MITIGATION OF METHANE EMISSION FROM RICE FIELDS USING DIFFERENT NITROGEN TYPES AND RICE VARITIES

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ABSTRACT

An experimental study was conducted to investigate the effect of different nitrogen fertilizers and rice cultivars on CH_4 emission from a rice paddy. The experiment was designed with two nitrogen fertilizer types, (ammonium sulfate and urea). Two rice cultivars (Giza 177 and Sakha106) were used for the plots experiment. Each experiment replicated triply. Methane flux was measured at different growth stages for the two rice cultivar treated with ammonium sulfate or urea fertilizer. There was significantly increase in methane emission fluxes due to plantation of $Sakha_{106}$ rice as a comparison of two rice varieties, Moreover, ammonium sulfate treatment significantly reduced CH_4 emissions by 50 to 55 % emissions compared to urea plots, also results indicated that the combination of $(NH_4)_2SO_4$ application and sakha $_{106}$ rice. It was concluded that the CH4 emission was dependent on the type of nitrogen fertilizer and rice varieties in Egypt paddy soils.

Keywords: Methane, Rice fields, Emission, Global warming

INTRODUCTION

Global warming is one of the challenges facing human being. This is caused by increasing concentration of greenhouse gases emit to the atmosphere. Methane (CH_4) is the most abundant organic trace gas in atmosphere. That has a significant effect on atmospheric temperature and chemistry (Anitha and Bindu, 2016). The Inter-governmental Panel on climate change points out that methane has 25 times higher global warming potential over 100 year time-horizon as compared to CO_2 (IPCC, 2007). Out of the anthropogenic sources rice paddies are considered a major source of methane (CH_4) emissions. Rice is one of the main food crops in many countries. N fertilizers may directly or indirectly affect all of the important processes involved in the CH_4 budget of rice paddies, i.e. the production, oxidation and transport of CH_4. However, studies investigating N fertilizer effects on these processes have yielded. For example, after fertilization with urea or $(NH_4)_2SO_4$, lower CH_4 emissions were detected and attributed to the direct inhibition of methanogenesis (Ma *et al.*, 2007). According to the IPCC (1996) there are several factors effect on the amount of methane emission from rice paddies. They are soil type and temperature, irrigation practices, duration and number of the harvest, rice species and fertilizer use. So, the objectives of this study are to investigating the effects of various nitrogen fertilizers and rice varieties on methane emission throughout the growth stages of rice from the paddy soils in Egypt, and to provide the data for estimation of the mitigation potentials in rice agricultural systems.

MATERIALS AND METHODS

1. Experimental site: Experimental paddy fields were located at the farm of CLAC (Central laboratory for Agricultural Climate), Agricultural Research Center (ARC), Dokki. Giza, Egypt, and the methane emission data were collected between May and September 2014. The soil characteristics were determined as follows: the physical and chemical characteristics of the soil were determined before planting (Table1). Soil mechanical was carried out by the international pipette methods (Piper, 1950) using sodium hexametaphosphate as a dispersing agent. Soil textural class was defined using the texture triangle diagram (Soil Survey Staff, 1962). Organic matter content was determined using the modified walkley and black method (Jackson, 1958). Soil pH was determined in 1:2:5 soil water extract using a glass electrode of Bechman apparatus (Richard, 1954). Electrical conductivity in 1:2:5 soil water extract were determined according to (Black *et al.*, 1982).

Table (1): Some physical and chemical characteristics of the soil before planting.

PH	EC ds m^{-1}	O.M. %	Particle size distribution %			Textural class
			Sand	Silt	Clay	
7.1	0.54	1.35	18.2%	27%	54.8%	alluvial

2. Rice varieties and nitrogen fertilizers: $Giza_{177}$ and Sakha $_{106}$ Japonica rice (Oryza sativa L.) were planted in 2014. A basal dose of phosphorus was applied at the rate of P_2O_5 36 kg ha^{-1} as triple super phosphate and $ZnSO_4$ in dry soil before sowing the seed., nitrogen was split-applied as (urea) and (ammonium sulfate) at rate of N 96 kg ha^{-1} 2/3 of urea and ammonium sulfate was incorporated before irrigation and 1/3 was applied at panicle initiation stage. There were four plots, plot A was Sakha $_{106}$ rice and urea, plot B was $Giza_{177}$ rice and urea, plot C was Sakha $_{106}$ rice and ammonium sulfate, plot D was $Giza_{177}$ rice and ammonium. Rice field operations were as follows: Plowing on 5May, Flooding on 18 May, Seeding on 20 May and harvesting on

25 September in 2014 (total cultivation period of 125 days) . Rice straw was removed from the field after harvest.

2.3. Measurement of methane flux: CH_4 flux was determined during one in the noon at every growth stage using closed chamber technique (Yang and Chang, 1998). The chamber was made from wood structure covered with polyethylene sheet (1 m^3) pushed into the soil approximately7-15cm depending on soil moisture content at the time of the sampling.

