

Nitrogen fertilizer replacement value of concentrated liquid fraction on grassland and effects on farm level

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Abstract

In the Netherlands, initiatives are taken to process animal manure. In a pilot of manure processing a liquid fraction of pig slurry with mainly mineral nitrogen (N) and potassium (K) is produced. The liquid fraction is concentrated into mineral concentrate (MC). To determine the nitrogen fertilizer replacement value (NFRV) on grassland, field experiments took place on sand and clay. The N yields with MC, calcium ammonium nitrate (CAN) and liquid ammonium nitrate (LAN) were compared. The responses to MC and LAN were lower than expected, compared to CAN. This resulted in NFRVs for MC that varied between 44 and 82%, with CAN as a reference fertilizer. To consider the consequences at farm level, a farm is simulated. By replacing 80 kg N ha⁻¹ of CAN with 10 m³ ha⁻¹ of MC, the farm saves €4,864 for fertilizers but yield reduction is 12 Mg DM of grass silage, which equals €2,040. This indicates that the MC should cost €7.40 m⁻³ maximum to reach an equal income on the alternative farm compared with the reference farm. If the NFRV were to reach 100%, the MC should cost €12.80 m⁻³ maximum, the costs of the replaced mineral fertilizers N and K₂O.

Keywords: liquid fraction, pig slurry, mineral concentrate, apparent N recovery, NFRV

Introduction

In the Netherlands, initiatives are taken to process animal manure to increase mineral efficiency and to export phosphorus (P) surplus. From 2009, a pilot is taking place of manure processing on industrial scale. Manure is separated into a liquid fraction with mainly mineral nitrogen (N) as ammonium and potassium (K) for application on farms in the Netherlands, and a solid fraction with mainly organic N and P for export. The liquid fraction is concentrated into mineral concentrate (MC) by reversed osmosis (Velthof *et al.*, 2012). For an efficient use of MC it is necessary to know the N fertilizer replacement value (NFRV). It was expected that the NFRV of MC on grassland would be slightly lower than 90% because of ammonia volatilization. To determine the NFRV on grassland, grassland field experiments took place from 2009 to 2012.

Materials and methods

In grassland experiments the N uptake after application of MC of pig slurry, calcium ammonium nitrate (CAN) and liquid ammonium nitrate (LAN), both with 50% ammonium, 50% nitrate, were compared at three application rates: 100, 200 and 300 kg N ha⁻¹, divided over three successive cuts, and a control (0 N). All plots received the same rate of P and K, and more sulphur than recommended in the fertilizer recommendation, from MC and/or from mineral fertilizers. The MC and LAN were injected approximately 5 cm into the soil. The CAN, P and K were applied with an accurate granulate spreader for experimental fields or by hand by experienced people. On the 0 N plots, the application machines were used without fertilizer. In 2009 and 2010 MC (from three producers), CAN and LAN were applied in one, two or three successive cuts; in 2011 the same treatments were applied, but MC was from one producer; finally, in 2012 MC was from one producer and CAN and LAN were applied in three successive cuts. In 2009 and 2010, the soil types were clay and sand, in 2011 sand, and in 2012 relatively wet sand and sand under hydrological circumstances considered as normal (for the Netherlands). On all

plots dry matter (DM) yield and N content of the grass were measured through the whole growing season in five cuts. At the end of the growing season soil mineral N (0-90 cm) was measured.

The results of annual DM yield, N yield and mineral soil N were statistically analysed with the Residual Maximum Likelihood method (Reml) (Harville, 1977). The initial model comprised type of fertilizer, year, soil type, N level, N level², number of fertilized cuts and the interactions. The random model was replicate×site. Non-significant terms and interactions were deleted. With the resulting model for N yield the NFRV was calculated by dividing the Apparent N Recovery (ANR) of MC by the ANR of the reference (CAN). ANR was calculated as (N yield at N-fertilization minus N yield at zero N-fertilization)/N-fertilization (Schroder *et al.*, 2007).

To consider the consequences oat farm level, a farm is simulated with DairyWise, a whole farm budgeting program (Schils *et al.*, 2007). The simulated farm is a dairy farm, 50 ha on sandy soil: 12 ha of forage maize, 38 ha of grassland, 110 dairy cows producing 8,600 kg milk, 41% calves, 39% heifers. The legal application standards are 250 kg N ha⁻¹ animal manure (including pasture excretion), legal NFRV 45% for animal manure, 250 kg plant available N ha⁻¹ (animal manure N × 45% + mineral fertilizer N). The reference scenario is a farm applying all mineral N as CAN compared with an alternative scenario that is a farm that replaces 80 kg N ha⁻¹ with 10 m³ MC ha⁻¹ grassland, NFRV 75%, 8 kg N and 8 kg K₂O m⁻³.

