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EFFECTS OF ORGANIC AMENDMENTS ON METHANE EMISSION AND YIELD OF RICE

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Abstract

The effect of FYM, poultry litter, livestock manure, biogas slurry, vermi-compost and municipal solid waste (MSW) combined with NPK was assessed on emission of CH_4 and yield of rice. The highest amount of CH_4 emission (815.04) kg ha^{-1} $season^{-1}$ was from MSW followed by (702.96 kg CH_4 ha^{-1} $season^{-1}$) from livestock manure. The lowest (365.14 kg CH_4 ha^{-1} $season^{-1}$) was produced in control treatment. The increasing trend of seasonal CH_4 emission was 55.20, 48.06, 35.71, 33.88, 21.13 and 17.57% respectively due to organic amenments against the control. The highest number of panicle $hill^{-1}$ (14.38), grain $panicle^{-1}$ (160.67), yield of grain (5.47 t ha^{-1}) and straw weight (4.56 t ha^{-1}) was observed due to application of FYM, vermicompost and poultry litter respectively. The highest percentage of harvest index and ripened grains (55.363 and 93.41) was found in biogas slurry and poultry litter treated plots and the lowest percentage (52.878 and 85.88) was with vermicompost and biogas slurry correspondingly. The highest Eh value (– 252.0 mV) was found in MSW and the lowest value was observed in poultry litter. Result suggests that combined use of inorganic fertilizer and organic amendments caused highest yield of rice with less CH_4 emission.

Key words: CH_4 emission, Organic amendments, Soil redox potential and Rice yield

Introduction

Methane (CH_4) one of the important greenhouse gases is regarded second only to carbon dioxide (CO_2) in its ability to cause global warming. This gas is a great concern because of its relatively fast increasing capability. More than 50% of the global annual CH_4 emissions are of anthropogenic origin, and the cultivation of irrigated rice may account for up to 12% of this flux (IPCC 2007). Rice fields are regarded as an important source of atmospheric methane. According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and country-specific activity data, the global CH_4 emission from rice paddy fields was estimated to be 14.8– 41.7 Tg $year^{-1}$ (Yan *et al.* 2009). The CH_4 emission rates are significantly higher from the lowland rice field as compared to upland rice field. This is likely due to the development of intense anoxic conditions (redox potential value -240 mV) and increases availability of labile organic carbon in the lowland rice field ecosystem, being supported with the findings of (Schutz *et al.* 1989 and Wassmann *et al.* 1993). The CH_4 is produced in soils by the microbial breakdown of organic compounds in strictly anaerobic conditions at redox potential less than -150 mV (Wang *et al.* 1993).

The increasing world population may cause an expected 50% increase in rice demand by 2020 (IRRI 1990). Emission through rice plant may be expected to show great seasonal variations as a function of changes in soil conditions and variations in plant growth. Different ability of rice cultivars in emitting CH_4 are mostly related to the growth performance, i.e. number of plant tillers, plant above and below ground biomass (Aulakh *et al.* 2001). Redox potential is one of the important factors to know the CH_4 emission from rice field whether it occurred or not. To date no systematic study on interaction of organic fertilizers and CH_4 emissions in rice field. Therefore, the present study was undertaken with a view to find out the suitable locally available organic amendments for minimizing CH_4 emission and increasing yield of rice.

Materials and Methods

This experiment was carried out at Environmental Science Field Laboratory of Bangladesh Agricultural University (BAU) during Aman season. The experimental field was well ploughed and divided into 21 plots. Each plot size was (4 m × 2.5 m) = 10 m^2. The treatments used were:T_1: Control plot (NPK, standard doze), T_2: NPK + FYM (4 kg $plot^{-1}$), T_3: NPK + decomposed poultry litter (2 kg $plot^{-1}$), T_4: NPK + decomposed livestock manure (4 kg $plot^{-1}$), T_5: NPK + biogas slurry (4 kg $plot^{-1}$), T_6: NPK + vermi compost (2 kg $plot^{-1}$) and T_7: NPK + Municipal Solid Waste (MSW) compost (4 kg $plot^{-1}$). Halves of all chemical fertilizers (urea pilled@150 kg ha^{-1}, TSP@110 kg ha^{-1} and MOP @ 60 kg ha^{-1}) were applied as basal dose during the final land preparation. Rest half of urea was top dressed in 2 equal splits at 30 and 60 days after transplanting (DAT) and other halves of TSP and MOP fertilizers were used as per recommended dose at 30 DAT. The experiment was laid out in a randomized complete block design with 3 replications. Composition of some selected organic manures mentioned in (Table 1) and using BINA dhan-7 as the test crop. One month aged seedling was uprooted carefully and was transplanted in row at the two seedlings per hill with 25 cm × 25 cm between row and hill spacing. The weeds were uprooted as and when appeared. Pest and diseases were managed accordingly. During harvesting at maturity stage five hills from each plot were collected randomly and moisture percentage (at 14%) was calculated following sun drying and then both grain and straw yields were recorded (t ha^{-1}) for recording the yield contributing characters.

