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Nitrogen release from organic fertilizers after short and long-term application to arable land

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Abstract

The general principles underlying N-availability from organic fertilizers are highlighted in this paper. Nitrogen from organic fertilizers often shows little effect on crop growth immediately after application. In this situation, the soil N-pool, which increases with the long-term use of organic fertilizers, instead supplies N for plant growth. Short-term N release from organic fertilizers, measured as mineral fertilizer equivalents varies greatly, from between 0 (some composts) to nearly 100% (urine). The most important parameters predicting the short-term availability of N are total and mineral (NH_4^+-N) nitrogen contents, C/N-ratio (especially of the decomposable organic fraction), and stability of the organic substances. Processing particularly influences the N-availability of organic fertilizers. In this respect, anaerobic fermentation increases both NH_4^+-nitrogen content and the stability of organic matter and produces an organic residue with rapid availability of N. Knowledge about the residual effects of the long-term application of organic fertilizers provides an important basis for developing environmentally and agronomically sound strategies.

Introduction

Our work summarizes the turnover of organic fertilizers in soils, focusing mainly on the quantification and utilisation of fertilizer-N by plants in the year of application as well as in the subsequent years. The main objective of this paper is to describe the conversion of organic fertilizers into readily plant available forms of nitrogen. Generalized rules for an appropriate product-specific use of organic fertilizers are also presented.

Materials and methods

This work is based on the findings of long-term research done at the Chair of Plant Nutrition of the Technical University of Munich (Gutser and Claassen, 1994; Gutser *et al.*, 2005) and results published elsewhere (e.g., Dittert *et al.*, 1998). Aerobic pot incubation experiments as well as field experiments for one or several years were designed to describe the N-turnover (net mineralisation rate) of organic fertilizers. The experimental site in Freising (40 km north of Munich) is characterized by a semi-humid climate with an annual precipitation of around 800 mm and an average air temperature of 7.8°C. Field experiments were carried out in a deep brown soil (silty loam with C_{org} and N_t contents of the topsoil ranged between 1.0%-1.4% and 0.12%-0.15%). The findings are discussed with reference to an optimal application of mineral fertilizers for plants (equivalents to mineral fertilizer, EMF in %), with an attempt being made to transfer them to other soil and climatic conditions.

Results

Mode of action of organic fertilizers

The main mode of action for the N derived from organic fertilizers occurs in the soil pool. The direct utilization in the year of application is small (0 to 35%) because of both the slow-release characteristics of organically bound N and the medium- and long-term N immobilization/fixation in soils. Figure 1 quantifies the N accumulation and availability in soils over time and also shows annual N utilization (immediate and residual effects) of two fertilizers with different N-availabilities in the year of application.

Fertilizer A, which has a slow release characteristic, displays a larger soil N accumulation than fertilizer B. Remarkably, even after long-term application (quasi steady state), fertilizer A does not match the efficiency of nitrogen usage of fertilizer B entirely.

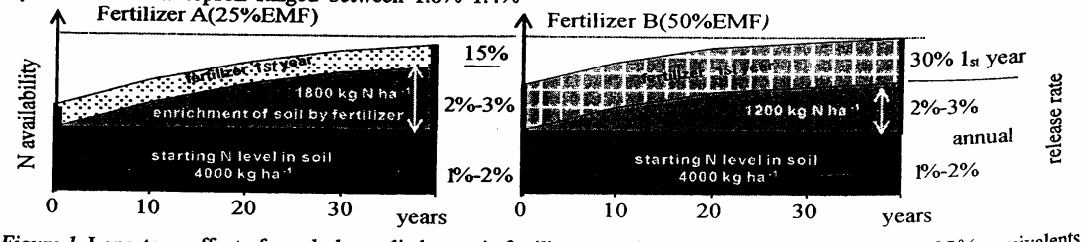

Figure 1. Long-term effect of regularly applied organic fertilizers on nitrogen availability. Fertilizer A: 25% equivalents to mineral fertilizer (EMF), Fertilizer B: 50% EMF. Fertilizer rate for both was 100-140 kg N ha^{-1} a^{-1}

Equivalents to mineral fertilizer (EMF) – standard of N-availability of organic fertilizers

The assessment of N release from organic fertilizers is based on the N available as compared to that available from optimally applied mineral fertilizers. For example, the application of 100 kg of N through an organic fertilizer providing an EMF of 30% equals that of 30 kg of N through a mineral fertilizer. Experiments conducted over several years also allow the determination of EMF for the long-term availability of N (i.e., the immediate and residual effect from the application in the former years; Fig. 2).

