

# The impact of long-term consecutive different N source management practices on greenhouse gases emission from paddy field

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**Abstract.** A field experiment was carried out at Yawara long-term experimental station of National Agricultural Research Center of Japan in 2002. The objective is to monitor the emission dynamics of N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> from paddy field under long-term application of different N sources and evaluate their impact on greenhouse effect. The results showed there was significant difference in N<sub>2</sub>O emission among treatments although their gross emission fluxes were very low during rice growing season. Nitrous oxide emission in CF treatment was 50% higher than that in OF and GM treatment but no statistical difference between OF and GM. It indicated that the application of organic fertilizer could reduce N<sub>2</sub>O emission. Also, there were significant differences in CH<sub>4</sub> and CO<sub>2</sub> emission among treatments. Both methane and carbon dioxide emission from OF and GM treatment were significant higher than that from CF treatment. It indicated that organic materials addition favored both CH<sub>4</sub> and CO<sub>2</sub> emission compared to chemical N application. Addition of green manure contributed more of CH<sub>4</sub> emission and less of CO<sub>2</sub> emission compared to composted organic fertilizer in this study. Gross greenhouse effect caused by CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission among treatments was in the order of OF>GM>CF>NF. However, Nitrous oxide emission was not the major factor influencing global warming but CH<sub>4</sub> and CO<sub>2</sub> in this study. It is much more effective to reduce CH<sub>4</sub> concentration than to reduce CO<sub>2</sub> concentration in atmosphere in practice. Hence, proper key measures should be taken to mitigate methane emission from rice paddies.

Key words: Greenhouse gases, Paddy rice, N sources, Long-term management

# 1. Introduction

Since the concept of sustainable development presented first in western developed countries during the early 1980s, it has become the theme of development in every walk of life quickly. Non-sustainability of agricultural environment has been given more and more concern, in particular for greenhouse gases emission from farmland (Wang et al. 1995; Cai et al. 1997; Moier et al. 1998; Heincke et al. 1999; Torstensson et al. 2000; Xing et al. 2000; Zhu et al. 2000; Di et al. 2002). Agricultural soils have been identified to be one of the major sources of greenhouse gases  $\text{N}_2\text{O}$ ,  $\text{CH}_4$  and  $\text{CO}_2$  emission which involves in the destruction of stratospheric ozone leading to global warming (Yagi et al. 1996, 1997; Moier et al. 1998; Cookson et al. 2000; Kumar et al. 2000). Global estimate of their emissions from agricultural soils by the Intergovernmental Panel on Climate Change (IPCC) has a large uncertainty and variation due to different land use types and different management practice. Mosier (1998) reported during the past few decades that atmospheric concentrations of  $\text{N}_2\text{O}$  have been increasing at an annual rate of  $0.3\% \text{yr}^{-1}$  based on its high global warming potential (310 times that of  $\text{CO}_2$ ). Atmospheric  $\text{CH}_4$  concentration is currently increasing at approximately 0.5% per year (Steele et al. 1992). Methane contributes 19% to the greenhouse effect and its rank is next to  $\text{CO}_2$  in the atmosphere (Bouwman, 1990). Although the greenhouse effect of  $\text{CO}_2$  is not rapid as  $\text{N}_2\text{O}$  and  $\text{CH}_4$ , its increasing emission has always been given special concern because of getting more and more serious deforestation driven by increasing human populations and great amount of combustion of fossil. If present situation remain un-changed, annual emission rate of  $\text{CO}_2$  will continue to increase by 0.5% per year, then the concentration of atmospheric  $\text{CO}_2$  will double its pre-industrial value of  $280 \mu\text{mol mol}^{-1}$  in the middle of next century (Minami, 1994; and IPCC 1996). In this case, the increasing atmospheric  $\text{CO}_2$  stimulates plant growth and benefits grain production, but the benefits of increased  $\text{CO}_2$  would be lost if temperatures also rise. Because increased temperature shortens rice growth period resulting in bad growth and harvest

It is therefore necessary to mitigate their emission rates and gross emission fluxes from various pathways. Rice is the staple food in most countries and rice paddies are not negligible emission sources because of large amount of chemical N compound and various organic fertilizers. Most investigations were conducted in paddy field with frequent change in planting plan and water-fertilizer management strategies (Yagi et al. 1990; Minami, 1995; Yagi et al. 1996, 1997; Cai et al. 1997). There were few reports on long-term consecutive management practices of different N

sources around the research theme of the sustainability of agriculture. Hence, the objective of present study was to monitor the dynamics of N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> emission from paddy field under long-term management practices of different N sources and to evaluate the impact of long-term different N source management on global warming.

