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Effect of Biopesticide on Nitrous Oxide Fluxes from Wetland Rice Paddy Ecosystems of South India

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Abstract: Wetland rice paddy ecosystems have been recently identified as a major source of atmospheric nitrous oxide which is currently increasing in the atmosphere at rates 0.7 ppbv yr^{-1}. The agricultural soil is the major anthropogenic N_2O source due to the application of synthetic fertilizers, organic nitrogen from animal excreta and crop residue and the amount of biological nitrogen fixation by leguminous crops. Thus in an effort to reduce uncertainties in the present study variation of N_2O fluxes were measured from Nemento amended rice microcosm and compared with control during different growth stages of rice plants. The N_2O fluxes from control cores varied from 1.2 mg m^{-2} d^{-1} at the time of transplantation to 2.44 mg m^{-2} d^{-1} during reproductive stage and 4.14 mg m^{-2} d^{-1} at harvest of rice plant. The N_2O fluxes from Nemento (nitrification inhibitor) amended cores varied from 1.49 mg m^{-2} d^{-1} at the time of transplantation to 1.84 mg m^{-2} d^{-1} during the reproductive stage and 2.32 mg m^{-2} d^{-1} at the time of harvest of the plant. The application of Nemento (Biopesticide) has thus resulted in reduction of N_2O emissions by 25% than control microcosms.
Key words: Agricultural soils, Anoxic paddy soils, Nitrous oxide emissions, N_2O flux, N_2O production, Rice paddies.

Introduction

Many natural and human-driven activities have caused significant changes in the atmospheric concentration of several greenhouse gases and are believed that these changes were leading to climate warming [1]. Besides affecting the climate, these gases play an important role in both tropospheric and stratospheric chemistry [2]. Nitrous oxide (N_2O) is an intermediate molecule formed during biological denitrification as well as a by-product produced during biological nitrification [3]. The atmospheric N_2O concentration has risen by about 12% from about 275 pp bv during pre-industrial times [4] to 311 pp bv [5,6]. [1]This growth rate clearly depicts the imbalance between sources and sinks with the source exceeding sink by 3.9 Tg yr^{-1}. Each molecule of N_2O traps outgoing infrared radiation within the troposphere up to 200 times more effectively than molecule of CO_2 [7]. The sources and sinks of N_2O are listed in Table 1. The total global emissions of N_2O from agricultural source in 1990 were 6.2 (1.2–16.9) Tg N_2O–N yr^{-1} [1]. The N_2O emission from rice field is generally low with only 0.01–0.1% of applied nitrogen is lost through emission [8,9]. But soil type, irrigation practices, type of fertilizer, method of fertilizer application, and soil temperature influence N_2O emission from rice paddy ecosystems.The N_2O emissions from paddy fields although small when compared with those from upland systems, represent a substantial source of atmospheric N_2O [10]. Mosier et al. (1990) demonstrated that young rice plants facilitated the efflux of N_2O from paddy soil to the atmosphere[11]. Yu et al. (1997) demonstrated that more than 80 % of the N_2O emission from paddy soil was through the rice plants[12]. Hence it is an open question as to what portion of N_2O emission to the atmosphere is

contributed from irrigated rice paddy fields. Thus in an effort to reduce uncertainties in the present study variation of N_2O fluxes were measured from control and Nemento amended rice cores during different stages of growth of rice plants.

Table 1: Estimated sources and sinks of Nitrous oxide in Tg yr^{-1} (IPCC, 1997)

Sources	Estimate	Range	Total
Natural			
1 Oceans	3.0	1 - 5	
2 Tropical soils			
Wet forests	3.0	2.2 - 3.7	
Dry savannas	1.0	0.5 - 2.0	
3 Temperate soils			
Forests	1.0	0.1 - 2.0	
Grasslands	1.0	0.5 - 2.0	
Total		4.3 - 14.7	9.0
Anthropogenic			
4 Agricultural soils	3.3	0.6 - 14.8	
5 Biomass burning	0.5	0.2 - 1.0	
6 Industrial sources	1.3	0.7 - 1.8	
7 Cattle and feedlots	2.1	0.6 - 3.1	
Total		2.1 - 19.7	7.2
		6.4 - 34.4	Total (Natural+Anthropogenic) = 16.2
Sinks			
1 Stratospheric sinks	12.3	9 - 16	
2 Soils			
Atmospheric Increase		3.1-4.7	3.9

