INFLUENCE OF CONTINUOUS AND INTERMITTENT WATER REGIMES ON METHANE EMISSIONS FROM IRRIGATED RICE CROPS IN SOUTHEAST BRAZIL

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ABSTRACT

Irrigated rice crops in Brazil correspond to 35% of the total rice area and the preferred irrigation method is continuous flooding. In this study two water management systems – continuous and intermittent flooding – were monitored for the purpose of comparing their methane emission potential. Intermittent flooding was characterized by alternating flooding and draining periods during the rice cropping cycle. In both systems nitrogen fertilizers were applied twice (NPK and urea alone). Methane fluxes were determined using a closed chamber method (boxes 60x60 cm), and analyzed by GC-FID. Samples were collected from 4 boxes (2 boxes for each water management system) twice a week, for a weekly total of 46 samples. Measurements of air and soil temperature, soil and water pH, redox potential, plant biomass were done. After 104 days the accumulated fluxes resulted in a mean methane emission of 21.1 9 g CH_4 m^{-2} d^{-1} under the continuous flooding regime and 23.9 g CH_4 m^{-2} d^{-1} under the intermittent flooding regime. After the two N fertilizer application, methane fluxes decreased in all boxes, with a more marked reduction occurring in the intermittent regime stands. Total accumulated methane emissions, as well as grain yield, were evaluated for each water management system at the end of the cropping season, showing 13% higher productivity in the field under intermittent flooding system. The objectives of the present study were (i) to improve methane emission estimates and compare the emission potential of traditionally managed crop systems and (ii) to study the possibility of minimizing water consumption and the influence on the methane fluxes without deleterious effects to the crop.

1.0. INTRODUCTION

Flooded rice farming is one of the main anthropogenic sources of methane (CH_4) in the world. Methane is an important greenhouse gas accounting for close to 15% of total anthropogenic gas emissions. Average, annual global methane emissions from flooded rice crops are estimated at 60 Teragrams, or 16% of total emissions from anthropogenic sources of methane (IPCC, 1995).

According to UNEP (1996), methane emission rates associated with rice farming under continuous flooding regimes are higher, per unit area, than those under other water management regimes, with a ratio of 1 for the continuous flooding regime to 0.2-0.8 for the intermittent flooding regime. IPCC inventory guidelines indicate a global seasonally integrated emission factor of approximately 20 g m^{-2} of methane. Using this default value, total emissions for 1994 have been estimated at 283 Gg, of which 261.08 Gg (92.2%) corresponded to continuous flooding rice farming; 0.58 Gg (0.2%), to intermittent flooding; and 21.38 Gg (7.6%), to rainfed crops (Embrapa, 1998, Lima *et al*, 2001). Irrigated and upland rice farming in Brazil account for 34.9% and 65.1% of the total rice farming area, respectively. Since most irrigated rice areas are under a continuous flooding regime, there is an interest in quantifying methane emissions from that production system in the various climatic regions of the country. The use of organic fertilizers is not usual in Brazil, and urea and ammonium sulfate is frequently applied on farms. In the Vale do Paraíba region, Southeast of Brazil, where there is a growing scarcity of water for irrigation purposes, the continuous flooding systems is still the most usual practice. The intermittent water regime could constitute a more adequate land use management, while it is recognized as a potential measure for reducing methane emissions.

This study is part of a project sponsored by the Ministry of Science and Technology (MCT), executed by Brazilian Agricultural Research Corporation (Embrapa) and the Dalmo Giacometti Foundation, with the collaboration of the Regional Agribusiness Development Center of the Paraíba Valley, an agency of the Government of the State of São Paulo (SP). The purpose of this project is to evaluate methane emissions from different management systems of flooded rice farming in the various rice-producing regions of the country, specially in the South and Southeast regions. The objective of the present study was to compare the emissions from continuous and intermittent water management systems aiming to identify the most efficient for methane emission mitigation.

2.0. MATERIALS AND METHODS

2.1. FIELD SITE

The study was carried out at the Experimental Area maintained by APTA (Agricultural Technology State Agency) in Pindamonhangaba, State of São Paulo (SP). It is a tropical region located in the Paraíba Valley, latitude 22^{o}55’ S and longitude 45^{o} 30’ W and altitude of 550 meters. According to the Köppen international classification, the climate at the Pindamonhangaba municipality falls in the CWA category: tropical altitude climate, with average temperatures of 22^{0} C in the hottest month and < 18^{0} C in the coldest month of the year, i.e. hot humid summers and dry cold winters. The soil was classified as Glei low humic, with clay texture and pH 7.3.

Two sampling sites were considered: A – continuous flooding rice farming site (10-cm average water layer) and B – intermittent flooding rice farming site (alternate wetting and drying). The rice seedlings (AC 103 variety) were manually transplanted on January 6, 2003 and the field was flooded on January 13, 2003 for both systems. Spacing was 30 cm between lines and 20 cm between 6-7 seedling clumps.

