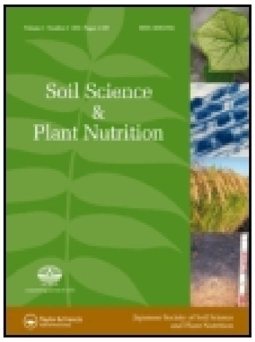

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Methane Emission from an Indonesian Paddy Field Subjected to Several Fertilizer Treatments

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Methane emission rates from a paddy field in Indonesia subjected to several fertilizer treatments were measured every week throughout the rice growing period.

The mean CH_4 emission rates (mg CH_4 m^{-2} h^{-1}) throughout whole growth period were in the ranges of 18.0–23.2 from chemical fertilizer plots and 19.5–27.1 from plots amended with both urea and organic materials. These rates were in the range of those reported from respective treatments in the temperate region. The effects of application of organic materials on the CH_4 emission rates were less conspicuous than those of the reported results. The total CH_4 emission (g CH_4 m^{-2}) throughout the growth period amounted to 31–40 from chemical fertilizer plots and 34–47 from plots amended with organic materials, respectively.

Methane was mainly emitted in the first half of the growth period irrespective of treatments, which was in accordance with the results obtained in Thailand, and in contrast to those reported in the temperate region, where CH_4 emission occurred mainly in the second half of the growth period.

Key Words: **fertilizer, methane emission, paddy field, seasonal variation, tropical country.**

Recently methane has received a great deal of attention as one of the important greenhouse gases. Among the sources of CH_4 emission, paddy fields are estimated to contribute to ca. 12% of the total emission (Watson et al. 1992).

Since the data on CH_4 emission rates from tropical paddy fields are comparatively limited (Denier van der gon et al. 1992; Yagi et al. 1994; Jermsawatdipong et al. 1994), the total amount of CH_4 emitted from the paddy fields in the world has been estimated by using data from paddy fields in the temperate region (Schütz et al. 1990; Mathews et al. 1991; Anastasi et al. 1992). Therefore direct measurement of CH_4 emission from paddy fields in various tropical countries are urgently needed.

In the present paper, the first data on CH_4 emission rates from a paddy field subjected to several fertilizer treatments in Indonesia and the total emission were reported.

MATERIALS AND METHODS

Experimental field and cultivation of rice plants. The experimental field was located in Taman Bogo, Central Lampung, Southern Sumatra, Indonesia. The soil was classified as a Typic Paleudult (Red Yellow Podzolic Soil). Chemical properties of the soil are listed in Table 1.

The experimental field consisted of 6 plots; 3 chemical fertilizer plots and 3 plots amended with both chemical fertilizer and organic materials (rice straw, *Sesbania rostrata* or cow dung manure) (Table 2). *Sesbania rostrata* is applied as green manure in Indonesia. The area of each plot was 7×22.5 m^2. Top-dressing of nitrogen fertilizer was performed twice.

Rice plants (*Oryza sativa* var. IR-64) were cultivated during the rainy season from December, 1992, to March, 1993. Twenty-day-old seedlings were transplanted (3 seedlings hill^{-1}) to the experimental field at a spacing of 20 cm$\times$20 cm, which was submerged before transplanting and irrigated when needed to maintain continuous flooded conditions throughout the growth period. The cultivation calendar is shown in Table 3.

Measurement of CH_4 emission. Methane emission rates were measured every week throughout the growth period. Four hills of rice plants were covered with an acrylic box chamber ($40 \times 40 \times 100$ cm^3). Stakes were driven into soil at the beginning of the experiment to set the chamber on the soil surface. A Tedlar bag (2 L) was attached to the chamber to keep the inside pressure equal to the atmospheric pressure. A rubber stopper, which was

Table 1. Physicochemical properties of soil.

pH(H_2O)	5.0
pH(KCl)	3.8
Total-C (10^{-2} kg kg^{-1})	1.15
Total-N (10^{-2} kg kg^{-1})	0.16
CEC (cmol(+) kg^{-1})	5.16
Available P (10^{-6} kg kg^{-1})[a]	1.50
Soil texture	LiC
Sand	51%
Silt	17%
Clay	32%

[a] Bray I (Bray and Kurtz 1945).

