USE OF A NOVEL INCUBATION TECHNIQUE TO MEASURE N_2O/N_2 FOLLOWING SURFACE OR INJECTED APPLICATION OF SLURRY

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ABSTRACT

Measurements of N_2O and N_2 efflux were made following surface or injected application of slurry to a wet, fine-textured pasture soil. Intact blocks of the slurry applied soil were incubated in a laboratory system that permitted replacement of the original N_2 in soil atmosphere with He, and thus the detection and estimation of N_2 arising from denitrification. Following application at a rate equivalent to 112 kg N ha^{-1}, 7.2 and 13.4 kg N ha^{-1} were lost from surface applied and injected slurry, respectively, during a 40 d period at 15 °C. Peak efflux of N_2O occurred after about 20 d from both the surface applied and injected slurry, and was 0.4 and 0.8 kg N ha^{-1} d^{-1}, respectively. The efflux of N_2 was undetectable (< 20 g N ha^{-1} d^{-1}), except during the first few days, and the overall N_2O/N_2 was 1.72 for both treatments.

KEYWORDS

Nitrous oxide, denitrification, slurry injection, soil cores

INTRODUCTION

Nitrogen is used with poor efficiency in intensively managed grassland, and there is currently great concern about the impacts of N losses on the aqueous and gaseous environment. The N cycle in grazed grassland is complex and effective reduction in N losses from one component pool via a given route is liable to result in increased losses from another pool or via a different route (Pain et al., 1990). Losses of NH_3 from slurry applied conventionally to the surface of grassland can be a large proportion of the NH_4^+-N applied, but such losses can be reduced by shallow injection (Frost, 1994). While an earlier study (Thompson et al., 1987) appeared to demonstrate that reduction in NH_3 loss through injection rather than surface spreading was associated with increased N loss through denitrification, a recent study has cast doubt on this result (Misselbrook et al., 1996). In neither study, however, was N_2O/N_2 assessed. The objective of the present research was to re-evaluate the effects of surface spread and injected slurry on denitrification with the use of a recently developed laboratory incubation system that enables direct measurement of both N_2O and N_2 efflux without recourse to acetylene inhibition.

METHODS

Intact, square-section blocks of soil (225 mm x 225 mm x 90 mm depth) were excavated from an extensively managed, grazed pasture at North Wyke during April, 1996, when the soil (a stagno-Dystric Gleysol) was at field capacity.(36.2% H_2O, v/v). The content of organic C, NO_3^- -N and NH_4^+-N was 5.3%, 0.9 kg ha^{-1} and 1.42 kg ha^{-1}, respectively. The pH was 5.7. Soil blocks were pared to fit one in each of six incubation vessels (Fig. 1) and the sward on each block was clipped to 25 mm. Three blocks were prepared for the slurry injection treatment by removing soil to create a slit (25 mm wide x 50 mm deep x 225 mm long) across the centre of each. Cattle slurry (4.1% dry matter) was applied to the slit, or evenly to the surface of the block at a rate of ~50 m^3 ha^{-1} (containing 109 and 3.3 kg N ha^{-1} of NH_4^+-N and NO_3^--N, respectively).

The vessels were sealed and the soil atmosphere was replaced by passing an He/O_2 mixture through each block at 400 ml $min.^{-1}$ for 24 h., with the O_2 content adjusted to that measured in the field soil. Gas flow was then switched to "flow-over" mode whereby the He/O_2 (now at 20% O_2) was allowed to pass across the surface of each block at 20 ml $min.^{-1}$. The effluent from each block was conveyed to either of two gas chromatographs for analysis of N_2O and N_2.The system was maintained at 15°C for 40 d. Values of efflux (kg N ha^{-1} d^{-1}) were calculated from gas concentrations (measured about every 6 h) and flow rates. Fuller details of the incubation system are given in Scholefield et al., (1996).

