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Temporal Variation in Methane Efflux from IR 64 Rice Cultivar

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Methane, a major component of natural gas, is only second in importance to global warming. In the last 200 years, methane concentration in the atmosphere has more than doubled. Its current atmospheric concentration of 1.7 ppm by volume, up from 0.7 ppm in pre-industrial times (Pearman *et al.*, 1986), is much lower than the 365 ppm of CO_2, which is the main culprit for global warming. But, it contributes 19% to global warming despite its low atmospheric concentration as one molecule of CH_4 traps approximately 30 times as much heat as does carbon dioxide. In recent years, concerns have been expressed worldwide at the increasing levels of CH_4 in the atmosphere at the rate of 1.1% per year. However, a decrease in the methane annual growth rate was also recorded between 1984 and 1990 (Dlugokencky *et al.*, 1998) but again a reverse increase in methane growth rate has been detected since 1993 (Gupta *et al.*, 1996).

Most of the atmospheric CH_4 is produced by the bacterial activities under extremely anaerobic conditions in the natural and cultivated wetlands, sediments, sewage, landfills and ruminants (Yagi *et al.*, 1994). Out of which, paddy fields are one of the dominant anthropogenic sources of methane emission to the atmosphere. As more than two-thirds of world rice production is from tropical and subtropical regions, India was surmised to be a major contributor to global methane budget. Based on the data of methane efflux, generated from the rice-fields measurement in Europe and the United States of America, methane emission was extrapolated to Indian conditions. According to EPA, Indian rice-fields contributed 37.8 Tg CH_4 per year to global CH_4 budget. However, a realistic budget prepared for the Indian rice fields based on CH_4 flux measurement in the rice growing season in different agro-climatic regions was found to be only 4.3 Tg CH_4/Yr (Parashar *et al.*, 1996).

Methane, produced at the reduced soil layer in rice fields, is not only transferred to the atmosphere and to the sub-soil (Murase *et al.*, 1993), but also oxidized at various sites in the rice fields. Rice plants also help in methane transport to the atmosphere as they have well-developed aerenchyma to serve as conduits for supply of atmospheric O_2 to roots for respiration and release of methane to the atmosphere (Agnihotri *et al.*, 1999). Nouchi *et al.* (1990) have reported the presence of micropores on the abaxial surface of leaf sheath, which remain open

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round the clock for CH_4 exit to atmosphere. Thus, about 90% of methane generated in the sediment is transferred through rice plant. The oxidation of remaining CH_4 is known to occur aerobically at the oxidized layer in the rice fields (Holzapfel-Pshorn *et al.*, 1985); the rice rhizospere (Holzapfel-Pshorn *et al.*, 1986), and probably also anaerobically at the reduced low layer and the subsoil (Murase and Kimura, 1994).

In the present communication, we have presented the trends in temporal variation in the CH_4 efflux from the rice cultivar IR 64, which is widely cultivated in this region. Apart from it, *in situ* relationship between methane emission and the edaphic factors has been discussed.

MATERIALS AND METHODS

The study site was at National Botanical Research Institute, Lucknow, situated in North India (26^0 45'; 80^0 51' E). The work period was from 15^{th} July 2001 to 30^{th} November 2001. Due to sandy loam texture of the soil, the waterlogged condition is not constantly maintained in the rice fields. Hence, in order to study the methane efflux from the water logged rice fields, this experiment was conducted in the plastic tubs (60 Liter) with high water regime. Rice seedlings were raised in the plots and transferred to plastic tubs when they were 20 days old. The soil in the plastic tubs was amended with compost manure (3:1) and were puddled before transplantation.

For the collection of gas samples from the sediment-water interface, a static closed chamber was used. The chamber was made of steel cylinder with one end open, rubber tube fixed around rim near open end and an air pump fixed at top. While measuring CH_4 flux, the chamber was floated on the water surface of the tub and the pump was kept running continuously to facilitate the proper mixing of air-cum-gas inside the chamber. The gas samples were collected at 0, 15 and 30 minutes, using sampling tubes, at weekly intervals for methane flux measurements for the seasonal variations through rice growing periods and at regular intervals of two hours for diuranal variations, starting from 6 AM in the morning to the next day 6 AM.

After collecting gas samples in the sampling tubes, they were brought to the laboratory for analysis on a Gas chromatograph (14 B Shimadzu, Japan) equipped with FID detector and molecular sieve column (5 Å), under the conditions of column temperature 80°C, injection temperature 120°C and detection temperature 120°C, using N_2 as the carrier gas. The methane flux was calculated using the following as described Verma *et al.* (1999):

$$F = \frac{\Delta x}{10^6} \times BV_{(STP)} \times \frac{16\times10^3}{22{,}400} \times \frac{1}{A} \times \frac{60}{t}$$

Where: F = efflux of methane in mg/m^2/hr, Δx = change in methane concentration in ppmv from time 0 to t min, $BV_{(STP)}$ = volume of the chamber (cm^3) at STP, A = Area of the chamber (cm^2), t = time interval (min).