## 2. Materials and methods

### 2.1 Study site

The field experiment was carried out at Yawara long-term fertilizer experiment station of National Agriculture Research Center (NARC) (36°0'16" N, 140°1'13" E) during the rice growing season in 2002. The climatic characteristics during the experiment period follow as: the annual average temperature 13.2 °C, the yearly mean value of radiation 12.3 MJ m<sup>-2</sup> d<sup>-1</sup>, total yearly precipitation 1186.5 mm.

### 2.2 Experimental design

The soil used in the experiment was classified as typical gray soil with a fine-texture. The recent characteristics on the soil after cultivated near to 80 years under the different N sources management practices were listed in Table 1. Historically, it was a fixed long-term experiment, the different N sources management patterns directly reflected corresponding four fertilization treatments which included no fertilizer (NF), chemical N fertilizer-Ammonium sulfate (CF), rice straw compost plus soybean cake (OF), and green manure - clover (GM). No replications were set up and the size of each experimental plot was 250 m<sup>2</sup>. The plots were adjacent to each other.

**Table 1. Description of the soil used in experimental plots**

Soils	Total N %	Total C %	C/N	CEC me.100g <sup>-1</sup>	Available mg P kg <sup>-1</sup>	pH soil:water=1:2.5
NF	0.202	2.083	10.31	21.12	20	6.07
CF	0.245	2.513	10.26	22.39	58	5.17
OF	0.318	3.054	9.60	22.70	138	5.30
GM	0.268	2.573	9.60	20.02	125	6.37

NF: no fertilizer CF: chemical N fertilizer OF: organic manure GM: green manure

In this experiment, no fertilizer meant no any fertilizer added besides no N fertilizer, other 3 experimental plots were fertilized almost equivalent net N (100kg.ha<sup>-1</sup>) and available potassium, phosphate and calcium nutrient according to the initial fertilization principle of experimental design (Table 2). Ammonium sulfate was fertilized about 300 kg N ha<sup>-1</sup> as basal and 200 kg N ha<sup>-1</sup> as top-dressing. Rice straw compost (T-N1.56%, C/N ratio 22.5 and moisture 72%) plus soybean cake (T-N 9.28%, C/N ratio 5.11 and moisture 8%) were incorporated into soil 3 wks

before transplanting. The fresh clove (T-N 3.28%, C/N ratio 13.0 and moisture 86.4%) was incorporated into soil one month before transplanting.

**Table 2. The rate of fertilizers application in per experimental plot (kg.ha<sup>-1</sup>)**

Items	Ammonium sulfate		Super-phosphate	Potassium sulfate	Soybean cake	Straw compost	Clover	Slaked Lime	Component			
	Basal	Add							N	P	K	Ca
	NF	0							0	0	0	0
CF	300	200	300	200	0	0	0	0	106	21.8	83	0
OF	0	0	150	50	600	12000	0	0	103	27.9	83	0
GM	0	0	200	30	0	0	23000	10000	102	23.6	83	429

NF: no fertilizer CF: chemical N fertilizer OF: organic manure GM: green manure

Rice of *musashikogane* was transplanted in four plots where matched consistently field irrigation management. The cultivation density of rice seedling is 15×30cm (22.2 seedlings/m<sup>2</sup>). The rice growth period is from the end of May to the beginning of Oct. every year.

### 2.3 Gas sampling and N<sub>2</sub>O, CH<sub>4</sub> & CO<sub>2</sub> analysis

During the rice growing period, the gas evolved from the combined soil and plant system was sampled by setting up a closed chamber (Chen et al. 1995) for the determination of N<sub>2</sub>O, CH<sub>4</sub> & CO<sub>2</sub> emissions. The sampling was done every 2 wks from 0900 to 1100 h to estimated average emissions of N<sub>2</sub>O (Chen et al. 1995; Hou et al. 2000) but every 2 days during the mid drainage period. From transplanting to before drainage during rice growing period and after harvest, small chamber (0.4×0.6×0.315 m<sup>3</sup>) was used and from after drainage to before harvest, big chamber (0.4×0.6×0.99 m<sup>3</sup>) with an electric fan was used. The fan was used to mix air evenly in the chamber during gas sampling. The gas collection chamber was placed in a water groove created by the wooden frame support in the field. The groove was watered to seal the bottom of chamber while sampling. Gas in the chamber was collected into a well-sealed specific polythene bag by a gas pump and then transferred to vials by syringe immediately at 0 and 60 min after setting of the chamber. The N<sub>2</sub>O, CH<sub>4</sub> & CO<sub>2</sub> concentrations were measured by a gas chromatograph equipped with ECD, FID and TCD detector, respectively. The N<sub>2</sub>O, CH<sub>4</sub> & CO<sub>2</sub> emission fluxes were calculated based on the difference in their respective concentrations at 0 and 60 min. In addition, at the corresponding time of gas sampling, the soil solution was sampled by porous cup (2 mm diameter) at 0.5 cm and 10 cm depth.

