Evaluation of Different Rates of Organic Manure and Water Management Practices on Methane Emission from Rice Production

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Abstract: To find out the water management and organic manures practices to obtain minimum methane emission, the pot experiments were conducted during the summer and rainy season 2017. Split plot design with three replications was used. Two water management practices and four cowdung manure rates were allocated in main and sub factor arrangement. IR 50 was planted with twenty one seedling age. In summer season, the gas sampling at 8 DAT expressed the second largest amount of methane emission. At 14 DAT, the largest methane emission was found. At later DATs until harvest, the smaller amount of methane emission was recorded. Numerically, the higher methane emission was observed from CF over AWD. The surface water pH was highly statistically correlated with methane emission. In continuous flooding, the highest methane emission was recorded from OM_3 and the lowest emission from OM_0. In alternate wetting and drying (AWD), the higher methane emissions were recorded from OM_0 and OM_3 and the lowest emission from OM_1. In rainy season experiment, there was statistically different in methane emission among the water management. CF gave the higher methane emission at every gas sampling over AWD practice. The surface water pH was highly correlated with methane emission. In continuous flooding, the highest methane emission was observed from OM_2 and the lowest emission from OM_0. In alternate wetting and drying practice, the highest methane emission was recorded from OM_0 and the lowest one from OM_3.

Key words: rice, organic manure, water management, methane emission

1. Introduction

Globally rice is a crucial crop: it has a central role in providing food, it has a central role in providing employment, and it has substantial environmental impacts. Globally rice is estimated to be responsible for 19% of anthropogenic methane emissions, second only to ruminants (Chen and Prinn 2006).

Most of the world's rice grows in inundated conditions, and one of the most promising techniques for reducing rice-related emissions is to reduce or interrupt the periods of flooding. The production of rice in flooded paddies produces methane because the water blocks oxygen from penetrating the soil, creating conditions conducive for methane-producing bacteria. Methanogenesis, methane production, is a microbial process strictly limited to anaerobic conditions (Ma et al. 2010).

Methane is produced from the respiration of organic matter in anaerobic conditions. Given the existence of abiotic conditions in a paddy soil, the supply of methanogen substrate – soil organic matter – is the commonest limiting factor for methanogenesis (Yao et al. 1999; Wang et al. 2000). Organic matter typically arise from four sources – three imported or easily controllable sources: animal manure, green manure and crop residues (straw, stubble, roots), and one by-product of rice production – this year's root exudates, sloughed off root cells, root turnover. The addition of 5t rice straw ha^{-1} increased CH_4 emissions tenfold compared to the use of urea alone (Neue et al. 1996), and the CH_4 reductions associated with alternate irrigation was lost when rice straw was added compared to continuously flooded paddy, measured per tonne of paddy (Adhya et al. 2000).

Rice farmers tend to keep their fields continuously submerged to control weeds, although long-term experiments suggest that continuous puddling for rice destroys soil physical properties and affects both the puddled rice yield and the following crop negatively (http: //www fao org/teca/content/alternatives-rice-puddlingand-transplanting). Rice environments with an insecure supply of water, namely rainfed rice, have a lower emission potential than irrigated rice.

Alternate Wetting and Drying (AWD) is a water-saving technology that lowland (paddy) rice farmers can apply to reduce their water use in irrigated fields. Hence, the field is alternately flooded and non-flooded. The number of days of non-flooded soil in AWD between irrigations can vary from 1 day to more than 10 days depending on the soil type. Water savings may be up to 15-25 percent with no yield penalty. The AWD promotes good root anchorage, thus reduction in plant lodging problems. The AWD reduces 30-70 per cent of methane emissions depending on the combination of water usage and management of rice stubble (FAO 2013).

Methane emission depends on soil type, weather condition (i.e. temperature, rainfall), varieties, water management, organic amendment and cultural practices. Nowadays human beings noticed well about the climate change and are alert in GHG emission mechanisms. A little has been known the methane emission from paddy fields in the country. This study was, therefore, carried out to investigate the methane emission from paddy field. The pot experiments were conducted in summer and rainy season 2017 with the following objectives: to evaluate the performance of rice plant as affected by different rate of organic manure and water management practice and to find out the suitable organic manure rate and water management practice on methane emission.

2. Materials and Methods

The pot experiment was conducted at farmer's field in Si Taing Kan village tract during the summer and rainy seasons. The pots were arranged in split plot design with three replications. The water management (continuous flooding (CF) and alternate wetting and drying (AWD)) was arranged as main plot factor. Different rates of organic manure were assigned as subplot factor. In this study, cowdung manure was applied as organic manure.

Soil was collected from paddy field to use as experimental pot soil. The soil and cowdung manure were analyzed at Water Science Section, Water Utilization and Agricultural Engineering Division, Department of Agricultural Research (DAR). The results of properties of soil and cowdung manure are shown in Appendix I. The meteorological data for the study period (February to October) are shown in Appendix II.

2.1 Treatment application

The calculated cowdung manure according to treatments (OM_0 = no cowdung, OM_1 = half of recommended cowdung (2.5 tons ha^{-1}), OM_2 = recommended cowdung (5 tons ha^{-1}) and OM_3 = one and half of recommended cowdung (7.5 tons ha^{-1}) were put at seven days before transplanting. The recommended cowdung manure is 5 t ha^{-1} (4 cart load ac^{-1}). Each pot received the recommended fertilizer at the rates of 86.8 kg N ha^{-1}, 30.2 kg P_2O_5 ha^{-1}, 18.9 kg K_2O ha^{-1}. Urea, T-super and Potash were used as nutrient element sources. Urea was applied as three equal splits at active tillering, panicle initiation and heading growth stages. T-super was applied only as basal at one day before transplanting and potash fertilizer was used for two equal splits at basal and panicle initiation.

Field water tubes were installed in the AWD pots at a depth of 15 cm below the soil surface in between the seedlings and base just after transplanting. For AWD pots, whenever there was no water in the field tube, irrigation water was applied until 5 cm depth above the soil surface. The irritation interval ranged from 4 to 9 days and the amount ranged from 7 to 13 liters depending on the different rates of cowdung manure in AWD pots. Withdrawal of water was started one week before the harvest period in all water treated pots.

2.2 Data Collection

Soil parameters

Surface water pH was recorded by using pH meter (HI8314, Hanna, Japan). Redox potential was taken by ORP meter (HI8314 Hanna, Japan) with probes. Soil temperature was collected with waterproof digital thermometer (CT-300WP, Tokyo, Japan). These parameters were recorded along with gas sampling time. Soil (15 g) was taken from soil surface of each pot for soil pH analysis. Soil pH was analyzed at Department of Agriculture, Madaya using pH meter in 25:1 ratio of deionized water and soil.

Gas sampling and calculation

Just after transplanting, the base was put to the gas sample plant to avoid the disturbance of the environmental conditions around the rice plants during chamber deployment. The base was equipped with a water seal to ensure gas-tight closure. The base remained embedded in the soil throughout the rice growing period. The two-binded chamber of total capacity of 77 L (93 cm height) was used for collecting gas sample. The mouth of closed chamber had diameter of 41 cm. Therefore the diameter of chamber base is wide to 40 cm with 3 cm wide-water seal. The chamber was painted with white color to prevent the absorption of temperature. To thoroughly mix the gases in the chamber, the chamber was equipped with a small fan of 12 volt DC connected with three 9-volts dry cells. For CH_4 calculation, temperature was recorded with a digital thermometer (TT-508 Tanita, Tokyo, Japan). For compensation of air pressures between increased temperature and gas sampling, an air buffer bag (1-L Tedlar bag) was attached to chamber. The silicon rubber tube together with the soft vinyl tube (In dia 3mm x out dia 5 mm) attached with double three-way stop corks was inserted air tight to a hole on chamber. The gas sample was taken with airtight 50 ml syringe by inserting it to the three way stop cock. The 50 ml syringe was stroke 5 times for air cleaning before collecting of gas sample. The air inside the chamber was thoroughly mixed by flushing the syringe three times before collection of the gas samples. The gas sample was drawn to the 50 ml volume of syringe through the three way cock from chamber and then transferred to 15 ml vacuum glass vial which were evacuated after adjusting the pressure to the 40 ml volume of syringe.

