Seasonal emissions of methane and nitrous oxide from rice-wheat cropping system during 2002 and 2003

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Methane (CH₄) and nitrous oxide (N₂O), important atmospheric greenhouse gases (GHGs) and rice-wheat ecosystem has been identified as one of the important anthropogenic sources of GHGs in agriculture sector. The water management in a given rice-wheat ecosystem plays a crucial role in its GHGs emission. It has been observed that the water regime in irrigated rice fields with sandy loam soils becomes intermittently flooded, due to high water percolation, which has a direct bearing on CH₄ emissions. Wheat crop on the other hand does not need water flooding; hence N₂O becomes important due to oxic environment. Intermittently flooded water regimes were simulated at NPL experimental fields to estimate the seasonal emissions of CH₄ and N₂O from rice-wheat cropping system during 2002-2003. The CH₄ and N₂O flux from wheat ecosystem was in the range of – 0.36-1.06 mg m⁻² h⁻¹ and – 0.10-1.22 mg m⁻² h⁻¹, respectively. The CH₄ and N₂O emission from rice cultivation was in the range of – 0.65-1.25 mg m⁻² h⁻¹ and – 0.32-0.43 mg m⁻² h⁻¹, respectively, from irrigated intermittently flooded (IR-IF) multiple aeration (MA) ecosystem. The CH₄ and N₂O seasonal integrated flux (Eₗ₃) from wheat culture were 1.02 ± 0.26 and 0.50 ± 0.12 gm⁻² respectively, and from rice cultivation for IR-IF-MA ecosystem 0.52 ± 0.36 and 0.28 ± 0.20 gm⁻², respectively. The CH₄ emissions were significantly low from IR-IF-MA rice ecosystem and were surprisingly higher comparatively, from the wheat crop. It may be because of frequent rainfall events and high soil temperature in wheat cropping season.

Keywords: Greenhouse gases (GHG); Rice-wheat ecosystem; Water management
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1 Introduction

Methane (CH₄) and nitrous oxide (N₂O), important atmospheric greenhouse gases (GHGs), have a global warming potential of 23 and 296, relative to CO₂ for a time horizon of 100 years, and a lifetime of 8.4 and 120 years, respectively. With their respective globally averaged ambient value of 1,745 ppb and 314 ppb in 1998, concentration of CH₄ and N₂O is increasing at an annual rate of about 0.5% and 0.25% yr⁻¹. Rice is generally grown in waterlogged condition, which creates an anoxic environment and is conducive for CH₄ production by the anaerobic methanogenic bacteria. The major sink for atmospheric CH₄ is by OH radical in the troposphere. For N₂O emission, soil is considered to be one of the major sources, contributing 65% to the total global emission. Annual emission of N₂O from agricultural system amounts to 6.3 Tg, which includes the direct emission from agricultural soil, animal system and the indirect emission from agricultural soil through loss of nitrogen to aquatic system and atmosphere. The emission of N₂O is an integral part of the N-transformation processes in soil. The biological processes of de-nitrification, nitrification, dissimilatory nitrate reduction and assimilatory nitrate reduction, as well as the abiological reactions of chemo-de-nitrification are the possible mechanisms of N₂O emission from soil. However, it has been established that de-nitrification and nitrification are the most important mechanisms, others contributing very little (< 1%) to this pool. De-nitrification in soils also consumes N₂O through its reduction to nitrogen. Hence de-nitrification may serve either as a source or as a sink for N₂O.

Out of several factors affecting GHGs emission, water management in a given rice-wheat ecosystem plays a crucial role. It has been observed that the water regime in irrigated rice fields with high water percolation and poor water supply, often results into multiple aeration, which has a direct bearing on CH₄ emissions. Wheat crop on the other hand does not have water flooding; hence due to oxic environment N₂O becomes important. Intermittently flooded water regimes were...
simulated at NPL experimental fields. This paper presents the measurements of CH$_4$ and N$_2$O seasonal emissions from rice (IR-IF-MA water regime) and wheat cropping system carried out during December 2002 to November 2003 period.

