Methane emission from T. Aman fields as affected by chemical fertilizer and manure management

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Abstract: Rice cultivation is one of the potential anthropogenic sources of CH_4 emission to the atmosphere. A study was carried out at the experimental field of Environmental Science, Bangladesh Agricultural University, Mymensingh during the period from August to December 2015 farming season to evaluate Methane emission from rice (T. Aman) paddy fields as affected by chemical fertilizer and manure management for Yield of T. Aman rice production (rice cultivar BRRI Dhan- 11). Five different treatments such as Control (No fertilizer no compost), 100% N (Prilled urea) PKS, 100% N (Urea super granule) PKS, 50% N (Prilled urea) PKS + 50% manure, 50%N (Urea super granule) PKS + 50% manure were used in this experiment. The treatments were replicated three times and arranged under RCBD. The highest CH_4 emission (8.36 mg m^{-2} h^{-1}) was found from the 50% N (Prilled urea) PKS + 50% manure treatment at ripening stage and the lowest methane flux (2.15 mg m^{-2} h^{-1}) was produced in control treatment. The second lowest methane flux (5.18 mg m-2 h-1) was found from the 100% N (Urea super granule). The methane emissions at ripening stage were 8.36 , 7.80 , 6.78 , 5.18 , 2.15 mg m^{-2} h^{-1} under 50% N (Prilled urea) P, K, S + 50% manure, 50% N (Urea super granule) P, K, S + 50% manure, 100% N (Prilled urea) P, K, S, 100% N (Urea super granule) P,K,S and control, respectively. Total grain yields ha-1 were found in 3.96, 5.79, 5.41, 5.83, 5.95 t ha^{-1} under control, 100% N (Prilled urea) PKS, 100% N (Urea super granule) P, K, S, 50% N (Prilled urea) P, K, S + 50% manure, 50% N (Urea super granule) P, K, S + 50% manure, respectively. Use of Urea Super Granule (USG) comparatively decreased methane emission and increases yield than prilled urea and manure combination treatment. So, USG could be used for reducing CH4 emissions and sustaining rice production under rice farming system.
Key words: Chemical fertilizer, manure, emission, methane, yield, T. aman rice.

Introduction

Greenhouse gases (GHGs) are the causes of global warming and global warming is the main cause of climate change, which is recognized to be a risk to human welfare. We use huge fertilizer to produce rice. Combined use of fertilizer and manure is supposed to influence GHG production. Greenhouse gases are mainly three types (CO_2, CH_4 and N_2O) with widely different warming potential. Though the concentration of CH_4 and N_2O in the atmosphere is lower than CO_2 but CH_4 has 22 times and N_2O has 300 times higher warming potential than CO_2 on a 100 yr time scale, so it may have significant impacts on global climate change (IPCC, 2007).

Rice (*Oryza sativa* L.) is the most important staple food in Asia, providing an average of 32% of the total calorie uptake (Maclean *et al*., 2002). About 75% of the global rice volume produced in the irrigated lowlands (Maclean *et al*., 2002). Profitable rice farming ensures political stability for the country and provides a sense of food security to the people (Bhuiyan *et al*., 2002). Bangladesh is an agricultural country and rice is the main food crops. Rice has been growing over 25 million hectares of land under irrigated and rain fed conditions, which cover about 84% of total cropped area in Bangladesh (BBS, 2008). Bangladesh is a small country with a large population and each year, nearly 1.47 million people are added to its current population of about 162.2 million and at present population growth is 1.29% (BBS, 2009). The pressure on Bangladesh land resources to produce more rice will aggravate in the coming years due to increasing population and demand for food. Rice demand would increase by 25% to keep pace with population growth (Maclean, 2002). Boro, T. Aman and Aus rice cover of 11,386, 12,474 and 2,270 acres with production of 17762, 9662 and 1507 MT respectively (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). 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).

Future technologies will rely on the adoption of high yielding cultivars, efficient water management, and increased use of different fertilizers. Some production practices may promote methane (CH_4) emissions while others may infer a net decrease of the CH_4 source strength. Recent studies have reported global annual CH_4 emissions from paddy fields to be 53 Tg CH_4 (Cao *et al*., 1998), 25-54 Tg CH_4 (Mosier *et al*., 1998) and 33-49 Tg CH_4 (Neue and Sass, 1998) and 29-61 Tg CH_4 (IPCC, 2002). It has been estimated that global rice production must also be doubled by the year 2020 in order to meet the growing demands (Hossain,1997) and this may increase CH4 fluxes by up to 50% (Bouwman, 1991).

