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Effects of different rates of manure application on methane emission and crop yield in aman rice

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Abstract: An experiment was set up to investigate the effects of organic fertilizer on CH_4 emission and yield of Aman rice. The experiment was laid out in Randomized Complete Block Design (RCBD) with 6 treatments and 3 replications in the experimental field of Environmental Science at Bangladesh Agricultural University, Mymensingh during July to November, 2013. The six treatments were recommended doses of inorganic fertilizer (NPKS), compost @ 10 tha^{-1}, 20 tha^{-1}, 30 tha^{-1}, 50 tha^{-1} and control. Air samples were collected from the different plots treated by different rates of fertilizers by the modified closed-chamber method. Samples were analyzed to determine the concentration of CH_4 gas by gas chromatograph equipped with a Flame Ionization Detector (FID) at Central Laboratory of Bangladesh Agricultural University. CH_4 emission is influenced by compost fertilizer application. The highest CH_4 emission (1655.71kg ha^{-1}season^{-1}) and second highest CH_4 emission (1260.29kg ha^{-1}season^{-1}) were found from higher rates of compost applications 50 tha^{-1} and 30 tha^{-1},respectively. The lowest CH_4 emission (789.12kg ha^{-1} season^{-1}) was found from control plot. Compost fertilizer application significantly affected the plant yield contributing parameters such as tillers and effective tillers hill^{-1}, number of panicle, grain number panicle^{-1}, grain yield ha^{-1}, biological yield ha^{-1} and harvest index percentages. The highest grain yield (5.8 tha^{-1}) and biological yield (13.37 tha^{-1}) were found from 20 tha^{-1}. The highest tiller hill^{-1} (16.31) and harvest index (43.94) were found from compost @ 50 tha^{-1} (T_6). The lowest effective tiller hill^{-1} (10.07), panicle length (10.03 cm), grain yield (4.51 tha^{-1}) and biological yield (11.58 tha^{-1}) were found from control plot. From the result in respect of rice yield and methane emission, compost @ 20 tha^{-1} (T_4) was better than other treatment.

Key words: Manure, application, methane, emission, crop, yield, aman rice.

Introduction

The application of NH_4^+ based fertilizers is a common practice in rice production. The immediate effect of urea application on the processes involved in CH_4 emission from a rice field was investigated on sandy loam soils. Urea, applied at a rate of 50 kgNha^{-1} on the 75th day after flooding, significantly stimulated both CH_4 production and CH_4 oxidation. During the following 9 days, the rates of CH^4 production and CH^4 oxidation in the 0–3 cm soil layer increased by 24-52 and 18-41%, respectively, of the fertilized plot compared to the unfertilized control plot (Dan *et al*., 2000). Rate of CH_4 emission from rice fields is affected by interacting soil, plant, management and climatic factors. Redox potential is one of the important factors to know the CH_4 emission from rice field whether it occurred or not. Therefore, changes in water management may help to save water resources without a compromise in yield and productivity, as well as to reduce CH_4 fluxes (Huang *et al*., 2000). Different ability of rice cultivars in emitting CH_4 were mostly related to the growth performance, i.e. number of plant tillers, plant above and below ground biomass (Aulakh *et al*., 2001). Setyanto *et al*. (2004) reported that differences in plant growth duration among rice cultivation affected the total seasonal CH_4 emission from flooded soil. 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). Recent estimates of CH_4 from rice fields range between 39 and 112 Tg CH_4 per year (Denman *et al*., 2007). The CH_4 plays a major role in global warming and climate change, and its reduced emission is essential without adversely affecting crop production. The balanced application of fertilizers is very essential for rice production and providing sufficient food to meet their demand. Application of chemical fertilizers is one of the main barriers for sustainable development of agriculture production, farm efficiency and land use and also production system, which is more complicated and more expensive. Better nutrient management of soil is essential for sustainable agriculture. Using organic fertilizer enriches soil fertility and reduces cost for longer time basis. Reduction of chemical fertilizing will help to lower environmental degradation. Besides, the demand of fertilizers would become significant in near future. The present research was design to quantify and investigate the pattern of CH_4 emission from using different rates of compost application, and to measure comparative rate of CH_4 emission by compost and standard inorganic fertilizers in terms of growth and yield of rice.