## 2.4 Soil solution analysis

The concentrations of inorganic  $\text{NO}_3^-$  in soil solution sampled from porous cup were analyzed by TRAACS 800 auto-analyzer (BRAN LUBBE Co.)

## 2.5 Statistical analysis

The effect of treatments on greenhouse gases was analyzed by IRRISTAT software.

# 3. Results and Discussions

## 3.1 $\text{N}_2\text{O}$ emission

The results showed (Figure 1) that there were almost no  $\text{N}_2\text{O}$  emissions from all experimental plots during the whole rice growing period except in the mid-drainage stage, during which there was a sudden increase in  $\text{N}_2\text{O}$  emission because of drainage event, but decreased gradually with the extension of drainage time. Although some literature reported that there would be an emission peak again after re-flooding (Yan et al. 1999), no peak was observed during that period in present study. It is known that  $\text{N}_2\text{O}$  is produced in soil by two dissimilar energy-producing microbial processes, nitrification and denitrification and very limited chemical process to contribute  $\text{N}_2\text{O}$  emission in soil (Williams et al. 1992; Rice and Rogers; 1993 Röver et al. 1998). Continuously flooded condition establishes anaerobic an environment which does not favor  $\text{N}_2\text{O}$  emission. Hence, flooded rice paddies are usually not considered to be an important source of atmospheric  $\text{N}_2\text{O}$  because  $\text{N}_2\text{O}$  would be rapidly reduced to  $\text{N}_2$  under such intensive anaerobic conditions (Erich et al. 1984; Duxbury and Mosier, 1993, Granli and Bockman, 1994). But frequent natural percolation creates fully or partially aerobic conditions, moreover, frequent irrigation add dissolved  $\text{O}_2$  into the soil system, making the first few mm of surface soil partially aerobic, even during submergence. Under such conditions, nitrification-denitrification may produce considerable amounts of  $\text{N}_2\text{O}$  (Kumar et al 2000). Hence, there was only less  $\text{N}_2\text{O}$  emission in flooding period than the mid-drainage aeration period in this study. On the other hand, the dramatic emission of  $\text{N}_2\text{O}$  during the drainage period could be attributed to the enhanced nitrification, because of a increase  $\text{NO}_3^-$  N content in soil solution in all treatments (Figure 2) are corroborated with findings of other researchers (Yan et al. 1999).

Although there was obvious  $\text{N}_2\text{O}$  emission within the drainage period, the total emission flux during the whole rice-growing season was very low (De Datta and Buresh 1989, Bronson et al. 1997a, Abao et al. 2000). There was significant difference among all treatments (Table 3) in terms of gross emission flux of  $\text{N}_2\text{O}$  during the whole rice-growing season in present study. The

treatment receiving chemical N fertilizer (CF) showed the highest N<sub>2</sub>O emission flux up to 24.66 N mg m<sup>2</sup>, and 50% higher than that from OF treatment but there was no significant difference between OF and GM treatment. Though there was no significant difference between NF and CF treatment, it can not be concluded that N<sub>2</sub>O emission rate from NF treatment was higher than that of applied organic fertilizer treatments because of its higher statistic variation. The lower N<sub>2</sub>O emissions in plots with organic fertilizers addition were thought to be due to the restriction of nitrification associated with reduced soil aeration following increased O<sub>2</sub> consumption due to organic matter addition, inhibition of nitrification by high concentrations of CH<sub>4</sub>, or increased immobilization of soil N.