However, GHGs emission mechanism and magnitude behind the CH4 flux exchange from rice ecosystem to the atmosphere is still unclear. Therefore, the research work was undertaken to evaluate and compare methane emission under different combination of chemical fertilizer and manure in rice field; and to compare Urea Super Granule and prilled Urea in combination with manure on growth and yield of rice.

Materials and Methods

The experiment was conducted in Transplanted Aman (T. Aman) seasons (BRRIdhan11) at the experimental field of Environmental Science, Bangladesh Agricultural University, Mymensingh during the period of August to December 2015 farming season. The experiment was laid out in a randomized complete block design (RCBD) with three replications. In 2015 T. Aman season, seeding was done in 20 August and twenty-one days old seedlings were transplanted in the main field at three seedlings per hill with 20cm×20cm row and hill spacing. Land preparation for rice cultivation was done by 3-4 times plowing and cross-plowing followed by laddering. Fertilizers and Manure were applied at the following doses: Prilled urea

250 kg ha^{-1}, Urea Super Granule (USG) 80 kg ha^{-1}, respectively in all plots. At the time of final land preparation nitrogenous fertilizer in form of urea (Prilled or USG) was applied as basal doze and rest of urea in two equal splits at 30 and 60 Days After Transplanting (DAT). But all other fertilizers (T.S.P. 90 kg ha^{-1}, M.O.P. 70 kg ha^{-1}, gypsum 40 kg ha^{-1}), were applied as per respective doses in two equal splits at the land preparation time and 30 DAT. Manure 5 t/ha is also applied as basal as respective dose. Hand weeding was done when deemed necessary. Two times Bittaku was used to prevent the plant from attack of insect. The water depth was 5 cm. The experimental field was divided into three blocks. Each block was divided into 5 plots. There are 5 treatments in each block. Thus the total numbers of unit plots were 15. The area of each plot was 4 square meter (2m × 2 m). The treatment combinations were randomly distributed to unit plots. The experimental treatments were: T_1: Control (No fertilizer, no compost); T_2: 100% Prilled Urea (250kg ha^{-1}) + TSP (90kg ha^{-1}) + MoP (70kg ha^{-1}) + Gypsum (40kg ha^{-1}); T_3: 100% Urea super Granule (170kg ha^{-1}) + TSP (90kg ha-1) + MoP (70kg ha^{-1}) + Gypsum (40kg ha^{-1}); T_4: 50% Prilled urea (125kgha) + TSP (45kg/ha) + MoP (35kg/ha) + Gypsum (20kg/ha) + 50% Manure (5t/ha); T_5: 50% Urea Super Granule (85kg/ha) + TSP (22.5kg/ha) + MoP (35kgha) + Gypsum (20kg/ha) + 50% Manure (5t/ha).

Analytical techniques: Gas samples were collected by using the closed-chamber method (Ali *et al*., 2008) 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 at different growth stages (vegetative and ripening) 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 CH_4 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 (m^3), 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 Chemical fertilizer and manure on soil pH and methane emission: In general soil pH was increased with the application of 50% Urea Super Granule +50% manure. It is observed that, in vegetative and ripening stage the highest pH value was found on treatment 50% N (prilled urea) P, K, S + 50% mannure and lowest value was found in Control. (Table 1. Fig 1) .The Methane emission was significantly influenced by the soil pH, methane emission rate was significantly increased with the increased of pH. Soil pH is also an important contributor to CH_4 production in the sediment as the methanogenic bacteria are pH-sensitive and can grow well in a relatively narrow pH range of 6-8.