Fertilization included 42 Kg N-urea, 10 Kg P_2O_5 and 42 Kg K_2O per hectare in a 20-5-20 formulation applied 15 days after transplantation (14 February 2003) and 45 Kg N/ha from urea, at the beginning of flower premordium (28/02/2003). Oxadiazon preemergence herbicide was applied at the rate of 2.5 l of the commercial product per hectare for weed control, mainly *Echinochloa sp* (barnyard grass) and *Ischaemum rugosum* Salisb (ribbed murainagrass), in addition to a post-emergence ethoxysulfuron application. This procedure ensured weed-free rice stands. Flowering occurred on 12 March 2003, and the rice was harvested on 7 May 2003.

2.2. IRRIGATION WATER MANAGEMENT

Both stands were flooded 7 days after rice seedling transplantation. In the continuous flooding stand, a 7-cm water layer was maintained until 20 days prior to harvest. In the intermittent irrigation stand, the first interruption in the water supply took place 30 days after transplantation and lasted 8 consecutive days, followed by another 22-day flooding period. This difference was due to rainfall frequency and volume during the period, which maintained the soil in a reduction state at the end of each interruption.

2.3. SAMPLING AND ANALYSIS

The chamber sampling technique used has been described by Sass et al. (1990, 1991a, 1991b, 1992). A locally fabricated aluminum chamber (60x60cm) with a thermometer was used, as well as a battery-operated air circulation device to mix the air inside the chamber.

Air samples were collected in four aluminum chambers, whose bases were fixed 10 cm into the soil throughout the experiment. Variable-height extensions were added to accompany rice growth. Samples were taken from the chambers using 60 ml polystyrene syringes with Luer Lok tips, so that five samples had been collected after 25 minutes. Two samples were taken per week throughout the rice-growing season (1^{st} January - 29 April 2003). Forty samples were collected every week, 20 of which were collected by site sampling. Each treatment was measured from two boxes representing two replications.

2.4. CH_4 CONCENTRATION ANALYSIS

The samples were analyzed using a Hewlet Packard gas chromatographer equipped with a 30-m, HP-Plot Al_2O_3 M deactivated megabore column (0.53) and a flame ionization detector using the 5 ppm CH_4 standard. Methane flows are expressed in $mg/m^2.d^{-1}$.

2.5. SOIL ANALYSIS

Soil samples were collected from the 0-10 cm and 10-20 cm layers at the beginning and end of the growing season in order to perform texture analysis and chemical characterization (pH, CTC, total organic N, total organic C, and aluminum). Soil pH was measured with water; the Walkley-Black method was used for measuring organic C and the Kjeldahl method for total organic N. Soil and water pH, Eh, and soil and water conductivity measurements were taken in the field at the time of each sampling using a Digimed digital pH meter.

2.6. METEOROLOGICAL INFORMATION

All weather data were obtained at the meteorological station of the Regional Paraíba Valley Center.

4.0. RESULTS AND DISCUSSION

4.1. SOIL ANALYSIS

Table 1 shows a summary of the results of the chemical analysis of the soil for each site (T1=continuous flooding regime and T2=intermittent flooding regime).

Table 1 – Chemical analysis of the soil at the research sites, Pindamonhangaba, SP

Parameter	T1= Continuous water regime				T2= Intermittent water regime			
	0-10 cm		10-20 cm		0-10 cm		10-20 cm	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Organic carbon (OC); g/kg	16.15	6.77	19.69	5.55	14.17	4.87	14.78	4.70
Organic Matter (OM); g/kg	27.73	11.68	33.87	9.57	24.37	8.40	25.42	8.10
N_{total}; mg/kg	1292	1180	1242	1122	1018	832.7	1008	864.7
P; mg/dm^3	47,7		43,1		55.9		50.03	
K; mg/dm^3	146.8		124.9		124.4		134.3	
CEC; cmol$_c$/dm^3	15.6		14.6		12.6		13.4	
pH (H_2O)	5.27		5.12		5.19		5.17	
V; %	57.4		57.1		60.6		59.5	

The soil OC contents in the intermittent flooding system were lower than those in the continuous flooding system at the beginning of the cycle, but in the end of the growing season the loss in OC content was greater in the continuous flooding system. It was observed a greater decrease in the total N contents at the end in the intermittent flooding system than in the continuous flooding system, which maybe could be explained by both N loss or production of biomass.

4.2. METHANE FLUXES

The methane flux results are shown in Table 2. Average methane emissions during the growing season under both the continuous and intermittent flooding regimes are shown in Figure 1.

Table 2 – Average methane emissions, seasonal fluxes, plant mass and grain productivity at the Pindamonhangaba experimental station in São Paulo.

