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Research Article

Impact of Nitrogen Application on Greenhouse Gas Emission from Flooded Rice Soils

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Abstract

Methane (CH_4) and nitrous oxide (N_2O) are the two potent greenhouse gases which contribute to global warming in the atmosphere. Rice crop require high amount of N based fertilizer for economical production and unmanaged application of these fertilizer may lead to higher emission of N_2O and CH_4 emission from rice soils. In this study we investigated the impact of nitrogen fertilizer on CH_4 and N_2O emission from rice soils. N1 (90 kg N ha^{-1}) treatment reduced total cumulative CH_4 and N_2O emission as compared to control (120 kg N ha^{-1}). The highest global warming potential of 1540 kg CO_2 eq. ha^{-1} was found with N2 (150 kg N ha^{-1}) followed by control (1498 kg CO_2 eq. ha^{-1}) and N1 (1317 kg CO_2 eq. ha^{-1}). On the basis of observed data, we concluded that application of urea at optimum level is potential in reducing both CH_4 and N_2O emissions from rice.

Keywords: Global warming potential, Greenhouse effect, Methane, Nitrogen, Nitrous oxide, Rice

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Introduction

Greenhouse effect resulting in global warming is currently one of the main environmental issues. Now a day's agricultural contribution to total global greenhouse gases (GHG) is around 10-12% constituting mainly nitrous oxide (N_2O) and methane (CH_4) emissions accounting for 60% and 50% of global, respectively [1, 2]. In the present scenario of climate change, various efforts are being employed out of concern to reduce the GHG emission from agricultural field. Rice which is one of the most important food grain and around 50 % of the world population rely on it as a source of food and nutrients. Upland cropping system is primarily responsible for the N_2O emission and on the other hand the lowland flooded rice cultivation system majorly contributes to the CH_4 emission. Accounting for annual global CH_4 emission from rice fields, it contributes 31-112 Tg (Tg = 10^{12} g), that is around 5%-19% of the overall CH_4 emissions [1]. Therefore, there is need for various efforts that must concentrate on reducing CH_4 emission in order to reduce the overall GWP of paddy field; besides CH_4 we should also consider N_2O emission as it has been reported that many strategies while reducing the CH_4emissions tend to upsurge N_2O emissions [3].

Among various strategies to reduce the CH_4 emission like direct seeding, limiting period of soil submergence, residue managements etc. [4]; fertilizer management can also affect CH_4 and N_2O emission and have been studied by many researchers [5-8] with various inconsistencies varying from place to place. Some recent field studies reported a decrease in net CH_4 emissions from paddy field by roughly 30–50% with high rates of N [9, 10]. However, some experimental results pointed out towards an increase in CH_4 emissions with fertilizer N addition which may be due to increased rice biomass facilitating the gas transport through arenchymatous tissue of rice plant [11], and/or by enhancing the carbon substrate availability for methane producing bacteria (methanogens) [12, 13]. Overall, the impacts of different N doses on CH_4 emission from flooded rice fields are mostly undefined and inconsistent. Therefore, there is a need for a quantitative synthesis and analysis of research data to analyze the impact of different nitrogen doses on GHGs emission from rice field under Indian condition in order to determine mitigation option for rice system. It has been shown that fertilizer N majorly influence CH_4 and N_2O emissions from flooded rice condition, however there is very limited research works related to the impact of N rate when evaluating global warming potential (GWP) per unit area on a seasonal basis.

Material and Methods

Site Descriptions

The experiment was carried out during the *kharif* season of the year 2015 on the research farm of Indian Agricultural Research Institute, New Delhi, India. The climate of Delhi is subtropical, semi-arid characterized by dry winters and most of the rainfall occurs during June to September (**Figure 1**). The physico-chemical properties of the soil are given in **Table 1**.

