Research article

Comparative Study of Methane Emission and Structural Development of Rice Plants from SRI and non-SRI Methods in a Lysimeter Experiment

ISHWAR PUN*
Graduate School of Frontier Science, The University of Tokyo, Chiba, Japan
Email: punisr@gmail.com

EIJI YAMAJI
Graduate School of Frontier Science, The University of Tokyo, Chiba, Japan

Received 16 December 2016 Accepted 5 May 2017 (*Corresponding Author)

Abstract Mitigating greenhouse gas (GHG) emission is a challenging issue in context of coping with the ongoing climate change. Rice farming is considered as the major emitter of CH_4 along with gaseous N_2O. There are several methods of irrigation management that reduces the amount of CH_4 and N_2O gases produced, such as intermittent irrigation and mid-season drainage. SRI (System of Rice Intensification) is one of the new methods known to increase the yield while mitigating GHGs by applying one of key elements intermittent irrigation, and is a method which is now disseminating in many tropical countries. This study was conducted to measure the effectiveness of SRI method by measuring rice plant development, yield component, and methane emission using a lysimeter facility. The transplanted nursery was *koshihikari*, a Japanese rice variety. The study compared between two plots with different water treatments. The results showed that a plant growth characteristics were better in a Continuous plot than in a Intermittent plot, while grain yield was not significantly different. Methane gas was almost 50% less in the Intermittent plot than in the Continuous plot. Total global warming potential from methane emission for Intermittent plot and Continuous plot were 50.41 g CO_2/m^2 and 100.53 g CO_2/m^2, respectively. The results suggest that SRI methodology could be an effective method for mitigating methane emission without reducing the grain yield.

Keywords methane, water management, system of rice intensification, climatic variability

INTRODUCTION

Mitigating greenhouse gases is a challenging issue in the present world. Exponential growth in world population against a linear growth of food supply, coupled with a decrease in agricultural land, are major problems for the world. To overcome the problems, several technologies are being applied to increase food supply to support the growing population. The development of rice technology is beneficial for both the environment and rice production. In rice production, technologies like SRI (System of Rice Intensification), and an irrigation management method called intermittent (Alternative Wetting and Drying) irrigation, are being practiced in areas with limited resources to adapt to the ongoing climate changes. SRI was originated in Madagascar in 1983, developed by Father Henri de Laulanı´e and later disseminated by Cornel University to more than 50 countries. SRI is broadly defined as an agro-ecological methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water, and nutrients (Cornell International Institute for Food, Agriculture and Development, CIIFAD). Moreover, SRI method is a single transplanting method that reduces seed requirement by 90%, increases yield by 20-100%, and saves water by 50%, according to the CIIFAD report. However, several issues are also known in implementation of SRI within local farming practices from region to region, because the rice production largely depends on the topography, climate conditions, and soil nutrients. Nonetheless, SRI method has shown positive synergies. Sato et al., (2005) reported that it is a method that saves water and costs, while also producing high yields in Indonesia. SRI method in India resulted in higher yields by almost 67% than a conventional method (Singh and Talati, 2006). Similarly, SRI method can save up to 25-50% water compared to conventional practices in Japanese rice farming (Chapagain and Yamaji, 2010). A study of the rice plant development in China (Defeng et al., 2002) under a wider space transplanting method resulted in a higher root number than a close transplanting method. SRI method itself is a single transplanting method of baby nursery with wider spacing. Chapagain et al., (2011) showed that the SRI method results in a higher development of roots, where root number was greater by 30% and tillering and early flowering increased by 25% during the paddy field experiment in Japan. Similarly, an experiment in India with the SRI method observed a significantly higher development in terms of physiological and plant development characteristics (Thakur et al., 2009).

Yet there are still a lack of reports for SRI adoption, particularly in Japan, since there are challenges that needs to be overcome against local methods. Therefore, a comparative study of SRI and non-SRI methods was conducted with a lysimeter facility of the University of Tokyo in Kashiwa, Chiba, Japan. The objectives of the study were to examine the structural development of rice plant and methane emission by two methods: the SRI method (intermittent irrigation) and non-SRI method (continuous flooding). The hypothesis was that the SRI method would perform better in comparison to the non-SRI method. In particular, the SRI method was expected to result in higher grain yield, biomass, and longer roots elongation, as reported in other countries. The experiment was conducted in the lysimeter with transplantation of single seedling in two plots, where the intermittent plot was irrigated by intermittent irrigation, and non-SRI method plot by continuous flooding. how high yields are achieved through SRI's key principles through a range of environmental factors and agronomic management practices including variety selection.