2.4 Analysis : Methane was measured by the Thermo Scientific Miran Sapphire Portable Ambient Analyzer from spaces in the chamber. The methane flux, F (mg $m^{-2}hr^{-1}$) was calculated (Marshall *et al*., 2010).

Statistical analysis: Treatments were replicated three times and flux data were subjected to analysis of variance and Duncan's multiple range test (p=0.05) (Duncan 1955) using the Statistical Analysis System (SAS, 2010) version 9.1. Correlation of methane with other growth parameters was done by Pearson correlation method.

RESULTS AND DISCUSSION

Table (2): Methane emission during different rice growth stages,(mg m^{-2} hr^{-1})**.**

Stages	Sakha rice (urea)	Giza rice (urea)	Sakha rice $(NH4)_2SO_4$	Giza rice $(NH4)_2SO_4$
Transplanting	2.93±0.81[d]	2.30±0.36[d]	1.17±0.49[d]	1.16±0.47[d]
Tillering	11.09±0.27[b]	9.50±0.36[b]	4.98±0.48[b]	4.80±0.10[b]
Booting	5.49±0.50[c]	4.73±0.64[c]	2.60±0.10[c]	2.45±0.05[c]
Flowering	38.00±1.00[a]	30.06±11.22[a]	15.00±1.00[a]	14.00±1.00[a]
Ripening	0.25±0.13[e]	0.22±0.07[e]	0.13±0.05[e]	0.10±0.08[e]
Average	**11.55**	**9.36**	**4.77**	**4.50**

1. Effect of nitrogen fertilizer on methane emission

Table3: Methane emission (mg m^{-2} hr^{-1}) as affected by two nitrogen fertilizers.

Fertilizer	Mean ± SD Methane Emission ($mgm^{-2}hr^{-1}$)
Urea	10.45 ± 12.94^{aA}
$(NH4)_2SO_4$	4.64 ± 5.29^{aA}
Average	**7.54**

N- Fertilizers may directly or indirectly determined the amount of methane emission through three processes: CH_4 production, oxidation, and transport from the soil to atmosphere that demonstrated by numerous previous studies (Cai *et al*., 2007., Banger *et al*., 2012 and Dong *et al*., 2011).

The positive effects of Ammonium-based fertilizer on methane emission were debated among research which is mainly attributed to inverse relationship between NH_4^+ availability in the rice rhisosphere with methane emission where CH_4 and NH_4^+ are similar in size and structure and as a result, CH_4 monooxygenase (the enzyme that oxidizes CH_4) bend and reacts with NH_4^+ instead of CH_4 so NH_4^+ prevents methane consumption. Chowdhury and Dick (2013). However, Palmer and Reeve (1993). reported that methanogens obtain a nitrogen source from NH_4^+. Furthermore, NH_4^+ specially increasing both root growth that provide larger arenchyma acts as a channel for methane transport from rhisosphere to air space, and release of root exudates Linquist *et al.* (2012) that enhancing methanogenic activity and increase CH_4 emission from soil .

Concerning the negative effect, NH_4^+ ions stimulate activity of oxidizing bacteria (methanotrophs) leading to a reduction in emission as reported by Bodelier and Laanbroek (2004) .Also Yao et al. (2012). found that treatment with urea stimulates rice biomass could lead to higher combination between NH_4^+ avability and O_2 input by roots to soil enhanced methane oxidation.

Our objective was to determine at the field level the net effect of nitrogen fertilizer on methane emission. In the present study which included urea and ammonium sulfate application it is shown that ammonium sulfate reduce CH_4 emission about 50-55 % as compared by urea. Likewise this in contrast to studies supported by other worker as Kimura confirmed the advantage of $(NH_4)SO_4$ in reducing CH_4 emission followed by ammonium chloride then urea. As well as Liou et al. (2003) observed the effect of ammonium sulfate on inhabitation methane emission as compered by potassium nitrate especially at the first crop season under title methane emission from fields with differences in nitrogen fertilizers and rice varieties in Taiwan paddy soils.

Also Lindau (1994) used several forms of N fertilizer (urea, $(NH_4)_2SO_4$, KNO_3) to study the effect of them on CH_4 emission at different loads (0, 60 and 120 Kg N ha^{-1}). Results showed that urea application stimulate the highest CH_4 emission, followed by KNO_3 and then $(NH_4)_2SO_4$ in the low N rate. Cai *et al*. (1997) found that $(NH_4)_2SO_4$ reduced CH_4 emission by (50-60%) as compared to urea indicating that the form of nitrogen fertilizer strongly effects methane emission.

Hence the real reason for lower CH_4 emission with ammonium sulfate in the present study is most likely due to addition of sulfate indicating that the type of nitrogen fertilizer affect CH_4 emission. That in contrast with Pennock *et al*. (2010) who found that annual CH_4 emission from a freshwater wetland declined when the concentration of SO_4^{-2} in the water increased, Segers (1998) summarized that the sulfate can reduced overall CH_4 emission by both suppressing methanogensis to anaerobic CH_4 oxidation.

Previous studies have shown that treatment rice field with sulfate fertilizers inhibited methane emission from rice fields (Gon *et al.,* 2001).

