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Influences of Application Rate of Rice Straw and Rice Cultivar on Methane Emission from Paddy Fields

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Introduction

During this decade, a large number of works have been carried out on the CH_4 flux from paddy fields in relation to the increase in the atmospheric CH_4 concentration. Temperature, soil properties, kind of fertilizers, and water management have been elucidated as the factors influencing the amount of CH_4 emitted.

It is generally recognized that rice straw (RS) application increased the CH_4 emission from paddy fields. The CH_4 emission from plots with RS application was reported to be 1.1-40 times as large as that from plots without RS. Although the increase in the application rate of RS results in the increase in CH_4 emission, their relationship is not necessarily linear. The author and coworkers conducted a pot experiment to analyze the relationship between the amount of CH_4 emission and the application rate of RS in 1993. Here the general equation for estimating the increase in CH_4 emission due to RS application from any paddy field in any region and in any year is proposed based on the experimental data.

In 1993, the author also investigated the CH_4 emission rates in relation to the morphological characteristics of rice plants with another coworkers using 8 rice cultivars, which were expected to have similar growth periods but to develop different number, length and weight of shoots and roots. It is said that more than 90% of CH_4 fluxes to the atmosphere from paddy soils are through the rice body. Methane emitted in the reproductive stage of rice growth is mainly ascribed to the photosynthesized organic materials exudated from rice root, while rice plants supplied oxygen to their rhizosphere to support respiration of roots. Thus, rice plant is deeply related to the production and emission of CH_4 in paddy soils, and the strength of their positive and negative effects on CH_4 emission is probably different among cultivars.

Relationship between CH_4 emission rates and application rate of rice straw

Two Japanese paddy soils, Anjo yellow soil (Hapludult) and Yatomi gray lowland soil (Anthraquic Haplaquept), were used. Application rates of RS were set at 0, 1, 2, 3, 4.5, 6 and 8 g kg^{-1}, which roughly correspond to 0, 1, 2, 3, 4.5, 6, and 8 t ha^{-1}, respectively. Methane emission rates from the pots were measured using

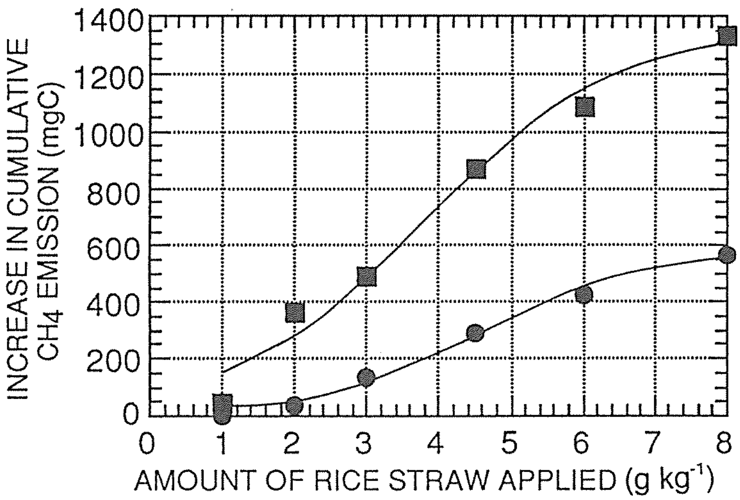

Fig. 1. Increase in the cumulative amount of CH_4 emitted from rice-planted pots (Anjo soil) with increase in the application rate of rice straw. ●, 49-d-period after transplanting. ■, 99-d-period after transplanting. Curves are the logistic curves (see text).

the closed chamber method.

The increase in the cumulative CH_4 emission to RS application was small at low application rate. It was enhanced with the increase in the amount of RS, but became smaller again at 6 and 8 g kg^{-1} (Fig. 1). In the treatments with Anjo soil, the relationships between the increase in the cumulative CH_4 emission and the increase in the application rate of RS could be expressed using a logistic equation:

$$Y=[a/(1+be^{-cx})] \quad (1),$$

where x and Y designate the application level of RS (g kg^{-1} soil) and the increase in the cumulative amount of CH_4 emitted (mg C pot^{-1}), respectively. Correlation coefficients of Equation (1) were more than 0.98 throughout the growth period.

