Nitrogen efficiency of solid animal manures

Efficacité azotée des déjections animales solides

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Abstract

An enormous increase of poultry meat production in the last decade increased the amounts of solid animal manure for use as a fertiliser in arable farming, but only poor knowledge about the N utilisation from these manures was available. Field experiments were carried out on three soil types to assess yield and nitrogen efficiency of broiler manure, turkey manure, layer dry manure and, as a well-known reference, cattle farmyard manure (FYM). Timing of application (autumn/spring) as well as manure rate and additional fertiliser N were varied. Soil mineral nitrogen at the end of the growing season was investigated to assess the potential for nitrate leaching. The cumulative results of the first five-year-period are reported here, and the following results were obtained :

- *Spring application was usually superior to autumn application.*
- *Nitrogen efficiency of solid animal manures increased with decreasing C/N ratio. Mineral fertiliser N equivalents for spring application were 12 kg (cattle FYM), 25 kg (turkey litter), 31 kg (broiler litter), and 49 kg (layer dry manure). Optimal grain yields were only obtained with additional fertiliser N.*
- *Soil mineral nitrogen after harvest was within the range of good agricultural practice.*
- *From year to year subsequently increasing soil mineral nitrogen after harvest indicates a residual effect. Because of annual variation in growing conditions and thus a varying nitrogen demand, further research is required to evaluate the residual effects with regard to the development of the nitrogen requirement for optimal yields.*

Résumé

L'augmentation considérable de la production avicole au cours des dix dernières années s'accompagne d'une augmentation des quantités de fumier utilisées comme fertilisants sur les terres cultivées.
Des essais au champ réalisés sur trois types de sol nous ont amené à préciser le rendement obtenu et l'efficacité de l'azote apporté suite à l'épandage de fumier de

volailles de chair, de fumier de dindes et de fumier de pondeuses sec, ainsi qu'un fumier bovin de référence.

Les dates d'apports (automne, printemps) ainsi que la dose apportée et les engrais chimiques complémentaires ont été modulés.

L'azote minéral du sol à la fin de la période de culture a été mesuré afin d'évaluer le potentiel de lixiviation. Les résultats cumulés des cinq premières années de ce travail sont décrits dans cet article. Les principales conclusions sont les suivantes :

- Les apports de fumier au printemps sont plus efficaces que les apports d'automne.
- L'efficacité azotée des fumiers augmente lorsque le ratio C/N diminue. L'équivalent azote minéral pour les apports de printemps s'établit à 12 kg (fumier bovins), 25 kg (fumier dindes), 31 kg (fumier de volailles de chair) et 49 kg (fumier pondeuses sec). Les rendements optimums n'ont été obtenus qu'avec un complément d'engrais chimique.
- L'azote minéral dans le sol à la récolte correspond à celui attendu par l'application de bonnes pratiques agricoles.
- L'effet résiduel de l'azote laissé dans le sol doit être mieux étudié.

1. Introduction

Heavily increasing poultry meat production (broilers and turkeys) during the last decade and the switch-over of nearly all layer farms from the slurry system to dry manure led to a strong increase in the amounts of solid manures produced by these animals. The manures are characterised by high dry matter contents and, hence, high concentrations of N, P and K which are often underestimated by farmers. Poor utilisation of nutrients and the risk of nitrate leaching may thus follow wrong application. This paper outlines ways to improve solid manure management and tries to find answers to the following questions :

1. When should solid animal manures be applied?
2. How is the nitrogen efficiency of solid animal manures?
3. Can optimal yields be obtained with solid animal manure alone, or is it necessary to add fertiliser N?
4. What is the effect of solid animal manures on soil mineral nitrogen after harvest?

2. Experimental details

Three static field experiments were established in 1993 in the Weser-Ems area, situated in the Northwest of Germany (average temperature of the year: 8.8 °C;

average annual precipitation rate: 770 mm). Cropping was winter cereals (four years) and potatoes (one year, 1995). The experimental design was the following (table 1) :

Factor	Treatment
Soil type	1̃ organic sandy soil 2̃ sandy soil 3̃ loamy soil
Manure type	4̃ cattle FYM 5̃ turkey litter 6̃ broiler litter 7̃ layer dry manure
Application time	8̃ autumn 9̃ spring
Application rate	10̃ ~ 100 kg/ha total manure N 11̃ ~ 200 kg/ha total manure N (only spring)
Fertiliser N	12̃ without 13̃ 40 - 60 kg/ha N 14̃ 80 - 120 kg/ha N

Table 1.
Experimental design.

