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| **MSAE2018-AMA001**  **Title of the Conference Paper Using 14 pt Times New Roman Bold, Centered, Single Spacing**   1. N. Author1, B. Coauthor2 and C. Thirdauthor3   IDept. of Abc  University Abc  Street Name Mno  State Aby, Country Abc  2Dept. of Mno  University Mno  Street Name Mno  State Aby, Country Mno  3Dept. of Xyz  University Xyz  Street Name Xyz  State Xyz, Country Xyz  **ABSTRACT**  A short summary of your contribution may be inserted here. Use short, direct sentences. It should be as concise as possible. It should be complete, self-explanatory and should not require reference to the paper itself. The whole write-up should be informative, giving the scope of work and emphasizing the results, main conclusions or significance of the described work. Use style 11 pt Times New Roman, justified, single spacing with not exceeding 150 words.  **KEYWORDS**  Abc, Def, Ghi, Jkl, Mno |

**INTRODUCTION**

Methane is a powerful greenhouse gas with global warming potential (GWP) of 72 over a 20 years period (IPCC, 2007). Paddy fields are important sources of methane, so that from 50% of global methane emissions by agriculture 11% come from cultivation of rice (USEPA, 2006). Since, rice (Oryza sativa L.) (2n=24) belonging to the family Graminae and subfamily Orazoidea, is the staple food for one third world’s population, its production is anticipated to increase from 458 million tonnes to over 750 million tonnes by the year 2020. Besides, methane emissions from flooded rice will increase to about 150 million tonnes in 2025 (IPCC, 2007).

Conventional rice cultivation uses flooding continuously method as water management. Likewise, natural wetlands, flooding rice field cuts off entering the oxygen from the atmosphere to the soil. Therefore, it could induce an anaerobic condition within the soil. Anaerobic condition is necessary for biodegradation of organic matter. Meanwhile, methanogens as methane producers motivate to be active (Singh, 2009) and produce methane as a metabolic by-product. Activation of these microorganisms can be influenced widely by water regime type. On the other hand, there are some microbial communities such as methanotrophic bacteria in the surface soil layer and the rhizosphere which are responsible for methane oxidation before release into the atmosphere (Singh et al., 2010). Aerating the soil can provide a favorable condition for methanotrophs to oxidize the methane effectively before it can escape to the atmosphere.

On the other hand, system of rice intensification (SRI) is a cultivation method which was developed during the early 1980’s in Madagascar (Glover, 2011). SRI oblong-triangular is a modified SRI which is similar to SRI original except for cultivation pattern. In this cultivation method 3 seedlings per hill separated by 7 cm with 40×45cm regular distances would be transplanted (24 plants per m2) (Zheng et al., 2004).

SRI utilizes a specific water management called alternate wetting and drying water management (AWD) (Krupnik et al., 2012). Avoiding flooding the soil continuously using AWD in 3-6 day cycles might make SRI capable to suppress methane emission. This way, we expect less methane emission compared to the conventional method. Besides, in aerated soils the aeranchyma texture in rice plant would not develop and thus, the methane transportation ability of rice will be low. Other principle of SRI method leading to less methane emission is planting single seedlings at two-leaf stage (8-15 days in tropical climates) 1-2 cm deep in original SRI (18 plants per m2) (Dobermann, 2004).

In conclusion, SRI method introduces some changes to management practices for rice cultivation that not only provide better condition for rice growing (Chapagain et al., 2011) but also could aerate the soil alternatively so that it can decrease methane emission from paddy soil. Moreover, other benefits of this cultivation method include increasing yield, saving the water, producing stronger rice plants with resistance to pests and diseases due to synergies among the practices of SRI have been reported as the reason (Glover, 2011); and its high potential to suppress the methane emission due to the AWD water management. Therefore, the aim of this study is to understand the effect of original and oblong-triangular SRI methods on methane emission from rice soil, which could lead to achieve possible methane mitigation option by replacing conventional method with SRI cultivation system.

