Diel and Seasonal Variations of Methane Flux from Bang Khen Paddy Field in Thailand

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Abstract

Diel and seasonal variations of CH_4 flux from a paddy field were measured at Bang Khen Rice Experimental Station in Thailand. Diel measurement at the heading stage of rice plants showed that the daily average flux, amounting to 24.2 mg m^{-2} hr^{-1}, was equivalent to the flux measured in the late morning. The average values of seasonal variations of CH_4 fluxes in 1992 major rice, 1993 second rice and 1994 second rice were 21.7, 4.3, and 6.7 mg m^{-2} h^{-1}, respectively*. The seasonal measurements in the second rice showed a relatively low CH_4 emission, due to the very shallow water depth because of the limitation of the amount of irrigation water in the dry season. The results suggest that water supply is an important factor the evaluation of the global emission rates of CH_4 from rice paddy fields.

Additional key words: global warming, methane flux, irrigation, paddy soil

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* Wet season rice cropping and dry season rice cropping are hereadter referred to as "major rice"and "second rice", respectively.

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Introduction

Flooded rice fields have been identified as a major source of atmospheric CH_4[1]. To estimate accurately the CH_4 flux in Thailand, NIAES-DOA collaborative research program was initiated in 1991. Yagi *et al.*[10] reported CH_4 flux from rice paddy fields in the central plain of Thailand ; Suphan Buri, Khlong Luang and Chai Nat. The low emission of CH_4 from the Khlong Luang and Chai Nat fields was attributed to the high concentration of sulfate in soil or high soil Eh due to the lower reducing capacity in relation to the oxidizing capacity of soil.

They estimated the seasonal emission rates by multiplying the averaged flux in duplicate both in the morning and in the afternoon. In most of the other studies the CH_4 emission rates were calculated using the data measured during daytime, without considering the pronounced diel variation of the flux. However, daily average values of CH_4 flux should be used to estimate the seasonal emission rates of CH_4, in considering the diel pattern of the flux.

Subsequently, JIRCAS-DOA collaborative research was initiated in 1993. In this paper attempts were made to evaluate the effect of the water regime and soil temperature on the methane emission rates from a paddy field in Bang Khen, Thailand.

Materials and Methods

1) Experimental site

Field measurements were performed at the Bang Khen Rice Experimental Station in the central plain of Thailand in 1992 (major rice) and 1993-1994 (second rice). This site is located in the lower reaches of the Chao Phraya River and the soil was formed from recent brackish alluvium. Soil properties were shown in Table 1. Methods of analysis of these properties were described in a previous paper[10]. Paddy field was irrigated prior to the transplanting of rice plants and surface water was maintained at depth ranging between 0 and 20 cm until the maturation stage of rice plants.

2) Diel variation of CH_4 flux

The diel variations of the CH_4 flux were measured at the heading stage during the period November 2-3 1993. Measurements were performed at 7:00, 9:00, 11:00, 13:00, 15:00, 17:00, 19:00, 21:00 and 23:00 h.

3) Seasonal variation of CH_4 flux

After the harvest of the previous crop, the roots and approximately half of the above ground-biomass of rice plants were incorporated into the paddy field. Chemical fertilizer at the rate of 37.5-37.5-37.5 kg N-P_2O_5-K_2O ha-1 was applied as basal fertilizer and 37.5 kg N ha^{-1} of urea was top dressed. Rice plants (Oryza sativa), Japonica-Indica hybrid type, were cultivated according to the conventional method. Dates of flooding, transplanting, drainage, harvest, duration of the flooding period, rice varieties used and rice yield are given in Table 2. Four, four, and nine measurements were performed during the cultivation period of the major rice in 1992, the second rice in 1993 and 1994, respectively.

Table 1. Some properties of the paddy soil

Series	Bang Khen (Bn)
Taxonomy	Typic Tropaquepts
Texture	heavy clay
pH (air-dried soil)	5.4
pH (flooded soil)	6.8
Total C ($g\ kg^{-1}$)	1.88
Total N ($g\ kg^{-1}$)	0.2
Available N ($\mu g\ N\ g^{-1}$)*	115
Free Fe_2O_3 ($g\ kg^{-1}$)	1.8
ER Mn ($\mu g\ g^{-1}$)**	59
SO_4^{2-} ($\mu g\ S\ mL^{-1}$)	454

*: NH_4-H measured from incubated submerged soil at 30℃ for 4 weeks.
**: Easily reducible manganese.

