SHALLOW INJECTION OF SLURRY IN OPEN AND CLOSED SLOTS ON LEY – TECHNOLOGY, PLACEMENT OF SLURRY AND AMMONIA EMISSIONS

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ABSTRACT

The main objective of the present study was to evaluate different injection methods for slurry on ley established on various soils. In full-scale experiments the placements of the slurry as well as ammonia emissions and yields were measured after injection in open slots with three techniques: pressurised injection (PI), shallow injection with V-shaped discs (SIO1), and shallow injection with two angled discs (SIO2). The performance between the injectors varied and only the SIO2 was able to place the slurry in ley below soil surface on all three soil types. The ammonia release was on average halved after injection with SIO2 compared to band spreading, however there was an average loss of 19 kg N ha^{-1}. A tine for shallow injection in closed slots (tubulator) was therefore developed. In small scale with single tines, the tubulator was compared to SIO2 with regards to slurry placement, ammonia emissions and draught requirements. Ammonia losses after injection with the tubulator tine were only 1.6% of the total applied ammoniacal nitrogen (TAN) compared to 27% with the SIO2. The draught requirement for the tubulator was roughly the same, or a little higher than the SIO2 tine. In the full-scale experiments, the reduced loss of ammonia nitrogen with SIO2 did not result in higher DM yield or higher nitrogen efficiency of the second cut as compared to band spreading.

INTRODUCTION

Incorporation of slurry into the soil can be an efficient way to reduce ammonia losses after spreading (Huijsmans et al., 2001; Misselbrook et al., 2002), reduce odour problems (Moseley et al., 1998) and improve the fodder quality (Steffens and Lorenz, 1998). Disadvantages of the injection technique are its high investment costs and the often reduced working capacity in comparison to surface spreading (Rodhe and Rammer, 2002). There is also a risk of crop damage which is caused by the injection tines. There are shallow injectors available for grasslands that incorporate the slurry into the upper soil level to a depth of less than 0.1 m. The injectors, however, are not pre-requested to work for all soil conditions, especially in dry and hard soils as the injectors cannot penetrate to a sufficient working depth (Rodhe and Rammer, 2002; Hansen et al., 2003). Consequently, the reduction of ammonia will not be so efficient. The main objective of this study was to evaluate different injection methods for slurry on ley used on various soil types.

MATERIALS AND METHODS

Full-scale experiments

Three injection methods and band spreading as a control were included:

- Pressurised injection (PI), slurry jet at high pressure, 0.3 m c/c distance between trails, distance in trail between injection points 0.13 m, 0.21 m, 0.20 m by year, respectively;
- Shallow injection 1 (SIO1), with open slot, V-shaped rotating disc tines, diameter 0.3 m, thickness of discs 0.02 m, and c/c distance of 0.2 m;

- Shallow injection 2 (SIO2) with open slot; tines consisting of two angled disc coulters with diameter of 0.4 m, and c/c distance of 0.25 m;
- Band application (BA) to soil surface, trailing hoses 0.3 m centre to centre (c/c) distance.

In the experiments the slurry placement in the soil profile, ammonia release and yield after application in the second harvest were studied following the shallow injection of cattle slurry. The slurry was applied to the second cut (mid-June) with a rate of 25 Mg ha^{-1}. The field experiments were organised in a randomised block designed with four replicates. Unfertilised plots were included on the same ley. Differences between treatments in the block experiment were analysed using a general linear model (GLM). The soils on which the experiment was carried out were classified as silty clay in year 1, silty loam in year 2 and silty (clay) loam in year 3 (FAO, 1990).

During ammonia measurements, the average air temperature was between 13.2 to 15.4 °C, average soil surface temperature between 13.9 and 18.1 °C and average wind speed from 2.1 to 4.1 m s^{-1}. In the last year, it rained directly after the spreading of slurry was finalised. 11mm fell during the first 24hrs and 19.5mm in total during the ammonia measurements.

Well-mixed cattle slurry from the same dairy farm was used in all three years of the experiments. The slurry had a dry matter content of approximately 7% and the TAN content was 1.9 to 2 kg $tonnes^{-1}$.

Pilot-scale experiments

In the pilot-scale experiments, a tubulator tine (Fig. 1) injecting the slurry in closed slots was compared to a tine of SIO2 (open slots) on a silty clay loam. The application rate was 25 Mg ha^{-1}.

