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# Influence of rice cultivar on methane emission from paddy fields

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## Abstract

Influence of rice cultivars on $CH_4$ emissions from a paddy field was studied using four Japonica types, two Indica types, and two Japonica/Indica $F_1$ hybrids. In addition, the suppression of $CH_4$ emission by interrupting irrigation at the flowering stage was investigated. Patterns of seasonal variation in $CH_4$ emission rates were similar among the eight cultivars. Two of the Japonica types showed the maximum and minimum $CH_4$ emissions among the cultivars investigated. Neither the number of tillers, shoot length, shoot weight, and root weight correlated with the $CH_4$ emission rates at the tillering and reproductive growth stages. Following temporary interruption of irrigation at the flowering stage, $CH_4$ emission rates decreased drastically and remained at very low levels until the harvesting stage, indicating its great effectiveness for the suppression of $CH_4$ emission from rice paddies.

## Introduction

During this decade, a large number of studies have been carried out on the $CH_4$ flux from paddy fields in relation to the increase in the atmospheric $CH_4$ concentration (Cicerone and Shetter, 1983; Holzapfel-Pschorn and Seiler, 1986; Jermsawatdipong et al., 1994; Khalil et al., 1991; Kimura et al., 1991a; Sass et al., 1990; Seiler et al., 1984). Temperature, soil properties, kind and amount of fertilizers, and water management have been elucidated as the factors influencing the amount of $CH_4$ emitted (Delwiche and Cicerone, 1993; Kimura et al., 1991b, 1992; Miura et al., 1992; Sass et al., 1991; Schütz et al., 1989; Watanabe et al., 1993; Yagi and Minami, 1989). However, there are no reports on the influence of rice cultivars.

There is strong evidence that more than 90% of $CH_4$ fluxes to the atmosphere from paddy soils are through the rice plant (Inubushi et al., 1989; Schütz et al., 1989). The rice plant as the route of $CH_4$ flux was also studied by Nouchi et al. (1990) and Watanabe et al. (1994b). Methane emitted in the reproductive stage of rice growth is mainly ascribed to the photosynthesized-organic materials exudet from rice roots (Minoda and Kimura, 1994). On the other hand, rice plants maintain their rhizosphere under oxidative conditions until around the maximum tiller number stage (Kimura et al., 1982). Therefore, the rice plant is considered to greatly influence $CH_4$ emission from paddy fields.

The strength of these positive and negative effects of rice plants on $CH_4$ emission is probably different among cultivars. In this paper, we report on measurements of $CH_4$ emission rates from plots with 8 rice cultivars, which were expected to have similar growth periods but to develop different number, length and weight of shoots and roots. The $CH_4$ emission rates were studied in relation to the morphological characteristics of the rice plants.

In Japan, the mid-summer drainage is a common cultivation practice. Although this practice is found to cause a drastic decrease of $CH_4$ flux temporarily (Yagi and Minami, 1990; Kimura et al., 1991b), $CH_4$ emission rates generally increase again due to a supply of organic materials from rice roots and high microbial activity under high temperatures. If irrigation is inter-

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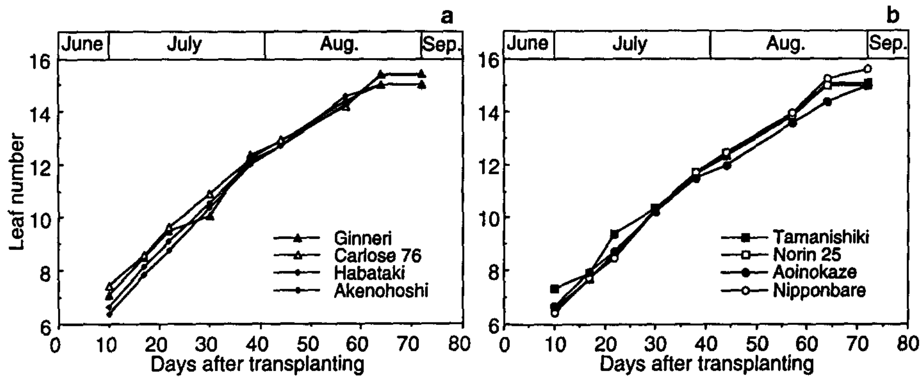


*Fig. 1.* Plant age in leaf number of (**a**) Indica type cultivars and Japonica/Indica hybrids and (**b**) Japonica type cultivars.