The seasonal variations in coefficients a, b and c in Equation (1) could also be formulated with a logistic or inverse proportion curves as the function of sum of effective temperature (E, $\Sigma(T-15)$; T, daily average temperature),

$$a(E)=1.58\times10^3/(1+14.2e^{-0.00504E}) \quad r=0.998^{***} \quad (2),$$

$$b(E)=-10.1+2.31\times10^4/(E-18.8) \quad r=0.999^{***} \quad (3),$$

$$c(E)=0.666+60.5/(E-64.9) \quad r=0.982^{***} \quad (4).$$

Therefore, the cumulative amounts of CH_4 emitted from a soil with the application of any rate of RS ($Y(x)$) can be estimated using the sum of effective temperature and the cumulative CH_4 emission from the same soil without RS ($Y(0)$) as follows:

$$Y(x,E)=[a(E)/(1+b(E)e^{-c(E)x}]+Y(0,E) \quad (5).$$

The rationale of the sum of effective temperature as a variable was confirmed using the data of CH_4 emission from the same Anjo soil in 1992 and 1991 (Fig. 2). Estimated amounts matched the observed ones. The differences between the observed and estimated ones were only 2.3 and 6.0% for the treatments applied with 6 and 4 g kg^{-1} RS in 1992, and it for the treatment with the application of 6 g kg^{-1} RS in 1991 was 15.3% at the harvesting stage. These findings strongly supported the feasibility of Equation (5) in other years/seasons.