RESULTS AND DISCUSSION

Figure 2 shows that substantial amounts of N were lost from both slurry treatments, and although no nil slurry control was included in order to increase the degree of replication, it is known from previous studies with this unfertilised soil that N losses without slurry addition would have been <1 kg ha^{-1} over the period. Initially, efflux of N_2 was greater than that of N_2O, and although this is an unusual result, this N_2 is unlikely to have originated from incomplete purging. After day 13, efflux of N_2 became undetectable (<20 g N ha^{-1} d^{-1}). After a few hours efflux of N_2O from the surface treatment began and increased at a steady rate for 15 d. Efflux of N_2O from the injected treatment was not detected until day 4, after which it increased at a steeper rate to equal that of the other treatment on day 15. Thereafter, efflux from the injected treatment was substantially greater. Peak efflux from both treatments (0.80 and 0.38 kg N ha^{-1} d^{-1}, from injected and surface, respectively) occurred on day 20. Total N losses were 13.4 and 7.2 kg N ha^{-1} from injected and surface treatments, respectively, while the overall N_2O/N_2 was 1.72 for both.

These results indicate the potential for serious atmospheric pollution through efflux of N_2O from both surface applied and injected cattle slurry. The peak rates were much greater than several previously reported (Maag, 1977; Cates and Keeney, 1987; Paul et al, 1993), and our results agree with those obtained by Thompson et al., (1987) in suggesting that losses of N through denitrification are increased when losses through NH_3 volatilisation are reduced.

The small efflux of N_2 during the incubations is surprising, considering the wet soil conditions, high pH of the slurry and the small concentrations of NO_3^- present. Maag (1977), using acetylene inhibition to monitor both denitrification and N_2O loss from pig slurry obtained N_2O/N_2 typically of 0.2. The contribution of nitrification to N_2O loss in the present experiment is unknown, but the result of imposing anaerobiosis by withholding O_2 after the 40 d had the effect of increasing both N_2O and N_2 efflux, but with N_2 efflux remaining smaller than N_2O efflux.

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Figure 1
Schematic diagram of flow-through incubation system.

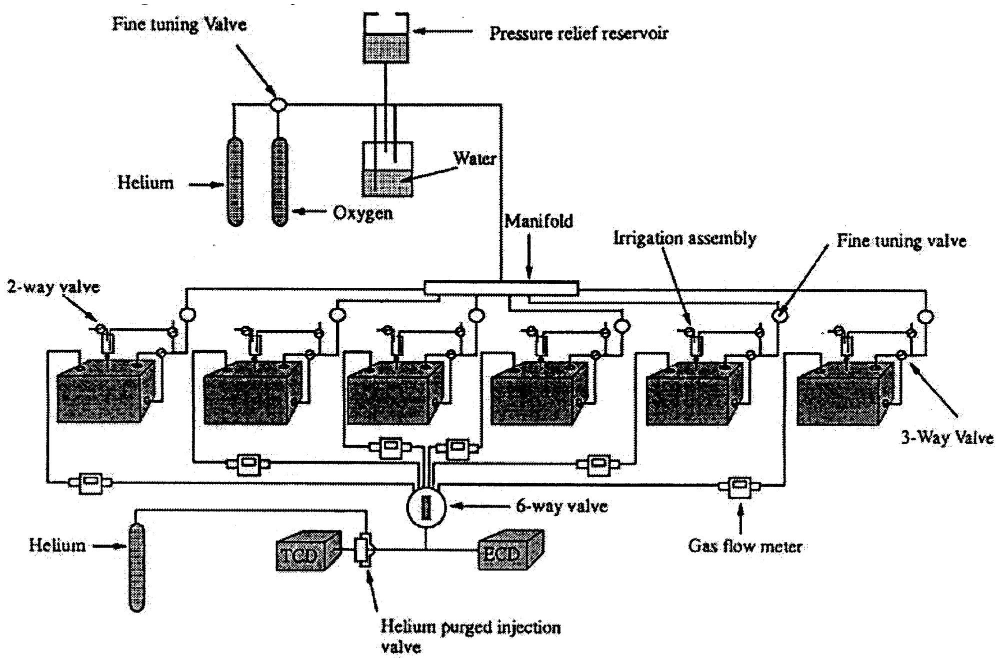

Figure 2
Efflux of dinitrogen (thick lines) and nitrous oxide (thin lines) following application of cattle slurry to soil blocks by injection (broken lines) or to the surface (solid lines). Bars represent two standard errors.