The Journal of Agriculture and Natural Resources Sciences, 2(3), 530-536. 2015

THE JOURNAL OF AGRICULTURE AND NATURAL RESOURCES SCIENCES

Journal homepage: http://www.journals.wsrpublishing.com/index.php/tjanrs

Online ISSN: 2383-238X Print ISSN: 2423-4397

Original Article

Effects of Different Rates of Compost Application on Methane Emission and Crop Yield in Aman Rice

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ARTICLE INFO

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How to Cite this Article
Hossen, S., Islam, N., Alam, R., & Baten, A. (2015). Effects of Different Rates of Compost Application on Methane Emission and Crop Yield In Aman Rice. *The Journal of Agriculture and Natural Resources Sciences,* 2(3), 530-536.

Article History
Received: 21 September 2015
Accepted: 30 October 2015

ABSTRACT

An experiment was conducted to investigate the effects of organic fertilizer rate on CH_4 emission and yield of Aman rice in the experimental field of Environmental Science at Bangladesh Agricultural University, Mymensingh during July to November, 2013. The study was conducted with six treatments of recommended doses of inorganic fertilizer, compost @ 10 t ha^{-1}, 20 t ha^{-1}, 30 t ha^{-1}, 50 t ha^{-1} and control (without fertilizer). Air samples were collected by the modified closed-chamber method and analyzed by gas chromatograph equipped with a Flame Ionization Detector (FID). CH_4 emission was influenced by compost fertilizer application rate. The highest CH_4 emission (1655.71kg ha^{-1}) and the lowest CH_4 emission (789.12kg ha^{-1}) was found from control plot. Compost fertilizer application significantly affected the plant yield contributing parameters. The highest grain yield (5.8 t ha^{-1}) and biological yield (13.37 t ha^{-1}) were found from 20 t ha^{-1}. The highest tiller $hill^{-1}$(16.31) and harvest index (43.94) were found from compost @ 50 t ha^{-1} (T_6). The lowest effective tiller $hill^{-1}$(10.07), panicle length (10.03 cm), grain yield (4.51 t ha^{-1}) and biological yield (11.58 t ha^{-1}) were found from control plot. In respect of rice yield and methane emission, compost @ 20 t ha^{-1}(T_4) was found better than other treatment.

Key words: Compost, methane, rice, gas chromatography, FID.

INTRODUCTION

Agriculture is a major source of greenhouse gases (GHGs), especially of methane (CH_4) and nitrous oxide (N_2O). Globally rice cultivation may account for up to 12% of CH_4 flux (IPCC, 2007) and 13-24% of N_2O emission from agricultural soils (Olivier *et al.*, 1998; Kroeze *et al.,* 1999). The warming potential of CH_4 is about 20 times more powerful than carbon dioxide. Bangladesh is the 4th largest rice producing countries in the world, where 80% of the cultivated area is used for rice cultivation either single, double even triple cropping pattern (Hossen *et al.*, 2012; Gumma *et al.*, 2012). Cultivation of rice production is increasing with increasing its population, Therefore, significant amount of GHGs has emitted from rice paddy cultivation of Bangladesh.

Continuous and intensive cultivation of rice poses further threat of soil degradation thus, maintaining and improving soil quality with less environmental impact is one of the important factors for sustainable crop production for future generations. Several factors affecting maintaince of soil organic carbon among them organic matter additions, moisture, temperature, and fertilization contribute a lots. Addition of organic matter (OM) improve soil organic carbon whereas higher rainfall and temperature favorable to rapid organic matter decomposition and loss of soil organic carbon. However, the application of OM also increases methane emission. It was observed that application of OM to rice fields increased methane emission rates by 2 to 4 times higher than other control (Yagi, and Minami, 1990; Bronson *et al.*, 1997).

The largest present anthropogenic sources of CH_4 are rice fields, cattle and biomass burning (KhaliI, and Shearer, 2000). The CH_4 emission is prominent in irrigated rice due to long periods of flooding and anaerobic decomposition of incorporated organic matter. Rate of CH_4 emission from rice fields is affected by a number of interacting soil, plant, management and climatic factors. The CH_4 plays a major role in global warming and climate change, so it is essential to reduce CH_4 emission without adversely affecting crop production. 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. Therefore, evaluation of CH4 emission and crop production is highly required with different rate of organic amendment to soil in different parts of rice growing world. The present study will be evaluated growth and yield of rice and the pattern of CH_4 emission by using different rates of compost application on Aman rice of Bangladesh.