2 Site description & measurement methodology

2.1 Site description

Field experiments were conducted in experimental plots in the nursery of NPL, New Delhi for rice-wheat systems from December 2002 to November 2003. The climate of Delhi is subtropical semi-arid. Under average climatic conditions, the area receives 750 mm annual rainfall, about 80% of which occurs from June to September. The mean annual maximum and minimum atmospheric temperatures are 35 and 18 °C, respectively. In general the alluvial soils of experimental site was sandy loam in texture (51% sand, 24% silt, 25% clay) and had a pH of 8.2, electrical conductivity 0.49 m-mhos cm$^{-1}$, CEC 1 5.2 meq/100g; soil organic carbon 0.4%, C-N ratio of 9.2 and water percolation rate of 480 mm day$^{-1}$.

Wheat (variety HD-2285) was sown in 10 cm (row-to-row) by 15 cm (hill-to-hill) spacing. Rice seedlings (variety – Pusa Basmati-I) 30 days old were transplanted at 15 cm (row-to-row) by 15 cm (hill-to-hill) spacing. Irrigation in rice was given at 3-4 days and for wheat at 20 days interval. There were four rainfall events at 1st, 29th, 49th and 50th day after sowing (DAS) during the wheat crop duration, and only one on the 7th day after transplantation (DAT) during the rice crop duration. Soil became aerated many times in rice field due to high water percolation. For the wheat crop (30 Dec. 2002 to 29 Apr. 2003) the fertilizer application was given as NPK in the ratio of 150:75:75 [150 kg N/ha as urea in three equally split doses viz. 50 kg N/ha as basal and 50 kg N/ha each at 28 and 49 DAS] was applied; and Phosphorus and Potassium (75 kg/ha each) were incorporated into the soil at the time of sowing using single super-phosphate (SSP) and muriate of potash (MoP), i.e. KCl, respectively. For the rice crop (29 July 2003 to 25 Nov. 2003) the fertilizer application was given as NPK in the ratio of 150:75:75 [150 kg N/ha as urea in three equally split doses viz. 50 kg N/ha on 29 July 2003 as basal and 50 kg N/ha each at 35 and 62 DAT] was applied; and phosphorus and potassium (75 kg/ha each) were incorporated into the soil at the time of sowing using SSP and MoP, respectively. Also 50 kg/ha ZnSO$_4$ was applied as a basal dose.

2.2 Collection of field gas samples

Collection of gas samples was carried out by closed chamber technique$^{5-8}$. This technique consisted of fixing rectangular aluminum bases (50 × 30 cm$^2$ area) inside the soil, mounted with a U-shaped channel filled with water to make the system airtight. Chambers of 52 × 32 × 72 cm$^3$ internal dimension made of 6 mm thick acrylic sheets with its open end rested on the channel. A pulse pump mixed the air inside the chamber. A thermometer was inserted in the box to monitor the inside box temperature. One 3-way stopcock was fitted at the top of chamber to collect gas samples by gas tight syringe. Gas samples at 0, 10, 20 and 30 min interval were collected from the chamber and one ambient sample was taken prior to the sampling. The chamber was lifted and kept aside after 30 min. Water level, channel height, plant height, number of panicles, paddy biomass volume, temperature inside the chamber, air and soil temperature were measured during each sample collection.

2.3 CH$_4$ and N$_2$O analysis

Methane concentration in the gas samples collected from the field was estimated by gas chromatograph (GC) (Model-SRI-8610C, USA) fitted with a flame ionization detector (FID), and 10’ × 1/8’’ o.d. stainless steel (ss) column filled with Porapak-Q (80-100 mesh). Column, injector, and detector temperatures were kept at 60, 160 and 270 °C, respectively with carrier gas as N$_2$ with a flow rate 10 cc min$^{-1}$. The GC calibration for CH$_4$ was done using NPL-India traceable secondary standard of 5.63 ppmv CH$_4$ in nitrogen. A NPL gas certified reference material (CRM) standard of 9.65 ± 0.66 ppmv CH$_4$ in nitrogen was also used for calibration. The N$_2$O concentration in the gas samples collected from the fields was estimated by GC (SRI-8610C) fitted with an electron capture detector (ECD), and 10’ × 1/8’’ o.d. ss column filled with Porapak-Q (80-100 mesh). Column, injector, and detector temperatures were kept at 50, 150, and 350 °C, respectively, with carrier gas as N$_2$ with a flow rate 10 cc min$^{-1}$. The GC calibration for N$_2$O was done using secondary standards of 1.05 ppmv N$_2$O, which had been compared with international standards traceable to world meteorological organization (WMO). The CH$_4$ and N$_2$O flux were calculated from the temporal increase of their mixing ratios inside the box$^{5-8}$. 