METHODOLOGY

Study Area and Experimental Set Up

The experiment was conducted on the lysimeter situated in the University of Tokyo in Chiba Prefecture during the rice growing season, from May to the end of October, in 2014. The lysimeter area was 500 x 160 cm, soil depth 25 cm, was equipped with a drainage system on the right border and irrigation tap on the left border (Fig. 1). The soil was puddled homogeneously at the time of soil preparation. 800 g of organic fertilizer was applied homogeneously. The composition of fertilizer was 1.3% nitrogen, 0.6% phosphorus, and 1.8% potassium, with C/N ratio of 22. The lysimeter was divided into two plots by along the center by a plastic sheet. Plot A was named Intermittent plot and plot B was named Continuous plot. Two water tubes of 25 cm length and 13.5 cm diameter were installed to monitor the ponding depth of the plots. The water tubes featured a fixed measuring scale made of aluminum to observe the water level in the lysimeter. Twelve days-old single nursery of Japanese rice variety (koshihikari) was transplanted. The nurseries were prepared by the local farmers under our request. Thirty-two nurseries were transplanted on May 23. The space between each hill was (30 x 30) cm. The Soil Eh (ORP) sensors were set up for both plots at 5 cm and 10 cm depths. Soil Eh data were recorded by EH-120 (Fujiwara Scientific Co. Ltd., Tokyo, Japan).

Management Method

Two types of water management were applied in the experiment. One was intermittent irrigation for the Intermittent plot, and the other was continuous flooding for the Continuous plot. For the first two weeks after the transplantation, shallow ponding condition was maintained in both plots until the young rice nurseries became stronger. Intermittent plot was then managed by intermittent irrigation method (Fig. 2). Water was drained by a pumping tube in case of excess rainfall. Continuous plot was ponded continuously during the vegetative phase. The first weed was removed from both plots three weeks after the transplantation. The plots were maintained by periodical weeding thereafter. The weeds removed from the plots were buried under the soil as practiced in the SRI method. The first flowering of the rice plant was observed on August 9th. The lysimeter was covered by a net on August 29th to prevent damage by birds. The rice was harvested on October 3, 2014. Lysimeter was kept dry for the last two weeks to prepare for the harvest.