*Table 1.* Date of heading for each cultivar

| Cultivar | Date of heading | Cultivar | Date of heading |
|---|---|---|---|
| Ginneri | August 26 | Tamanishiki | August 28 |
| Carlose 76 | August 28 | Norin 25 | August 29 |
| Habataki | August 27 | Aoinokaze | September 6 |
| Akenohoshi | August 29 | Nipponbare | August 28 |

rupted in a later stage of rice growth, it may suppress $CH_4$ emission more effectively. Therefore, the influence of temporary interruption of irrigation at flowering stage on $CH_4$ emission was also investigated.

## Materials and methods

### *Cultivation of rice*

An experiment was carried out at the Nagoya University Farm (Togo, Aichi Prefecture, Japan) in 1993. Characteristics of the soil were as follows: total C = 11.7 g $kg^{-1}$, total N = 1.0 g $kg^{-1}$, pH ($H_2O$) = 5.7, texture = clay loam. Chemical fertilizers, 52 g $m^{-2}$ of "Yorin" which includes 20% of citric acid-soluble phosphate, 20% of water-soluble silica, and 15% of citric acid-soluble Mg, and 52 g $m^{-2}$ of "Rinkaan" which includes 14% of ammonium N, 16% of water-soluble phosphate, and 14% of water-soluble K, were incorporated on June 11.

Four cultivars of Japonica type (*Oryza sativa* L.), Norin 25, Tamanishiki, Aoinokaze, and Nipponbare, two Indica type cultivars (*Oryza sativa* L.), Ginneri and Carlose 76, and two Indica/Japonica $F_1$ hybrids, Habataki and Akenohoshi, were cultivated in a paddy field of 24×8 m. Three seedlings of each cultivar (37 or 38 days old) were transplanted at spacings of 15×30 cm on June 19. Single plot of 1.2×6 m was prepared for each cultivar with a 30 cm of space between two cultivars. Top dressing of 21 g $m^{-2}$ of chemical fertilizer "N-K kasei" containing 3.36 g N, 2.52 g P, and 3.36 g K, was performed on the 12th and 20th of August. Plant age in leaf number and the date of heading are shown in Figure 1 and Table 1, respectively.

Irrigation was interrupted from the 24th to 28th of August.

### *Measurement of $CH_4$ emission rates*

Methane emission rates were measured with 7 days intervals using the chamber method. Each acrylic chamber (50×50×height 120 cm) with a fan attached inside, and a Tedler bag (2 L) outside, was put on stakes to cover 6 hills of rice. On three occasions with 20 min interval (5, 25, and 45 min after enclosure), inner air was collected from the lateral mouth equipped with a septum, into a vacuum glass tube (10 mL) with double rubber stopper using a double-ended needle. Methane concentration in the sampled air was measured using a FID-GC (Shimadzu GC-14APF). Measurements were