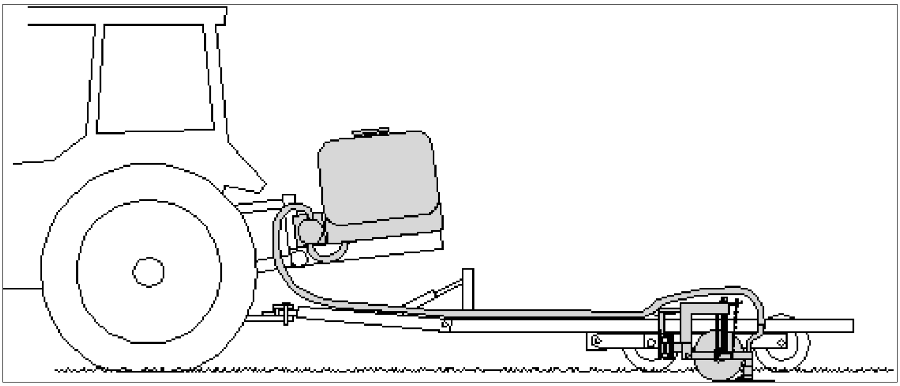

***Figure. 1**. Trailer and slurry tanker used in the pilot-scale experiments. The figure shows the tubulator tine designed for shallow injection in closed slots.*

Measuring methods

The placement of slurry was determined directly after spreading. At three randomly selected locations in each plot, cross-sections were made through the slurry trails with a spade according to Rodhe (2003). The width at soil surface and the depths of the slurry trails were then measured. Ammonia emissions were measured using the equilibrium concentration method, based on passive diffusion sampling close to the ground (Svensson, 1994; Rodhe and Rammer, 2002). On each plot, two chambers to estimate the equilibrium concentration were used and each was placed in order to cover one trail of slurry outside the wheel tracks. Additionally, one ambient measuring unit was placed between the chambers to estimate the ambient concentration of NH_3. The crop was harvested with a plot harvester, (1.5 m working width) at the normal time for silage making (end of July to beginning of August). In the middle of each plot a 10 m long cut was made. The fresh crop was weighed and samples taken for analysis of DM content and Kjeldahl-N.

In the pilot-scale the horizontal and vertical forces were measured on both types of tines (SIO2 and tubulator) at a depth of 5 cm. The octagonal ring sensor for the force measurements was designed and made as described by Godwin (1975).

RESULTS AND DISCUSSION

In full-scale, the performance varied between the injectors. Only SIO2 was able to place the slurry in ley satisfactorily on all three soils (Table 1.). This injector placed the slurry under the soil surface in open slots about 4 to 5 cm deep in the three different soils. In year two, pressurised injection (PI) also placed most of the slurry beneath the soil surface in one of the three soils.

Table 1. *Average depth and width of slurry observed in sections, made into the soil perpendicularly to the direction of driving for the different spreading methods. The actual widths for the shallow injection 1 and 2 have been recalculated to a common basis of 0.3 m working width. The widths of the pressurised slurry were not included in the statistical analysis.*

		Year 1		Year 2		Year 3		Year 4 (pilot-scale)	
Application method	Between trails*, m	Width, mm	Depth, mm	Width, mm	Depth, mm	Width, mm	Depth, mm	Width, mm	Depth, mm
PI	0.30	147	19^{a}	79	47^{a}	93	20^{a}		
SIO1	0.20	70^{a}	26^{a}	61^{a}	20^{b}	69^{a}	16^{a}		
SIO2	0.25	24^{b}	50^{b}	23^{b}	45^{a}	33^{b}	39^{b}	21	0-50
Tubulator								2	13-45
BA	0.30	88^{a}	-	59^{a}	-	69^{a}	-		

a, b Means with different letters within each year are significantly different ($p < 0.05$)
** Distance measured centre to centre*

Table 2. *Mean nitrogen lost as ammonia after spreading of cattle slurry on ley during three years, using different spreading methods. The loss is presented as kg [N] ha^{-1} or in % of total ammoniacal nitrogen [TAN] applied.*

