Methane Emisions from Some Rice Cultivars in Rainfed Rice Field

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ABSTRAK

Emisi Gas Metana pada beberapa Varitas Padi di Lahan Sawah Tadah Hujan. Keragaman emisi gas metana dipengaruhi oleh karakteristik pada varitas tanaman padi yang berbeda umur, sifat, dan aktivitas sistim perakarannya. Penelitian lapang dilaksanakan di lahan sawah tadah hujan pada musim penghujan 2003/2004 dengan tujuan untuk mengetahui emisi gas metana dari beberapa varitas padi unggul yang dibudidayakan secara gogorancah dan untuk mengetahui varitas tertentu yang mampu mengemisi metana rendah sekaligus memberikan hasil gabah tinggi. Percobaan disusun menggunakan rancangan acak kelompok dengan 3 ulangan pada 7 varitas padi, yaitu IR64, Cisantana, Sintanur, Way Apoburu, Dodokan, Silugonggo, Mentik (varitas lokal). Pengambilan contoh gas di lapangan dilakukan dengan sungkup dan contoh gas diinjeksikan ke alat kromatografi gas dengan detektor FID untuk menetapkan fluks metana. Hasil penelitian menunjukkan bahwa emisi gas CH_4 dari tanaman padi varitas Way Apoburu < Dodokan < Silugonggo < Cisantana < Sintanur < lokal Mentik < IR64. Potensi daya hasil varitas lokal Mentik lebih rendah daripada IR 64 dan IR 64 lebih rendah daripada varitas Silugonggo, Cisantana, Way Apoburu, Dodokan, dan Sintanur. Varitas Way Apoburu yang dibudidayakan dengan sistem gogorancah mengemisi gas metana paling sedikit dan memberikan hasil gabah paling tinggi.

Kata kunci : Emisi metana, varitas padi, sawah tadah hujan

INTRODUCTION

Estimation of methane emission from the rice field varies, and the average emission is predicted as 100 Tg year^{-1} (Yagi & Minami 1990; ALGAS 1998). According to Dober-mann & Fairhurts (2000), global methane emission from flooded lowland is about 40-50 Tg year^{-1}, or ~10% of total global methane emission. Indonesia's rice fields cover 8.97 million ha or 6.8 % of world's rice fields which are predicted to emit CH_4 gas in range of 3,4-9.8 Tg year^{-1} (ALGAS 1998, Bachelet & Neue, 1993, Japan Environmental Agency 1992). Methane emission contributes 15% of GHGs effect which is lower than CO_2 emission (Mosier *et al.* 1994).

Rice crop has an important role in releasing methane to the atmosphere, more than 80% methane is released from soil to atmosphere through rice crop which act as a chimney. Methane diffusion from reducted soil also takes place through aerenchyma tissues (Neue

& Sass 1994). Other ways of releasing methane from rice soil to atmosphere are smaller ammount of bubble up to the water surface (ebullition) or diffuse slowly through the water (Holzapfel-Pschorn *et al.* 1986). Methane gas is released to atmosphere through the micro pores of crop (Nouchi 1992).

Related to technique of environmental culture, rice cultivars selection should consider their ability in releasing atmospheric CH_4 which depend on cultivar characteristics and soil condition (Neue & Roger 1993). Each cultivar has different root activities, like root exudates and gas change rate, which is related to the volume of CH_4 emission (Wagatsuma *et al.* 1990). The difference of magnitude and property of root exudates in different cultivars is influenced by the ammount of CH_4 magnitude as methanogenesis product which uses root exudates as carbon sources (Neue *et al* 1990; Shalini-Singh *et al.* 1997).

Root exudates is highly produced at reproductive growth stage, especially at heading stage, because of the suitable environmental conditions. Root exudates are organic substances such as carbohydrate, organic acids, amino acids which are fermented to acetate or CO_2 and H^+, that it willl be transfered into methane through methanogenic bacteria (Holzapfel-Pschron *et al.* 1986).