**Table 3. Gross emission fluxes of N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> from experimental plots during rice growing period**

		NF	CF	OF	GM
N mg.m <sup>-2</sup>	N <sub>2</sub> O-N	22.74	24.66	12.44	12.02
	<i>sd</i>	29.34	13.35	10.49	9.56
C g.m <sup>-2</sup>	CH <sub>4</sub> -C	3.38	1.74	5.18	10.88
	<i>sd</i>	1.91	1.17	2.14	5.55
C g.m <sup>-2</sup>	CO <sub>2</sub> -C	270.06	562.24	687.27	600.64
	<i>sd</i>	35.87	175.80	172.51	115.27

NF: no fertilizer CF: chemical N fertilizer OF: organic manure GM: green manure *sd*: standard error

However, gradual increase in nitrification in the surface layer (Figure 3) during the fallow period of long-term paddy field experiment might be the major cause for potential higher N<sub>2</sub>O emission than that during rice growing period. Bronson et al (1997b) observed that addition of residues in rice-based cropping systems resulted in higher N<sub>2</sub>O emissions in rainfed fallow periods than during wet and dry growing seasons. Especially, when the soil water content was less than field capacity, N<sub>2</sub>O emission between wetting event averaged 10 times higher than that emitted during the flooded rice season. Higher emissions during the fallow periods were most likely a result of increased accumulation of available NO<sub>3</sub> – N but there was significant effect on N<sub>2</sub>O emissions between OF and GM treatments during fallow periods.

### 3.2 CH<sub>4</sub> Emission

Methane emission dynamic from paddy field under long-term different N management practice is depicted in figure 4. Methane emission was majored in flooding period of the entire rice-growing season. In general, its emission increased gradually from after transplanting to before drainage during rice-growing season, then suddenly reduced because of drainage event and further

decreased with the extension of drainage stage. When rice field was re-flooded, methane emission rate gradually increased again and a peak appeared at the heading stage, thereafter, gradually decreased till to harvest. The results indicated that flooding condition favored methane emission than drainage event. This was consistent with the general observations that alternate flooding and drainage should be meritorious in reducing CH<sub>4</sub> emission from rice paddy soils as compared to the continuously flooding soils with a water layer. Yu et al (2001) noted that there was significant CH<sub>4</sub> emission under strict anaerobic conditions. The CH<sub>4</sub> oxidation activity has been found mainly under aerobic conditions (Yu et al. 2001). However, there is evidence that CH<sub>4</sub> can be oxidized under anaerobic conditions, but the oxidation rate was comparatively low (Miura et al. 1992). Many results have demonstrated that about 80% of CH<sub>4</sub> formed in rice fields was oxidized by methanotrophic bacteria in the soil before release into atmosphere (Holzapfel-Pshorn et al. 1986; Conrad and Rothfuss, 1991; Frenzel et al. 1992). Thus, the emissions of CH<sub>4</sub> from these soils treated by long-term different N sources management practices were the net result of CH<sub>4</sub> production and oxidation.

Methane is produced under low redox potential conditions by obligate anaerobes through either carbon dioxide (CO<sub>2</sub>) reduction or transmethylation processes (Vogels et al. 1988, Shangguan et al. 1993a and Wang et al. 1993). A well-oxidized soil has a redox potential range up to +400 to +700 mV, flooded soils may reach redox potential values of lower than -300 mV due to the absence of O<sub>2</sub> and the activity of facultative and obligate anaerobic bacteria (Patrick and Mahapatra 1968). Figure 5 depicts the dynamics of redox potential (Eh) during rice-growing period under long-term different N management practices in this study. The maximum emission of CH<sub>4</sub> in this experiment occurred at the early growth stage of rice (tillering stage) and reached 16.51 C mg m<sup>-2</sup> h<sup>-1</sup> in GM (-239.2 mV), 7.01 C mg m<sup>-2</sup> h<sup>-1</sup> in OF (-216.5mV), 3.16 C mg m<sup>-2</sup> h<sup>-1</sup> in CF (-133.7 mV) and 2.51 C mg m<sup>-2</sup> h<sup>-1</sup> in NF (-125.8mV). However, at the end of mid-drainage period, the methane emission rate was decreased to 0.28 mg m<sup>-2</sup> h<sup>-1</sup> in GM (455.8 mV), 0.27 mg m<sup>-2</sup> h<sup>-1</sup> in OF (289.7 mV), 0.18 mg m<sup>-2</sup> h<sup>-1</sup> in CF (361.5 mV), and 0.07 mg m<sup>-2</sup> h<sup>-1</sup> in NF (352.5 mV). The effect of drainage event on mitigation of CH<sub>4</sub> emission was very significant for each treatment. It was found that CH<sub>4</sub> emission increased with the decrease of redox potential in all the treatments and vice versa.

