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Reduction of Ammonia Emission by Direct Ground Injection (DGI)

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Summary

A research was carried out to determine the ammonia losses when applying slurry with a conventional spreader equipped with a splash plate, a shallow injector (open slot) and a Direct Ground Injector (DGI) under Dutch conditions.

The ammonia emission after application of the slurry was determined using a micro-meteorological mass balance method. Four experiments were carried out on a peat soil and four on a heavy clay soil.

The average losses from the surface applied high and low application rate, the DGI and the shallow injector were 81, 88, 23 and 24% of the ammonium applied, respectively. Average emission reduction of the DGI was 71% when compared with the low application rate surface spreading and 74% when compared with the high application rate surface spreading; for the shallow injection these reductions were 70 and 74%, respectively.

The experiments showed that some aspects of the DGI need further consideration for a successful introduction under Dutch conditions. Points for further attention are blockage prevention, power requirement and contamination of the grass with slurry.

1 Introduction

Surface spreading of slurry has the disadvantage of a considerable emission of ammonia into the environment. In recent years new slurry application techniques have been developed for grassland in order to reduce ammonia emissions. In the past five years injection (closed slot), shallow injection (open slot) and narrow band spreading by trailing feet have been investigated in field trials to evaluate their emission-reducing effect when compared to surface-spread slurry (Huijsmans *et al.*, 1997). The results show a significant reduction of the emission by narrow band spreading with trailing feet and by shallow injection (open slot) or injection (closed slot). These application techniques are nowadays commonly in use in The Netherlands; broadcast surface spreading by splash plate is not allowed anymore.

Recently a new concept of slurry injection has been developed in Norway (Morken and Sakshaug, 1996). This Direct Ground Injection (DGI) system is based on a slurry jet instead of tines or discs that enter the soil. The DGI exists of elements that slide on top of the sward, spacing between the shoes is 30 cm. Slurry is injected under high pressure by pulses per sliding shoe. Compared to common (shallow) injection systems, the DGI does not cut the sward. This was seen as an advantage on stony soils on which conventional injection systems encounter problems with cutting a slit and with wear of the tines and coulters. Furthermore, conventional shallow injection systems require draught force (Huijsmans *et al.*, 1998); it was also shown that systems that do not cut the sward but slide on it, like a trailing foot system require low draught force. The injection elements of the DGI also slide on the sward and a low draught force requirement is assumed. This may be a solution for low emission manure application on peat and heavy clay soils. On these soil types problems with the draught of the soil are met in early spring when cutting a slit or draught force requirement causes slippage and damage to the sward. There is hardly any experience with the DGI concept on these soil types. The soil type may effect the performance of the DGI and the resulting reduction of ammonia losses.

A research was carried out to determine the ammonia losses when applying slurry with a conventional spreader equipped with a splash plate, a shallow injector (open slot) and a DGI under Dutch conditions.

2 Materials and methods

Experiments

In a series of experiments the ammonia emission when applying slurry with the DGI-injector was investigated under Dutch conditions. The ammonia losses were compared with the ammonia losses from surface applied manure and manure applied with a shallow injector (open slot). In total 8 experiments were carried out at different times during the growing season (June to September) to meet different soil conditions and weather conditions. In each experiment slurry was applied with the DGI, with a shallow injector (open slit) and a conventional spreader equipped with a splash plate. Four experiments were carried out on a peat soil (location Zegveld) and four on a heavy clay soil (location Duiven). Slurry was surface applied at a low (12-17 m3/ha) and a high (circa 20 m3/ha) rate. The DGI applied 20-30 m^3/ha; the shallow injector applied 15-35 m3/ha and 20-25 m3/ha on the peat and the clay soil, respectively. In all experiments cattle slurry was applied. In Table 1 the average characteristics of the slurries used on both research locations are given.