CH_4 concentration was analyzed with a gas chromatograph (GC 2014, Shimadzu Corporation, Kyoto, Japan) equipped with a flame ionization detector (FID). The amount of CH_4 flux was calculated by using the following equation;

$$Q = (V/A) \times (\Delta c/\Delta t) \times (M/22.4) \times (273/K)$$

Where, Q = the flux of CH_4 gas (mg m^{-2} min^{-1})

V = the volume of chamber (m^3)

A = the base area of chamber (m^2)

$(\Delta c/\Delta t)$ = the increase or decrease rate gas concentration (mg m^{-3}) per unit time (min)

M = the molar weight of the gas,

K = Kelvin temperature of air temperature inside the chamber

Total emissions were calculated by multiplying the daily gas flux at each measurement for the time interval and summing up the values for the growing period.

2.3 Statistical analysis

The data were analyzed by using Statistix (version 8.0). Mean comparisons were done by Least Significant Difference (LSD) at 5% level.

3. Results and Discussion

Soil parameters during the summer season, 2017

Soil temperature: Different levels of organic manure application gave different mean values of soil temperature (Figure 3.1). In continuous flooding, the start-up high temperature was found at 8 DAT due to the stimulation of organic manure in the soil. The high soil temperature was given by OM_0 and the low soil temperature from OM_2. It sharply decreased to minimum value throughout the growing season at 14 DAT. This might be due to soil physiocochemical changes affected by weather. Khalil el al. (1998) reported that during the growing season, the temperature changes was driven by diurnal cycles of sunlight and cycles of soil temperature are sometimes observed as weather systems come and go. The high soil temperature was recorded from OM_0. Then the soil temperature slowly increased until 34 DAT. At that time, the high soil temperature was found in OM_1 and the low soil temperature from OM_3. This could be due to the decomposition of organic matter. Again at 44 DAT, the soil temperature slightly decreased (about 25 °C), which coincided with panicle initiation stage. From that stage, the soil temperature is gradually increased until 64 DAT and then, decreased again at 74 DAT. From that, the soil temperature increased until harvest because of substrate decomposition.

In AWD, the same trend of soil temperature was recorded. However, the peak soil temperature values were changed depending on growth stages. At 8 DAT, OM_3 gave high soil temperature, OM_1 at 14 DAT, OM_2 at later sampling dates.

The mean effects of soil temperature of different cowdung manure rates under both water regimes were not much different. This result supported the finding of Haque et al. (2016) who stated that the soil temperature was slightly lower when the paddy was flooded than when it was midseason draining. Xu and Hosen (2010) stated that the soil temperature was affected by activity of methanogenic bacteria, the decomposition rate of soil organic matter.

Soil redox potential: The different trends of soil redox potential (Eh) of variation was observed in Figure 3.2. In continuous flooding, the soil redox potential was observed between -350 mV and -100 mV. The low redox potential values were recorded from OM_1 at 8 and 14 DAT, OM_3 at 24 DAT, and OM_1 at 34 DAT. During the later growth stage, the redox potential was relatively stable because of microbial process of organic substrates. But mostly low redox potential was given by OM_3. Jain et al. (2004) reported that in soil with high amount of organic matter, Eh falls to -50 mV and may then slowly decline over a period of a month.

In alternate wetting and drying, the soil redox potential was in the range of -300 to 0 mV. The different trend of soil redox potential was also found. In the early growth stage (8, 14, 24, and 34 DAT), mostly the low redox potential was recorded from OM_2 but in later growth stage, the high fluctuation was found. At 54 DAT, the low value was resulted from OM_2. OM_1 gave low redox potential at 64 and 84 DAT, OM_3 at 74 and 94 DAT. This is due to the microbial process of organic matter. Ascar et al. (2008) stated that some of abiotic environmental factors such as Eh are strongly influenced by biotic environmental factors.

The mean effects of soil redox potential to different cowdung manure rates were different in both water regimes. After flooding the rice field, the soil Eh values decreased sharply in both continuous flooding and alternate wetting and drying practice within 2 weeks of rice transplanting (Haque et al. 2016). The cowdung manure affected the soil redox potential especially in the continuous flooding. The higher cowdung manure caused the higher reduction condition in the soil. According to the report of Nieder and Benbi (2008), application of organic matter will decrease Eh depending on the degree of humification.

Surface water pH: Different mean values of surface water pH were resulted from different levels of organic manure application (Figure 3.3). The values of surface water pH were decreased at 14 DAT and thereafter increasing trends were observed upto 44 DAT. At each DAT, different level of organic manure application showed different values of surface water pH. It was observed that mean values of surface water pH were higher in the early growth stages (from 8 to 64 DAT) as compared to those in the later growth stages (from 74 to 94 DAT) under continuous flooding. This may be due to the microbial breakdown of organic substrates in the early stages and depletion of them in the later growth stages. Gambrell (1994) and Guo et al. (1997) have reported on the influence of soil microbial activities on pH. Zoltan (2008) stated that solute macro- and microelement content may influence on spatial and seasonal variations of surface pH.

Like under continuous flooding, similar trend was observed under AWD. At each DAT, different values of surface water pH were resulted from different levels of organic manure application.

In comparison of both CF and AWD, the pH values under CF were generally higher than those under AWD during 24 – 44 DAT. This period ranged in panicle initiation stage. This increased pH value in CF may be due to the rapid decomposition process by active microbes in the favor of organic substrates in that stage. It was obvious that the range of surface water pH under CF was more wider than that under AWD because some of abiotic environmental factors was strongly influenced by biotic environmental factors, which are also influenced by cultural practice such as water management (Ascar et al. 2008). Oo et al. (2015) found high standing water pH in submerged rice soil. Zoltan (2008) reported that difference in water regime is one of the most important abiotic factors for pH variations.

Soil pH**:** Different mean values of soil pH were observed in different levels of organic manure application (Figure 3.4). The values of soil pH were decreased to 44 DAT and thereafter sharply increasing trends were observed upto 94 DAT except at 84 DAT which showed rapidly decreased. At each DAT, different level of organic manure application showed different values of soil pH. It was observed that mean values of soil pH were lower in the early growth stages (from 14 to 44 DAT) as compared to those in the later growth stages (from 54 to 94 DAT) under continuous flooding. In the early stage of irrigation, neutralized soil condition was resulted because of active microbial process with trapped oxygen.

Like under continuous flooding, similar trend was observed under AWD. Mean values of soil pH were different in different levels of organic manure at each growth stage.

In comparison of both CF and AWD, it was noticed that the soil pH values under CF were generally slightly lower than those under AWD throughout the growing season. The AWD showed slightly alkaline condition. Some microorganisms such as methanotrophs developed in the presence of oxygen and organic substrates, and kept the soil under slightly alkaline condition. Mer and Roger (2001) reported that methanotrophs are ubiquitous in ricefield soils, where their densities were not strongly affected by oxidation status of soil.

