WATER MANAGEMENT AND METHANE EMISSION FROM RICE CULTIVATION: A CASE STUDY IN AN GIANG PROVINCE, VIET NAM

Duong Mai Linh¹, Kenji Ishido², Tomohiko Taminato³, Nguyen Huu Chiém⁴, Nguyen Xuan Loc⁴,*

¹Faculty of Science - Technology - Environment, An Giang University, 18 Ung Van Khiem, Long Xuyen City, An Giang, Vietnam
²Japan International Research Center for Agriculture Sciences, 1-1 Ohwashi, Tsukuba City, Ibaraki Prefecture, Japan;
³Agriculture, Forestry and Fishery Department, Cabinet office Okinawa General Bureau, Japan
⁴College of Environment and Natural Resources, Can Tho University, 3/2 Street, Ninh Kieu District, Can Tho City, Vietnam

*Email: nxloc@ctu.edu.vn

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ABSTRACT

Rice cultivation causes the emission of CH₄ consequenced to the global warming. Reduction of irrigation in rice cultivation is not only saving water resources but also reducing greenhouse gases emission. The objectives of this study was to determine impacts of water management on the emission of CH₄ and rice yield. Experiment was conducted in field conditions in An Giang province, Viet Nam with three treatments as continuous flooding (CF), An Giang Alternative Wetting and Drying (AAWD) which is mostly applied by farmers in An Giang province-Viet Nam, and Alternate Wetting and Drying (AWD). Water levels in the field +5 cm, ± 5 cm and -15 cm were controlled higher, fluctuated and lower than soil surface, respectively for CF, AAWD and AWD. CH₄ emission determined every week during 13 weeks of the experiment. Rice yield was determined in 1 m² at the end of the experiment. The results showed that AWD and AAWD, respectively decreased 78.7 % (p < 0.05) and 6.8 % (p > 0.05) CH₄ emission compared to the CF 11.9 mg CH₄/m²/h. The rice yield of CF was 6.32 ton/ha lower than AAWD 7.8 ton/ha (p < 0.05) but not different with AWD 6.67 ton/ha. AAWD had higher rice yield but same emission than the CF. Farmers in An Giang province should consider application of AWD in rice cultivation in term of saving water and reduction of CH₄ emission.

Key words: An Giang, AWD, CH₄ emission, rice, water management.

1. INTRODUCTION

Among sources of CH₄ emission, agricultural production accounts for 50.6 % of annual greenhouse gases (GHGs) mission [1], in which wet rice cultivation accounts for a large amount.
Vietnam is one of the most countries emitting CH$_4$ [2]. Rice production activities produce 37,429 thousand tons of CH$_4$, contributing 58% of total GHGs emission [3]. Main source of emission in wet rice cultivation is overuse of chemical fertilizers, resulting an increase fertilizer loss and causing soil pollution and N$_2$O emission [4]. Besides, stagnant water in rice field consequence to CH$_4$ and CO$_2$ emission. Therefore, reducing GHGs emission in agriculture production attracts attentions of public over the world and in Vietnam. This study was conducted to test whether water management in the paddy field affects CH$_4$ emission and the rice yield of farmers in Chau Thanh village, An Giang province.

2. METHODOLOGY

2.1. Experimental site

The study was conducted on rice fields in Binh Hoa village, Chau Thanh district, An Giang province in Winter-Spring season 2015. The treatments were arranged in a randomly completed design with 3 treatments and 3 replicates (plots) for each treatment. The rice variety Jasmine 85 was used in the experiment.

2.2. Experimental set-up

Treatment 1 (CF - continuous flooding): the water level was maintained at + 5cm above the soil surface.

Treatment 2 (AAWD – An Giang alternative wetting and drying): current cultivation of farmers in Binh Hoa village followed the handbook of the Department of Agriculture & Rural Development, An Giang province [5]. The water level was controlled -5 cm to +5 cm compared to soil surface.

Treatment 3 (AWD - alternative wetting and drying): irrigation followed alternative wetting and drying. The water level was controlled at -15 cm below the soil surface.

Figure 1. The locations and experimental design.
The Figure 1 showed the locations and experimental design. The water levels in each plot were recorded every day during the experiment by water gauges. Soil reduced and oxidized potential (Eh) and gas samples collected in closed chambers were sampled weekly. The gas samples in each chamber were collected at 3rd and 23rd minute after setting the chamber on the field. CH₄ was analysed with FID detector, Shimadzu.

The CH₄ emission is estimated by the following Taminato equation [6]:

\[
m_{\text{CH}_4} = \frac{M_c \times V \times S \times 3600 \times \left(\frac{273}{273 + T}\right)}{22,4} \]

where: \(m_{\text{CH}_4}\): emission flux of CH₄ (mg CH₄/m²/h); \(M_c\): molecular weight of carbon (12 g/mol); \(V\): volume of chamber (cm³); \(S\): chamber area (cm²); \(T\): absolute temperature calculated as 273 + temperature (°C) in the chamber.

2.3. Statistics analysis

The software SPSS 21.0 (IBM Inc., USA) was used to analyse one-way ANOVA for CH₄ emission and rice yields among treatments and correlation between CH₄ emission and rice growth stage. The data was tested homogeneity and transformed (if necessary) before analysing.

3. RESULTS AND DISCUSSIONS

3.1. Water management in the experimental fields

Figure 2. The mean of water level in experimental models in Winter-Spring season.

- CF: continuous flooding; AAWD: An Giang alternative wetting and drying;
- AWD: alternative wetting and drying.

