Tropentag 2024
September 11-13, 2024

Conference on International Research on Food Security, Natural Resource Management and Rural Development
organised by the University of Natural Resources and Life Sciences, Vienna (BOKU), Austria

Nitrogen availability as result of interaction between fertilizer and soil properties

Robert Kahle[a] and Hans Jürgen Reents[a]

[a] Technical University of Munich, TUM School of Life Sciences, Institute of organic agriculture and plant production systems, Freising, Germany.

Abstract

Scientific studies as well as observations and experiences in gardening practice have shown that soils have a highly varied ability to release nutrients, especially nitrogen (N). Organic fertilizers can exhibit very different rates of N release also at different locations. Understanding N release from organic fertilizers and its interaction with soil properties is essential for estimating N mineralization potential, adapted fertilization and reducing negative environmental impacts. We conducted incubation and plant experiments with agricultural and horticultural soils to study the impact of clay content and carbon to nitrogen ratios (C/N) of organic fertilizers on nitrogen mineralization and plant nitrogen availability. Results showed soil and fertilizer N mineralization varying by farm, with management system and clay content as significant factors, whereas no soil-fertilizer interaction across sites could be observed. Soil clay content influenced the magnitude and course of N release, but this was inconsistent across the different farms. Agricultural soils had higher N mineralization and plant N uptake, whereas fertilizer effects were greater in horticultural soils. The higher the C/N ratio of the fertilizer, the lower the nitrogen release, with differences in magnitude and course as well as farm-specific variations. This study suggests that plant-based fertilizers with C/N ratios greater than 10 may not suit short cultivation periods and thus applicability in organic vegetable production. Site-specific management history influences nitrogen mineralization greater than soil clay content and fertilizer carbon to nitrogen ratio. These findings highlight the importance of the specific investigation of management history for further understanding and improving of fertilization efficiency.

Keywords: Clay content, C/N-ratio, N-mineralization, soil-fertilizer-interaction

*Corresponding author Email: r.kahle@tum.de

Introduction

Soils vary in their capacity to release nitrogen (N), with organic fertilizers exhibiting different N release rates (Stadler and Heuwinkel, 2008). To adjust fertilization to plant growth, it is necessary to understand not only factors like total nitrogen (N_t), organic carbon (C_{org}), and microbial activity (R_h) but also the role of soil type, particularly clay content, and the management system. The clay content influences the soil structure, formation of clay-humus-complexes, exchange capacity (CEC), soil moisture and aeration as well as functions as habitat for soil microbes. The management system affects the balance, resilience and productivity of the agro-ecosystem, e.g. by framing practice, such as tillage and crop rotation as well as by type and amounts of inputs and outputs. Additionally, fertilizer characteristics such as the C/N ratio and origin influence their depletion in soil (Laber, 2001, 2013) while building up a site and farm specific soil microbiome. The aim was to identify factors affecting N dynamics, estimate N mineralization, and provide data for fertilization models (NDICEA, N-Expert). We hypothesize that (1) higher soil clay content results in lower relative soil N mineralization, (2) net N mineralization is independent from clay content and (3) horticultural soils release more N than agricultural soils.

Material and Methods

The effects of clay content, farming systems and carbon to nitrogen (C/N) ratios of organic fertilizers (3-28) on N mineralization (N_{min}) and plant N availability (plant growth and N uptake) were investigated in incubation and plant trials. We categorized clay content in three groups of ~14 % (sandy loam: „sand“), ~22 % (silt loam: „silt“) and ~31 % (clay loam: „clay“). The soils were sampled from two agricultural and two horticultural farms (A1, A2 and H1, H2) from uniformly managed fields within each farm, exhibiting soil textural differences. The incubation trials lasted 35-88 days at 18 °C and 50 % max. water-holding capacity, with a fertilization rate equivalent to 100 kg N ha^{-1}, involving weekly sampling of mineral nitrogen (N_{min}). Plant trials were conducted with rye and broadleaf cress for 27-42 days at 18-24 °C (av. night-day temperature) at 67 % max. water-holding capacity. Plant heights were measured three times per week, along with final total nitrogen (N_t) content of aboveground plant biomass.

Results and Discussion

Averaged across all farms, clay content had no influence on N mineralization (Fig. 1), which changed when differentiating in management systems. Agricultural soils showed higher N mineralization ($F = 41$, $p < 0.001$) compared to horticultural soils, alongside increased microbial activity ($F = 302$, $p < 0.001$; data of R_h not shown here).

