Nitrogen efficiency of farm manure on permanent grassland in mountainous regions

Poetsch, E. M.[1], and R. Resch[1]

[1]*Institute of Plant Production and Cultural Landscape, Federal Research and Education Centre Raumberg-Gumpenstein, 8952 Irdning, Austria, erich.poetsch@raumberg-gumpenstein.at*

Abstract

By means of exact field trials comprehensive studies on the nutrient efficiency of different farm manure systems have been carried out on permanent grassland at three different sites in Austria. Slurry, solid manure and liquid slurry from cattle were applied on three cut and four cut meadows in different doses for a period of six years. Analyses on yield, forage quality and floristic diversity have been done as well as investigations on nutrient fluxes and on nutrient efficiency. Compared with mineral fertiliser systems, farm manure showed a high efficiency, which is not only based on the content of main nutrients but also on some additional effects (e.g. organic matter input). The results clearly indicate the high efficiency of farm manure on permanent grassland and show that sufficient yields and forage quality can be reached without the use of any additional mineral nitrogen.

Keywords: farm manure, N-efficiency, nitrate directive, permanent grassland

Introduction

Due to the regulations of the European nitrate directive, the yearly application rate of manure on grassland is limited by the load of nitrogen to avoid negative impact on the environment. The amount of 170 kg N ha^{-1} ex storage represents the general limit, which in Austria can be extended to 230 kg in compliance with some special obligations (Aktionsprogramm, 2008). Most of the Austrian grassland and dairy farmers take part in the Austrian agri-environmental programme ÖPUL. Therefore the sustainable and efficient use of farm manure is of great importance and is beside an optimal use of home-grown forage an important strategy of low input farming. Due to unavoidable N-losses mostly occurring via NH_3-volatilization, the nitrogen efficiency of farm manure is lower than that of mineral nitrogen fertilizer. Following the official Austrian guidelines for an appropriate fertilization (BMLFUW, 2006), the assumed nitrogen efficiency of farm manure considers unavoidable N-losses for stable, storage and application and is additionally reduced due to a low yearly efficiency. By means of comprehensive field experiments on three Austrian grassland sites basic aspects of nitrogen and system efficiency of farm manure have been considered and critically discussed.

Material and methods

Different fertilizer systems have been tested on permanent grassland under a medium intensive three cut and a high intensive four cut regime, each on three Austrian sites. The used farm manure derived from dairy cattle and was applied at two different intensity levels and split in three respectively four doses depending on the cutting frequency. The applied nitrogen amount is based on an ex storage level, which considers unavoidable N-losses for stable and storage according to the European Nitrate Directive (EU-Nitratrichtlinie, 1991). The variants in the high intensity system received each an additional amount of 50 kg mineral nitrogen ha^{-1} $year^{-1}$.

Table 1. Description of the experimental sites

site	altitude	average yearly temperature	average yearly precipitation
Kobenz	627m	8,2 °C	856 mm
Winklhof	490m	8,2 °C	1400 mm
Gumpenstein	710m	6.8 °C	1010 mm

Table 2. Treatments and average nutrient application rates in the farm manure experiment during the project period (2001 – 2006)

intensity systems/ treatments	number of cuts year^{-1}	average nutrient application (kg ha^{-1} year^{-1})		
		$N_{ex\ storage}$	P	K
NPK	3	92.2	20.2	91.4
slurry	3	94.5	13.6	84.0
stable manure + liquid slurry	3	103.8	28.5	176.3
composted manure + liquid slurry	3	118.8	31.6	185.8
NPK	4	234.3	40.3	182.9
slurry + 50 kg N	4	236.6	26.1	162.4
stable manure + liquid slurry + 50 kg N	4	239.0	49.4	317.9
composted manure + liquid slurry + 50 kg N	4	256.5	54.1	310.9

The field experiments were established in the year 2000 and recordings and analyses have been done from 2001 to 2006 for all variants, each with four replications. A strong focus was given on the nitrogen efficiency of farm manure, which was related to yield production by means of the following calculation scheme:

$$N_{eff\text{-}yield}\ (\text{kg DM kg N}^{-1}) = \frac{\text{yield of variant (kg DM ha}^{-1}\text{ year}^{-1})}{\text{kg N-Input of variant (kg N ha}^{-1}\text{ year}^{-1})}$$

The results of this calculation were placed in relationship to the N-efficiency of the particular mineral nitrogen variant within the two intensity systems which were fixed at 100% each.