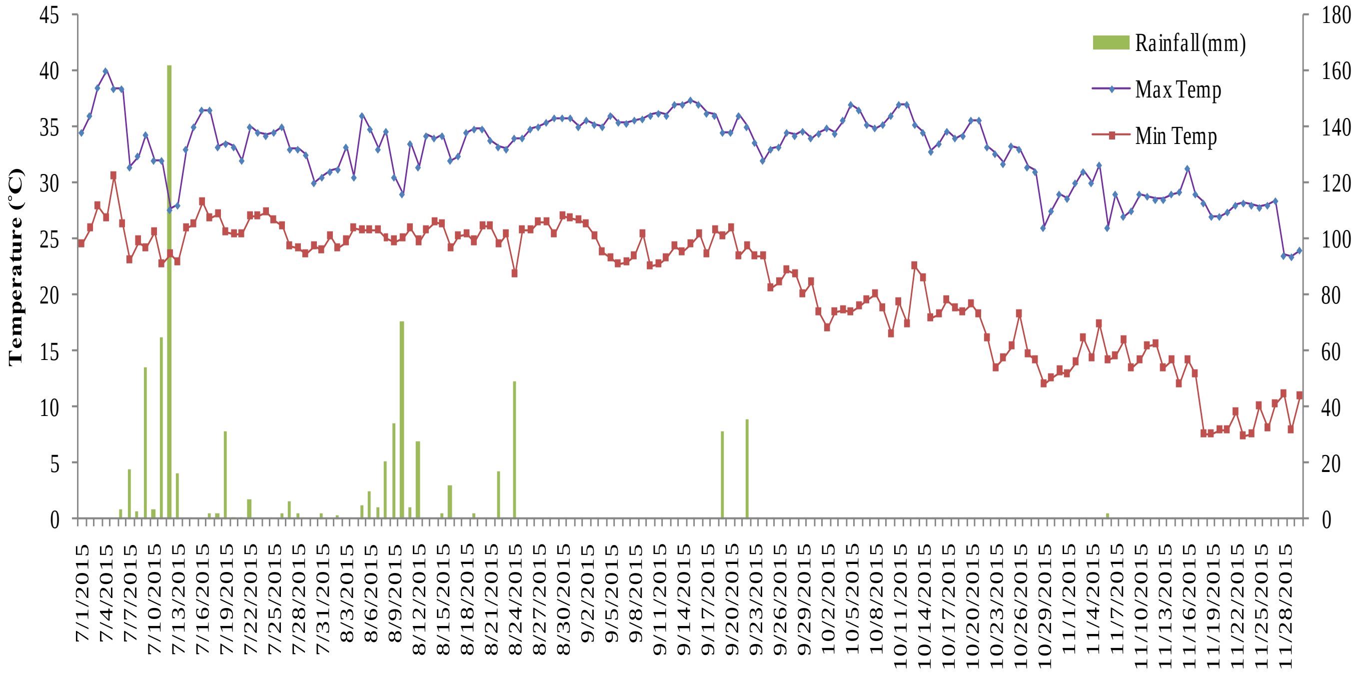

Figure 1 Temporal variation in temperature and mean rainfall during rice growing season

Table 1 Pre-transplanting physicochemical properties of the experimental site

Soil parameter	Value
Sand (%)	46
Slit (%)	31
Clay (%)	24
pH (1:2.5 : soil: water)	8.5
Organic C (%)	0.46
Hydraulic conductivity (cm d^{-1})	4.5
Olsen P (kg ha^{-1})	29.9
$KMnO_4$ extractable N (kg ha^{-1})	248
NH_4^+-N (kg ha^{-1})	26.8
NO_3^--N (kg ha^{-1})	33.1
Moisture content at field capacity (%)	23.2

Experimental design and treatments details

The experimental field trial was arranged as a randomized complete block design (RCBD) with three replications. The crop was treated with three different levels of N with three replications each. Complete treatment details are listed in **Table 2**. Rice (*Oryza sativa* L.) variety Pusa Basmati 1509 was adopted for conducting the experiment. Two to three rice seedlings (23 days age) were transplanted at 15 x 20 cm spacing. Continuous flooded condition was maintained with a water level of 8 ± 4 cm using groundwater for irrigation for the entire cropping season. Weeding was done manually and no chemicals (pesticide and herbicide) were used in order to avoid their additional effects. Irrigation was stopped and field was allowed to dry naturally for three weeks before the harvesting of crop.