Flooded soil has ideal condition in forming methane with potential redox (Eh value) less than -150 mV (Neue & Scharpenseel 1990). According to Wang *et al.* (1993), CH_4 fluxes significantly decreased with the increase of soil redox potential. Draining of water from flooded soil could deplete the methane formation in the soil rhizosphere.

MATERIALS AND METHODS

Field experiment was carried out in farmers fields of Pucakwangi, Pati District (15 m Asl, 111°10' E and 6°45' S) during wet season (2003/2004). The soil is classified as Vertic Endoaquepts which is a type of soil Inceptisol which has swelling and shrinkage of slickenside in its structure (Soil Survey Staff 1998). Characteristics of Vertic Endoaquepts in 0-20 cm depth were moderately acid at pH-H_2O 5.6, low total N content (0.3 mg g^{-1}), low C-organic content (3.2 mg g^{-1}), low P extracted Bray 1 (5.06 ppm P), low CEC (6.96 cmol(+) kg^{-1}), low base cations contents of 0,12; 0,24; 3,05; and 0,61 cmol(+) kg^{-1} of K, Na, Ca, Mg, respectively. The status of soil nutrients was based on classification of soil chemical evaluation (Sarief 1985).

Experiment was arranged by using randomized block design with three replicatios and seven rice cultivars, namely IR64, Cisantana, Dodokan, Sintanur, Silugonggo, Way Apoburu, and local variety of Mentik. The short-duration cultivars such as Dodokan and Silugonggo have less than 100-day maturity, and moderate-duration cultivars such as IR64, Cisantana, Sintanur, Way Apoburu have a range 100 to 110-day maturity, whereas deeper-duration cultivar such as Mentik has more than 110-day maturity (De Datta, 1981).

Rice cultivars were planted using direct seeded system on 23 October 2003 and were harvested on 4 February 2004 for Dodokan and Silugonggo whereas R64, Cisantana, Sintanur, Way Apoburu cultivars were harvested on 27 February 2004, and 15 March 2004 for local cultivar of Mentik.

Seeds were planted using dibble in plots with size of 5 m X 6 m and spacing of 20 cm X 20 cm. Each dibbling hole was laid with 5-8 grains. Before transplanting, intensive land preparation was done by twice plowing, once harrow followed by plotting. Pre-emergence herbicide of oxadiazon was applied after planting.

The fertilizers were applied fit to site of specific recommended rates, which are 120 kg N of urea, 25 kg P of SP36, 50 kg K of KCl/ha. Nitrogen fertilizer was applied three times, 40 kg N at 20, 40, and 50 days after germination (DAG). Phosphorus fertilizer was applied once at 20 DAG, whereas 25 kg K potassium fertilizer was applied two splits at 20 and 40 DAG.

Parameters of observation were plant height, tillers number, yield components, grain yield, methane flux and soil pH, moisture, and water fluctuation. Plant height and tiller number were measured from 16 hills each plot at active tillering and maturity stages. Yield components that covered total grain number, percentage of filled grains, 1000-grains were measured from three hill samples per plot. Grain yield at 14% moisture content and straw weight were observed from area harvest of 2 m X 3 m. Soil moisture content during plant growth was observed to determine soil water fluctuation. Each plot was taken at two soil depths, 0-15 cm and 15-30 cm soil depth.

The daily methane fluxes were measured from the early growth stage of rice. The chamber that was used to trap the methane emitted by the plants was composed of gas-collecting plexiglass boxes with the dimension of 40 cm X 40 cm X 100 cm. The air samples within the chamber were drawn with time interval of 5, 10, 15, and 20 minutes after laying the chamber in the plots using a 5-ml plastic syringes. After 20 minutes of measurement, the chamber was removed and the rice crop was exposed to normal condition. The gas sample was analyzed using gas chromatography model Shimadzu equipped with a flame ionization detector (FID) to determine methane fluxes. The methane flux was calculated using Khalil *et al.* (1991).