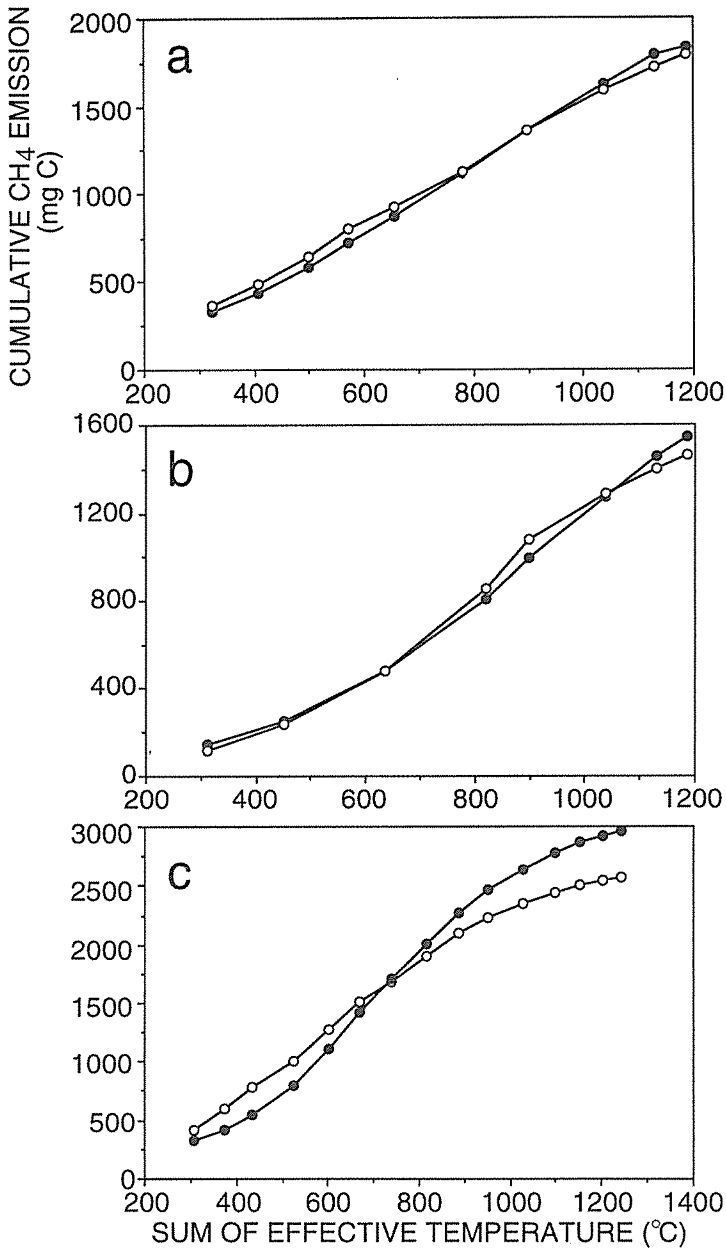

Fig. 2. Comparison of estimated amounts of CH_4 emitted from the pots with Anjo soil with observed values. ●, estimated value. ○, observed value. a, Treatment with the application of 6 g kg^{-1} rice straw (RS) in 1992. b, Treatment with the application of 4 g kg^{-1} RS in 1992. c, Treatment with the application of 6 g kg^{-1} RS in 1991.

The applicability of Equation (5) to other soil was examined using the data of Yatomi soil. To correct the difference in the absolute amount of CH_4 emitted between the two paddy soils, the coefficient for relative CH_4 emission, k, was calculated:

$$k = [Y_y(6, E) - Y_y(0, E)] / [Y_a(6, E) - Y_a(0, E)] \quad (6),$$

where Y_y and Y_a designate the cumulative

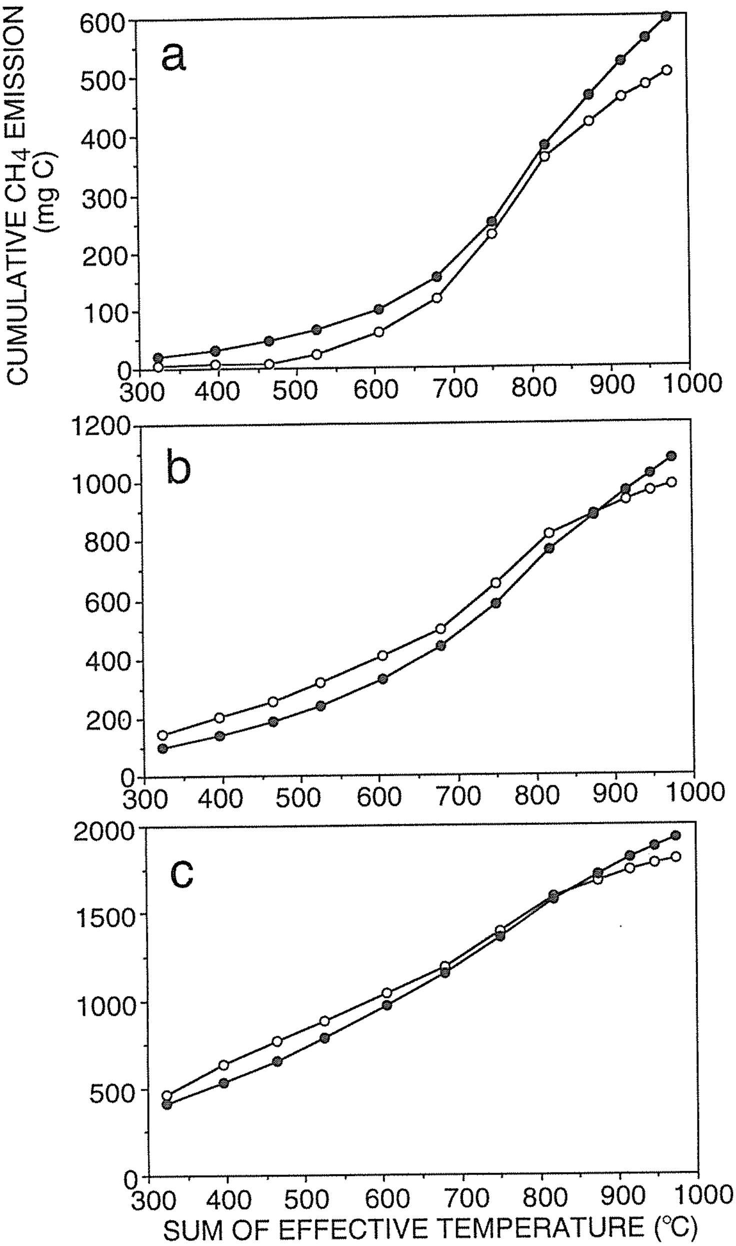

Fig. 3. Comparison of estimated amounts of CH_4 emitted from the pots with Yatomi soil with observed values. ●, estimated value. ○, observed value. a, b, and c are the treatments with the application of 1, 3, 5 g kg^{-1} rice straw, respectively.

