Effects of slurry application method on grassland yield, nitrogen utilisation and silage quality

Latsch A.[1], Huguenin-Elie O.[2], Wyss U.[3] and Nyfeler D.[4]
[1]*Agroscope, Digital Production, Tänikon, 8356 Ettenhausen, Switzerland;* [2]*Agroscope, Forage Production and Grassland Systems, Reckenholzstrasse 191, 8046 Zürich, Switzerland;* [3]*Agroscope, Ruminant Nutrition and Emissions, Rte de la Tioleyre 4, 1725 Posieux, Switzerland;* [4]*Rural Centre of Canton Thurgau, Arenenberg 8, 8268 Salenstein, Switzerland*

Abstract

The use of low-emission equipment has become mandatory for slurry distribution in a number of countries. However, the effects on yield, nitrogen (N) utilisation and silage quality are still intensively debated. In a 3-year field experiment at two experimental sites in Switzerland, we tested the effects of broadcast equipment (BC) and the low-emission devices band-spread (BS) and trailing-shoe (TS) on dry matter yield, N utilisation by plants and silage quality. The different equipment was tested in combination with two slurry consistencies (unaltered dilution; extra dilution), two timings of application (immediately or delayed after preceding harvest), and two sward types (with legumes; without legumes). BS compared to BC revealed positive effects on dry matter yield and N utilisation at one, but not the other site. Delayed application improved apparent N recovery but not yield, and only at one of the two sites. Extra slurry dilution proved positive for both yield and N recovery. In terms of silage quality, low-emission equipment had no relevant detrimental effects, while early application with extra diluted slurry was advantageous. We conclude that slurry application by low-emission equipment can be advantageous in terms of yield and N utilisation without being detrimental in terms of silage quality.

Keywords: apparent N recovery, broadcast, band-spread, trailing-shoe, distribution equipment, forage

Introduction

The need for reduced ammonia (NH_3) emissions in agriculture is attended by the mandatory use of low-emission equipment for slurry distribution. Due to reduced NH_3 emissions, plant N availability of slurry N should be improved. Results of previous studies in grassland are however not conclusive, having revealed sometimes positive, sometimes indifferent yield effects (Huguenin-Elie *et al.*, 2018). In addition, slurry consistency and timing of application after the preceding harvest might also affect slurry N utilisation due to their impact on slurry infiltration into the soil and protection by the plant canopy, respectively. Finally, the presence of legumes in a sward might offset effects of the slurry application methods by buffering the amount of N available to the swards. Apart from uncertainties in terms of yield and N utilisation, many farmers refrain from using low-emission equipment, because of concerns regarding slurry residues (band-spreading) or soil particles (trailing-shoes) in the harvested plant material. In a field experiment, we aimed at assessing the effects of different slurry distribution devices, slurry consistency, application timing and sward type on yield, N utilisation and silage quality during several years and for different site conditions.

Material and methods

A 3-year field experiment was established at two sites on the Swiss Plateau, on intensively managed temporary grassland: (1) Site1 (535 m a.s.l.; average annual temperature 7.9°C; 1124 mm precipitation), 18 m^2-large plots, fully randomized, and (2) at about 30 km distance, Site2 (470 m a.s.l.; average annual temperature 9.4°C; 956 mm precipitation), 135 m^2-large plots in a randomized block design. The experiment at Site1 included different types of slurry distribution equipment (BC: broadcast, BS: band-spread, TS: trailing-shoe), slurry consistency (unaltered dilution: 4–5% DM content, extra dilution:

2–3% DM content), timing of application (early: 1–3 days after the preceding cut, late: 7–10 days delayed), and sward type (with and without legumes) in a multifactorial design. At Site2, the number of treatments was reduced (without trailing-shoe and diluted slurry). The plots were harvested five times a year (in year 1 however, with only two harvests remaining after the establishment phase), and slurry was applied to each regrowth at a targeted amount of 30 kg NH_4-N ha^{-1}. Dry matter yield and forage N content was determined at each harvest. Slurry was sampled at each application to be analysed for its NH_4^+-N content. Apparent slurry N recovery, henceforth denominated as N_{rec}, was calculated from the difference in N yield with the unfertilised control-plots and the amount of applied NH_4^+-N (only plots without legumes). At Site1, plant samples of the first, second and fourth harvest of the third experimental year were ensiled in 1.5 l laboratory silos and analysed before (clostridial bacteria occurrence measured as most probable number g^{-1}) and after the fermentation process (butyric acid content) to determine silage quality (only plots with legumes). Data were analysed using generalised linear models or generalised linear mixed-effect models with distribution equipment, slurry consistency, application timing and sward type as fixed effects. All interactions were included in the analysis. Differences between the different treatments were then tested by the Tukey range test. All analyses were performed using the statistical software R (R Core Team, 2023).