Measurements (average values)	T1= Continuous flooding	T2= Intermittent flooding
Average emission (mg m^{-2} d^{-1})	198.96	233.98
Seasonal flux (g m^{-2})	21.10	23.94
Plant mass (g)	712.30	825.13
Grain production per box (g)	317.9	281.6
Productivity (Kg/ha)	6,231	7,068

Average daily methane emissions were 198.96 mg CH m^{-2} d^{-1} and 233.98 mg CH_4 m^{-2} d^{-1} in the continuous and intermittent flooding systems, respectively. Average seasonal methane emissions were 21.1 g CH_4 m^{-2} d^{-1} for the stands under a continuous flooding regime (stands A and B) and 23.9 g CH_4 m^{-2} d^{-1} for the stands under intermittent flooding (stands C and D). Nugroho *et al*. (1994) also obtained higher, similar or lower emission values in different stands under an intermittent flooding regime when compared with stands under continuous flooding regime. They also found lower emission values under an intermittent flooding regime than under the continuous flooding regime during the last stage of the treatment cycle. In addition, there were simultaneous decreases in both treatments, after urea fertilization, which was carried out at two point in time (14 and 28 February).

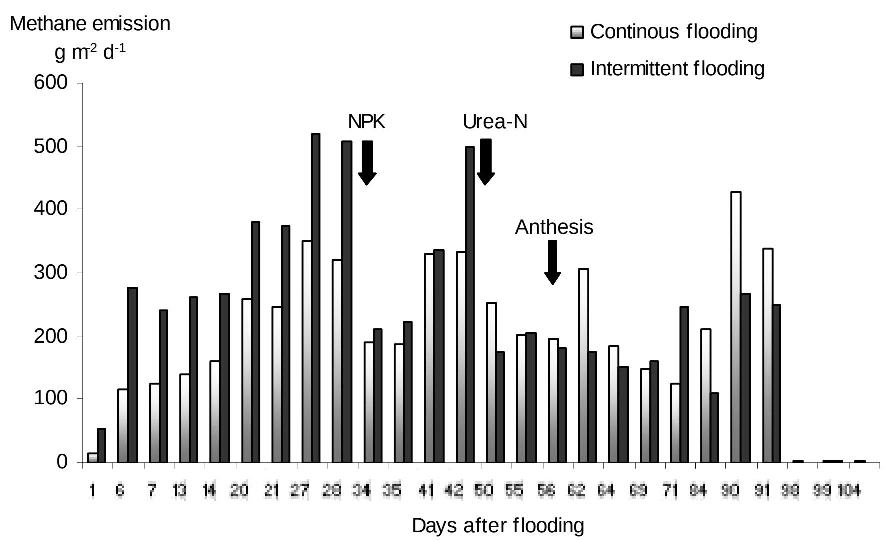

Figure 1 – Seasonal methane fluxes (g/m^2) under the continuous flooding regime – average of chambers A and B – and intermittent flooding regime – average of chambers C and D – at the Pindamonhangaba experimental station, in the State of São Paulo.

According to Sass (1992), the water regime strongly influences the methane emission rate. In this study it was observed no significant difference in methane emission between the treatments of water regime. .

During the heading phase, there were not emission peaks in the intermittent flooding regime, while an increased flux was observed in the continuous flooding regime 64 days after flooding. In addition, there was a marked methane emission peak at the end of the cycle, after pre-harvest drainage, with an increased amplitude in the rice field under continuous flooding regime, which could be attributed to the release of the soil entrapped CH_4. The occurrence of this latest peak has been documented by several authors (Wassman et al., 1994, Neue et al. 199, Jain et al., 2000).

No significant correlation was observed between methane fluxes and soil temperature in both flooding systems (Figures 2a and 2b). Regards to the electrical condutivity it was verified a low positive correlation under the continuous flooding treatment throughout the growing season.

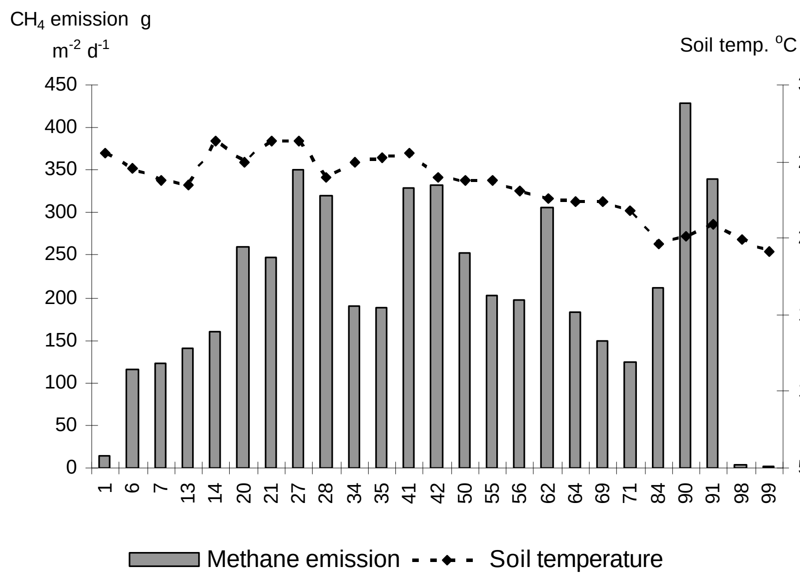

Figure 2a - Seasonal patterns of methane emissions and soil temperature in the continuous flooding treatment.

