Litter controls on soil nitrous oxide emission

Nitrous oxide (N_2O) constitutes 6% of the anthropogenic greenhouse effect[1], and contributes to stratospheric ozone depletion. Fertilized agriculture is the single most important anthropogenic source of N_2O, accounting for ca. 45% of the anthropogenic sources of this greenhouse gas[2]. Plant litter, especially crop residues, have been considered as sole sources of N_2O emitted directly from agricultural soils in the global N_2O budget[3]. The emission factor of N_2O for fertilizers has been used as default to account for the N_2O emitted from the residues, which represents ca. 20% of the emissions. However, it was recently shown that soil surface plant litter, when applied as a mulch, can considerably mitigate soil N_2O emissions at a temperature encountered in tropics[4]. It is speculated that this is either because of a decrease in the N_2O production in the soil with the mulch or due to an increase of N_2O consumption by microbes in the mulch or soil, although the underlying mechanism is still unclear. The present study investigates this and concludes that physical quality of the litter is more important than the microbial interference in this mitigation. Gross calculations show that if this effect persists in terrestrial ecosystems, present global N_2O budgets of the IPCC will need a revision for a reduction of up to ca. 45%, a major revision for which further studies in the field are needed immediately to fully understand this. In agroecosystems, this needs to be done on a cropping system approach since different residues are used in different agricultural systems. Forest systems provide a totally different ecosystem, which should be studied separately.

Soil used in this study was a Rhodustalf collected from a cropland in Anuradhapura district, a typical dry zone in the north central province of Sri Lanka. Initial characteristics of the soil were: pH 7.2, 1.7% organic carbon, 0.068% total nitrogen and 4.1 and 3.4 μg/g oven-dry soil of NH_4^+-N and NO_3^--N, respectively. Samples (20 g) of dried and sieved (< 2 mm) soil were put into Erlenmeyer flasks of 100 ml to form ca. 1 cm thick layers of soil at the base of the flasks. Soil in each flask was sprayed with 4.2 ml of water to adjust water filled pore space (WFPS) to 60%, which produces highest N_2O in this soil (data not shown). The sprayed water contained glucose and KNO_3 to give 300 μg C/g dry soil and 50 μg NO_3^--N/g dry soil for optimal gas emission from this soil (G. Seneviratne, unpublished). The wet soil layer in the flasks was mulched with chopped and treated (Table 1) pieces (ca. 4 mm) of wet rice (*Oryza sativa*) straw, at a rate of 0.8 g dry weight per flask (i.e. ca. 3 t/ha). The flasks were air-tight and arranged in a completely randomized design in 5 replicates, and incubated at 27°C for 4 days. After 4 days of incubation, gas emissions diminish of the present soil (G. Seneviratne, unpublished). Samples (1 ml) from the gas phase of the flasks were removed using a syringe (5 ml) and the flasks were then opened to flush and refresh the gas phase on day 2. At day 4, the second sample was taken. The gas samples were injected immediately into a standardized gas chromatograph (Shimadzu GC 9AM with a thermal conductivity detector and a Porapack Q (50/80) column) to measure the contents of N_2O and CO_2 simultaneously.

Rice straw mulch significantly reduced soil N_2O emission by 67% (Figure 1). However when the mulch was autoclaved, the reduction in the emission was only ca. 10%. This shows the important role played by microorganisms associated with rice straw in the reduction of the emission, which is 57%. Plant litter is a vast source of organic carbon compounds; hence a rich microbial biomass with a wide composition grows on it. This creates anaerobic microsites in the aqueous phase of the litter, due to extensive microbial respiration. Denitrifiers and some other reducing bacteria growing in association with the litter may convert N_2O to N_2. It has been shown in the Amazon flood plain forest that the denitrification activity in the litter layer was higher than that in the soil[5]. In addition, a large community of asymbiotic N_2 fixers such as *Azotobactor* and *Clostridium* associates with crop residues like rice straw[6]. Nitrogenase enzyme contained in these bacteria can also convert N_2O to N_2 (ref. 7). It is clear from these results that there is no decrease in the N_2O production in the soil due to the

Table 1. Treatments with wet soil mulched with wet rice straw, and their objectives

Treatment	Objective
Soil alone (S)	To quantify gas emissions from bare soil
Soil with wet rice straw mulch (SR)	To quantify the gas emissions with the mulch application
Soil with autoclaved rice straw mulch (SRA)	To quantify the effects of microbes associated with the mulch on the gas emissions
Soil with autoclaved and vaseline-coated rice straw mulch (SRAV)	To quantify the physical effects of the mulch on the gas emissions

