13th ESAFS 2017 Thailand

13th International Conference of
The East and Southeast Asia Federation
Of Soil Sciences (13th ESAFS)

"Soil Quality for Food Security and Healthy Life"

E-proceedings

12-15 December 2017

Nong Nooch Tropical Garden, Pattaya, Thailand

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CONTENTS

PREFACE

Soil quality is directly related to the capability of a soil to produce safe and nutritious crops in a sustained manner over the long-term, without impairing the natural resource base or harming the environment. Therefore, soil quality has important effects on the nutritional quality of the food produced in those soils. It is recommended that we should protect the soil's capacity to serve several functions simultaneously including the production of food, fiber and fuel; nutrient and carbon storage; water filtration, purification, and storage; waste storage and degradation; and the maintenance of ecosystem stability and resiliency.

Good soil quality is required for food security and healthy life of world population. The attempt to obtain significant crop yield increase, however, had a price in terms of the environmental degradation. Therefore, ESAFS 2017 Conference intensively aims to provide the advanced scientific information on the researches in soil quality and capacity for crop production. The conference provides the better understanding of the attributes of soil quality and the way of improving soil and associated environmental quality for sustainable food security and healthy life of East, Southeast Asia as well as world population.

The 13th ESAFS 2017 Conference also provide a variety of opportunities to exchange ideas and expertise as well as network among East, Southeast Asia and worldwide research groups. This conference is hosted by Soil and Fertilizer Society of Thailand, Soil and Water Conservation Society of Thailand and Department of Land Development, Thailand. It aims to provide the high qualified scientific information and emphasized the multidisciplinary collaboration to promote the development of “Soil Quality for Food Security and Healthy Life”. This conference also provides both scientific value and implementation strategies on soil quality management, which consists in two days of presentations with ample time for discussion. Oral presentations and posters are focus on soil quality research and its practical applications. There is also a field trip (covering medicinal herbs botanical garden and soil morphology).

The Organizing Committee would like to thank a number of people who helped us to achieve our aims and we would like to thank all of them: the all committees, the private sector sponsors and the abstract reviewers. We also would like to give special thanks to the president of the Fertilizer and Agricultural Supplied Association and the president of Thai Fertilizer Producer Trade Association on their tireless assistance and support this conference.

Pitayakon Limtong

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Mitigating of Greenhouse Gases Emission through Application of Soil Amendment in Flooded Rice Field

Rina Kartikawati[1]*, Miranti Ariani[1], Anicetus Wihardjaka[1], Dedi Nursyamsi[2] and Prihasto Setyanto[3]

[1]Indonesia Agriculture Environment Research Institute
Jalan raya Jakenan-Jaken km 05 Jaken, Pati, Central Java
Telp (+62 295) 4749044
[2]Indonesian Center for Agricultural Land Resources Research and Development
Jalan Tentara Pelajar No. 12 Cimanggu, Bogor, West Java
Telp (+62 251 8323012)
[3]Directorate General of Horticulture
Jl. AUP No. 3 Pasar Minggu, Jakarta Selatan
Telp (+62 21) 78832048
**corresponding author: rinak_iaeri@yahoo.com*