MATERIALS AND METHODS

Experimental Site

A field experiment was carried out during Aman season (20 July, 2013 to 28 November, 2013) in the field of the Department of Environmental Science at BAU farm. The location experiences a tropical monsoon-type climate, with a hot and rainy summer, and dry winter. Annual mean air temperature around 25.22 °C and the highest mean temperature is reached in the month of April. Annual rainfall is about 2249 mm where 70% of the annual rainfall is received during monsoon season (June to August). The relative humidity varies from 60-98% with some diurnal fluctuations in the various seasons with annual average of 56.8. The soil is dark gray non-calcareous floodplain) with a sandy loam and loam texture (UNDP and FAO, 1988).

Treatments

The experiment was laid out in a randomized complete block design (RCBD) with 6 treatments and 3 replications. The area of each plot was $10m^2$ (4m × 2.5m). The treatments were T_1: Control plot (No fertilizer); T_2: Inorganic fertilizers N, P, K (Standard doses); T_3: Compost 10 t ha^{-1}; T_4: Compost 20 t ha^{-1}; T_5: Compost 30 t $ha^{-1}$and T_6: Compost 50 t ha^{-1}.

At the time of final land preparation compost fertilizer was applied at the rate of 10, 20, 30 and 50 t ha^{-1} for T_3, T_4, T_5 and T_6 plots respectively. At that time Urea fertilizer (granular) 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). Triple super phosphate (TSP) and muriate of potash (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.

Forty five days old rice seedlings of cultivar BRRI dhan49 was transplanted in July 2013. The crops were harvested on 25 November, 2013 (110 DAT).

Plant Sampling

Data on growth and yield components were recorded from 5 randomly selected hills for each plot. Grain and straw yield were recorded on the whole plant basis. The grain and straw weight were expressed in t ha^{-1}. The 1000 grain weight was taken from oven dried (72^0 C for 48 hours) grain samples of each unit plot.

Harvest index was calculated by using the following formula as described by Fageria *et al.*, (2011):

$$HI = \frac{Grain\ yield}{Biological\ yield} \times 100$$

$$= \frac{Grain\ yield}{Grain\ yield\ + Straw\ yield} \times 100$$

Where, HI = Harvest index

Gas Sample Collection and Analysis

Gas samples were collected using a modified closed-chamber method during the rice cultivation (Khan *et al.,* 2015). The dimension of close chambers was 60cm x 60cm x 75cm that was equipped with an electronic fan. Six chambers were installed for three times in each treatment of the experimental plot. Gas was sampled at 7-10 days interval and sampling time was 12.00-2.00 pm. 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 pre-evacuated gas vials. The samples were analyzed to determine the concentration of CH_4 gas by gas chromatograph equipped with a Flame Ionization Detector (FID) (Shimadzu-2014, Japan). The analysis column used a stainless steel column packed with HAYSEP Q 80/100.The temperatures of column, injector and detector were adjusted at 120ºC, 200ºC, and 220ºC respectively. The column flow was 25 ml/min.

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).

Soil Analysis

After the harvest of rice crop soil samples from 0 – 15 cm depth were taken from individual plots. After completion of collecting soil samples, the unwanted materials like stones, granules, plant parts, leaves etc. were discarded from sample. The samples were dried at room temperature, crushed, mixed thoroughly and sieved with a 2 mm sieve. Soil pH and soil EC were analyzed by using pH meter electrode (McLean, 1982) and soil organic matter by The Walkley-Black Wet digestion method (Walkley and Black, 1934).

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

CH_4 Emission from Rice Field

Application of organic fertilizers significantly influenced the CH_4 emission from rice field. The highest CH_4 emission (61.49 mg m^{-2} h^{-1}) was observed at the flowering stage of treatment of T6. The second highest CH_4 emission (53.78 mg m^{-2} h^{-1}) was observed at the flowering stage of T5 [Fig.1]. The lowest CH_4 emission (18.93 mg m^{-2} h^{-1}) was observed at the transplanting stage of control plot and the second lowest CH_4 emission (19.37 mg m^{-2} h^{-1}) was observed at ripening stage at control plot. There was distinct variation of CH4 emission at different stages of rice cultivation and maximum CH4 emission was observed at flowering stages in all treatments. It was reported that CH4 emission increased from transplanting to flowering stage and decreased to ripening stages of rice (Yang and Chang, 1999). Treatment T6 showed higher CH4 emission in respect of growing stage and control was lower in our experimental results. In another experiment of rice cultivation it was found that highest CH_4 emission (44.47 mg m^{-2} h^{-1}) with organic fertilizer application and lowest CH_4 emission (8.39 mg m^{-2} h^{-1}) from control (Jahangir, 2012). Changes in the management of organic fertilizers have been identified as the main driving force for long term changes of CH_4 emission from rice field (Denier, 2000). The increment in CH_4 emissions following organic fertilizer application depends on quantity, quality and timing of the application [Yagi, and Minami, 1990; Sass *et al.*, 1990).

