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THE DEVELOPMENT AND EVALUATION OF DAIRY FARMING SYSTEMS WITH MINIMAL EMISSIONS OF NITROGEN AND PHOSPHORUS

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ABSTRACT

The Minimal Impact Dairy Systems (MIDaS) project aims to develop environmentally improved dairy systems, each incorporating a combination of techniques to reduce emissions, and compare them with a conventional system. Two year's results, using 36 cows per system, demonstrate that nitrate leaching under grassland can be reduced from 70 kg/ha N down to less than 20 kg/ha N. Leaching under maize was relatively high at around 40 kg/ha N. Ammonia losses following manure application were generally lower than predicted, but were reduced from 16 kg N/ha to 3 kg N/ha. It is concluded that, using a package of practical measures, surpluses of N and P, and emissions, can be substantially reduced. But it is likely that a large quantity of N will remain unaccounted for, raising the need to increase efforts to measure denitrification and soil N fluxes.

KEYWORDS

Dairy systems, Nitrogen, Phosphorus, Leaching, Ammonia, Grassland, Maize.

INTRODUCTION

In the UK, as in many areas of Northern Europe and elsewhere, there is concern over emissions of nitrogen (N) and phosphorus (P) from agriculture. Dairy farming is a sector of particular concern since these farms have high inputs of N and P, and are often specialist units with no arable enterprise to utilise wastes.

To address this problem the Minimal Impact Dairy Systems (MIDaS) project was established at ADAS Bridgets, Hampshire, in 1994 on well-drained shallow soil over a chalk aquifer. The objective is to develop environmentally improved dairy systems incorporating a combination of techniques to reduce leaching and gaseous losses, and compare them with a conventional system. The inputs, outputs and emissions from each system are compared with models based on experimentation. The results are used to target research efforts, to improve systems, and to act as a focus for industry discussion.

MATERIALS AND METHODS

Three self-contained dairy systems have been established, each with 36 cows, summer calving, with a target milk yield of 6000 litres/cow.

System 1 Control. Good commercial practice, high output.
System 2 Reduced loss, high output.
System 3 Minimal loss, reduced intensity.

In System 1, the full economic optimum rate of N is applied, slurry (manure) is only stored for 1 month, and supplementary feed is formulated to > 18% Crude Protein, at least cost. Systems 2 and 3 incorporate a package of measures designed to reduce losses, including:

- use of maize as a low N feed, with undersown cover crop;
- diet formulated to minimise surplus degradable protein;
- reduction in fertiliser N:
  - tactical (System 2);
  - strategic (System 3);
- no application of slurries during:
  - September - November (System 2);
  - September - January (System 3);
- slurry application to maize by rapid ploughing-in;
- slurry application to grass by :
  - dilute broadcast (System 2);
  - shallow slit injection (System 3).

Leaching is measured using 150 ceramic cup samplers per system, 60 cm deep, at 30^0 from vertical (Webster *et al*, 1993). Ammonia flux is measured for 7 days following slurry applications using the mass balance micrometeorological technique with passive shuttle samplers (Leuning *et al*, 1985). Similar measurements of ammonia flux on grazing fields are made, supplemented by wind tunnel measurements on urine treated areas. Limited measurements of denitrification have been made; nitrous oxide was measured using small enclosures and a portable trace gas analyser (De Klein *et al*, 1996) and total denitrification losses by incubation. The fate of nitrogen in each system has been predicted using the N cycle model, experimental data and best estimates, using the approach described by Jarvis (1993).

RESULTS AND DISCUSSION

The external 'mineral balance' of each system is shown in Table 1. Inputs were higher than planned, due mainly to extra purchased forage, and use of extra fertiliser because insufficient manure was available in the introductory winter. Milk yield targets were achieved or exceeded in all systems in both years, despite the greatly reduced surplus N in systems 2 and 3.

Leaching. Table 2 shows that N leaching from grassland was substantially less in the improved systems than in System 1. Losses from maize were relatively high, particularly in the first year, despite very limited manure applications and use of Italian ryegrass as an undersown cover crop. For the second year fertiliser N input to maize was reduced. Whole system N leaching losses met the target of 30 kg/ha and were indeed rather less than predicted, despite N inputs being higher than planned. There was, however, great variation between fields. P leaching was very small: 0.03 kg P/ha.

Gaseous emissions. Ammonia loss from broadcast slurry was, on average, 26% of ammonium N applied; lower than predicted. Loss from injected slurry was measured on 2 occasions in 1995, and averaged 17% of ammonium N applied; higher than expected. Nevertheless, whole system estimates of annual ammonia N loss following slurry applications were low: 16, 10 and 3 kg/ha on Systems 1, 2 and 3 respectively.

System estimates of denitrification losses are not possible from the limited measurements made so far. However these show that fluxes could be relatively high even on this well drained soil. Rates of emission were higher following injected compared with broadcast slurry.

CONCLUSIONS

The MIDaS study so far demonstrates that the surplus of N and P on dairy farms can be reduced substantially by a package of practical measures. N leaching from grassland can be greatly reduced, but is very variable between fields. Leaching from maize is relatively high. Ammonia losses from broadcast slurry have been substantially less than predicted, and hence the benefit of injection may be less than anticipated.

It seems likely that large quantities of N will remain unaccounted for. This raises the need for re-targeting the measurement programme towards denitrification and N fluxes to and from soil organic matter. There is also a need for a better understanding of the manipulation of nutrient flow through the dairy cow.

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Table 1
Annual Nitrogen balance sheet, mean of 1994/95 and 1995/96

	System 1	System 2	System 3
Inputs			
Fertiliser	319	190	142
Feed	120	115	89
Atmosphere (estd)	30	30	30
Total	469	335	261
Outputs			
Milk	66	64	55
Liveweight	6	7	5
Total	72	71	60
Surplus	397	264	201

Table 2
Nitrogen leached (kg N/ha)

		1994/95	1995/96
System 1			
	Permanent grass	70	69
	Italian ryegrass	40*	40*
	Whole system	61	60
System 2			
	Permanent grass	16	28
	Maize	50	41
	Whole system	27	32
System 3			
	Permanent grass	15	18
	Maize	79	36
	Whole system	32	23

* Estimates based on soil mineral N measurements.