KKU Res. J. 2012; 17(2):211-216
http : resjournal.kku.ac.th

Effects of Sulfate Fertilizer on Rice Yield cv. Sakon Nakhon and Global Warming Potential

*Jamnong Tragoolram and Patcharee Saenjan**

Land Resources and Environment Section, Department of Plant Science and Agricultural Resources, Faculty of Agriculture, Khon Kaen University
**Correspondent author: patsae1@kku.ac.th*

Received January 27,2012
Accepted March 20,2012

Abstract

Ammonium phosphate sulfate fertilizer (16-20-0, 42% SO_4) is widely used by the Thai rice farmers. Sulfate's inhibition of methanogenesis in flooded paddy soil has been reported by many scientists in previous years. This study aimed to investigate the effect of different rates of sulfate (SO_4) on rice yield, seasonal methane emission (SME) and global warming potential (GWP). The experiment was conducted in a farmer's rice field in Khon Kaen, Northeast Thailand, during the dry season of 2011. Ammonium phosphate sulfate fertilizer was used as the main source of sulfate at the rates of 0, 100, 200, and 300 kg SO_4 ha^{-1}. All plots with SO_4 were adjusted to have the same amount of N, P_2O_5 and K_2O. The control plot had neither SO_4 nor fertilizers. The experiment was laid out in randomized complete block design (RCBD) with four treatments and three replications. Methane emissions were measured in one week intervals during the growing season, and calculated as SME and GWP. Rice yields were also measured. The results showed that the application of fertilizer containing SO_4 gave higher yields with a range of 7.7 – 8.4 t ha^{-1}; four times that of the control with no fertilizer. The application of sulfate had no distinguishable effect on SME and GWP reduction in silty-clay rice soil.

Keywords: sulfate, rice yield, methane, GWP.

1. Introduction

Thailand is a major rice growing country and ranks as one of the top six rice producers (19 million tons $year^{-1}$) and the top one rice exporter in the world (1). However, paddy fields are a major source of methane (CH_4) emission; and CH_4 is known to be one of the greenhouse gases causing global warming. Liou et al. (2) reported that irrigated rice fields emit methane in the range of 25.4 to 54 million tons $year^{-1}$ from the total 410 to 660 million tons $year^{-1}$ globally.

Sulfate can reduce methane emissions due to the competition of methanogens and sulfate-reducing bacteria to use hydrogen and organic substrates (3, 4). In addition, sulfate plays an important role in amino acids and protein synthesis; and is an essential nutrient =for rice growth and productivity. In previous research, ammonium phosphate sulfate (42% SO_4) fertilizer was applied to investigate the effect of sulfate on methane emissions from paddy fields and rice production with Chainat 1 rice variety (5). Similarly, the difference in type and rate of sulfur compounds were used for mitigation of methane emission from Suphanburi 1 rice variety in a potted experiment (6). However, information on the effect of sulfate on Sakon Nakhon rice variety growing in the flooded and irrigated dry season production system is lacking. The objectives of this experiment aimed to study the effect of sulfate on the rice yield of Sakol Nakhon rice variety and the influence of sulfate on seasonal methane emission (SME) and global warming potential (GWP).

2. Materials and Methods

This experiment was conducted in irrigated paddy fields in Ban Nong Kha, Non Thon sub-district, Muang district, Khon Kaen province of Thailand, from January to May 2011 during the dry season. The soil was classified as Si Song Khram (Ss) soil series (7). Soil samples were taken from the paddy field at the depth of 0-15 cm before starting the experiment and analyzed to determine soil texture, bulk density, pH, electrical conductivity (EC), total nitrogen, organic carbon, ammonium ion (NH_4^+), available P, Exchangeable Ca, K and Mg, Sulfate (SO_4^{2-}) and cation-exchange capacity (CEC) (Table 1).

The experiment was laid out in randomized completely block design (RCBD) with four treatments and three replications. Ammonium phosphate sulfate (16-20-0, 42% SO_4) fertilizer was applied as the source of sulfate fertilizer. The treatments used in this experiment are shown in Table 2. All treatments containing sulfate content were balanced to be N, P_2O_5 and K_2O at the rate of 123, 188 and 75 kg ha^{-1} respectively, by adding di-ammonium phosphate (18-46-0) fertilizer, urea (46% N), rock phosphate (3% P_2O_5), and potassium chloride (60% K_2O).