Table 2. Kinds and amounts of chemical fertilizers and organic materials applied to plots (kg ha^{-1}).

Plot No.	1	2	3	4	5	6
Chemical fertilizer[a]						
Urea+$(NH_4)_2SO_4$	200+100					
Urea		250		250	250	250
$(NH_4)_2SO_4$			500			
Organic materials						
Rice straw				5,000		
Sesbania rostrata					5,000	
Cow dung manure						5,000

[a] Of the total amount of the respective forms of nitrogen fertilizer, one-third was applied as basal-dressing and the first and the second thirds as top-dressing. Two hundred and 100 kg ha^{-1} of triple superphosphate and KCl were applied as basal fertilizers in all the plots, respectively.

Table 3. Cultivation calendar.

Plowing	Nov. 19, 1992
Flooding	Nov. 21, 1992
Transplanting	Dec. 17, 1992
Fertilizer application	
Organic fertilizer	Dec. 10, 1992
Chemical fertilizer	Dec. 17, 1992
Top dressing (1st)	Jan. 6, 1993
Top dressing (2nd)	Feb. 1, 1993
Heading	Feb. 1, 1993
Drainage	Mar. 4, 1993
Harvesting	Mar. 18, 1993

pierced with a glass tube and plugged with a septum (Shimadzu Co. Japan), was attached on the ceiling of the chamber for collecting gas samples. The gas samples were taken three times at 20 min intervals by transferring the inside air into an evacuated 10 mL glass tube through the septum using a double-ended hypodermic needle. The measurement was conducted in triplicate with 3 chambers in each plot.

The tubes with the samples were brought back to the Laboratory of Soil Biology, Faculty of Agriculture, Lampung University, and the CH_4 content in the tube was determined on the same day with a gas chromatograph equipped with a flame ionization detector (GC-8AIF, Shimadzu Co.). Methane emission rate was calculated from the increase of CH_4 concentration in the air with time and the volume in the chamber.

RESULTS AND DISCUSSION

Methane emission rates from chemical fertilizer plots. Figure 1 shows the 5 d running means of daily mean temperature and 5 d total amount of rainfall. Figure 2a shows the CH_4 emission rates from chemical fertilizer plots throughout the growth period. Methane emission rates fluctuated with time with a small peak in the middle growth stage. Methane emission rates from Plot 1 (urea and ammonium sulfate plot) increased slowly with time, and were larger than those from the other chemical fertilizer plots until February 2. Afterwards they decreased to a level similar to that of the CH_4 emission rates from the other plots. Plot 2 (urea plot) recorded 2 small peaks on January 12 and February 9, while Plot 3 (ammonium sulfate plot) showed a peak on January 26.

The influence of the kinds of nitrogen fertilizers on CH_4 emission to the atmosphere was reported by Kimura et al. (1992). In their experiment, CH_4 emission from the plot with ammonium sulfate treatment was the lowest, followed by the plot with ammonium chloride and urea treatments, in this order. However, such an effect was not observed in the ammonium sulfate and urea plots in the present experiment.

Methane emission rates from plots amended with both urea and organic materials. Figure 2b shows the CH_4 emission rates throughout the growth period from the plots amended with both urea and organic materials. For comparison, Plot 2 is also shown in Fig. 2b.