Results and discussion

In both intensity systems and at all sites a high productivity level could be observed at the beginning of the project period followed by a strong decline, which was mainly caused by drought in 2002 and 2003 (figure 1).

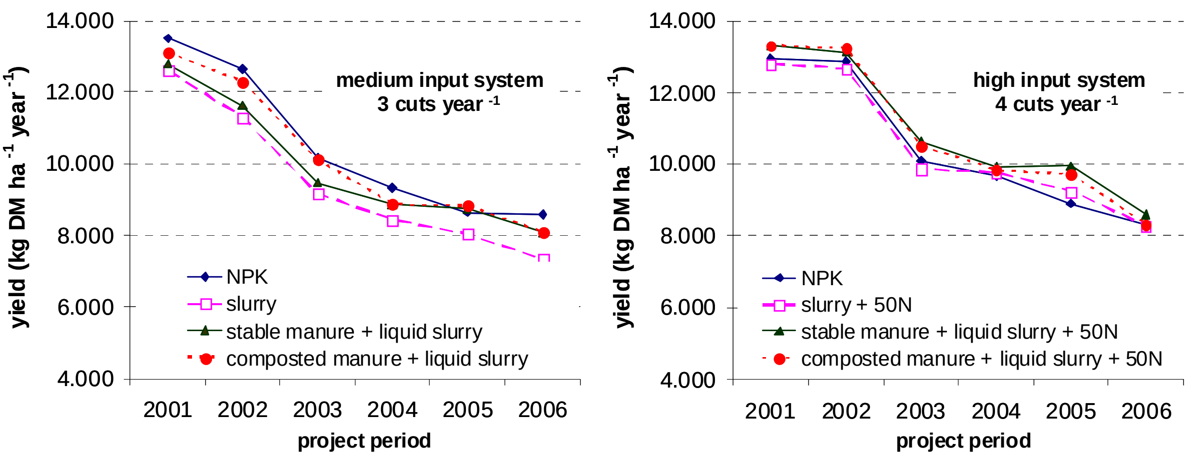

Figure 1. Yield productivity (kg DM ha^{-1} year^{-1}) of different variants during the project period (average of all three sites)

All variants were similarly influenced but at a different yield level which ranged between 9,480 and 10,920 kg DM ha^{-1} year^{-1} for the total observed period. It is evident that there was just a minor difference between the yield level of the medium and the high intensive system even though the nutrient input varied strongly. Within the two intensity systems significant differences were found between the treatments. In the 3-cut system the mineral NPK variant showed the highest average yield during the project period, whereas in the intensive 4-cut system the variant receiving stable manure + liquid slurry + mineral NPK performed best.

Table 3. Relative nitrogen efficiency (%) of different fertilizer systems on three sites (average of 2001 – 2006)

intensity systems/ treatments	Kobenz	Winklhof	Gumpen-stein	assumed efficiency
mineral NPK	100	100	100	100
slurry	84	90	92	61
stable manure + liquid slurry	75	87	89	38
composted manure + liquid slurry	73	79	86	21
mineral NPK	100	100	100	100
slurry + mineral NPK	96	101	99	69
stable manure + liquid slurry + mineral NPK	100	102	103	51
composted manure + liquid slurry + mineral NPK	91	96	97	36

The observed N-efficiency of farm manure ranges between 73% and 92% compared with mineral nitrogen (= 100%) in the medium intensive 3-cut system. A strong variation occurred both within the project period of 6 years and between the tested sites. But in any case the observed N-efficiency was significantly higher than the assumed N-efficiency according to the Austrian guidelines for an appropriated fertilization (BMLFUW, 2006). This result was also confirmed in the high intensive 4-cut system with an even higher relative N-efficiency of the used farm manure (91% to 103%). Within this group the stable manure system resulted in the highest efficiency at all three sites. The absolute average N-efficiency was significantly higher in the medium intensive system (101 kg DM kg N^{-1}) compared with the high intensive system (42.5 kg DM kg N^{-1}). This clearly shows that high nutrient input does not automatically result in high yields. Therefore especially the additional use of mineral nitrogen on grassland has to be seriously reconsidered.

Conclusions

The current procedure for the valuation of farm manure which is regularly used on permanent grassland should be reconsidered. It is evident, that the efficiency of farm manure which is not only based on the content of nitrogen but also on other nutrients and on additional effects (e.g. organic matter input) is higher than assumed. This is especially applied to stable manure and composted manure, whose efficiency seems to be strongly underestimated. This approach reduces both the real and the ideological value of farm manure, which should be the main nutrient source in sustainably managed grassland farms.

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