Materials and Methods

The experiment was conducted in transplanted Aman seasons (BRRIdhan 49) at Departmental experimental field of Environmental Science, Bangladesh Agricultural University, Mymensingh during the period of 20 July, 2013 to 28 November, 2013. The experiment was laid out in a randomized complete block design (RCBD) with three replications. At the time of final land preparation compost fertilizer was applied at the rate of 10, 20, 30 and 50 tha^{-1} at T_3, T_4, T_5 and T_6 plots respectively. At that time Urea fertilizer (prilled) was applied to T_2 plots as basal dose @ 150 kg ha-1. Rest of Urea was applied at 2 equal splits at 30 and 60 DAT (Days After Transplanting). TSP and MoP were applied as basal dose (at the time of final land preparation) @110 and 60 kg ha-1. Sulphar and Zinc fertilizers were also applied as basal dose @45 kg ha-1 both. Hand weeding was done when deemed necessary. Two times Koratral was used to prevent the plant from attack of insect. The water depth was 40-45 cm. The experimental treatments were: T_1: Control plot (No fertilizer), T_2: Inorganic fertilizers N, P, K (Standard doses), T_3: Compost 10 tha^{-1}, T_4: Compost 20 tha^{-1}, T_5: Compost 30 tha^{-1}, T_6: Compost 50 tha^{-1}. Data were collected on the following parameters .

Growth parameters: (i). Plant height (cm), (ii). Number of tillers hill^{-1}**.**

Yield components: (i). Panicle hill^{-1}, (ii). Effective tiller hill^{-1}, (iii). Length of panicle (cm), (iv). Shoot weight (g), (v). Root weight (g), (vi). 1000 grain weight (g), (vii).

Grain yield (tha^{-1}), (viii). Straw yield (tha^{-1}), (ix). Biological yield (tha^{-1}).

Gas sample collection: Gas samples were collected by the modified closed-chamber method during the rice cultivation. The dimension of close chambers was 60cm x 60cm x 75cm. Six chambers were installed for three times in each treatment of the experimental plot. Gas samples were collected at different growth stages (transplanting, tillering, flowering, heading, panicle initiation and ripening stage) of rice cultivation. Gas samples were collected in 50 ml gas-tight syringes at 5, 10 and 30 minutes intervals after chamber placement over the rice planted plot separately. The gas samples were stored on 6.5cm vials. The samples were analyzed to determine the concentration of CH_4 gas by gas chromatograph equipped with a Flame Ionization Detector (FID).

Gas chromatography: The work of gas chromatography was done at Professor Muhammad Hossain Central Laboratory of BAU. It was done by gas chromatograph named SHIMADZU-GC-2014 and Column name HAYSEP Q 80/100. In the instrument, temperature of Injector and FID was 120°c and 220°c respectively. The column flow was 25 ml/min.

Calculation of methane gas flux: Flux ($F = mg\ m^{-2}\ hr^{-1}$) was calculated as, $F = \rho.\ V/A \times \Delta c/\Delta t \times 273/T$. Where, ρ = gas density (CH_4 = 0.714); V = volume of the gas chamber (m^3); A = area of the gas chamber (m^2); $\Delta c/\Delta t$ = average increase of gas concentration in the chamber; T = 273 + mean temperature of the chamber (°C).

Statistical analysis: Data were analyzed for CH_4 emission and yield characteristics statistically by Analysis of Variance (ANOVA) to examine whether treatment effects were significant or not. Mean values were compared by Duncan's Multiple Range Test (DMRT). The software package, MSTAT-C was used for statistical analysis.