Table 2. Cultivation practices and rice variety

Year	Rice cultivation	Flooding	Trans-planting	Drainage	Harvest	Floofing period (days)	Rice variety	Rice yield (kg ha^{-1})
1992	Major*1	20 Jul	11 Aug	9 Nov	16 Nov	112	SPR90	5300
1993	Second*2	5 Feb	26 Feb	4 Jun	5 Jun	120	SPR90	2700
1994	Second*2	10 Feb	8 Mar	8 Jun	8 Jun	118	RD25	2440

*1: wet season rice.
*2: dry season rice.

4) Sampling and determination of CH_4 emission, soil temperature and redox potential (Eh)

The closed chamber method was used for CH4 sampling from paddy fields as described by Yagi and Minami[8, 9]. Methane concentration was measured by gas chromatography (FID). Soil temperature and redox potential (Eh) were monitored at the depths of 2, 5 and 10 cm separately.

Results and Discussion

1) Diel variation of CH_4 flux

Diel variation of CH_4 flux, soil temperature and soil Eh measured at the heading stage are given in Fig. 1. The CH_4 flux showed a distinct diel variation with a higher value in the afternoon and lower value at night. The maximum value was observed in the late afternoon at 3:00 p.m. Soil temperature measured at the depths of 2, 5 and 10 cm ranged from 22-29, 22-28 and 23-26℃, respectively. Diel variation of CH_4 flux was positively correlated with the soil temperature at a 2-5 cm depth. The soil Eh decreased below the values of -200 mV at all depths. Yagi et al.[9] found that CH_4 fluxes from Japanese paddy fields also showed a clear diel variation and the flux was well correlated with the variation of the temperature in the surface soil layer. Other studies also confirmed the positive correlation[5, 6]. The results obtained in Thailand were consistent with these studies.

Daily average of CH_4 flux which amounted to 24.2 mg m^{-2} h^{-1} was roughly equivalent to the measurement performed at 11:00 a.m. Therefore, we used the measurement in the morning for calculation of seasonal emission rates of CH_4.

2) Seasonal variations of methane flux

Seasonal variations of CH_4 flux, soil temperature and soil Eh in the major rice in 1992 are given in Fig. 2. Methane flux values ranged from 11.1 to 29.3 mg m^{-2} h^{-1} with an average value of 21.8 mg m^{-2} h^{-1}. Soil temperature measured at a depth of 2 cm ranged from 21 to 28℃. Soil Eh at all the depths was always lower than -200 mV.

Seasonal variations of CH_4 flux, soil temperature and soil Eh in the second rice in 1993 and 1994 are given in Figs. 3 and 4, respectively. Methane flux values in the second rice never exceeded 10 mg m^{-2} h^{-1}, except on June 6, 1994 (116 days after flooding), when the value was as high as 28.5 mg m^{-2} h^{-1}. The average values of the CH_4 fluxes in 1993 and 1994 were 4.3 and 6.7 mg m^{-2} h^{-1}, respectively. These values were smaller than those measured in the major rice, which was grown from July to October. Soil temperature measured at a depth of 2 cm in 1993 and 1994 ranged from 27 to 30℃ and 27 to 36℃, respectively (Fig. 3 and 4). Soil Eh decreased with the time elapsed since flooding (Fig. 3 and 4). Soil Eh at all the depths was lower than -200 mV after March 22, 1993 for the second rice (46 days after flooding). However, soil Eh at 5 and 10 cm depths in 1994 second rice was higher than -200 mV until April 25 (74 days after flooding). The standing water in the paddy field often disappeared during these periods. Therefore, the low emission of CH_4 in the second rice was attributed to the very shallow water depth with intermittent aeration of soil due to the limited

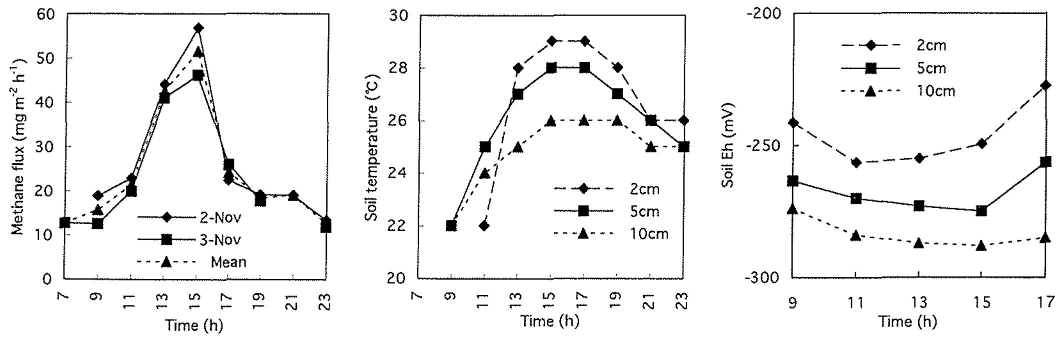

Fig. 1. Diel variation of methane flux, soil temperature and soil Eh in Bang Khen paddy field