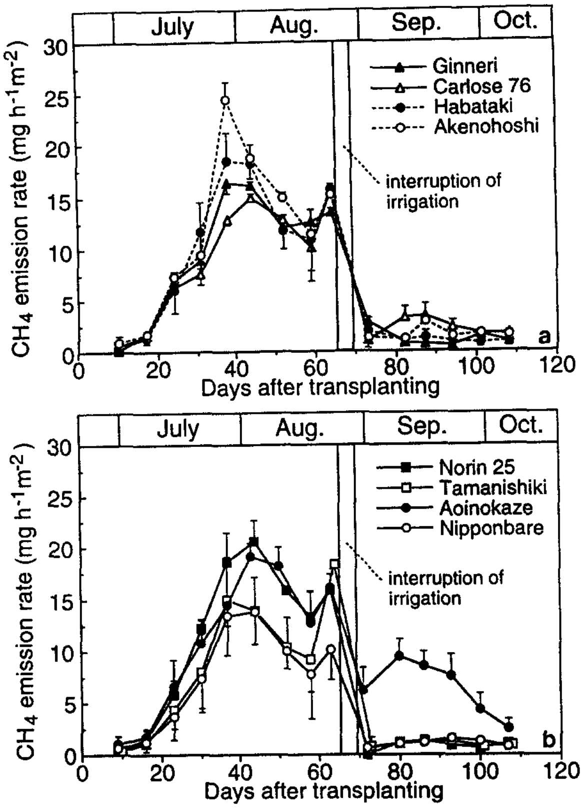


*Fig. 2.* Seasonal variation in $CH_4$ emission rates from paddy fields planted with (**a**) Indica type cultivars and Japonica/Indica hybrids and (**b**) Japonica type cultivars. Bars indicate the standard deviation.

conducted in triplicate for different hills of each cultivar using three chambers.

*Measurement of weights of shoots and roots*

Five hills each from 8 cultivars, and 5 hills each from 4 cultivars, were harvested on July 12–15 and August 2–5, respectively. After the shoots were cut, roots were collected together with soil as a block (15×30×15 cm depth) using a plastic pipe of rectangular parallelepiped. Soil was completely washed out. Weights of shoots and roots were measured after drying at 70°C for 48 h.

## Results and discussion

The seasonal variations in $CH_4$ emission rates are shown in Figure 2. The $CH_4$ emission rates increased from 3 weeks after transplanting, and showed a maximum in the end of July, or on the day 37–43 after transplanting. Methane emission rates decreased once and then increased again on August 22 or 23 (the day 63 or 64 after transplanting). Methane emission rates decreased drastically following the interruption of irrigation from August 24.

*Table 2.* Total amount of $CH_4$ emitted from each plot (June 20–August 22 or 23)

| Cultivar | g C m$^{-2}$ | Cultivar | g C m$^{-2}$ |
|---|---|---|---|
| Ginneri | 13.02±0.57 ab | Tamanishiki | 11.56±3.92 ac |
| Carlose 76 | 11.91±0.70 ac | Norin 25 | 15.54±0.78 b |
| Habataki | 13.85±2.04 ab | Aoinokaze | 14.69±0.73 b |
| Akenohoshi | 15.53±1.42 b | Nipponbare | 10.04±1.99 c |

Values are means ± standard deviation of three replicates, and those not followed by the same letter differ significantly at $p<0.05$ (Duncan's multiple range test).

The rice cultivar did not influence the pattern of the seasonal variation in $CH_4$ emission rates. The same pattern mentioned above was observed in all the 8 plots. 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 was in the plot with Nipponbare (Japonica). From 30 days after transplanting to the interruption of irrigation, the $CH_4$ emission rates from the plots with Norin 25 and Nipponbare differed significantly ($p < 0.05$).

Total $CH_4$ emissions from transplanting until August 22 or 23, the last days of $CH_4$ monitoring before the interruption of irrigation, are shown in Table 2. The total $CH_4$ emission from the plot with Nipponbare was only 65% of that from the plot with Norin 25. There was no significant differences in the $CH_4$ emission 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. 3a). Ginneri, one of the Indica type cultivars, also showed the largest length of shoots, and Tamanishiki (Japonica) was the second (Fig. 3b). 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 tillers or lower height.

