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SHORT COMMUNICATION

CH_4 OXIDATION IN SOILS FERTILIZED WITH ORGANIC AND INORGANIC-N; DIFFERENTIAL EFFECTS

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The significance of soils as a sink for CH_4 has only recently been recognized, and the environmental variables that regulate the strength of the sink are poorly documented. The use of N fertilizer has been shown to reduce rates of CH_4 uptake in forest, pasture and arable soils (Stuedler *et al.*, 1989; Keller *et al.*, 1990; Mosier *et al.*, 1991; Adamsen and King, 1993; Hütsch *et al.*, 1993). Work at Rothamsted has shown that the form of N fertilizer is also important: in a pasture soil, NO_3-N fertilizer had no effect on CH_4 uptake rates, whereas NH_4-N fertilizer completely inhibited net CH_4 oxidation (Hütsch *et al.*, 1994; Willison *et al.*, 1994). It has been reported from studies in pure culture that NH_4^+ ions will competitively inhibit the oxidation of CH_4 by methanotrophs (Whittenbury *et al.*, 1970), and this could be an explanation for the reduction of CH_4 oxidation in soils following the long-term application of NH_4-containing fertilizer (Hütsch *et al.*, 1993). However, our work at the Broadbalk long-term experiment on plots receiving large amounts of farmyard manure (FYM) (Hütsch *et al.*, 1994; Willison *et al.*, 1994), which supplies 240 kg N ha^{-1}, much of which is released as NH_4-N, does not show an inhibitory effect on CH_4 oxidation. Measurements of microbial biomass on the plots receiving FYM show that it has risen to over twice that on the plots receiving solely inorganic-N fertilizer (Jenkinson and Powlson, 1976). This elevated total biomass may buffer the FYM plots against any inhibitory effect on CH_4 oxidation of NH_4 derived from the mineralization of FYM. We describe an experiment to further investigate these interactions, using soil from the long-term experiments at Bad Lauchstädt, Germany.

The Static Fertilization Experiment, began in 1902 at Bad Lauchstädt, Germany (51°24′N. 11°53′E.), is on a haplic chernozem overlying loess over boulder clay. There is a four-course rotation (sugar beet, spring barley, potato, winter wheat) and the experiment has been subdivided into plots receiving different rates and combinations of fertilizers. Soil samples were taken from the following plots: plot 18, which receives no N fertilizer (Control) in any form; plot 13, which receives inorganic-N but no organic manure (N); plot 12, which receives 20 t ha^{-1} FYM but no inorganic fertilizer (FYM); and plot 7, which receives both 20 t ha^{-1} FYM and inorganic fertilizer (FYM + N). Inorganic fertilizer is added annually in the spring as a top dressing according to calculated crop requirements usually between 40–130 kg N ha^{-1} y^{-1} as NH_4NO_3 (M. Körschens, pers. commun.).

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CH_4 oxidation rates were measured on undisturbed soil cores (Hütsch *et al.*, 1993), cores were collected on 21 April 1994 (8 per plot), before the current year's inorganic-N fertilizer was applied. Additional soil was collected for measurement of soil water content, pH and mineral-N content. Incubation experiments were carried out using a modification of the procedure described by Hütsch *et al.* (1993). Cores were conditioned at 25°C for 24 h. The samples were then incubated at 13°C in jars fitted with an injection septum. At the start of the incubation the jars were flushed with ambient air and sealed. Headspace concentrations of CH_4 were measured on a GC fitted with a f.i.d. after 0, 6, 24, 48 and 72 h. The concentration of CH_4 at 0 h was slightly higher than that normally quoted for ambient (1.72 $\mu l\ l^{-1}$), we believe the reason for this is the proximity of buildings. The decrease in the CH_4 concentration in the headspace followed first-order kinetics and could be described by an exponential function ($y = ae^{bt}$) (Hütsch *et al.*, 1993). A log-transformation, $\ln y = a + bt$ resulted in straight lines where the slope of the lines can be interpreted as CH_4 oxidation rates (*b*-values).

Mineral-N measurements were made on individual samples at the end of the incubation (Table 1). All samples were sieved ($\leqslant 4$ mm) and 50 g (fresh wt) extracted by shaking with 200 ml 2 M KCl for 1 h and filtered through Whatman No. 1 filter paper. The extracts were stored frozen until measurement of NO_3^- and NH_4^+ with an ALPKEM rapid flow analyser. The concentrations are expressed as kg N ha^{-1}.