Table 1. NPK contents of organic amendments.

Organic amendments	Nutrient content (%)			
	N	P	K	C:N
Livestock manure	0.35	0.18	0.16	15:1
Poultry manure	1.6	1.5	0.85	6:1
Farmyard manure	0.51	0.40	0.51	8:1
Biogas slurry (cowdung)	1.29	2.80	0.75	8:1
Vermi compost	0.81	0.60	0.61	4:1
MSW compost	0.70	0.60	0.91	16:1

The harvest index in the percent expression of the ratio between grain yield and biological yield was assessed on absolute moisture basis and can be calculated by the following formula (Gardner *et al.* 1985).

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Grain yield + Straw yield}} \times 100.$$

Eh and pH of soil were measured in three times by Eh meter (Model NU HACH, USA) and pH meter (Model NU HACH, USA) respectively. After placement of seven close chamber in the field (dimension of each chamber was 62 cm×62 cm ×112 cm), air samples data were collected in 50 ml gas-tight syringes at 0 and 30 minutes intervals in each block at different growth stages to get the average CH_4 emissions during the cropping season. The collected air samples were analyzed for concentration of CH_4 gas by Gas Chromatograph equipped with a Flame Ionization Detector (FID) at Soil Chemistry Laboratory, Gyeongsang National University, Gazwadong and Jinju, South Korea. The analysis column used was a stainless steel column packed with Porapak NQ (Q 80-100 mess). The temperatures of column, injector and detector were adjusted at 100°C and 200°C, respectively.

CH_4 Flux ($F = mg\ m^{-2}\ hr^{-1}$) was calculated:

$$F = \rho.\ V/A \times \Delta c / \Delta t \times 273 / T$$

Where, ρ= gas density (CH_4= 0.714); V = volume of the chamber (m^3);

A = area of the chamber (m); $\Delta c / \Delta t$ = average increase of gas conc. in the chamber; and T= 273 + mean temperature of the chamber (°C) [Conversion factor from ^{0}K to ^{0}C]. Data of yield contributing characteristics and CH_4 emission were statistically analyzed by DMRT following MSTATC program.

Results and Discussion

Redox potential (Eh) and CH_4 emission: Results showed a significant negative relation between CH_4 emission rate and Eh value (Table 2). The Eh values ranged from −62.0 mV to − 252.0 mV and the corresponding CH_4 emission rates were 8.39 mg CH_4 m^{-2} h^{-1} to 44.47 mg CH_4 m^{-2} h^{-1}. The CH_4 emissions associated with Eh values in this range was previously reported (Yagi and Minami 1990 and Setyanto *et al.* 2004). In an oxidized (aerobic) soil the redox potential (Eh) ranges from about + 600 to + 350 mV, whereas in most reduced (anaerobic) soils the Eh varies from about -300 to +350 mV (DeLaune *et al.* 1990 and Masscheleyn *et al.* 1993). The critical soil Eh for CH_4 production was reported to be approximately -150 mV (Jugsujinda *et al.* 1995). Similar trend was also found in MSW compost treated plot where the Eh significantly decreased (−252.0 mV) at the reproductive stage and caused the highest CH_4 emission (44.47 mg CH_4 m^{-2} h^{-1}). The lowest CH_4 emission was with the application of decomposed poultry litter which is statistically similar to control.