Total CH<sub>4</sub> emissions from these rice paddies during rice-growing period were 10.88 C g.m<sup>-2</sup>, 5.18 C g.m<sup>-2</sup>, 3.38 C g.m<sup>-2</sup> and 1.74 C g.m<sup>-2</sup> in GM, OF, NF and CF treatment, respectively (Table 3). The significant difference in the effect of CH<sub>4</sub> emission was mainly attributed to different

fertilization patterns. Among treatments, CH<sub>4</sub> emission from both OF and GM treatments was 2 to 6 times higher than that from CF treatment. It implied that application of organic fertilizers greatly promoted methane emission than chemical N fertilizer. Yang et al. (1997) reported that application of organic fertilizer hastened the decrease in redox potential and increased CH<sub>4</sub> production and emission. But the effect of green manure-fresh clover as soil amendment on CH<sub>4</sub> emission was 2 times higher than that of rice straw plus soybean cake addition in this study. Addition of green manure stimulated CH<sub>4</sub> emission and the effect was more significant at the vegetative growth stage of rice. It can be mainly due to rapid decomposing fresh green manure at the early stage of rice growth in flooded condition where promoted CH<sub>4</sub> emission.

Yagi et al. (1990) found that CH<sub>4</sub> emission from paddy field applied un-composted rice straw at 6 to 10 t ha<sup>-1</sup> was 2 to 3.5 times higher than that from receiving no rice straw. But application of the equivalent amount of composted rice straw caused a little amount of CH<sub>4</sub> emission. Shangguan et al. (1993) also noted that addition of fresh organic fertilizers greatly promoted CH<sub>4</sub> production and emission than that of composted one. Cai et al. (1994) found that addition of pig manure increased CH<sub>4</sub> flux, but its effect was not so pronounced as expected presumably due to the low content of easily decomposable organic matter in pig manure. Hou et al. (2000) also reported that the different effect of organic matter might be closely related to the content of easily decomposable organic matter based on the bacteria group experiments. So, in order to mitigate CH<sub>4</sub> emission while improving soil fertility through organic fertilizers addition, it can be an effective option to apply composted organic fertilizer in rice production practice. In addition, CH<sub>4</sub> emission from CF treatment was 50% lower than that from NF treatment in this study. It indicated that application of ammonium sulfate as chemical N fertilizer greatly reduced CH<sub>4</sub> emission. The basic reason was probably that SO<sub>4</sub><sup>-</sup> in soil greatly suppressed CH<sub>4</sub> production and then reduced CH<sub>4</sub> emission (Schutz et al. 1989; Liandau et al. 1990; Cai et al. 1994).

### **3.3 CO<sub>2</sub> Emission**

CO<sub>2</sub> emission is usually taken as standard tool for estimating microbial activities. The factors which influence the production and emission of CO<sub>2</sub>, are soil moisture, organic matter content, temperature and pH etc. In this experiment, CO<sub>2</sub> emission dynamics for all treatments was almost similar to that of CH<sub>4</sub> during rice-growing period, but the emission rates of CO<sub>2</sub> were significantly higher than that of CH<sub>4</sub> (Figure 6). Lower CH<sub>4</sub> emission was mainly attributed to oxidation of small amount of CH<sub>4</sub> to CO<sub>2</sub> as evidenced by Cai (1999). Similarly, the treatment

receiving organic fertilizers here showed stronger CO<sub>2</sub> emission rate than other treatments. This indicated that organic matter addition enhanced microbial activity resulting in strengthening of CO<sub>2</sub> emission. Cai (1999) found that addition of organic fertilizer could increase CO<sub>2</sub> emission no matter in aerobic or anaerobic condition in paddy soils. In this study, OF treatment showed higher CO<sub>2</sub> emission rate than that of GM treatment during the whole rice-growing season. Application of composted organic fertilizer was probably the main reason for increased CO<sub>2</sub> emission. Particularly, there was very high CO<sub>2</sub> emission at the tillering stage and heading stage for all other treatments besides OF treatment. It was closely related to the vigorous growth of rice besides the contribution of anaerobic microbial activities during these periods.

The total CO<sub>2</sub> emission in different treatments was in the order of OF>GM>CF>NF (Table 3). CO<sub>2</sub> emissions from CF, OF and GM treatments were 1 to 2 times higher than that from control treatment. The emission of CO<sub>2</sub> in OF and GM treatment was 22% and 7% higher than that of CF treatment, respectively and the addition of green manure (GM) decreased the CO<sub>2</sub> emission to an extent of 13% compared to OF treatment.

