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WATER MANAGEMENT AND METHANE EMISSION FROM RICE FIELDS IN AN GIANG PROVINCE, VIET NAM

Tran Thi Thanh Thuy[1], Nguyen Trung Thanh[2], Kenji Ishido[3], Kenichi Uno[3], Nguyen Huu Chiem[1], Tran Duc Thanh[1], Nguyen Xuan Loc[1,*]

[1]*College of Environment and Natural resources, Can Tho University, 3/2 street, Can Tho city, Viet Nam*

[2]*Faculty of Engineering- Technology-Environment, An Giang University, 18 Uong Binh Khiem, Long Xuyen city, An Giang province, Viet Nam*

[3]*Japan International Research Center for Agriculture Sciences, 1-1 Ohwashi, Tsukuba, Ibaraki 305-8686, Japan*

[*]Email: nxloc@ctu.edu.vn

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ABSTRACT

This study was carried out to investigate the effects of irrigated water management to CH_4 emission from the paddy fields. It was designed with (1) continuous flooding (CF) and (2) alternate for wetting and drying (AWD) which the water level was controlled + 5 cm and ± 5 cm than the soil surface, respectively at Cho Moi, Chau Thanh, Thoai Son and Tri Ton districts of An Giang province. The soil samples were collected to determine their physico-chemical properties. CH_4 was collected weekly during the rice cultivation, and the rice yield was determined at the harvest. The results showed that pH 4.55 – 5.93, EC 105 – 175 $\mu S.cm^{-1}$, organic matter 3.21 – 3.94 %, CEC 25.05 – 33.33 $cmol.kg^{-1}$ of the soil were suitable for rice growth. The average rice yield was about 4.5 - 6.52 $ton.ha^{-1}$. CH_4 emissions of the AWD decreased 59.1 % compared to the CF which was 14.6 mg $C\text{-}CH_4.m^{-2}.h^{-1}$. Therefore, the AWD is better than the CF in term of reducing CH_4 emissions to the environment.

Keywords: irrigated water management, alternate for wetting and drying (AWD), continuous flooding (CF), methane (CH_4).

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a major crop with more than 50 kg of rice being consumed per capita per year worldwide [1]. According to the results of the greenhouse gas inventory in 2000, growing rice is the largest source of CH_4 emissions, accounting for 57.5 % of total agricultural air emissions [2]. In 2010, greenhouse gas emission and absorption were 246.8 million tons which agriculture accounting for 33.2 % of the total emissions [2]. One practice that has been shown to reduce water use in rice systems is an irrigation management practice referred to as Alternate Wetting and Drying (AWD) [3, 4]. AWD has been reported to reduce water inputs by 23 % [5] compared to continuously flooded rice systems. AWD also has the potential of reducing greenhouse gas emissions, especially CH_4 [6, 7]. AWD reduced global warming potential (GWP − $CH_4 + N_2O$) by 45–90 % compared to continuously flooded systems [3] and increased 9 – 15 % of the rice yield [8]. However, AWD areas were applied 3.22 % of the cultivated rice paddy areas of Viet Nam (7,753,200 ha). Chau Thanh, Thoai Son, Cho Moi and Tri Ton were the four districts with large rice planted, contributing to the An Giang rice yield. Aim of this study is to investigate the effects of irrigated water management to CH_4 emission from the paddy fields in An Giang province.

2. MATERIALS AND METHODS

2.1 Experiment design

The study was conducted in Autumn – Winter crop in 2016 in Cho Moi, Chau Thanh, Thoai Son and Tri Ton districts. The Continuous Flooding (CF) and Alternate Wetting and Drying (AWD) water levels were controlled +5 cm and ± 5 cm than the soil surface, respectively by checking the water level from the water gauge. The paddy fields selected had the area in range of 0.25 – 0.8 ha (Table 1).

Table 1. Experimental description.

Treatment	District	Water level (cm)	Area of paddy fields (ha)	Water management
CF	Cho Moi Chau Thanh Thoai Son Tri Ton	+ 5	0.25 0.45 0.30 0.60	Keeping water level always 5 cm above soil surface by pumping water from canals
AWD	Cho Moi Chau Thanh Thoai Son Tri Ton	± 5	0.25 0.60 0.80 0.80	Pumping water at the day 7-8th, 16-17th, 42-43th, 60th and 70th after broadcasting

2.2 Sample collection and processes

2.2.1. Soil sample

Table 2. Determination of soil physico-chemical properties.