Table 1. The average contents of the used manure on the peat and clay soils expressed in NH_4-N, N_{total}, dry matter and pH with their lowest and highest values between brackets

Soil	NH_4-N ($g.kg^{-1}$)	N_{total} ($g.kg^{-1}$)	Dry matter ($g.kg^{-1}$)	pH
Peat	1.91 (1.51-2.36)	3.66 (2.85-4.91)	6.9 (6.7-7.1)	7.1 (6.5-7.4)
Clay	1.85 (1.71-2.00)	3.44 (3.17-3.81)	7.2 (7.0-7.4)	6.9 (6.3-7.8)

Measurements

The ammonia emission after application of the slurry was determined per plot using the micro-meteorological mass balance method as described by Denmead (1983) and Ryden and McNeill (1984). By applying the slurry in parallel passes varying in length over a pre-marked area, circular plots were achieved with a radius varying between 20 and 24 m. As soon as the slurry was applied at the first half of a plot (usually within 5 minutes) a mast supporting 7 NH_3 traps at heights between 0.25 and 3.30 m was placed in the centre of the plot. At the windward boundary of the plot, a mast was placed with 4 NH_3 traps at heights between 0.40 and 2.30 m. Each trap contained 20 ml 0.02 M HNO_3 held in 100 ml collection tubes. Air was drawn through the acid via a sintered gas dispersion tube at rates of 2-4 l min^{-1}, measured with flow meters. Ion-chromatography was used to analyse the NH_4^+-concentration in the HNO_3 solution.

In the experiments slurry was applied before noon. All plots in an experiment received slurry at approximately the same time to avoid the influence of changing soil and weather conditions on the ammonia emission during the measurements. The measurements on each plot continued for at least 4 days (96 hours) after slurry application. Traps were replaced five times the first 24 hours when the highest NH_3 loss rates occur. From day 2 till day 4 the traps were replaced in early morning and late afternoon. The time of each period and average airflow through each NH_3-trap were recorded. Wind speed at different heights and wind direction were measured on a mast outside the plot. Temperature and humidity were recorded on all sites during the experiments (Table 2). Field conditions of the shallow injection plot were very wet in week 30.

Table 2. The average temperature at 1 m height (T ; °C) and wind speed at 2.4 m height ($m.s^{-1}$) after 6 hours after spreading the manure and after 96 hours.

Soil type	Week	T 6 h	T 96 h	Wind 6 h	Wind 96 h
Peat	24	19.9	18.2	3.1	3.0
	25	15.3	15.0	3.4	3.1
	30	20.0	18.4	3.9	2.8
	31	21.5	18.3	2.3	2.8
Clay	26	15.7	14.7	3.6	2.6
	28	17.2	18.5	2.5	2.3
	29	20.1	18.2	2.7	2.5
	33	26.6	22.0	2.4	1.9

3 Results

In Table 3 and 4 the NH_4-N contents of the slurries used, the application rates and the ammonia emissions are given for each application method and experiment on both experimental sites, respectively.

Table 3. NH_4-N contents of the slurries, the application rates and de ammonia emissions after 96 hours for the experiments on peat soil (Zegveld), in week 24, 25, 30 and 31.

	NH_4-N content (kg.m^{-3} slurry)	Application rate (m^{3}slurry.ha^{-1})	Application rate NH_4-N (kg.ha^{-1})	Emission (% of the NH_4-N application)
Week 24				
Reference low	2.04	12.1	24.7	46.4
Reference high	1.98	20.8	41.2	70.0
DGI	2.03	26.2	53.2	12.8
Shallow injection	2.12	15.5	52.8	3.4
Week 25				
Reference low	2.36	13.6	32.2	-
Reference high	2.30	20.8	47.8	89.6
DGI	2.28	26.0	59.3	21.5
Shallow injection	2.20	20.1	44.3	17.5
Week 30				
Reference low	1.51	15.1	22.8	80.9
Reference high	1.54	19.4	29.9	107.3
DGI	1.73	22.6	39.2	12.7
Shallow injection	1.68	31.6	53.0	33.5
Week 31				
Reference low	1.68	14.3	24.0	96.3
Reference high	1.70	21.3	36.2	64.6
DGI	1.70	26.6	45.2	12.8
Shallow injection	1.67	34.4	57.5	15.3

Table 4. NH_4-N contents of the slurries, the application rates and de ammonia emissions after 96 hours for the experiments on clay soil (Duiven), in week 26, 28, 29 and 33.

