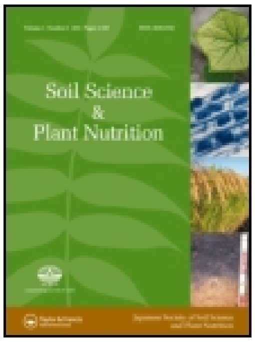

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Methane Emission from an Indonesian Rainfed Paddy Field

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In relation to global warming, a great deal of attention has been paid to methane (CH_4) emission from paddy fields. The amount of CH_4 emitted from paddy fields is now estimated to account for about 12% of the total CH_4 emission according to Prather et al. (1995). Harvested area of rough rice in Asia covered 1,320,000 km^2 in 1990 and 38% of the area was estimated to be maintained under rainfed conditions (IRRI 1991).

Though among factors such as temperature, soil properties, kind and amount of fertilizers applied, and rice cultivars, water management is known to be a major factor determining the amounts of CH_4 emission from paddy fields (Yagi and Minami 1990; Sass et al. 1992; Murase et al. 1993; Nugroho et al. 1994b), there is no report on the direct comparison of CH_4 emission from continuously flooded paddy fields with that from rainfed paddy fields, which has resulted in the wide estimation range of annual CH_4 emission from paddy fields in the world.

In this study, we prepared a continuously flooded plot and a rainfed plot side by side in an Indonesian paddy field during two successive rainy seasons, and compared the amounts of CH_4 emission throughout the growth period of rice plants.

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). This field was the same field in which Nugroho et al. (1994a, b, 1996) carried out studies to determine the yearly and seasonal (rainy and dry seasons) variations of CH_4 emission (Nugroho et al. 1996) and the effects of the kind of fertilizer applied (Nugroho et al. 1994a), intermittent irrigation (Nugroho et al. 1994b), and rice variety on CH_4 emission. Chemical properties of the continuously flooded paddy field at the time of plowing in November, 1993, were as follows: total C, 11 g kg^{-1}; total N, 1.4 g kg^{-1}; pH(H_2O), 5.0; CEC, 5.2 cmol(+) kg^{-1}; sand, 51%; silt, 17%; clay, 32%.

The experiments were conducted twice during the 1993/1994 and 1994/1995 rainy seasons. The experimental field consisted of 4 plots: two plots with chemical fertilizer application and the other two plots with application of both chemical fertilizer and rice straw. The area of each plot was 7×11 m. Twenty-one-d-old seedlings were transplanted (3

Key Words: **Indonesia, irrigation, rainfed, rice paddy, rice straw.**

Table 1. Caltivation calendar.

	Irrigated paddy field		Rainfed paddy field	
	1993/1994	1994/1995	1993/1994	1994/1995
Plowing				
1st	Nov. 23, 1993	Nov. 28, 1994	Nov. 23, 1993	Nov. 21, 1994
2nd	Dec. 3	Dec. 14	Dec. 3	Nov. 28
Flooding	Nov. 16	Nov. 30		
Direct sowing				Dec. 1
Transplanting	Dec. 14	Dec. 28	Dec. 14	
Fertilization[a]				
Rice straw	Dec. 4	Dec. 21	Dec. 4	Nov. 30
Chemical fertilizer				
Basal	Dec. 14	Dec. 28	Dec. 14	Dec. 14
Top dressing (1st)	Jan. 4, 1994	Jan. 16, 1995	Jan. 4, 1994	Jan. 16, 1995
Top dressing (2nd)	Jan. 27	Feb. 11	Jan. 27	Feb. 11
Weeding				
1st	Dec. 28	Jan. 11	Dec. 28	Dec. 28
2nd	Jan. 26	Feb. 9	Jan. 26	Feb. 9
Heading	Jan. 27	Feb. 11	Jan. 27	Feb. 4
Drainage	Mar. 8	Mar. 18		
Harvest	Mar. 18	Mar. 29	Mar. 18	Mar. 22

