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Efficient management of nitrogen fertilization in modern cropping systems

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Abstract

Management of nitrogen fertilizing can be optimized in different ways:
A clear calculation of the required amount of nitrogen for the expected yields is necessary on an input–output basis.
Nitrogen losses and agro-techniques to avoid them;
— ammonia volatilization, by immediate incorporation of the inorganic or organic fertilizers into the soil
— denitrification, by optimizing soil structure
— nitrate leaching, by straw manuring, late application of slurry and late incorporation of green manure.
Nitrification inhibitors (e.g. dicyandiamide, DCD);
— when added to ammonium or urea fertilizers, they show economic advantages (lower labour costs) and preserve fertilizer N from being translocated out of the rooting zone or leached out
— as an additive to organic waste materials from plant and animal production or industrial processings they inhibit nitrification.
Efficient nitrogen management in cropping systems is a necessary demand both for economic and ecological reasons.

Introduction

The goal of nitrogen fertilizer management is an optimal feeding of plants, not only for economic benefits but also in order to avoid environmental pollution.

Results and discussion

I. The nitrogen requirements of crops must be calculated on basis of the expected yields. The amounts of nitrogen needed to produce one ton of a specific crop (e.g. small grains, potatoes) are well-known figures.

1. The first step is to determine the amount of available nitrogen (N_{min}) in the soil profile in spring (Wehrmann und Scharpf, 1987).
2. As a next step, nitrogen has to be supplemented for early growth up to 120 kg N/ha, followed by split applications later on, up to the calculated total fertilizer amount (Wehrmann und Scharpf, 1987).
3. The extent of net mineralization in the soil during the growing season is still an open question, because mineralization and immobilization are opposing processes depending on site and cropping conditions. For small grains – as experiments have demonstrated – mineralization is nearly equal to immobilization. However, for

crops with slow initial growth (e.g. sugar beets, maize, potatoes) leaving the soil uncovered for a long period, mineralization exceeds immobilization by far (Gutser et al., 1989; Kuhlmann and Engels, 1992). Definite figures can be obtained from field experiments or from long-term experiences of the farmer on the respective site.

4. The nitrogen import from organic residues of plant or animal production (e.g. sugar beet leaves or animal slurry) must also be considered in this calculation according to their availability (Amberger, 1987b). Mineral nitrogen fertilizers may be utilized generally by about 70%, depending on location, crops and agro-techniques, the remainder being immobilized or lost (Vilsmeier et al., 1989).

II. Nitrogen losses and agro-techniques to avoid them.

Nitrogen losses are not only an economic but also an environmental problem.

1. Ammonia volatilization predominately is a matter of inappropriate fertilizer application (Amberger, 1989). Among mineral fertilizers, ammonium containing or ammonia liberating products are concerned. In case of urea, volatilization on the average, can amount up to 20–30%, and even higher, with broadcast application. Incorporation into the soil minimizes volatile losses to only a few percent (Amberger, 1990 a,b; Döhler, 1990).

   A very serious situation arises in the case of animal slurry which contains 60–70% of total N in form of ammonium-N. More than 90% of ammonia pollution of the air is caused by animal production (KTBL, 1990). Ammonia volatilization takes place already in the first hours after spreading and can amount up to 80% depending on air temperature and wind flow, soil type (high pH, compact soil structure), soil cover (stubbles of small grains), and also on the dry matter content of slurry – thick slurry infiltrates the soil very slowly (Amberger, 1991). For minimum losses, animal slurry therefore has to be incorporated immediately after spreading (Rank et al., 1987; Rank, 1988). When slurry is applied to growing crops (e.g. small grains), the crop canopy and the reduced air flow decrease ammonia losses to about 10–20% (Huber und Amberger, 1989). In case of grassland, dilution of slurry with water is recommended.

2. Denitrification losses are a further problem relevant mainly in heavy soils. Estimates of losses generally range between 15 and 20 kg N y^{-1} (Amberger, 1987a), assuming a high nitrate concentration in the soil, high temperature and moisture as well as high amounts of microbial decomposable carbon. These losses can only be reduced by improving soil structure with appropriate agro-techniques.

3. Nitrate leaching not only means a substantial economic loss but also a hazard to ground and drinking water. It happens predominately in the fallow period during winter and early spring and can be assessed to 50–70 kg N ha^{-1} y^{-1} (Amberger, 1987 a,b) depending on site conditions and the cropping system. The main determinants are the amount of unused fertilizer N after harvest and the mineralization rate during autumn.

   Straw manuring (without additional fertilizer N) is an effective measure to preserve nitrate in the soil from leaching (0.1 ton of straw blocks about 1 kg N). However, it has to be kept in mind that this biologically blocked nitrogen is not available to the following crop, and therefore cannot enter into the fertilizer calculation (Amberger, 1991).

   Slurry and nitrogen-rich waste water (e.g. from potato starch production, Amberger and v. Tucher, 1989) when applied in autumn and incorporated into the soil, will be nitrified already within a few weeks, and are then readily leached out. The same is the case when green manure (or sugar beet leaves) is incorporated in early autumn (Schweiger, 1991). Therefore it is recommended to combine the nitrogen-rich slurry or waste water with straw poor in nitrogen, or to apply slurry

($20–30\ m^3\ ha^{-1}$) as late as possible (during winter on slightly frozen unslopy soils with only a thin snow cover or spring) maybe with a nitrification inhibitor (Amberger, 1991; Vilsmeier und Amberger, 1987).

Catch crops or plant residues should also be incorporated as late as possible or – on sandy soils – better in early spring. The goal is to cover the soil as long as possible with crops preventing nitrate leaching. The utilization of nitrogen from green material by the following crop will be about 30% (Amberger, 1988; Gutser und Vilsmeier, 1988; Gutser, 1988).

III. Nitrification inhibitors (e.g. dicyandiamide, DCD) are also very effective instruments to control and optimize nitrogen management; they inhibit the first step of nitrification resulting in an accumulation of ammonium (Amberger, 1986).

Fertilizers on ammonium or urea basis can be amended with 8–10% DCD-N of total N, – trade names are Alzon, Basammon etc. When applied to small grains or leaf crops, they show convincing economic advantages (lower labour costs by concentration in two or even one single application) and produce the same or even higher yields with reduced amounts of nitrogen. Applied to leaf crops with slow early growth, they prevent translocation of nitrogen out of the rooting zone, nitrate leaching and denitrification, especially in a rainy spring and in sandy soils (Klasse, 1991).

Dicyandiamide, when added in powder or liquid form to

— organic material from plant production, rich in nitrogen (e.g. vegetable residues, sugar beet leaves)
— waste water (e.g. from potato starch production)
— animal slurry

inhibits nitrification and finally nitrate leaching, (Kölbl, 1987; Müller-Wiesenfeld 1987; Schweiger, 1991) which is of great importance especially for water catchment areas. A very important point is that the preserved ammonium N is fully available to the following crop contrary to the microbially blocked nitrogen with straw manuring and can be included in the fertilizer balance-sheet. Besides, DCD will be decomposed without further residues to NH_3, CO_2 and water, thus acting also as a slow-release N fertilizer.

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