Table 1. Effect of chemical fertilizer and manure on soil pH value of vegetative and ripening stage of BRRI dhan11

Treatments	pH value	
	Vegetative stage	Ripening stage
T_1	4.18	4.2c
T_2	4.28	4.43bc
T_3	4.30	5.13ab
T_4	4.19	4.89b
T_5	4.32	5.34a
LSD at 5%	0.18	0.23
Level of Significance	NS	**

** = Significant at 1% level of probability; NS= Non-Significant

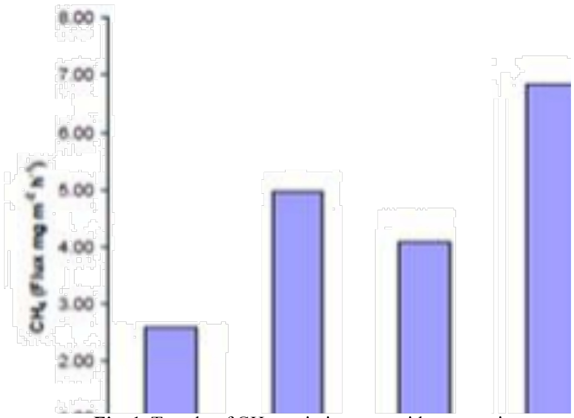

Fig. 1. Trends of CH_4 emission rate with vegetative stages in different treatments

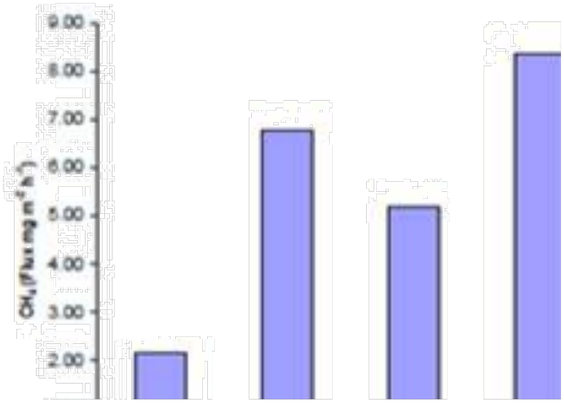

Fig. 2. Trends of CH4 emission rate with ripening stages in different treatments

CH_4 emission on vegetative and ripening Stage: Methane emission was highest 6.84 mg m^{-2} h^{-1}CH_4 in BRRIdhan11 in the treatment of 50% Urea Super Granule + 50% manure in vegetative stage while the lowestmethane emission 2.59 mg m^{-2} h^{-1} CH_4 in this rice cultivation; in the treatment of Control.(Fig 2). On the other hand the highest methane emission was observed 8.36 mg m^{-2} h^{-1} CH_4 in BRRIdhan11 in the treatment of

50% Urea Super Granule + 50% manure in ripening stage and the lowest methane emission 2.15 mg m^{-2} h^{-1} CH_4 in this rice cultivation in the treatment of control (Figs. 1& 2).

Comparing the values of emission at vegetative and ripening stages of rice, flux of CH_4 was found less in vegetative (2.59 mg m^{-2} h^{-1}) but more in ripening stages (8.36 $mgm^{-2}h^{-1}$) of rice growth in this study. It might be due to the decomposition of older root and leaves, which enhances the activities of methanogenic bacteria in the soil for producing methane. Neue *et al*. (1997) reported that methane emission increased during the growing season with peaks early in the season at panicle initiation or flowering, and, especially at the final ripening stage. Plant borne carbon (decaying roots) was the major source of increased emission during ripening stage. Results of this site on CH_4 emission are nearly similar with the findings of Neue *et al*. (1997).

Effect of Chemical fertilizer and manure on agronomic characters:

Plant height: The highest plant height (79.67and117.67) was found in the treatments of 100% N (Prilled Urea) P, K, S at 60 and 90 DAT respectively. The lowest plant height was found in control treatments. It was observed that at treatment 100% N (Urea super granule), P, K, S and 50% N (Urea super granule) PKS + 50% manure plants height are maximum whereas in 50% N (Prilled urea) P, K, S + 50% manure methane emission rate was maximum. So if we use USG methane emissions are comparatively low and overall yield are maximum (Table 2).

Table 2. Effect of Chemical fertilizer and manure on rice growth and yield components of BRRIdhan11.