Parameter	Methods
Electrical conductivity (mS/cm)	Extracted with deionized water with ratio 1:5 (5 g soil:25 ml distilled water) then using EC meter (Hach-HQ14d, USA) for record data
Soil pH	Extracted with deionized water with ratio 1:5 (5 g soil:25 ml distilled water) then using pH meter (Hach - HQ11d, USA) for record data
Eh (mV)	By Eh meter (TOA-DKK HM31P, Japan)
Cation exchange capacity (cmol(+)/kg)	Extracted with 0.1 M $BaCl_2$ without buffering then titrate with Ethylenediaminetetraacetic acid (EDTA)
Organic Matter (%)	Walkley - Black colorimetric method

The soil samples were collected at 0 – 20 cm depth, at 5 positions of the AWD and CF (collected from the center and four corners of each plot), then mixed thoroughly to a representative sample before sowing and at the harvest. Soil physico-chemical characteristics and methods for analysis were presented in Table 2.

2.2.2 Methane

Closed chambers 100 cm × 80 cm × 60 cm (height × width × length) were used for gas sampling at 0 minute, 20th minute and injected to 10 mL vacuumed vials. The gas samples were collected weekly from seedling to harvest which were 11-13 gas sampling times during the crop.

CH_4 was measured by gas chromatography (Shimadzu GC2014, Japan) and the emission rates were calculated followed [9]:

$$F= (M_c/22,4) \times a \times h \times 60 \times (273/(273 + T))/100$$

in which: F: emission rate (mg C-CH_4/m^2/h); M_c: Mass of carbon molecular (12 g/mol); a: Slope from y = ax + b; S: Area of the chamber on the field; T: the air temperature in the chamber (^oC).

Water level were recorded manually from seedling stage to the day of harvest at 3 positions in each AWD or CF.

2.2.3 Rice yield

Rice was harvested in 5m^2 with three replicates [10]. Seeds were separated for sunk grains with salt solution (87 g NaCl in 1 L tap water), dried at room temperature for 1 week and recorded the weight as yield data.

3. RESULT AND DISCUSSION

3.1 Soil physico-chemical properties

Soil physico-chemical properties at districts, at the time of sowing, harvest and AWD and CF treatments (Table 3) was suitable for the growth of rice with pH agreed with Hari Eswaran [11] for rice ranged from 4.5 to 6. EC was in range of 0.11 - 0.18 mS/cm. Soil EC < 0.4 mS/cm might not limit crop yields and organic matter range was in range of 3.1 - 5.0 % suitable for growing rice [12]. The CEC before and after the crop were in range from 15.1 to 30 cmol/kg. High CEC causing high soil ability to retain and exchangeable nutrients [12]. The Eh in range of -89.13 to -198.93 suitable for CH_4 emission. Patrick and Reddy [13] reported that the redox potential of soil lower than -150 mV enhanced CH_4 emission. Yamane [14] also showed that the evolution of CH_4 from flooded paddy soils when Eh fell below -150 mV.

3.2 Water level of rice cultivation

The water level of AWD treatment was lower than the CF. The number of the days which water level above the soil surface level in CF were 69 days; 79 days; 81 days; and 76 days Cho Moi, Chau Thanh, Thoai So and Tri Ton, respectively. Meanwhile, these of the AWD were 32 days; 55 days; 58 days and 38 days. The water level of CF was higher than AWD as in Figure 1b, 1d. Water levels in the rice fields were found 3-5 cm in the Mekong delta [15] and 10 cm [16] for CF. Meanwhile, the water levels was found -15 to +5 [17] for AWD. The water levels with CH_4 emission in this study was in the range of 0-5 cm and agreed with water levels reported by Alessandra *et al.* [18].

Table 3. Soil physico-chemical properties.

Treatment			Parameter				
			pH	*EC (mS/cm)*	*Organic matter (%)*	*CEC (cmol(+)/kg)*	*Eh (mV)*
Cho Moi	before sowing	CF	5.01	0.11	3.94	29.78	-120.13
		AWD	4.59	0.11	3.91	28.31	-142.20
	harvest	CF	5.46	0.16	3.21	29.92	-112.80
		AWD	5.06	0.15	3.36	27.50	-89.13
Chau Thanh	before sowing	CF	4.65	0.13	3.86	29.90	-146.00
		AWD	5.10	0.16	3.62	28.89	-126.27
	harvest	CF	5.52	0.14	3.34	30.32	-105.87
		AWD	5.38	0.17	3.57	28.14	-95.73
Thoai Son	before sowing	CF	4.55	0.12	3.52	28.33	-116.00
		AWD	4.56	0.16	3.39	29.77	-124.00
	harvest	CF	5.33	0.13	3.36	33.33	-147.60
		AWD	5.69	0.16	3.26	28.72	-164.60
Tri Ton	before sowing	CF	4.57	0.15	3.27	25.05	-146.00
		AWD	4.56	0.15	3.46	27.49	-126.27
	harvest	CF	5.57	0.18	3.21	26.95	-198.93
		AWD	5.93	0.16	3.38	27.16	-197.00