### 3.4 Gross greenhouse effect

Based on the global warming potential (CO<sub>2</sub>:CH<sub>4</sub>:N<sub>2</sub>O=1:21:310) (IPCC, 1996), the contribution of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission to gross greenhouse effect from these long-term experimental plots varied from 87% to 97%, 2% to 12%, and less than 1%, respectively (Table 4). It implied

**Table 4. The contributions of N<sub>2</sub>O, CO<sub>2</sub> and CH<sub>4</sub> to gross greenhouse effect**

		Gross emission rate				Emission percentage			
		NF	CF	OF	GM	NF	CF	OF	GM
g CO <sub>2</sub> .m <sup>-2</sup>	N <sub>2</sub> O	11.1	12.0	6.1	5.9	1.0%	0.6%	0.2%	0.2%
g CO <sub>2</sub> .m <sup>-2</sup>	CH <sub>4</sub>	94.6	48.6	144.9	304.8	8.6%	2.3%	5.4%	12.1%
g CO <sub>2</sub> .m <sup>-2</sup>	CO <sub>2</sub>	990.2	2061.5	2519.9	2202.4	90.4%	97.1%	94.3%	87.6%
g CO <sub>2</sub> .m <sup>-2</sup>	Total	1095.8	2122.2	2671.0	2512.9	-	-	-	-

NF: no fertilizer CF: chemical N fertilizer OF: organic manure GM: green manure

N<sub>2</sub>O was not the major factor influencing global warming but CO<sub>2</sub> and CH<sub>4</sub> in the present study. However the residence time of CH<sub>4</sub> in atmosphere is much shorter and its infrared absorbing potential is 21 times higher than that of carbon dioxide. Therefore, to reduce CH<sub>4</sub> concentration in the atmosphere is much more effective than to reduce CO<sub>2</sub> concentration to alleviate global warming (Hogan et al. 1991). Hence, there should be some cultural practices to mitigate CH<sub>4</sub> emission from rice paddies. The practices such as mid-season aeration during rice growth period is required to increase rice grain yield besides minimizing CH<sub>4</sub> emission. In comparison with

these four treatments, the ranking of gross greenhouse effect was OF>GM>CF>NF (Table 4). It revealed that organic fertilizers addition increased greenhouse effect to a greater extent than chemical N fertilizers and there is a greater concern to overcome the problem resulted from organic materials application.

## 4. Conclusions

Nitrous oxide emission was very low during rice growing season although obvious emission resulted during mid-drainage event for each treatment. There was a significant difference in gross emission fluxes among treatments. Nitrous oxide emission in CF treatment was 50% higher than that in OF and GM treatment but no statistical difference between OF and GM. It indicated that the application of organic fertilizer would greatly reduce N<sub>2</sub>O emission. A gradual increase in nitrification in surface soil layer during fallow period of paddy field experiment may help N<sub>2</sub>O emission. Also, there were significant differences in CH<sub>4</sub> and CO<sub>2</sub> emission among treatments. Average CH<sub>4</sub> emission from OF and GM treatment was 4 times higher than that from CF treatment and from GM treatment was 2 times higher than that from OF treatment. Carbon dioxide emission from OF and GM treatment was 22% and 7% higher than that from CF treatment and from OF treatment was 13% higher than that from GM treatment. It indicated that organic materials addition favored both CH<sub>4</sub> and CO<sub>2</sub> emission compared to chemical N application. Addition of green manure contributed more of CH<sub>4</sub> emission and less of CO<sub>2</sub> emission compared to composted organic fertilizer in this study. Matured compost showed superiority in reducing CH<sub>4</sub> emission compared to green manure if reasonable irrigation was adopted. The contribution of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission to greenhouse effect in this experiment was in the order of OF>GM>CF>NF. However, Nitrous oxide emission was not the major factor influencing global warming but CH<sub>4</sub> and CO<sub>2</sub> in this study. There is a great concern to overcome the problem resulted from organic materials addition as soil amendment, but it is much more effective to reduce CH<sub>4</sub> concentration than to reduce CO<sub>2</sub> concentration in atmosphere to alleviate global warming. Hence, proper key measures should be taken to mitigate methane emission from rice paddies.