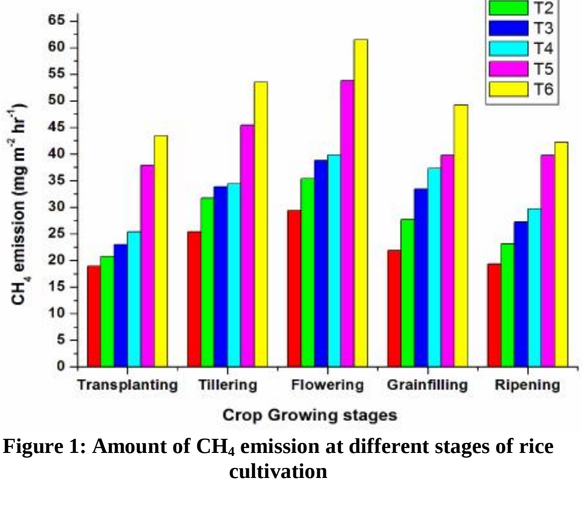

Figure 1: Amount of CH_4 emission at different stages of rice cultivation

Seasonal methane emission from different treatment plot was varied markedly in the experiment. The highest seasonal CH_4 emission (1655.71 kg ha^{-1}) found from the treatment of compost @ 50 t ha^{-1}(T_6). The lowest CH_4 emission (789.12 kg ha^{-1}) was observed from the control plot (Fig. 2). Many previous studies agreed that the application of compost and other organic fertilizers strongly increases CH_4 emission rates over that from inorganic fertilizer application (Yagi, and Minami, 1990; Wassmann *et al.*, 2000). Emission rate is dependent on amount, kind and prior treatment of the organic fertilizers.

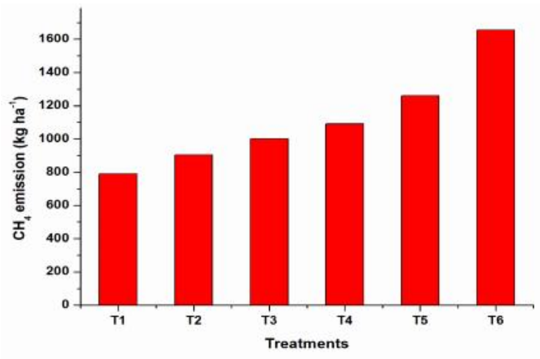

Figure 2: Amount of total CH_4 emission from different treatments

Table 1. 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
T1	57.27	78.7	96.67
T2	59.36	80.37	101.3
T3	57.5	77.93	96.01
T4	61.17	80.87	101.87
T5	55.23	74.2	90.9
T6	53.17	74.63	90.83
LSD (0.05)	NS	NS	NS
CV (%)	5.93	4.86	7.40

Crop Growth and Yield

Statistically non-significant variation was observed for plant height of BRRI dhan 49 for compost application rate with inorganic fertilization and control at 30, 60 DAT and at harvest. The highest plant height (101.87 cm) was found at harvest from Compost @ 20 t ha^{-1} (T_4). The plant height was also highest at 30 DAT and 60 DAT for same treatment. The combined application of fertilizers and manures influence on plant height compared to single application of any one. It was stated that plant height was significantly influenced by the application of organic manure and chemical fertilizers (Babu *et al.*, 2001).

It revealed that all the treatments influenced significantly maximum number of tiller compared to the control treatment. The maximum number of effective tillers per hill (14.84) was found from T5. The lowest number of effective tillers $hill^{-1}$ (14.84) was found in T_1. The response of compost fertilizer application was significant at 5% level of significance. It was reported that significant increase in effective tillers hill-1 due to application of higher doses of nitrogen in rice crop (Chander and Pandey, 1996).