CH_4 emission rate at different growth stages: Application of organic amendments significantly influenced CH_4 emission at different growth stages of rice cultivation. The highest CH_4 emission (44.47 mg CH_4 m^{-2} h^{-1}) was observed in the treatment of MSW at the ripening stage. Similar result was observed in active (20.56 mg CH_4 m-^2h-^{1}), reproductive (36.85 mg m-^2h-^{1}) stages too with increase of slight increase at the ripening stage (Table 2). The increment in CH_4 emissions following organic inputs depends on quantity, quality and timing of the application (Yagi and Minami 1990 and Sass *et al.* 1991).

Table 2. Effect of organic amendments on Eh and CH_4 emission at different growth stages of rice.

Treatment	Eh (mV)	Amount of CH_4 (mg CH_4 m^{-2} h^{-1})			CH_4 emission (g m^{-2} h^{-1})
		AT	Rp	Ri	
T_1	-62.00a	8.39d	15.47d	21.79f	1.521e
T_2	-231.40d	15.98b	25.63b	27.39d	2.301c
T_3	-109.50b	12.56c	20.84c	21.47f	1.845d
T_4	-245.00f	19.56a	33.84a	34.47b	2.933b
T_5	-235.60e	17.56b	23.84bc	29.47c	2.363c
T_6	-158.80c	13.56c	20.85c	23.47e	1.929d
T_7	-252.00g	20.56a	36.58a	44.47a	3.396a
LSD at 5%	2.32	0.94	1.75	0.71	0.26

AT: Active tillering stage; Rp: Reproductive stage; and Ri: Ripening stage. In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT)

Panicles $hill^{-1}$ and Grains $panicle^{-1}$: Application of organic fertilizers significantly influenced the panicles numbers $hill^{-1}$ (Table 3). A significant increase in the grain yield and panicles numbers of rice due to organic manures and chemical fertilizers has been reported (Calendacion *et al.* 1990 and Ahmed and Rahman 1991). The highest panicles numbers $hill^{-1}$ (14.38) was found due to application of FYM which was statistically similar to decompose poultry litter (14.33) and the lowest (11.33) was in control. The highest grains numbers $panicle^{-1}$ (160.67) was found with the application of vermicompost and the lowest (102.67) was observed in control (Table 3). Similar results were also found by Sharma and Mitra (1991) and Channabasavanna and Birandar (2001) due to organic amendments.

Table 3. Effect of different organic amendments on yield components of Binadhan-7.

Treatment	Panicle $hill^{-1}$	Grain $panicle^{-1}$	Unfilled grain $panicle^{-1}$	HI (%)	Ripened grain (%)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
T_1	11.33e	102.67f	14.33a	53.470	86.44e	4.38c	3.81d
T_2	14.38a	141.00d	14.67a	54.835	90.38d	5.33a	4.39ab
T_3	14.33a	156.00b	11.00c	54.537	93.41a	5.47a	4.56a
T_4	12.33c	152.00c	12.00bc	54.825	92.68ab	5.17ab	4.26abc
T_5	12.00cd	140.00d	12.67abc	55.363	85.88e	4.8bc	3.87d
T_6	13.00b	160.67a	14.00ab	52.878	92abc	4.5c	4.01cd
T_7	11.67de	132.33e	13.00abc	54.803	91.03bc	5.02ab	4.14bcd
LSD at 5%	0.26	1.38	1.21	2.33	1.63	0.42	0.32

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).

Harvest Index (HI) and Percentage of ripened grains: Due to application of organic amendments, the harvest index and percentage of ripened grain were considerably influenced at different stages of Binadhan-7 (Table 3). The highest harvest index and ripened grains (55.363% and 93.41%) were found with use of biogas slurry and decomposed poultry litter. Bhuiyan (1994) reported that the application of cow dung, compost (FYM) and compost (MSW) improved rice production. Channabasavanna and Biradar (2001) also reported that the application of poultry manure increased 0.26 to 19% higher grain yield of rice compare to control respectively.

Grain and Straw yield t ha^{-1}: Grain and straw yield t ha^{-1} were significantly influenced by the organic amendments (Table 3). Islam (2006) reported that grain and straw yields of T. Aman rice (var. BRRI Dhan-3l) responded significantly to the different treatments of organic combinations. The highest grain and straw yield ((5.47 t ha^{-1} and 4.56 t ha^{-1}) were observed due to application of decomposed poultry litter. Khan *et al.* (2007) also observed that combined application of NPK and organic manures significantly increased the leaf and straw yields of rice.