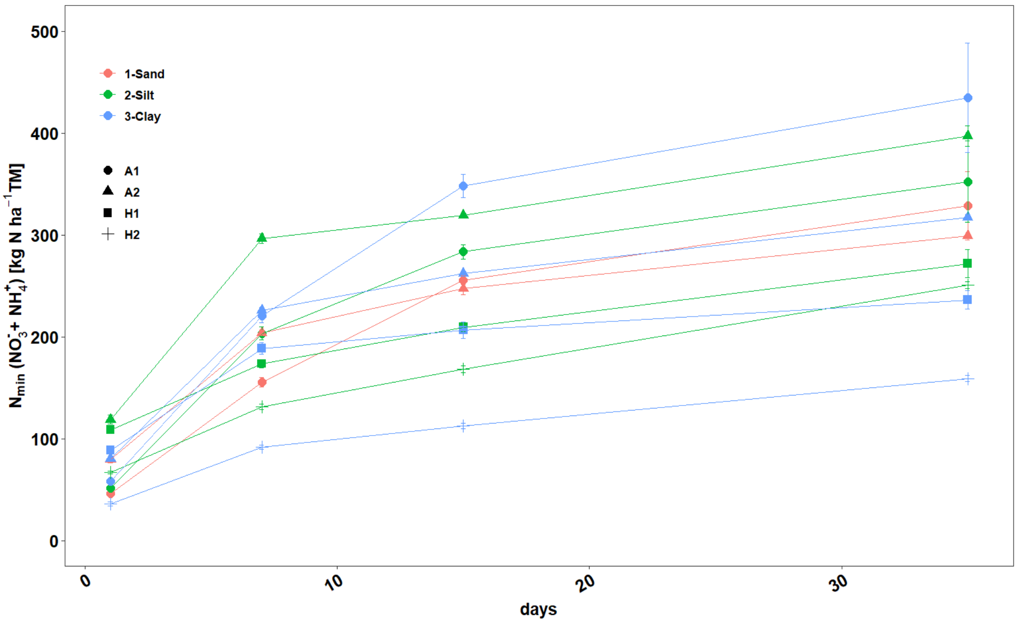

Figure 1: soil N mineralization (N_{min}) and plant height at different clay contents (~14 % / sandy loam: „sand“, ~22 % / silt loam: „silt“, ~31 % / clay loam: „clay“) of two agricultural (A1, A2) and two horticultural sites (H1, H2).

Plant development confirmed these findings ($F = 74$; $p < 0.01$; Fig. 2). Within each management group, an interaction between farm and clay content was identified ($F = 6$; $p < 0.05$), with differences in mineralization ($F = 29$; $p < 0,001$) and growth development ($F = 29$; $p < 0.001$). The sandy loams of the agricultural farms exhibited higher mineralization than the more clay-rich horticultural soils (Fig. 1).