Treatment	Plant height (cm)	No. of tillers / hill	Panicle length (cm)	No. of panicles /hill	No. of grains /panicle	No. of grains /hill	Ripened grain %	1000 rains wt.(g)	Grains wt. /hill	Straw wt./hill
T_1	84.67	12	9.74	10	106	1060	50	23.90	16.83	14.00
T_2	113	16	10.23	13	146	1898	76.02	23.92	23.85	27.65
T_3	117.67	13	9.75	11	129	1419	65.11	24.02	19.74	33.08
T_4	113.67	14	9.95	11	138	1518	72	25.79	22.18	30.73
T_5	112	15	10.16	10	145	1450	73.79	23.94	22.56	30.58
LSD	1.63	1.72	0.16	1.37	2.71	8.84	4.84	1.21	1.34	1.34
Level of Sign.	**	**	**	**	**	**	**	NS	**	**

** = Significant at 1% level of probability

No. of tiller: The highest tiller no, (9 and 15) was found in the treatments of 50% N (Urea super granule) P, K, S + 50% manure at 40, 60 DAT and the highest tiller no. (14) was found in the treatments of 100% N (Prilled Urea), P,K,S at 90 DAT. The lowest plant growth was found in control treatments 90 DAT. The lowest tiller no. was found in control treatments at 40 DAT (Table 2).

Panicle length: The highest Panicle size (10.23cm) was found in the 100% N (prilled urea) P, K, S treatment and the lowest panicle size (9.74cm) was found in the control treatment (Table 2).

Number of tillers hill^{-1}: The highest number of tillers hill^{-1} (16) was found with application of 100% N (Prilled Urea) + P, K, S followed by (15) with 50% N (Urea super granule) + 50% manure, while the lowest number of tillers hill^{-1} (12) was found in control treatments (Table 2).

Number of panicle hill^{-1}: The highest number of panicle hill^{-1} (13) was obtained from 100% Urea (Prilled) P, K, S. The lowest number of panicle hill^{-1} (10) was found in control treatment (Table 2).

Number of grains panicle^{-1}: The highest number of grains panicle^{-1} (146) was obtained from 100% N (Prilled urea) + P, K, S. The lowest number of grains panicle^{-1} (106) was found in control treatment (Table 2).

No. of grains hill-1 : In BRRIdhan11 the highest No. of grains hill^{-1} (1898) was found with the treatment of 100% N (Prilled Urea) + P, K, S. The lowest no. of grains hill^{-1} (1060) was found with the treatment of control (Table 2).

Percentage of ripened grains: The highest percentage of ripened grains (76.02%) was obtained from 100% N (Prilled Urea) P, K, S. The lowest percentage of ripened grains (50%) was found in control treatment (Table 2).

1000 grains weight: It was observed that highest 1000 grains weight (25.79g) was found in 50%Urea (Prilled) + 50% Manure. Lowest (23.90g) was obtained from control treatment (Table 2).

Grains weight hill^{-1}: The highest grains weight hill^{-1}(23.85g) was obtained from 100% N ((Prilled Urea) + P, K, S. The lowest grains weight hill^{-1}(16.83g) was obtained from control treatment (Table 2).

Straw weight hill^{-1}: The highest Straw weight hill^{-1} (33.08g) was found in 100% Urea super Granule + P, K, S. which was statically similar to the poultry manure + Urea (23.38g). The second highest Straw weight hill^{-1} (30.73g) obtained from 50% Prilled Urea + 50% Manure, which was statically similar to the 50% Urea super Granule + 50% Manure (30.58g), 100% N(Prilled Urea) + P, K, S (27.65g). The lowest Straw weight hill^{-1} (14g) found in control treatment. (Table 2).

Grain yield ha^{-1}: The highest grain yield ha^{-1} (5.95 ton/ha) was observed in 50%Urea Super Granule + 50%Manure, which was statiscally similar to the 50% N (Prilled Urea) + 50% Manure (5.83t/ha) and 100% N (Prilled Urea) P, K, S (5.79 ton). The lowest grain yield (3.96t/ha) was obtained from control treatment (Table 3).

Table 3. Effects of Chemical fertilizer and manure on yield of BRRIdhan11

Treatment	Grain yield t/ha	Straw yield t/ha	HI%
T_1	3.96b	10d	24.00b
T_2	5.79a	18.5a	24.52b
T_3	5.41ab	16.25b	24.97b
T_4	5.83a	15.62c	27.17a
T_5	5.95a	16.20b	26.86ab
LSD	0.38	0.73	1.39
Level of Sign.	**	**	**

Straw yield ha^{-1}: The highest straw yield ha^{-1} (18.5 ton) was obtained from 100% N (Prilled Urea) + P, K, S. The second highest straw yield ha^{-1} (16.25 ton) obtained from 100% Urea super Granule + P,K,S which was statically similar to the 50% N(Urea super granule) + 50% manure

(16.20 ton), 50% N (Prilled Urea) + 50% manure (15.62 ton). The lowest straw yield (10 ton) was obtained from control treatment (Table 3).

