Total number of enchytraeids in the soil predicts the response of grasslands N yield to N fertilization on sandy soils

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Abstract

Soil biotic parameters have seldom played a role in practical soil assessment and management of grasslands, so far. However, the ongoing reduction of external inputs in agriculture would imply an increasing reliance on ecosystem self-regulating processes. Since soil biota play an important role in these processes and in the provision of ecosystem services, soil biological parameters should be an integral part of soil assessment. The general objective of this study is to investigate to what extent soil biotic parameters provide additional value in soil quality assessment of grassland. In Experiment I, we measured in 2006 soil abiotic, biotic and process parameters together with N-yield and N-yield response in twenty permanent grasslands on sandy soils. The response of N yield to N fertilization ranged from 35–102%. This wide range underscores the importance of a better recommendation base to target N fertilizer. The response of N yield to N fertilization was predicted by the total number of enchytraeids in the soil. In 2010 this relation was checked in an identical experiment on three grasslands on sandy soil (Experiment II). Again a strong relation was found. This knowledge can be important for the optimal use of fertilizer and its consequences for environmental quality.

Keywords: grassland, soil quality, soil biota, apparent nitrogen recovery, enchytraeids, fertilizer recommendation

Introduction

Soil quality can be assessed by parameters based on chemical, physical and biological properties. However, biological soil properties have so far seldom played a role in practical soil assessment. The reduced use of external inputs implies a greater reliance on self-regulating processes (Brussaard *et al.*, 2007). Since soil biota play an important role in these processes and in the provision of ecosystem services, soil biological parameters should be an integral part of soil assessment. The general objective of this study is to investigate the extent to which biotic soil parameters have indicative and explanatory values in soil quality assessment of grassland on sandy soils. In Experiment I, conducted in 2006, abiotic and biotic soil parameters were measured in twenty grasslands with comparable management histories. In the growing season, grass yield at 0 kg N ha^{-1} and response of grass yield to N fertilizer was measured. In Experiment II, conducted in 2010, this was repeated in three grasslands to check whether the results of 2006 could be repeated in time.

Materials and methods

Experiment I

This experiment was conducted in 2006, on twenty permanent grasslands on sandy soil distributed over ten conventional dairy farms. On each grassland, an experimental field (15 m × 9 m) was laid out. The first 10 m of the experimental field was split into three plots of 10 m × 3 m and the last 5 m in one plot of 5 m × 9 m. Over the three plots (10 m × 3 m), a fertilization treatment was randomized. Plots were fertilized with 0, 150

and 300 kg N ha^{-1} yr^{-1} with calcium ammonium nitrate (CAN, 27% N), respectively. The remaining 5 m × 9 m plot was not fertilized and was used to determine soil quality properties. All plots, except the 5 m × 9 m plot, received ample fertilization of P, K and S.
Soil samples were taken between 28 April and 2 May 2006 in the unfertilized 5 m × 9 m plot. In total 17 soil abiotic, 39 soil biotic and 17 soil process parameters were measured, including soil organic matter (SOM) and enchytraeids abundance ('potworms'). Grass was harvested four times using a 'Haldrup' small-plot harvester (J. Haldrup a/s, Løgstør, Denmark). Grass was weighed and sampled for dry matter and total N analysis (Kjeldahl). N yield as function of N level was modeled by a linear trend:

$$Y = \beta_{0i} + \beta_{1i} * Ngift + \varepsilon_{ij}$$

with the terms:

Y N yield;

β_{0i} N yield intercept, or N yield of field i with 0 kg N ha^{-1};

$\beta_1 i$ N yield response to N fertilizer; or the slope of the linear correlation between N yield and N application;

ε_{ij} random field effect, $\varepsilon_{ij} \sim N(0, \sigma_V^2)$.

Data analysis was performed with Matlab (version 7.6.0 R2008a, Mathworks). Cross-validated stepwise regression was applied to find parameters that most accurately explained the N yield intercept (N yield at 0 kg N ha^{-1}) and the slope of the N yield representing the response to N fertilization. More detailed information on sampling method and statistical analysis is referred to Van Eekeren *et al*. (2010).

