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University of Veterinary Medicine
Research Institute of Veterinary Medicine
Hlinkova 1/A
040 01 Košice
Slovak Republic

NITROGEN AND PHOSPHORUS LOSSES IN DRAINAGE WATER FOLLOWING PIG SLURRY APPLICATIONS TO A DRAINED CLAY SOIL

***J.R. Williams*[1]*, K.A. Smith*[2]*, B.J. Chambers*[3] *and R.B. Cross*[1]**

[1] *ADAS Boxworth, Battlegate Road, Boxworth Cambridge, CB3 8NN, UK.*
[2]*ADAS Wolverhampton, Wergs Road, Woodthorne, Wolverhampton, WV6 8TQ, UK.*
[3] *ADAS Gleadthorpe, Meden Vale, Mansfield, Notts., NG20 9PF, UK.*

ABSTRACT

Nitrogen (N) and phosphorus (P) losses in drainage water following contrasting pig slurry application timings to autumn and spring cultivated clay soils were quantified over one drainage season (1999/2000). N losses were highest (9% of slurry total N applied) following autumn application to uncultivated stubble, and lowest following autumn applications to autumn cultivated land (2% of slurry total N applied). P losses following autumn and winter slurry applications to uncultivated stubble were greater ($P<0.05$) than from the untreated control, whilst losses following autumn applications to autumn cultivated land were not different ($P>0.05$) from the untreated control. The results indicate that cultivation before the start of winter drainage is an effective method of minimising N and P losses via drainflow following autumn slurry applications to drained arable clay soils.

Key words: Nitrogen leaching, phosphorus leaching, pig slurry

INTRODUCTION

An estimated 90 million tonnes of farm manures are applied to agricultural land in the UK, supplying c.450,000 tonnes of total nitrogen (N) and 119,000 tonnes of phosphorus (P) per annum (Williams *et al*., 2001). Typically 60 % of the total N content of pig slurry is present as readily available (ammonium) N, with the remainder present as organic N which will mineralise slowly over a period of months to years. Phosphorus in manures is mainly present as solid-phase inorganic P (Smith *et al*., 1998). Whilst clay soils are generally considered retentive of N and P, there is a risk of nutrient loss via rapid macropore flow to drains, especially following slurry applications to intensively drained clay soils.

There are in the region of 6.4 million hectares of drained soils in England and Wales (Withers *et al*., 2000). The majority of schemes (60%) have been installed on medium and heavy textured soils to correct surface wetness problems. On clay soils, manures are commonly applied in the autumn when soils are dry and can carry the weight of heavy application machinery, without causing damage to the soil structure. However, autumn application timings are widely recognised as presenting the biggest potential risk of diffuse nutrient pollution, as crop nutrient uptakes are low and over winter drainage means that applied manure nutrients can be lost from the soil via percolation to ground waters, in drainflow and surface runoff. Nitrate leaching losses following autumn-winter manure applications in the UK have been estimated at 58,000 tonnes N/annum (Chambers and Smith, 1995). The transfer of particulate and dissolved P from agricultural land has been estimated to contribute c.43% of P loads in watercourses (Shepherd and Withers, 2001).

This paper reports results from the first year of a three year experiment to quantify the effects of different pig slurry application timings and cultivation strategies on N and P losses from drained arable clay soils.

MATERIALS AND METHODS

The experiment was undertaken at ADAS Boxworth in Cambridgeshire, UK (average annual rainfall 550 mm) on clay soils of the Hanslope Association . There were three replicates of three pig slurry application and two cultivation timings (Table 1) arranged in a randomised block design. The slurry was applied (50m^3/ha; supplying target rates of 250 kg/ha total N and 60 kg/ha P) to hydrologically isolated plots (12 m x 48 m) using a vacuum tanker fitted with a 12 m Tramspread boom. The slurry used for each application timing was sourced from the same unit to minimise variability between treatments.

