Impact of different fertilization intensity on nutrient leaching in ley-based farming systems

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Abstract

Ley farming based on highly productive grass-clover mixtures can be an interesting amendment to permanent grassland, but during the course of grassland ploughing until the full establishment of the ley-farming vegetation there is an extended risk for nutrient leaching. By means of a perennial field experiment, equipped with gravitation lysimeters, nutrient leaching has been investigated in an intensive grassland region of Austria. High nitrate concentrations in the leachate (up to 360 ppm) and high nitrogen losses of up to 184 kg ha^{-1} occurred during the year of establishment. In the following period, nitrogen losses were reduced to a level comparable to permanent grassland. Therefore special attention has to be given to the fertilization level in the establishment year of ley-farming areas to avoid nutrient losses and negative environmental consequences.

Keywords: grassland ploughing, grass-clover mixtures, water quality, nitrate leaching

Introduction

Permanent grassland covers up to 90% of agriculturally used areas in mountainous regions of Austria and another 145,000 ha farmlands (≈ 10%) are temporarily cultivated with grass, clover or grass-clover mixtures. These ley farming areas provide around 19% of the net yield, 20% of the energy yield and 26% of the protein yield that is in total harvested from grassland-based areas (BMLFUW, 2012). The use of legumes in seed mixtures for ley farming and permanent grassland is an efficient strategy to reduce the external N-input on farms, which is especially important regarding the European-wide discussion about protein substitution in feeding. Although consisting of typical grassland plants, ley-farming stands are declared as arable land and have to be renewed within 5 years according to EC-legal regulations (Poetsch *et al*., 2007). Apart from high costs of establishment there are some ecological risks, which have to be considered seriously to avoid environmental problems, e.g. nitrate leaching.

Materials and methods

A field experiment was established at Winklhof in the province of Salzburg in 2007. This site is located at 452 m a.s.l and characterized by an average rainfall of 1500 mm yr^{-1} and a mean temperature of 9.1°C during the observation period of 4 years. After ploughing, a grass-clover mixture (80% grass and 20% clover) was sown at the end of April 2007. Two fertilization intensities (85 and 170 kg $N_{ex\ storage}$ ha^{-1} yr^{-1} using cattle slurry) were used and the plots were cut four times per year. To determine the amount and quality of leachate, gravitation lysimeter chambers (1.1 m diameter, 1.4 m depth) were permanently installed in the plots, including three replications of all treatments.

Results and discussion

In the year of establishment the yield productivity was at a disappointing low level, without significant differences between the fertilization intensities (Table 1). By reason of weed control two cleaning cuts were necessary in this year, followed by two late harvest cuts in September and October. In 2008 the yield level in both systems strongly increased but continuously dropped again in the following two years in both systems, due to unfavourable weather conditions with heavy rainfall during the growing season. Indeed, from 2008 to 2010 a significantly higher yield could be observed for the intensive fertilization level, but the potential of the ley-farming mixture, which usually provides up to 12 t ha^{-1} yr^{-1} in favourable regions, could not be obtained at the experimental site.

Table 1. Dry matter yield (t ha^{-1} yr^{-1}).

	Medium fertilization level					High fertilization level				
	$\bar{x}$	Median	σ	Min.	Max.	$\bar{x}$	Median	σ	Min.	Max.
2007	$3.88^{a, e}$	3.54	0.78	3.33	4.78	$4.25^{a, e}$	4.10	0.67	3.66	4.98
2008	$9.37^{a, f}$	9.29	0.23	9.19	9.63	$10.52^{b, f}$	10.34	0.44	10.20	11.02
2009	$7.17^{a, g}$	7.46	0.54	6.54	7.89	$8.66^{b, g}$	8.70	0.08	8.58	8.71
2010	$5.71^{a, g}$	5.99	0.50	5.13	7.50	$7.73^{b, g}$	7.88	0.30	7.38	7.93

a, b – indicate sign. differences between fertilization levels; e, f, g – indicate sign. differences between years

Compared with the seed mixture composition, legumes contributed a disproportionately large component of the yield in all years at both fertilization levels (Table 2). In grassland-based farming systems with a low input of external feedstuff the protein content of forage is of great importance. In our experiment the protein concentration in forage differed significantly between the two fertilization levels and showed a declining tendency in the course of the observation period. The removal of nitrogen, calculated on the basis of yield and its related protein content, clearly exceeded the nitrogen input via fertilization, which indicates that other N-sources such as biological N-fixation, N-deposition and N-mineralization also contributed. The high fertilization level (+ 85 kg N) representing the upper limit of the Council Directive 91/676 (EEC, 1991), indeed had a significant but disappointingly low effect on yield productivity and consequently on nitrogen removal (+ 14.5 kg N).