Methane emission during the summer season, 2017

The different amounts of methane emission were observed in the present study (Figure 3.5). In continuous flooding, at 8 DAT, the high methane emission was found, and then it was dramatically increased to highest emission at 14 DAT. This was due to the intrinsic methane production potential of soil and rapid decomposition of cowdung manure. Zou et al. (2005) mentioned that when the field was waterlogged, CH_4 emissions ascended steadily until the peak fluxes were attained approximately 25 days after rice transplanting. Rennenberg et al. (1992) reported that the first emission maxima, observed shortly after flooding, could be attributed to the degradation of organic matter present in the soil. In the present study, small amount of emission was observed in later growth stages to harvest. This might be due to impedition of methanogenic activity and limited carbon source for methanogens. In general, the high methane emission was recorded from OM_3 at all DAT, and the low methane emission was mostly resulted from OM_0. Khosa et al. (2010) stated that application of organic materials to rice fields significantly increased the rate of methane emission as compared to control plots receiving only inorganic fertilizer as the addition of organic matter selectively enhanced the growth of particular methanogenic populations by providing them carbon source.

In AWD, the same trend of methane emission was observed. The most high methane emission was resulted from OM_2 and low methane emission from OM_1. The mean values of methane emission in different cowdung manure rates were not different in both water regimes. The methane emission ranged from 0.22 to 511.93 mg CH_4 m^{-2} in continuous flooding and 0.03 to 372.25 mg CH_4 m^{-2} in AWD. Alternate wetting and drying reduce the amount of time rice fields are flooded and can reduce the production of methane by about 60% or even up to 90% (IRRI, 2009). The total CH_4 emission from intermittently irrigated fields was found to be 22% lower as compared with continuous flooding (Jain et al. 2000). Alternate wetting and drying results in a significant reduction of CH_4 emission, and water drainage and resulting aerobic soil conditions allow the oxidation of CH_4 and avoid CH_4 production (Hussain et al. 2014). Katayanagi et al. (2012) reported that alternate wetting and drying has the potential to reduce CH_4 emission by 73 % compared with traditional flooded rice.

Mean values of cumulative methane emission of rice were different in different levels of organic manure (Table 3.1). Higher cumulative methane emission (2645.6 kg CH_4 ha^{-1}) was found in CF as compared to AWD (792.2 kg CH_4 ha^{-1}). The high organic manure rate gave higher amount of methane emission (1968.0 kg CH_4 ha^{-1}) as compared to others. The mean values of methane emission in different cowdung manure rates were not different in both water regimes (Figure 3.6). However, in concern with water regimes, the higher methane emissions were recorded in CF plots as compared with AWD plots. In CF, the methane emission was found increasing trend depending on the increased cowdung manure rates. Multiple aeration for 2-3 days at 3, 6, and 9 weeks after initial flooding reduced CH_4 emission by 88% and did not reduce rice yields compared with the normal irrigation (Sass et al. 1992). Wassmann et al. (2000) reported that in alternate wetting and drying, the time intervals between dry and wet conditions appear to be too short to facilitate the shift from aerobic to anaerobic soil conditions resulting in a significant reduction of CH_4 emission. Water drainage and resulting aerobic soil conditions allow the oxidation of CH_4 and avoid CH_4 production. Katayanagi et al. (2012) reported that alternate wetting and drying has the potential to reduce CH_4 emission by 73% compared with traditional flooded rice. Methane emission from the flooded paddy increases by applying different organic matter sources. Methane production, oxidization and emission from the flooded paddy are highly affected by the added organic matter (Jean and Pierre 2001). Application of organic materials to rice fields significantly increased the rate of methane emissions as compared to control plots receiving only inorganic fertilizer as the addition of organic matter selectively enhanced the growth of particular methanogenic populations by providing them carbon source. The organic materials significantly increased the organic carbon content over the control (Khosa et al. 2010). Schutz et al. (1989), Yagi and Minami (1990), Sass et al. (1991), Cicerone et al. (1992), and Neue et al. (1994) observed that organic amendments to flooded soils increase CH_4 production and emission by enhancing the reduction of soils and providing carbon sources. Nayak et al. (2013) concluded that livestock manure application in rice increased CH_4 emission and soil organic C sequestration while considerably decreased N_2O emission.

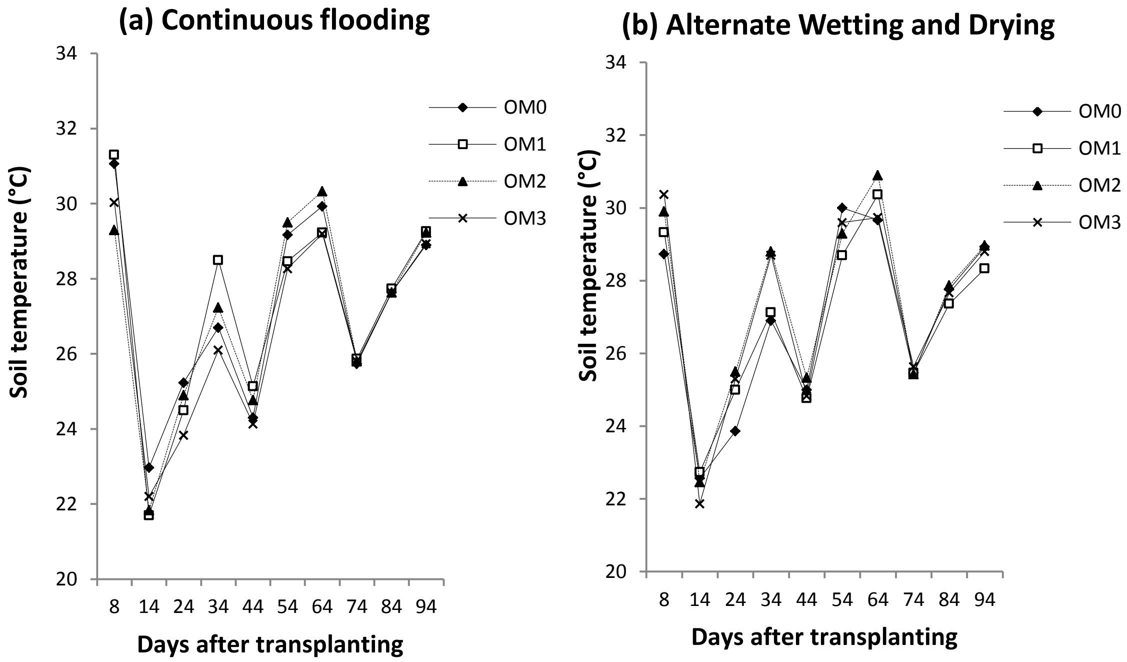

Figure 3.1: Variation in soil temperature (a) continuous flooding and (b) alternate wetting and drying during the summer season, 2017