Abstract

Flooded conditions in rice cultivation are involved in methane transport and production. Those conditions are indicated by oxygen limitation because of high soil moisture and organic substrate level which provide ideal environment to activity of methanogenic bacteria. Rice cultivation was not only as contributor of methane emission but also N_2O emission which related to application of nitrogen fertilizer. Therefore, reducing GHGs emission from rice field should be conducted. Management practises on rice cultivation such as soil amendments were expected could reduce GHGs emission. Objective of the study was to investigate the effect of soil amendment on reducing GHGs emission from flooded rice field. The study was conducted at Research Station of Indonesia Agriculture Environment Research Institute located in sub district of Sidomukti, district of Pati, Central Java province. Six treatments were used for this study including control or without fertilizer (P1), urea prill 250 kg ha^{-1} (P2), urea + natural nitrification inhibitor (NI) (50 kg ha^{-1}) (P3), urea + activated charcoal (50 kg ha^{-1}) (P4), compound fertilizer (1200 kg ha^{-1}) (P5) and urea + chitosan (10 kg ha^{-1}) (P6). Rice variety of Inpari 13 was cultivated using transplanting system on 21 days old seedling with 20 cm x 20 cm plant spacing. Water level was maintained on 5 cm above soil layer during plant growth and dried on 10 days before harvest time. Flux of GHGs (CO_2, CH_4 and N_2O) were measured manually using close chamber method. Methane gas was captured using 50 cm x 50 cm x 103 cm closed chamber covered rice plant, taken using 10 ml plastic syringe with 3 minute time interval after closing the chamber during 18 minute and analyzed using *Gas Chromatography* (GC) equipped by Flame Ionization Detector (FID). Whereas CO_2 and N_2O gases were captured using 40 cm x 20 cm x 20 cm closed chamber with 10 minute time interval after closing the chamber during 40 minute closing. Closed chamber for capture CO_2 and N_2O gases were installed covering soil. Measurement of GHG emission was conducted a weekly interval. The study showed that methane emission was significant different between application of Urea prill, Urea+NI and Urea+AC with Urea+Chitosan. But both of CO_2 and N_2O emission were not significant different. The highest GHGs emission was contributed by application of Urea prill (10.04 t CO_2e ha^{-1} $year^{-1}$) followed by Urea+Activated Charcoal (9.96 t CO_2e ha^{-1} $year^{-1}$). Application of Urea+Chitosan showed the lowest GHGs emission and could reduce around 31% and 12% of GHGs emission compared to application of Urea prill and control, respectively. The rice yield showed different significant between control and other treatments, and the highest was produced from application of Urea+NI (5.74 t ha^{-1} $season^{-1}$). The highest and lowest ratio of GHGs emission and grain yield were produced by control and application of Urea+Chitosan, respectively. According to the ratio, application of Urea+Chitosan could be used to mitigate GHGs emission from flooded rice field.

Keywords: mitigation, GHGs emission, soil amendment, flooded

Introduction

Flooded conditions in rice cultivation are involved in methane transport and production. Those conditions are indicated by oxygen limitation because of high soil moisture and organic substrate level which provide ideal environment to activity of methanogenic bacteria. Rice cultivation was not only as contributor of methane emission but also N_2O emission which related to application of nitrogen fertilizer. Therefore, reducing GHGs emission from rice field should be conducted. Management practises on rice cultivation such as soil amendments were expected could reduce GHGs emission

Fertilization and irrigation management are two important factor directly influence nitrification and denitrification process produced N_2O and NO. Difference of distribution and water suppy which was applied with irrigation system should result a better condition to denitrification process (Martin et al., 2010). A proper of N fertilizer use play important role to reduce soil nitrat residue and decrease N_2O emission (Snyder *et al*., 2009). Management of irrigation was essential to methane production due to anaerob condition, therefore water management will be an important effort to reduce methane emission from rice field.

Nitrification process produced nitrate, has occurred and required naturally by plant. However, when the nitrification process faster than nitrat absorption promote environmental pollution. Then nitrification which is followed by denitrification could produce N_2O gases and release to the atmosphere. Because of this process the efficiency of N fertilizer could be low (around 20-30%), conseqeuntly lead to air pollutian and N_2O emission. Nitrification inhibitor (NI) could prevent nitrogen losses and reduce N_2O and CH_4 emission from rice field. Previous research in IAERI (2011) showed that 100 % of NPK fertilizer combined with 120 kg/ha of NI from *Ageratum conizoides* (*Babadotan in Indonesia*) could reduce N_2O emission approximately 12-18%. Other natural materials could also be used to inhibit GHGs emission from rice field.

