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FEASIBLE OPTIONS TO REDUCE GREENHOUSE GASES EMISSION FROM AGRICULTURE AND ITS EFFECT TO MICROBIAL COMMUNITIES IN INDONESIA

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Abstract

Agriculture sectors can affect the net emissions of the greenhouse gases methane (CH4), nitrous oxide (N2O), as well as carbon (C) sources and sinks. Applying nitrogen fertilizers such as urea to soils have greatly increased N2O emission, meanwhile keeping water flooding in rice field lead the emit of CH4. Several options were propose for mitigate the greenhouse gases from agriculture land that including water management and apply organic material in rice field, while in arable field usually corporate a nitrification inhibitor with nitrogen fertilizer to reduce the emission of CH4 and N2O, respectively. In this paper, several works have been done to find-out the effectiveness and feasibility of options to reduce greenhouses gases fluxes from agriculture land. The experiments were consisted field works by collecting greenhouse gases by closed-chamber technique. The changes of microbial community structure were observed both by most probable number and standard plate count. The results suggest that 1) There are a potential for reducing emissions of N2O by applying nitrification inhibitor in arable land, while The CH4 flux was reduced by controlled water level in rice field, 2) Types of nitrogen fertilizers influenced the N2O productions but did not significantly alter the structure of microbial communities.

INTRODUCTION

Application of nitrogen (N) fertilizers increases the amount of available N in the soil and improves the productivity of agricultural crops. However, up to about 60% of N fertilizers can be lost as pollutants through leaching of mobile N compounds such as nitrate (NO3-) and emission of nitrous oxide (N2O) as one of potent greenhouse gas. Inhibition of this process will reduce rate of nitrogen lost in the soil. Therefore, one of the effective strategies for reducing N loses in soil would be inhibition of nitrification (IPCC, 2007).

The rates of processes to emit N2O mostly depend on the amount of NH4+ and NO3- in the soil as well as other factors including soil water content, organic matter availability, temperature and pH of soil. In nitrification, N2O is produced as a by-product of NH3 oxidation. In nitrifiers denitrification, N2O is an intermediate of the reduction of NO2- to N2. Denitrifiers produce N2O as an intermediate and possible end product of the reduction of NO3- to N2. Beside these main sources, other sources like chemodenitrification or heterotrophic nitrification contribute substantially under some conditions to the production of N2O.

Changes in CH4 and N2O emissions can substantially alter the overall greenhouse gas balance of a system. Intermittent drainage or late flooding of rice paddies can greatly diminish the seasonal emission of CH4 compared with continuous flooding (Yagi et al. 1997). Changes in N2O emissions following land use change from forest or grassland to agriculture vary between climatic zones, and the net impact varies with time. Applying nitrogen fertilizers to forests could increase the forest carbon sink, but may be accompanied by a net increase in N2O; conversely, adding lime to acid forest soils can decrease the N2O emission. Nitrification can have important effects on retention of nitrogen in the ecosystem such as loss of nitrogen in the form of nitrate via runoff and leaching to downstream ecosystems or through transfer of N2O to the atmosphere.

Change in microbial population size is often observed after addition of organic or inorganic amendments (Sarniguet et al.1992: Jumadi et al. 2008ac). Analysis of the spatial distribution of bacteria at microhabitat level showed that in soil subjected to different fertilization treatments show a shifted of bacteria population and more than 80% of the bacteria were located in micropores of stable soil micro-aggregates, which is a favorable condition for microbial growth with respect to water, substrate availability and gas diffusion.

A potentially effective strategy for N loss and reducing of N2O emissions of would be the inhibition of nitrification and denitrification. Nitrification inhibitors have been used in the field to improve the efficiency of fertilizers and to reduce both nitrate leaching and denitrification by maintaining the N in the soil as NH4+ (Francis et al. 1995; Venterea and Rolston, 2000; Jumadi et al. 2008b). One of nitrification inhibitor is Dicyandiamide (DCD) acts by inhibiting the first stage of the nitrification process, the oxidation of NH4+ to NO2-, and by rendering bacterial enzymes ineffective (Di and Cameron, 2002). However, nitrification inhibitor can be hypotheses have a potential to inhibit the growth of bacteria due to the effect repress to enzymatic mechanism.

RESEARCH METHOD

Maize (Zea mays L.) seeds were sown in well drained fields of the State University of Makassar experimental farm in Makassar city, South Sulawesi province, Indonesia (5m asl., 05°11.221`S119°25.750`E). The soil has loam-clay texture with soil types described as an alluvial. Three replicates of five treatments were laid out in a completely randomized design. The field has an area of around 48 m2 (6 m wide x 8 m long) and each micro-plot measures 1.68 m2 (1.2 m wide x 1.4 m long). The nitrogen (N) fertilizer types applied in the field were urea, urea coated neem (2.5%), urea coated neem (5%), urea coated DCD (5%).