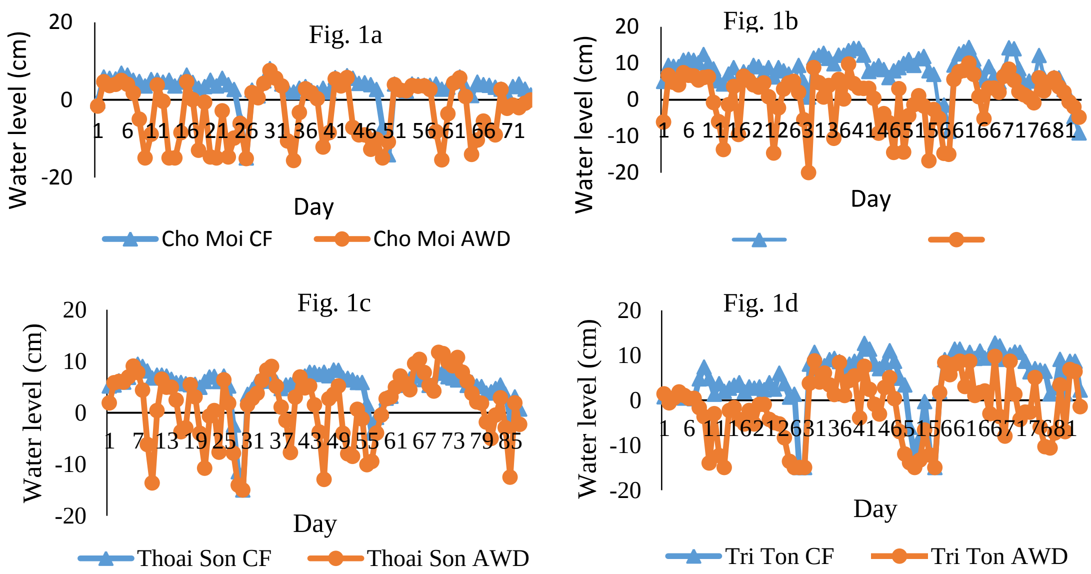

Figure 1. Water levels of CF and AWD on paddy fields.

3.3. CH_4 emissions

CH_4 emissions were from 0 to 133 (mgC-CH_4.m^{-2}.h^{-1}) (Figure 2). In Cho Moi districts, CH_4 emissions from CF and AWD were high at 3rd and 4th week. At this stage the number of days water level > 5 cm and 0 - 5 cm were 2 days; 12 days, respectively. The soil of CF was in anaerobic conditions than AWD, therefore CH_4 emissions of CF higher than AWD. This results were consistent with Amnat Chidthaisong *et al.* [16] showing that the implementation of AWD reduced the seasonal CH_4 emission compared to CF. At Tri Ton, CF had an extreme CH_4 emissions at 10th week (70th day) due to water on the field had been continuously flooded from 55th day to the highest at 73th day. Similarity, at 8th week (56th day), CH_4 emissions at AWD of Chau Thanh was higher due to water level was high (0-5 cm). The total CH_4 emission from AWD was 59.1 % smaller than that from CF compared to study of Amnat Chidthaisong *et al.* [16] was 49 %.