The influence of compost fertilizer application on panicle length at harvest was significant at 1% level of significance. It was observed that the longest panicle (12.83 cm) and the shortest panicle (10.03 cm) were observed in treatments of T_4 (20 t ha^{-1}) and control plot respectively. Similar observation was reported for effect of chemical fertilizers and integrated nutrient management practices on growth and yield of rice (Singh *et al.*, 2010).

In case of grain number per panicle the response of compost fertilizer application was significant at 1% level of significance. The highest number of grains $panicle^{-1}$ (213.33) was found in treatments of T_4 (20 t ha^{-1}) and the lowest (179.67) was recorded in control plot.

The influence of compost fertilizer application on filled grain per panicle was significant at 1% level of significance. It was observed that the highest filled grain $panicle^{-1}$ (186.33) was found in T_4 treatment which was statistically identical with T5, andT6 treatment and the lowest was recorded (163.67) in T_1 (control plot).

Weight of 1000 seeds of BRRI dhan 49 showed statistically non significant variation due to the application of various organic compost and inorganic fertilizer. The highest weight (23.77g) was found in T_6 (50 t ha^{-1}) and the lowest weight (22.1g) was found in T_3 (10 t ha^{-1}) (Table 2). It was reported that the combined application of organic manure and chemical fertilizers increased the 1000-grain weight of rice (Abedin *et al.*, 1999).

Grain yield of BRRI dhan 49 was significantly influenced by the compost fertilizer application and it was varied from 4.51 to 5.8 t ha $^{-1}$. In case of grain yield, T4 (compost 20 t ha $^{-1}$) performed the highest result (5.8 t ha^{-1}) .On the other hand, the lowest grain yield (4.51 t ha^{-1}) was found from control condition (Table 2). It was stated that application of organic manure and chemical fertilizers significantly increased the grain yield of rice (Haque *et al.*, 2001). On the other hand, straw yield shown non-significant variation with the application of compost and inorganic fertilizer on Aman rice. The highest straw yield (7.55 t ha^{-1}) was found in compost @ 20 t ha^{-1} (T_4) and the lowest (6.13 t ha^{-1}) was obtained from the compost @30 t ha^{-1} (T_5).

Table 2: Effects of compost fertilizer application on yield and yield components in rice production

Treatment	Effective tiller no. hill^{-1}	Panicle length (cm)	Grain no panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1	10.07^{c}	10.03^{c}	179.67^{b}	23.17	4.51^{b}	7.06	11.58^{b}	39.07^{bc}
T_2	11.67^{bc}	10.36b^{c}	185.33^{b}	22.23	4.52^{b}	7.46	11.98^{b}	37.7^{c}
T_3	13.12^{ab}	11.57^{b}	195.67^{b}	22.1	5.2^{ab}	7.04	12.24^{b}	42.48^{ab}
T_4	14.84^{a}	12.83^{a}	213.33^{a}	22.63	5.8^{a}	7.55	13.37^{a}	43.5^{a}
T_5	11.83^{bc}	11.8^{ab}	193.67^{ab}	22.64	5.13^{ab}	6.13	11.75^{b}	43.83^{a}
T_6	13.39^{ab}	11.0^{bc}	193.33^{ab}	23.77	5.1^{ab}	6.51	11.61^{b}	43.94^{a}
LS	5%	1%	1%	NS	1%	NS	5%	5%
CV (%)	7.76	4.45	4.04	5.83	5.29	7.46%	4.8	5.48

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

From the study it was found that the biological yield was significantly influenced by the application of compost fertilizer. The highest biological yield (13.37 t ha^{-1}) was obtained from the compost @ 20 t ha^{-1} (T_4) and the lowest (11.58 t ha^{-1}) was recorded from control plot (T_1). The better result of biological yield might be due to the significant increase in grain and straw yield. The influence of compost fertilizer application on harvest index was significant at 5% level of significance. From the results (Table 2) it was observed that the highest HI (43.94%) was recorded from T_6 and the lowest (37.7%) was recorded from T_2).

It was found that 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}, grain yield ha^{-1}, biological yield ha^{-1} and harvest index. CH_4 emission was also influenced by compost fertilizer application.

Effect of Compost Application Rate of Soil Properties

Soil pH

Generally the changes in the chemical properties of soil after application of compost are related to chemical composition and organic matter contents of the added compost. As regards to soil pH, the increase of soil pH was pronounced at high rate of compost application. The lowest soil pH was observed in the standard NPK fertilizer applied plot, it may be due to higher nitrification of N-NH_4^+ from urea fertilizer. Treatment T6 followed statistical similar result with T3, T4 and T5 for soil pH. Gabriela found that application of medium and high doses of compost raised pH from 6.5 to 6.9 (Civeira, 2010). It was also stated that soil pH increases when mature composts were applied (Tognetti *et al.*, 2007).