Results and Discussion

Effect of compost fertilizers on CH_4 emission from rice field: Application of organic fertilizers significantly influenced the CH_4 emission from rice field. In different stages of rice cultivation data of CH_4 emission were recorded. The stages of data collection were namely transplanting, tillering, flowering, heading, panicle initiation and ripening. The highest CH_4 emission (57.49 $mgm^{-2}h^{-1}$) was observed in the flowering stage at treatment of 50 tha^{-1}. The second highest CH_4 emission (53.48 $mgm^{-2}h^{-1}$) was observed in the flowering stage at treatment of 50 tha^{-1}. The lowest CH_4 emission (19.37 $mgm^{-2}h^{-1}$) was observed in the ripening stage at control plot and the second lowest CH_4 emission (21.9 $mgm^{-2}h^{-1}$) was observed in the panicle initiation stage at control plot (Table 1).

Table 1. Amount of CH_4 emission at different stages of rice growth

Treatment	Amount of CH4 emission at different stages of rice growth ($mgm^{-2}h^{-1}$)					
	Transplanting	Tillering	Flowering	Heading	Panicle initiation	Ripening
T_1	21.93	25.37	27.40	23.41	21.90	19.37
T_2	24.73	31.71	31.39	29.63	27.67	23.14
T_3	27.0	37.89	34.76	30.46	33.41	27.23
T_4	29.37	43.37	37.86	33.50	37.32	29.69
T_5	37.87	45.40	43.76	37.11	39.79	39.73
T_6	43.40	53.48	57.49	49.23	49.22	42.23

At different stages of rice growth viz., transplanting, tillering, flowering, panicle initiation, heading and ripening the lowest CH_4 emissions were found at the control plots at the rate of 21.93, 25.37, 27.4, 23.41, 21.9 and 19.37 $mgm^{-2}h^{-1}$, respectively. The highest rate of CH_4 emissions were founded at the T_6 plots at the rate of 43.4, 53.48, 57.49, 49.23, 49.22 and 42.23 $mgm^{-2}h^{-1}$, respectively. The application of compost fertilizers significantly increased the CH_4 emission from rice field at various stages of rice production. Jahangir, (2012) observed highest CH_4 emission (44.47 $mgm^{-2}h^{-1}$) and lowest (8.39 $mgm^{-2}h^{-1}$) from rice cultivation with organic fertilizer application. The increment in CH_4 emissions following organic fertilizer application depends on quantity, quality and timing of the application (Yagi and Minami, 1990).

Effect of compost fertilizers on growth, yield and yield contributing characteristics:

Tiller number per hill: The number of tiller production at three stages of time has been presented in (Table 2). Tiller number in all the treatments increased almost exponentially up to 60 DAT. From 60 DAT a decline in tiller number was noticed. This might be due the fact that the mortality rate of secondary and tertiary tillers was much during the late phase of growth. At 30 DAT the highest tiller number $hill^{-1}$ (15.02) was recorded in compost @ 50 tha^{-1} (T_6) and the lowest (12.07) was found in compost @ 10 tha^{-1} (T_3). At 60 DAT the highest tiller number $hill^{-1}$ (17.01) was recorded in compost @ 50 tha^{-1} (T_6) and the lowest (15.0) was found in compost @ 10 tha^{-1} (T3). At harvest the highest tiller number $hill^{-1}$ (16.31) was recorded in compost @ 50 tha^{-1} (T_6) and the lowest (14.64) was found in compost @ 30 tha^{-1} (T_5). Similar observation was also revealed by Pandey *et al*. (2007).