[a] Application rates were the same in the 1993/1994 and 1994/1995 growth seasons. Rice straw: 5 t ha^{-1}. Chemical fertilizer (basal): urea 67 kg ha^{-1}, $(NH_4)_2SO_4$ 33 kg ha^{-1}, TSP 200 kg ha^{-1}, KCl 100 kg ha^{-1}; (1st top dressing): urea 67 kg ha^{-1}, $(NH_4)_2SO_4$ 33 kg ha^{-1}; (2nd top dressing): urea 67 kg ha^{-1}, $(NH_4)_2SO_4$ 33 kg ha^{-1}.

seedlings $hill^{-1}$) at a spacing of 20×20 cm in the experimental plots except for the rainfed plots in 1994/1995 where seeds were directly sown of the same spacing. Each of the respective two plots was flooded before transplanting and was irrigated when needed to maintain flooded conditions until the harvesting stage (continuously flooded plot). The remaining two plots were left under rainfed conditions without irrigation. The cultivation calendar is shown in Table 1. Dry season rice cultivation was conducted from April to July in the continuously flooded plots, then the plots were left under fallow conditions afterwards until the rainy season rice cultivation in 1993 and 1994 dry seasons (Nugroho et al. 1996). In the rainfed plots, soybean was planted from March to June followed by cowpea during the dry season.

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). Gas samples inside the chamber were taken three times at 20 min intervals into an evacuated 10 mL glass tube by the method described by Nugroho et al. (1996). When the flood water level was near the soil surface, the acrylic box chamber was inserted into the soil at a 3–5 cm depth to prevent gas leakage from the chamber. The measurement was conducted in triplicate with 3 chambers in each plot. Every time, we conducted the gas sampling between 10:00 h and 13:00 h.

Methane content in the tubes was determined on the same day with a gas chromatograph equipped with a flame ionization detector (GC-8AIF, Shimadzu Co.). Methane emission rates were calculated from the increase in the CH_4 concentration in the chamber with time and its volume. As the results of CH_4 emission from the continuously flooded plots had already been reported by Nugroho et al. (1994a, b, 1996), the effect of rainfed conditions will mainly be described in this report.

Results and discussion

Figure 1 shows 5-d means of daily mean atmospheric temperature and the monthly rainfall. Although the temperature was similar between the 1993/1994 and 1994/1995 cultivation periods, the amount of rainfall during the growth period was 1,166 mm in 1993/1994 and 1,709 mm in 1994/1995.

The grain yields were in the ranges of 5,230–5,920 and 6,030–6,370 kg ha^{-1} for the continuously flooded plots, and 5,580–6,030 and 5,980–6,700 kg ha^{-1} for the rainfed plots with chemical fertilizer application and with both chemical fertilizer and rice straw applica-

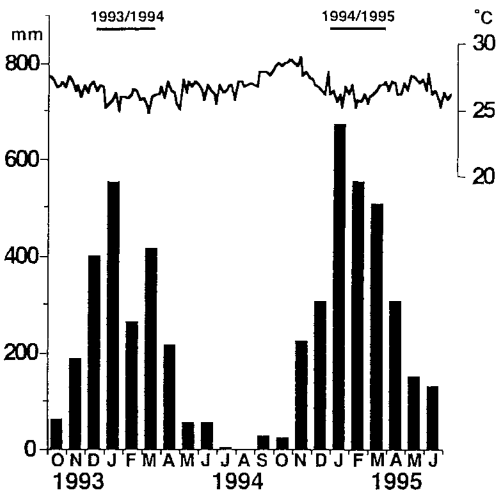

Fig. 1. Five-day means of daily mean atmospheric temperature and the monthly rainfall. Bars indicate the period of rice growth.