The total rate of N applied in each treatment was 120 kg-N ha-1. Plots without N application were also set up as a control. Soil samples were taken from triplicate plots at a depth of 0–10 cm and sieved through 2.00 mm mesh to analyze the NH4+-N (ammonium) and NO3--N (nitrate) contents of the soil by calorimetrically. The percentage of N2O-N lost per amount of N applied as fertilizer to the field (EF= emission factor) was calculated using the following equation EF (%) = (TF – TUF)/ N x 100, where: TF = Cumulative N2O flux emitted from the nitrogen-applied plot (kg N2O-N ha-1 season-1), TUF = Cumulative N2O flux emitted from the non-nitrogen applied plot (control) (kg N2O-N ha-1 season-1) and N = Total nitrogen applied in the field (kg N ha-1 season-1).

The percentage reduction of N2O emitted from the fields with nitrification inhibitors was calculated using the following equation. N2O reduction (%) = (A – C) / (A – B) x 100, where A is the cumulative N2O emission in the urea plot, B is the cumulative N2O emission in the control plot, and C is the cumulative N2O emission with a nitrification inhibitors plots. While, The rice field experiment site was located in the Maros district, South Sulawesi province as described by Jumadi et al (2012). The viable populations of ammonium oxidizers (AOB) and soil fungi were estimated by most probable number (MPN) and standard plate methods, respectively.

RESULT AND DISCUSSION

Patterns of N2O emissions were affected by fertilizer with different nitrification inhibitor (Fig.1). The urea+neem 2.5% plots started to release considerable amounts of N2O at 10 DAS (days after sowing) or it was about 11 days after fertilizers were applied, and continue emitted N2O until 25 DAS then declined thereafter. The urea and urea+neem 5% plot produced amount of N2O at 25 DAS. In contrast, N2O emission from the urea+DCD and control plots remained low during the crop season. Total N2O emission during the cultivation period was highest from the urea plot, followed by the urea+neem 5% plot. An emission from the urea+DCD plots was higher comparing to control plot (Tab. 1).

The reduction of N2O emissions by DCD counted 68%, more effective compare to neem amended (Tab.1). However, neem amended retained more NH4+ in soil (Fig.1). The nitrification inhibitor is effective only in aerobic conditions, partly due to the greater contribution of denitrification to N2O production under wet conditions, therefore we speculated that soil in the field was aerated enough to nitrification condition.

The emission factors (EF) range 0.4% to 1.2% (Tab.1). These EFs were not different with our previous studies in same field which were 0.71% to 1.6% (Jumadi et al, 2008). However, those EF values were higher compare with Andisol (a typical Japanese soil) amended with chemical fertilizer in a temperate region which were 0.05% to 0.35%.

Table 1. Total N2O emitted from the field during cultivation, emission factor (EF), percentage of N2O emission reduction by addition nitrification inhibitors and number of soil microbial properties (CFU, cell/gram dry soil) counted at 40 days after sowing.

Treatments	N_2O-N kg ha^{-1} $season^{-1}$	EF (%)	Reduction(%)	AOB (10^4)	Fungi (10^3)
Control	0.33	-	-	94	12c
Urea	1.81	1.2	-	103	19c
Urea+Neem 2.5%	1.47	1.0	23	114	16c
Urea+Neem 5%	1.60	1.1	14	193	18c
Urea+DCD 5%	0.81	0.4	68	143	10c

In contrast, in acid oxisol in Puerto Rico, where a chemical fertilizer was also applied, emission factors ranged from 0.5% to 5% (Mosier et al. 1998). Hence, these emission factor values are possible mostly dependent on fertilizer types, and climatic and soil conditions.

Application of N fertilizers increased the concentrations of NH4+ and NO3- in the soil (Fig. 1 and 2). The level of NH4+ started at 2 until 25 days after sowing and significantly higher in the treated plot than control plots, but no differences in NO3- content were found at 10 and 25 DAS. At 40 DAS NH4+ was monitored higher in urea plot due to urea was applied in this plot two days before soil sampling. The decrease in the NH4+ content of the soil was accompanied by an increased in NO3-content, but found lower at 40 DAS which might be dense intensity of precipitation during days sampling lead NO3- were leached.

