling were 10, 20, and 30 minutes. The gas was taken from the chamber using a 10 ml of syringe then the methane was analyzed by Gas Chromatography 8A which has an FID detector (Flame Ionization Detector) to analyze CH_4 concentration. The CH_4 gas was observed 3 (three) times in 1 (one) growing season according to the growth development phase of rice plants. The Global Warming Potential (GWP) of methane was calculated using the CO_2 equivalent weight (kg CO_2eq/ha). The potential radiative value of methane, as a relative value to CO_2, was used at 25 (Houghton et al., 2001).

According to Khalil et al. (1991), the methane emissions from methane concentration can be calculated using the equation:

$$F = \frac{dc}{dt} \; x \; \frac{Vch}{Ach} \; x \; \frac{mW}{mV} \; x \; \frac{273{,}2}{(273{,}2+T)}$$

Annotation:

F : Flux of methane (mg/m^2/minute)

dc/dt : Slope concentration of methane/time sampling (ppm/minute)

Vch: Volume of the chamber (m^3)

Ach : Base area of the chamber (m^2)

mW : The molecule weight of methane (g)

mV : The molecule volume of methane (22.41 l)

T : Average temperature during gas sampling (°C)

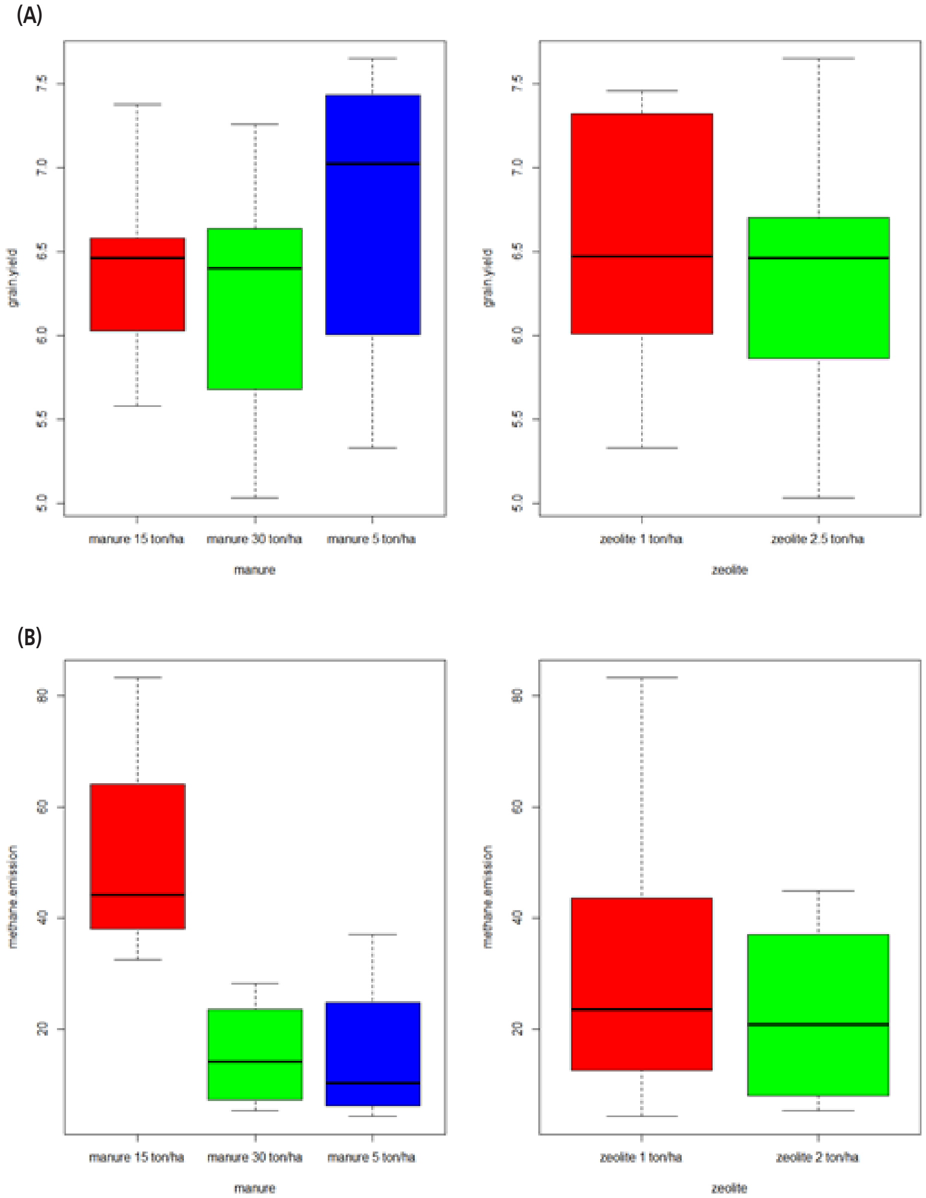

Figure 2. Boxplot FF ANOVA of the Effect of Manure and Zeolite Treatment on Methane Emissions (A) and Grain Yield (GKP) (B)

Data Analysis

For statistical analysis, the R Studio (version 3.2.1) was used to analyze the data. The Levene test and Shapiro-Wilk was used to analyze the homogeneity and normality distribution of the parametric data. Meanwhile, FF ANOVA was used to analyze methane emission and yield. Post hoc test was used to examine the differences between the treatment.

