Combined effect of organic manure, silicate fertilizer and bio-fertilizer with different forms of urea on methane emission during T. aman rice cultivation

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Abstract: An experiment was conducted to evaluate the effect of soil amendments with different forms of urea fertilizer on methane (CH_4) emission during T. Aman (July to November 2010) rice (BINA Dhan-7) cultivation at the experimental field of Environmental Science, Bangladesh Agricultural University, Mymensingh. Ten different treatments such as prilled urea (urea fine granules), gooti urea (urea super granules), prilled urea plus water hyacinth, gooti urea plus water hyacinth, prilled urea plus sesbania biomass, gooti Urea plus sesbania biomass, prilled urea plus silicate fertilizer, gooti urea plus silicate fertilizer, prilled Urea plus bio-fertilizer (cyanobacteria plus azolla) and gooti urea plus bio-fertilizer were applied in this experiment following RCB design with three replications. In general, combined effect of organic manure, silicate fertilizer and biofertilizer with gooti urea showed lower CH_4 emission compared to prilled urea treated plots. CH_4 emission showed a gradually increasing trend in all treatments at vegetative stage; while CH_4 emission was highest in all treatments during reproductive stage. The highest amount of CH_4 (14.32 $mgm^{-2}h^{-1}$) emission was observed from prilled urea plus sesbania treatment where the lowest CH_4 emission (9.6 $mgm^{-2}h^{-1}$) was found in gooti urea plus silicate fertilizer. Silicate fertilization in the paddy soil significantly increased the soil redox potential (Eh) as compared to other treatments which may reduce CH^4 emission. CH_4 emissions were decreased at ripening stage in all treatments. Rice grain yield were found 4.69, 4.64, 5.25, 5.23, 5.70, 5.81, 5.97, 6.03, 6.15 and 6.07 tha^{-1} under prilled urea, gooti urea, prilled urea plus water hyacinth, gooti urea plus water hyacinth, prilled urea plus sesbania biomass, gooti urea plus sesbania biomass, prilled urea plus silicate fertilizer, gooti urea plus silicate fertilizer, prilled urea plus bio-fertilizer (cyanobacteria plus azolla) and gooti urea plus bio-fertilizer, respectively. Application of bio- fertilizer and silicate fertilizer in combination with prilled urea and gooti urea enhanced rice productivity and lowered CH_4 emission. However, among the treatments gooti urea application with Silicate or Bio-fertilizer was found very effective to reduce CH_4 emission. Therefore, silicate fertilizer or bio-fertilizer in combination with gooti urea might be introduced in the paddy soil for reducing CH_4 emissions and sustaining rice productivity under rainfed condition.
Key words: Organic Manure, silicate fertilizer, bio-fertilizer, different forms of urea, methane emission, T. aman rice.

Introduction

The economic development of Bangladesh is mainly dependent on rice productivity. Profitable rice farming ensures political stability for the country and provides a sense of food security to the people (Bhuiyan *et al*., 2002). Rice has been growing over 25 million hectares of land under irrigated and rainfed condition which cover about 84% of total cropped area in Bangladesh (BBS, 2008). Aman rice covers the largest area of 9.82 million hectares with production of 12.84 million tons. The yield of rice in Bangladesh is 2.21 ton per hectare (AIS, 2008). The pressure on Bangladesh land resources to produce more rice will aggravate in the coming years due to increasing population and demand for food. High fertilizer responsiveness is an essential criterion for a high yielding rice varieties and nitrogen is one of the major nutrient elements for crop production that can contribute a lot for higher yield of rice (Chang *et al*., 1964). However, of rice production under irrigated condition may promote methane (CH_4) emissions while others may infer a net decrease of the CH_4 source strength. Sustainable production of crops cannot be maintained by using only chemical fertilizer and similarly it is not possible to obtain higher crop yield by using organic manure alone (Bair, 1990). So, the combined fertilizer application is more effective for rice cultivation. Modern cultivation has the option to choice the best combination of fertilizer application for higher yield and environmental sustainability. It is the present day's headache to fulfill the food demand and also mitigate Green House Gases (GHG) in rice cultivation. Water hyacinth compost, sesbania biomass, silicate fertilizer and bio-fertilizer play vital role enhancing rice productivity. Many researchers have tried to find out the best one which is more positive and eco- friendly.