The rice field with its rice stubble (average 3282 t ha^{-1}) was plowed up and over in the paddy field two weeks prior to soil preparation. The plot size was 4 m×4 m. Tillaging and puddling were completed, and rice seeds (Sakon Nakhon variety) were broadcasted at the rate of 125 kg ha^{-1}. The fertilizers were applied two times: at the sowing date (January 22, 2011) and at 51 days after sowing (March 14, 2011).

Water level was kept at 5-10 cm throughout the growing season. Weeds, plant diseases, and insect pests were controlled. Rice yield was determined by defining 1 m^2 areas with two replications per plot. The plot was then manually harvested at 109 days after sowing. Grain weight was determined at 14% moisture content.

Methane emission was collected once a week by the chamber method (4). Methane concentration was analyzed using a gas chromatograph (Shimadzu

GC14B) equipped with a flame ionization detector (FID), then calculated to determine methane flux (data not shown), SME (kgCH_4 ha^{-1}season^{-1}) and GWP (kgCO_2-e ha^{-1}) using the GWP of methane 23 (8). Methane emission rate was calculated from the increase in CH_4 concentration with time using the volume of the gas chamber, corrected with the temperature inside the chamber, plant height and water level. The calculation of CH_4 emission rate is expressed in the following equation:

$$E = C \times Vh \times \frac{mW}{mV} \times \frac{273.2}{(273.2+T)} \times 60 \times 24$$

Where, E: CH_4 emission rate (mg CH_4 m^{-2} day^{-1})

C: Change in CH_4 concentration (ppm minute^{-1})

Vh: Height of head space (m)

mW: Molecular weight of CH_4 (16.04 g mol^{-1})

mV: Molecular volume of CH_4 (22.41 liter at standard temperature and pressure)

T: Temperature inside the chamber (^{0}C)

The calculation of seasonal CH_4 emission (SME) was based on the equation as following:

$$SME = \sum_{1-i}^{n}(R_i \times D_i) \times 10^{-2}$$

Where, SME: in kg CH_4 ha^{-1} season^{-1}

R_i: the rate of CH_4 emission (mg m^{-2} day^{-1}) in i^{th} sampling interval

D_i: the number of days in the i^{th} sampling interval

n: the number of sampling intervals in growing season.

Global Warming Potential (GWP) has been always calculated by converting from CH_4 to CO_2 equivalent over a specific time perspective. Supposing our GWP is based on 100-yr global warming potential (IPCC, 2001) and the warming forces of CH_4 is 23 times higher than CO_2 per unit of weight, the GWP CO_2 equivalent can be obtained by following equation:

$$GWP\ CO_2\ \text{equivalent}: SME \times 23 \times \frac{12}{44}$$

The data was statistically analyzed using ANOVA and Least Significant Difference (LSD) for mean comparison, by using the Statistix 8 program (version 8.0).

3. Results and Discussion

3.1 Rice yield

Rice yield was affected by various rates of sulfate fertilizer (Table 3). The addition of sulfate gave significantly higher yields (7.7 to 8.4 t ha^{-1}) when compared to treatment without sulfate fertilizer (1.9 t ha^{-1}) ($p \leq 0.01$), resulting in a four-fold increase in the rice yield. Rice production obtained from plots with sulfate in this experiment gave an increase two-fold higher than the average rice yield (2.9 t ha^{-1}) of the same variety (9). This was believed to have been caused by the different kinds and rates of fertilizers.

The Rice Department of Thailand reported that the Sakon Nakhon variety gave the average rice yield (2.9 t ha^{-1}) by using the following recommendation: Ammonium phosphate sulfate (16-20-0, 42% SO_4) fertilizer of 188 kg ha^{-1} with potassium chloride (60% K_2O) of 31-63 kg ha^{-1} for basal application, and urea (46% N) of 125 kg ha^{-1} or ammonium sulfate (21-0-0, 72% SO_4) of 250 kg ha^{-1} at 30 days before the flowering stage of rice growth for top dressing (10). It can be seen that the recommended application contains total sulfate of (79+180 = 259 kg ha^{-1}). Accordingly, it is thought that this high dose of sulfate should have provided a higher rice yield than the mentioned average 2.9 t ha^{-1}. The low average was probably due to an insufficient level of sulfate in the soil. It also may be that in general, farmers preferred the use of urea to ammonium sulfate.