Results and discussion

The responses of DM and N yield to N-fertilization were positive for all fertilizers. The resulting model was:

$$N_{\text{yield}}_{\text{year} \times \text{site}} = \text{Constant}_{\text{year} \times \text{site}} + \beta_{\text{year} \times \text{fertilizer type} \times \text{site}} \times N_{\text{fertilization}} + \mu_{\text{replicate} \times \text{site}} + \varepsilon_{\text{plot} \times \text{site}}$$

In which: N_{yield} is N yield (in kg N ha⁻¹) for specific year and site, Constant (in kg N ha⁻¹) is intercept for specific year and site, β is a coefficient depending on year, fertilizer type and site for N fertilization, and N fertilization is N application rate (in kg N ha⁻¹), μ is the random model, ε is residual variance. Other factors or interactions were not significant (*P*<0.05).

With the model results of CAN, LAN and MC, the ANRs and NFRVs are calculated, respectively (Table 1). The variance between years was large, including responses to the reference fertilizers CAN and LAN. The responses to MC and LAN were lower than expected compared to the response to CAN. Overall the NFRV of MC with CAN as reference was 75% on sand and 58% on clay. On sand the lowest NFRV of MCs was 61% in 2009 and the highest was 82% on dry sand in 2012. On clay NFRVs were 44% in 2009 and 67% in 2010. The lower NFRV on clay soil was (mathematically) caused by a relatively high ANR of CAN, the ANR of MCs on clay was in the same range as on sand. A high ANR of CAN, however, is normal for this site (Schils and Snijders, 2004).

It is not clear why, in most of the experimental years, the response of DM and N yield to liquid fertilizers (LAN and MC) is lower than to CAN. The application method was accurate and control plots (0N) with slits from the application machine showed an equal yield as plots without slits.

The NFRV of MC was in general lower than of LAN. This difference might be explained by ammonia volatilization as MC has a high ammonia concentration and pH (ca. 8). The mineral soil N under MC and LAN, however, was not different from those under CAN. It was unlikely that the non-recovered N was lost through leaching. Possibly it was lost through gaseous N emissions (ammonia volatilization) and/or stored as organic N in the soil.

Table 1 Apparent nitrogen recovery (ANR, kg N kg⁻¹ N) of calcium ammonium nitrate (CAN), liquid ammonium nitrate (LAN) and mineral concentrate (MC), and nitrogen fertilizer replacement value (NFRV), on sand and clay in 2009 to 2012, based on nitrogen yield, with CAN and LAN as reference.

Year	Soil	ANR, kg N kg ⁻¹ N			NFRV, %			
		CAN	LAN	MC	Reference: CAN		Reference: LAN	
					MC	LAN	MC	CAN
2009	Sand	0.58	0.41	0.35	61	70	86	143
	Clay	0.78	0.45	0.34	44	58	76	174
2010	Sand	0.74	0.55	0.58	78	74	105	135
	Clay	0.84	0.54	0.56	67	65	104	155
2011	Sand	0.65	0.65	0.52	80	100	80	100
2012	Dry sand	0.70	0.71	0.57	82	102	80	98
	Wet sand	0.84	0.78	0.65	77	92	83	109
Overall	Sand	0.68	0.57	0.51	75	84	89	119
	Clay	0.81	0.51	0.47	58	62	92	160

The relatively low NFRV has economic consequences for the use on high productive dairy farms. The farm applying MC saves €3,040 for CAN (€1 kg⁻¹ N) and €1,824 for K₂O (€0.60 kg⁻¹ K₂O) but cannot replace 20 kg N ha⁻¹ from MC that is not represented in the NFRV due to the legal application standards. The yield reduction at farm level is 12 ton DM of grass silage, which equals €2,040 (€0.17 kg⁻¹ DM). The decrease of feeding value by lower N fertilization rate is not taken into account. This indicates that the MC should cost €7.40 m⁻³ maximum to reach an equal income on the alternative farm compared with the reference farm. In 2014, however, MC was sold for €14 m⁻³ by the processing companies. If the NFRV would reach 100%, MC should cost €12.80 m⁻³ maximum, the costs of the replaced mineral fertilizers N and K₂O.

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