This required expansion and intensification of rice cultivation and as a consequence it is likely that CH_4 fluxes will be increased to the atmosphere if current technologies are continued. It is now certain that factors such as temperature, soil properties, kind and amount of fertilizers, Organic matter content, fertilizer application, rice plant, pH, redox potential and water management are major factors affecting CH_4 emission from rice field (Adhya *et al*., 1994). Supplementation of rice straw, green manure and compost has a stimulating effect on methane production (Buendia *et al*., 1998). Silicate fertilizer contains higher concentrations of active iron, free iron which acted as electron acceptor and CH4 flux was significantly decrease and grain yield increase by using silicate fertilizer in rice field. Sesbania amendment stimulates both grain yield and CH4 emission and the effect was more significant at the early growth stage of rice and decreased gradually during rice cultivation (Yang and Chang, 2001). Water hyacinth compost (WHC) in combination with N fertilizer significant increase in the N uptake of the rice (Sharma and Mitra, 1991). Urea in combination with a cyanobacteria plus Azolla enhance rice grain yield and to play a major role in mitigation of CH_4 emission from rice fields-through enhanced CH_4 oxidation (Prasanna *et al*., 2002).

Inadequate information is available on feasible soil amendments and suitable form of urea fertilizer increasing rice productivity and decreasing CH_4. Therefore, the experiment was undertaken to investigate the effects of organic manure, silicate fertilizer and bio-fertilizer with different forms of urea on CH_4 emission rate during rice cultivation, and to identify the best combination of organic manure, silicate fertilizer and bio-fertilizer along with urea for mitigation of CH_4 emission and maintenance of soil fertility.

Materials and Methods

The experiment was conducted in Transplanted Aman seasons using BINA dhan-7 at the experimental field of Environmental Science, Bangladesh Agricultural University, Mymensingh during the period from July to

November 2010 farming season. The experiment was laid out in a randomized complete block design (RCBD) with three replications.

Fertilizers and Manure were applied at the following doses: prilled urea 180 kg ha^{-1}, gooti urea 180 kg ha^{-1}, water hyacinth 2 tha^{-1}, sesbania biomass 2 tha^{-1}, silicate fertilizer 150 kg ha^{-1} and bio-fertilizer (cyanobacteria and azolla) 1 tha^{-1}, respectively in all plots. At the time of final land preparation nitrogenous fertilizer in form of urea (prilled or gooti) was applied as basal doze and rest of urea in two equal splits at 30 and 45 DAT per specification of the treatments. But all other fertilizers were applied as per respective doses in two equal splits at the land preparation time and 30 DAT in the selective plots. Soil amendments such as water hyacinth, sesbania biomass, silicate fertilizer and bio-fertilizer were applied 3 days before final land preparation. Water hyacinth and sesbania biomass were applied as compost. Hand weeding was done when deemed necessary. Carbofuran (Agrofuran 5g) was used at the rate of 10 kg ha-1 to prevent the plant from attack of insects and irrigation was given when it needed under water as 5cm. The area of each plot was 80 square meter (8m×10 m). The treatment combinations were randomly distributed to unit plots. The experimental treatments were: T_1: Prilled Urea (Urea fine granules), T_2: Gooti Urea (Urea super granules), T_3: Prilled Urea + Water hyacinth, T_4: Gooti Urea + Water hyacinth, T_5: Prilled Urea +Sesbania biomass, T_6: Gooti Urea +Sesbania biomass, T_7: Prilled Urea +Silicate fertilizer, T_8: Gooti Urea +Silicate fertilizer, T_9: Prilled Urea + Bio-fertilizer (Cyanobacteria+ Azolla), T_{10}: Gooti Urea + Bio-fertilizer (Cyanobacteria+ Azolla).

Analytical techniques : Gas samples were collected by using the closed-chamber method during the rice cultivation. The dimensions of close chamber were 62 × 62 × 112 cm. Two chambers were installed in each experimental plot. Gas sample was collected vegetative and ripening stage to get the CH_4 emissions during the cropping season. Gas sample was collected in 50 ml gas-tight syringes at 0 and 30 minutes intervals after chamber placement over the rice planted plot. The samples were analyzed for CH_4 by using gas chromatograph (Varian star 3400, equipped with an FID (flame ionization detector). The analysis column used a stainless steel column packed with Porapak NQ (Q 80-100 mess). The temperatures of column, injector and detector were adjusted at 100ºC, 200ºC, and 200ºC, respectively.