**MATERIALS AND METHODS**

**Set-up of the cultivation tanks**

Three tanks with the dimension of 1 m × 0.6 m × 0.6 m (height × length × width) have been prepared as cultivation medium. The tanks were filled according to the soil profile of rice field due to simulate the hydraulic conductivity in the field condition. Therefore, the filling layer included large gravels (2-3 cm) at 10 cm height, small gravels (0.5-1 cm) at 10 cm height, second layer soil (which is the soil from below 10 cm depth) at 20 cm height, and top soil at 10 cm height respectively from bottom to the top. Methane emission was measured applying static chamber (Figure 1). Therefore, three chambers with dimension of 1 m × 0.2 (length × diameter of basement) made of transparent Plexiglas have been applied (Figure 1). Tedlar® bags made of transparent 2 ml film were attached to the chambers from the top to collect the gas emitted from paddy tanks. The methane in gas bags was measured by portable gas detector (Crowcon, Oxfordshire England). Chambers were put on the soil, so that the edge of chambers was located in depth 7 cm. This way, we could collect the produced methane after passing from the oxic area of the soil (0-10 cm depth) which is the overall methane emission. On the other hand, for measuring methane emission from below 10 cm depth, top 10 cm soil below the chamber has been removed. Therefore, the edge of chamber could be inserted into depth of 12 cm and thus, it can be supposed that the methane emission is from anoxic area without a significant methanotrophic activity.

**Cultivation techniques**

Three cultivation methods have been applied including, Malaysia conventional method (C), original system of rice intensification (SRI-O) and modified system of rice intensification oblong-triangular pattern (SRI-T) (Dobermann, 2004). Table 1 shows the conventional method practice description. Moreover, irrigation pattern in this method was conducted according to FAO (1989). In SRI-O and SRI-T, AWD irrigation with 3-6 days interval and 1–2 cm water depth was conducted until the flowering stage. Afterwards, the paddies remained continuously flooded (Ceesay, 2011) until 15 days before harvest, when the paddy tanks were drained (Table 1).

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| *SNC02287.jpg* |
| *Figure 1: A static chamber with a gas bag at 77days after transplanting* |

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| *Table 1: Cultivation practices generally recommended for SRI compared to conventional methods* | | | | |
| Practices | SRI methods | | Conventional methods | |
| Original SRI | Oblong-Triangular SRI |
| Nursery bed | One of the paddy tanks will allocate to nursery purpose | | | |
| Seed Variety | MR219 | MR219 | | MR219 |
| Seedling age at Transplanting | 8–12 days at transplanting | 8–12 days at transplanting | | 21–30 days at transplanting |
| Seedling no. | 1 seedling in each hill transplanted at 1–2 cm depth; | transplanting 3 seedlings per hill separated by 7 cm | | 3–5 seedlings in each hill, plunged into soil |
| Spacing | 25 × 25 cm with regular distances | 40×45cm with regular distances | | 15–20 cm at random intervals |
| Irrigation |  |  | |  |
| Vegetative growth stage | Intermittent irrigation with wet–dry cycle; only shallow standing water during wet periods (±2 cm) | | | Continuous irrigation, keeping ±10 cm of standing water on fields |
| Reproductive stage | Continuous irrigation, keeping 2–5 cm of standing water | | | Continuous irrigation, keeping ±10 cm deep standing water |
| Weeding Method | Rotary weeder, weeding tools, or manual weeding every 10-12 days starting 10-12 days after transplanting | | | Use of weeding tools, or manual weeding\_whenever its needed |
| Fertilizer use  Type | Chemical fertilizers plus organic inputs | | | Chemical fertilizer used by farmers  (Urea, Compound Fertilizer, Mixed Fertilizer) |

**Data analyses**

Closed-chamber model (1) by Rolston (1986) has been used for calculation of CH4 flux :

F = ρ . V/A . Δc/Δt . 273/T (1)

Where :

*F* = CH4 flux, mg CH4 m-2 h−1

*Ρ =* methane gas density, 0.714 mg cm−3

*V* = volume of chamber, m3

A = surface area of chamber, m2

*H* =height of the chamber, m

Δc/Δt = increasing rate of methane concentration in the chamber, mg m−3 h−1

*T* = 273 + mean temperature in chamber, °C

Theflux formula (2) by Singh et al. (1999) has been used for determining the total CH4 for the entire crop period :

Total CH4 flux = ∑ in (Ri × Di) (2)

Where:

*Ri* = rate of CH4 flux in the ith sampling interval, g m−2 d−1

*Di* = number of days in the ith sampling interval, numeric

*N* = number of sampling intervals, numeric

Analyzing the data including analysis of variance (ANOVA) has been conducted by Microsoft Excel. In case of significant differences, Duncan Multiple Range test (DMRT) implemented to compare the means by MSTAT-C statistical software.

