

# Nitrogen fertilization management can decrease methane emission from wetland rice fields of Central Vietnam

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## Abstract

Wetland rice is the largest source of CH<sub>4</sub> emission from cropping and also offers the most options to modify crop management for reducing these emissions. The experiment was conducted in two rice cropping systems in 2014 and 2015 to assess the influence of rates and types of nitrogen fertilizer on CH<sub>4</sub> emission in rice fields of Central Vietnam. Results show that high fertilizer N rates (120 kg N ha<sup>-1</sup>) increased seasonal cumulative CH<sub>4</sub> emissions from 11.6 – 26.7 g m<sup>-2</sup> for urea and 6.7 – 19.5 g m<sup>-2</sup> for ammonium chloride in winter spring and summer cropping seasons relative to when no N fertilizer was applied. Replacing urea with ammonium chloride at the same N rate significantly reduced CH<sub>4</sub> emissions by 35% (winter spring cropping season) and 32% (summer cropping season) at the rate of 120 kg N ha<sup>-1</sup>. Average CH<sub>4</sub> emission was about 2.1 – 2.2 times higher in summer season as compared in winter spring season. To develop effective GHG mitigation strategies future work is needed to (i) quantify the effects on both CH<sub>4</sub> and N<sub>2</sub>O emissions), (ii) investigate options for combining mitigation practices.

## Key Words

Ammonium chloride, cropping seasons, rate, type, urea

## Introduction

Agricultural activities influence atmospheric concentrations of the greenhouse gases (GHG), carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide, (N<sub>2</sub>O), and contribute about 20% of the world's global radiative forcing (Lal et al 1999). Globally, agricultural CH<sub>4</sub> and N<sub>2</sub>O emissions have increased by nearly 17% from 1990 to 2005, an average annual emission increase of about 60 Mt CO<sub>2</sub>-eq/yr (IPCC 2007). CH<sub>4</sub> is produced when organic materials decompose in oxygen-deprived conditions, notably from fermentative digestion by ruminant livestock, from stored manures, and from rice grown under flooded conditions (Mosier et al. 1998). Nitrogen is generally the most limiting nutrient in intensive crop production systems (Robertson and Vitousek 2009), and N fertilizer is commonly applied to rice, corn, wheat and other non-leguminous crops. There is an increasing pressure on the rice-growing resources, especially in Asia where more than 90% of rice is grown and consumed (Becker 1993). Knowledge of the trade-offs between CH<sub>4</sub> emission and N fertilizer management practice is therefore an essential requirement for informing management strategies that aim to reduce the agricultural CH<sub>4</sub> burden without compromising productivity and economic returns. A number of management technologies have been proposed to reduce agricultural CH<sub>4</sub> emission (Mosier et al 2001; CAST 2004; Follett et al 2005). Agricultural management can mitigate global radiative forcing by increasing storage of soil organic carbon (SOC), increasing oxidation of CH<sub>4</sub> in soil (Mosier et al 2006). Improving nitrogen use efficiency (NUE) through nitrogen fertilization management has been identified to reduce farm costs and CH<sub>4</sub>, N<sub>2</sub>O emission. It has been found some researches in different countries on the effect of nitrogen fertilizer types and rates on methane emissions from rice field (Bruce et al 2012; Ibrahim et al 1999), but there is still lack of this information in Central Vietnam. Therefore, this study was conducted to assess the influence of rates and types of nitrogen application on CH<sub>4</sub> emission in the two rice cropping seasons in Central Vietnam.

## Methods

### *Experimental site*

The site of field experiment was located in Huong An village (16°28'2"N and 107°31'2"E), Huong Tra town, Thua Thien Hue province, Central Vietnam. The typical paddy soil was classified as Dystric Fluvisols (Gleyi-Dystric Fluvisols) (Le Thai Bat and Pham Quang Khanh 2015). A tropical monsoon climate prevailed in the area with mean annual temperature and precipitation of 26.7°C and 2300 mm, respectively. The basic properties of topsoil (0–20 cm) before the experiment are given with pH<sub>KCl</sub> (4.10); OC (1.14%); total N (0.085%), total P (0.034%); total K (0.48%) and clay content (60%).

### *Nitrogen and fertilization treatment*

The field experiment was conducted with four rates of nitrogen (0, 40, 80 and 120 kg N/ha) and two types of

nitrogen namely urea and ammonium chloride (NH<sub>4</sub>Cl) for rice cropping. The experiment was arranged in a split plot design with N rates in subplots and N types in main plots. Each treatment subplot was 3 x 5 m and each treatment main plot was 60 m<sup>2</sup>. Each treatment was carried out in triplicate. The individual plots were separated by protection rows that were 0.6 m in width, each with an irrigation and drainage outlet. Lime was applied 15 days before sowing and incorporated into soil. Farmyard manure (C 25%; N 0.89%; P 0.30% and K 0.5%) at 5 t ha<sup>-1</sup> was spread on the surface, thoroughly mixed with soil by a wooden rake, and incorporated to a depth of over 10 cm. The N fertilizers were applied with 30% as a basal fertilizer before sowing, another 10% at 10 days after sowing, 45% at the tillering stage and the remaining 25% at the panicle initiation stage. Superphosphate was also applied as basal fertilizer before sowing at the rate of 60 kg P<sub>2</sub>O<sub>5</sub>/ha. KCl was applied at 60 kg K<sub>2</sub>O/ha (50% at 10 days after sowing and 50% at panicle stage) in 2014 and 2015.