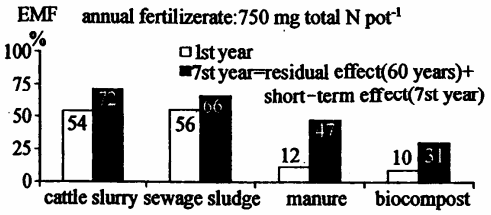

Figure 2. Model experiments on short- and long-term effects of organic fertilizers on nitrogen availability, expressed as equivalents to mineral fertilizer (EMF %).

Factors influencing the short-term N-availability

The short-term N-availability of organic materials depends largely on two factors:

High mineral nitrogen content: Plant biomass after processing (fermentation or hydrolysis) as well as animal excreta (urine) usually contain high amounts of NH_4^+-nitrogen. The availability of NH_4^+-N can be limited by immobilisation in soil, when the fertilizers consist of N-poor (C/N-ratio > 15) degradable organic substances.

N-rich decomposable organic substances: These include organic fertilizers with high N content and low C/N-ratio: e.g., animal (C/N-ratio = 3-4: horn and meat meals) or plant residues (N-content >5%: coarse meal of legumes) or sewage sludge (C/N-ratio = 3-5). When the C/N_{org}-ratio of the degradable substance is below 6-7, high N release is expected.

Both composting and anaerobic fermentation form mature products that are generally characterized by low or high contents of NH_4^+-nitrogen along with stable organic substances. For these reasons, short-term availability of organic-N from mature compost is low and from fermentation residues high.

N-availability from selected organic fertilizers

The N-availability from fertilizers varies in their EMF, ranging from 0 to 90% (Fig. 3). The quantitatively important residual effect increases with decreasing short-term N release as well as with the frequency and level of fertilization. After long-term application (e.g. 10 to 15 years or more) the annually effective percentage of the fertilizer can be calculated as follows, giving a useful orientation for optimizing the N strategy:

EMF (short-term, %)	→	EMF (long-term, %)
< 20	→	40-50
20-40	→	50-60
40-60	→	60-70

Conclusions

General rules for the application of organic fertilizers can be deduced from short-term N availabilities:

(i) Fertilizers rich in ammonium N (>25% of total N) have to be used with NH_4^+-conserving techniques.

(ii) The use of fertilizers with more than 30% EMF has to be avoided during winter season.

(iii) In future maximum loads for organic fertilizers should be calculated not only from N loads (currently 170 kg N ha^{-1} a^{-1} in Germany), but also from C loads and the expected humus production in soil. In consequence neither an overly strong exhaustion (decreasing yields), nor an overly strong accumulation (increasing risk for N losses) of soil organic matter, should result.

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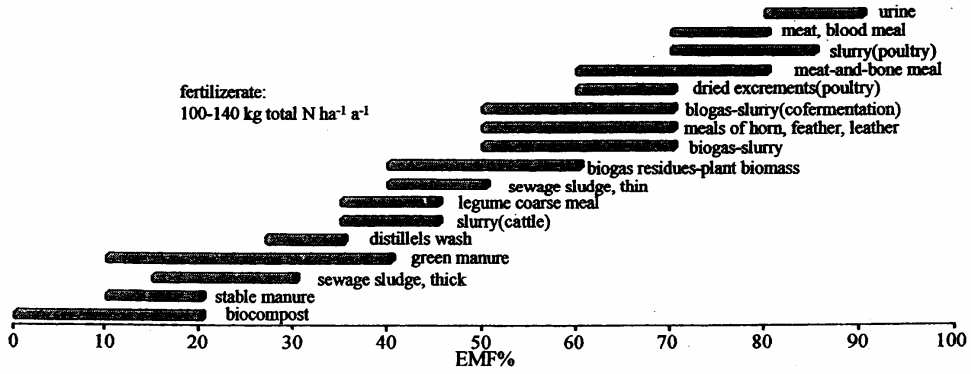

Figure3. Nitrogen availability from organic fertilizers in the year of application calculated as equivalents to mineral