Estimation of methane emission: Methane emission from the paddy field was calculated from the increase in CH_4 concentrations per unit surface area of the chamber for a specific time intervals. A closed-chamber equation (Rolston, 1986) was used to estimate methane fluxes from each treatment. Calculation of CH4 flux: $F = \rho*(V/A)*(\Delta c/\Delta t)*273/T$. Where, F = methane flux (mg $m^{-2}hr^{-1}$), ρ = gas density (0.714 mg CH_4 m^{-3}) , V=volume of the chamber (m3), A = surface area of chamber (m^2), $\Delta c/\Delta t$ = rate of increase of methane gas concentration in the chamber (mg $m^{-3}hr^{-1}$) ,T = 273 + mean temperature in chamber (°c).

Statistical Analysis: Data on the plant characteristics and CH_4 emission were analyzed using the analysis of variance (ANOVA) technique with the help of computer package program MSTATC and mean differences were adjusted by Duncan's Multiple Range Test (DMRT).

Results and Discussion

Effect of organic manure, silicate fertilizer and bio-fertilizer with different forms of urea on soil pH, Eh and CH4 emissions during rice cultivation: Effects of Soil amendments with different forms of Urea fertilizer significantly influenced on CH_4 emission. The highest CH_4 emission (14.32 $mgm^{-2}ha^{-1}$) was observed in prilled urea plus sesbania Biomass at the reproductive stage which was statically similar to the prilled urea plus water hyacinth treatment (13.61 $mgm^{-2}ha^{-1}$). The lowest CH_4 emission (1.52 $mgm^{-2}ha^{-1}$) was found in gooti plus silicate fertilizer treatment which was statically similar to prilled urea plus silicate fertilizer (1.57 $mgm^{-2}ha^{-1}$), prilled urea plus biofertilizer (1.58 $mgm^{-2}ha^{-1}$) at the vegetative stage. CH_4 emission was increased at the reproductive stage of all treatment and decreased all at the ripening stage. The highest decreased CH_4 emission rate in the treatment of prilled urea plus silicate fertilizer (Fig. 1).

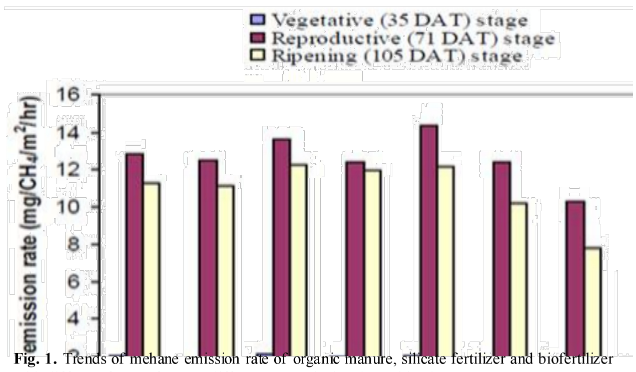

Fig. 1. Trends of mehane emission rate of organic manure, silicate fertilizer and biofertilizer with different forms of urea at different stages during rice cultivation

Effect of organic manure, silicate fertilizer and bio-fertilizer with different forms urea on the yield and yield attributes of rice cultivar BINA Dhan-7:

Plant height: The highest plant height (98.33 cm) was found in the gooti Urea + bio-fertilizer (cyanobacteria + azolla) plot, which was statistically similar to the treatment of prilled urea + silicate fertilizer (97.33 cm), gooti urea +silicate fertilizer (95.33 cm) and prilled urea + bio-fertilizer (93.67 cm). The lowest plant height (89.67 cm) was found in only gooti urea treatment (Table 1).

Number of tillers hill^{-1}: The highest number of tillers hill^{-1} (15.67) was found with application of gooti urea + bio-fertilizer followed by (15.33) with prilled urea + bio-fertilizer while the lowest number of tillers hill^{-1} (12.33) was found in only gooti urea treatment (Table 1).

Number of panicle hill^{-1}: The highest number of panicle hill^{-1} (14.53) was obtained from prilled urea + bio-fertilizer. The lowest number of panicle hill^{-1} (10.93) was found in only gooti urea treatment (Table 1).