**Calculation of Yield**

Rice plants were harvested at physiological maturity stage (almost 95% of grains were turned to yellow). The grains of all panicles in each tank were separated and dried in 70°C until constant weight. The yield per tank calculated and applied to estimate yield per hectare (Formula 3-1). Then 10% grain loss was subtracted to obtain the estimated grain yield per hectare.

Gt / Ta ×10000 m2 = Gha (3-1)

Gha – (10% × Gha) = GYha (3-2)

Where:

*Gt* = grain yield per tank, ton

*Ta* = tank area, 0.36m2

*Gha* =grain yield, ton/hectare

*GYha*=estimated grain yield, ton/hectare

**RESULTS AND DISCUSSIONS**

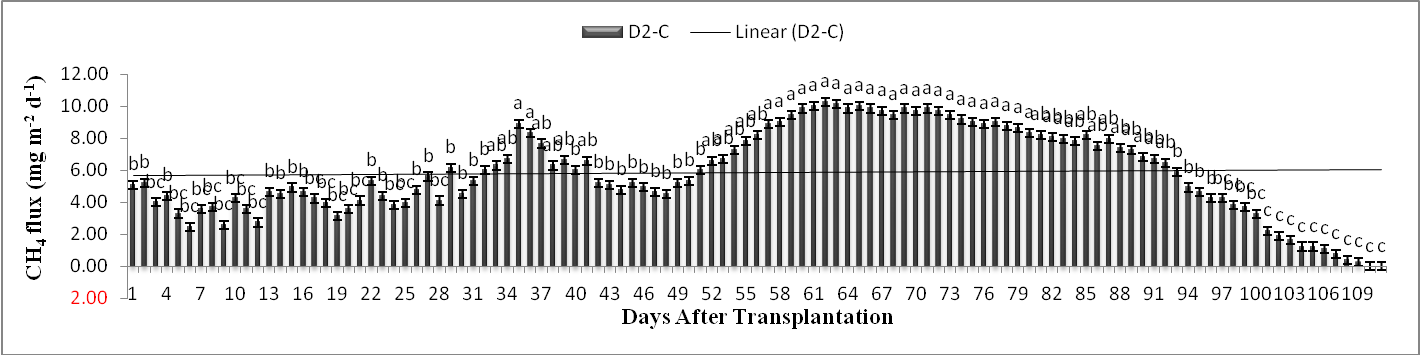
**Effect of cultivation technique on methane emission**

In control treatment, daily methane emission increased until 62 days after transplanting (DAT) (panicle initiation stage). From this stage until 80 DAT (heading stage), methane emission remained high. Afterwards, it declined gradually, so that it reached 0 at harvest stage when the soil was dried completely (Figure 2). This pattern has been reported before as a constant pattern of several rice fields with different soil properties and climate conditions. It is a considerable fact which could be due to the methanogen’s population changes during the rice growing season (Yue et al., 2007). There were two peaks in 35 days after transplanting (at vegetative stage) and 62 days after transplanting (at panicle initiation stage). Similarly, SRI-O and SRI-T showed two peaks at 35 and 65 days after transplanting coincide with vegetative and panicle initiation stage respectively. This result is in agreement with previous works (Hou et al., 2012). The first peak might be due to decomposition of the organic matter that was existed in soil before the plantation of rice (Gogoi et al., 2008). This decomposed organic matter will be a carbon source for methanogenic bacteria. The second peak was due to increasing in the soil carbon content by root exudate and litters which are important sources for methane emission (Neue et al., 1996). A fluctuation occurred in daily methane emission of SRI treatments (Figures 3, 4 and 5). This fluctuation seems due to alternative wetting and drying the soil. Consequently, the methane emission flux during drainage was lower than flooding period. In fact, imposing the drainage alternatively suppressed methane emission, so that it could not exceed 3.15 mg m-2 d-1. Contradictory, control exhibited a maximum emission higher than SRIs remarkably (8.36 mg m-2 d-1).