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Results and discussion

The CH$_4$ and N$_2$O flux data at each channel site was found to vary for each set of flux measurement carried out simultaneously within single plot, during whole cropping period, having the same paddy variety and age, because of the inherent variability in soil composition and water management. The mean seasonal integrated flux ($E_{sif}$) and its ranges were worked out by taking the daily mean of the flux data obtained, once during every week and integrating it over the whole cropping season (for rice as well as wheat crop, separately). Standard deviations from the mean flux for data, every week over the cropping season, are used to obtain the maximum and minimum ranges of $E_{sif}$.

The wheat crop duration of 120 days was from 30 Dec. 2002 to 29 Apr. 2003. The temporal variation in CH$_4$ flux from wheat ecosystem was in the range of $-0.36-1.06$ mg m$^{-2}$ h$^{-1}$ (Fig. 1) with seasonal integrated flux ($E_{sif}$) of $1.02 \pm 0.26$ gm$^{-2}$. The frequent
rainfall, high biomass and soil temperature after mid season (Fig. 1), led to more seasonal methane emission from wheat crop in comparison to rice, even though there were instances of methane sinks also due to in-between dry periods. The temporal variation in N₂O flux from wheat cropping system was in the range of – 0.10-1.22 mg m⁻² h⁻¹ (Fig. 1) with $E_{sat}$ as 0.50 ± 0.12 gm⁻². Initially, emission of N₂O was high, which decreased considerably on 2nd DAS and kept decreasing until the next dose of urea. High emission may be due to formation of N₂O during nitrification of ammonium nitrogen [(NH₄⁺)-N] already present in soil as well as NH₄⁺-N produced by the hydrolysis of urea given as basal dose. Subsequently, when NH₄⁺ contents in soil decreased as a result of nitrification, N₂O emission declined. The N₂O peaks were observed following the addition of urea at 28 DAS and 49 DAS intervals, followed by a decline in levels of N₂O emissions.

The rice crop duration was of 120 days from 29 July 2003 to 25 Nov. 2003. The temporal variation in flux of CH₄ from rice was between – 0.65 and 1.25 mg m⁻² h⁻¹ (Fig. 2) with $E_{sat}$ of 0.52 ± 0.36 gm⁻² from IR-IF-MA water management ecosystem. Rainfall event on 7 DAT resulted in the first methane peak at 8 DAT due to diffusion from soil followed by more peaks at 35, 70 and 98 DAT, corresponding to tillering, heading and flowering stages of rice crop, respectively. However, negative peaks were also observed, the first one around 2-6 DAT due to negligible biomass and low soil temperature; and the second one around 42 DAT due to reduced water and oxic soil conditions. Temporal variation in N₂O flux from rice field was between - 0.32 and 0.43 mg m⁻² h⁻¹ (Fig. 2) with $E_{sat}$ of 0.28 ± 0.20 gm⁻² for IR-IF-MA water management ecosystem. N₂O emission had shown an increase near harvest of rice crop (Fig. 2) due to soil aeration.

4 Conclusions

The CH₄ emissions were, unexpectedly higher in wheat ecosystem vis-à-vis intermittently flooded multiple aeration water regime of rice ecosystem, which may be mainly because of the rainfall events during wheat season coupled with high soil temperature. Rice fields had few rain events and multiple aeration due to high water percolation. Fluxes of N₂O from wheat ecosystem, was more following the applications of urea and reduced thereafter in a few days. Rice crop has shown less seasonal N₂O emission in comparison to wheat crop.

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