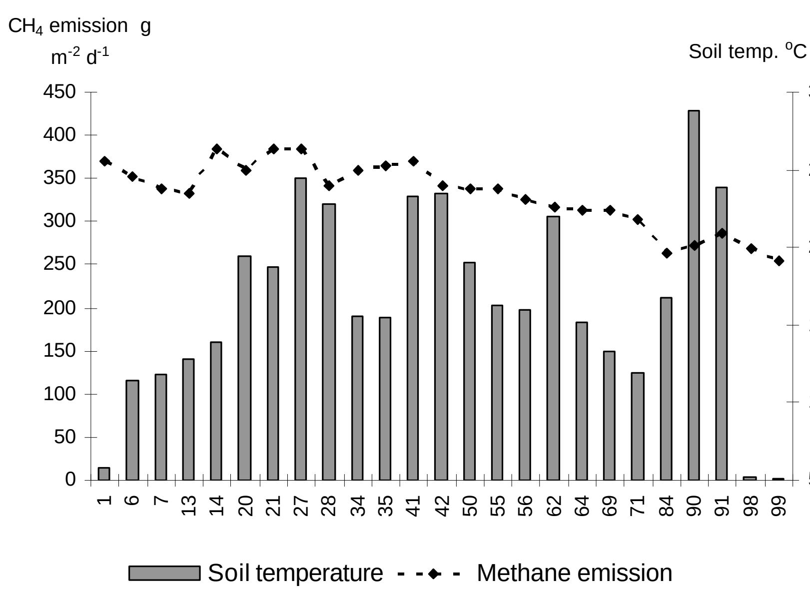

Figure 2b - Seasonal patterns of methane emissions and soil temperature in the intermittent flooding treatment.

4.3. MINERAL FERTILIZER

Some studies associate urea applications with increased methane emissions in paddy rice fields (Mikkelsen et al., cited by Rath *et al*. (1999), Aulakh *et al*., 2001). This increased methane emission resulting from the application of fertilizer is frequently attributed to an increased plant mass. Lindau (1994) also reported increased methane emissions with increasing urea-N applications (100, 200 or 300 Kg N ha^{-1}). According to Sass and Fisher (1994), maximum emissions correspond to the application of 200 and 300 kg ha^{-1} of urea-N and lower emissions, to 100 and 0 kg ha^{-1} urea-N. Thus, it is possible that the amount of urea-N used in our experiments (42 kg ha^{-1} initially and 45 kg ha^{-1} later) was insufficient to promote higher methane emissions in both irrigation systems. Methane emissions decreased after mineral fertilizer (urea) applications. Our data base does not allow us to explain the causes for this decrease.

4.4. YIELD

Despite the lower grain yield inside each box under the intermittent flooding system, the productivity of the whole sampling site was 7,068 Kg/ha, higher than that of the continuous flooding site, whose productivity was estimated at 6,231 Kg/ha (Table 2). The increased plant mass associated with the intermittent flooding regime could be explained for a more extensive root system that favors methane emissions (Wang *et al*., 1997). The intermittent regime did not affect yield while contributed for water saving. Taking into account the 22 days corresponding to the two flooding interruption periods and the 1.0 l/s discharge required to maintain the flood level over one hectare of rice, water saving totaled 1,900,800 liters/hectare.

5.0. <u>CONCLUSIONS</u>

The average methane emission was 11.8% higher (23.94 g/m^2) under the intermittent flooding regime than under the continuous flooding regime (21.10 g/m^2). The intermittent flooding system did not affect the yield, while showed to be benefic to water saving. The productivity (kg grain ha^{-1}) was 13% higher than in the continuous system, which coincided with 16% (825,1 g) higher average plant mass (712,3) in the intermittent system. These results do not allow to conclude that the adopting of the intermittent system do not reduce methane emission, since they are based in only one crop season, and many studies points out to significant annual variations in one same area. This experiment will be repeated in the next growing season, with a higher number of repetitions, in order to monitor annual seasonal variations in methane emissions and find the best water management regime to mitigate both methane emissions and the impact on water resources.

6.0. <u>REFERENCES</u>

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