3.2 Methane emissions and global warming potential.

Seasonal methane emission (SME) and global warming potential (GWP) are shown in Table 3. SME from soil with the application of sulfate fertilizer treatments was observed in a range of 84.8 to 119.9 kg CH_4 ha^{-1}. Similarly, GWP was observed in a range of 1950.4 to 2756.6 kg CO_2-e ha^{-1}. However, there were no significant differences for SME and GWP among the rates of sulfate. It might be explained, that the fine-textured (silty-clay) soil had a low quantity of remaining rice stubble; which was incorporated and had decomposed two weeks prior to soil preparation. In addition the original soil organic carbon was low, 1% (Table 1). The soil, therefore, emitted small amounts of methane. Consequently, fine-textured paddy soil in this experiment had not responded to the effect of sulfate rates on SME.

Saenjan et. al. (5) had previously reported that high sulfate rates of 210 kg ha^{-1} significantly decreased seasonal methane emissions in medium-textured (loamy) soil by 66.68%. In this soil the original organic carbon content was 0.87% and sulfate was 6.4 ppm. Accordingly, higher organic carbon and lower sulfate in loamy soil compared to clay soil (Table 1), therefore results in loamy soil showed not only a higher methane flux, but also an obvious response of the sulfate effect on methane reduction. More methane emissions were found from soil with no addition of sulfur than that of soil with the addition of sulfur (6).

4. Conclusion

Application of sulfate (ammonium phosphate sulfate as 16-20-0, 42% SO_4 fertilizer) in silty-clay rice soil resulted in a four-fold increase in rice yield when compared to that with no fertilizer. However, there were no effects of applied sulfate on seasonal methane emissions and global warming potential in this study. Similar on farm trials on effect of sulfate with different soil types of various organic carbon contents and soil characteristics should be trialed to obtain more insightful observation on methane emissions and rice production in paddy fields of Northeast Thailand.

5. Acknowledgement

We are grateful to Program: World Class Research University, KKU and Office of Higher Education Commission for financial aid to the project Cluster: Holistic Watershed Management.

6. References

(1) East Asia watch. Summary of the lecture on Rice Export Market: Opportunity and Threats of Thailand [Internet]. 2011 [update 2010 June 15; cited 2011 November 28]. Available from: http://www. eastasiawatch.in.th/article.php?section=6&id=207. Thai.

(2) Liou RM, Huang SN and Lin CW. Methane emission from fields with differences in nitrogen fertilizers and rice varieties in Taiwan paddy soils. Chemosphere. 2003;(50): 237-246

(3) Mukherjee R, Barua A, Sarkar U, De BK, Mandal AK. Role of Alternative Electron Acceptors (AEA) to control methane flux from waterlogged paddy fields: Case studies in the southern part of West Bengal, India. International Journal of Greenhouse Gas Control. 2009;3(5): 664-72.

(4) Minamikawa K, Sakai N, and Hayashi H. The effects of ammonium sulfate application on methane emission and soil carbon content of a paddy field in Japan. Agriculture, Ecosystem and Environment. 2005;(107): 371-379.

(5) Saenjan P, Ro S, Lawongsa P and Tulaphitak, D. Effect of sulfate containing fertilizer on methane emission from rice soil and global warming potential. Procedding of The Second National Soil and Fertilizer Conference; 2011 May 11-13; Maejo University, Chaing Mai, Thailand; 2011. P 135-143. Thai.

(6) Jankaewrae R. Impact study of sulfur on growth and methane emission of rice (Oryza sativa) cv. Supanburi 1. [MSc Thesis]. King Mongkut's University of Technology Thonburi, Bangkok, Thailand; 2001. Thai.

(7) Land development department. Soil series map (scale 1:50000): Khon Kaen province. Office of Soil Survey and Research, Land Development Department, Bangkok, Thailand; 2000. Thai.