Chitosan is a natural biopolymer derived from deacetylation of chitin. Chitosan has been investigated for various applications such as for food preservation, medicine, cosmetic and agricultural industries due to its antimicrobial properties (Henry et al., 2015). Goiri et al (2009) showed that CH_4 production reduced when adding chitosan to batch culture and continuous fermentation. While charcoal or biochar significantly increased rice yield and decreased N_2O emission on rice paddy (Zhang et al., 2010). Biochar could be a strategy to increase carbon sequestration and yield of wheat (Vaccari et al., 2011).

By knowing the importance of fertilizer and soil amendment on GHGs emission from previous studies, we expected that the particular soil amendment could reduce GHGs emission. Therefore we conducted the research to investigate the effect of soil amendment on reducing GHGs emission from flooded rice field.

Materials and methods

Study was conducted in The Research Station of Indonesian Agricultural Environment Research Institute, located at Sidomukti, subdistrict of Jaken, district of Pati, Central Java Province. The location lies between 111^{o}10' E longitude and 6^{o}45' S latitute.

Six treatments were used for this study which consisted of Control (P1), urea 250 kg ha^{-1} (P2), urea 250 kg ha^{-1} + NI 50 kg ha^{-1} (P3), urea 250 kg ha^{-1} + activated charcoal 50 kg ha^{-1} (P4), NPK 1200 kg ha^{-1} (P5) and urea + chitosan 10 kg ha^{-1} (P6). Fertilizer and soil amendment were applied three times during growing season. All of treatment have received phospor and pottasium fertilizer, except on NPK treatment. Rice variety of Inpari 13 was cultivated using transplanting system on 21 days old seedling with 20 cm x 20 cm plant spacing. The water was maintained on 5 cm above soil layer during growing season and dried on 10 days before harvest time.

Measurement of greenhouse gas emission was conducted manually in each plot experiment every a week until harvest time or 10 times during growing season. Fluxes of greenhouse gas was calculated by equation :

$$\mathrm{E} = \frac{dc}{dt} x \frac{Vch}{Ach} x \frac{mW}{mV} x \frac{273.2}{(273.2 + T)} \qquad (1)$$

Where E is flux of either CH_4, CO_2 or N_2O (mg m^{-2} day^{-1}), dc/dt is difference of gases concentration per time (ppm minute^{-1}), Vch is volume of chamber (m^{-3}), Ach is large of chamber (m^{-2}), The size of chamber was 1 m x 1 m x 1.25 m mW is weight of gases molecule (g), mV is volume of gases molecule (22.41 l) and T is average of temperature during gases sampling (^{o}C).

Result

a. Methane flux

The methane flux gradually increased from 1 DAT and reached the peak on 48 DAT (Fig. 1). The average of methane flux for whole of growing season was 318 mg m^{-2} day^{-1}. While the average of methane flux for each treatments were 264, 372, 357, 361, 332 and 220 mg m^{-2} day^{-1} for P1, P2, P3, P4, P5 and P6, respectively. Application of fertilizer and soil amendment affected to methane flux particularly on the first and third application indicated by increase in methane flux after the application. Methane flux from all of treatment increased sharply on 48 DAT, except on Urea prill application. The effect of N fertilizer on those treatment was showed on 58 DAT. Urea + chitosan treatment was consistently produce lower methane flux during growing season compared to others. Harvest was conducted on 84 DAT or 105 days old of plant period and methane fux decreased during drying period before harvest time.

