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Nitrate leaching following the cultivation of silage maize

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Introduction

In the last 30 years the proportion of fields planted with maize (*Zea mays*) in Germany has greatly increased and today, maize ranks as the third important crop in Germany. In the Weser-Ems district in northwest Germany, the use of maize as a forage crop for silage-making is predominant und covers almost a quarter of the arable land. Given the scale of this use, the management of silage maize production is important as it has a great impact on groundwater quality at the catchment scale. High amounts of soil mineral nitrogen are often found after harvest in autumn, and this is related to nitrogen from organic fertilizer like manure or slurry. This short paper is aimed at presenting some data on the question, of whether the form and amount of nitrogen fertilization have an effect on N losses with leaching water following the harvest of silage maize in autumn. Conclusions drawn from the results might help to develop strategies for a groundwater protective management of silage maize.

Material and methods

The experiment on silage maize has a two-factorial design (Table 1). The experimental site is located in northwest Germany on a sandy soil with a relatively high organic matter content of up to 7 %.

Table 1: Experimental design of the experiment on silage maize

Factor	Level	Abbr.	Main parameters
1. Form of N input	1.1 mineral fertilizer*	KAS	• DM-yield
	1.2 cattle slurry	RG	• N-conc. In plant material
	1.3 pig slurry	SG	• N-yield plant
2. Amount of N input	2.1 0 kg N ha^{-1}	N0	• NO_3^--N conc. in leachate
	2.2 80 kg N ha^{-1}	N80	• NO_3^--N loading rate
	2.3 160 kg N ha^{-1}	N160	• Soil mineral nitrogen
	2.4 240 kg N ha^{-1}	N240	
4 replications; plot size is: 72 m^2; 3 suction cups per plot at 70 cm depth			

* mineral fertilizer = calcium-ammonium-nitrate

The N fertilization was divided into two applications, with 70 % applied after ploughing and 30 % given at a later date. Phosphorus and potassium were provided either by cattle or pig slurry or added in mineral form to plots that received no nitrogen (N0) or received N as

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calcium-ammonium-nitrate (KAS). The need for P was met by the application of a band of mineral fertilizer placed 5 cm below and 5 cm to the side of the maize seed, with 20 kg N ha^{-1} and 30.5 kg P ha^{-1} to all treatments. K in mineral form was applied broadcast and amounted to 200 kg K ha^{-1}. Weeds were controlled by herbicides. Further details on the experiment can be found at 'Materials&Methods'.

Results and discussion

Leaching losses after harvest of the maize amounted to 114 kg N ha^{-1} averaged over all years and treatments. These high losses might be attributed not only to the effects of N fertilization, but also predominantly to a site-specific high mineralization rate – N leaching from the nil N plots is already at a very high level (Figure 1).
During the four years of the experiment, the effect of the factor year has been greater than the variation in N leaching that was caused by the different forms and levels of N fertilizer. Nitrate leaching varied among the years from 44 to 168 kg N ha^{-1} averaged over all fertilizer treatments.

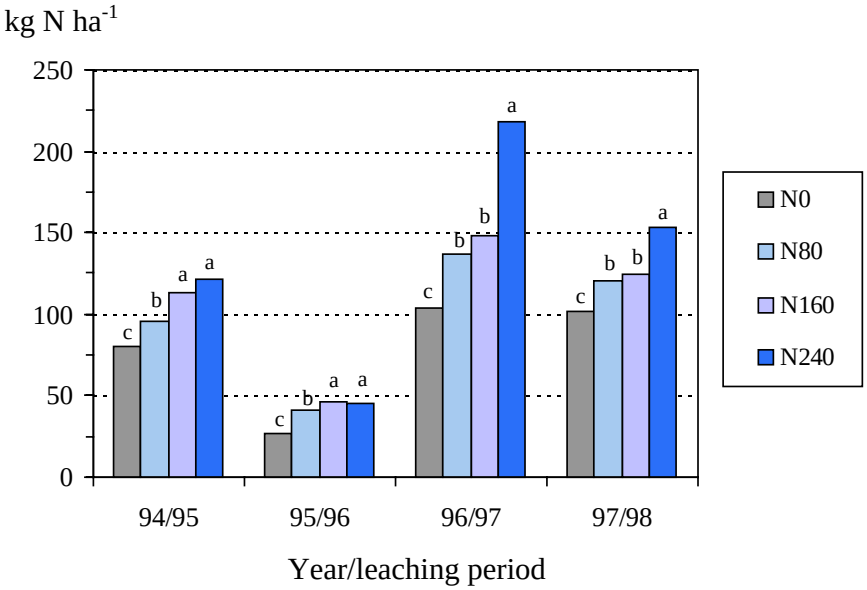

Figure 1: Nitrate leaching after the harvest of silage maize as an effect of the amount of N fertilization for four leaching periods from 1994/95 to 1997/98. Values with different letters within one leaching period are significantly different at the <0.05 level.