Number of grains panicle^{-1}: The highest number of grains panicle^{-1} (97.21) was obtained from gooti urea + bio-fertilizer and gooti urea + silicate fertilizer (97.16). The lowest number of grains panicle^{-1} (77.54) was found in only prilled urea (Table 1).

Percentage of ripened grains: The highest percentage of ripened grains (90.67%) was obtained from prilled urea + bio-fertilizer. The lowest percentage of ripened grains (87.8%) was found in only gooti urea treatment (Table 1).

1000 grains weight: The highest 1000 grains weight (21.03 g) was found in gooti urea + silicate fertilizer and prilled urea + bio-fertilizer. The lowest (20.27 g) was obtained from only gooti urea treatment (Table 1).

Table 1. Effect of soil amendments with different form of Urea fertilizer on rice growth and yield component

Treatments	Plant height (cm)	No. of tiller/hill	No. of panicle/ hill	No. of grain/ panicle	No. of grain/ hill	Ripened grain %	1000 grains wt (g)	Grain wt/hill (g)	Straw wt/hill (g)	Grain Yield/ha (ton)	Straw yield /ha (ton)	HI%
T_1	91.00 c	13.00 ef	11.93 e	77.54 c	925.86 f	88.07 cd	20.33 cd	19.37 e	21.96 d	4.69 e	5.49 ef	46.07 c
T_2	89.67 c	12.33 f	10.93 f	83.44 bc	912.00 f	87.80 d	20.27 d	19.25 e	21.80 d	4.64 e	5.45 f	45.99 c
T_3	90.00 c	13.67 cde	12.27 e	85.64 b	1050.80 e	89.67 abcd	20.37 bcd	21.16 d	22.65 bcd	5.25 d	5.66 cd	48.12 b
T_4	90.00 c	13.33 def	11.93 e	86.50 b	1032.06 e	88.60 bcd	20.34 bcd	21.11 d	22.42 cd	5.23 d	5.60 de	48.29 b
T_5	92.00 bc	13.33 def	12.33 e	95.09 a	1172.53 d	88.10 cd	20.75 abc	22.82 c	22.69 bcd	5.70 c	5.70 cd	50.13 a
T_6	90.33 c	14.33 bcd	13.00 d	90.06 ab	1257.53 c	89.27 abcd	20.85 ab	23.21 c	23.03 abc	5.81 bc	5.76 bc	50.17 a
T_7	97.33 ab	14.67 abc	13.40 cd	96.38 a	1291.00 bc	89.03 abcd	20.85 ab	23.88 b	23.43 ab	5.97 ab	5.86 ab	50.46 a
T_8	95.33 abc	15.00 ab	13.73 bc	97.16 a	1333.73 b	90.07 abc	21.03 a	24.02 b	23.72 a	6.03 a	5.93 a	50.42 a
T_9	93.67 abc	15.33 ab	14.53 a	96.57 a	1403.40 a	90.67 a	21.03 a	24.61 a	23.80 a	6.15 a	5.95 a	50.83 a
T_{10}	98.33 a	15.67 a	14.27 ab	97.21 a	1386.86 a	90.23 ab	20.86 ab	24.27 ab	23.97 a	6.07 a	5.99 a	50.21 a
LSD 0.05	5.513	1.190	0.577	6.597	45.51	1.781	0.4023	0.5397	0.888	0.1879	0.1213	1.377
Level ofsign.	*	**	**	**	**	*	*	**	**	**	**	**
CV%	3.46	4.93	2.62	4.25	2.26	1.16	1.13	1.40	2.26	1.96	1.23	1.63

**= Significant at 1% level of probability; *= Significant at 5% level of probability

Grain yield ha^{-1}: The highest grain yield ha^{-1} (6.15 t) was observed in prilled urea + bio-fertilizer which was statically similar to the gooti urea + bio-fertilizer (6.07 t) and gooti urea + silicate fertilizer (6.03 t). The lowest grain yield (4.64 t) was obtained from only gooti urea treatment (Table 1).

Straw yield ha^{-1}: The highest straw yield ha^{-1} (5.99 t) was obtained from gooti urea + bio-fertilizer which was statically similar to prilled urea + bio-fertilizer (5.95 t) and gooti urea + silicate fertilizer (5.93 t). The lowest straw yield (5.45 ton) was obtained from only gooti urea treatment (Table 1).