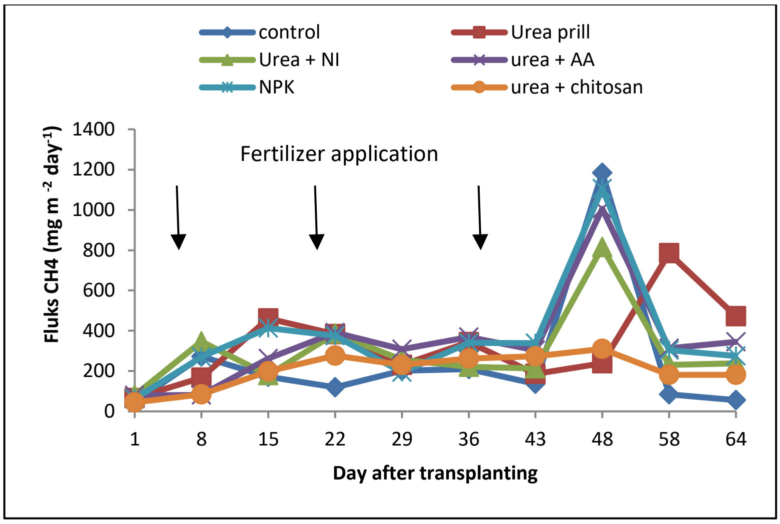

Figure 1. CH_4 flux from soil amendment treatments in flooded rice field

b. Nitrous oxide flux

The nitrous oxide flux tended to increase following the application of fertilizer and soil amendment (Fig.2). The obvious evidence was showed by increase in N_2O flux after the first application and the Urea prill showed the clear pattern. In the second application, N_2O flux decreased in all of treatment and increased extremely after the third application then gradually decreased before harvest time. The average of N_2O flux during growing season was 2447 µg m^{-2} day^{-1}. While the average of N_2O fluxes from each treatment were 2251, 2466, 2556, 3032, 2311 and 2064 for P1, P2, P3, P4, P5 and P6, respectively.

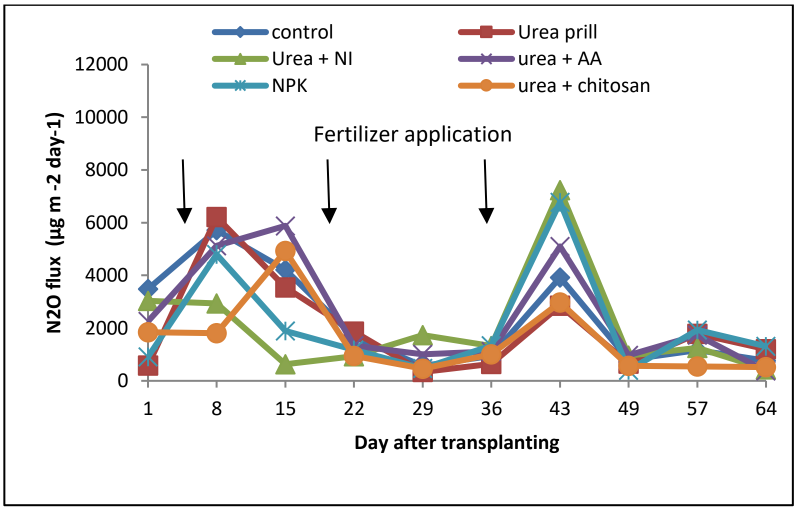

Figure 2. N_2O flux from soil amendment treatments in flooded rice field

c. Carbondioxide flux

Effect of fertilizer and soil amendment application was different on producing CO_2 fluxes compared to CH_4 and N_2O . CO_2 fluxes decreased after first and third application, but increased after second application (Fig.3). The average of CO_2 flux for whole growing season was 1672 mg m^{-2} day^{-1}. While the average of CO_2 for each treatment were 1848, 1655, 1595, 1666, 1795 and 1474 mg m^{-2} day^{-1} for P1, P2, P3, P4, P5 and P6, respectively.