Figure 1 shows the rate of disappearance of CH_4 in the four treatments. When plot 18 (Control) and plot 13 (N) are compared the rate of oxidation was reduced from 4.60 to 1.34 nl CH_4 l^{-1} h^{-1} (Table 1). Figure 1 also shows the same application rate of inorganic-N, but to plots that have received 20 t y^{-1} FYM. The rate of CH_4 oxidation in plot 07 (FYM + N) was 33% of that in plot 12 (FYM). When the comparison is made between plots that received different rates of FYM, the FYM plots oxidized CH_4 at approximately 2.5 times the rate of the control plots receiving no FYM (Table 1).

There is good evidence that the addition of inorganic-N fertilizer reduces the rate at which CH_4 is oxidized in forest, pasture and arable soils. However, there is still uncertainty regarding the relative importance of methanotrophs and NH_4 oxidizers in regulating this flux (Hütsch *et al.*, 1993). The reason for this uncertainty is largely due to the ability of the enzymes CH_4 monooxygenase and NH_3 monooxygenase to co-metabolize compounds which cannot be used as an energy source for growth (Bedard and Knowles, 1989). It

Table 1. CH_4 oxidation rates (*b*-values) and mineral-N content at the end of the incubation, pH and moisture content at the start of the incubation ($n = 8$)

	Start of incubation		End of incubation		
Plot	pH (in H_2O)	Moisture (%)	NO_3-N (kg ha^{-1})*	NH_4-N (kg ha^{-1})*	*b*-value (nl CH_4 l^{-1} h^{-1})
Plot 18: Control	6.8	13.1	0.83	0.20	−4.60†
Plot 13: N	6.9	14.0	15.36	3.1	−1.34
Plot 12: FYM	7.0	14.6	1.98	0.22	−11.2†
Plot 7: FYM + N	7.2	15.3	5.01	0.71	−3.76

*Values are means, $n = 5$.
†Indicates where *b*-values are significantly different ($P \leqslant 0.05$) between treatments receiving the same amount of organic-N with or without inorganic-N.

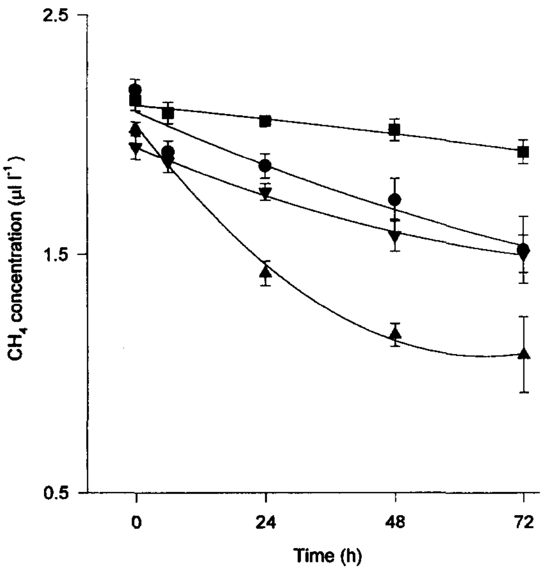

Fig. 1. Plots of CH_4 oxidation in soils from Bad Lauchstädt. Lines are means ± 1 SD. Control (●) received no N fertlizer in any form, N (■) received only inorganic-N fertilizer, FYM (▲) received only organic-N fertilizer and FYM + N (▼) received organic-N and inorganic-N fertilizer.

has been suggested that the long-term addition of inorganic fertilizer increases the populations of nitrifiers at the expense of methanotrophs (Hütsch *et al.*, 1993). The validity of this explanation relies on the two populations competing for, and being limited by, ecological niches (Bedard and Knowles, 1989). Though both groups of microorganisms may favour the same aerobic–anaerobic interface this hypothesis requirers further testing. It has been a weakness of this hypothesis that plots receiving FYM have oxidised CH_4 as strongly as plots receiving zero N, although having as great an NH_4 input as plots receiving large inorganic-N inputs (see Hütsch *et al.*, 1994; Willison *et al.*, 1994). The data in this experiment show the same reduction of CH_4 oxidation following the long-term application of inorganic-N that has been reported at Rothamsted (Hütsch *et al.*, 1993). A more rapid oxidation of CH_4 in the FYM plot receiving no inorganic-N compared to a plot receiving no N, shows the overall effect of FYM addition in increasing microbial biomass. However, and most significantly, for the first time it has been possible to show a reduction of CH_4 oxidation rate in a site receiving FYM by the addition of inorganic-N. This supports the contention of Hütsch *et al.* (1993) that the NH_4 oxidizer population increases at the expense of methanotrophs.

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