Soil pH were observed every day from 10 to 85 days after germination (DAG) using pH meter model Scott Handy Lab 1. The collected data was analyzed using analysis of variance, followed by LSD test at 5% to determine the significance of inter treatments.

RESULTS

Methane Gas Emission.

Characteristics of certain rice cultivar affect magnitude of methane flux. Figure 1 shows CH_4 flux from some superior rice cultivars cultured with direct seeded system. The highest emission was released by IR64 (73 kg CH_4 ha^{-1} $season^{-1}$) followed by Mentik

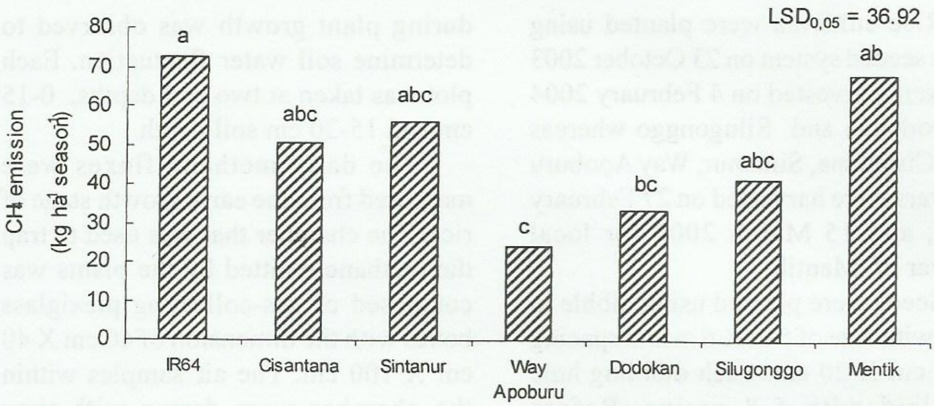

Figure 1. Methane emission from some cultivars in rainfed rice field of Pucakwangi, Pati District, during the 2003/2004 wet season. The same letter was not significant different at 0.05 according to LSD test.

(68 kg), Sintanur (56 kg), Cisantana (51 kg), and Silugonggo (42 kg). On the other hand, the lowest emission was achieved on plot planted with Way Apoburu (24 kg CH_4 ha^{-1} season^{-1}) followed by Dodokan cultivar (34 kg). Based on statistical analysis, CH_4 flux of IR64 was not significantly different from Mentik, Sintanur, Cisantana, and Silugonggo cultivars, although maturity time among cultivars were different. Way Apoburu did not also differ from Dodokan, Silugonggo, Cisantana, and Sintanur. This indicates that either moderate duration cultivars (IR64, Cisantana, Sintanur, Way Apoburu) or deeper-duration cultivar (Mentik) inconsistently fluxed methane higher than shorter-duration cultivars (Dodokan, Silugonggo).

The low daily methane emission was found from cultivars of Dodokan, Silugonggo, and Way Apoburu. The highest emission was occurred at range of early of reproductive stage – heading growth stage or at 58 – 74 days after sowing (Figure 2). IR 64 cultivar emitted highest daily CH_4 followed by local cultivar of Mentik, Cisantana, and Sintanur. During vegetative growth stage (active tillering–panicle initation), daily CH_4 emission patterns among cultivars were relatively similar (less than 0.5 mg m^{-2} jam^{-1}). The methane flux at ripening growth stage was further as same as vegetative stage.

Direct Seeded Rice Yield

Local cultivar of Mentik with slower growth (> 120 days) grow better, but it was able to generate lower tillers than others under rainfed rice field system (Table 1). However, plant height and tiller number in more slower growth cultivar of Dodokan and Silugonggo (80–90 days) not significantly differ with moderate growth of IR 64, Cisantana, Sintanur, Way Apoburu (110-120 days).

Grain yield among rice cultivars significantly varied and yield potency also differed (Table 2). All of rice cultivars fitted to be cultured as a direct seeded system which was showed by trend of lower grain yield. Grain yield of Cisantana, Sintanur, Way Apoburu, Dodokan and Silugonggo cultivars did not significantly differ, but higher than IR 64 and Mentik.