Each plot contained two sub-surface lateral drains (24 m spacing) with gravel fill to within 30 cm of the surface, supplemented by mole drains at 2 m spacing and 50 cm depth, installed during autumn 1998. The drains flow through a 1/4 90° V-notch weir allowing drainage volumes from each plot to be quantified. Data loggers were used to record flow electronically and to control automatic sampling of drainage water on a flow proportional basis.

Table 1. Pig slurry application and cultivation timings (drainage season 1999/2000)

Autumn cultivations (winter cereal crop)	Spring cultivations (spring cereal crop)
Control (no slurry)	Control (no slurry)
September ploughed down	September to uncultivated stubble
September disc cultivated	December to uncultivated stubble
December topdressed to growing crop	March to uncultivated stubble
March topdressed to growing crop	

Inorganic fertiliser N applications to meet crop needs were made in mid March and early May 2000, and were adjusted for the N supplied by the different slurry application timings using MANNER (Chambers *et al*., 1999). Samples of the applied slurry were analysed for dry matter, total N, nitrate-N ammonium-N, total P, water soluble P and Olsen P. Drainage water samples were analysed for nitrate-N, ammonium-N, soluble organic N, total P, total dissolved P (TDP) and molybdate reactive P (MRP). N and P losses were calculated using mean drainage volumes from the autumn and spring cultivated plots.

RESULTS AND DISCUSSION

(i) Manure applications

Slurry dry matter, nitrogen and phosphorus loadings were similar for the three application timings (Table 2). The proportion of total N present as ammonium-N (mean 60%) and slurry phosphorus content (mean 1.3 kg/m^3 total P) was similar to standard values for UK pig slurries (Anon., 2000).

(ii) Drainflow

Total annual rainfall during 1999/2000 was 652 mm, compared with a long-term average of 550 mm. August and September were both wetter than average, and as a consequence drainage commenced soon after the September slurry application, rather than the 'typical' time of mid-December. The period following the spring slurry application was very wet, with 197 mm of rainfall in April and May (two and a half times the long-term average), which meant that drainage continued until the end of July 2000. Mean drainage volumes were lower ($P<0.05$) on the autumn (130 mm) than the spring (180mm) cultivated treatments reflecting greater evapotranspiration from the winter wheat compared with the spring sown cereal crop.

Table 2. Slurry dry matter, nitrogen and phosphorus loadings for each application timing

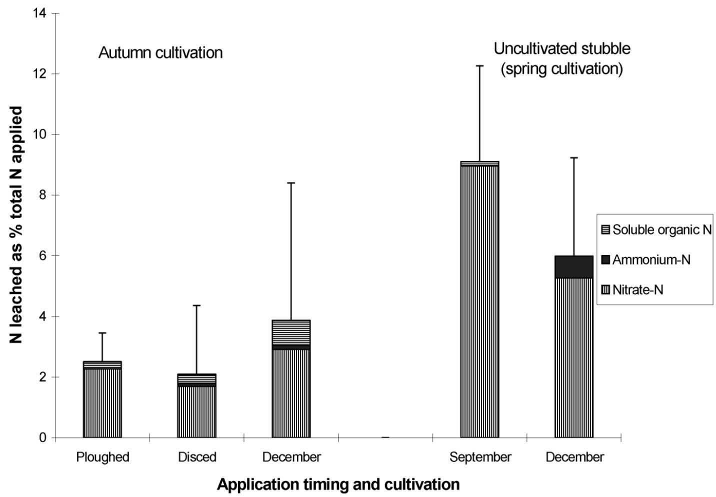
Application timing (date)	Autumn (23/09/99)	Winter (22/12/99)	Spring (17/03/00)
Volume (m^3/ha)	52	49	51
Dry matter (%)	4.8 *(0.2)*	6.1	5.1
Total N (kg/ha)	178 *(21.3)*	153 *(18.7)*	192 *(15.0)*
Ammonium-N (kg/ha)	105 *(2.4)*	102 *(3.8)*	104 *(6.0)*
Total P (kg/ha)	60 *(2.4)*	63 *(5.1)*	71 *(14.2)*

Figures in brackets are standard errors of the mean.