All manures were applied at the same time, in October (autumn application) with shallow incorporation before sowing and top-dressed in March (spring application). Spring application to potatoes was before planting, with shallow incorporation. Table 2 shows the average manure composition.

%	cattle manure	turkey litter	broiler litter	layer dry manure
DM	23.9	52.5	56.9	64.9
Total N	0.6	1.9	2.9	3.8
NH_4^+-N	0.1	0.8	0.7	0.6
P_2O_5	0.4	3.1	2.0	3.4
K_2O	0.9	2.1	2.1	1.8
C/N ratio	1:14.9	1:12.7	1:8.8	1:6.5

Table 2
Composition of manures, given in % of fresh matter, and C/N ratio.

The nitrogen efficiency of the animal manures was evaluated in comparison to a fitted response curve, calculated from spring applied fertiliser.

Fertiliser N was applied at mid of March for all autumn and spring treatments. Plot size was 42 m², and 21 m² out of these were harvested. Soil mineral nitrogen (SMN) samples were taken after harvest down to a depth of 90 cm and analysed for NO_3^--N and NH_4^+-N.

All treatments were fully randomised within 4 replicates. For the cereal crops, the results are shown on average of the three experimental sites and the four years. The statistical analysis showed no significant effect of the soil and the year factor on the yield. Potatoes were evaluated separately.

3. Results and discussion

3.1. Timing of application

Fig. 1 shows the effect of manure application in autumn and spring on grain yield. Yield increased in the order cattle FYM < turkey manure < broiler manure < layer dry manure. The result was the same for autumn and spring application. On average of the four years, spring application was more favourable than autumn application. This was especially true for broiler litter and layer dry manure with their high content of soluble nitrogen. A high portion of layer dry manure nitrogen (about 30%) consists of soluble nitrogen (ammonia N and uric acid, CHAMBERS *et al.* 1994) which is easily mineralised to ammonium N and further to nitrate N under aerobic conditions. Soil mineral nitrogen dynamics after autumn application (fig. 2) point also in this direction. In autumn, soil mineral nitrogen (SMN) increased, due to N mineralisation in the soil. If cattle manure was applied, the release of nitrogen was higher than in the unfertilised plots; but it was significantly higher if layer dry manure was applied. The figure demonstrates also that, from a peak in December, a net loss of soil mineral nitrogen until spring occurred for all treatments. In this situation, on a sandy soil and a lot of rainfall over winter, it is supposed that at least a part of that loss was leached over winter. Differences in SMN amounts between years are mainly caused by variations in climatic conditions and cropping. In 1995, potatoes were grown, and mineralisation of the residues led to an enormous increase of SMN in autumn.

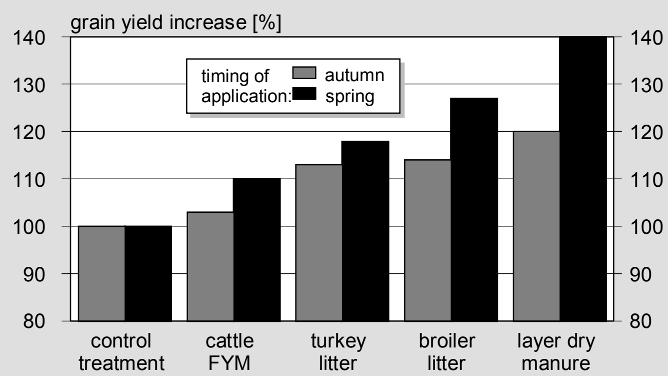

Fig. 1: Effect of autumn and spring application of solid animal manures on grain yield

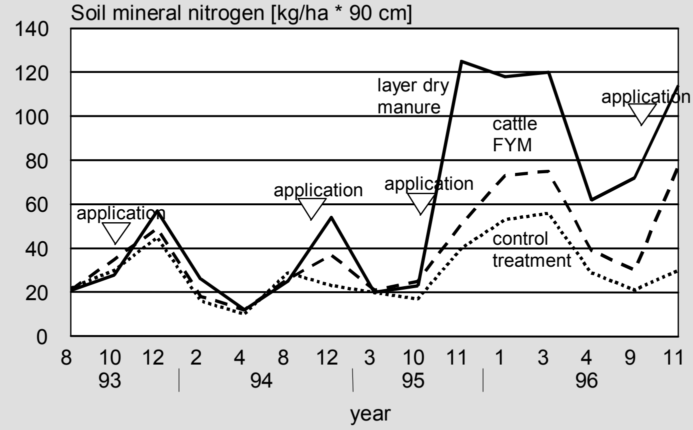

Fig. 2: Effect of solid animal manure application each year in October on soil mineral nitrogen on a sandy soil.