The shorter-duration cultivars such as Silugonggo and Dodokan yielded lower straw and roots mass than that of medium-duration cultivars such as Cisantana, Sintanur, Way Apoburu, and IR64 (Table 2). The Silugonggo gave the lowest straw yield and roots mass. Yield components among cultivars such as grain number per panicle and weight of 1000 grains varied significantly, where grains number of local cultivar of Mentik was lower than Sintanur but unsignificant different with cultivars of IR 64, Cisantana, Way Apoburu, Dodokan. The 1000-grains weight and

Table 1. Plant height and tiller number of some rice cultivars cultured with direct seeded system, Pati District, the wet season of 2003/2004.

Cultivars	Plant height (cm)		Tiller number per hill	
	Max. tillering	Maturity	Maximum	Productive
Mentik	52.2 a	127.2 a	12.8 c	11.2 d
IR64	35.7 c	89.5 cd	21.8 a	19.0 ab
Cisantana	34.5 cd	93.7c	18.2 ab	17.2 b
Sintanur	36.9 c	112.9 b	15.8 bc	14.6 c
Way Apoburu	31.6 d	89.5 cd	17.2 abc	18.8 ab
Dodokan	41.3 b	92.3 c	19.7 ab	19.5 a
Silugonggo	36.[illegible]	79.8 d	18.4 ab	18.0 ab
$LSD_{0,05}$	4.07	9.83	5.30	2.15
CV (%)	5.94	5.65	16.86	7.15

Mean in column followed by same letter did not significantly differ at 0.05 level according to LSD test

Table 2. Yield of some rice cultivars cultured with direct seeded system in Pati District during the wet season of 2003/2004.

Cultivars	Grain number per panicle		1000-grains weight (g)	Root weight per hill (g)	Yield (t ha^{-1})	
	Total	Filled (%)			Grain	Straw
Mentik	94.7 bc	63.8 bc	19.63 c	7.87 a	2.51 c	9.88 cd
IR64	90.3 c	71.7 a	24.26 b	5.07 b	3.61 b	10.90 b
Cisantana	99.4 b	72.6 a	23.56 b	4.63 b	4.56 a	11.64 b
Sintanur	110.5 a	72.5 a	24.55 ab	4.83 b	4.88 a	13.69 a
Way Apoburu	92.0 bc	68.4 ab	25.50 a	4.80 b	4.36 ab	10.80 bc
Dodokan	98.3 bc	67.4 abc	23.39 b	2.48 c	4.88 a	9.24 de
Silugonggo	98.1 bc	62.7 c	24.00 b	1.75 c	4.24 ab	8.37 e
$LSD_{0,05}$	8.40	5.39	1.16	1.96	0.79	0.93
CV (%)	4.84	4.43	2.77	24.60	10.67	4.92

Mean in column followed by same letter did not significantly differ at 0.05 level according to LSD test

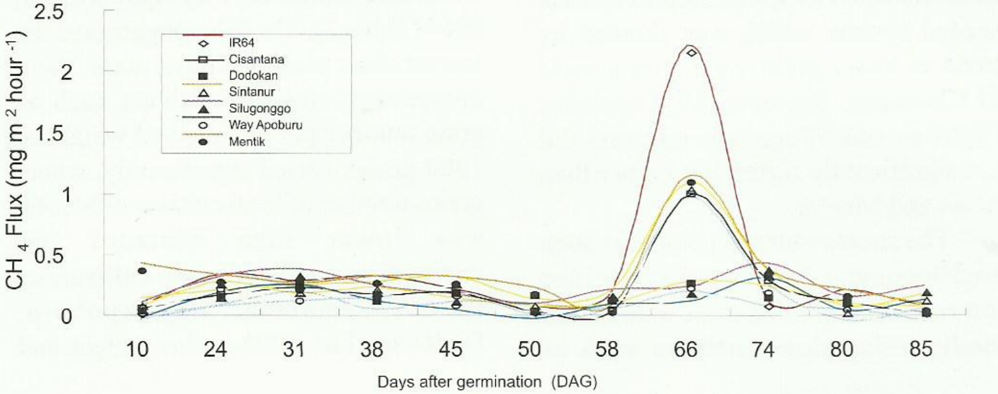

Figure 2. Daily methane emission pattern during direct seeded rice growth in Pati District During the 2003/2004 wet season