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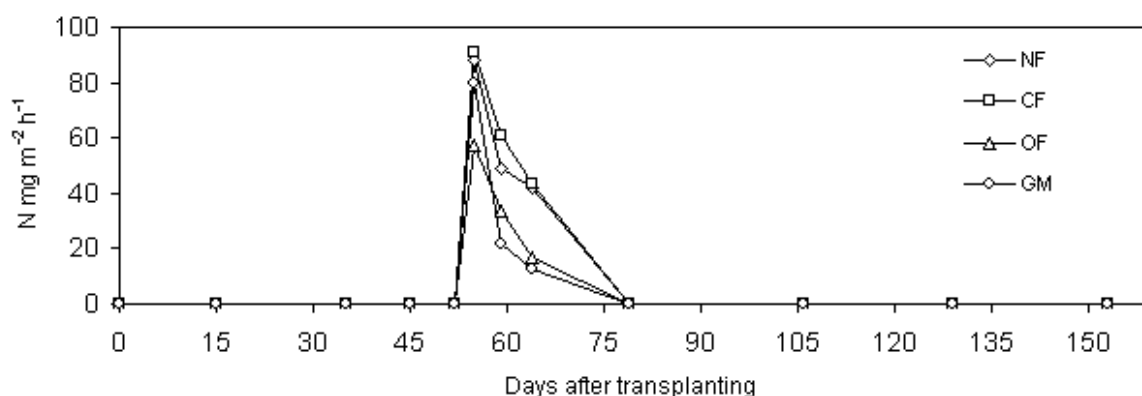
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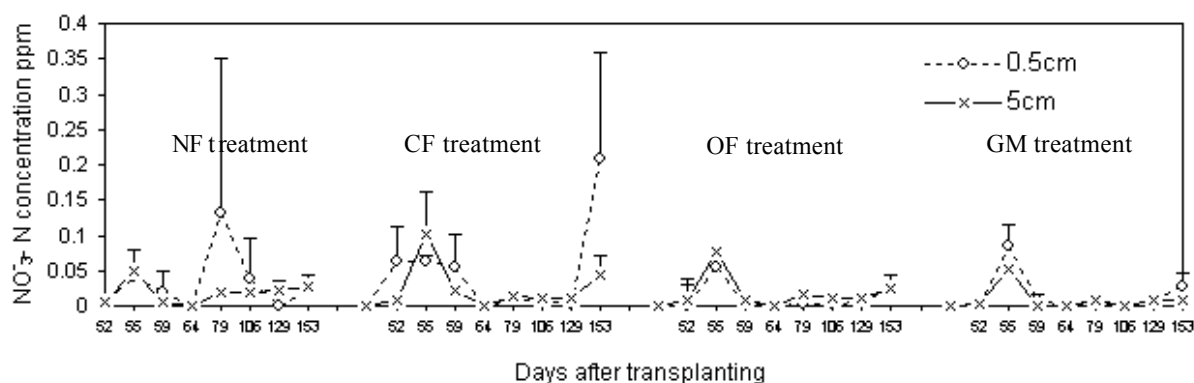
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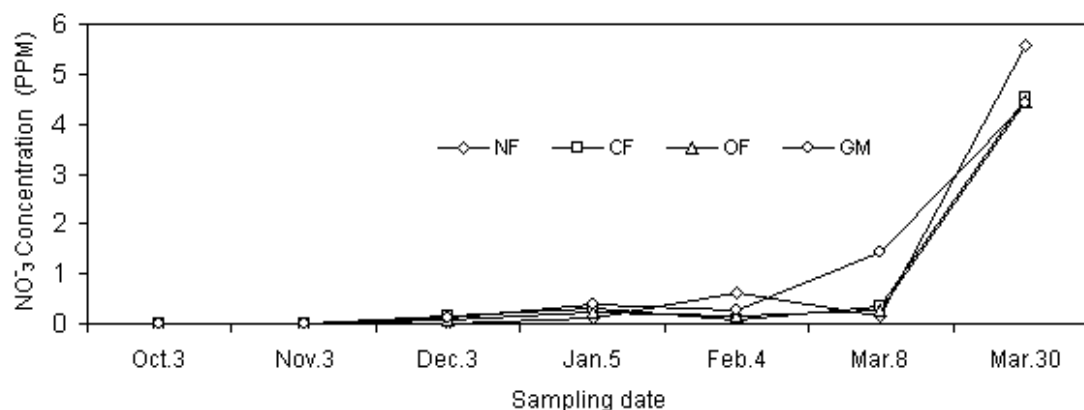
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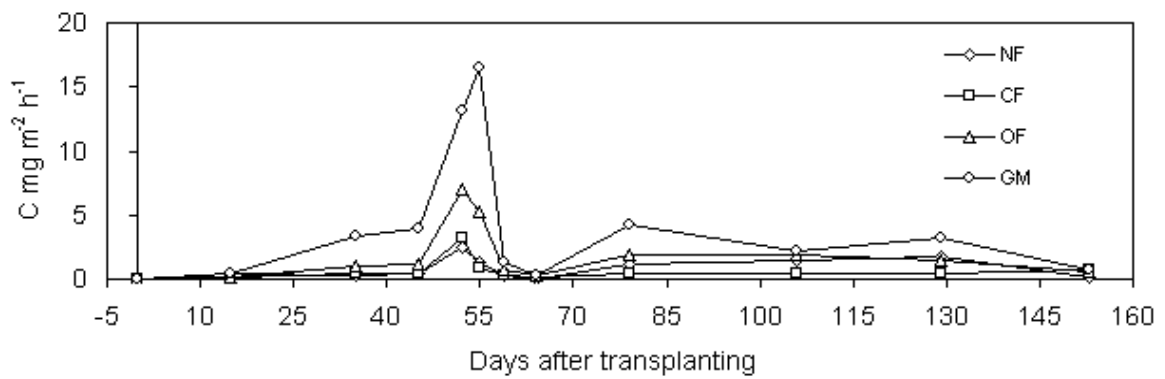
**Figure 1. Nitrous oxide emission flux from paddy ecosystems under long-term different N management practices**