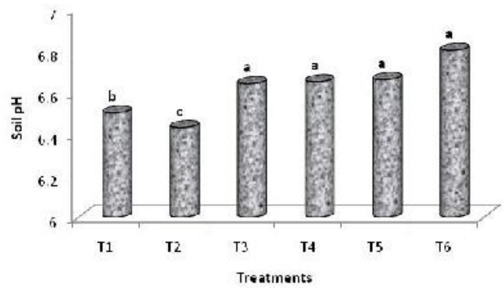

Fig. 3: Soil pH as affected by compost doses. Different letters indicate differences among estimated treatment means at the 0.05 probability level

EC of Soil

Soil Electrical conductivity (FC) indicates indirectly the total concentration of soluble salts and is a direct measurement of soil salinity. Application of compost increase salt concentration in soil has great environmental concern. The lowest EC (2.40 dS.m-1) was in control treatment (without fertilizer) increased to 3.5 dS m^{-1} in treatment that received compost 50 t ha^{-1} followed by treatment 5 (compost 30 t ha^{-1}) (fig. 4). The decomposition of organic materials released acids or acid forming compounds that reacted with the sparingly soluble salts already present in the soil and either converted them into soluble salts or at least increased their solubility. Hence, the EC of soil was increased. The soil EC increased with increasing an application rate of compost in soil as reported by previous studies (Atiyeh *et al.,* 2001; Sarwar *et al.,* 2003). Although EC of the soil increased in different treatments but the actual values did not cross the critical limit of 4.0 dS m^{-1}.

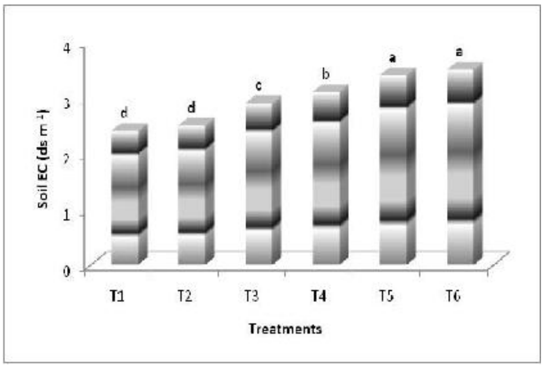

Fig. 4: Soil EC as affected by compost doses. Different letters indicate differences among estimated treatment means at the 0.05 probability level.

Soil Organic Matter

Soil organic matter (SOM) showed a tendency to increase in comparison to the control soils. The sites that had the highest rates of compost application showed the most significant increases in soil carbon. Maximum OM of soil was found under the treatment of T6 (fig. 5).

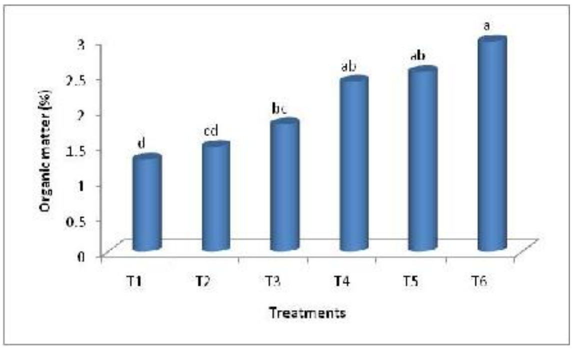

Fig. 5. Effect of compost application rate on soil organic matter. Different letters indicate differences among estimated treatment means at the 0.05 probability level

Treatment T5 and T6 showed statistically similar SOM. Minimum SOM was found under the control treatment. Inorganic fertilizer did not increase much SOM as compared with compost fertilizer. Soil analysis showed more pronounced increases in total soil carbon for field that had received higher loading rates of compost. Higher rate of compost increased greater percent of SOM was also reported in past (Angelova *et al.,* 2013).

CONCLUSION

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. The seasonal methane emission from rice fields range between 789.12 to 1655.71 kg m^{-2} h^{-1} with different rates of compost amendment. When compared with the control soil, soil treated with organic amendments showed apparent increases of organic matter, soil pH and soil EC. From the result in respect of rice yield and methane emission, compost @ 20 t ha^{-1} (T_4) was better than other treatment. 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 millions 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.

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