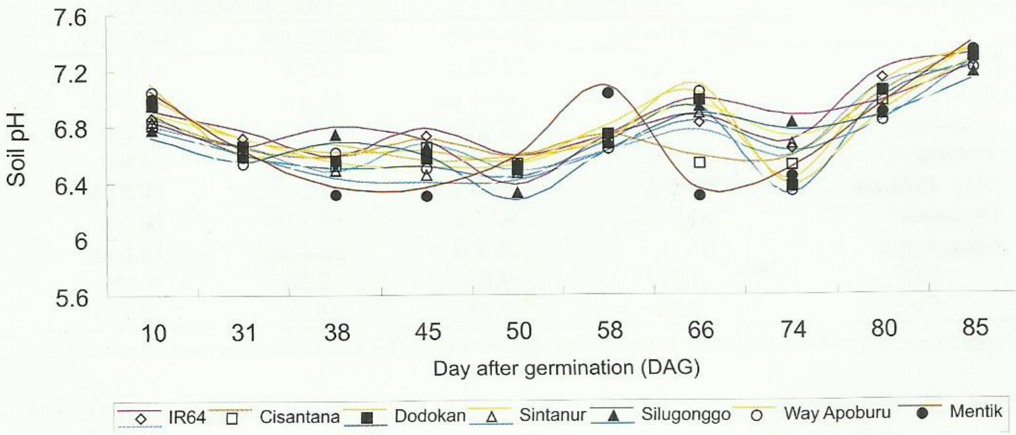

Figure 3. Soil reaction change on some rice cultivars treated in Pati during the wet season of 2003/2004

filled grains of Mentik was relatively lower than others. The filled grains number of Silugonggo was also lowest. High grain number and filled grains reflected high grain and straw yield (Table 2).

DISCUSSION

The IR64 cultured in rainfed lowland with soil classified as Vertic Endoaquepts emitted the significantly highest methane compared with either moderate or deeper cultivars. If compared with IR 64, the following cultivars could reduce atmospheric methane emission: 6.0% (Mentik), 22.5% (Sintanur), 30.3% (Cisantana), 39.0% (Silugonggo), 31.0% (Dodokan), and 66.5% (Way Apoburu). Variability of methane emission magnitude among such cultivars, also depend on physiological and morphological properties of rice cultivars. According to Yagi & Minami (1990), each rice cultivar has certain maturity time, characteristic, and roots activity, so that released methane magnitude through rice crop also differs. Neue *et al.* (1993) added that methane flux is affected by diameter of aerenchyma space of rice cultivars, tillers number, rice plant biomass, rooting pattern, and metabolism activity.

Methanogenic bacteria will more active in producing methane at optimum pH surrounding rhizosphere of 6.4–7.2 (Figure 3). Neutral soil reaction favors methanogenic bacteria in its metabolism processes. Most of methanogenic bacteria grow under relatively narrow range of pH 6 – 8, and the optimum pH for CH_4 formation is about 7 (Neue & Scharpenseel 1990; Neue & Sass 1994). Acidification in surrounding of rhizosphere affects activity of methanogenic bacteria. The highest production rate of methane in acidic rice field occur on pH 6.9 –7.1 (Wang *et al.*1993).

The highest daily methane emission was gained at 58–74 days after germination (DAG) when soil moisture content was relatively high at 58–68 DAG (Figure 4) . The vegetative growth stage usually occurs at 43-84 days after germination. The reproductive stage occurs at 62-109 days after germination depend on cultivar type (De Datta 1981). It is predicted that crops produce root exudates more in these conditions compared with other growth stages, and soil moisture suitable for methanogenic bacteria activity to produce high methane.

