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Nitrous oxide emissions from organic farming: the importance of well-timed ley cultivation

By B C BALL

SAC Crop and Soil Systems Research Group, West Mains Road, Edinburgh EH9 3JG, UK

Summary

The period after ploughing of grass-clover within a ley-arable rotation is when nitrogen accumulated during ley cropping is most vulnerable to loss. I investigated how date of ploughing and date of cessation of grazing before ploughing influenced losses of nitrogen as nitrous oxide during establishment of the first cereal crop. Crop nitrogen uptake was also assessed. Nitrous oxide (N_2O) emissions in the 1-2 month period after autumn or spring ploughing or after sowing were typically between 20 and 150 g N ha^{-1} day^{-1} and increased with temperature and rainfall. Tillage and sowing operations on previously ploughed soil stimulated N_2O emissions even several months after ploughing. Cumulative N_2O emissions were highest (~8 kg ha^{-1} over 17 months) after late cessation of grazing and late ploughing, and lowest (~5.5 kg ha^{-1}) after early cessation of grazing and early ploughing. The optimum time of ploughing appears to be midwinter when the cold restricts nitrogen mineralisation, but sufficient nitrogen subsequently becomes available for early spring crop growth and satisfactory N offtake. Restricting tillage operations to cool conditions should help to reduce N_2O emissions. However, the soil should also be dry enough to reduce the risk of damage to soil structure.

Key words: Greenhouse gas, ley-arable, nitrogen offtake, ploughing and grazing

Introduction

Organic rotations rely heavily on nitrogen fixation by clover during the period under grass-clover as an external source of nitrogen. Ploughing of the grass-clover ley stimulates mineralisation of this nitrogen. Mineralised nitrogen may be lost as nitrous oxide if the ley is ploughed in late summer or if tillage occurs in a very wet spring (Ball *et al*., 2002; Vinten *et al*., 2002). Nitrous oxide is a potent greenhouse gas which also catalyses destruction of the stratospheric ozone layer. The mineralised nitrogen is also vulnerable to leaching loss. Vinten *et al*. (2002) suggested that N mineralisation rate and N leaching losses may be reduced by removal of grazing animals well before ploughing. Thus the objective was to assess how the timings of ploughing and tillage and of cessation of grazing influenced N_2O losses and N uptake in the first cereal crop after ley.

Materials and Methods

The field experiment (Ball *et al.*, 2006) was located at Craibstone, Aberdeenshire, UK (57°10′ N /2°16′ W) a sandy loam soil with good-moderate drainage. Treatments began in November 2001 and were applied over two seasons i.e. the soil was ploughed in both seasons. Grazing was by sheep. Treatments were no grazing after late autumn, ploughed in January; grazed until January, ploughed in January; grazed until January, ploughed in March and grazed until March and ploughed in March. Spring barley was sown and grass/clover was undersown in mid April in 2002 and 2003. Crop N uptake was measured from the dry matter yield and nitrogen content of the grain plus straw at harvest.

Nitrous oxide fluxes were measured using a manually closed chamber system (Scott *et al.*, 1999). The atmosphere (0.125 m^3 volume) immediately above the soil surface was enclosed by a chamber and was sampled 1 h after closure. Gas samples were stored in aluminium tubes and analysed in the laboratory by gas chromatography (Scott *et al.*, 1999).

Results

Cumulative N_2O fluxes are given in Fig. 1. Although we monitored N_2O fluxes after January ploughing in 2003 only, these were minor.