Plot 4 (urea and rice straw plot) recorded the largest emission rates among the plots amended with organic materials throughout the rice growing period except for the first measurement on December 29. Methane emission rates from Plot 5 (urea and *Sesbania* plot)

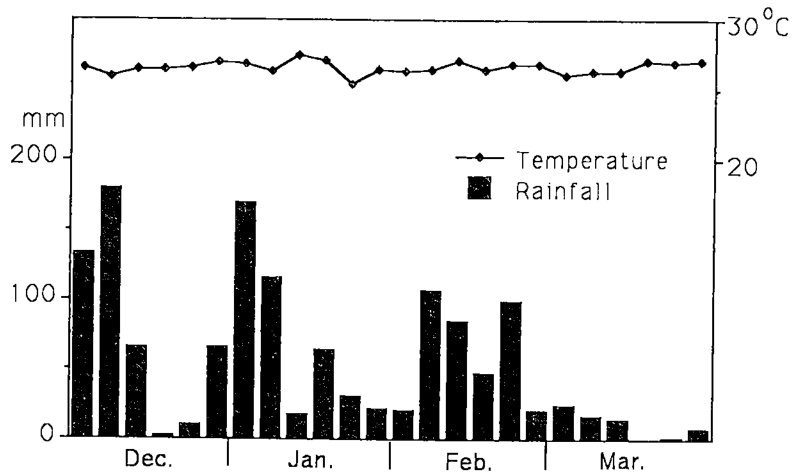

Fig. 1. Five day running means of daily mean air temperature and 5-d total amounts of rainfall.

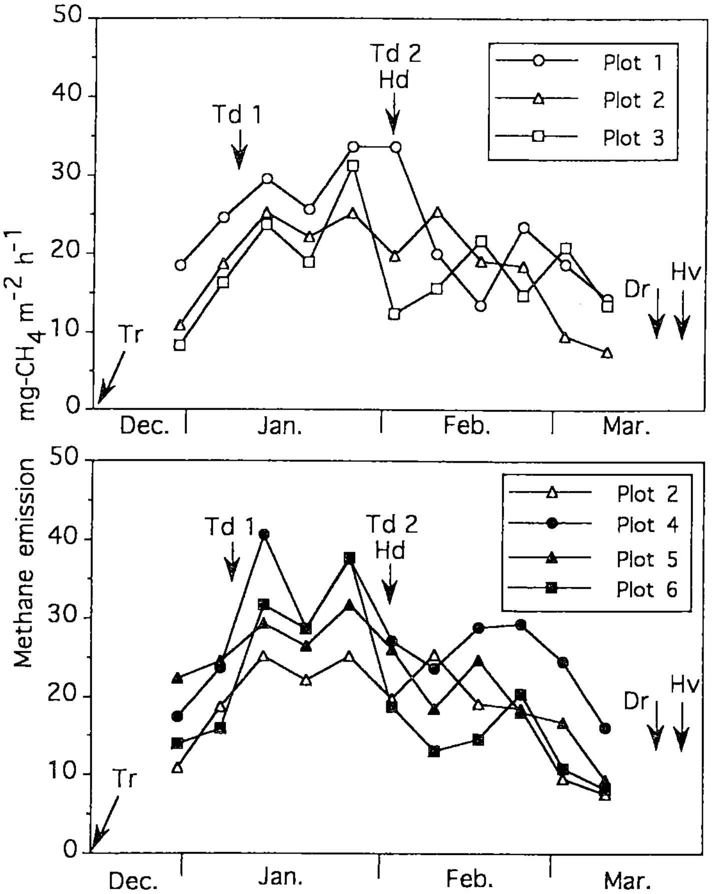

Fig. 2. Seasonal variations of methane emission rates. Plot 1: urea 200+$(NH_4)_2SO_4$ 100 kg ha^{-1}; Plot 2: urea 250 kg ha^{-1}; Plot 3: $(NH_4)_2SO_4$ 500 kg ha^{-1}; Plot 4: urea 250 kg ha^{-1}+rice straw 5,000 kg ha^{-1}; Plot 5: urea 250 kg ha^{-1}+ *Sesbania rostrata* 5,000 kg ha^{-1}; Plot 6: urea 250 kg ha^{-1}+cow dung manure 5,000 kg ha^{-1}. Tr, transplanting; Td1 and Td2, first and second top dressings, respectively; Hd, heading date; Dr, drainage; Hv, harvest.

and Plot 6 (urea and farmyard manure plot) were larger than those from Plot 2 until February 2, when they showed similar emission rates to those from Plot 2.