Correlation of CH_4 emission with yield components and soil parameters: Results showed that CH_4 emission was negatively correlated with panicle $hill^{-1}$, grain yield, HI and soil Eh and positively correlated with the straw yield and soil pH of Binadhan-7 (Table 4). CH_4 flux showed a strong positive correlation with the availability of soil organic carbon, while there were negative correlations with soil Eh at rice harvesting stage. Rice grain yield was negatively correlated with seasonal CH_4 flux which was supported by Denier van der Gon *et al.* (2002). The addition of nitrate as chemical fertiliser to flooded soils may suppress the production of CH_4, because nitrate acts, as well as Fe^{3+}, Mn^{4+}, as a terminal electron acceptor in the absence of molecular oxygen during anaerobic respiration and poises the redox potential of soils. The released iron and sulfate ions from the applied soil amendments acted as electron acceptors and eventually suppressed CH_4 emissions (Jackel and Schnell 2000).

Table 4. Correlation of CH_4 emission with yield components and soil Eh.

	g CH_4 m^{-2} $season^{-1}$	Panicle $hill^{-1}$	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	HI (%)	Soil Eh
g CH_4 m^{-2} $season^{-1}$	1	-0.248	-0.360	0.160	-0.580	-0.860(*)
Panicle no. $hill^{-1}$		1	0.683	0.818(*)	0.081	0.020
Grain yield (t ha^{-1})			1	0.924(**)	0.656	-0.378
Straw yield (t ha^{-1})				1	0.319	-0.140
HI (%)					1	-0.664
Soil Eh						1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Seasonal CH_4 emission: The highest and the second highest seasonal CH_4 emission (815.04, 702.96 kg CH_4 ha^{-1} $season^{-1}$) were found in the treatments of MSW compost and decomposed livestock manure respectively. However, the lowest CH_4 emission was recorded (365.14 kg CH_4 ha^{-1} $season^{-1}$) from the control (Table 5). Similar results were also reported by other investigators (Yagi and Minami 1990, Chen *et al.* 1993, Lindau and Bollich 1993, Wassmann *et al.* 1993, Neue *et al.* 1994). It was found that the increasing trend of seasonal CH_4 emission varied from 55.20, 17.57% due to application of MSW compost over decomposed livestock manure, biogas slurry, FYM, vermicompost and decomposed poultry litter respectively at the ripening stage (Table 5).

Table 5. Changes in seasonal CH_4 emission over the control (%) in relation to soil Eh during rice cultivation.

Treatments	CH_4 emission (kg CH_4 h^{-1} $season^{-1}$)	Trend over control (%)
T_1	365.14g	--
T_2	552.24d	33.38
T_3	442.95f	17.57
T_4	702.96b	48.06
T_5	567.96c	35.17
T_6	462.95e	21.13
T_7	815.04a	55.20
LSD at 5%	0.38	--

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT)

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References

Ahmed. M., S. Rahman. 1991. Influence of organic matter on the yield and mineral nutrition of modern rice and soil properties. *Bangladesh Rice Journal.* **2**(1-2):107-112.

Aulakh MS, Wassmann R, Bueno C, Rennenberg H (2001). Impact of root exudates of different cultivars and plant development stages of rice (*Oryza sativa* L.) on methane production in a paddy soil, *Plant and Soil,* **230** (1): 77-86.

Bhuiyan, N.I.1994. Crop production trends and need of sustainability in agriculture. Paper management workshop on Integrated Nutrient Management for Sustainable Agriculture held at SRDI, Dhaka, Bangladesh. June 20-28.

Calendacion, A.N., D.P. Garrity, P. A. Batugal and S.K. De Datta.1990. Increased Productivity and Profitability through a Potato-Wet Seeded Rice-Ratoon Cropping System. *Philipp J. Crop Sci.* **15**(2): 85-98.

Channabasavana, A. S. and D.P. Biradar. 2001. Yield and yield attributes of transplanted summer rice as influenced by organic manures and Zinc levels, *J. Maharashtra Agric. Univ.* **26** (2):170-176.

Chen, Z., D. Li, K. Shao and B. Wang. 1993. Features of CH4 emission from rice paddy fields in Beijing and Nanjing. *Chemosphere.* **26**: 239-245.

DeLaune, R.D., S.R. Pezeshki, J. H. Pardue. 1990. An oxidation-reduction buffer for evaluating physiological response of plants to root oxygen stress. *Environm. Exp. Bot.* **30**(2): 243-247.