A lower nitrogen efficiency from autumn application of poultry manures was also reported by CHAMBERS *et al.* (1994). They found, however, that on heavy soils in low rainfall areas, autumn and spring application may not differ in nitrogen efficiency, due to fewer N leaching losses.

3.2. Mineral Fertiliser N equivalents

Nitrogen efficiencies are given as mineral fertiliser N equivalents. In fig. 3, the mineral fertiliser N equivalents for autumn and spring application to cereals of 100 kg/ha N as solid animal manures are shown. For cattle FYM (10-12 kg), only a small difference could be found between spring and autumn application, due to its wide C/N ratio and low ammonia N content. For broiler litter and particularly for layer dry manure, spring application resulted in a much better N utilisation than autumn application. For application in spring, about 30 kg N per 100 kg of broiler litter N and about 50 kg N per 100 kg of layer dry manure could be accounted for.

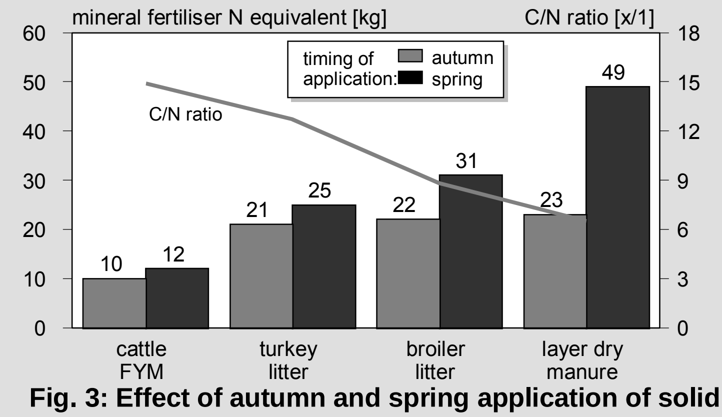

Fig. 3: Effect of autumn and spring application of solid animal manures to cereals on mineral fertiliser N equivalents.

Fig. 4 shows the effect of solid animal manures applied to potatoes. Spring application was much better than autumn application. With spring application, fertiliser N equivalents of 60-80 kg fertiliser N per 100 kg manure nitrogen could be obtained. However, this is only the result from a single harvest, but results with cattle FYM carried out in the past by various researchers show a better nitrogen utilisation by root crops like potatoes and sugar beet compared to cereals. Nitrogen mineralisation in spring comes usually too late to be of great importance for cereal nutrition.

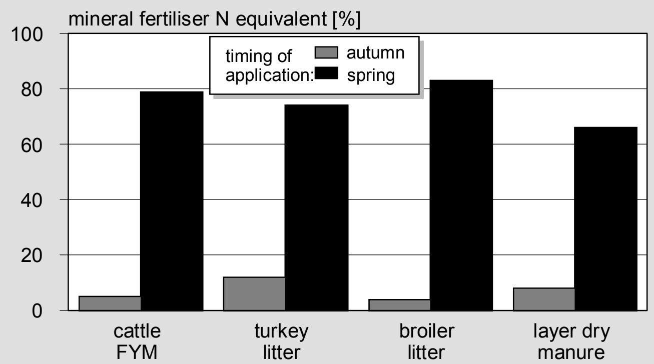

Fig. 4: Effect of autumn and spring application of solid animal manures to potatoes on mineral fertiliser N equivalents.

3.3. Addition of mineral fertiliser N

In the experiments, two manure N rates (100 and 200 kg/ha N) were each combined with three rates of fertiliser N (none, 40-60 kg/ha or 80-120 kg/ha N). Fig. 5 shows the effect on grain yield if either 100 kg/ha manure N or two different rates of fertiliser N had been applied additionally to 100 kg/ha of manure N applied in spring. For cattle FYM and turkey litter, the effect of additionally 100 kg/ha manure N (i. e. 200 kg/ha manure N in total) was smaller than the effect of additionally 40-60 kg/ha fertiliser N, whereas for broiler litter and for layer dry manure, additional manure N was able to increase the grain yield in about the same way as the small fertiliser N rate. A rate of 80-120 kg/ha fertiliser N increased the grain yield of all kinds of manure to about the level of optimum N fertilisation (max. yield). This yield, however, was obtained with a N rate of 130 kg/ha on average of the years. Additional fertiliser N was more efficient in those manures which were low in soluble nitrogen and high in C/N ratio, like cattle FYM and turkey litter. In general, it makes sense not to cover the crops' nitrogen demand with animal manure alone since this would lead to an over-supply with other nutrients like phosphorus and potassium.