Table 2. Effect of treatments on tiller number per hill

Treatment	Tiller number $hill^{-1}$		
	30 DAT	60 DAT	At harvest
T_1	12.50ab	16.03b	4.77bc
T_2	13.10ab	16.70ab	15.40ab
T_3	12.07b	15.0c	4.90b
T_4	12.10ab	16.83ab	15.73ab
T_5	12.37b	15.63bc	14.64bc
T_6	15.02a	17.01a	16.31a
LS	5%	1%	1%
CV (%)	8.28	5.15	6.8

The figures having different letter(s) in a column are significantly different at 1% and 5% level and the figures having same letter(s) in a column are not significantly different by DMRT. DAT = Days After Transplanting; LS = Level of Significance; CV= Co-efficient of Variation.

Plant height: The highest plant height (101.87 cm) was found at harvest from Compost @ 20 tha^{-1} (T_4). The plant height was also highest at 30 DAT and 60 DAT (61.17 cm and 80.87 cm respectively) (Table 3). These results are quite similar with the findings of Muhammad *et al.* (2004).

Table 3. Effects of compost fertilizers on plant height (cm) in rice at different days after transplanting (DAT)

Treatment	Plant height (cm)		
	30 DAT	60 DAT	At harvest
T_1	57.27	78.7	96.67
T_2	59.36	80.37	101.3
T_3	57.5	77.93	96.01
T_4	61.17	80.87	101.87
T_5	55.23	74.2	90.9
T_6	53.17	74.63	90.83
LS	NS	NS	NS
CV (%)	5.93	4.86	7.40

LS = Level of Significance; NS = Non Significant, CV= Co-efficient of Variation.

Functional relationship between effective tiller number hill^{-1} and grain yield (tha^{-1}): Grain yield had positive regression with effective tillers. Fig. 1 showed that grain yield increased with the increase of effective tiller and above 80 % of the variation in grain yield could be explained.

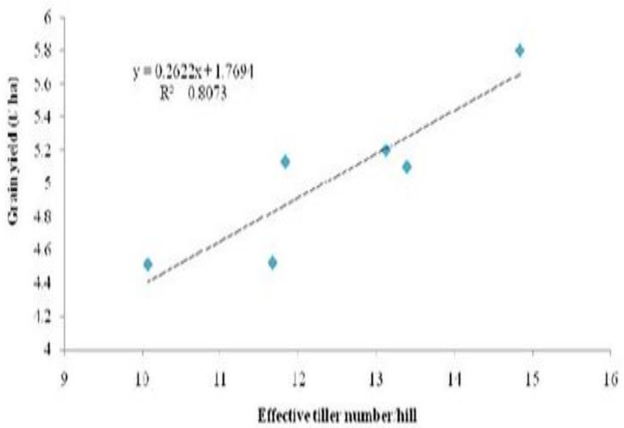

Fig. 1. Functional relationship between effective tiller hill^{-1} and yield

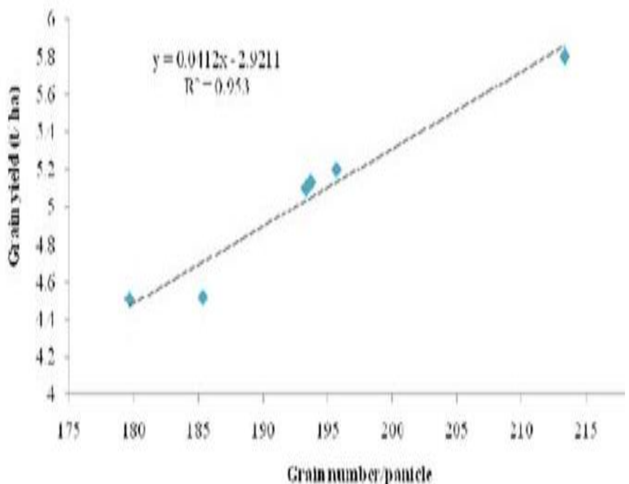

Fig. 2. Functional relationship between grain panicle^{-1} and yield

Functional relationship between grain panicle^{-1} and yield (tha^{-1}): Grain yield had positive regression with grain number panicle^{-1}. Fig. 2 showed that grain yield increased with the increase of grain number panicle^{-1} and above 95 % of the variation in grain yield could be explained.