Table 2. Legume proportion (weight-%), protein concentration in forage (g kg DM^{-1}) and N-removal (kg N ha^{-1} yr^{-1}) - average data of four cuts yr^{-1}.

	Medium fertilization level			High fertilization level		
	Legumes	Crude protein	N-removal	Legumes	Crude protein	N-removal
2007	$38.0^{a, e}$	n.a.	n.a.	$37.7^{a, ef}$	n.a.	n.a.
2008	$47.3^{a, f}$	$155.1^{a, e}$	$232.5^{a, e}$	$44.9^{a, e}$	$151.4^{b, e}$	$254.8^{b, e}$
2009	$44.3^{a, ef}$	$148.8^{a, f}$	$170.8^{a, f}$	$42.7^{a, ef}$	$146.6^{b, f}$	$203.2^{b, f}$
2010	$36.0^{a, e}$	$138.8^{a, g}$	$126.8^{a, g}$	$35.0^{a, f}$	$141.3^{b, g}$	$174.8^{b, g}$

a, b – indicate sig. differences between fertilization levels; e, f, g – indicate sig. differences between years

In the establishment year an average nitrate concentration of nearly 80 mg L^{-1} leachate was detected with maximum values of more than 350 ppm (Table 3). In both fertilization systems more than 40% of all leachate analyses (15-20 yr^{-1}) were beyond the EU-wide existing nitrate threshold of 50 ppm whereas in the following years no values exceeded the threshold. The combination of low yield, high (but still legal) nitrogen load and an obviously strong mineralisation pulse in the soil system led to extremely high rates of N-losses via leachate in the year of establishment.

Table 3. Nitrate concentration in percolating water and nitrogen leaching data.

	Medium fertilization level				High fertilization level			
	mg NO_3^- L water^{-1}		N-leaching (kg ha^{-1} yr^{-1})		mg NO_3^- L water^{-1}		N-leaching (kg ha^{-1} yr^{-1})	
	x̄	Max.	x̄	σ	x̄	Max.	x̄	σ
2007	76.9$^{a, e}$	355.3	167.9$^{a, e}$	11.6	75.9$^{a, e}$	366.2	183.9$^{a, e}$	13.9
2008	9.9$^{a, f}$	47.1	17.2$^{a, f}$	10.7	7.1$^{a, f}$	26.8	14.1$^{a, f}$	7.9
2009	13.1$^{a, f}$	36.1	25.5$^{a, f}$	11.9	8.1$^{b, f}$	18.9	16.7$^{a, f}$	8.9
2010	10.3$^{a, f}$	23.6	15.2$^{a, f}$	6.1	8.8$^{a, f}$	24.7	15.1$^{a, f}$	4.7

a, b – indicate sig. differences between fertilization levels; e, f, g – indicate sig. differences between years

Nitrogen balances were established at the field level, including N-fertilization, N-deposition, biological N-fixation, N-removal, unavoidable gaseous N-losses and N-leachate. The total N-input was strongly influenced by biological N-fixation (up to 150 kg N ha^{-1}, estimated by N-difference method) whereas nitrogen leaching significantly contributed to the total N-output in the first year. Nitrogen balances should therefore not only be scaled to nitrogen fertilization and nitrogen removal by plants but should also consider other important partitions.

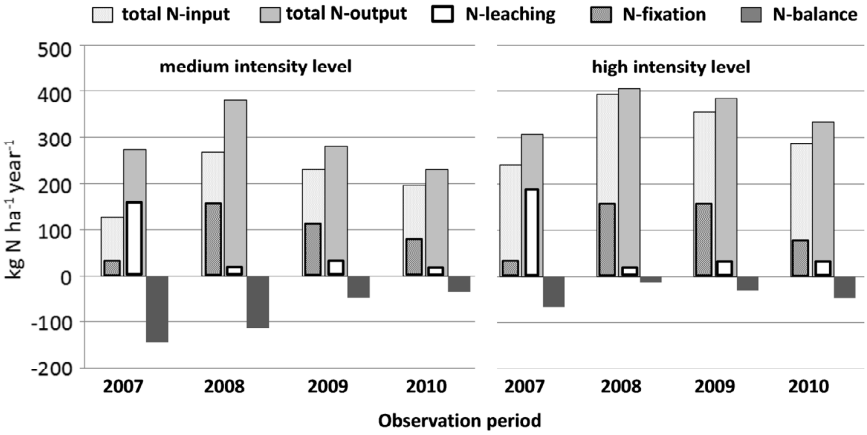

Figure 1. Nitrogen field balance in the lysimeter experiment at Winklhof, Austria.

Conclusions

Ley farming provides an attractive option to produce forage of high quality, but compared with permanent grassland there is a considerable risk for high nitrate concentration in the leachate and nitrogen losses, especially in the year of establishment. To avoid such environmental problems, the awareness of farmers has to be raised to adapt the fertilization level to the expected lower yields in this critical period.

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