(iii) Nitrogen and phosphorus losses

Losses of manure N (treatment - untreated control) between September 1999 and March 2000 were greatest (9% of total N applied) following autumn slurry application to uncultivated stubble that was ploughed the following spring, and lowest (2% of total N applied) following autumn application to the autumn cultivated (ploughed or disced) treatments (Figure 1). Lower losses on the autumn cultivated treatments were probably a reflection of slurry being mixed within the soil matrix providing 'protection' against leaching. N losses following the winter timing were intermediate between the autumn ploughed and uncultivated stubble treatments. Around 90% of N losses from all application timings were as nitrate-N, with soluble organic N and ammonium-N making up c. 9% and 1% of total N losses, respectively.

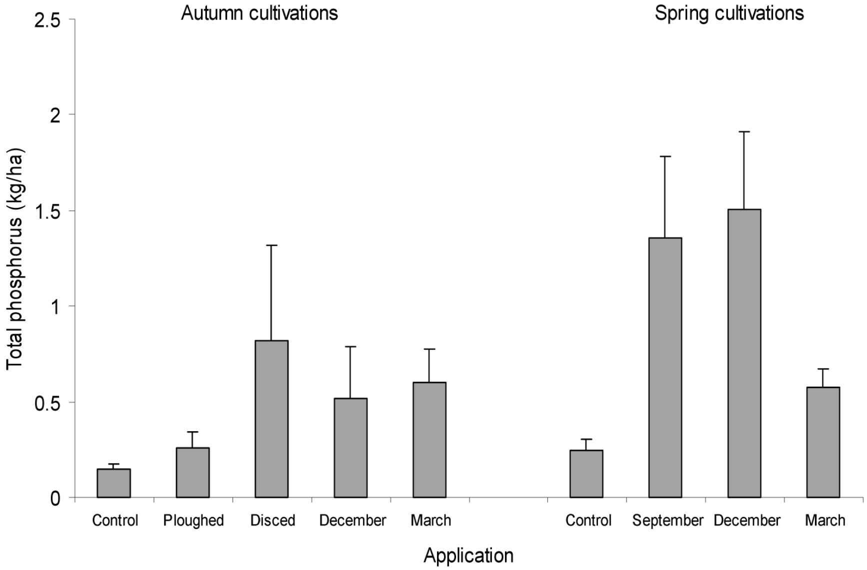
Figure 1. Slurry N losses in drainage water (September 1999 to March 2000)



It was not possible to identify how much of the N supplied in the spring slurry applications was lost by leaching in the April - July 2000 drainage volumes, as inorganic fertiliser N had been applied to the plots to meet crop needs.

P losses over the whole drainage season (September 1999 - July 2000) were increased when slurry was applied to both the autumn and spring cultivation treatments (Figure 2). On uncultivated stubble (spring cultivated land) P losses following autumn and winter applications (1.35 and 1.51 kg/ha P, respectively) were greater ($P<0.05$) than those on the untreated control (0.24 kg/ha P). However, P losses following autumn and winter slurry applications to autumn cultivated land (0.26, 0.82 and 0.52 kg/ha P from autumn plough, autumn disc and winter applications, respectively) were not significantly different ($P>0.05$) to those from the untreated control (0.15 kg/ha P). Similarly, P losses following spring application timings to autumn cultivated land and uncultivated stubble at c.0.6 kg/ha P were not different ($P>0.05$) from the untreated controls.

Figure 2. Total P losses in drainage water (September 1999-July 2000).



The results indicate that the risks of nitrogen and phosphorus losses following autumn and winter slurry applications to drained arable clay soils are reduced if slurry is applied to land that is ploughed before the start of winter drainage. The reduced losses from autumn ploughed soils most probably reflect the disruption of soil macropores and increased mixing of slurry within the soil matrix, inhibiting slurry nutrient movement through the soil to the drains.

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