The increase of soil moisture content tends to increase methane emission. It was showed by linier equation of $CH_4 = 0.0014+0.00004$ MC ($r = 0.87^*$), whit MC is moisture content. The increase of soil moisture will rise up methane formation because methanogenic bacteria as a facultative anaerobic bacteria by redox potential ranged between -150 and -200 mV (Wang *et al.* 1993, Neue & Sass 1994).

The lowest grain yield was obtained by Mentik, whereas the highest grain yield was produced by Sintanur and Dodokan (Table 2). According to Yoshida (1981), cultivar with longer growth duration such as Mentik may not have high yield because of the excessive vegetative growth which may cause lodging.

The low straw yield was obtained by Silugonggo, Dodokan, and Mentik , whereas the moderate straw yield cultivars was more than 10 t/ha. The highest straw yield was gained by Sintanur cultivar. The lowest straw yield may be caused by limited vegetative growth for the shorter growth duration cultivars and excessive vegetative growth for cultivar of deeper growth duration (Yoshida, 1981).

Root biomass of sequence cultivars were Silugonggo < Dodokan < Cisantana < Way Apoburu < Sintanur < IR 64 < Mentik (Table 2). According to Neue & Roger (1993) and Neue & Sass (1994), amount of roots mass could increase methane produced, where root biomass has a significant positive correlation with

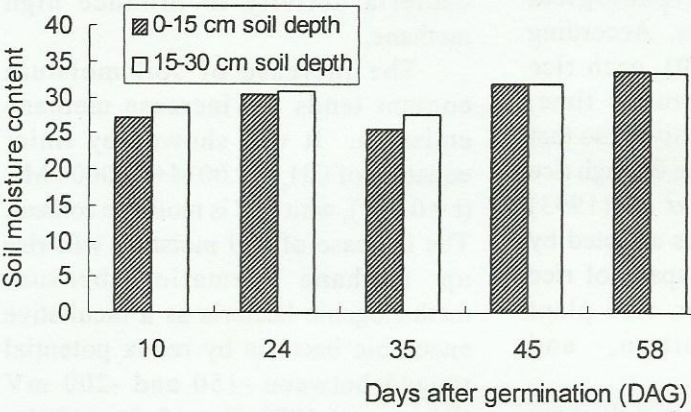

Figure 4. Soil moisture content during growing direct seeded rice crop in Pati District during the wet season of 2003/2004

CH_4 production. The higher roots mass of rice plants increase amounts of carbohydrate from their roots and root exudates which may represent a significant source of methane in lowland. The reduced exudation of carbon compound can be used directly or indirectly by methanogenic bacteria for methane production (Wassman *et al.* 1993).

Subadiyasa *et al.* (1997) used ratio between methane emission and rice grain yield to predict rice cultivar that potentially give highest grain yield and contribute lowest methane emission. Based on Figure 1 and Table 2, the highest ratio was achieved Mentik cultivar (27.1 kg CH_4 t^{-1} grains), followed by IR64 (20.2 kg CH_4 t^{-1} grains), Sintanur (11.5 kg CH_4 t^{-1} grains), Cisantana (11.2 kg CH_4 t^{-1} grains), Silugonggo (9.9 kg CH_4 t^{-1} grains), Dodokan (7.0 kg CH_4 t^{-1} grains), and the lowest ratio of Way Apoburu cultivar (5.5 kg CH_4 t^{-1} grains). It means that Way Apoburu cultivar give relatively high grains yield and low methane emission.

CONCLUSION

1. Production of methane emission from seven rice cultivars showed that Way Apoburu < Dodokan < Silugonggo < Cisantana < Sintanur < local cultivar of Mentik < IR64.
2. Yield potency of Mentik cultivar was lower than that of IR 64, whereas IR 64 cultivar was lower than Silugonggo, Cisantana, Way Apoburu, Dodokan, and Sintanur cultivars.
3. Among the rice cultivars which have been tested, Way Apoburu cultivar could emit the lowest methane gas and highest grain yield.

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