Harvest Index (HI %): It was evident that the highest harvest index (27.17%) was found in 50%N (Prilled Urea) + 50% manure. The lowest harvest index (24%) was obtained from control treatment (Table 3).

Table 4. Soil properties at harvesting stage of BRRIdhan11

Treatment	% OC	pH	T-N %	P (ppm)	K (ppm)	S (ppm)
T_1	1.41	6.33	0.125cd	4.74c	31.13c	9.34bc
T_2	1.45	6.52	0.127c	7.58a	33.46b	10.01b
T_3	1.27	6.3	0.113d	6.05bc	35.80a	13.51a
T_4	1.53	6.36	0.135a	6.08bc	34.25ab	9.05c
T_5	1.48	6.26	0.130b	6.25b	29.57d	13.62a
LSD	0.30	0.18	0.02	0.61	1.32	1.19
Level of Significance	NS	NS	*	**	**	**

Table 5. Correlation of BRRIdhan11 growth, yield and soil parameter with CH_4 emission

Parameter	CH4 flux on vegetative stage	CH_4 flux on ripening stage	Plant height (cm)	No. of tillers/ hill	No. of panicles/hill	Grain yield/ha	Straw yield/ha	HI %	% OC	pH	T-N %
CH4 flux on vegetative stage	1										
CH4 flux on ripening stage	0.975(**)	1									
Plant height (cm)	0.670(**	0.783(**)	1								
No. of tillers/ hill	0.575(**)	0.649(**)	0.452(*)	1							
No. of panicles/hill	0.087	0.206	0.385	0.394	1						
Grain yield/ha	0.875(**	0.938(**)	0.848(**)	0.729(**)	0.238	1					
Straw yield/ha	0.612(**)	0.764(**)	0.890(**)	0.688(**)	0.501(*)	0.866(**)	1				
HI %	0.764(**)	0.711(**)	0.410(*)	0.529(**)	-0.168	0.621(**)	0.282	1			
% OC	0.337	0.281	-0.013	0.295	-0.104	0.295	0.021	0.368	1		
pH	0.057	0.111	0.060	0.326	0.336	0.200	0.220	-0.037	0.789(**)	1	
T-N %	0.326	0.303	-0.065	0.290	-0.158	0.127	0.135	0.292	-0.013	-0.123	1

Chemical properties of soil after rice harvest: T_2 treatments 100%N (Prilled urea), P, K, S fertilizer significantly increased active Phosphorus in soil after rice harvesting (Table 4), which increased the methanogens bacteria. As a result methane emission increased.

Correlation of yield component and Soil parameter with methane emission : Methane emission were positively correlate with No. of tillers/hill, No. of panicle/hill, grain yield, HI and also positively correlate with the plant height, straw yield, organic carbon and soil pH on BRRIdhan11 (Table 5).

Different type of fertilizer and manure significantly effect on plant parameter such as plant height, number of tillers hill^{-1}, number of panicle hill^{-1}, number of grain panicle^{-1}, ripened grain %, 1000 grain weight, grain weight hill^{-1}, straw weight hill^{-1}, grain yield ha^{-1}, straw yield ha^{-1} and HI %). In Variety BRRIdhan11 give highest yield (5.95 t/ha) and comparatively lowest methane emission 7.80 mg m^{-2} h^{-1} were observed at treatment 50% N (Urea super granule), P, K, S which is less than treatment 50% N (Prilled urea), P, K, S + 50% manure where methane emission was found 8.36 mg m^{-2} h^{-1} respectively. It was observed that yield was maximum at treatment 50% N (Urea super granule), P, K, S + 50% manure but methane emission rate was maximum at treatment 50% N (Prilled urea), P, K, S + 50% manure. So to mitigate methane emission from rice field it is better to use USG rather than prilled urea. From this research work, I found lower CH_4 production and highest yield in urea super granule treated plot. Therefore, urea super granule could be practiced for sustainable rice production and minimization of CH_4 emission from rice field.

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