#### *Rice cultivation and water regime management*

Rice (*Oryza sativa* L., cv. Khang Dan 18) from China was cultivated for the field experiment in 2014 (summer season from June to August) and in 2015 (spring season from January to May), respectively. Rice seeds were directly sowed in plots on 1<sup>st</sup> June, 2014 and 17<sup>th</sup> January, 2015, respectively. Rice was harvested on 1<sup>st</sup> September 2014 and on 10<sup>th</sup> May 2015, respectively. For rice production, field water regime was maintained by flooding at 3 – 7 cm depth at nursery, tillering, panicle initiation and spiking stages followed by a subsequent drainage from ripening till harvesting stages.

#### *CH<sub>4</sub> emissions*

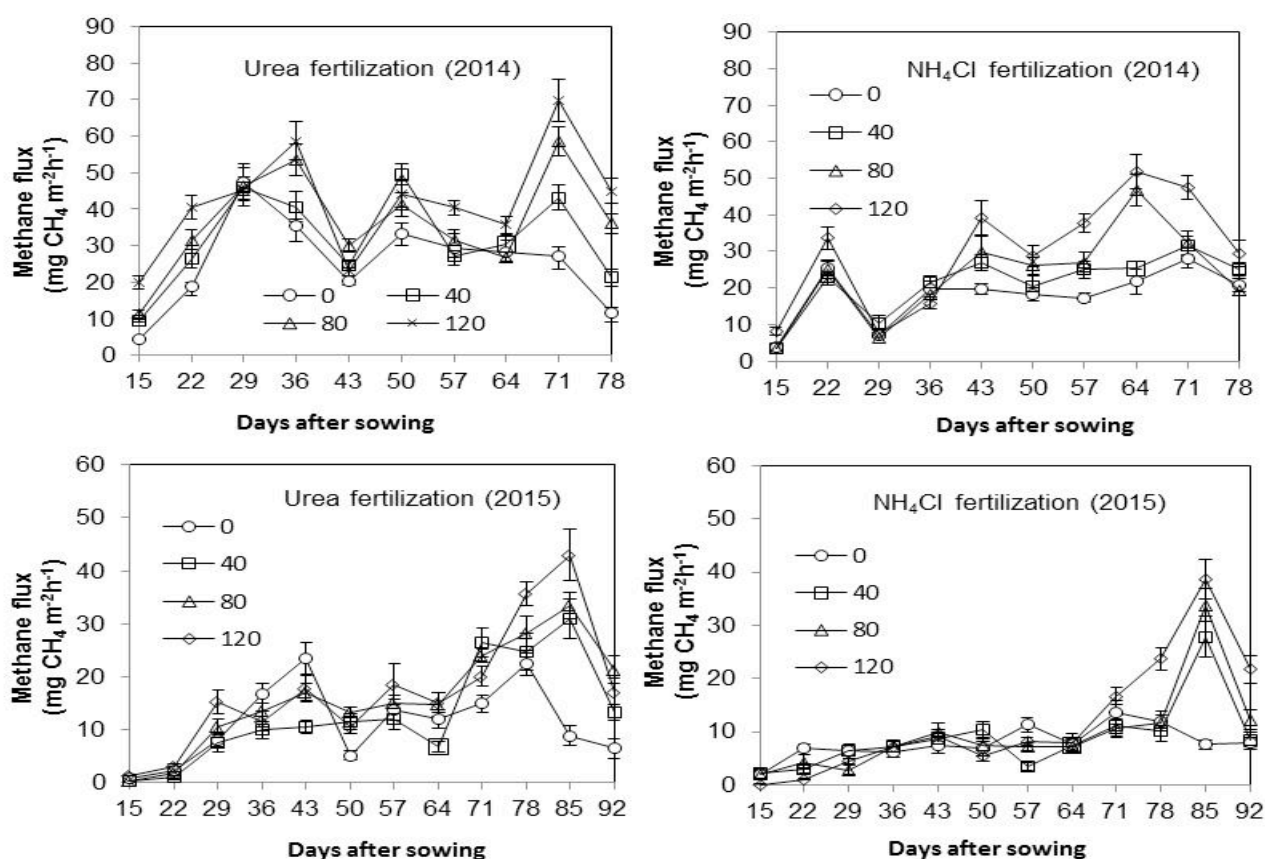
Gas flux measurements started at two weeks after direct seedling to ripening stage. Methane flux was measured in three replicates of the experiment using the static chamber method as described by Parkin and Venterea (2010) every seven days for the period 8 to 10 am. Closed polyethylene bucket with diameters of 40 cm (top) and 50 cm (bottom) x 70 cm height were used to quantify the CH<sub>4</sub> flux from all plots during the rice growing seasons. A round polyethylene base, with dimensions of 50 cm length x 30 cm height, served as the anchor for each chamber. The anchor was inserted about 10 cm into the soil with two rice hills on the inside and installed in the plots at least one day before the first sample collection to allow stabilization, and they were left in the field throughout the growing period of the crop. The base height and water depth inside the round polyethylene frames were measured at each gas sampling time. At the time of sampling, the gas collection chambers were placed on the trough of the polyethylene bases with a water seal. Gas samples inside the chambers were collected using a 60-mL syringe fitted with a stopcock at 0, 10, 20, and 30 min after chamber closure. Then the gases in the chamber were drawn off with a syringe and immediately transferred into a 20 ml vacuum glass container. When gas samples were collected, air temperature and soil temperature in chamber were measured simultaneously. Temperature was recorded using digital thermometer when the reading was stable within 5 seconds after insertion of the probe at depth of 5 cm. CH<sub>4</sub> concentrations were measured with gas chromatograph (GC- SRI 8610) by a flame ionization detector.