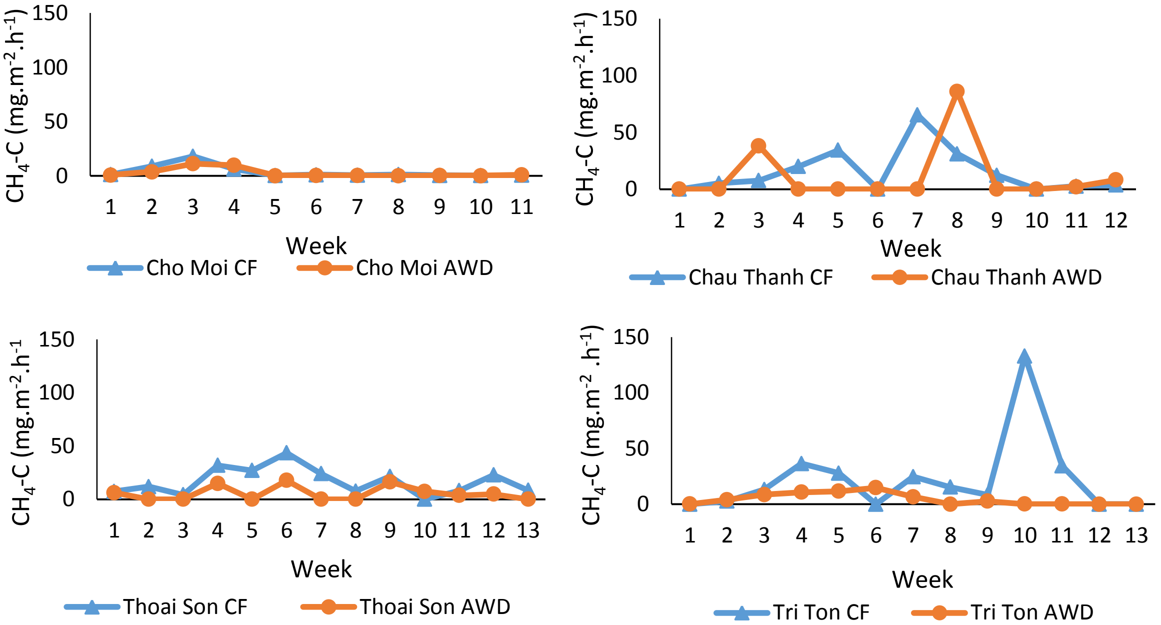

Figure 2. CH_4 emissions from rice fields of CF and AWD.

CH_4 emission from the AWD was 59.46 mgC-CH_4.m^{-2}.h^{-1} and from CF 195.81 mgC-CH_4.m^{-2}.h^{-1}. The highest emission at the stage of rice flowering (55th – 65th day) when soil continuously flooded. During this stage, rice roots and stems developed, then released CH_4 from the soil into the air through the roots system and the stems of the rice was high [19, 15]. The lowest CH_4 emission was found at the stage of 35th – 45th and the stage of rice ripe (75 – 95 days). Neue and Sass [20] reported the CH_4 emission rate in rice fields in China, India, Indonesia, Italy, Korea, the Philippines, Thailand and the United States were 340; 240; 520; 290; 240; 250; 480 and 270 mg.m^{-2}.day^{-1} respectively. Meanwhile, Bhattacharyya *et al.* [21] showed that the CH_4 emission in rice fields in India was between 45.6 -137 mg/m^2/day. Thus, the CH_4 emission from the rice fields of this research was agreed with the previous studies. In addition, the CH_4 mission increased due to the organic decomposition of rice leaves [19]. The factors e.g. temperature, water level in the fields, soil Eh also affected CH_4 emission through each stage of the rice growth [22]. The CH_4 emission on cultivated field CF was higher than on cultivated field AWD in Autumn – Winter crop.

3.4. Rice yield

Table 4. Rice yield of CF and AWD.

Rice yield ($ton.ha^{-1}$)	District				Average ± st.d
	Cho Moi	Chau Thanh	Thoai Son	Tri Ton	
Cultivating soil CF	5.21	5.71	6.50	4.53	5.48 ± 0.83^{ns}
Cultivating soil AWD	5.71	6.10	6.52	4.67	5.75 ± 0.79^{ns}

ns: non-significant detected by sample T-test at significant level 0.05

Rice yield ranged from 4.53 $ton.ha^{-1}$ to 6.52 $ton.ha^{-1}$ (Table 4). Rice yield of CF were same as AWD ($p > 0.05$). According to Nguyen Quoc Khuong *et al.* [23] nitrogen was the main determinant of rice yield but not the water level in the rice field in the Mekong Delta. Limeng Zhang [24] and Nguyen Quoc Khuong *et al.* [23] concluded that the rice yield was not affected by irrigated water management.

4. CONCLUSIONS

Physico-chemical properties were not different between CF and AWD in the Autumn-Winter rice crop. CH_4 emissions were high at the 3^{rd} - 4^{th} week of the rice growth stage. The CH_4 emissions of the AWD decreased 59.1 % compared to the CF which was 14.6 $mgC\text{-}CH_4.m^{-2}.h^{-1}$. Therefore, the AWD is better than the CF in term of reducing CH_4 emissions to the environment. All four districts, the rice yield of CF and AWD was not different and in range of 4.53 - 6.52 $tons.ha^{-1}$.

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