The pattern of sub soil emission in control (D2-C) was almost similar to its top soil (Figure 6). Daily methane flux showed a decreasing trend in SRI (Figure 7). Contradictory an increasing trend observed in control. This finding shows that, SRI cultivation practices could control the methane emission effectively. Control showed highest total methane flux (26.4 g CH4 m-2) compared to both SRI-O (7.7 g CH4 m-2) and SRI-T (8.9 g CH4 m-2) (Figure 8). There was not any significant difference between SRIs treatments. In terms of sub soil emission, control represented remarkably higher total CH4 emission than SRI. In addition, methane emission was reduced by 66.06% and 60.90% from SRI-O and SRI-T respectively compared to control. It seems that water regime is the most effective factor in this order (Khosa, et al., 2011). The methane emission from sub soil of control was higher than the top soil intensely (Figure 9). This difference between sub soil and top soil emission also can be observed in SRI (Figure 10). It shows that a significant amount of methane produced in subsoil oxidized by methanotrophs in top soil before releasing to the atmosphere. ANOVA analysis showed higher methanotrophic activity in SRI especially in vegetative growth stage. This is due to the two side effect of irrigation pattern in SRI. In fact, the SRI irrigation method has suppressing effect on methanogenic activity while, it increases methanotrophic activity by providing an aerobic condition in soil.

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| *Figure 2: Methane emission in the control treatment (mg m-2d-1) during the rice growth season and its linear regression*  *line* |

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| *Figure 3: Methane emission in the SRI-O treatment (mg m-2d-1) during the rice growth season and its linear regression*  *line SRI-O: original system of rice intensification* |
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| *Figure 4: Methane emission in the SRI-T treatment (mg m-2d-1) during the rice growth season and its linear regression*  *line SRI-T: system of rice intensification-oblong-triangular pattern* |



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| *Figure 5: Methane emission in the D2- SRI treatment (mg m-2d-1) during the rice growth season and its linear regression*  *line D2-SRI: The methane emission from anoxic area of the system of rice intensification treatment* |

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| *Figure 6: Methane emission in the C- D2 treatment (mg m-2d-1) during the rice growth season and its linear regression*  *line D2-C: The methane emission from anoxic area of the conventional treatment* |

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| *Figure 7: Comparison of the linear regression slope between treatments in order to comparing the trend of changes in*  *methane emission* |

**Effect of cultivation on grain yields**

Lower methane emission from SRI in compare with control can be a promising result (Figure 9) especially while both SRI-O and SRI-T (6.987 and 7.08 t ha-1) produced higher grain yield rather than conventional cultivation method (6.74 t ha-1) (figure 11). More intense competition between plants in control comparing to SRI and synergies between cultivation practices in SRI might be the reasons. Higher yield of SRI-T seems due to higher plant density (27 plants per m2) compared to SRI-O (16 plants per m2). This finding shows the obvious advantage of SRI cultivation practice over the conventional method.

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| *Figure 8: Comparison of total methane flux between treatments* |

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| *Figure 9: Difference between sub soil (C-D2) and top soil (C) in methane emission from control* |

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| *Figure 10: Difference between sub soil (SRI-D2) and top soil (SRI-O) in methane emission from original SRI* |

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| *Figure 11: Comparison of grain yield of between treatments* |

**CONCLUSIONS**

Our results suggest that, SRI-T is the most satisfactory cultivation system to mitigate methane emission from rice soil. Outstandingly, rice plants produced highest grain yield under this cultivation method. The most effecting factor to reduce CH4 emission was draining the soil in SRI. Moreover, the important aspect was the pattern of wetting and drying alternatively, which not only reduced the yield but also increased it compared to conventional cultivation system. In conclusion, the current study suggests SRI-T as an appropriate low emitting methane cultivation system for rice production. Nevertheless, we did not assess the nitrous oxide (N2O) emission of SRI method. Therefore, further studies are needed to evaluate the N2O emission from SRI in association with some N2O mitigation approaches such as utilizing coated nitrogen fertilizers.

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