Study Area

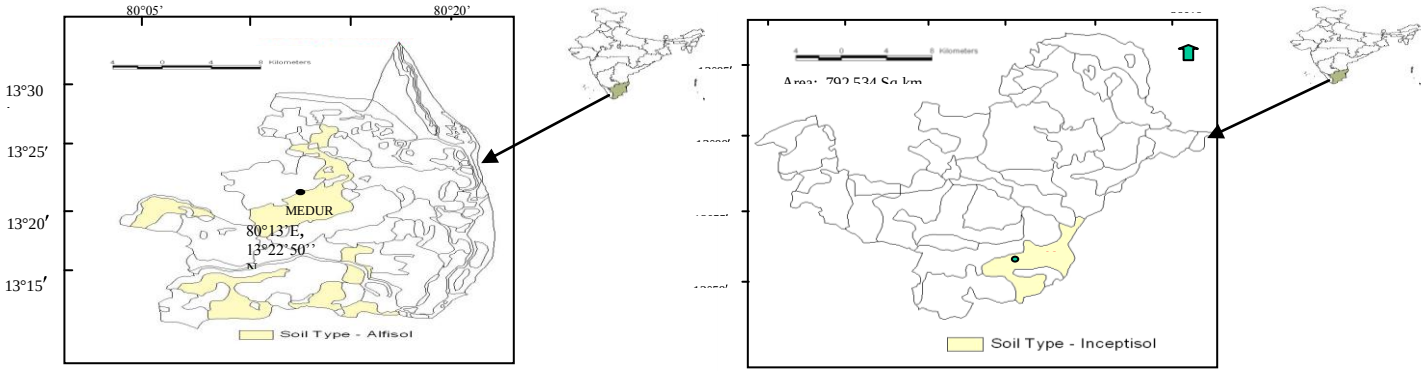
Agricultural Soil & Cultivar Type

The agricultural soils for rice microcosm studies were collected mainly from Medur and Paddapai located on the suburbs of Chennai, Tamilnadu. The physical and chemical characteristics of soil types are shown in (Table- 2). Medur is geographically located in 80°13'12" E longitude and 13°22'50" N latitude respectively (Figure- 1). Paddapai is geographically located in 80°1'15" E longitude and 12°52'40" N latitude respectively. The agricultural soils from irrigated rice paddy fields were uniformly spread in the shade and it is air dried for about a week at ambient temperature [13]. The air dried soil was uniformly crushed to a size less than 2mm diameter to give a homogenized sample. The homogenized soil was then thoroughly mixed with water in the ratio (2:1 w/w). The cylindrical acrylic cores of height 0.2 m and diameter 0.07 m were filled up to the height of 0.14 m (Figure- 2). The soil cores were left undisturbed in the shade for about a week and any water loss by evaporation was replaced by adding water to keep the water level 0.5- 1 cm above the soil surface. The rice variety IR 50 (short duration crop) was used to study the methane flux measurement in rice cores. It is a hybrid variety of IR 2153-14 x IR 28 x IR 36 and has the cultivation period of 110 days.[14]

Table 2: Physical and Chemical characteristics of Agricultural soil (Soil survey report, 1985)