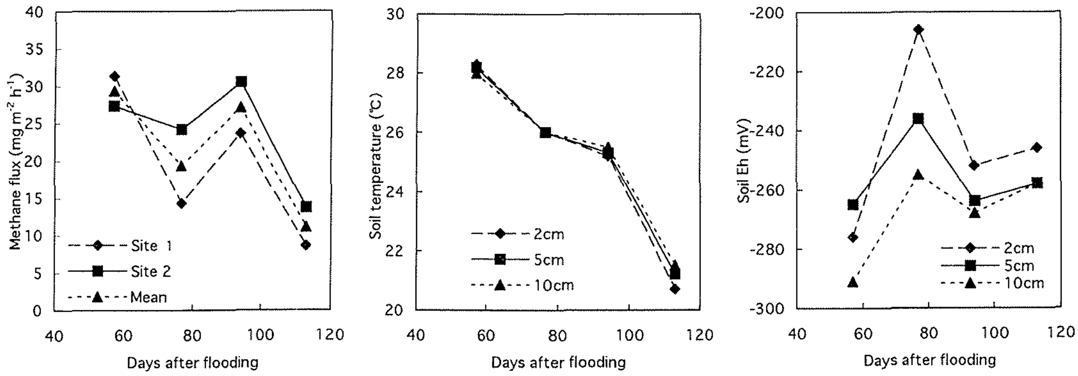

Fig. 2. Methane flux, soil temperature and soil Eh in Bang Khen paddy field (1992 major rice)

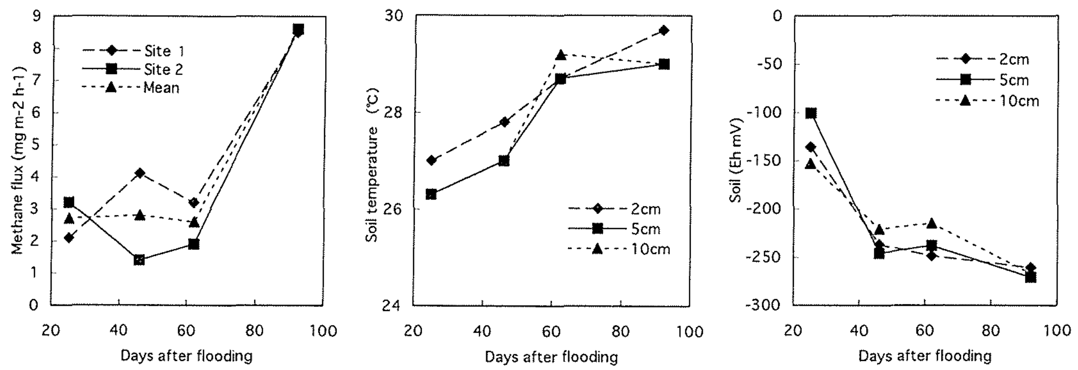

Fig. 3. Methane flux, soil temperature and soil Eh in Bang Khen paddy field (1993 second rice)

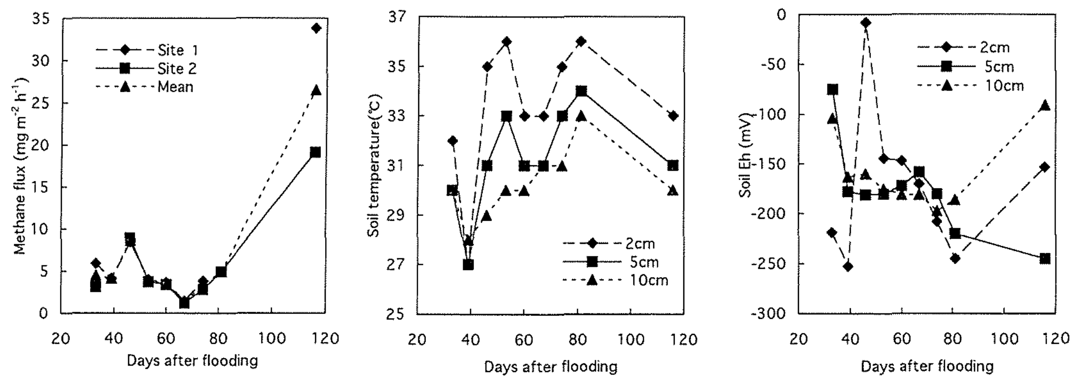

Fig. 4. Methane flux, soil temperature and soil Eh in Bang khen paddy field (1994 second rice)

irrigation water available in this season. However, heavy rainfall in May and June caused flooding continuously, and a decrease in the soil Eh and, consequently, the CH_4 flux increased. The highest flux was observed at the late stage of cultivation.