Figure 4 shows the weight of shoots and roots as well as the $CH_4$ emission rates on July 12–15 and August 2–5. In this figure the data were arranged in order of $CH_4$ emission rate. Although Sass et al. (1990) found a positive correlation between the above ground biomass and the $CH_4$ emission rates in two fields using

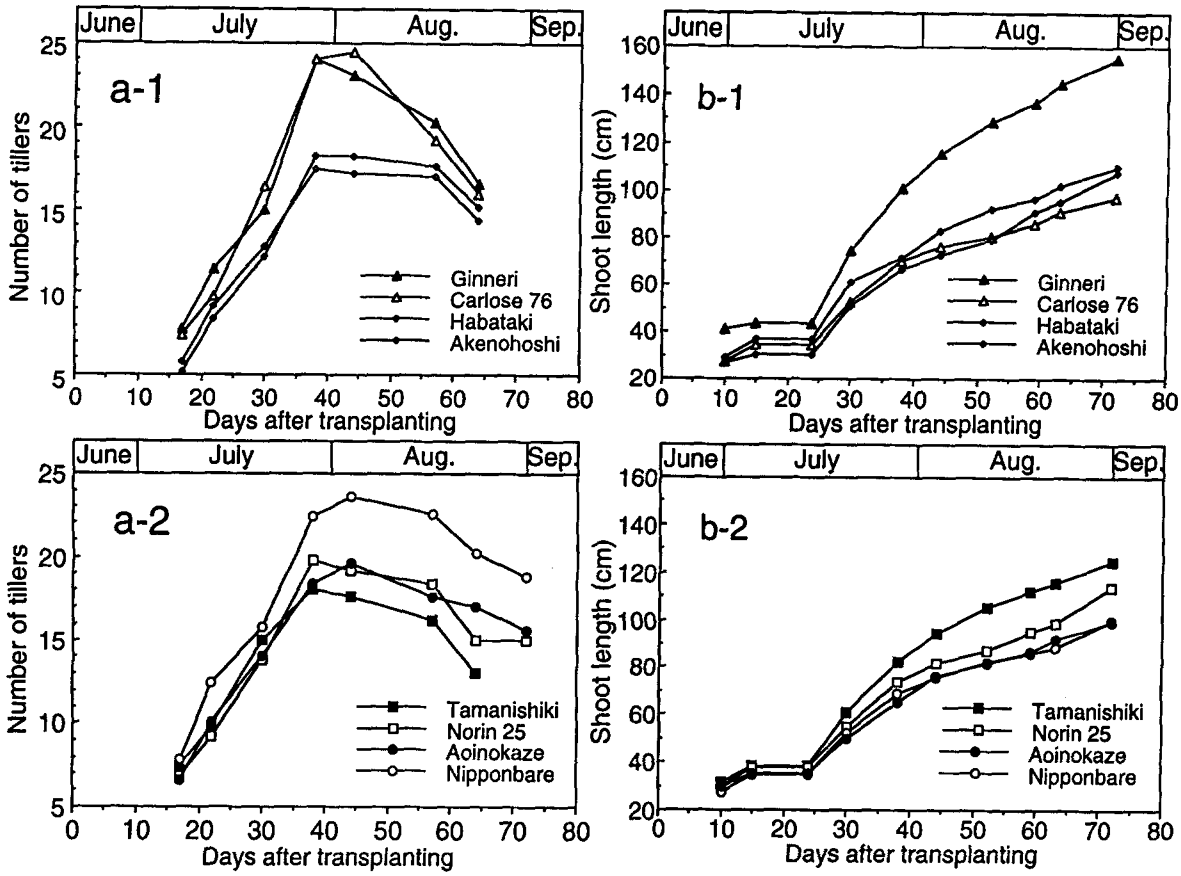


*Fig. 3.* Changes of (**a**) number of tillers and (**b**) shoot length of rice plants.