Mean emission rates and total emission during the rice growing period. Figure 3 shows the mean CH_4 emission rates throughout the growth period. They were in the range of 18.0–23.2 mg CH_4 m^{-2} h^{-1} for the chemical fertilizer plots and 19.5–27.1 mg CH_4 m^{-2} h^{-1} for the plots amended with organic materials, respectively. These emission rates were in the reported range from similar plots in temperate regions (Cicerone and Shetter 1981; Cicerone et al. 1983; Seiler et al. 1984; Holzapfel-Pschorn et al. 1986; Schütz et al. 1989; Khalil et al. 1990; Sass et al. 1990; Yagi and Minami 1990).

The total amount of CH_4 emitted during the rice growing period is shown in Table 4. In the calculation, the CH_4 emission during the interval between transplanting and the first sampling (12 d), and that between the last sampling and harvest were neglected (drainage occurred 1 week after the last sampling). The emission was estimated at 31–40 g CH_4 m^{-2} for the chemical fertilizer plots, and 34–47 g CH_4 m^{-2} for the plots amended with both urea and organic materials, respectively. Thus, the effect of the application of organic materials was not as conspicuous as that observed in Thailand (Jermsawatdipong et al. 1994), and Plot 1 emitted a larger amount of CH_4 than Plots 5 and 6, though in Plots 4, 5, and 6 with additional application of organic materials to urea methane emission increased by 9 to 51% compared with the respective plot amended with urea alone (Plot 2).

Methane emission distribution during the rice growing period. Figure 4 shows

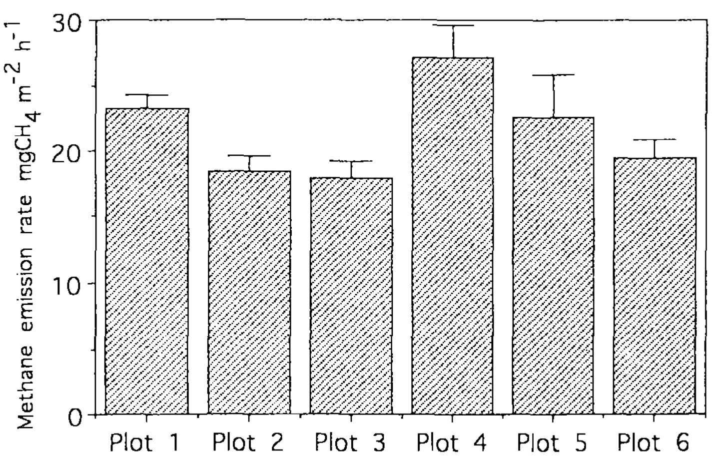

Fig. 3. Mean rates of methane emission throughout the growth period. Plot 1–Plot 6: see Fig. 2. Bars show the standard deviation.

Table 4. Total amount of CH_4 emitted, yield (unhulled rice), and CH_4 emission rate for production of a unit weight of grain.

