Sulfate fertilizer influencing methane emissions in paddy field and rice (cv. Chainat1) production

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ASBTRACT: Methane (CH_4) is one of the most important greenhouse gases having a significant impact upon global warming. Today, paddy fields are a major source of methane production. The objective of our experiment is to investigate whether sulfate fertilizer can reduce the amount of methane emissions from the paddy field into the atmosphere, while maintain or increase fertility of the paddy soil, and the rice production of Chainat1. The experimental plan was structured using the Randomized Complete Block Design (RCBD), consisting of four treatments: 1) Incorporation of rice stubble without the usage of sulfate fertilizer, 2) Incorporation of rice stubble using sulfate fertilizer, 18 kg SO_4/rai, 3) Incorporation of rice stubble using sulfate fertilizer, 32 kg SO_4/rai, and 4) Incorporation of rice stubble using sulfate fertilizer, 48 kg SO_4/rai. Sulfate was used in the form of fertilizer 16-20-0 (42% SO_4). Results showed that there was no significant effect of sulfate on the physical and chemical properties of soil after harvest. The sulfate, at the rates of 18, 32 and 48 kg SO_4/rai, insignificantly reduced the amount of methane emissions and released 19.3, 14.2, and 11.6 kg CH_4/rai. Moreover, sulfate also reduced the quantity of Global Warming Potential (GWP) in decreasing order of 443.9, 326.6, 266.8 kg/rai, respectively; though comparatively insignificant. Additionally, the application of sulfate fertilizer increased rice production two-and-a-half times (1001 to 1094 kg/rai) that of the control without sulfate fertilizer (476 kg/rai). We have concluded that the application of sulfate fertilizer boosts rice yield, but could not mitigate methane emission or GWP in fine textured paddy soil.
Keywords: methane, paddy field, ammonium phosphate, rice production

Introduction

Methane (CH_4) is currently ranked as the second most important greenhouse gas. Rice paddy soil acts as one of the main sources of atmospheric CH_4. One of the greatest sources of atmospheric methane is irrigated rice cultivation, which accounts for around 15-25% of total methane emissions per year (Sass and Fisher Jr., 1997). Almost half of the world population depends on rice as a staple food, leading to the advancement of rice growing activities worldwide. Consequently, the emission of methane shares in this advancement (Rath et al., 2002). One way to mitigate global warming is to decrease methane (CH_4) emissions from paddy fields (Minamikawa et al., 2004).

Thailand, a rice producing country, is the top rice exporter in the world. There are currently 14.72 million hectares of irrigated land in Thailand. In Central Thailand, the area of irrigated rice cultivation is 6.8 million hectares, 3.8 million hectares in Northern Thailand; and in the Northeast, 3.32 million hectares of irrigated rice (Office of Agricultural Economics, 2006). The rice field is a well known as a source of atmospheric methane emissions. Added organic materials in rice soil, as well as the incorporation of the remaining rice stubble in soil before planting rice, is well recognized to enhance soil productivity. However, it is claimed to elevate methane production and emissions. Chemical fertilizer with electron acceptors, like sulfate, was reported to suppress methane formation in soil. Sulfate

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is an essential nutrient for rice growth and rice yield production. However, information on this viewpoint within the conditions of Thai rice fields is currently limited.

The aims of this experiment were to study the effects of ammonium phosphate, containing 42% sulfate, on rice production of Chainat1; and methane emissions from paddy fields and soil properties.

Materials and Methods

Experimental site

Field experiments were conducted in a famer's irrigated paddy field at Ban Nong Kha, Tambol Non Thon, Muang district, Khon Kaen province; during the dry season from January to May, 2011. The soil was classified as Sri-Songkhra soil series (Land development department, 2000).

Experimental design, fertilizer and rice cultivation

The plots were laid out in randomized complete block design (RCBD) with four treatments and three replications. The sulfate component for fertilization used in this experiment was ammonium phosphate, containing 42% sulfate. The four treatments were as follows: 1) incorporation of rice stubble without the use of fertilizer, 2) incorporation of rice stubble using sulfate fertilizer, 18 kg SO_4/rai, 3) incorporation of rice stubble using sulfate fertilizer, 32 kg SO_4/rai and 4) incorporation of rice stubble using sulfate fertilizer, 48 kg SO_4/rai. All treatments were adjusted to have equal amount of N, P_2O_5 and K_2O by using various fertilizers, the amount and kind of fertilizer were shown in **Table 1**. The entire experiment consisted of 12 plots.

The rice stubble in the rice field was burned unevenly by the farmer. The remaining rice stubble was measured, yielding 525 kg dried weight /rai. Before experimentation, rice stubble was ploughed up in the soil for two weeks prior to soil preparation. The plot size of 4 x 4 m, totaling 12 plots, was set up by making soil ridges. They were then manually harrowed and puddled to smooth the soil. Germinated rice seeds, Chainat1 variety, were broadcasted at a rate of 20 kg/rai. The field was flooded to a height of around 7-10 cm throughout the growing season.

Soil samples were collected before the experiment on 22 December, 2010 and after the harvest on 11 May, 2011; to analyze the chemical and physical properties of soil as shown in **Table 2**.

Sampling of methane

Methane gas was sampled by using the close chamber method. Methane concentration samples were analyzed once a week by using GC (Saenjan, 2004). Calculations of the rate of methane emission (data not shown) and total methane emission (kg CH_4/rai) during the entire growing season were performed.