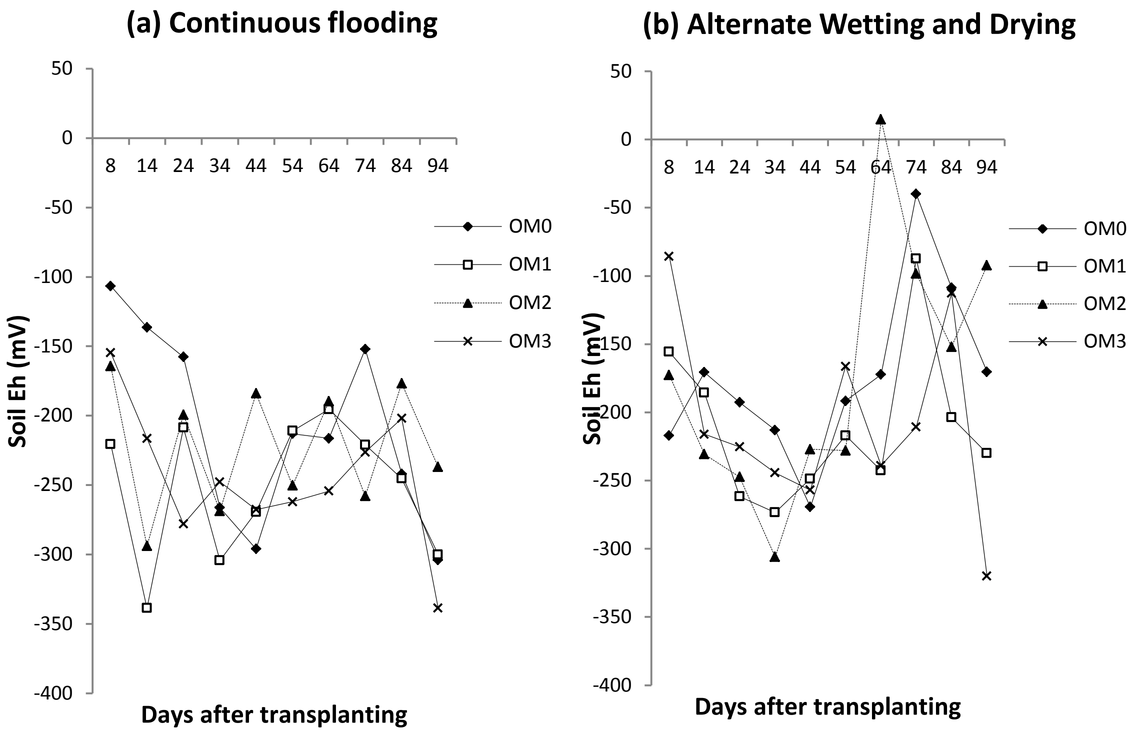

Figure 3.2: Variation in soil redox potential (Eh) (a) continuous flooding and (b) alternate wetting and drying during the summer season, 2017

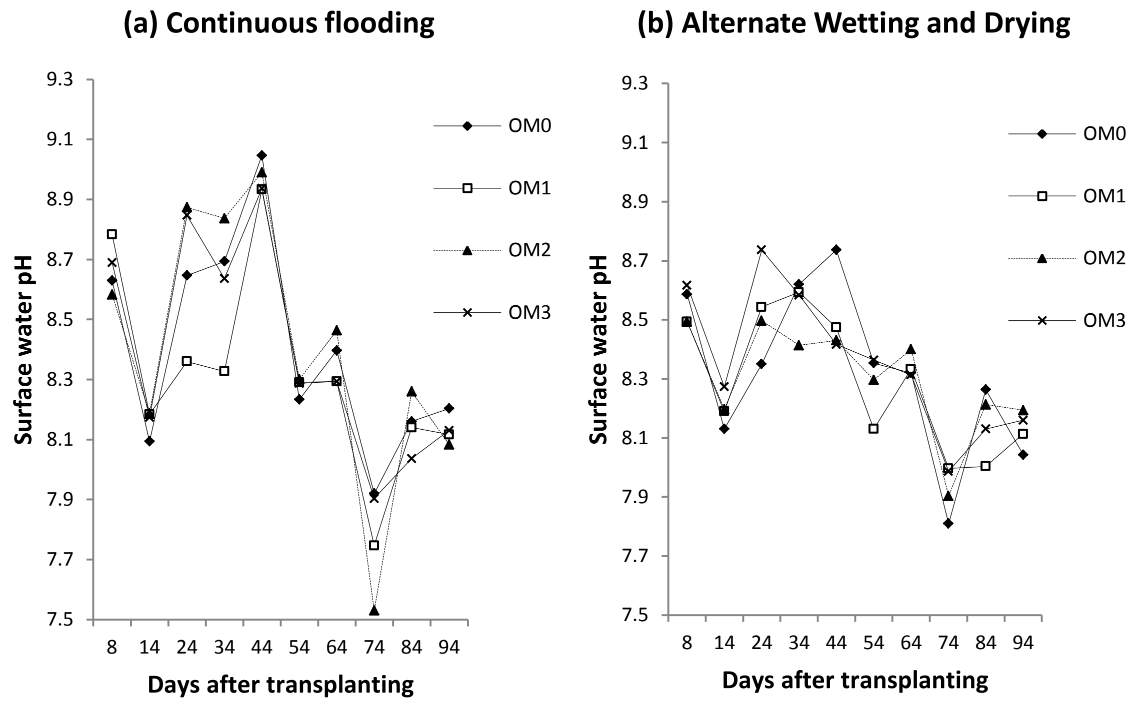

Figure 3.3: Variation in surface water pH (a) continuous flooding and (b) alternate wetting and drying during the summer season, 2017

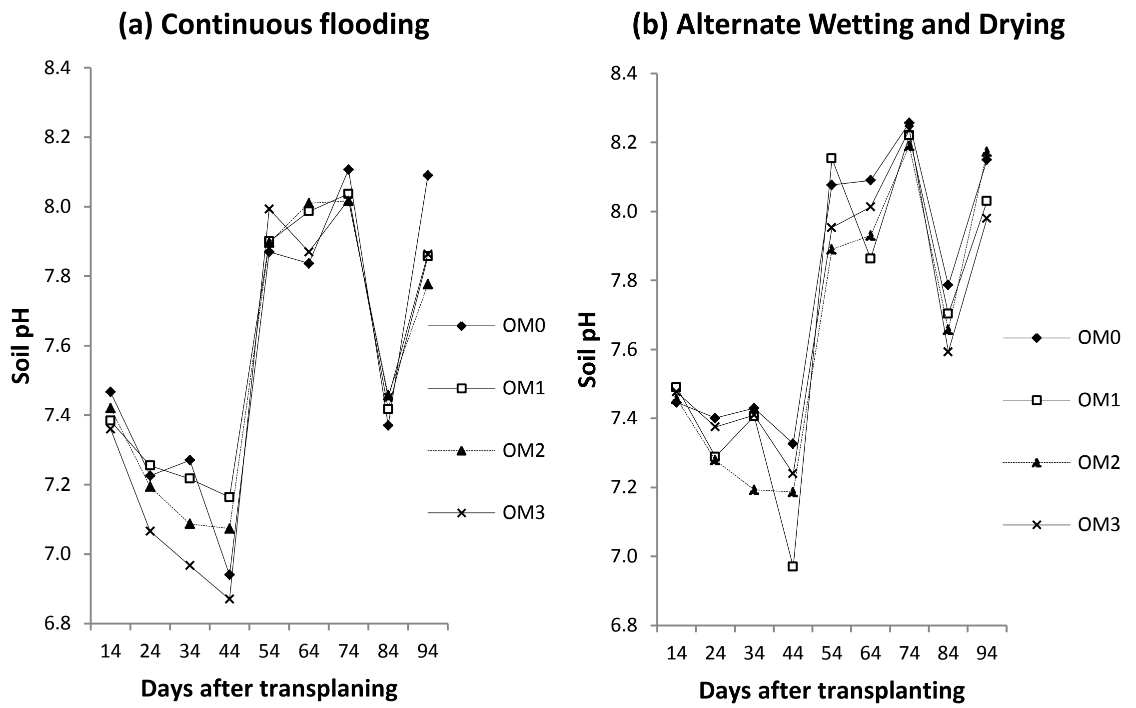

Figure 3.4: Variation in soil pH (a) continuous flooding and (b) alternate wetting and drying during the summer season, 2017