The flux data and estimated seasonal emission of CH_4 from Bang Khen paddy fields are summarized in Table 3. The seasonal emission was estimated by multiplying the averaged flux by the duration of the flooding period. There was a large difference in the CH_4 flux between the second rice (4.3 and 6.7 mg m^{-2} h^{-1}) and the major rice (21.7 mg m^{-2} h^{-1}). The estimated seasonal emissions for the second rice (1993 and 1994) and the major rice (1992) were 12.4, 19.0 and 55.2 g m^{-2} per cultivation, respectively. These values were within the range reported for the estimated seasonal emission values from paddy fields in Thailand[2, 10]. However, the emissions from the Bang Khen field were relatively higher than those from acid sulfate soils reported previously. These results can be attributed to the relatively high content of labile organic matter in the Bang Khen soil which reflected in the content of available nitrogen, and also to the low content of free Fe_2O_3 in the soil. Parashar[4] reported that the CH_4 emission rates from irrigated fields in India ranged between 0.20 and 3.6 mg m^{-2} h^{-1} (corresponding to a seasonal emission of 0.05 to 2 g m^{-2}). Our results indicated that the emission rates of CH_4 from the Bang Khen paddy fields were higher than those from the Indian irrigated paddy fields.

It is well known that strictly anaerobic conditions are required for the activities of methanogenic bacteria. Anaerobic layers in flooded soils are developed due to the limited diffusion of molecular oxygen from the atmosphere into soil through the surface water layer, and methanogenesis occurs after the sequential reduction of several chemical species[7]. Therefore, the development of an anaerobic layer in soil due to continuous flooding of the fields is essential for CH_4 production in flooded soils and the interruption of flooding inhibits CH_4 production in soil, because it supplies molecular oxygen into the soil layer and increases the redox potential of the soil.

Neue[3] pointed out that rice fields can be classified into irrigated, rainfed, deepwater and upland fields. In irrigated rice fields, the floodwater is fully controlled and remained shallow. Japanese paddy fields are characterized by a fairly low water table and intermittent irrigation practice. Yagi et al.[11] demonstrated that the intermittent flooding practice which is commonly performed in Japanese flooded rice cultivation significantly reduces CH_4 emission compared with the continuous flooded treatment. These results indicated that the variation of the redox conditions in the surface soil layer which resulted from intermittent irrigation exerted a strong influence on seasonal and inter-annual variations of the CH_4 flux.

In the 1994 second rice, the irrigated area in the central plain accounted for 88% of the total irrigated area of Thailand. Irrigation of paddy fields leads to shallow flooding during the dry season cropping (second rice) from November to

Table 3. Seasonal emission rates of methane from Bang Khen paddy field

Year	Rice cultivation	Flooding periods (days)	CH_4 flux (mg m^{-2} hr^{-1})	Estimated seasonal emission (g m^{-2} seaseon^{-1})
1992	Major*1	106	21.7	55.2
1993	Second*2	120	4.3	12.4
1994	Second*2	118	6.7	19.0

*1: wet season rice.
*2: dry season rice.

April. The low emission of CH_4 in the second rice was attributed to the very shallow water depth. On the other hand, rain-fed rice fields are naturally flooded during the rainy season from May to October. Annual rainfall in 1993 in Bangkok was 1543 mm. The high emission of CH_4 in the major rice was due to the presence of deep water. The results suggest that the water supply is an important factor for the evaluation of the global emission rates of CH_4 from rice paddy fields.

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タイ王国バンケン水田におけるメタンフラックスの日変動と季節変動

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摘　要

タイ王国バンケン稲作試験場の水田圃場において，メタンフラックスの日変動と季節変動の測定を行った。水稲出穂期における日変動の測定結果から，日平均フラックス（24.2 mg m^{-2} hr^{-1}）が午前から正午に測定された値と同等であることが示された。1992年雨季作，1993年乾季作，および1994年乾季作における，水稲栽培期間のメタンフラックスの平均値は，それぞれ，21.7，4.3，および6.7 mg m^{-2} h^{-1}であった。乾季作における測定値は比較的低い値であったが，これは，乾季における潅漑水の制限によるものと思われる。この結果は，地球規模での水田からのメタン発生を評価する場合，水の供給が重要な要因となることを示唆している。

キーワード：地球温暖化，メタンフラックス，潅漑，水田土壌

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