amount of CH_4 emitted from Yatomi and Anjo soils, respectively. Although the k value fluctuated during the growth period, it was roughly regarded as constant because of its narrow fluctuation. Here the k value at heading stage was used.

The differences between the observed amounts of cumulative CH_4 emission and the ones estimated using the equation:

$$Y_y(x, E) = k[a(E)/(1+b(E)e^{-c(E)x})] + Y_y(0, E)) \quad (7),$$

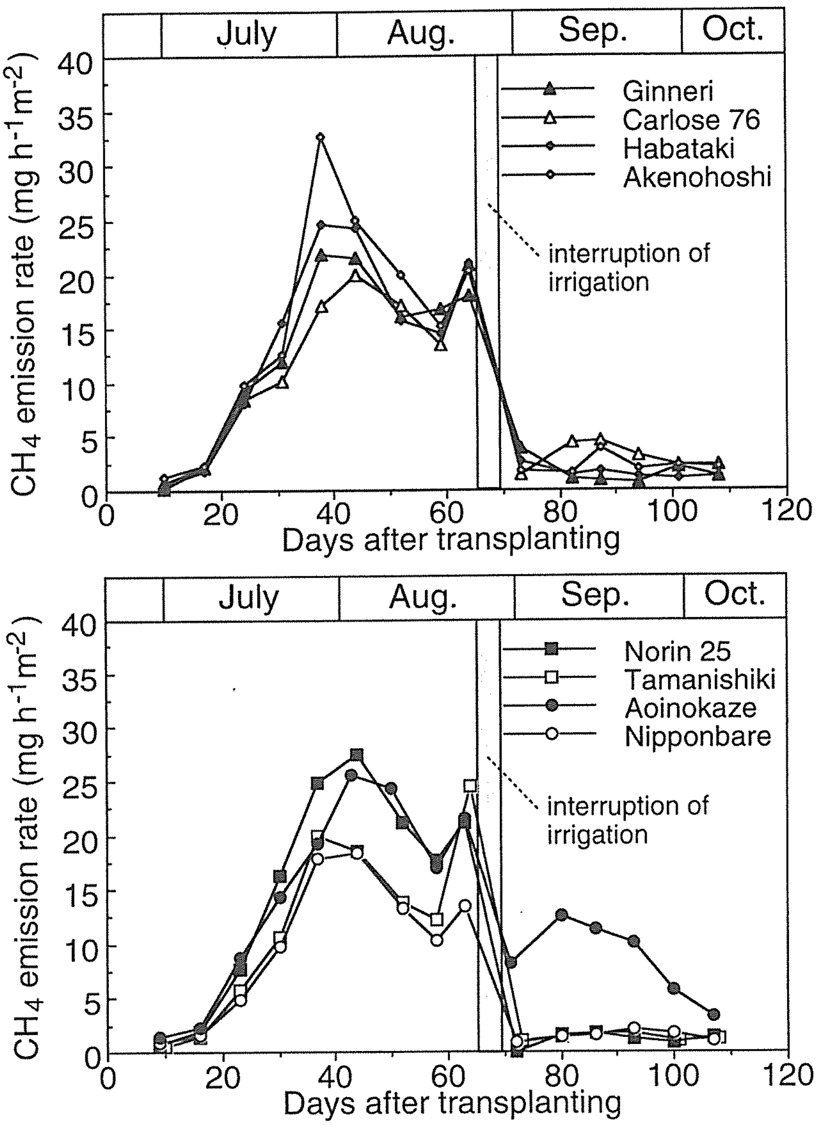

Fig. 4. Seasonal variation in CH_4 emission rates from paddy fields planted with (a) Indica type cultivars and Japonica/Indica hybrids and (b) Japonica type cultivars.

at the harvesting stage were 19, 32, 9.2, 21, 7.1, and 5.3% for the treatments with the application of 1, 2, 3, 4.5, 6, and 8 g kg^{-1} of RS, respectively (Fig. 3). These results indicated that the estimation of the increase in CH_4 emissions due to RS application from any paddy field in any region is possible.