Filled grain per panicle: The highest filled grain panicle^{-1} (186.33) was found in T_4 (20 tha^{-1}) and the lowest was recorded (163.67) in T_1 (control plot).

Effect of compost fertilizers in grain yield and straw yield:

Grain yield: The highest grain yield (5.8 tha^{-1}) was obtained from compost @ 20 tha^{-1} (T_4) and the lowest was recorded (4.51 tha^{-1}) from control plot with no fertilizer application (T_1) (Fig. 3). Similar observation was also revealed by Chaudhary *et al*. (2011).

Straw yield: The highest straw yield (7.55 tha^{-1}) was found in compost @ 20 tha^{-1} (T_4) and the lowest (6.13 tha^{-1}) was obtained from the compost @ 30 tha^{-1} (T_5) (Fig. 3). Similar observation was also revealed by Chaudhary *et al.* (2011).

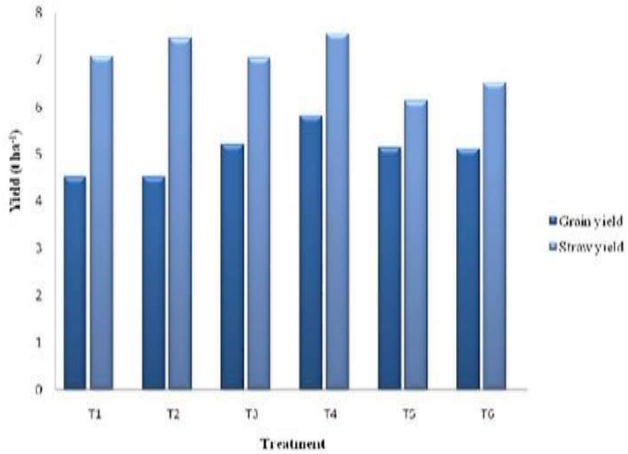

Fig. 3. Effect of compost fertilizers on grain and straw yield

Different rates of compost fertilizer application significantly affected the plant yield contributing parameters such as tillers and effective tillers hill^{-1}, number of panicle, grain number panicle^{-1}, filled grain panicle^{-1}, grain yield ha^{-1}, biological yield ha^{-1} and harvest index percentages. CH_4 emission was also influenced by compost fertilizer application. The highest CH_4 emission (1655.71kg ha^{-1} season^{-1}) and second highest CH_4 emission (1260.29kg ha^{-1} season^{-1}) were found from higher rates of compost applications. The lowest CH_4 emission (789.12kg ha^{-1} season^{-1}) was found from control plot. The highest plant height (101.87 cm), effective tiller hill^{-1} (14.84), panicle length (12.83 cm), grain yield (5.8 tha^{-1}) and biological yield (13.37 tha^{-1}) were found from compost @ 20 tha^{-1} (T_4). The highest tiller hill^{-1}(16.31) and harvest index (43.94) were found from compost @ 50 tha^{-1} (T_6). The lowest effective tiller hill^{-1}(10.07), panicle length (10.03 cm), grain yield (4.51 tha^{-1}) and biological yield (11.58 tha^{-1}) were found from control plot. From the result in respect of rice yield and methane emission, compost @ 20 tha^{-1} (T_4) was better than other treatment.

Compost fertilizer is very much effective for supplying plant nutrients. Rice fields enriched with organic fertilizers are significant source of nutrients. Today it's a matter of concern that organic matter of soil is depleting fast for increasing cropping intensity and cultivation of HYVs. It's also a worldwide apprehension that by using chemical fertilizers environment getting degraded once and again. As rice is our staple food and there is still shortage of food, it's obvious to add organic matter to improve soil fertility and thereby to yield to feed the teeming million of starving people. But at the same time it is also worldwide concern that higher rates of organic fertilizers emit higher amount CH_4 gas. Therefore we have to think sustainable production with environmental consideration.

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