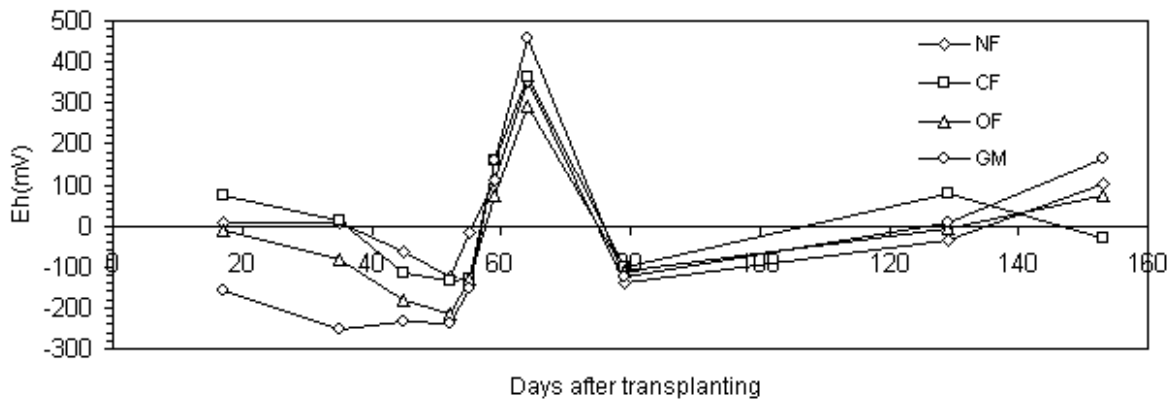
**Figure 2. Changes of Nitrate N content at 0.5 and 5 cm below soil surface in experimental plots under long-term different N management practices**



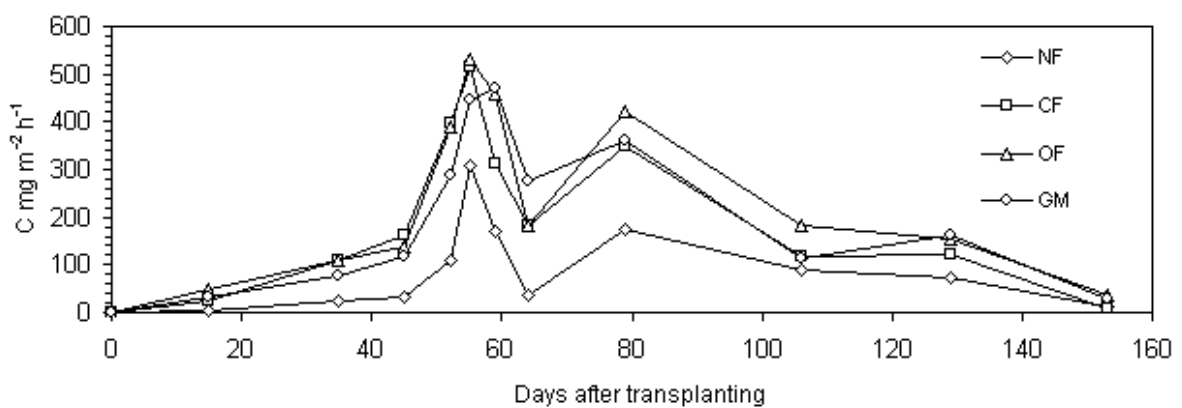
**Figure 3. Changes of Nitrate N at 0-15 cm depth in paddy field fallow period under long-term different N source management practices**



**Figure 4. Methane emission flux from paddy ecosystems under long-term different N management practices**



**Figure 5. Dynamics of redox potential during rice growth period under long-term different N management practices**



**Figure 6. Carbon dioxide emission flux from paddy ecosystems under long-term different N management practices**