Methane is the end product of a serious reduction process and sulfate are known as a strong competent with methanogens for H_2 as a result inhibiting methane production when added to methanogenic rice fields Kluber and conrad. (1998). That matching with Sahrawat. (2004) who found that the activity of methanogens need a large availability from free electron which in turn increased the methane emission.

Three possible mechanisms for how sulfate (and other electron acceptors) could suppress methanogensis were proposed. First, the reduction of electron acceptors serves as an alternative to CO_2 and leads to oxidation of organic matter thus could reduce substrate concentrations to a value that is too low for methanogenesis (Banger2012). Second, the presence of electron acceptors could result in a redox potential that is too high for methanogenesis. Third, the product of sulfate reduction (electron acceptors) could be toxic for methanogenic bacteria (Minami and Neue 1994).

Also in the present study results showed that urea specifically enhances yield and growth parameter (Table 4). However that's may be another reason for a significant increase in CH_4 emission from urea applied plots.

From the previous results, it was concluded that the treatment (planting rice with ammonium sulfate) could probably a suitable strategy for methane mitigation for rice crop in Egypt.

Table 4: The effect of fertilizer on growth characters and yield component for the two varieties at ripening.

Production Parameters	Urea (Mean±SD)	Ammonium sulphate(Mean±SD)
Plant height (cm)	99.36±3.19[a]	95.41±0.75[b]
No. of tiller	26.80±1.18[Ns]	25.83±1.06[Ns]
No. of panicle	24.95±1.79[a]	22.75±1.15[b]
Panicle length (cm)	23.91±0.71[a]	21.23±0.95[b]
Panicle weight (g)	3.53±0.16[a]	2.93±0.38[b]
Dry root (g)	7.35±0.47[a]	5.82±0.22[b]
1000 Grain weight (g)	27.45±0.86[Ns]	26.87±0.83[Ns]
Root length (cm)	26.98±0.92[a]	24.63±0.57[b]
Straw yield (t/f)	5.10±0.12[a]	4.24±0.21[b]
Grain yield (t/f)	4.17±0.16[Ns]	4.08±0.09[Ns]

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2 The relation between type of fertilizer and growth characters: It was found that urea amendments significantly stimulate some of the measured rice plant and yield components in both varieties (Table 3). The yield components such as number of panicle, panicle length, Panicle weight, 1000grain weight and straw yield were increased significantly ($p<0.05$) by urea amendments(Table 4). The same results supported by Singh *et al*, (1999) who found that application of urea stimulate the growth and yield of rice.

Plant height and root growth parameters such as dry root and root length were significantly ($p<0.05$) increased by urea amendments which were positively correlated with total seasonal methane emission (Table 2) That represents one of the causes of rising methane emissions from plots treated with urea.

It is worth to be mentioned that Singh *et al.* (1999) found the response of different varieties to fertilization is varied indicating the differential resource employment prospect of the varieties when they studied methane emission and response of the three rice varieties to urea fertilization in India.

CONCOLUTION

CH_4 emission from excessive planting rice in paddy fields can significantly contribute to global warming. The effects of N-fertilizer and rice variety on methane emission were determined by static chamber method once every growth stages during the overall growing period as a way of the more feasible ways of limiting methane emission. Results indicated that combination of $(NH_4)_2SO_4$ application and $sakha_{106}$ rice plantation is recommended for the benefit of both the environment (methane mitigation strategy) and the food security in Egypt paddy soil.

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تخفيف انبعاث الميثان من حقول الأرز باستخدام أنواع مختلفة من السماد النتروجينى وأصناف الارز

[٥]

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المستخلص

تم إجراء تجربة حقلية لدراسة تأثير انواع من الاسمدة النيتروجين واصناف من الأرز على انبعاث الميثان من حقول الأرز. تم تصميم التجربة باستخدام نوعين من الأسمدة النيتروجينية، (كبريتات الأمونيوم واليوريا). واستخدام صنفين من الأرز (الجيزة ١٧٧ و سخا ١٠٦) بنظام القطع التجريبية. وقد تم قياس فيض غاز الميثان فى ثلاث مكرارات لكل معامله. وقد تم قياس فيض الميثان في مراحل النمو المختلفة لصنفي الأرز المعامل بكبريتات الأمونيوم وسماد اليوريا. كان هناك فرق معنوى في انبعاث غاز الميثان بسبب زراعة الأرز سخا ١٠٦ وعلى سبيل المقارنة لصنفي الأرز، وعلاوة على ذلك، هناك خفض معنوى فى انبعاث الميثان من معاملات كبريتات الامونيوم بنسبة ٥٠ الى ٥٥٪ مقارنة مع معاملات اليوريا، وأشارت النتائج أيضا أن الجمع بين زراعة الصنف سخا ١٠٦ مع تطبيق سلفات الامونيوم هى افضل المعاملات. وخلص البحث إلى أن انبعاثات CH_4 تتوقف على نوع السماد النتروجينى وصنف الأرز المستخدم فى التربة المصرية.