Table 2 Treatment details

Treatment	Dose	Remarks
Control	N (120 kg N ha^{-1}), P (60 kg P_2O_5 ha^{-1}), K (40 kg K_2O ha^{-1})	N (Urea) applied in three splits in 50% (basal), 25% (tillering) and 25% (panicle initiation) of total dose, while P and K were applied in single dose as basal
N1	N (90 kg N ha^{-1}), P (60 kg P_2O_5 ha^{-1}), K (40 kg K_2O ha^{-1})	N (Urea) applied in three splits in 50% (basal), 25% (tillering) and 25% (panicle initiation) of total dose, while P and K were applied in single dose as basal
N2	N (150 kg N ha^{-1}), P (60 kg P_2O_5 ha^{-1}), K (40 kg K_2O ha^{-1})	N (Urea) applied in three splits in 50% (basal), 25% (tillering) and 25% (panicle initiation) of total dose, while P and K were applied in single dose as basal

Gas sampling and analysis

Gas samples were collected manually in the early morning between 9 am to 10:30 A.M. by using closed chamber technique [14]. During gas sampling event, gas samples were withdrawn from top of the closed chamber (closed for 60 min) using 20 ml air-tight syringes fitted with hypodermic needle at 0, 30 and 60 min at 7 days of regular interval throughout the rice season (**Figure 2**). Gas chromatography was used for further analysis of the gas sample for CH_4 and N_2O concentration using flame ionization detector (FID) and Electron capture detector (ECD) respectively.

Estimation of global warming potential

In this study, the Global warming potential (GWP) on a 100 year time horizon was calculated for each treatment by using equation:

$$\begin{aligned} GWP &= CH_4 + N_2O \ (\text{kg } CO_2 \text{ eq. } ha^{-1}) \\ &= CH_4 \ (\text{kg } ha^{-1})*34 + N_2O \ (\text{kg } ha^{-1})* 298 \end{aligned}$$

where 298 and 34 are GWP coefficients to covert N_2O and CH_4, respectively, to CO_2 equivalents [15].

Figure 2 Closed chamber and sampling set up for GHGs (CH_4 and N_2O) sampling from paddy field, IARI, New Delhi

Results and Discussion

Emission of CH_4 from rice soils

In the present study we found that methane emission was low during the first three weeks which further increased significantly with crop growth and lowering of soil redox potential. CH_4 emission increases after 21 days after transplanting (DAT) and first highest peak of CH_4 flux was observed at 35 DAT. Similar pattern of CH_4 flux has been also reported by Malyan and their coworkers [16]. Continued flooding conditions create an anaerobic environment in soil which enhances the process of methanogenesis. In methanogenesis process, soil anaerobic bacteria (methanogens) consume soil organic carbon and liberate CH_4 as a byproduct [4, 17]. The flux was found to be highest in N2 treatment which ranged from 0.01 kg CH_4 ha^{-1} d^{-1} to 0.69 kg CH_4 ha^{-1} d^{-1} (Figure 2). Urea on application in rice soil gets hydrolysis into ammonium ions which were further consumed by rice plant. CH_4 molecule and ammonium ion have similar structure (tetrahedral) and on application of excessive urea in soil result in higher ammonium ions concentration in soil. Under high ammonium ion concentration in soil, methanotrophic bacteria (CH_4 oxidizing bacteria) consume ammonium ion instead of CH_4 which may be the reason of higher CH_4 flux in N2 treatment [13]. Methane emission in every treatment drops after maturity (**Figure 3**) and it may be due to higher soil redox potential and less aerenchymal function in late period of crops. The cumulative CH_4 emission was highest in N2 treatment (33.75 kg CH_4 ha^{-1}) flowed by control and N1 treatments (**Table 3**).