	Nitrogen loss as ammonia							
	Year 1		Year 2		Year 3		Average	
Application method	Kg [N] ha^{-1}	% of [TAN] applied	Kg [N] ha^{-1}	% of [TAN] applied	Kg [N] ha^{-1}	% of [TAN] applied	Kg [N] ha^{-1}	% of [TAN] applied
PI	31	65^{a}	35	74^{ab}	38	69^{ab}	35	69^{ab}
SIO1	40	83^{a}	48	101^{a}	25	50^{ab}	38	78^{a}
SIO2	16	33^{a}	23	49^{b}	18	34^{b}	19	39^{b}
BA	21	44^{a}	45	95^{a}	45	82^{a}	37	75^{a}

a, b Means with different letters within each year are significantly different ($p < 0.05$)

The spreading of slurry on grassland under the prevailing conditions led to high losses of ammonia (Table 2.). On average, the ammonia release was halved after injection with SIO2 as compared to band spreading. This meant an average reduced loss of nitrogen equivalent to18 kg N ha^{-1}.

In the pilot scale, the nitrogen loss was 27% of TAN applied for SIO2 and 1.6% for the tubulator. These correspond to 11 and 0.7 kg N ha^{-1}, respectively. The draught requirement for the tubulator was roughly the same, or a little higher than the SIO2 tine. The tabulator, however, penetrated the soil more easily as it requires less force to be pressed into the soil than SIO2. This could be important for hard soils in order to reach a satisfying working depth.

CONCLUSIONS

The performance varied between the injectors (open slots). Only the SIO2 was able to place the slurry satisfactorily in ley on all three soils. This shallow injector placed the slurry under the soil surface in open slots about 5 cm deep. Pressurised injection (PI) also placed most of the slurry beneath soil surface on the softest soil in year 2.

The spreading of slurry on grassland under prevailing conditions led to high losses of ammonia. On average, the ammonia release was halved after injection with SIO2 compared to band spreading. A tine for shallow injection in closed slots (tubulator) placed the slurry below a soil cover approximately 13 mm thick, to a depth of 45 mm. After this injection, the ammonia emissions were very low, 1.6% of TAN applied. The draught requirement for the tubulator was roughly the same, or a little higher than for the SIO2 tine. An advantage was that the tubulator penetrated the soil more easily than SIO2, which is important on hard soils. This shows that with a tubulator tine, the ammonia loss can be reduced to a minimum with the same working depth and close to the same draught force as a double disc tine.

REFERENCES

FAO (Food and Agriculture Organisation of the United Nations). 1990. Guidelines for soil profile description (3rd ed., revised), 1-70. Rome, Italy

Godwin, R. J. 1975. An extended octagonal ring transducer for use in tillage studies. J. Agric. Engng. Res., 20: 347-352

Hansen, M. N., Sommer, S. G., Madsen, N. P. 2003. Reduction of ammonia emission by shallow slurry injection: Injection efficiency and additional energy demand. J. Environ. Qual., 32: 1099-1104

Huijsmans, J. F. M., Hol, J. M. G., Hendriks, M. M. W. B. 2001. Effect of application technique, manure characteristics, weather and field conditions on ammonia volatilization from manure applied to grassland. Netherlands J. Agric. Sci., 49: 323-342

Misselbrook, T. H., Smith, K. A., Johnson, R. A., Pain, B. F. 2002. Slurry application techniques to reduce ammonia emissions: Results of some UK Field-scale experiments. Biosys. Eng., 81: 313-321.

Moseley, P. J., Misselbrook, T. H., Pain, B. F., Earl, R., Godwin, R. J. 1998. The effect of injector tine design on odour and ammonia emissions following injection of bio-solids into arable cropping. J. Agric. Engng. Res., 71: 385-394

Rodhe, L., Rammer, C. 2002. A comparison of methods for applying cattle slurry to ley. Biosys. Engng., 83: 107-118.

Rodhe, L., 2003. Methods for determining the presence of slurry on the crop and in the upper soil layer after application to grassland. Biores. Technol., 90: 81-88.

Steffens, G., Lorenz, F. 1998. Slurry application on grassland with high nutrient effeciency and low environmental impact. In: *Proceedings of International Workshop on Environmentally Friendly Management of Farm Animal Waste*. T. Matsunaka, (ed). Sapporo, Japan.

Svensson, L. 1994. A new dynamic chamber technique for measuring ammonia emissions from land-spread manure and fertilizers. Acta Agr. Scand. Sect. B, Soil Plant Sci., 44: 33-46.