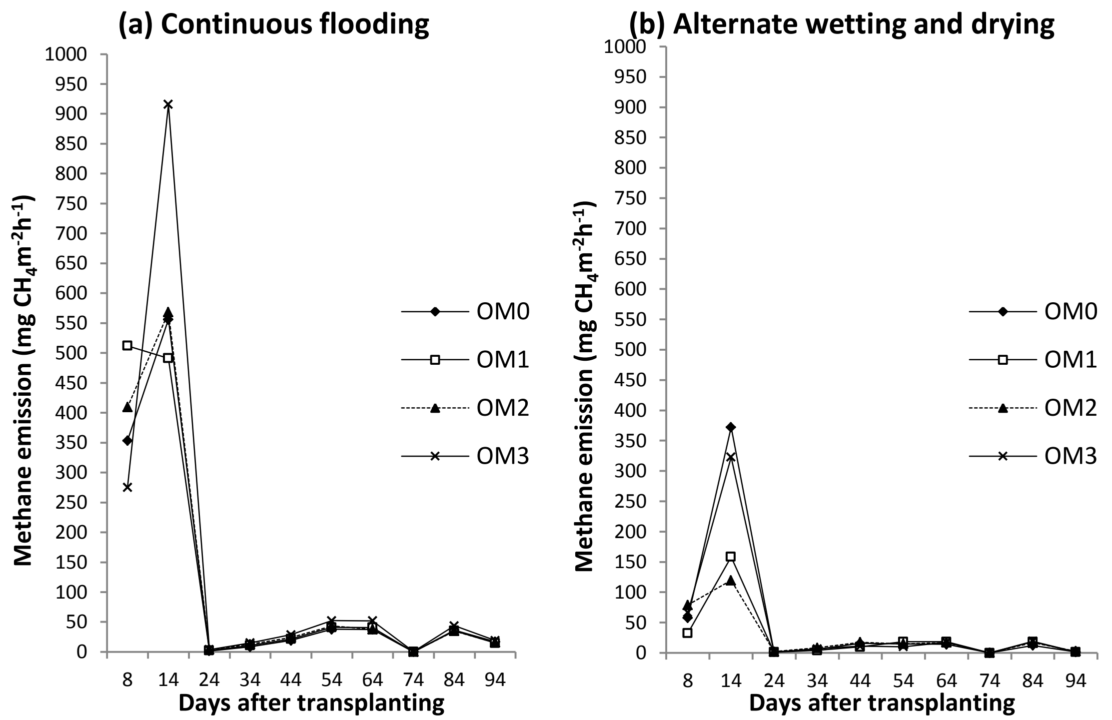

Figure 3.5: Methane emission of rice (a) continuous flooding and (b) alternate wetting and drying during the summer season, 2017

Table 3.1: Mean effects of water regime and the rate of cowdung manure applied on cumulative methane emission of rice during the summer season, 2017

Treatment	Cumulative methane emission (kg CH_4 ha^{-1})
Water	
CF	2645.6 a
AWD	792.2 a
LSD $_{0.05}$	1967.1
Manure	
OM_0 (0 t ha^{-1})	1692.7 a
OM_1 (2.5 t ha^{-1})	1619.2 a
OM_2 (5 t ha^{-1})	1595.7 a
OM_3 (7.5 t ha^{-1})	1968.0 a
LSD $_{0.05}$	905.3
Pr>F	
Water	0.0558
Manure	0.7974
Water x Manure	0.7822
CV_a (%)	65.15
CV_b (%)	41.87

Means followed by the same letter are not significantly different at 5% LSD.

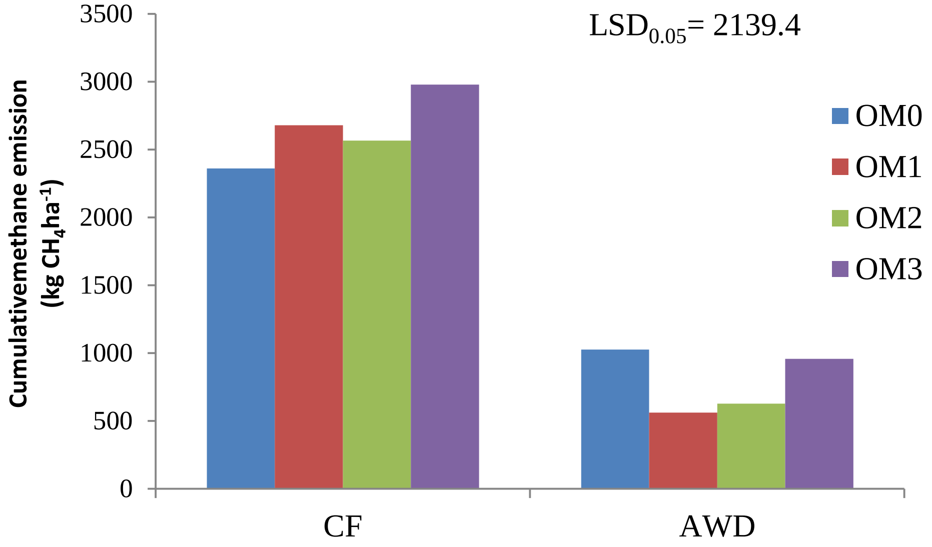

Figure 3.6: Mean values of cumulative methane emission of rice as affected by water regime and the rate of cowdung manure applied during the summer season, 2017

Relationship between methane emission and soil parameters during the summer season

Variation in seasonal methane emission from rice paddies are complex and differ among several reported studies. Relationship between methane emission and soil parameters was observed in Table 3.2. From rapidly increase at the beginning of the season, methane emissions show relatively increase in the vegetative phase peaking near panicle differentiation, a period of rapid root development. Emission afterwards is relatively constant during the reproductive stage, and decrease during the late grain filling because of root degradation. In this study, the methane emission was significantly not correlated with soil temperature, soil redox potential and soil pH. A correlation with soil temperature has been reported in some studies (Schutz et al. 1989), but not in others (Cicerone et al. 1983; Neue and Sass 1994). However, it was significantly correlated with surface water pH (Pr > F 0.01). The surface water pH significantly affected on methane emission (Table 3.2).

Table 3.2: Relationship between methane emission and soil parameters during the summer season, 2017

	ST	EH	SWPH	SPH
CH4	0.1297^{ns}	-0.3683^{ns}	0.5755**	-0.0563^{ns}

CH4 – Cumulative methane emission (kg ha^{-1})

ST – Average soil temperature (°C) EH – Average soil redox potential (mV)

SWPH – Average surface water pH SPH – Average soil pH

Soil parameters during the rainy season, 2017

Soil temperature: Different mean values of soil temperature were observed in different levels of organic manure application (Figure 3.7). In continuous flooding, the start-up high temperature was found at 7 DAT. The high soil temperature was given by OM_2 and the low soil temperature from OM_1. It decreased at 15 DAT. The high soil temperature was recorded from OM_2. Then at 24 DAT, the soil temperature increased and maintained level off until 54 DAT. Again at 64 DAT, it decreased to about 28°C. This coincided with heading stage. From that stage, the soil temperature increased to maximum value at 84 DAT throughout the growing season. At 94 DAT, it again slightly decreased. Most high soil temperature was observed in OM_2 and low soil temperature was resulted from OM_0.

In AWD, the same trend of soil temperature was recorded. The most high soil temperature was recorded from OM_2 and low soil temperature was resulted from OM_1.

The mean effects of soil temperature in different cowdung manure rates were not different in both water regimes.