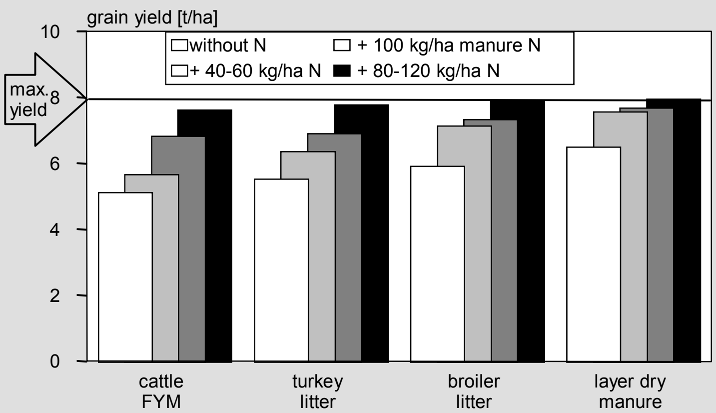

Fig. 5: Effect of either manure N or fertiliser N applied additionally to 100 kg/ha manure N on grain yield.

3.4. Soil mineral nitrogen after harvest

Rates of 100 kg/ha manure nitrogen (applied in spring) + 100 kg/ha mineral fertiliser N left about 50-60 kg/ha soil mineral nitrogen (SMN) after harvest (fig. 6); the amount of SMN after application of poultry manures exceeded the amounts from the optimal N treatment. From year to year subsequently increasing soil mineral nitrogen after harvest indicates a residual effect (fig. 7). Because of annual variation in growing conditions and thus varying nitrogen demand, further research is required to evaluate the residual effects with regard to the development of the nitrogen requirement for optimal yields.

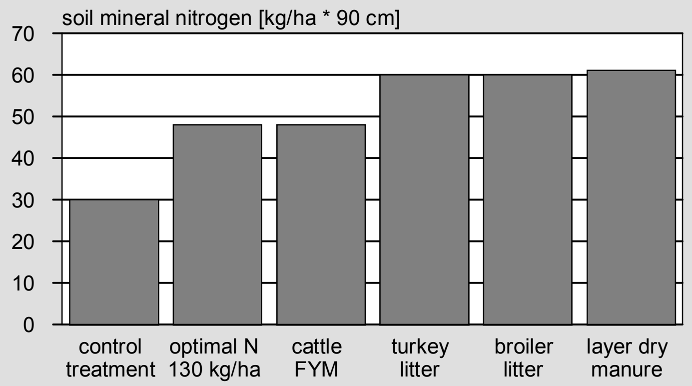

Fig. 6: Effect of spring application of solid animal manures (100 kg/ha N) + 100 kg/ha additional fertiliser N to cereals on soil mineral nitrogen after harvest

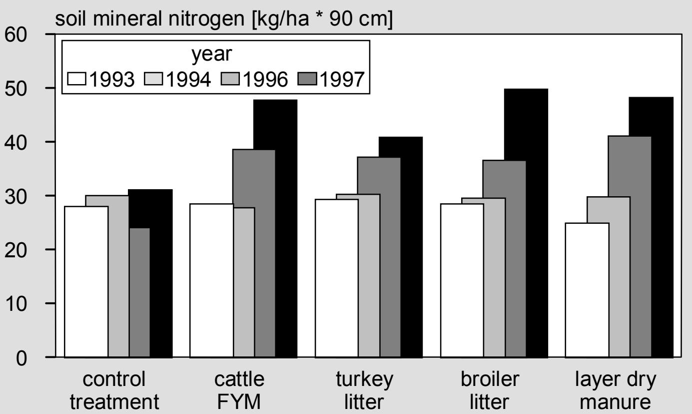

Fig. 7: Increase of soil mineral nitrogen after harvest during the experiment (solid animal manure without additional N).

4 Reference

CHAMBERS, B. J., K. A. SMITH and R. B. CROSS (1994) Effect of poultry manure application timing on nitrogen utilization by cereals. In: HALL, J. E (*ed.*) *Animal Waste Management*, Proceedings of the Seventh Technical Consultation on the ESCORENA Network on Animal Waste Management, 199-205.