Denier van Der Gon, H.A.C., M.J. Kropff, N. van Breemen, R. Wassmann, R.S. Lantin, E. Aduna and T.M. Corton. 2002. Optimizing grain yields reduces CH4 emissions from rice paddy fields. *Proc Natl Acad Sci. USA.* **99**:12021–12024.

Gardner, D. (Eds.). 1995. *Fertilizer Additive Stops Nitrogen Loss. Ag Retailer*. pp.45-47.

IPCC. 2007. Summary for Policymakers. In: Climate change-2007. The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the *Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2007.

IRRI (International Rice Research Institute). 1990. IRRI-Cambodia Project 1990. Annual Research Report 1989. Phnom Penh. Cambodia. pp.33-45.

Islam M.S. 2006. Use of Bioslurry as Organic Fertilizer in Bangladesh Agriculture. Prepared for the presentation at the International Workshop on the Use of Bioslurry Domestic Biogas Program, Bangkok, Thailand, pp. 35-40.

Jackel, U. and S. Schnell. 2000. Suppression of methane emission from rice paddies by ferric iron fertilization, *Soil Biol. Biochemistry.* **32**(11-12): 1811-1814.

Jugsujinda, A., R. D. DeLaune, C. W. Lindau, E. Sulaeman, S.R. Pezeshki. 1995. Factors controlling carbon dioxide and methane production in acid sulfate soils. *Water Air Soil Pollut.* 84:1-11.

Khan, S.A., R.L. Mulvaney, T. R. Ellsworth and C.W. Boast. 2007. The myth of nitrogen fertilization for soil carbon sequestration. *Journal of Environmental Quality*. **36**: 1821-1832.

Lindau, C.W. and P.K. Bollich.1993. Methane emissions from Louisiana first and ratoon crop rice. *Soil Sci.***156**: 42-48.

Masscheleyn, P.H., R. D. Delaune and W.H. Patrick. 1993. Methane and nitrous oxide emission from laboratory measurements of rice soil suspension. Effect of soil oxidation - reduction status. *Chemosphere.* **26**: 251-260.

Neue, H.U., R.S. Latin, R. Wassmann, J.B. Aduna, C.R. Alberto and M.F. Andales.1994. Methane emission from rice soils of the Philippines. In CH_4 and N_2O. *National Institute of Agro-Environmental Science.* Taskuba, Japan. pp. 53-63.

Sass R. L., F.M., Fisher, Y.B. and F. T. Wang Turner. 1991. Mitigation of methane emissions from rice fields: possible adverse effect of incorporated rice straw, *Global Biogeochem. Cycle.* **5**: 275-287.

Schütz, H., W. Seiler and R. Conrad. 1989. Influence of soil temperature on methane emission from rice paddy fields. *Biogeochemistry.***11**: 77-95.

Setyanto, P., A. B. Rosenani, R. Boer, C. I. Fauziah and M.J. Khanif. 2004. The effect of rice cultivars on methane emission from irrigated rice field; *Indonesian J. Agric. Sci.* **5**(1): 20-31.

Sharma, A. R. and B.N. Mitra.1991. Direct and residual effect of organic material and phosphorous fertilizers in rice (*Oryza sativa* L.) Based cropping System. *Indian J. Agron.* **36**(3): 299-303.

Wang, Z. P., R. D. Delaune, W.H. Jr. Patrick and P. H. Masscheleyn. 1993. Soil redox and pH effects on methane production in a flooded rice soils. *Soil Sci. Soc. Am. J.* **57**: 382-385.

Wassmann, R., H. U. Neue and R.S. Lantin. 1993. Characterization of methane emissions from rice fields in Asia. 1. Comparison among field sites in five countries, *Nutrient Cycling in Agro ecosystems.* **58**: 1–12.

Yagi, K. and K. Minami. 1990. Effects of organic matter application on methane emission from some Japanese paddy fields. *Soil Sci. Plant Nutri.* **36**: 599-610.

Yan, X.Y., H. Akiyama, K. Yagi and H. Akimoto. 2009. Global estimations of the inventory and mitigation potential of methane emissions from rice cultivation conducted using the 2006 Intergovernmental Panel on Climate Change Guidelines. *Global Change Biol.* **9**: 237-254.

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