Plot	Total emission and standard dev. (g CH_4 m^{-2})	Yield (kg ha^{-1})	CH_4 emission rate for 1 kg grain production (g CH_4 kg^{-1})
1	40.2±1.6	5,800	69.3±2.8
2	32.4±2.1	5,500	58.9±3.8
3	31.4±2.5	5,700	55.1±4.4
4	47.2±4.7	6,400	73.8±7.3
5	39.0±5.8	6,100	63.9±9.5
6	34.1±2.7	6,300	54.1±4.3

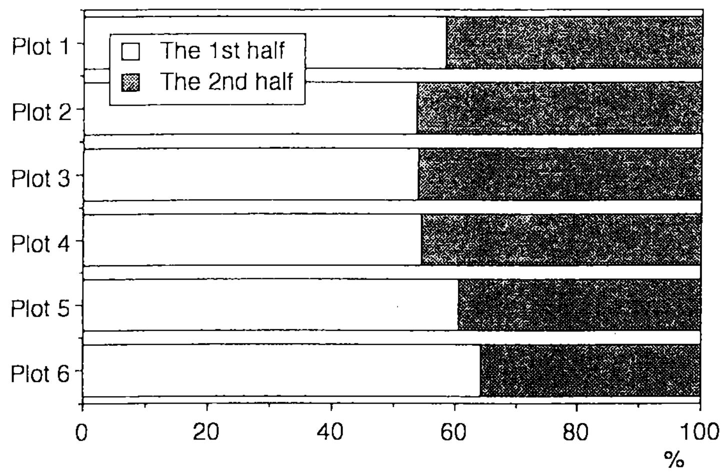

Fig. 4. Percentage distribution of the total amount of methane emitted in the first and second halves of the growth period. Plot 1–Plot 6: see Fig. 2.

the percentage distribution of CH_4 emission in the first and the second halves of the growth period from each plot. The period of measurement of the CH_4 emission rates was equally divided into halves and the total amount of CH_4 emitted in the first and second halves of rice growing period was calculated. More than 50% of CH_4 was emitted in the first half of the growth period, which was in accordance with the results observed in Thailand irrespective of plots, and in contrast with the results obtained in Japan (Jermsawatdipong et al. 1994). This finding reconfirmed the assumption that due to the high temperature from the beginning of rice growth in the tropics (Indonesia) the main decomposition stage of soil and applied organic materials shifted to the early growth stage, which resulted in active CH_4 production from the very beginning of rice growth (Jermsawatdipong et al. 1994).

Methane emission rates for production of a unit weight of grain. The yields of rice and the CH_4 emission rates for the production of a unit weight of grain are shown in Table 4. Yields were in the ranges of 5,500 to 5,800 kg ha^{-1} for the chemical fertilizer plots, and 6,100 to 6,400 kg ha^{-1} for the plots ammended with both urea and organic materials, respectively. These values were higher than the 1991 national average reported in Indonesia (4,600 kg ha^{-1}, National Bureau of Statistics of Indonesia 1992).

The CH_4 emission rates for the production of a unit weight of grain were lowest (54.1 g CH_4 kg^{-1} of grain) for Plot 6 and largest (73.8 g CH_4 kg^{-1} of grain) for Plot 4. Thus, they were relatively similar to each other among plots in this field. These rates were in the ranges of those from a fresh water alluvial soil (21.7–201 g CH_4 kg^{-1} of grain) and an acid sulfate soil (2.3–71.9 g CH_4 kg^{-1} of grain) in Thailand and two clay soils (Pelluderts) in the United States (7.5–63.2 g CH_4 kg^{-1} of grain), and lower than those from a low humic gley soil (106–219 g CH_4 kg^{-1} of grain) in Thailand (Sass et al. 1991; Jermsawatdipong et al. 1994).

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REFERENCES

Anastasi, C., Dowding, M., and Simpson, V.J. 1992: Future CH_4 emissions from rice production. *J. Geophys. Res*, **97**, 7521–7525

Bray, R.H. and Kurtz, L.T. 1945: Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.*, **59**, 39–45

Cicerone, R.J. and Shetter, J.D. 1981: Sources of atmospheric methane: Measurements in rice paddies and a discussion. *J. Geophys. Res.*, **86**, 7203–7209

Cicerone, R.J., Shetter, J.D., and Delwiche, C.C. 1983: Seasonal variation of methane flux from a California rice paddy. *J. Geophys. Res.*, **88**, 11022–11024