Since the present experiment was conducted using pots, another set of the coefficients *a*, *b*, and *c* should be obtained from a paddy field (reference paddy field). The *k* values are recommended to obtain from dominant soil groups in the target regions.

Influence of rice cultivars on CH_4 emission

Four cultivars of Japonica type, Norin 25, Tamanishiki, Aoinokaze, and Nipponbare, two Indica type cultivars, Ginneri and Carlose 76, and two Indica/Japonica F_1 hybrids, Habataki and Akenohoshi, were cultivated in a paddy

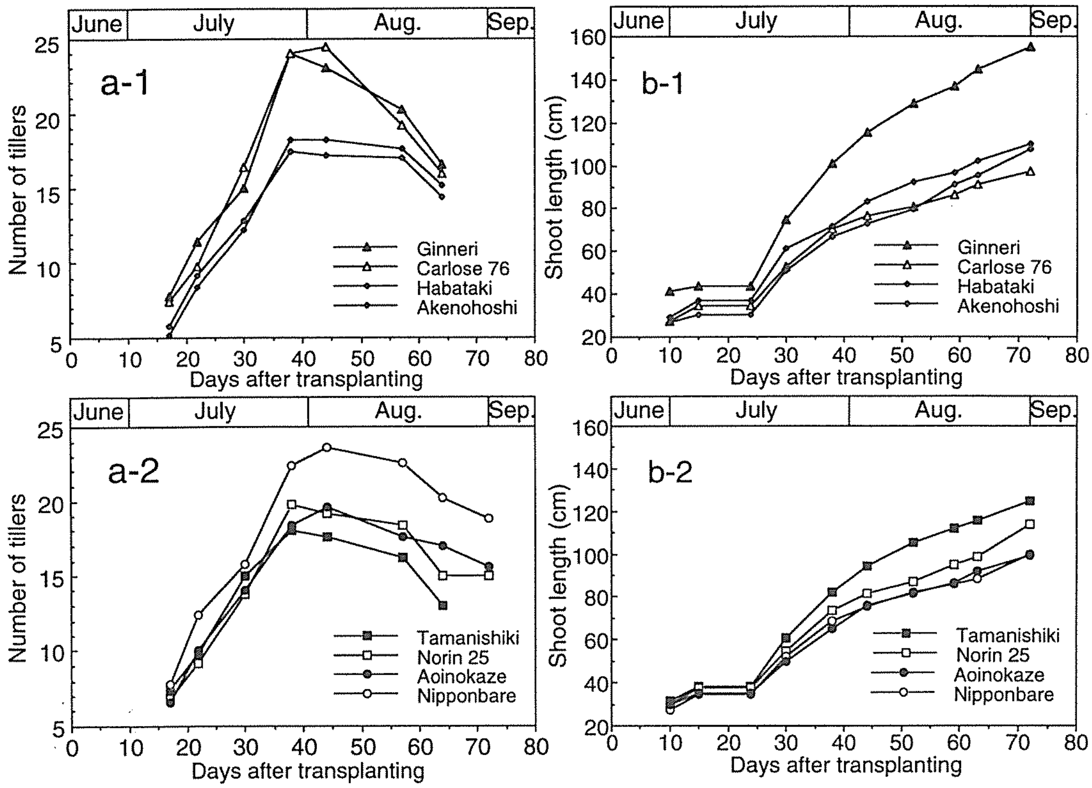

Fig. 5. Changes of (a) number of tillers and (b) shoot length of rice plants.

field at the Nagoya University Farm (Aichi, Japan). Irrigation was interrupted from 24 to 29 August. Methane emission rates were measured using the chamber method in triplicate for each cultivar.