Soil redox potential: The complex trend of soil redox potential (Eh) was observed in Figure 3.8. In continuous flooding, the soil redox potential was observed between -378.67 mV and -77.00 mV. The low redox potential values were recorded from OM_0 in the early growth stage and from OM_2 in later growth stage.

In alternate wetting and drying, the soil redox potential was in the range of -366 to 33 mV. The complex trend of soil redox potential was also found. Mostly the low redox potential was recorded from OM_0 and the high soil redox potential values were resulted from OM_3.

The mean effects of soil redox potential to different cowdung manure rates were not different in both water regimes. However, the high soil redox potential was observed in AWD because of soil aeration. However in this study, the soil redox potential is not an indicator for methane emission and it was not affected by water and cowdung manure rates on methane emission.

Surface water pH: Different mean values of surface water pH were resulted from different levels of organic manure application (Figure 3.9). In continuous flooding, the surface water pH ranges were higher in early growth stages than in later growth stages. The high pH was recorded from OM_3 at 7 DAT, OM_2 at 15 DAT, OM_0 at 24, 44, 54 DAT and OM_2 at 34, 64, 94 DAT. The low surface water pH was resulted most from OM_0.

In AWD, the different trend was found. The high surface water pH was observed in OM_0 at 7, 34, 94 DAT, from OM_1 at 15, 24, 44 DAT and from OM_3 at 54, 64, 74, 84 DAT. The most low surface water pH was resulted from OM_1 and OM_2.

The surface water pH range was from 7.89 to 9.06 in CF and 8.13 to 9.09 in AWD throughout the growing period. In this study, the surface water pH was affected by water and cowdung manure rates. The mean effects changes were found depending on water regime and cowdung manure rates.

Soil pH: Different levels of organic manure application gave different mean values of soil pH (Figure 3.10). In the initial stage, the soil pH was a little bit high and gradually decreased fluctuating in some points until harvest. The soil pH was not affected by water regime. The high soil pH was resulted from OM_0, OM_2 and OM_3. The most low soil pH was observed in OM_0.

In alternate wetting and drying, the same trend of soil pH was observed. Mostly the high soil pH was recorded from OM_0 and the low pH from OM_3.

In both water regimes, the mean effects of soil pH to different cowdung manure rates were not significantly different. The soil pH ranged from 7.24 to 8.01 in continuous flooding and from 7.18 to 8.02 in AWD. In this study, the soil pH was not affected by water and cowdung manure rates.

Methane emission during the rainy season, 2017

Different mean values of methane emission of rice were resulted from different levels of organic manure application (Figure 3.11). In continuous flooding, at the start-up gas collection, a little increase of methane was recorded. In the middle growth stage, the highest emission was found and gradually decreased to harvest. The decreased methane emission in the beginning was due to restricted supply of organic substrates for methanogenesis. Two peaks of methane emission was recorded in the middle stage; the first peak at 34 DAT and the second peak at 54 DAT. The first peak was dominantly resulted by decomposition of soil organic matters which provide carbon source for methanogenic activity (Fazli and Man 2014). At the second peak, the carbon source for methanogens were available from the plant related organic matters entering into the soil from rice roots (Khosa et al. 2011). More carbon source was available for methanogenic activity at 54 DAT and thus resulted in higher methane emission than 34 DAT (Neue et al. 1996; Gogoi et al. 2008). Methane emission decreased in the later growth stage because of depletion of organic substrates for methanogen. The most high methane emission was resulted from OM_3 and low methane emission was recorded from OM_1 throughout the growing season.

In AWD, the same trend of methane emission was observed. The maximum methane emissions have been observed at panicle initiation stage. This increase was in consequence of decomposition of root exudates, rice plants' litters (Gogoi et al. 2008) and soil organic matters. The most high methane emission was recorded from OM_0 and low methane emission was resulted from OM_3. Irrigation could affect methane emission pattern indirectly by influencing the availability of organic matters and influencing microbial process of methane production in the soil (Fazli and Man 2014).

The cumulative methane emission of rice during the growing season was shown in Table 3.3. Significant difference of methane emission was recorded among the water treatments at Pr > F 0.05. The higher emission (1597.6 kg CH_4 ha^{-1}) was found in CF as compared to AWD (542.7 kg CH_4 ha^{-1}). No significant difference among the cowdung manure treatments and no interaction between the factors were also observed. In both water regimes, the mean effect of methane emission to different cowdung manure rates was illustrated in Figure 3.12. In this study, the methane emission was affected by water regime. But the cowdung manure rate did not affect on methane emission. Milkha et al. (2001) pointed out that quality and quantity of organic materials influence CH_4 formation. Small differences in the carbon balance between fields and seasons can result in large differences of CH_4 emissions.

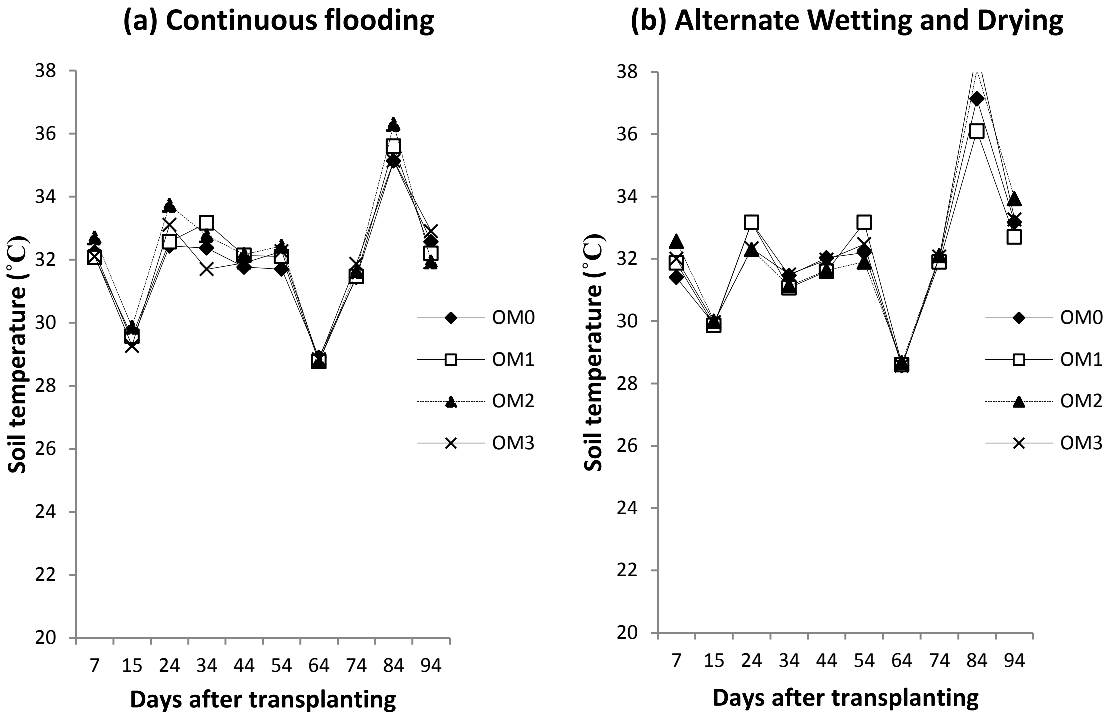

Figure 3.7: Variation in soil temperature (a) continuous flooding and (b) alternate wetting and drying during the rainy season, 2017