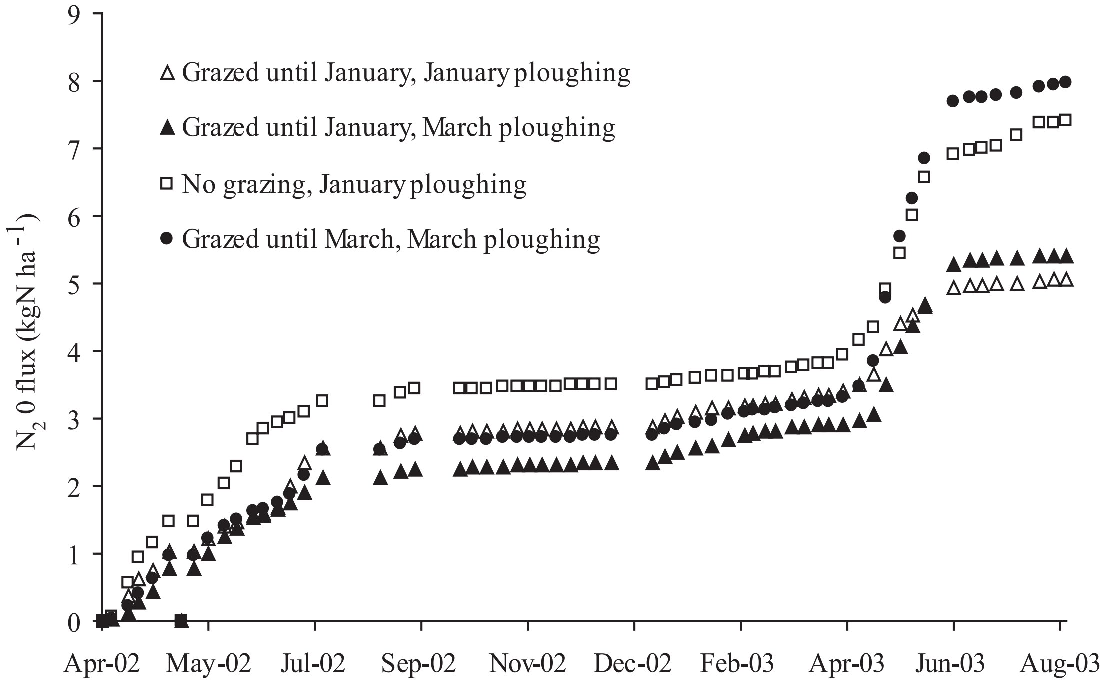

Fig 1. Cumulative nitrous oxide emissions between April 2002 and August 2003. The average standard error of the overall cumulative totals was 2.3 kg N ha^{-1}.

The main peaks of N_2O flux occurred after secondary cultivation and sowing. Variability of flux within treatments was large. The total fluxes produced in the active period from April-July 2002 were ~2 kg N_2O-N ha^{-1}. Treatment differences were more apparent in April–May 2003 when the total fluxes ranged from about 1.2 kg N_2O-N ha^{-1} from the grazed until January, January ploughing treatment to about 4 kg N_2O-N ha^{-1} from the grazed until March, March ploughing treatment. There was also a marked temporal variability of flux. Although crop N offtakes did not differ significantly between treatments in either season (Table 1), treatments effects were consistent.

Table 1. *Crop N offtake (kg ha^{-1}) in grain plus straw*

	2002	2003
Grazed until January, January ploughing	105	51
Grazed until January, March ploughing	106	59
No grazing, January ploughing	109	62
Grazed until March, March ploughing	103	52
LSD ($P = 0.05$)	*22*	*19*

Overall spring barley grain plus straw N offtakes were lower in 2003 than in 2002 (Table 1). The grazed until March, March ploughing treatment had the lowest N offtake (difference not significant) and greatest cumulative N_2O emission. Nevertheless, there was no consistent beneficial effect of winter ploughing as the grazed until January, January ploughing treatment gave lower N offtakes than the no grazing, January ploughing treatment.

Discussion

Nitrous oxide emissions after autumn or spring ploughing were between 20 and 150 g N ha^{-1} day^{-1}. This is of the same scale as measured previously on similar soils (Ball *et al*., 2002). Ploughing in mid-winter was the only time that N_2O emission was not stimulated, though further tillage in the spring for crop establishment caused N_2O emissions of a similar magnitude to those after spring ploughing and tillage for crop establishment. The flush of N_2O emission after ploughing may result from the supply of readily available carbon for microbial activity (Davies *et al*., 2001). The significant N_2O emissions from April to June when the soil is usually relatively dry are likely to have resulted mainly from nitrification. Nevertheless the soil was wet at times during this period, particularly in 2003, suggesting that anaerobic zones were likely to have developed and that denitrification may have occurred. The annual N_2O fluxes were between 2.5–4 kg ha^{-1} and, though not particularly high, were generally higher than those found for arable land in conventional production by Dobbie *et al.* (1999). These fluxes correspond to a loss of 1.2–3.9 % of the N inputs, substantial emission factors.

Conclusions

Within an organic rotation, establishment of the first arable crop after grass-clover is a point of potential loss of nitrous oxide. Thus leys should be tilled in cool, dry conditions in order to reduce N_2O emissions. This is preferably in mid-winter, but care should be taken to ensure that the soil is dry enough to prevent damage to soil structure. However, mid-winter (January) ploughing reduced emissions and increased crop N offtake only after grazing.

Acknowledgements

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