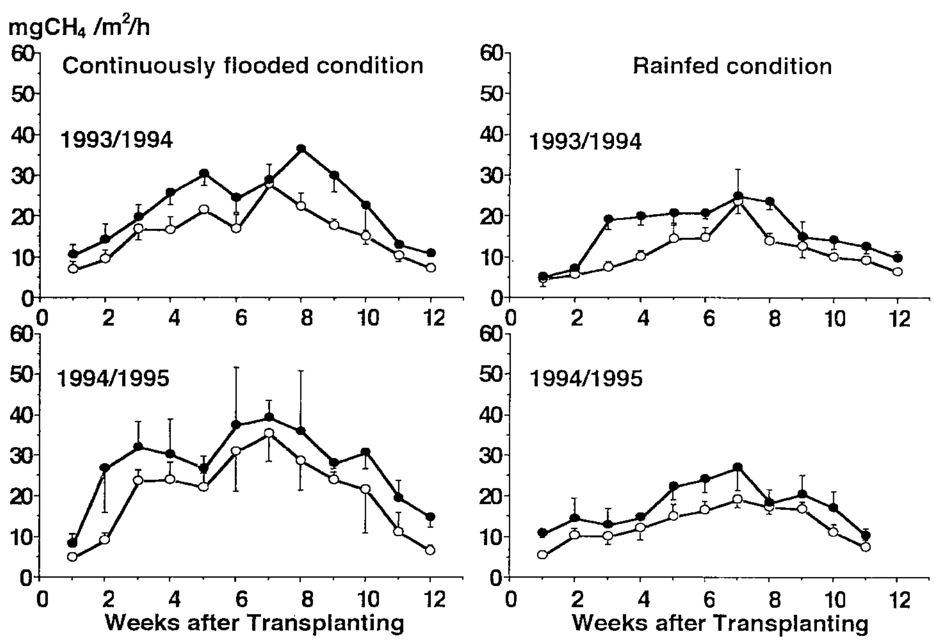

Fig. 2. Seasonal variation of methane emission rates. ○, plots with chemical fertilizer application; ●, plots with both chemical fertilizer and rice straw application. Bars indicate the standard deviation.

tion, respectively. Thus, the effect of water on grain yield management was not observed irrespective of rice straw application.

As shown in Fig. 2, the CH_4 emission rates increased from the first measurement onward, and decreased at the stage near harvest. Methane emission rates from the plots with chemical fertilizer showed a broad peak around 7 weeks after transplanting irrespective of water management. The emission rates from the continuously flooded plot amended with rice straw showed two broad peaks, one of which appeared in the early growth stage (by 6 weeks after transplanting), while only a shoulder appeared in the early growth stage in the rainfed plots with rice straw application.

The mean CH_4 emission rates were in the range of 16.6-21.5 and 11.7-13.6 mg CH_4 m^{-2} h^{-1} for the chemical fertilizer plots and 23.4-29.0 and 17.0-18.4 mg CH_4 m^{-2} h^{-1} for the plots with rice straw application under continuously flooded and rainfed conditions, respectively. The increase in the amounts of CH_4 emission by rice straw application was 1.3-1.4 times for the continuously flooded plots and 1.3-1.5 times for the rainfed plots.

Total amounts of CH_4 emitted during the period of rice growth were compared. In the calculations, CH_4 emission during the period between transplanting and the first measurement (7 d after transplanting) and during the period between the last measurement and harvest was omitted. Drainage was performed 0-3 d after the last measurement in the continuously flooded plot. The amounts were in the ranges of 30.8-39.8 and 21.6-22.9 g CH_4 m^{-2} for the plots amended with chemical fertilizer and 43.2-53.6 and 30.8-31.4 g CH_4 m^{-2} for the plots with rice straw application under continuously flooded and rainfed conditions, respectively. Thus, the rainfed paddy field emitted 27-30% less CH_4 in 1993/1994 and 37% less CH_4 in 1994/1995 than the continuously flooded paddy field.

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