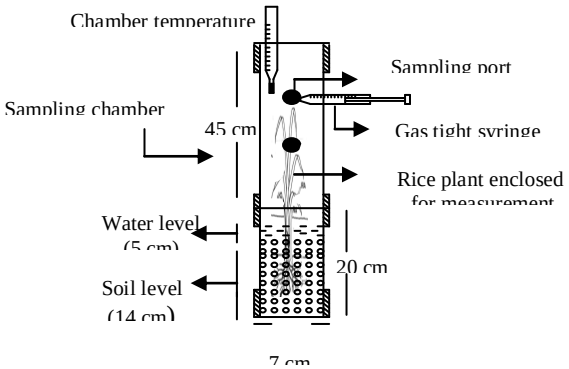
Soil Type	Colour	pH	Sand (%)	Silt (%)	Clay (%)	Organic Carbon (%)	Moisture (%)
Order: Alfisol **Family**: Fine loamy Udic Haplustalfs	Dark Brown	6-6.7	50-60	-	30-40	0.08-0.4	1.8-2.8
Order: Inceptisol **Family**: Fine Typic Ustochrepts	Light yellow brown	7-8	60-80	3-10	8-26	0.15-0.3	-

Figure 1: Schematic representation of agricultural soil from Medur and Paddapai



MEDUR PADDAPAI

Figure 2: Schematic diagram of nitrous oxide flux measurements in rice cores



Methology

Table 3: Dosage levels of different organic and inorganic amendment

Treatments	Concentration
Biopesticide (Nemento)	2 ml of culture was applied to rice cores after transplantation

The IR 50 germinated paddy seeds were allowed to grow undisturbed for about three weeks and the seedbed was moistened periodically to prevent the rice plant form wilting. The healthy rice seedlings were removed from the seedbed and transplanted in the cylindrical cores (Figure- 2). The details of the amendments, its dosage mode of application is given in Table 3. The gas fluxes was collected at regular intervals both in the morning and evening for one hour using static chamber method from during the entire growth period. The acrylic cylindrical chamber of 45 cm height is placed over the cores and gas samples were drawn for analysis at regular intervals of 30 minutes for 24 hours using nitrogen flushed 1 ml gas tight syringe. The open end of the Perspex chamber was placed on the core and both the core and the chamber is connected with a help of cylindrical connector so that the air inside the chamber was isolated from the outside atmosphere making the system airtight. A single rice plant was enclosed inside the cores during gas flux measurements. The gas samples collected in sterilized gas tight syringes from rice paddy cores were immediately analyzed for N_2O in Gas Chromatograph (5890) fitted with electron capture detector (ECD) and Porapak Q column. The column, injector, and detector temperatures were maintained at 60°C, 100°C and 350°C respectively, with high purity N_2 as a carrier gas and the flow rate 10 ml min^{-1} was maintained during analysis. During the N_2O analysis for the samples obtained from rice cores gas chromatograph (5890) was calibrated before and after each set of measurements using 1.46 ppmv N_2O in N_2 obtained from National Physical Laboratory, New Delhi. A regular check for linearity of gas chromatograph was also made with the N_2O standards of concentration 1.46 ppmv and at various volumes (0.1- 0.5 ml) using a gas tight syringe.

Calculation

N_2O fluxes from rice cores (mg m^{-2}) = $\frac{44 \times N_2O\ (\mu mol) \times 100}{1000^* \text{ Chamber volume}}$

N_2O (μmol) = $\frac{\text{Chamber volume}}{\text{Molar volume} \times N_2O \text{ conc. of sample (ppmv)}}$

N_2O (ppmv) = $\frac{\text{Standard } N_2O \text{ concentration}}{\text{Area of standard}} \times \text{Area of sample}$

Molar Volume = Gas constant x chamber temperature (K)

Chamber Volume = $\pi r^2 h$ (m^3)

44 = Atomic mass of N_2O

Discussion

In the present study the N_2O fluxes from control cores varied from 1.2 mg m^{-2} d^{-1} at the time of transplantation to 2.44 mg m^{-2} d^{-1} during reproductive stage and 4.14 mg m^{-2} d^{-1} at harvest (Table- 4). The mean seasonal integrated flux was found to be 0.20 ± 0.07 g m^{-2}. The N_2O fluxes from Nemento (nitrification inhibitor) amended cores varied from 1.49 mg m^{-2} d^{-1} at the time of transplantation to 1.84 mg m^{-2} d^{-1} during the reproductive stage and 2.32 mg m^{-2} d^{-1} at the time of harvest of the plant (Table- 4). The mean seasonal integrated flux was found to be 0.14 ± 0.04 g m^{-2}.