#### *Statistical Analysis of Data*

The SPSS 16.0 software package was used for all statistical analyses. All data (mean±SE, *n* = 3) were checked for normal distribution. Statistical analysis was performed by two-way ANOVA to analyze the effects of N fertilizer (rate and type) on the CH<sub>4</sub> flux, using the SPSS general linear model procedure.

## **Results**

Increasing rates of N application for rice resulted in increasing CH<sub>4</sub> emission (Figure 1). The highest CH<sub>4</sub> flux was found at 120 kg N/ha for both types of N fertilizer. According to Schimel (2000), N fertilizers stimulate CH<sub>4</sub> production by increasing rice plant growth, thus, increasing the carbon supply for methanogenic bacteria. Under flooded conditions, the growth of rice crop plants increases CH<sub>4</sub> emission by providing C sources and by favoring CH<sub>4</sub> transport to the atmosphere (Dannenberg and Conrad 1999). A stimulatory effect of rice plant growth on CH<sub>4</sub> production potential by providing CH<sub>4</sub> substrates has been demonstrated in pot experiments (Jia et al 2006) and in field experiments (Xu et al 2004). Zheng et al (2006) found that high rates of N application stimulated CH<sub>4</sub> emission more than low N application under a FACE environment because high N application improved the C/N ratio in crop straw and roots, and rice yield. Singh et al (1999) studied the effect of urea application at 100 kg N/ha on CH<sub>4</sub> emissions from rice fields planted with three rice varieties and found that CH<sub>4</sub> emissions from fertilized fields were all greater than those from unfertilized fields. A stimulatory effect of chemical N fertilizers on CH<sub>4</sub> emissions was also observed by Rath et al (1999) in an irrigated rice field. CH<sub>4</sub> emission from application of urea fertilizer was higher than from NH<sub>4</sub>Cl fertilizer. The commonly applied chemical N fertilizer is urea, which is rapidly hydrolyzed into ammonium soon after its application to rice fields. Generally speaking, less CH<sub>4</sub> is emitted from rice fields supplied with NH<sub>4</sub>Cl compared with fields supplied with urea (Cai et al 1997).



**Figure 1: Effect of N rates and types on CH<sub>4</sub> emission flux in two rice cropping systems**

A number of comparisons of CH<sub>4</sub> emissions from treatments supplied with different types of N fertilizers are available in the literature. However, there have also been many reports demonstrating that the application of fertilizers containing ammonium (e.g. ammonium chloride) decreased CH<sub>4</sub> emission from rice paddies as compared to urea application due to along with the quick decomposition of NH<sub>4</sub>Cl in flooded conditions during a long rice growing period (Kimura et al 1992; Ibrahim et al 1999). The CH<sub>4</sub> emission was higher in summer rice crop season as compared with winter spring rice crop season at the same rate and type of N fertilizer application. Jain et al (2004) indicated that CH<sub>4</sub> oxidation by methanotrophs in rice paddies shows pronounced seasonal variation. According to Van Hulzen et al (1999), temperature influences CH<sub>4</sub> production by regulating anaerobic carbon mineralization, availability of alternative electron acceptors and methanogen activity. At higher temperature, mineralization increases and more carbon substrate become available, resulting in faster depletion of the alternative electron acceptor pool. Neue and Scharpenseel (1984) reported that most of the methanogenic bacteria display optimum rates of CH<sub>4</sub> production at around 30°C. Daily variations of CH<sub>4</sub> emission in rice fields are related with temperature variations.

## Conclusion

The effect of inorganic fertilizer N on CH<sub>4</sub> emission depends on rate of N application: high N rates of either urea or ammonium chloride increase CH<sub>4</sub> emissions relative to when no N is applied. Of the two types of N fertilizer tested, ammonium chloride reduced CH<sub>4</sub> emissions relative to urea. CH<sub>4</sub> emission from rice growing in winter spring season was much lower than in summer season. Our analysis has focused on the effect of N fertilizer management practices on CH<sub>4</sub> emissions, but further research should aim at quantifying the effects of it on N<sub>2</sub>O emission and combining mitigation options.

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