Denier van der gon, H.A.C., Neue, H.U., Lantin, R.S., Wassmann, R., Alberto, M.C.R., Aduna, J.B., and Tan, M.J.P. 1992: 5. Controlling factors of methane emission from rice fields. *In* World Inventory of Soil Emission Potentials, Ed. N.H. Batjes and E.M. Bridges, p. 81–92, ISRIC, Netherlands

Holzapfel-Pschorn, A., Conrad, R., and Seiler, W. 1986: Effect of vegetation on the emission of methane from submerged rice paddy soil. *Plant Soil*, **92**, 223–233

Jermsawatdipong, P., Murase, J., Prabuddham, P., Hasathon, Y., Khomthong, N., Naklang, K., Watanabe, A., Haraguchi, H., and Kimura, M. 1994: Methane emission from plots with differences in fertilizer application in Thai paddy fields. *Soil Sci. Plant Nutr.*, **40**, 63–71

Khalil, M.A.K., Rasmussen, R.A., Wang, M.X., and Ren, L. 1990: Emissions of trace gases from Chinese rice fields and biogas generators: CH_4, N_2O, CO, CO_2, chlorocarbons and hydrocarbon. *Chemosphere*, **20**, 207–226

Kimura, M., Asai, K., Watanabe, A., Murase, J., and Kuwatsuka, S. 1992: Suppression of methane fluxes from flooded paddy soil with rice plants by foliar spray of nitrogen fertilizers. *Soil Sci. Plant Nutr.*, **38**, 735–740

Mathews, E., Fung, I., and Lerner, J. 1991: Methane emission from rice cultivation: Geographic and seasonal distribution of cultivated areas and emissions. *Global Biogeochem. Cycles*, **5**, 3–24

National Bureau of Statistics of Indonesia 1992: Indonesian Statistics, CBSI, Jakarta

Sass, R.L., Fisher, F.M., and Harcombe, P.A. 1990: Methane production and emission in a Texas rice field. *Global Biogeochem. Cycles*, **4**, 47–68

Sass, R.L., Fisher, F.M., and Harcombe, P.A. 1991: Mitigation of methane emissions from rice fields: Possible adverse effects of incorporated rice straw. *Global Biogeochem. Cycles*, **5**, 275–287

Schütz, H., Holzapfel-Pschorn, A., Conrad, R., Rennenberg, H., and Seiler, W. 1989: A three years continuous record on the influence of daytime, season and fertilizer treatment on methane emission rates from an Italian rice paddy field. *J. Geophys. Res.*, **94**, 16405–16416

Schütz, H., Seiler, W., and Rennenberg, H. 1990: Soil and land use related sources and sinks of methane (CH_4) in the context of the global methane budget. *In* Soils and the Greenhouse Effect, Ed. A.F. Bouwman, p. 269–285, John Wiley and Sons, Chichester

Seiler, W., Holzapfel-Pschorn, A., Conrad, R., and Scharffe, D. 1984: Methane emission from rice paddies. *J. Atmos. Chem.*, **1**, 241–268

Watson, R.T., Meira Filho, L.G., Sanhueza, E., and Janetos, A. 1992: Green house gases: Sources and sinks. *In* Climate Change 1992, The Supplementary Report to the IPCC Scientific Assessment, Ed. J.T. Houghton, B.J. Callander, and S.K. Varney, p. 29–46, Cambridge University Press, Cambridge

Yagi, K., Chairoj, P., Tsuruta, H., Cholitkul, W., and Minami, K. 1994: Methane emission from rice paddy fields in the Central Plain of Thailand. *Soil Sci. Plant Nutr.*, **40**, 29–37

Yagi, K. and Minami, K. 1990: Effect of organic matter application on methane emission from some Japanese paddy fields. *Soil Sci. Plant Nutr.*, **36**, 599–610