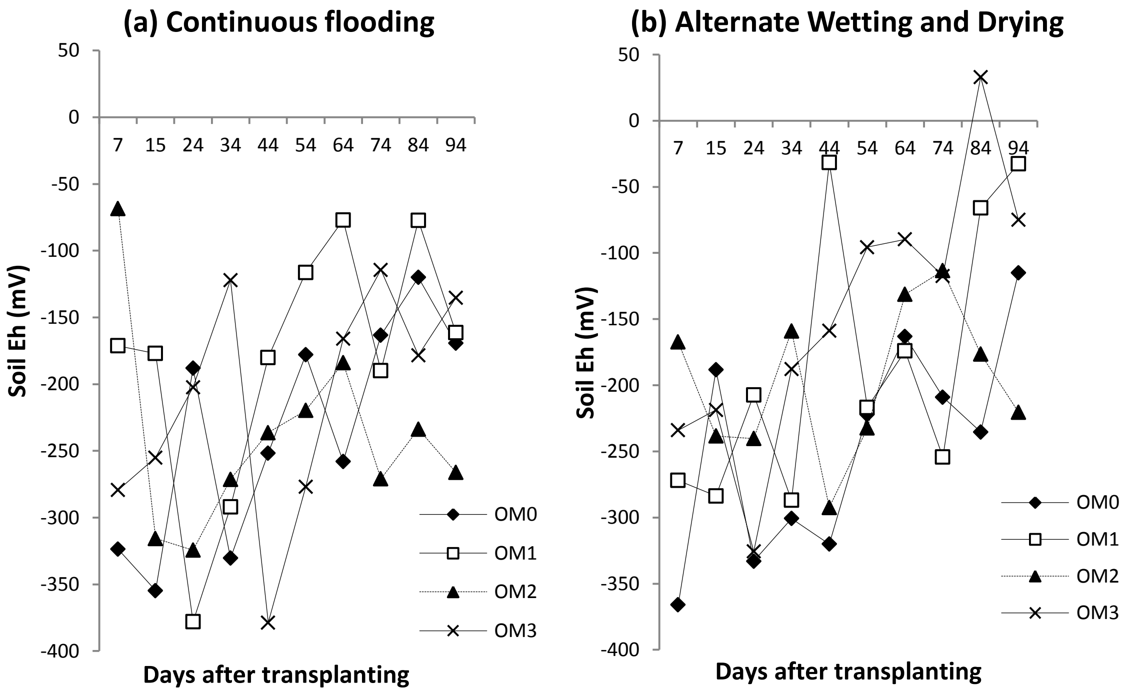

Figure 3.8: Variation in soil redox potential (Eh) (a) continuous flooding and (b) alternate wetting and drying during the rainy season, 2017

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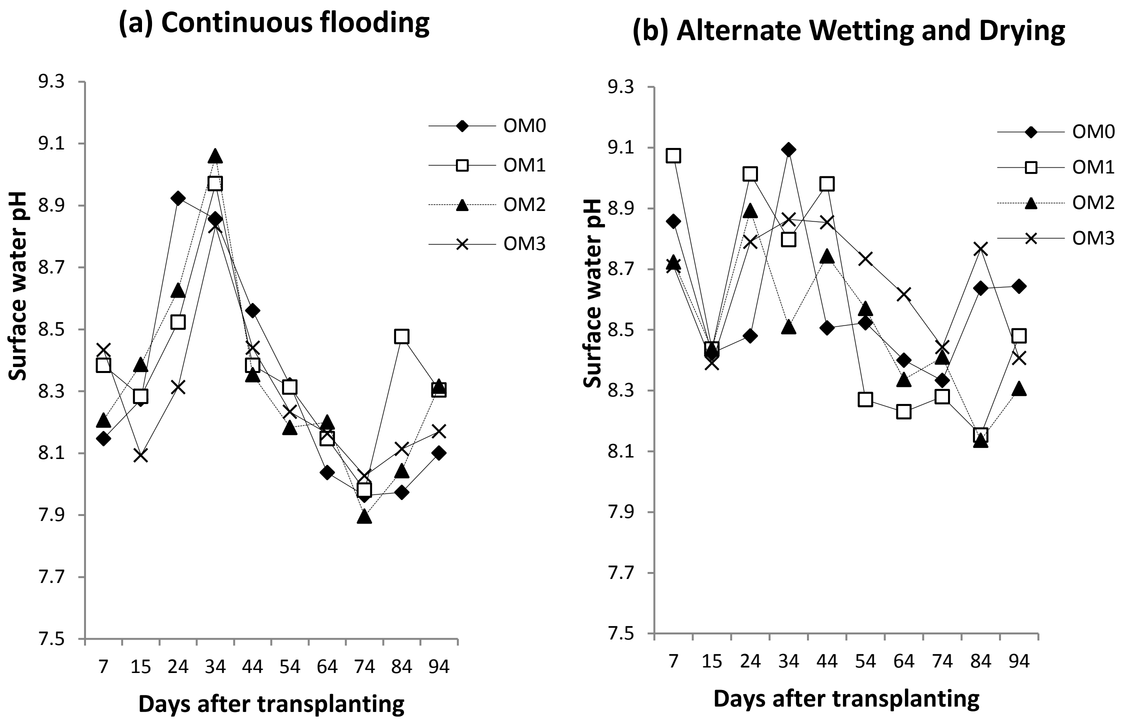

Figure 3.9: Variation in surface water pH (a) continuous flooding and (b) alternate wetting and drying during the rainy season, 2017

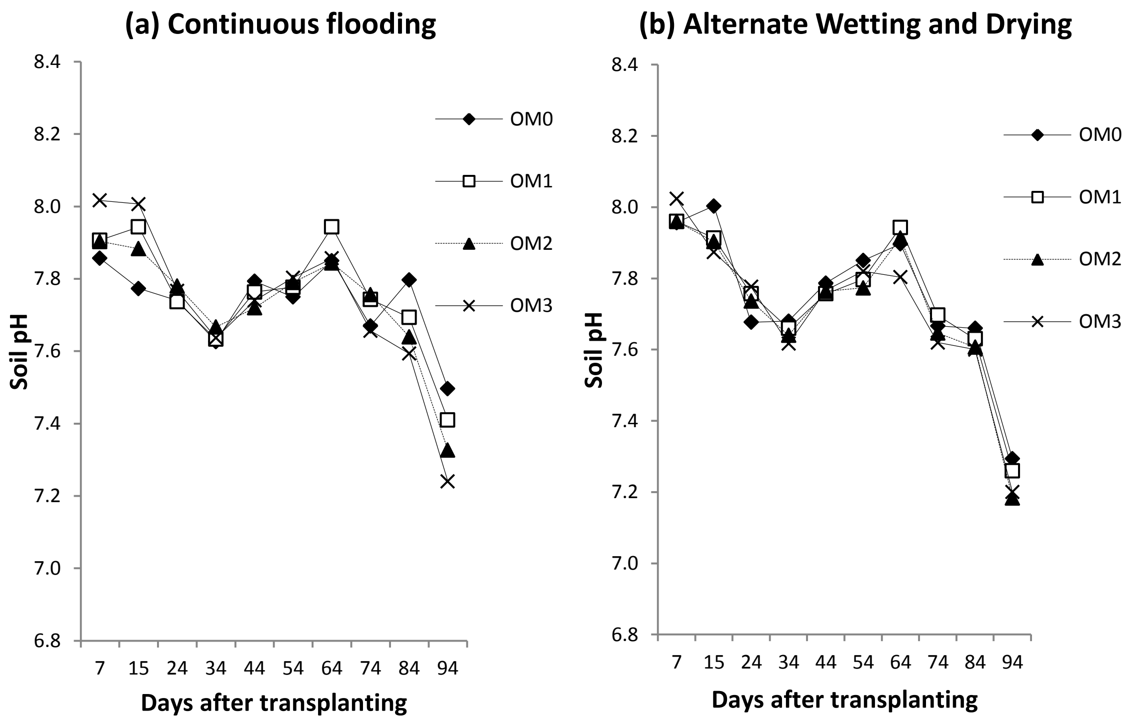

Figure 3.10: Variation in soil pH (a) continuous flooding and (b) alternate wetting and drying during the rainy season, 2017