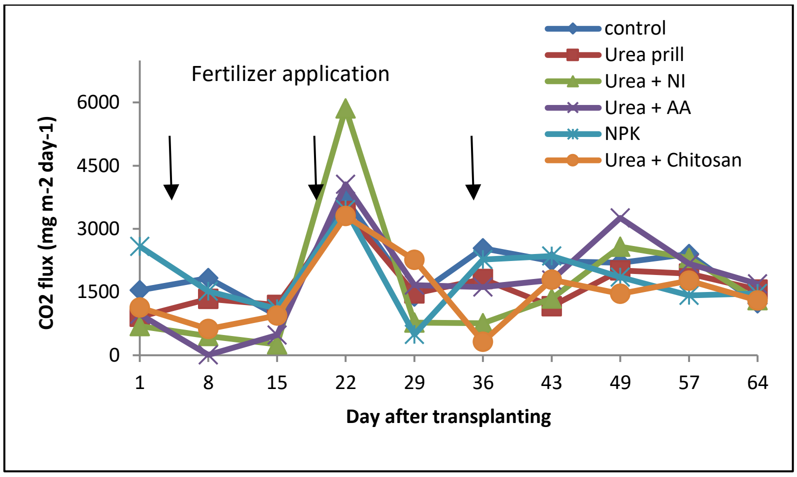

Figure 3. CO_2 flux from soil amendment treatments in flooded rice field

d. Seasonal GHG emission and Global warming potential (GWP)

Seasonal methane emission was significant different between Urea prill and Urea + Chitosan (Table 1). The highest methane emission was produced by application of Urea prill followed by Urea + AC and Urea + NI. Seasonal CO_2 and N_2O showed not significant different among the treatment. The highest CO_2 emission was contributed by control followed by application of compound fertilizer (NPK) and Urea + AC. Application of Urea + Chitosan was consistent to produced lower emission both on CO_2 and N_2O emission.

The GWP was significant different between Urea prill, Urea + NI, Urea + AC with Urea + Chitosan. The highest GWP was contributed by application of Urea prill. The GWP of Urea + Chitosan application was 31 % and 12% lower than application of Urea prill and control, respectively.

Table 1. Seasonal GHG emission (CH_4, N_2O and CO_2) and GWP from application of fertilizer and soil amendment

Treatments	Code	GHG emission*						GWP*	
		CH_4		CO_2		N_2O			
Control	P1	221	ab	1793	a	1,89	a	7,89	ab
Urea prill	P2	313	a	1605	a	2,07	a	10,04	a
Urea + NI	P3	300	ab	1547	a	2,15	a	9,69	a
Urea+AC	P4	302	ab	1616	a	2,55	a	9,96	a
Compound fertilizer	P5	279	ab	1741	a	1,94	a	9,30	ab
Urea+Chitosan	P6	201	b	1430	a	1,73	a	6,97	b

* GHG emission: kg $ha^{-1}season^{-1}$; GWP: t CO_2eq ha^{-1} $season^{-1}$.

e. Grain yield and yield-scaled global warming potential

Tillering number and plant height in the early plant growing were not significant different among the treatment. The application of fertilizer and soil amendment affected to plant development, showed by significant different between control and others treatment on 29 DAT, 36 DAT and 54 DAT. The highest of active tillering number was produced by application of Urea + AC, but high reduction of tillering was found on application of Urea prill, compound fertilizer and Urea + Chitosan (3 number of tillering). Plant height was correlated to plant biomass. Therefore, the highest biomass was produced by rice which received application of Urea + AC and the lowest was on control.

Table 2. Number of tillering and plant height from variety of Inpari 13 in different kind of soil amendment

Treatments	Code	Number of tillering							
		15 DAT		29 DAT		36 DAT		54 DAT	
Control	P1	4	a	9	b	10	b	9	c
Urea prill	P2	4	a	14	ab	14	a	11	abc
Urea + NI	P3	5	a	15	a	15	a	13	abc
Urea+AC	P4	5	a	15	a	17	a	15	a
Compound fertilizer	P5	7	a	15	a	17	a	14	ab
Urea+Chitosan	P6	5	a	13	ab	13	ab	10	bc
		Plant height*							
Control	P1	33	a	43	b	48	b	76	b
Urea prill	P2	33	a	50	a	59	a	93	a
Urea + NI	P3	33	a	52	a	59	a	94	a
Urea+AC	P4	34	a	52	a	61	a	98	a
Compound fertilizer	P5	34	a	52	a	63	a	97	a
Urea+Chitosan	P6	32	a	51	a	59	a	91	a

*plant height: cm

Fertilizer and soil amendment significantly contributed to grain yield. Table 3 showed that without treatment, the grain yield was lowest and significant different among the fertilizer and soil amendment treatment. The yield-scaled GWP showed that rice cultivation using Urea + chitosan application produced lowest GHGs emisson in grain rice yield. Lower of yield-scaled GWP is better to determine the mitigation action.