(8) IPCC. Climate Change 2001: In the Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Eds JT Houghton, Y Ding, DJ Griggs et al. Cambridge University Press, Cambridge; 2001. p. 239-288.

(9) Rice Department of Thailand. Rice Knowledge Bank: Sakol Nakhon variety. 2010 [cited November 26, 2010]. Available from http://www.brrd.in.th/rkb/data_002/a2/rice_xx2-03_ricebreed_Sakon_ Nakhon.html. Thai.

(10) Rice Department of Thailand. Rice Knowledge Bank: cultivation and fertilization management in irrigated sowing rice field. 2011 [cited December 11, 2011] Available from http://www.brrd.in.th/rkb/data_004/ rice_xx2-04_manage_001-6.html. Thai.

Table 1. Soil physical and chemical properties before experiment.

Parameters	Value	Method
Soil Texture	Silty Clay	Hydrometer
Sand (%)	6.00	
Silt (%)	46.95	
Clay (%)	47.05	
Bulk density (g/cm3)	1.40	
pH (1:1)	5.14	pH meter
EC (1:5, dS m-1)	0.04	EC meter
Total Nitrogen (g/kg)	0.83	Kjeldahl method
Organic carbon (g/kg)	10.08	Walkley and Black
NH_4^+ (mg/kg)	15.40	KCl extraction and distillation method
Available P (mg/kg)	3.27	Bray II extraction and Murphy and Riley method
Exchangeable Ca (mg/kg)	1239	NH_4OAc extraction and Atomic Absorption Spectrophotometer and Flame photometry
Exchangeable K (mg/kg)	80	
Exchangeable Mg (mg/kg)	203	
SO_4^{2-} (mg/kg)	46	KH_2PO_4 extraction and turbidimetric method
Cation Exchange Capacity (cmol kg^{-1})	14	NH_4OAc extraction and distillation method

Table 2. Treatments and rates of sulfate used in this experiment.

Treatment (kg SO_4 ha^{-1})	Rates of sulfate application (kg SO_4 ha^{-1})		Ammonium phosphate sulfate fertilizer[1/] (kg ha^{-1})
	First time[2/]	Second time[3/]	
1) Control	0	0	0
2) 100	25	75	238
3) 200	50	150	476
4) 300	75	225	714

[1/] Ammonium phosphate sulfate (16-20-0, 42% SO_4) fertilizer was applied as a source of sulfate fertilizer, [2/] All treatments with added sulfate were adjusted to have N, P_2O_5 and K_2O as 38, 81 and 38 kg ha^{-1} with Di-ammonium phosphate (18-46-0), Rock phosphate (3% P_2O_5) and Potassium chloride (60% K_2O), [3/] All treatments with added sulfate were adjusted to have N, P_2O_5 and K_2O as 85, 107 *and* 37 *kg ha^{-1} with Urea (46-0-0), Rock phosphate (3% P_2O_5) and Potassium chloride (60% K_2O) Finally all treatments with sulfate received N, P205 and $k_2$0 as 123, and 75 kg ha^{-1}*

Table 3. Rice yield, seasonal methane emission (SME), and global warming potential (GWP).

SO_4[1/] (kg ha^{-1})	Rice yield (t ha^{-1})		SME (kgCH_4 ha^{-1})		GWP[4/] (kg CO_2-e ha^{-1})	
	Aver.[2/]	SE[3/]	Aver.	SE	Aver.	SE
0	1.9 b[5/]	0.1	100.6	23.7	2313.5	544.6
100	8.3 a	0.3	119.9	21.6	2756.5	496.5
200	8.4 a	1.1	100.6	14.9	2313.1	342.7
300	7.7 a	1.0	84.8	12.5	1950.4	288.4
F-test	**		ns		ns	
CV (%)	20		32		32	

[1/] Ammonium phosphate sulfate fertilizer (16-20-0, 42% SO_4) was used, [2/] Average (n=3), [3/] Standard error (SE), [4/] GWP of methane is 23 (IPCC, 2001), [5/] the same letters are not significantly different at 5% as determined by Least Significance Difference (LSD), ** significantly different at $p \leq 0.01$, ns: not significant.