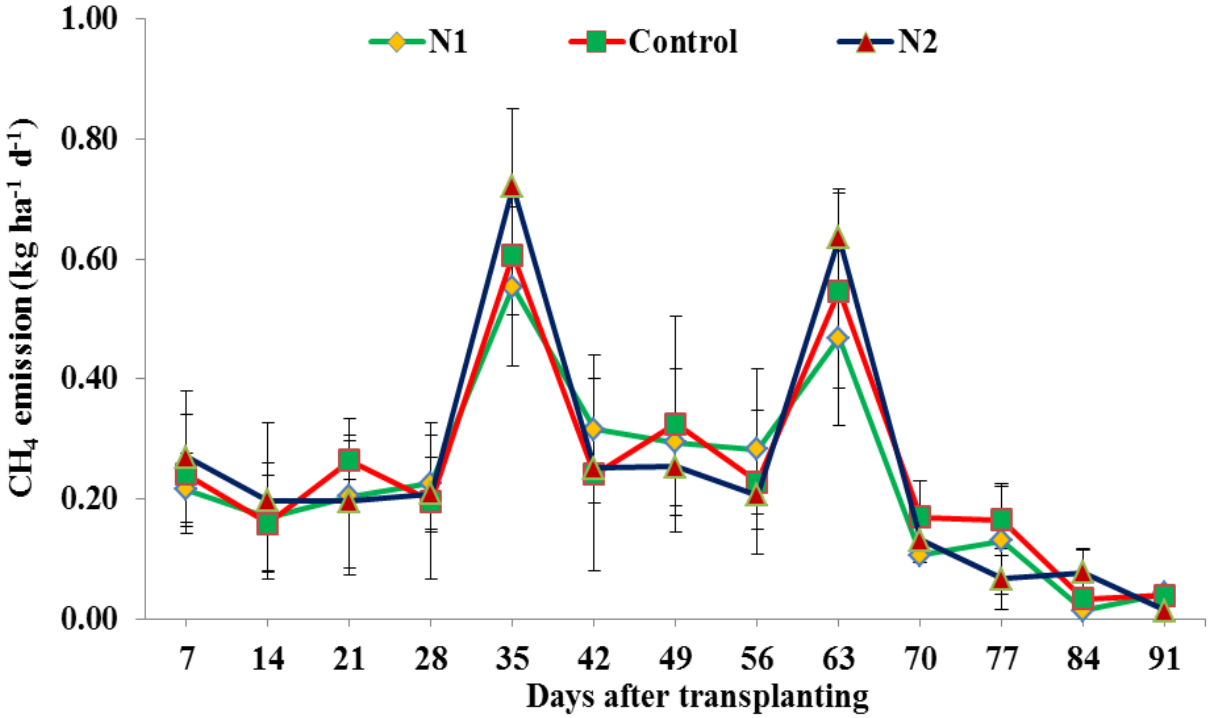

Figure 3 Temporal variation in CH_4 emissions from rice soil under different nitrogen doses

Table 3 Global warming potential (GWP) of rice system per unit area per season

Treatment	**CH_4 (kg ha^{-1})**	**GWP (CH_4)**	**N_2O (kg ha^{-1})**	**GWP (N_2O)**	**GWP (kg CO_2 eq. ha^{-1})**	**Reduction in GWP (%)**
Control	33.45	1137	1.21	361	1498	Control
N1	31.42	1068	0.83	249	1317	12.08
N2	33.75	1148	1.32	393	1540	-2.80*