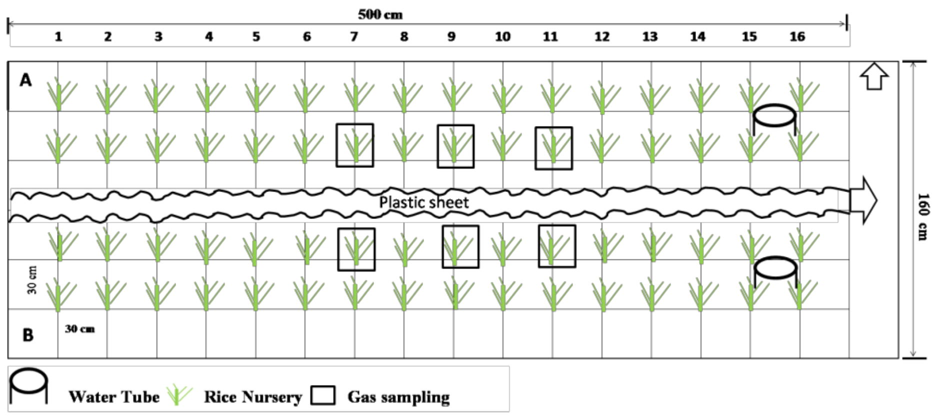

Fig. 1 Layout of lysimeter

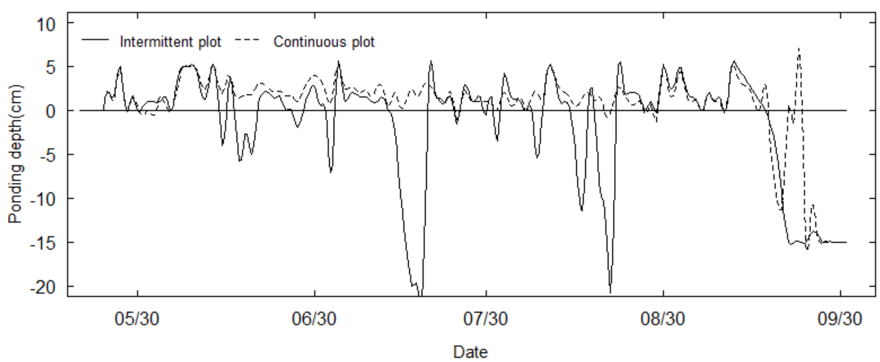

Fig. 2 Ponding condition in lysimeter

RESULTS AND DISCUSSION

Rice Plant Development

The rice plant development in this study is divided into three phases. The day from the transplantation to panicle formation is the vegetative phase. From panicle formation to the fertilization is the reproductive phase. The final phase is the ripening phase, which includes maturity of rice grains. During the vegetative phase, rice plant height was similar in growth (Fig. 3a). After the vegetative phase, plant height grew significantly higher in the Continuous plot, suggesting that plant height grows more favorably without water stress. The development of rice tillers during the first three weeks after the transplantation was similar. Afterwards, a significant increase in the number of tillers was observed in the Continuous plot ($p<0.01$). Higher number of tillers was observed in Continuous plot DAT (Days After Transplant) 49 and 56. Intermittent plot showed a higher number of tillers in DAT 70 (Fig. 3c). After DAT 70, tiller number decreased as the lower parts of small tillers decayed in both plots, which was not included in counting. Higher number of leaves was observed in DAT 70 in both plots (Fig. 3b). Average number of leaves for the Intermittent plot and Continuous plot were 51.90 and 66.06, respectively. In the reproductive phase, similar cases of descending number of leaves were observed after the dry leaves were excluded from the count. The first panicle was counted on DAT 78. Lower number of panicles was recorded in Intermittent plot because of lower tiller number compared to the Continuous plot. The number of panicles and tillers were same at the time of harvest (Fig. 3d).

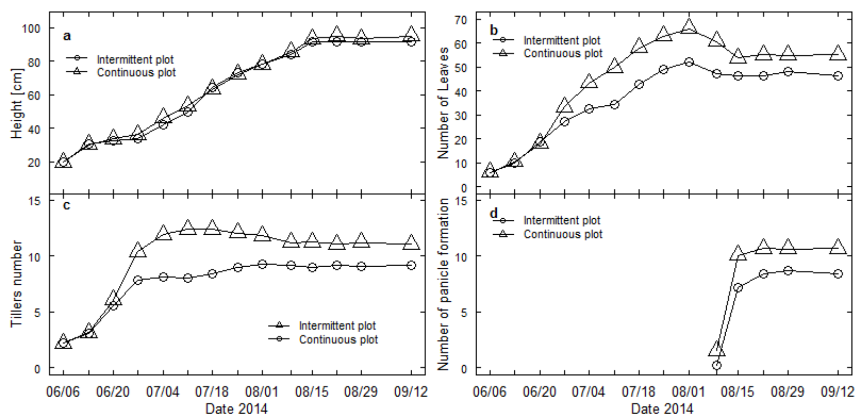

Fig. 3 Rice plant development: (a) plant height, (b) number of leaves, (c) number of tillers, and (d) number of flowerings

Rice Yield and Root Development

Table 1 Comparisons between number of grain, branch, rice root, and methane

Measurement indicators	Significant level	Intermittent plot		Continuous plot	
		Mean	SD†	Mean	SD†
Number of grains	-	1086.10	395.49	1198.30	383.15
Grain weight (gram)	-	21.03	6.82	21.97	5.95
Panicle branches (number)	**	95.50	36.08	117.30	39.19
Panicle weight without grain (gram)	*	1.09	0.41	1.34	0.49
Root length (centimeter)	-	19.20	2.53	20.60	2.63
Dry root weight (gram)	***	5.07	2.21	7.62	3.23
Methane flux (mg/m^2/hr.)	**	0.82	0.73	1.77	1.70

** Significant level at 0.1, ** Significant level at 0.05, *** Significant level at 0.01, - Not Significant*
† Standard deviation

To study the yield component, ten rice plants were selected from both plots. The rice plants were selected from both sides of the plot borders in order to make the sampling process uniform. Larger panicles were observed in rice plants from borders than from the middle of the plot. The number of grains, panicle branches, and roots were measured from the same rice plant samples. Every measurement indicators are an average of ten plants from each plot. The average grains number and weight were higher in the Continuous plot, but without significant difference compared to the Intermittent plot. A significant difference was observed in panicle branches. Higher number of panicle branches were found in the Continuous plot than in the Intermittent plot (Table 1). In terms of dry root weight, Continuous plot had a higher weight of total root than the Intermittent plot, but there was no difference between root lengths. Thakur et al., (2009) reported a higher elongation and better distribution of root system by SRI method, and several other studies from outside Japan has also reported of high yield and water savings by SRI. In this study, however, no significant difference was observed in terms of the yield and grain numbers.