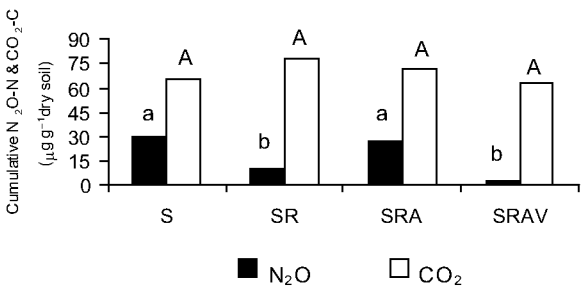

Figure 1. Cumulative N_2O and CO_2 emissions from the treatments of Table 1. S, soil alone; SR, soil with rice straw; SRA, autoclaved rice straw; SRAV, autoclaved and vaseline-coated rice straw. Treatments of the columns headed by a same letter are not significantly different at 5% probability level.

presence of the mulch. Apparently, there is also no increase of the N_2O consumption in the soil, caused by reduced conditions created with increased microbial respiration by the mulch application, because CO_2 emissions of the all treatments were comparable (Figure 1). Solubility of N_2O (ca. 55 cm^3 per 100 cm^3 of water at 1 atm, and ca. 30°C, ref. 8) is ca. 40 times higher than that of N_2. Therefore, dissolved N_2O in the aqueous phase of the litter is first converted into N_2, which is then emitted immediately, thus litter degrading microbial activity acts as a naturally occurring enzymatic converter of N_2O.

When the mulch was autoclaved and vaseline-coated, the N_2O emission was lowered by ca. 90% (Figure 1). However, when the mulch was only autoclaved, the reduction in the emission was only ca. 10%. This is an interesting result where vaseline-coated mulch restricted gas permeability, possibly increasing the residence time of N_2O produced in the soil, which contributed to the completion of the conversion of N_2O to N_2. The implication of this is that mulches of leaves, etc. with a thick waxy cuticle that are only partially permeable to gas diffusion may contribute to this mode of mitigation of soil N_2O emission before their slow decomposition.

It is not known accurately to what extent this natural process contributes to control N_2O emission in managed and natural ecosystems. Further studies are therefore needed, particularly under field conditions to fully evaluate its effects and potential. By field measurements taken repeatedly over years of varying climatic conditions, trends would emerge on the N_2O emission and its suppression by the residues.

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ACKNOWLEDGEMENTS. K.L.A.S. thanks Dr Sudas D. Wanniarachchi of the Department of Agricultural Chemistry, Faculty of Agriculture, University of Ruhuna, Sri Lanka for providing an opportunity to conduct this study. Ms K. Karunaratne of the project of the Institute of Fundamental Studies helped in the laboratory analyses.

Received 13 September 2002; revised accepted 2 November 2002

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Methane emission from community biogas plant at Masudpur, Delhi

Methane, a combustible gas, is exploited as a source of heat and light. Anaerobic digesters are used to generate CH_4 in the form of biogas by decomposition of biomass in the absence of O_2 (ref. 1). The conventional biogas digesters like floating gas holder-type installed by the Khadi Village and Industries Commission (KVIC) plant have exposed areas, from which CH_4 is emitted continuously to the atmosphere[2]. Methane is the second most important anthropogenic greenhouse gas after carbon dioxide[3,4], and contributes substantially to warming of the atmosphere, with the continuous increase in atmospheric carbon ratio[5]. Among the various identified CH_4 sources, emissions from community biogas plants have not been estimated. In this communication, we present the results of a quantitative analysis of CH_4 emission from the exposed areas of biogas plants, between the gap of floating gas-holder and digester wall and slurry drying pits.

The four biogas plants under study, each of 85 m^3, were located at Masudpur village, in the southwest fringe of Delhi, India. All the biogas plants were of floating gas holder-type (KVIC model), having a total installed capacity of 4×85 m^3 equalling 340 m^3. The plants cater to the need of the community as a whole and some institutions. The plants are fed with cattle dung procured from a nearby dairy. One of the plants is attached to a community latrine. Biogas generated is supplied to about 75 subscribers of the Masudpur village and Harijan Basti through a gas distribution network of 1.5 km. The digested slurry from the biogas plants is collected into four different slurry pits, each having an area of around 30 m^2, with depth varying between 20 and 60 cm.

The gas samples were drawn from the exposed area around the gas holder and the slurry drying pits using the closed-chamber technique described by Hutchinson and Moiser[6], with floatable cylindrical iron sheet chambers of 25 cm diameter and 30 cm height. Gas samples (5 ml) were drawn from the chamber in a 20 ml air-tight syringe at time intervals 0, 5 and 10 min. All the samples were collected in triplicate from each plant and slurry pit, once in a day between 11.00 and 11.30 h at weekly intervals, for studying seasonal variation. Diurnal variation in CH_4 flux was recorded every