Temperature of soil was measured by a thermometer, while Eh and pH of the sediment were measured by a pH/Eh meter (Orion, model 290A, USA), at 5 cm depth of sediment.

For the analysis of organic carbon, soil samples were collected from tubs, air dried and sieved and then the titration method of Walkley and Black (Piper, 1966) was followed.

RESULTS AND DISCUSSION

Seasonal variation in methane efflux from rice cultivar IR 64, grown in plastic tubs in continuous waterlogged condition with high carbon, shows that the methane emission was initially very low, then increased with the advancing age of plants reaching maximum at the flowering stage and declined at the ripening stage (Figure 1). Low methane efflux just after transplantation was might be due to low availability of the substrate and undeveloped plant vascular system. As 95% of the total methane emission from sediment to the atmosphere is mainly plant mediated, plant activity plays a major role in methane emission (Inubushi *et al.*, 1990). Peak methane efflux (142.91 $mg/m^2/h$) after 84 days of transplantation (flowering stage) might be attributed to recent plant borne materials, either root exudates or decaying root tissues. As root exudates contain carbohydrate, organic acid, amino acid and phenolic compounds (Martin, 1977), their decomposition and fermentation releases acetate, formate and CO_2, which serve as substrates for methanogenic bacteria. At the flowering stage of the rice plants, root exudation is generally at peak because of maximum root mat extension in the flooded soil (Dommergues and Rinaudo, 1979).

While analyzing the edaphic factors controlling the methane production and emission, it was noted that the soil organic carbon content followed the same trend of seasonal variation as observed in methane efflux. Hence, a positive correlation between CH_4 efflux and soil organic carbon was observed (R^2=0.86). This indicates that stimulation of methane efflux in our study till flowering stage was probably under the control of labile carbon content in the soil. Three main sources that supply carbon for methanogenic bacteria are; the original soil organic matter, the exogenous supply of organic matter to the soil and root litter and root exudates. The labile carbon is very much needed for methanogenesis process (Neue *et al.*, 1995). During ripening and maturity stage of the rice plants, methane efflux could decline as the labile carbon becomes limiting and the root porosity and root transport capacities also declined because of root aging and degradation (Wang *et al.*, 1993). In this experiment, soil redox potential was very low and was always noted on the negative side, indicating that the soil was adequately reduced due to continuous water logging. The redox potential ranged between –495.8 to –328.7 mV through out the growing season of paddy cultivar (Table 1). Flooded rice fields are mainly characterized by lack of sufficient O_2 to act as electron acceptor (Reddy and Patrick, 1984). Among all other edaphic factors, the redox potential (Eh) was found to be the most important because it initiates methanogenesis process in the soil for methane formation.

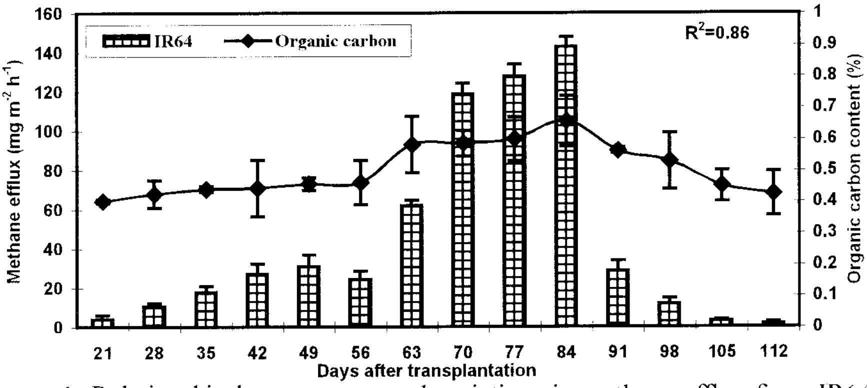

Figure 1. Relationship between seasonal variations in methane efflux from IR64 cultivar and sediment organic carbon content.

Negative redox potential (-150 mV) is essentially required for the initiation of action of methanogenic bacteria for methane formation (Seiler *et al.*, 1984). At the depth of 5 cm, there was a positive correlation between sediment temperature and methane efflux (Khalil *et al.*, 1991). The range of sediment temperature was between 26.5^{O}C to 36.5^{O}C, which was favorable for methanogenes to produce methane (Dunfield *et al.* 1993).

A typical pattern of diel variation in CH_4 efflux was observed in the rice cultivar IR64 grown in plastic tubs at the flowering stage (Figure 2).

Table 1. Edaphic conditions during methane efflux from IR 64 cultivar.