Harvest Index (HI): the highest harvest index (50.83%) was found in prilled urea + bio-fertilizer. The lowest harvest index (45.99%) was obtained from only gooti urea treatment (Table 1).

Correlation of yield component and soil parameter with methane emission: CH_4 emissions were negatively correlated with plant height, no. of tillers/hill, no. of panicle/hill, no. of grain/hill, no. of grain/ panicle, grain yield/ha, straw yield/ha, Harvest Index (HI %), Eh, Soil NPKS, active iron and positively correlated with soil Organic Matter (OM %), pH at different stages (Table 2).

Table 2. Correlation of yield component and soil parameter with methane emission

Plant Parameter	CH_4 emission at Vegetative stage	CH_4 emission at Reproductive stage	CH_4 emission at Ripening stage
Plant height (cm)	-0.738**	-0.556*	-0.820**
No. of tiller/hill	-0.671**	-0.457*	-0.748**
No. of panicle/hill	-0.646**	-0.420	-0.730**
No. of panicle/hill	-0.646**	-0.420	-0.730**
No. of grain/ hill	-0.683**	-0.413	-0.730**
No. of grain/ panicle	-0.647**	-0.385	-0.660**
1000 grains wt (g)	-0.597**	-0.433	-0.682**
Grain wt/hill (g)	-0.616**	-0.392	-0.686**
Straw wt/hill (g)	-0.684**	-0.466*	-0.754**
Harvest Index (HI%)	-0.536*	-0.330	-0.597**

Soil Parameter	CH_4 emission at Vegetative stage	CH_4 emission at Reproductive stage	CH_4 emission at Ripening stage
N	-0.556**	-0.264	-0.562**
P	-0.669**	-0.349	-0.617**
K	-0.059	-0.098	-0.030
S	-0.546	-0.336	-0.457
(OM%)	0.575**	0.251	0.602**
pH	0.254	0.161	0.097
Eh	-0.446*	-0.362	-0.595**
Active Fe	-0.564**	-0.728**	-0.727**

**= Significant at 1% level of probability; *= Significant at 5% level of probability

At reproductive stage CH_4 emission was highest in all treatments and the highest amount of CH_4 (14.32 $mgm^{-2}ha^{-1}$) emission from prilled urea plus sesbania treatment and second one, 13.61 $mgm^{-2}ha^{-1}$was produced in prilled urea plus water hyacinth treatment where the lowest CH_4 (9.6 mg m-2 h-1) was found in gooti urea plus silicate fertilizer and second lowest was 10.23 $mgm^{-2}ha^{-1}$ in prilled urea plus silicate fertilizer. Because silicate fertilization in paddy soil significantly increased the soil redox potential (Eh) as compared to other treatments which may reduce CH_4 emission. The CH_4 emission was decreased at ripening stage in all treatments. Among all treatments bio- fertilizer plus gooti urea or prilled urea emitted lower amount of CH_4. Different type of fertilizer with different forms of urea significantly affect plant parameters (eg., Plant height, no. of tillers $hill^{-1}$, no. of panicle $hill^{-1}$, no. of grains $panicle^{-1}$, grains $panicle^{-1}$, ripened grain %, 1000 grains wt, grain yield ha^{-1}, straw yield ha^{-1} and HI%). The highest plant height (98.33 cm), no. of tillers $hill^{-1}$ (15.67), no. of grains $panicle^{-1}$ (97.21) and straw yield ha^{-1} (5.99 t) were observed in gooti urea plus biofertilizer and the highest no. of panicle $hill^{-1}$ (14.53), grain wt $hill^{-1}$ (24.61g), grain yield ha^{-1} (6.15 t), ripened grain % (90.67%) and Harvest Index (50.83%) were observed in prilled urea plus biofertilizer treatment. The highest 1000 grains wt (21.03 g) was found in both gooti urea plus silicate fertilizer and prilled urea plus biofertilizer treatment. Bio-fertilizer plus prilled urea or gooti urea plus bio-fertilizer enhanced rice productivity and emitted lower amount of CH_4. Among these treatments gooti urea plus silicate or bio-fertilizer was very effective to reduce CH_4 emission. Therefore, silicate fertilizer or bio-fertilizer with gooti urea could be introduced in the rice paddy soil for reducing CH_4 emissions and sustaining rice productivity under rainfed rice farming system.

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