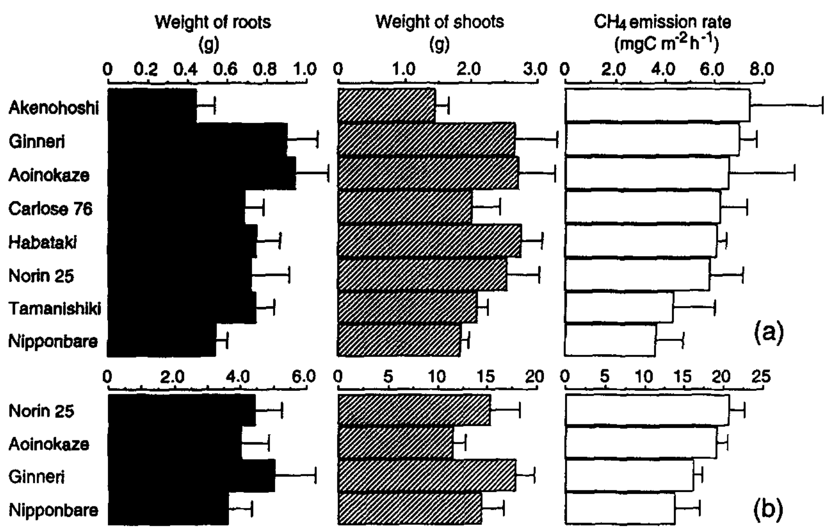


*Fig. 4.* Weights of shoots and roots of rice plants as well as $CH_4$ emission rates on (**a**) July 12–15 and (**b**) August 2–5. Bars indicate the standard deviation.

one cultivar, whereas in the present study the above ground biomass was not correlated to the $CH_4$ emission rates among plots growing different cultivars even in the same field. Rice roots are believed to be associated with the collection, production and oxidation of $CH_4$. However, the $CH_4$ emission rates were not correlated with the weight of roots. Some differences in cultivar rhizosphere oxygenation (per unit area of root and per plant) have been recorded by Armstrong (1969) and Kludze et al. (1994). Differences in the amount of oxygen or exudate release per unit weight of root among cultivars may have more influence than total weight of roots.

Temporary interruption of irrigation at the flowering stage had a great influence on further $CH_4$ emissions (Fig. 2). After the resumption of irrigation, the $CH_4$ emission rates in the 7 out of 8 plots remained at very low levels until the harvesting stage. Relatively high $CH_4$ emission rates in the plot with Aoinokaze were considered to be due to its location in the field, which was the nearest to the outlet of irrigation water and poorly drained during the period of the interruption of irrigation.

Generally, the mid-summer drainage is performed for 7–10 days after establishment of productive tillers, and corresponds to almost 45 days before heading. Its effect on the suppression of $CH_4$ emissions is smaller where $CH_4$ emission rates are still low. Even if $CH_4$ emission rates have already been large, the $CH_4$ production recovers quickly again after the re-irrigation (Yagi and Minami, 1990). In the present experiment, the $CH_4$ emission rates had started to increase again before irrigation was interrupted. According to a large number of reports, it was anticipated that a peak of emission rates would appear if the field was left under flooded conditions. Although the $CH_4$ retained in soil should be released after the water surface falls down below soil surface (Watanabe et al., 1994a), its amount would correspond only to the amount of $CH_4$ emitted during 1–2 days at that time and should be much smaller than the amount of $CH_4$ released after drainage at the harvesting stage in the field under permanent flooding (Watanabe and Kimura, 1995).

It is concluded that the effect on suppression of $CH_4$ emission is quite large when irrigation is temporarily interrupted at the flowering stage. Sass et al. (1992) also carried out drainage for 2 or 3 days in the latter period of rice growth (after 9 weeks from flooding) and found its remarkable effect on suppression of $CH_4$ emission. In our experiment, the temporary interruption of irrigation did not affect the grain yield. However, to prevent a decrease in the grain yield, the interruption of irrigation at the booting stage should be avoided and the period of interruption at the flowering stage should be shorter.

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