Days after transplantation	Phenological stages	Edaphic factors			
		PH	Redox Potential (mV)	Soil Temperature (^{O}C)	Organic carbon (%)
21 Days	Vegetative growth	7.74±0.25	-208.7±20.82	33.5±0.50	0.401±0.016
28 Days	Vegetative growth	7.47±0.34	-234.9±24.95	34.0±1.50	0.423±0.024
35 Days	Vegetative growth	7.17±0.16	-266.4±30.08	31.5±1.00	0.439±0.030
42 Days	Tillering	7.16±0.40	-219.2±35.46	34.0±1.00	0.442±0.014
49 Days	Tillering	7.78±0.31	-281.0±21.94	34.5±0.50	0.455±0.018
56 Days	Tillering	7.14±0.26	-314.4±22.85	33.0±0.50	0.460±0.025
63 Days	Heading	7.29±0.20	-289.3±20.22	30.5±2.00	0.581±0.014
70 Days	Flowering	7.63±0.39	-213.2±24.68	33.0±1.50	0.585±0.018
77 Days	Flowering	7.28±0.19	-275.0±26.71	31.0±1.00	0.599±0.021
84 Days	Flowering	7.54±0.15	-219.2±16.20	32.5±1.00	0.656±0.029
91 Days	Ripening	7.20±0.28	-206.5±30.87	31.0±1.50	0.562±0.018
98 Days	Ripening	7.25±0.30	-210.5±18.66	33.5±0.50	0.528±0.024
105 Days	Ripening	7.33±0.27	-222.1±20.53	31.0±1.50	0.450±0.016
112 Days	Ripening	7.15±0.20	-184.1±25.84	29.0±1.00	0.425±0.021

Mean±SD (n=3)

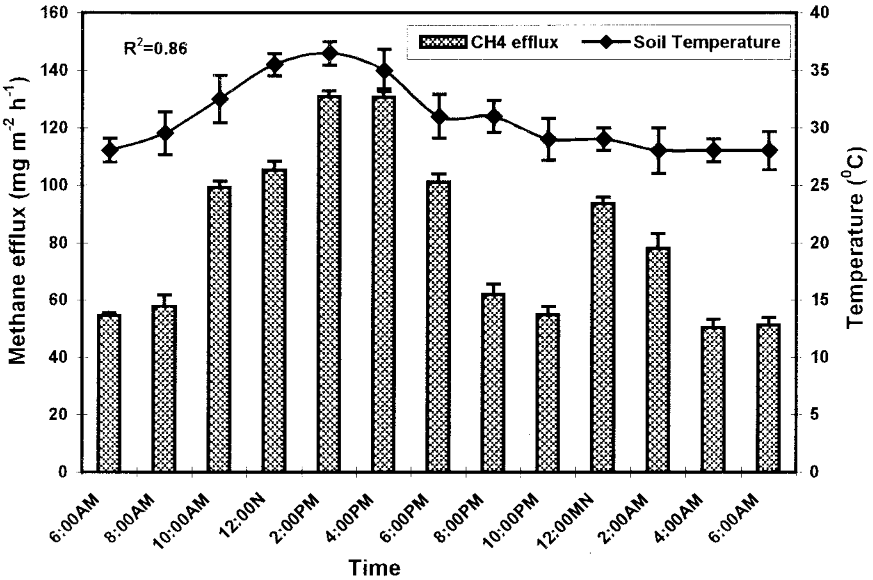

Figure 2. Diurnal variation in methane efflux at the flowering stage of IR64 rice cultivar

It was observed that in the after noon, the emission of CH_4 was about two and half times higher (130.87 mg/m^2/h) than that of early morning efflux (50.26 mg/m^2/h). On comparing the day and night efflux, it was observed that during the daytime, the CH_4 efflux was generally higher than during the night hours despite of the fact that micropores, which are considered as CH_4 exit ports, remain open round the clock. These results were in agreement with the findings of many other workers (Wang *et al.*, 2000). Seiler *et al.* (1984), working on Italian rice fields observed 15% higher CH_4 efflux during afternoon as compared to that of morning hour. Wang *et al.* (1993) observed that out of total day time emission, about 60% was between noon and afternoon hours. Neue *et al.* (1994) also reported that CH_4 emission increased rapidly after sunrise, reaching a peak in the afternoon and the pattern remained the same even if the rice shoots were cut above the water.

Normally, CH_4 production is favored by a soil Eh value lower than −150 mV, a pH between 6 and 8, temperature above 10°C and supply of low molecular fatty acids derived from easily degradable organic matter (Neue *et al.*, 2000). As the values of soil Eh and pH remained almost constant through out this experiment, these factors could not be responsible for the fluctuation in diel CH_4 efflux. However, the sediment temperature, which increased until afternoon and then declined, was found to be positively correlated with CH_4 emission (R^2=0.86). This could be possible because the sediment temperature largely controlled CH_4 production. In this experiment, the sediment temperature ranged between 28°C and 36.5°C. A relation between sediment temperature and diel variation in CH_4 emission was reported by several other workers under field and laboratory conditions (Yagi *et al.*, 1994; Singh, 2001).

We showed that seasonal variation was mainly linked to plant activities, while the diurnal variation was the function of sediment temperature. A higher efflux from the IR 64 grown in the plastic tub was the result of high water regime, which favored methanogenesis.

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