When increasing amounts of N were applied, nitrate leaching losses increased from 83 kg N ha^{-1} for the plots that received no N (N0) to 152 kg N ha^{-1} at an N level of 240 kg N ha^{-1} (N240). Differences are statistically significant. This means that an increase in N applied of 240 kg led to additional N leaching losses of about 69 kg N ha^{-1}.

Nitrate leaching was significantly higher after application of N in mineral form (KAS) and after application of pig slurry compared to cattle slurry as an N source (Figure 2). It should be considered, however, that the amounts of N applied with the slurries refer to total N – the proportion of NH_4 in pig slurry and cattle slurry is about 70 % and 55 %, respectively.

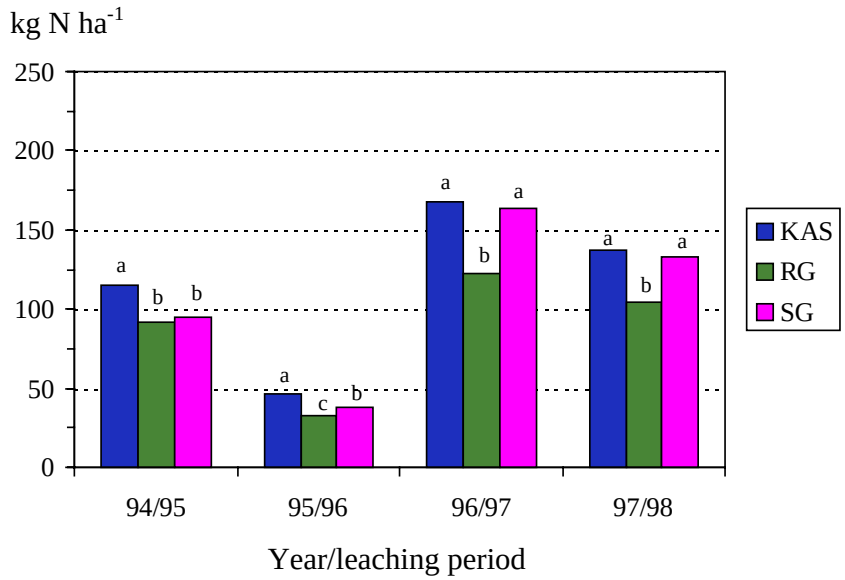

Figure 2: Nitrate leaching after the harvest of silage maize as an effect of the form of N fertilization for four leaching periods from 1994/95 to 1997/98. Values with different letters within one leaching period are significantly different at the <0.05 level.

The smaller leaching losses from the cattle slurry treatments can be largely explained by the high proportion of organically bound nitrogen and also partly by volatile losses during application.

Conclusions

- Site and soil-specific effects and environmental factors (weather/year) have a stronger effect on N leaching losses following the harvest of silage maize than the amount and form of N fertilizer. Fields, like the experimental site, with relatively high total C and total N content in the soil as well as a high biological activity, have to be regarded as problematic for cultivation of maize and need, at least, special consideration with respect to management activities.
- The application of greater amounts of N fertilizer results in increasing nitrate leaching losses. This increase can be described by an almost linear function and this allows for a good estimation of an expected reduction in N losses with reduced N fertilization in groundwater catchment areas.
- The general statement that the application of organic fertilizer necessarily leads to higher N leaching losses or that it is solely responsible for high nitrate concentrations in groundwater can not be proved here. A more pronounced effect of the slurries on N leaching could have been produced in this experiment, if only the proportion of NH_4-N had been considered and not the total N content of the manure as has been done here.
- Nevertheless, if high N leaching losses are often observed following the cultivation of silage maize and the application of slurries, this would more likely be caused by a wrong and usually too high amount of N applied, than by the use of manures in general.