Methane Emission

The methane gas emission from the Intermittent plot was typically lower than the Continuous plot. The methane gas reduction process by intermittent irrigation is already known by many researchers (Hadi et al., 2010; Kudo et al., 2014). The pattern of methane emission in both plots were increasing during the vegetative phase and decreasing during the reproductive phase. The rapid development of rice plants during the vegetative phase and longer application of irrigation caused the higher emission of methane. Soil Eh was measured as an indicator of methane gas emission from both plots. A significantly positive correlation between methane flux and soil water content was found in the lysimeter experiment in 2013 (Pun et al., 2013).

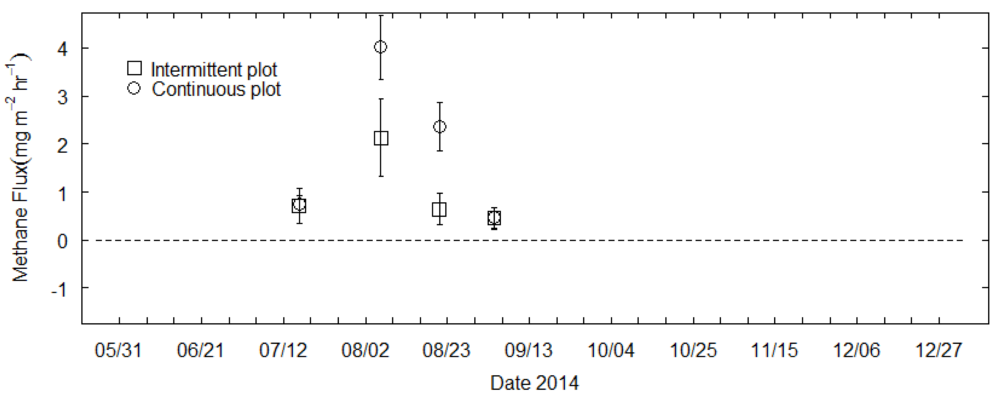

Fig. 4 Methane gas emission in Intermittent plot and Continuous plot

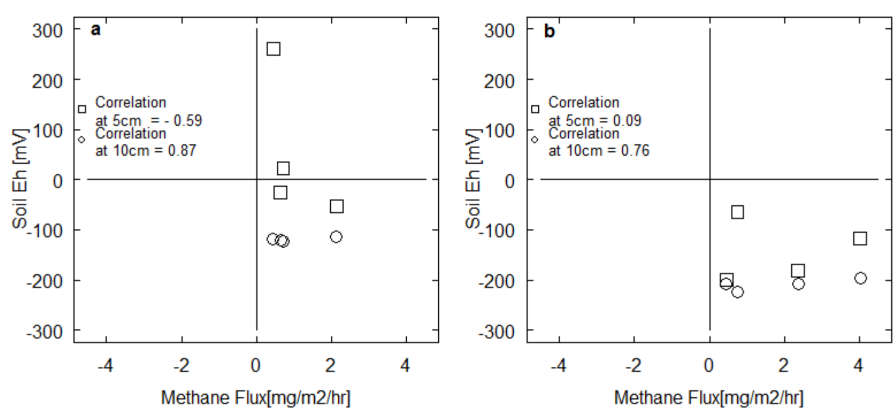

Fig. 5 Relation between methane flux and soil Eh

Moreover, to understand the mechanism of methane gas flux with soil layer condition, depth-wise measurements of soil Eh were taken. In both plots at 10 cm depth, positive correlation was observed between methane flux and soil Eh in Figs. 5a and 5b. However, Intermittent plot showed a negative correlation at 5 cm depth in Fig. 5a. In the Intermittent plot, the soil surface was alternatively kept wet and dry by intermitttent irrigation, resulting in a soil Eh fluctuation and low level of methane formation. The aerobic condition of the soils kept the emission low in the Intermittent plot. In case of the Continuous plot with continuous water ponding, soil Eh was lower at both 5 cm and 10 cm depths with higher methane flux. During the continuous flooding, the soil was under a reducing condition and thus emitted the methane gas. Cumulative methane flux during the rice growing season was reduced by nearly 50% in the Intermittent plot compared to the Continuous plot. Total methane flux emitted from the Intermittent plot and the Continuous plot were 50.41 g CO_2/m^2 and 100.53 g CO_2/m^2 per rice growing season, respectively. Another anthropogenic gas, N_2O emission, occurred when the flooding water disappeared from paddy field and fertilizer was applied (Cai et al., 1997).