	NH_4-N content ($kg.m^{-3}$ slurry)	Application rate ($m^3 slurry.ha^{-1}$)	Application rate NH_4-N ($kg.ha^{-1}$)	Emission (% of the NH_4-N application)
Week 26				
Reference low	1.99	12.5	24.8	76.6
Reference high	2.00	19.4	38.7	93.2
DGI	1.99	29.4	58.3	18.4
Shallow injection	1.99	23.3	46.4	25.1
Week 28				
Reference low	1.75	16.7	29.1	80.6
Reference high	1.73	20.1	34.7	105.1
DGI	1.71	25.3	43.3	43.5
Shallow injection	1.73	24.3	42.1	43.1
Week 29				
Reference low	1.94	16.4	31.9	80.8
Reference high	1.93	19.9	38.3	77.9
DGI	1.91	25.5	48.6	31.2
Shallow injection	1.93	20.6	39.7	27.9
Week 33				
Reference low	1.79	14.9	26.6	105.7
Reference high	1.77	19.4	34.2	99.9

The average losses from the surface applied high and low application rate, the DGI and the shallow injector were 81, 88, 23 and 24% of the ammonium applied, respectively. The measurement in week 25 on the plot with low application rate was lost due to malfunctioning of equipment.

In Table 5 the reductions of the ammonia emission compared with broadcast surface spreading at high application rates (19-22 m^3 ha^{-1}) and low application rates (12-16 m^3 ha^{-1}) are given. Average emission reduction of the DGI was 71% when compared with the low application rate surface spreading and 74% when compared with the high application rate surface spreading; for the shallow injection these reductions were 70 and 74%, respectively.

Table 5. Reduction of the ammonia emission compared with broadcast surface spreading at low application rates (12-16 m^3 ha^{-1}) and high application rates (19-22 m^3 ha^{-1}).

Soil type	Week	DGI compared with:		Shallow injection compared with:	
		Low application rate	High application rate	Low application rate	High application rate
Peat	24	72	82	93	95
	25	-	76	-	80
	30	84	88	59	69
	31	87	80	84	76
Clay	26	76	80	67	73
	28	46	59	47	59
	29	62	60	66	64
	33	69	67	77	75
	Average	71	74	70	74

4 Discussion

Ammonia losses

In three experiments measured ammonia losses were a little higher than 100%; this is assumed to be within the limits of the accuracy of these kind of measurements.

Performance

Dry soil conditions at the clay soil made the surface layer of the soil very hard. In this soil condition the DGI was not able to inject slurry. Therefore experiments on the clay soil were delayed and experiments were first started the peat soil location.

Power requirement of the DGI

Experiments were set up for an application rate of 25-30 m^3 cattle slurry per ha. To achieve this application rate forward speed of the DGI needed to be at least 8 km/h. At the experimental plots no variation on application rate was allowed. This job could not be handled by a 70-80 hp tractor; when starting the application this tractor could not continue its forward speed. A tractor of more than 120 hp was hired for the experiments in Zegveld and in Duiven. It was experienced (also by the contractors) that the power requirement of the pump was relatively high.

Blockages

During the experiments no problems occurred with blockages. The slurry applied was handled "properly" at both experimental farms and intensively mixed before each experiment. Most shallow injectors, in use by contractors in the Netherlands, have a filter/cutting system on their application system to prevent blockages. When using the DGI in practice, blockage prevention needs to be considered.

Application result

Slurry application systems, which are nowadays allowed in the Netherlands, apply slurry in narrow bands on the soil surface by a trailing foot system (no contamination of the grass) or apply the slurry in shallow slits by a shallow injector, leaving the slit open. The DGI is presented as a system that applies the slurry in small holes, created by under high pressure pulswise injected slurry. At the application rate (and forward speed) and at the soil conditions in the experiments, the DGI injected the slurry in the holes and left a band of slurry on the grass between the following holes. The amount of slurry in these bands is not expected to be much, but it might effect the ammonia losses. At first sight, it shows as contamination of the grass. In the experiments on the peat soil the mixing of the slurry and the soil (peat, organic matter) in the holes could be (visually) observed; this could not be observed at the heavy (dried) clay soil.

Points of further attention

- slurry dripping , when lifting the DGI
- placement of the valves to fill the tank: front side of the tank (both sides) and at the rear of the tank. The rear valve could also be used to empty the tank.
- control of the application rate: range to achieve a lower application rate at an even lower forward speed
- the use of the DGI in combination with an umbilical system instead of a tank
- the use of the DGI on a sand soil and in a contractor practice

5 Conclusion

The average losses from the surface applied high and low application rate, the DGI and the shallow injector were 81, 88, 23 and 24% of the ammonium applied, respectively. Average emission reduction of the DGI was 71% when compared with the low application rate surface spreading and 74% when compared with the high application rate surface spreading; for the shallow injection these reductions were 70 and 74%, respectively.