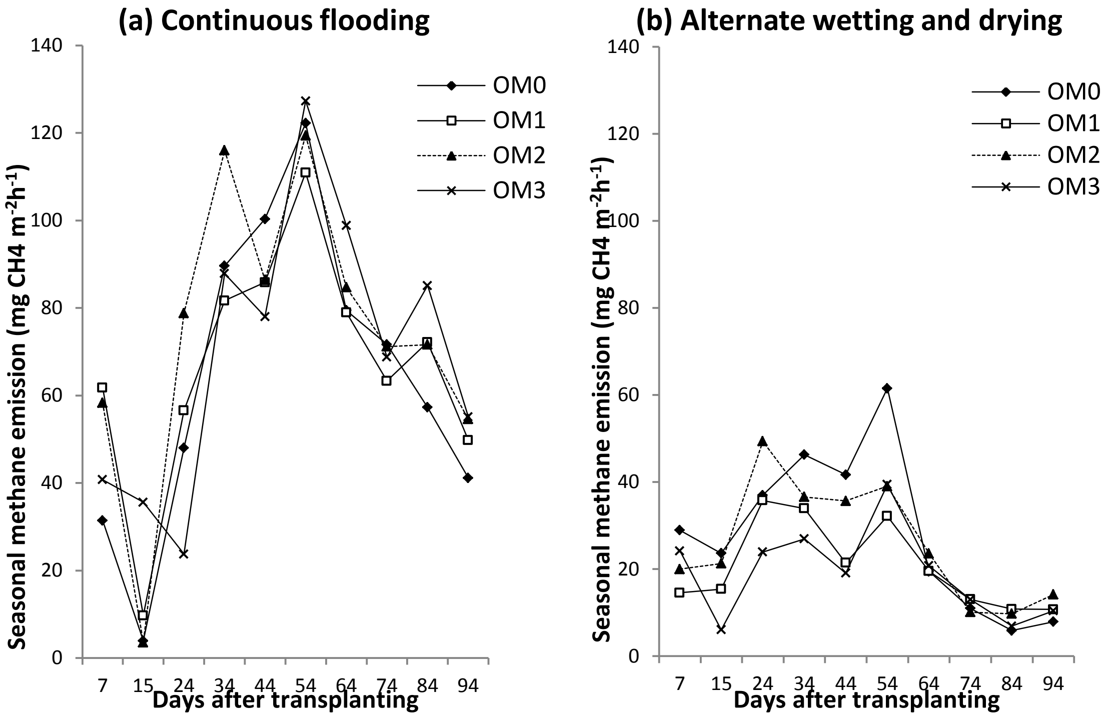

Figure 3.11: Methane variation of rice (a) continuous flooding and (b) alternate wetting and drying during the rainy season, 2017

Table 3.3: Mean effects of water and cowdung manure applied on cumulative methane emission of rice during the rainy season, 2017

Treatment	Cumulative methane emission (kg CH_4 ha^{-1})
Water	
CF	1597.6 a
AWD	542.7 b
LSD $_{0.05}$	737.19
Manure	
OM_0 (0 t ha^{-1})	1082.2 a
OM_1 (2.5 t ha^{-1})	1016.9 a
OM_2 (5 t ha^{-1})	1161.2 a
OM_3 (7.5 t ha^{-1})	1020.3 a
LSD $_{0.05}$	372.11
Pr>F	
Water	0.0254
Manure	0.8147
Water x Manure	0.7545
CV_a (%)	39.22
CV_b (%)	27.64

Means followed by the same letter are not significantly different at 5% LSD.

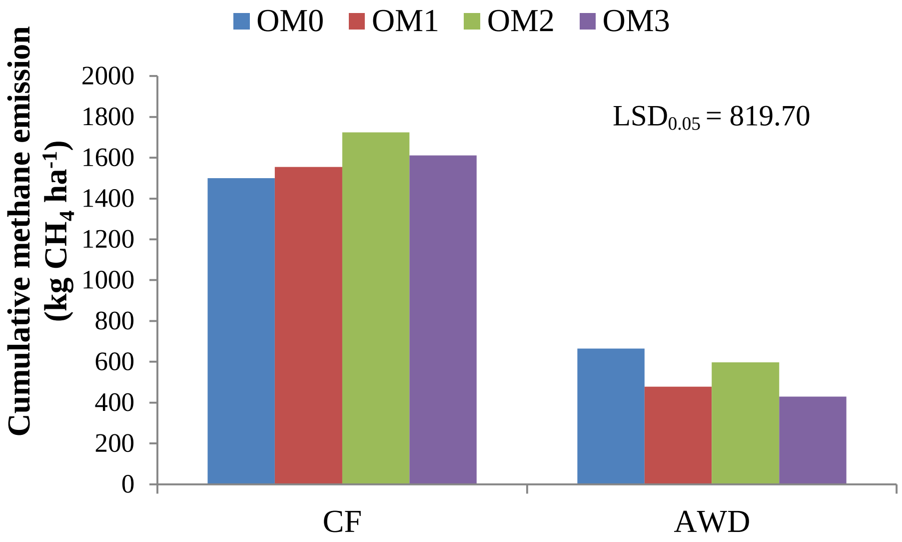

Figure 3.12: Mean values of cumulative methane emission of rice as affected by water and cowdung manure applied during the rainy season, 2017

Relationship between methane emission and soil parameters during the rainy season

Relationship between methane emission and other parameters was described in Table 3.4. In this pot experiment of rainy season 2017, the methane emission was not significantly correlated with soil parameters (soil temperature, soil redox potential, soil pH) except surface water pH. Methane was significantly negative correlated with surface water pH (Pr > F 0.01).

Table 3.4: Relationship between methane emission and soil parameters during the rainy season, 2017

	ST	EH	SWPH	SPH
CH4	-0.2806 ^{ns}	-0.3343 ^{ns}	-0.7992**	-0.1044 ^{ns}

CH4 – Cumulative methane emission (kg ha^{-1})

ST – Average soil temperature (°C) EH – Average soil redox potential (mV)

SWPH – Average surface water pH SPH – Average soil pH

4. Conclusion

According to these pot experiments, the methane emission was significantly correlated with surface water pH and the methane emission was significantly higher in continuous flooding than alternate wetting and drying. The cowdung manure did not significantly affect on yield and methane emission. However, its effect was influenced by water management.

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Appendix I. Physiochemical properties of experimental soil and cowdung manure

No.	Analytical Item	Unit	Analytical Result	
1	Soil pH		7.4	Moderately alkaline
2	Available N	mg kg^{-1}	50	Low
3	Available P	mg kg^{-1}	13	Medium
4	Available K	mg kg^{-1}	78	Low
5	Total N	%	0.17	
6	Organic matter	%	1.8	Low
7	CEC	$cmol_c$ kg^{-1}	11	Low
8	Sand	%	87	
9	Silt	%	4	
10	Clay	%	9	
11	Textural class			Loamy sand

No.	Analytical Item	Unit	Analytical Result	
			Summer season	**Rainy season**
1	Total N	%	1.32	1.2
2	Organic carbon	%	16	23.3

Appendix II. Daily rainfall, maximum and minimum temperatures in Madaya township, Myanmar during the summer and monsoon rice growing seasons, 2017