Sampling of rice production

Rice harvest at 108 days after sowing was done by hand in a 1 m^2 quadrant on May 10, 2011. The rice was air dried, the moisture content was determined, and grain weight was calculated at a rate of 14 % moisture.

Statistical analysis

The significant differences between treatments were assessed using ANOVA and Least Significant Difference (LSD) for mean comparison. Computations were carried out using the Statistics 8 program (version 8.0).

Results and Discussion

Chemical properties of soil before the experiment and after the rice harvest

In **Table 2**, it was found that the chemical properties of soil; such as pH, organic matter (OM), cation exchange capacity (CEC), available phosphorus (avai. P), exchangeable potassium, calcium and magnesium (exch. K, Ca and Mg), total nitrogen content (TN), ammonium (NH_4^+) and particulate organic residue (POR, smaller than 2 mm); both before the experiment and after rice harvest, were not significantly different among the varied rates of sulfate 0, 18, 32, and 48 kg/rai. The use of this fertilizer had not affected the chemical and physical properties of the soil in one growing season. The applied fertilizers were mostly expended by rice plants during the growth period.

Table 1 Quantity of each fertilizer used in this experiment

Treatment	Fertilizers					Soil
SO_4 (kg/rai)	16-20-0 (42%SO_4) (kg/rai)	*DAP (18-46-0) (kg/rai)	**Urea (46%N) (kg/rai)	***RP (3% P_2O_5) (kg/rai)	KCL (60% K_2O) (kg/rai)	N, P_2O_5, K_2O (kg/rai)
0	0	0	0	0	0	0
18	38.90	24	20.22	380.95	20	20, 30,12
32	76.18	16	10.11	249.14	20	20, 30, 12
48	114.27	8	0	117.33	20	20, 30, 12

* DAP (18-46-0) is for adjusting N content in soil but this fertilizer makes increase in P_2O_5.

** Urea (46%N) is for adjusting N content in soil. *** RP(3% P_2O_5) is for adjusting P_2O_5.

Table 2 Chemical and physical properties of the soil before the experiment and after the rice harvest, of Chainat1

SO_4^{2-} (kg/rai)	Chemical properties																		Physical	
	pH		OM (%)		CEC (cmol/kg)		avai. P (ppm)		K (ppm)		Ca (ppm)		Mg (ppm)		TN (%)		NH_4 (ppm)		POR[1] (kg/rai)	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
0	5.8	5.4	1.51	1.19	12	12	8	5	102	60	1115	1027	168	154	0.05	0.07	8.8	5.6	3.5	22.4
18	5.9	5.5	1.40	1.35	11	12	10	9	101	57	1086	1000	163	151	0.05	0.07	10.0	5.6	3.2	13.5
32	5.7	5.5	1.61	1.58	12	11	12	7	98	71	1052	1118	161	160	0.04	0.06	8.7	5.4	1.9	16.4
48	5.6	5.4	1.60	1.55	12	12	10	10	101	66	1055	1018	158	154	0.06	0.05	9.3	5.0	1.7	10.9
F-test	NS		NS		NS		NS		NS		NS		NS		NS		NS		NS	
CV (%)	3		16		11		20		17		11		8		35		20		72	

[1] Particulate organic residue (POR) in soil which remained on the sieve hole of 2 mm. NS stands for no significant difference at 99 %. B means before, A means after.

Table 3 Total methane emissions (TME) during the growing season and global warming potential (GWP, CO_2-e) in rice plots grown with Chainat1 rice variety

SO_4^{2-} (kg /rai)	Grain yields (kg/rai)[1]	TME (kgCH_4/rai)	GWP CO_2-e (kg/rai)[2]
0	476 b	15.8	363.4
18	1,094 a	19.3	443.9
32	1,053 a	14.2	326.6
48	1,001 a	11.6	266.8
F-test	**	NS	
CV (%)	7.52	28.59	

The average of the data (n = 3) with the same letter in the same column are not significantly different at 99 % by Least Significant Different (LSD). [1]Rice yields at 14% moisture content. [2]GWP: global warming potential (CO_2 : CH_4 = 1 : 23)(IPCC, 2001)

Methane emissions and productivity of rice Chainat1

Table 3 shows that the control soil without fertilizer produced a rice yield of 476 kg/rai. Using fertilizer (16-20-0, 42% sulfate) at the sulfate rates of 18, 32 and 48 kg/rai, significantly boosted rice production to a range of 1001-1094 kg/rai (though they were not significantly different in sulfate rates.)

Accordingly, the addition of a low rate of sulfate can yield a high increase in rice production. The amounts of total methane emission (TME) in this experiment were quite low, 11.6-19.3 kg CH_4/ rai. This could be due to low amount of remaining rice stubble prior rice cultivation. No significant differences of TME were found among the rates of sulfate. The addition of sulfate fertilizer in this experiment did not affect methane emission reduction during the rice growing season, as well as global warming potential (GWP).

The high production of Chainat1 (740 kg/ rai) was reported by the Rice Department of Thailand (RD) (August 26, 2011). In this experiment, rice production obtained from the addition of sulfate fertilizer produced a higher yield of production. This further illustrates the efficiency of sulfate fertilizer on the direct growth and yield of rice. Moreover, further study on remaining sulfate in soil should be performed to better understand the sulfate status in soil.

Conclusions

Rice yield was significantly increased by the application of sulfate fertilizer, whereas total methane emission and global warming potential were not affected by the usage of this fertilizer. This was due to the low quantity of methane emissions occurring in heavy textured soil, with a small amount of incorporated rice stubble, causing no response to the effect of sulfate fertilizer on methane mitigation.

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