RESULS AND DISCUSSION

There was no significant interaction effect between manure and zeolite on the methane emissions (F = 1.8; df = 2; P = 0.24). Based on the statistical tests (FF ANOVA), manure had a significant effect on CH_4 emissions (F = 7.39; df = 2; P = 0.24), while zeolite did not significantly affect CH_4 emissions (F = 1.06; df = 1; P = 0.34) (Figure 2a). The post hoc test at 95% level showed that manure treatment at 5 tons/ha (P = 0.01) and at 30 tons/ha (P = 0.03) significantly affected CH_4 emissions from the rice fields with *surjan* planting system.

The application of manure and zeolite did not significantly affect the daily CH_4 flux (P> 0.05) (Table 1). At 69 DAT, the addition of 2.5 tons/ha of zeolite showed a smaller CH_4 flux compared to the addition of 1 ton/ha of zeolite. The addition of 2.5 tons/ha zeolite was able to suppress CH_4 flux by 80%, 46% and 24% in the treatment of 5 tons/ha, 15 tons/ha, 30 tons/ha of manure at 69 DAT, respectively.

There was no significant interaction effect between manure and zeolite on the grain yield (F = 1.94; df = 2; P = 0.17). Manure treatment (F = 1.08; df = 2; P = 0.36) and zeolite treatment (F = 0.37; df = 1. P = 0.55) had no significant effect on the grain yield (*GKP*) (Figure 2b). The harvested grains in all treatments were between 5.7 to 6.9 tons/ha (Table 2). The manure treatment at 5 tons/ha combined with zeolite at 2.5 tons/ha produced grain yield 21% greater than the treatment of 30 tons/ha combined with zeolite at 2.5 tons/ha that produced the lowest grain yield. Treatment of zeolite at 2.5 tons/ha combined with 5 tons of manure tended to increase the grain yield (GKP) significantly than the treatment of zeolite at 1 ton/ha. Similarly, the research result from Al-Jabri, (2009)stated that the application of zeolite combined with manure will increase the grain yield (GKP).

The post hoc test showed that manure treatment at 15 tons/ha combined with Zeolite at 1 ton/ha produced a CH_4 emission level that was significantly different from all treatments except the treatment of manure at 15 tons/ha combined with zeolite at 2.5 tons/ha (Table 3). It showed that the treatment of zeolite can reduce methane emissions. Zeolite can be used as an addictive substance to inhibit methane emissions (Mukesh et al., 2016), moreover, zeolite is a cheap ameliorant as a mitigating agent for reducing methane emission (Hui and Chao, 2008). Zeolite, as a stable material, has a capability of storing methane (Joseph et al.,

Table 1. Flux of CH_4 during three rice plant growth periods as affected by the application of manure and zeolite at various doses

Flux ($mg/m^2/day$)	40 DAT	55 DAT	69 DAT
Manure 5 ton/ha + Zeolite 1 ton/ha	10.65	6.65	70.65
Manure 5 ton/ha + Zeolite 2.5 ton/ha	27.15	3.25	14.15
Manure 15 ton/ha + Zeolite 1 ton/ha	59.90	5.20	76.40
Manure 15 ton/ha + Zeolite 2.5 ton/ha	58.70	3.50	40.95
Manure 30 ton/ha + Zeolite 1 ton/ha	29.80	3.55	35.25
Manure 30 ton/ha + Zeolite 2.5 ton/ha	3.30	8.90	26.95

Table 2. Grain yield (*GKP*) with 14% water content as affected by the application of manure and zeolite at various doses

Flux ($mg/m^2/day$)	Grain yield 14% (ton/ha)
Manure 5 ton/ha + Zeolite 1 ton/ha	6.461
Manure 5 ton/ha + Zeolite 2.5 ton/ha	6.992
Manure 15 ton/ha + Zeolite 1 ton/ha	6.465
Manure 15 ton/ha + Zeolite 2.5 ton/ha	6.292
Manure 30 ton/ha + Zeolite 1 ton/ha	6.668
Manure 30 ton/ha + Zeolite 2.5 ton/ha	5.761

Table 3. Methane emission, Global Warming Potential (GWP), Global Warming Potential-Yield (GWPy) as affected by the application of manure and zeolite at various doses

Flux (mg/m^2/day)	CH_4 kg CH_4 / ha / season	GWP kg CO_2-eq/ ha / season	GWPy kg CO_2-eq/ ton/ season
Manure 5 ton/ha + Zeolite 1 ton/ha	17.2 b	430.3	67
Manure 5 ton/ha + Zeolite 2.5 ton/ha	22.5 b	563.8	81
Manure 15 ton/ha + Zeolite 1 ton/ha	63.4 a	1585.8	245
Manure 15 ton/ha + Zeolite 2.5 ton/ha	38.6 ab	966.5	154
Manure 30 ton/ha + Zeolite 1 ton/ha	23.6 b	590	88
Manure 30 ton/ha + Zeolite 2.5 ton/ha	7.4 b	185.3	32

Remarks: Means followed by the same letters in the same column are not significantly different according to post hoc test at a 95% level.

1983; Eckhard and Matthias, 1997; Myrsini et al., 2014). Therefore, manure amendment to the soil as an organic fertilizer and as a substrate of methanogenesis to produce methane has no significant effect on methane emissions.

CONCLUSION

All treatments had no significant effect on the daily methane flux and harvested grain yield in the rice field with *surjan* system. The application of manure at 15 tons/ha combined with zeolite at 1 ton/ha promoted higher methane emission at 63.43 kg CH4/ha/season than the combination of other treatments. The great grain yield (GKP) was obtained in the application of manure at 5 tons/ ha combined with 2.5 tons/ha of zeolite, reaching 6.9 tons/ha of rice grain yield.

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