The kind of rice cultivar did not influence the pattern of the seasonal variation in CH_4 emission rates (Fig. 4). However, amounts of CH_4 emitted differed among the plots. The largest CH_4 emission was recorded in the plot planted with Norin 25 (Japonica), while the smallest in the plot with Nipponbare (Japonica). Total CH_4 emission from transplanting until 22-23 August, the last days of CH_4 monitoring before the interruption of irrigation, from the plot with Nipponbare was only 65% of that from the plot with Norin 25. There was no significant difference in the CH_4 emission rates between the Japonica and Indica types in this experiment.

The number of tillers was larger for the two Indica type cultivars and Nipponbare than that for the others (Fig. 5a). Ginneri (Indica) also showed the largest length of shoots, and Tamanishiki (Japonica) was the second (Fig. 5b). However, the CH_4 emission rates from the plots with these cultivars were not larger than those from the plots with cultivars showing smaller number of tilliers or lower height. The dry weights of shoots and roots were also not correlated to CH_4 emission rate (Fig. 6).

Temporary interruption of irrigation at the flowering stage had a great influence on further CH_4 emission (Fig. 4). A large peak of emission rates at around the heading stage disappeared. Generally, the mid-summer drainage is performed for 7-10 days almost 45 days before heading. Its effect on the suppression of CH_4 emission is smaller because CH_4 production recovers quickly again after the re-irrigation. The effect on suppression of CH_4 emission was quite

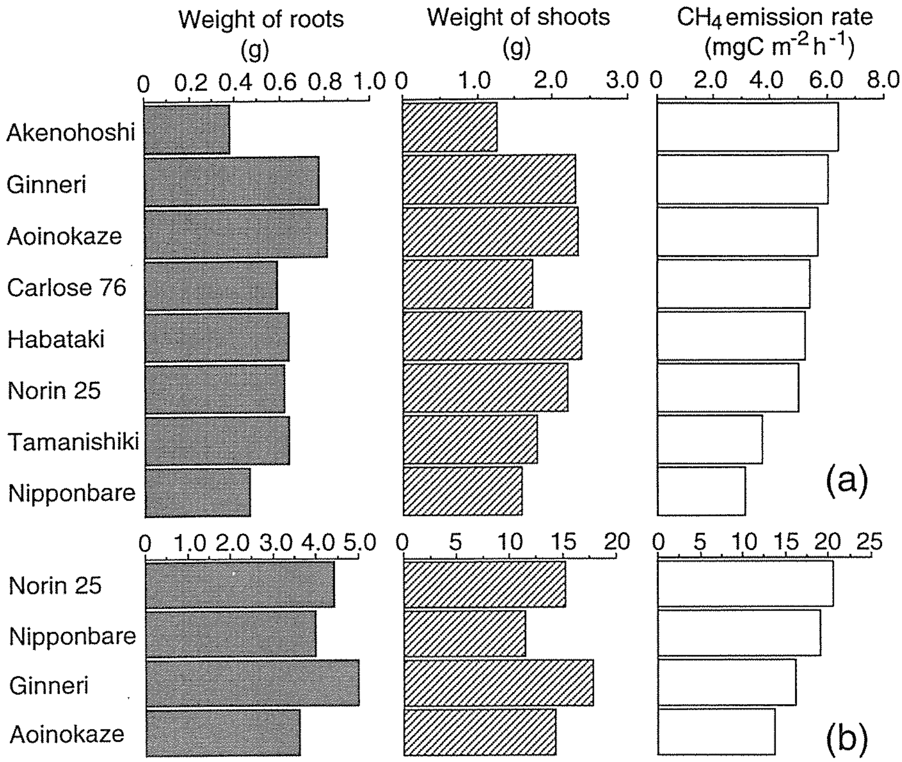

Fig. 6. Weights of shoots and roots of rice plants as well as CH_4 emission rates on (a) 12–15 July and (b) 2–5 August.

large when irrigation was temporarily interrupted at the flowering stage. Although the grain yield was not affected in our experiment, to prevent a decrease in the grain yield the interruption of irrigation at the booting stage should be avoided and the period of interruption should be shorter.

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