CONCLUSION

The experiment was conducted to measure methane emission and the structural development of rice plant by SRI and non-SRI methods. The structural development of rice plant in the Continuous plot was significantly greater than the Intermittent plot. Young single seedlings were used in both plots, and there was no difference in grain yield. Dry root weight was greater in the Continuous plot but no difference was observed for root length. The methane flux in Intermittent plot was significantly lower than the Continuous plot, with almost 50% reduction in emission. The methane flux peak was mainly observed during the vegetative and pre-reproductive phases. If the water could be managed without stress to the plant, then SRI method can be the appropriate method for reducing global warming potential. The higher correlation between soil Eh and methane flux were found at 10 cm depth in both plots. The experiment was conducted on concrete made Lysimeter, and the heat from the concrete may have affected the measurements for soil temperature and Eh. To clearly understand soil Eh in relation to depth, tests in real paddy fields are needed. SRI method itself is a new environment-friendly method, and while several researchers produced higher yields than a conventional rice cultivation method, the results from this study was different. The dissemination of SRI method is still a work in progress, where key basic elements are being identified by particular local areas, since different areas have different climate conditions and resource availability. The difference in result was because the same number of rice seedling was transplanted in both plots. In other to further understand the structural development in SRI and non-SRI methods, an experiment is needed to test by seedling densities.

REFERENCES

Cai, Z., Xing, G., Yan, X., Xu, H., Tsuruta, H., Yagi, K. and Minami, K. 1997. Methane and nitrous oxide emissions from rice paddy fields as affected by nitrogen fertilisers and water management. Plant and Soil, 196, 7-14.

Chapagain, T. and Yamaji, E. 2010. The effects of irrigation method, age of seedling and spacing on crop performance, productivity and water-wise rice production in Japan. Paddy Water Environ, 8 (1), 81-90.

Chapagain, T., Yamji, E. and Riseman, A. 2011. Assessment of system of rice intensification (SRI) and conventional practices under organic and inorganic management in Japan. Rice Science, 18 (4), 311-320.

Defeng, Z., Shibua, C., Yuping, Z. and Xiaqing, L. 2002. Tillering patterns and the contribution of tillers to grain yield with hybrid rice and wide spacing. In Assessments of the System of Rice Intensification: Proceedings of International Conference, Sanya, China, 1-4 April 2002, 125-131. Eds N. Uphoff et al. Ithaca, New York: Cornell International Institute for Food, Agriculture and Development. Retrieved from http://ciifad.cornell.edu/sri/proc1/sri_28.pdf.

Hadi, A., Inubushi, K. and Yagi, K. 2010. Effect of water management on greenhouse gas emissions and microbial properties of paddy soils in Japan and Indonesia. Paddy Water Environ, 8, 319-324.

Kudo, Y., Noborio, K., Shimoozono, N. and Kurihara, R. 2014. Effects of water management practices for mitigating gas emission and maintaining rice yield in central Japan. Agriculture, Ecosystem and Environment, 186, 77-85.

Pun, I, Yamaji, E. and Ches, S. 2015. Effect of INTERMITTENTI Practices on methane gas emission in a small scale lysimeter. Paper presented at: The THA 2015 International Conference on "Climate Change and Water & Environment Management in Monsoon Asia", Bangkok, Thailand.

R Core Team. 2014. R: A language and environment for statistical computing. R foundation for statistical computing, Vienna, Australia. Retrieved from https://www.R-project.org/

Sato, S. 2005. 3 years experience of SRI (System of Rice Intensification) under SSIMP-DISIMP in eastern Indonesia. Paper presented at: Integrated Citarum Water management Project, 4-5 July, 2005, Jakarta.

Sato, S., Yamaji, E. and Kuroda, T. 2010. Strategies and engineering adaptations to disseminate SRI methods in large-scale irrigation systems in Eastern Indonesia. Paddy water environ, 9, 79-88.

Singh, S.K. and Talati, J. 2006. Productivity impacts of the system of rice intensification (SRI), A case study in West Bengal, India. Agricultural Water Management, 87, 55-60.

Thakur, A.K., Uphoff, N. and Antony, E. 2009. An assessment of physiological effects of system of rice intensification (SRI) practices compared with recommended rice cultivation practices in India. Expl. Agric., 46 (1), 77-98. Doi: 10.1017/S0014479709990548