Table 3. Grain yield and yield-scaled GWP on different soil amendment.

Treatments	Code	GWP*		Yield*		Yield-scaled GWP
Control (without fertilizer)	P1	7,89	ab	2,15	b	3,7
Urea prill	P2	10,04	a	5,19	a	1,9
Urea + NI	P3	9,69	a	5,72	a	1,7
Urea+AC	P4	9,96	a	5,17	a	1,9
Compound fertilizer	P5	9,30	ab	5,34	a	1,7
Urea+Chitosan	P6	6,97	b	5,11	a	1,4

*GWP : t CO_2eq ha^{-1} season^{-1}; yield : t ha^{-1}.

Discussion

Flooded rice field provides appropriate condition to metabolism and activity of metanogen bacteria and will influence soil reduction-oxidation. Minamikawa and Sakai (2005) stated that CH_4 will be produced in redox potential -150 until -200 mV. In this range, metanogen actively conduct its metabolism. Increasing of CH_4 flux sharply in 43 DAT was due to effect of decreasing redox potential during sampling period and also contributed by application of third fertilizer. Dubey (2005) mentioned that urea use increase CH_4 flux during plant growth along with increasing of pH and followed by urea hydrolisis and decreasing of redox potential. Chemical fertilizer has effect to CH_4 emission and it depend on amount of fertilizer, type and aplication way of the fertilizer. Therefore, in our study there was different CH_4 emission between Urea prill and compound fertilizer which consist of N, P and K fertilizer.

N_2O flux tended to increase after fertilizer application. According to Pathak et al (2001), increasing of N_2O flux after urea fertilizer could be proceeded by nitrification. Denitrification of nitrate in anaerobic condition responsible to N_2O production. However, N_2O emission was also produced in aerobic condition by nitrification process.

Application of Urea + NI could reduce CO_2 flux compared to other application (except Urea + Chitosan). According to Pfab et al (2012) application of nitrification inhibitor (DMPP) could reduce mineralization of carbon which was showed by low of CO_2 flux. Even though the field experiment have not explained reason of this process, however result laboratory experiment showed that CO_2 flux decreased using nitrification inhibitor. Reducing of CO_2 using NI in whole of plant periode was also reported by Wieske et al (2001).

The GWP showed that application of Urea + chitosan produced lowest GHGs emission. It might be related to antimicrobial activity of chitosan. Many studies conducted to determine effect of chitosan but almost on enteric CH_4 production and nutrient digestibility. The chitosan could also used as soil amendment to reduce pathogen attrack and infection in the soil. According to Manucharova et al (2007), the intensity of anaerobic and facultative anaerobic chitinolytic was determined by the soil moisture.

Our study showed that fertilizer and soil amendment significantly supported to plant growing to produce grain yield. Deng et al (2012) mentioned that rice yield increased significantly along with level of N fertilizer, dry weight of yield in without N fertilizer only 4 – 6 t ha^{-1} and increase to 7 – 9 t ha^{-1} with N fertilizer dose 195 – 302 kg N ha^{-1}.

Conclusion

1. Methane emission was significant different between application of soil amendment, but both of CO_2 and N_2O emission were not significant different.
2. The highest GHGs emission was contributed by application of Urea prill (10.04 t CO2e ha^{-1} $year^{-1}$). While Urea+Chitosan showed the lowest GHGs emission and could reduce around 31% and 12% of GHGs emission compared to application of Urea prill and control, respectively.
3. According to the yield-scaled GWP, application of Urea+Chitosan could be used to mitigate GHGs emission from flooded rice field

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