Experiment II

This experiment was conducted in 2010 in three permanent grasslands on sandy soil distributed over one dairy farm. Plots were established and grassland production was measured using the same methods as in Experiment I. A selection of soil samples were taken in spring 2010 including determination of SOM and enchytraeids abundance.

Results

Experiment I

N yield intercepts ranged from 78 kg to 263 kg N ha^{-1}. The response of N yield to N fertilizer ranged from 0.35 to 1.02 kg N yield per kg N ha^{-1} applied. SOM explained most of the variance in the N yield intercept and was selected in the stepwise regression as the best explanatory parameter for the N yield intercept ($cvR^2 = 0.59$, $P = 0.001$). One gram of SOM per kg dry soil meant 3.21 kg N yield ha^{-1}, in addition to a constant of 15.4 kg N ha^{-1}. In contrast to the intercept, the N fertilizer responses were not significantly correlated with the different abiotic soil parameters, except for a negative correlation with the C/N ratio in the soil. In the stepwise regression the response of N yield to N fertilization was significantly explained by the total number of enchytraeids ($cvR^2 = 0.36$, $P = 0.047$) (Figure 1).

Experiment II

The N yield intercept of the three grasslands in Experiment II were 123, 141 and 293 kg N ha^{-1} respectively. The response of N yield to N fertilizer was 0.56, 0.66 and 0.74 kg N yield per kg N ha^{-1} applied. One gram of SOM per kg dry soil meant 3.39 kg N yield ha^{-1}, in addition to a constant of 19.3 kg N ha^{-1}. Like in experiment I the response of N yield to N fertilization was significantly explained by the total number of enchytraeids ($R^2 = 0.94$) (Figure 1).

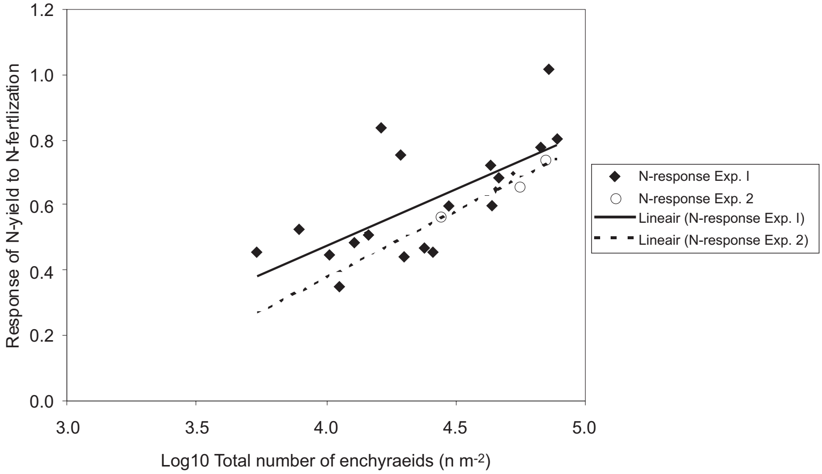

Figure 1. Linear regression between total number of enchytraeids (^{10}log n m^{-2}) and response of N yield to N fertilization (Exp. I: R^2 = 0.47, *cross validated* R^2 = 0.36, P = 0.047, Exp. II: R^2 = 0.94)

Discussion and conclusions

One of the main objectives of this study was to identify soil parameters in general, and soil biotic parameters specifically, that explain grassland production. It is interesting that variation of the response of N yield to N fertilization (0.35–1.02%) could not be explained by an abiotic soil parameter but only by a soil biotic parameter, the total number of enchytraeids. A possible explanation could be that enchytraeids indicate a nutrient-rich environment. A second explanation could be the effect of the historical grass production on the enchytraeids abundance measured at the start of both experiments. A third possible explanation is the important role of enchytraeids in decomposition processes. It is clear that the underlying mechanisms of this response need further investigation. This knowledge can be important for the optimal use of fertilizer and its consequences for environmental quality.

References

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