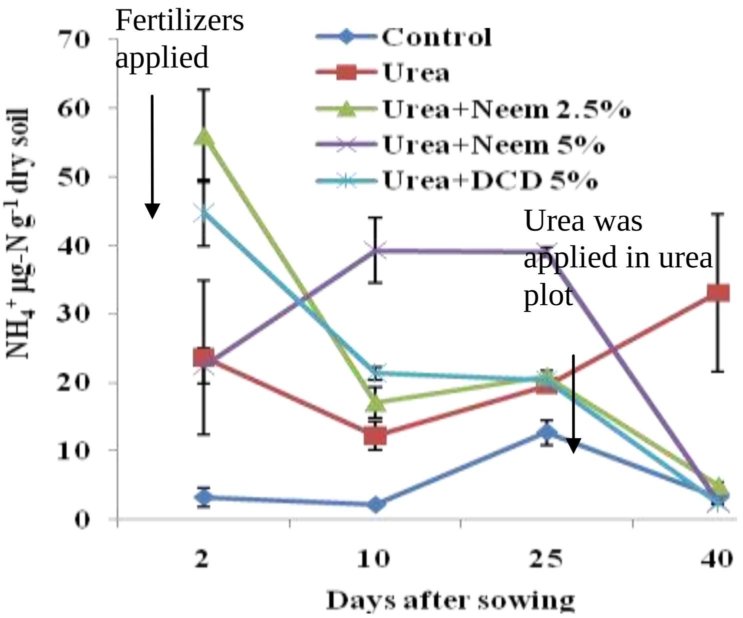


Figure 1. Change of NH4+ during cultivation. Vertical bar ± indicated standard deviation

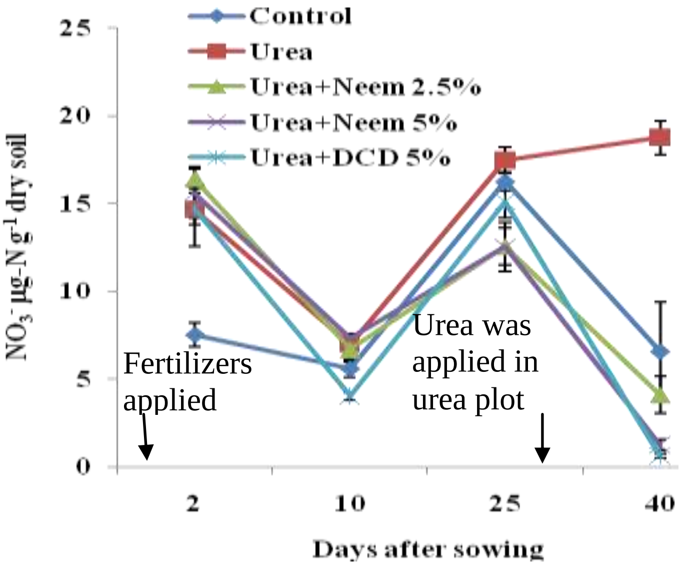
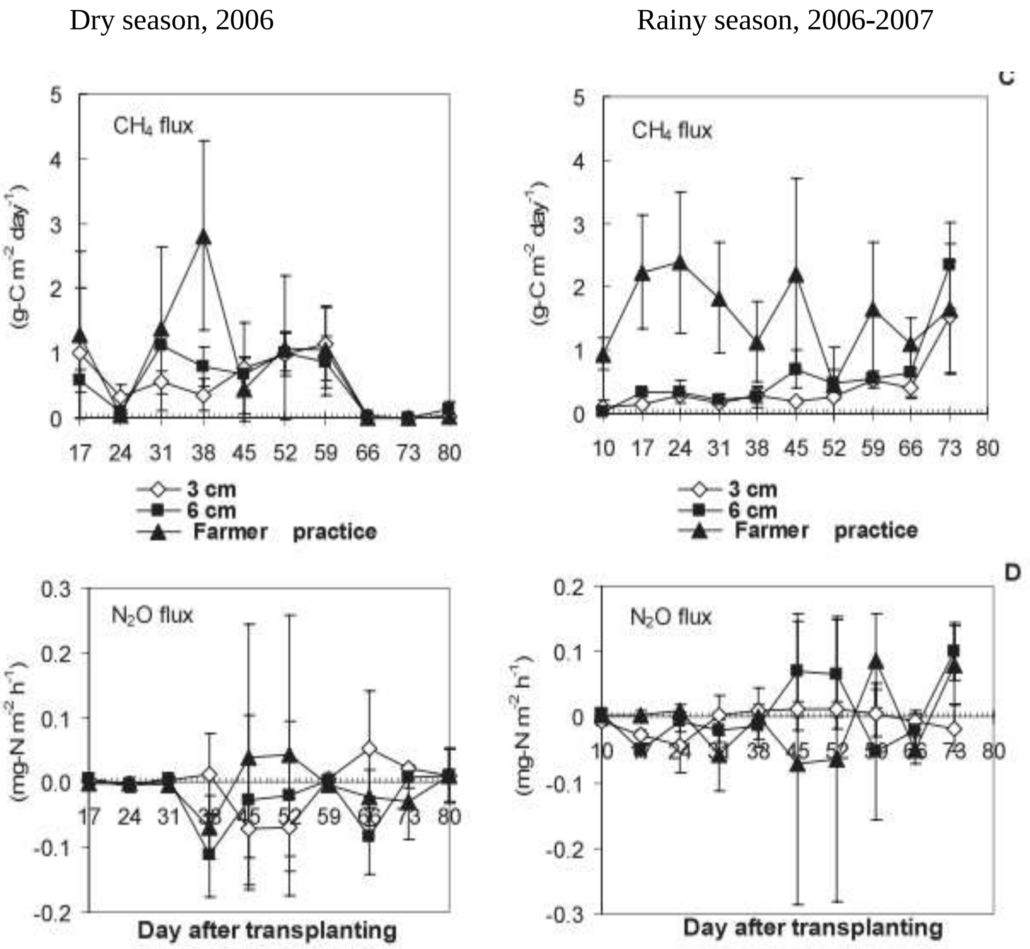