*Higher emission than control

Emission of N_2O from rice soils

During the rice growing season, the N_2O flux was found to be high on the 1st DAT which further decreased with days afterwards (**Figure 4**). High rate of N_2O emission was observed due to the process of nitrification and denitrifcation in rice soils [18Anderson et al., 1988; Davidson, 1992; Skiba et al., 1996). During initial days, we observed higher peak of N_2O in N2 treatment as compared to control which was due to basal application of N fertilizer in N2 treatment. As soil nitrate N content decreased due to loss through denitrification, the flux declined few DAT. The cumulative N_2O emission was found to be highest in N2 treatment (1.32 kg N_2O ha^{-1} $season^{-1}$) while lowest in N1 treatment (0.83 kg N_2O ha^{-1} $season^{-1}$).

Cumulative greenhouses gas emission in terms of global warming potential

The GWP of different treatments in rice crop varied from 1317 to 1540 kg CO_2 eq. ha^{-1} (Table 3). The higest GWP was observed in N2 treatment while lowest was in N1 treatment (Table 3). As compared to control N1 treatment reduced GWP about 12% and we observed higher GWP in N2 treatment as compared to control (Table 3). The order of GWP among the treatments was as follows: N2 < Control < N1 (Table 3).

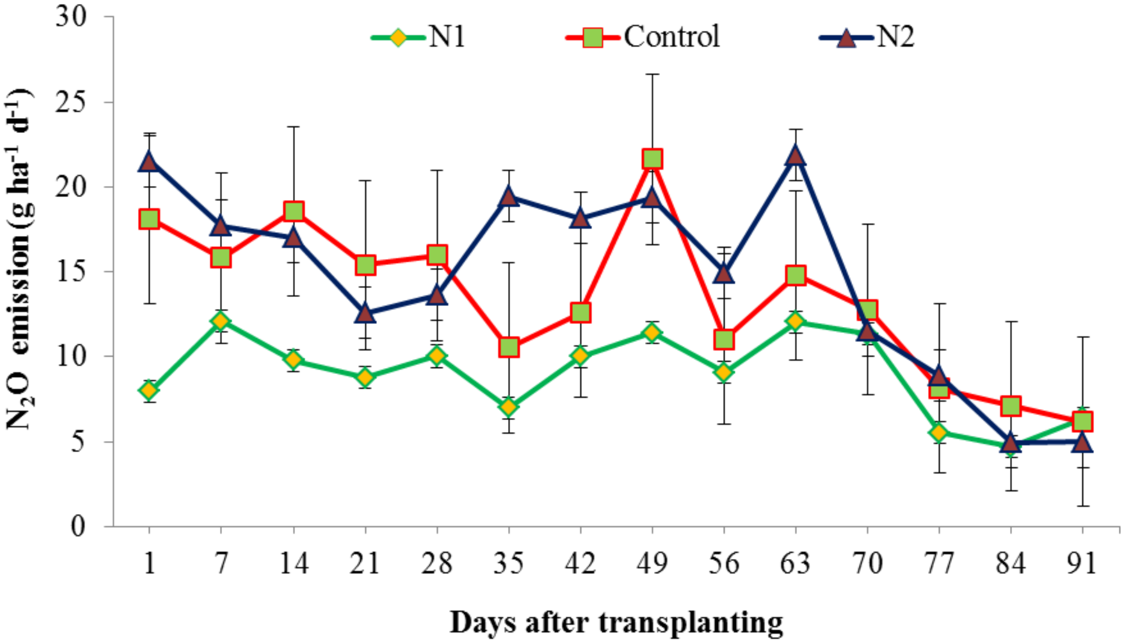

Figure 4 Temporal variation in N_2O emissions from rice soil under nitrogen application

Conclusions

The flooded rice is a major source of CH_4 and N_2O emssions. The adoption of different management practices such as water management, fertlizer management and application of optmuin organic fertlizer can reduce emission from rice. This study indicated that, application of urea as nitogenous fertiliser at optmiun level could be a viable option to reduce GWP (about 12%) as compared to control.

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