Figure 2 showed that water level fluctuation of the 3 treatments. At the beginning of the crop (5 days after sowing), the rice needed water to germinate and elongate roots. During 60th to 75th day after sowing, the rice also needed water to produce flowers and seeds. And, at the end of the crop (5 days before harvesting), the water was withdrawn for rice ripening and harvesting [5].
3.2. CH₄ emission

CH₄ emission was different among the treatments (Fig. 3). The variation of CH₄ emission of the 3 treatments had the same patterns through rice growth stages. At 5 days after sowing, CH₄ emission was 0.24 mgCH₄/m²/h in CF treatment, 0.74 mgCH₄/m²/h in AAWD treatment and 0.40 mgCH₄/m²/h in AWD treatment. Then, the emission increased continuously and respectively reached peaks of 28.52 mgCH₄/m²/h in CF, 35.80 mgCH₄/m²/h in AAWD and 9.92 mgCH₄/m²/h in AWD in the tillering stage. The CH₄ emission decreased gradually, then increased slightly in the week 11th in the flowering stage which were 12.81 mgCH₄/m²/h, 8.82 mgCH₄/m²/h and 2.45 mgCH₄/m²/h in CF, AAWD and AWD, respectively. After the 7 weeks, CH₄ emission continued to decline until the end of crop.

![Figure 3. CH₄ emission in Winter-Spring season.](image)

CF: continuous flooding; AAWD: An Giang alternative wetting and drying; AWD: alternative wetting and drying.

CH₄ emission fluctuated through the growth stages of rice and had 3 peaks at week 3rd after sowing, tillering stage and flowering stage (week 6th) [7]; and reduced the emission at the end of tillering stages and the maturity stage (week 11th). This result was consistent with studies of Baharati [8]. The CH₄ emission were also reported highest 30-40 mg/m²/h [9, 10].

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average</th>
<th>Compared to control</th>
</tr>
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<tbody>
<tr>
<td>CF</td>
<td>11,93 ± 7.17b</td>
<td>257.69</td>
</tr>
<tr>
<td>AAWD</td>
<td>11,12 ± 9.81b</td>
<td>240.19</td>
</tr>
<tr>
<td>AWD</td>
<td>2.54 ± 3.52a</td>
<td>54.86</td>
</tr>
</tbody>
</table>

Table 1. CH₄ emission.

CF: continuous flooding; AAWD: An Giang alternative wetting and drying; AWD: alternative wetting and drying; mean± std.

At the beginning of the crop (5 days after sowing), the CH₄ emission increased gradually and there were no significant differences among treatments (p<0.05). In this stage, all plots were stagnant to keep soil anaerobic and limit grass germination. In the tillering stage (30-40 days after sowing), CH₄ emission was the highest in the 3 treatments. In this stage, the rice was
tillering and had root elongation to deep soil; hence, CH$_4$ emitted quickly to the air. During the day 41$^{th}$ to 61$^{th}$, water was withdrawn from the field because the rice needed less water. In this stage, the CH$_4$ emission also decreased gradually since soil became dry. In the flowering stage (61-75 days after sowing), CH$_4$ emission increased insignificantly slightly through the root systems and stems [11]. After the flowering stage, CH$_4$ emission decreased until the end of crop because the water level in the field was low for rice ripening and for introduction of machine to the field for easily harvest.

The CH$_4$ emission for the whole crop showed that AWD reduced the emission compared to CF and AAWD. Application of AWD on rice cultivation could reduce nearly 80% CH$_4$ emission compared to CF (Table 1).

3.3. Rice yield

Table 2. Rice yield.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (ton/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>6.32 ± 0.06$^{a}$</td>
</tr>
<tr>
<td>AAWD</td>
<td>7.80 ± 0.93$^{b}$</td>
</tr>
<tr>
<td>AWD</td>
<td>6.67 ± 0.68$^{ab}$</td>
</tr>
</tbody>
</table>

CF: continuous flooding; AAWD: An Giang alternative wetting and drying; AWD: alternative wetting and drying; mean± std,

Table 2 showed that AAWD treatment had the yield 7.80 ton/ha higher than CF 6.67 ton/ha ($p < 0.05$) but not different ($p > 0.05$) with AWD treatment 6.36 ton/ha. Therefore, AWD application should be considered to apply in An Giang province.

3.4. The correlation between CH$_4$ emission and rice growth stage

Figure 4. The correlation between CH$_4$ emission and rice growth stage.

CF: continuous flooding; AAWD: An Giang alternative wetting and drying; AWD: alternative wetting and drying
Correlation of CH$_4$ emission in three treatments (reference data from Summer-Autumn crop 2014 and Autumn-Winter crop 2014) had an upward trend from the sowing stage, had a peak in the tillering stage, then decreased to the end of the crop (Fig. 4). CH$_4$ emission in rice fields was depend mainly on the growth stages of the rice. The CH$_4$ emission the paddy field may be reduced in terms of water management. This result was agree with the previous study of Yingming [7, 9].

Additional discussions are needed, especially by considering this finding with others in Vietnam or in the worlds.

4. CONCLUSIONS

AWD and AAWD, respectively decreased 78.7 % (p < 0.05) and 6.8 % (p > 0.05) CH4 emission compared to the CF 11.9 mg CH$_4$/m$^2$/h. The rice yield of CF was 6.32 ton/ha lower than AAWD 7.8 ton/ha (p < 0.05) but not different with AWD 6.67 ton/ha. AAWD had higher rice yield but same emission than the CF. Farmers in An Giang province should consider application of AWD in rice cultivation in term of saving water and reduction of CH$_4$ emission.

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