Figure 2. Change of NO3- during cultivation. Vertical bar ± indicated standard deviation

The seasonal variations of CH4 production from the rice field during the two cultivation periods are shown in Fig. 3. The rice field acted as a source of CH4 during the observation periods. However, the controlled water levels (CWL) of the rice field exerted a significant effect on the reduction of CH4 production, compared to the water level in the farmer practice.


Dry season, 2006

Rainy season, 2006-2007

Figure. 3 Measurements of CH4 and N2O during a one-year period and effect of controlled water level

CH4 flux was higher when the level of water increased in the rice field experiment in both cultivations. In the 1st cultivation (May 14, 2006 or 17 DAT), CH4 fluxes monitored were 1.0, 0.6 and 1.3 g- C m-2 day-1 in the 3 cm, 6 cm and farmer practice plots, respectively, and then they decreased at 24 DAT when the water level in the field decreased due to the field drainage before the 2nd fertilizer application. in the farmer practice plot, the CH4 flux peaked with a value of 2.8 g-C m-2 day-on June 4, 2006 or at 38 DAT, and then decreased to the values as recorded in the other plots at 45 DAT. In the 2nd cultivation, the CH4 flux production was larger in the farmer practice plot than in the other plots until harvested. The CH4 flux from the FP plot was consistently higher than that of other plots, except of the end of measurements at 73 DAT. The CH4 flux in the FP plot rose sharply from 10 DAT and reached the highest recorded seasonal value of 24 DAT, and then fluctuated toward the end of cultivation. Meanwhile, CH4 flux productions in the other plots were lower compared to those in the FP plot.

CWL below 6 cm in this area of rice cultivation is a promising option to mitigate the CH4 production without hampering the rice yield as well as to save water. However, these practices cannot be easily adopted by the local farmers because they must determine whether the water level is above or below 6 cm and pump out water when the water level is exceeds 6 cm, once a week. Therefore, convenient method to monitor the water level by the farmers should be developed a long with some incentives to the local government to save water in order to reduce the CH4 flux. The CH4 flux in rice fields can be readily predicted by using soil redox potential indices (Yagi et al., 1997; Lumbanraja et al., 1998).

Water management by intermittent drainage or midseason drainage is one option to reduce the CH4 flux from paddy field. However, this practice also enhances the rate of N2O flux from the field during the drainage period (Cai et al., 1997). N2O is produced in flooded paddy soils via nitrification of ammonium to nitrate and denitrification, and nitrate tends to accumulate in soils with an aerobic surface layer and under anaerobic condition, respectively (Arth et al., 1998; Suratno et al., 1998; Akiyama et al., 2005).

CONCLUSION AND SUGGESTION

There were substantial capacities of neem (Azadirachta indica) as nitrification inhibitors with repressions of N2O emission and retained nitrogen in corn field. The use of urea+nitrification inhibitors can minimize nitrification rate and seems increased soil microbial population. The study also suggests that the addition of neem with urea is recommend as nitrification inhibitor. While, maintaining flood water levels up to 3 cm and 6 cm the N2O emission was not stimulated, however, CH4 emission were reduced.

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