Table 4: Nitrous oxide fluxes from control and Nemento amended rice cores

D.A.T.[$]	Water level (cm)		Soil Temperature (°C)		N_2O fluxes (mg m^{-2} d^{-1}) Control cores			N_2O fluxes (mg m^{-2} d^{-1}) Nemento amendment		
	F.N.[@]	A.N.[#]	F.N.	A.N.	Morning	Evening	Average	Morning	Evening	Average
2	1.0	1.0	40.0	38.7	1.34	1.06	1.20	1.47	1.50	1.49
6	2.0	2.0	38.0	41.0	3.40	2.45	2.92	1.06	1.03	1.05
10	3.5	3.5	36.0	41.0	1.51	1.05	1.28	1.28	1.41	1.35
14	5.0	5.0	37.0	40.5	4.23	1.58	2.91	1.84	1.94	1.89
19	5.0	5.0	38.0	41.3	5.19	2.05	3.62	1.13	0.90	1.01
23	5.0	5.0	37.0	39.0	4.03	3.36	3.70	1.81	1.93	1.87
27	5.0	5.0	38.0	40.0	1.95	4.51	3.23	0.95	1.77	1.36
30	5.0	5.0	37.5	41.3	3.32	3.92	3.62	1.42	0.90	1.16
35	5.0	5.0	36.5	43.0	1.56	1.79	1.68	2.37	2.26	2.32
39	5.0	5.0	36.0	39.3	1.05	2.73	1.89	1.60	1.31	1.46
44	5.0	5.0	36.0	40.0	2.91	1.98	2.44	1.98	2.35	2.16
49	5.0	5.0	38.0	39.6	1.36	1.28	1.32	2.60	2.55	2.58
54	5.0	5.0	37.0	39.2	1.28	3.00	2.14	2.26	2.15	2.20
58	5.0	5.0	37.5	39.5	1.28	2.96	2.12	1.84	1.62	1.73
66	5.0	5.0	36.0	41.0	3.27	1.62	2.44	2.04	1.64	1.84
70	5.0	5.0	39.0	41.3	3.69	2.84	3.26	2.02	1.76	1.89
75	3.0	3.0	38.5	40.7	3.14	1.79	2.47	2.10	1.94	2.02
80	1.5	1.5	37.0	41.0	5.50	2.78	4.14	2.40	2.24	2.32
Average seasonal integrated flux (g m^{-2})							**0.20**			**0.14**
Standard deviation (g m^{-2})							**0.07**			**0.04**
Standard error							**0.01**			**0.008**

[$] - Days after transplantation, [@] - Forenoon, [#] - Afternoon

Nitrous oxide emissions from paddy fields, although small compared with those from upland systems are main source of atmospheric N_2O [15]. Nouchi et al. (1990) reported that N_2O transport through the rice plants follows a transport similar to CH_4[16]. The two important processes involved in N_2O production are nitrification and denitrification. Denitrification occurs in the top few cm of anoxic sediments and results in the microbial breakdown of organic substrate in the absence of oxygen, where nitrate is preferentially used as an electron acceptor. It is subsequently reduced to gaseous end products, namely N_2O and N_2. Nitrification is the biological process in which N_2O is produced as the by-product of bacterial oxidation of NH_4^+ [17-19]. The application of Nemento (nitrification inhibitor) has resulted in reduced N_2O emissions from rice cores. The use of nitrification inhibitors slows down the oxidation of NH_4^+ to NO_3^- thus preventing N_2O formation before uptake of nutrients by plants. The Pseudomonas amended rice microcosms reduced N_2O by 25% than control rice microcosms.

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