Results and discussion

Treatment effects on DM yield and N_{rec} were not consistent across the two sites: whereas the distribution equipment had no effect at Site1, there was a significant increase when slurry was applied by BS compared to BC in terms of DM yield (+9%; $P \leq 0.001$) and N_{rec} (+16%; $P \leq 0.001$) at Site2. This inconsistency is in line with literature, where both positive and indifferent yield effects have been reported for grassland experiments (Huguenin-Elie *et al.*, 2018). Such results might be explained by the relatively small NH_3-N quantities being spared with low-emission equipment in comparison with the total amount of plant available N in intensive grassland systems (Häni *et al.*, 2016). Extra slurry dilution affected DM yield (+6%; $P \leq 0.01$) and N utilisation (+24%; $P \leq 0.05$) positively compared to unaltered slurry dilution, which may be associated with both an enhanced soil infiltration and reduced ammonia emissions (Sommer *et al.*, 2006). Delayed application improved only N_{rec} and this only at Site2 (+20%; $P \leq 0.05$). The presence of legumes had no influence on the effects of type of distribution equipment but generally increased yield at both sites (+19% and +21% at Site1 and Site2, respectively; $P \leq 0.001$), confirming the well-documented advantages by symbiotic nitrogen fixation (Nyfeler *et al.*, 2011). Evaluated parameters of silage quality were only slightly affected by the tested experimental factors. At the three harvests, there was no indication for consistent detrimental effects by low-emission equipment on silage quality (three inconsistent significant differences for clostridial bacteria occurrence or butyric acid content; $P \leq 0.05$), but rather an indication for early application and extra diluted slurry being advantageous (each one time; $P \leq 0.05$ at harvest 2 and 1, respectively).

Conclusions

Slurry application with low-emission equipment compared to broadcast distribution can be favourable in terms of yield and N utilisation. The positive effect of extra slurry dilution on yield and N utilisation was in the same order of magnitude as the one of low-emission equipment. In terms of silage quality, we did not find any consistent detrimental effect of distribution by low-emission equipment. Variability of silage quality across harvests indicates that forage preparation for ensiling (e.g. ideal degree of wilting, avoiding soil residues in the forage) might have a stronger impact on bacteria-related quality parameters than distribution equipment.

Table 1. Dry matter yield (Mg ha^{-1}) and proportion of N recovered from slurry-N averaged for each experimental factor level (both sites) as well as silage quality parameters clostridial bacteria occurrence (CL: most probable number g^{-1}) and butyric acid content (g BA kg^{-1}) (only Site1).

	DM yield and N_{rec}				Bacteria-related silage quality parameters					
	Site1		Site2		Harvest 1		Harvest 2		Harvest 4	
	DM	N_{rec}	DM	N_{rec}	CL	BA	CL	BA	CL	BA
Distribution equipment										
Broadcast (BC)	20.6	0.42	23.9^{a}	0.67^{a}	90	1.6^{a}	163^{ab}	24.6	5.0^{a}	26.4
Band-spread (BS)	20.3	0.36	26.0^{b}	0.78^{b}	60	2.1^{ab}	64^{a}	23.2	6.7^{b}	23.6
Trailing-shoe (TS)	21.3	0.46	-	-	123	4.8^{b}	138^{b}	24.2	5.8^{ab}	29.2
Slurry consistency										
Unaltered dilution	20.2^{a}	0.37^{a}	-	-	113^{b}	2.7	104	24.1	5.8	27.3
Extra dilution	21.3^{b}	0.46^{b}	-	-	45^{a}	2.1	140	23.8	5.8	23.7
Application timing										
Early	21.0	0.40	25.0	0.66^{a}	75	2.8	74^{a}	22.8	5.7	24.4
Late	20.5	0.42	25.0	0.79^{b}	96	2.1	164^{b}	25.0	6.0	27.3
Averaged SEM	0.46	0.033	0.86	0.048	25.9	0.74	40.1	1.31	0.51	1.53

Letters indicating significant differences are only given for factors being significant in the model of the statistical analysis ($P \leq 0.05$). Dry matter yield is shown as the sum over the entire period of the experiment and N_{rec} as the proportion of N in the harvested plant material (only swards without legumes) apparently recovered from slurry NH_4-N (as weighted averages from all harvests). Silage quality was only determined at Site1 and for harvest 1, 2 and 4 in year 3. SEM is only given as average over the means of each treatment level.

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