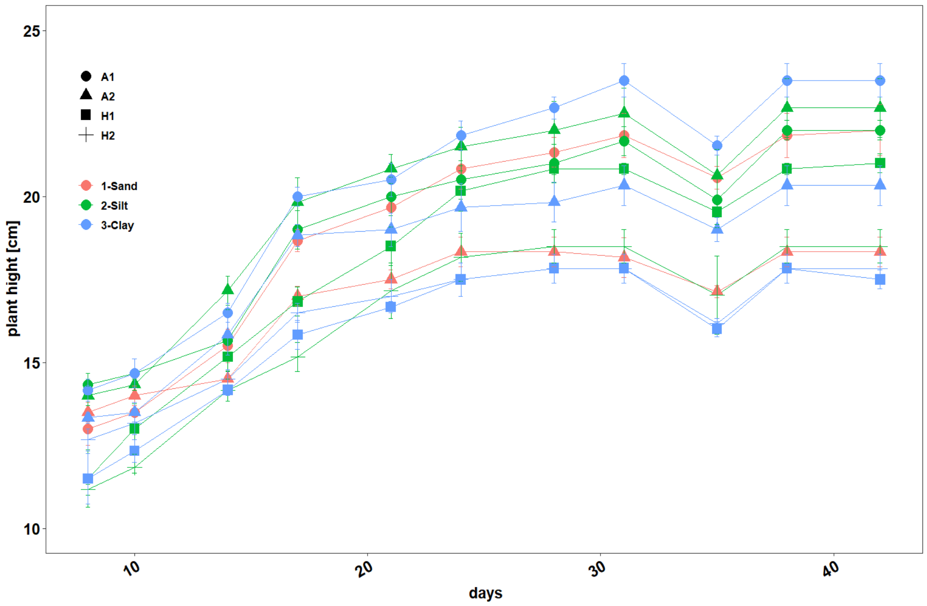

Figure 2: soil N mineralization (N_{min}) and plant height at different clay contents (~14 % / sandy loam: „sand“, ~22 % / silt loam: „silt“, ~31 % / clay loam: „clay“) of two agricultural (A1, A2) and two horticultural sites (H1, H2).

Generally, it could be observed that the higher the N mineralization, the higher the plant N uptake (Fig. 1; Fig. 2; Fig. 3). Although this was not as consistent in plant growth development. The highest plant N uptake overall and largest plants were observed on clay loam of A1, followed by silty loams of A2 and H1, while not different at H2 (Fig. 3).

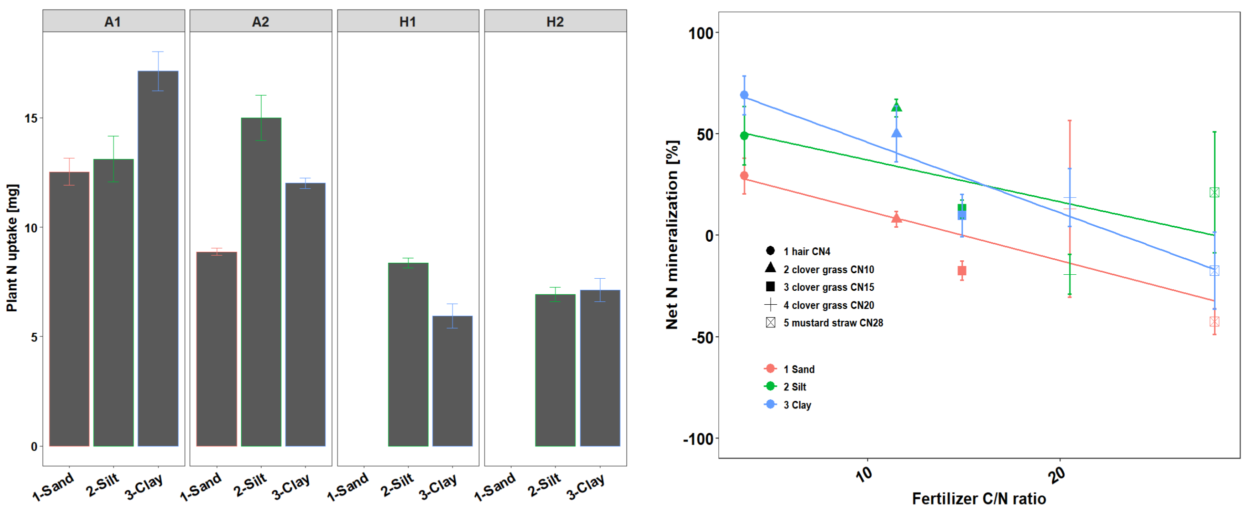

Figure 3: left: Plant N uptake (42d) per farm (A1, A2, H1, H2) and clay content (~14 % / sandy loam: „sand“, ~22 % / silt loam: „silt“, ~31 % / clay loam: „clay“); right: Max. (88d) net N mineralization vs. fertilizer C/N ratio of farm A1.

When applying different fertilizers on soils of farm A1 (Fig. 3), clay content ($F = 6$; $p < 0.001$) and the C/N ratio of the fertilizer between 11-15 ($F = 36$; $p < 0.001$) influenced net N mineralization, which generally decreased with increasing C/N ratio, supporting findings by Laber (2013). For example, depending on clay content, hair meal with a C/N of 4 was mineralized to 29 %, 49 %, and 69 % in sandy, silty, and clay loams, respectively, while clover grass with a C/N of 15 mineralized to -17 % (N immobilization), 13 %, and 10 %, respectively.

Net N uptake in plants was significantly affected by farm (F = 32; p < 0.001), clay content (F = 29; p < 0.001), fertilizer type (F = 6; p < 0.001), and their interactions (F = 4; p < 0.001); Fig. 4.

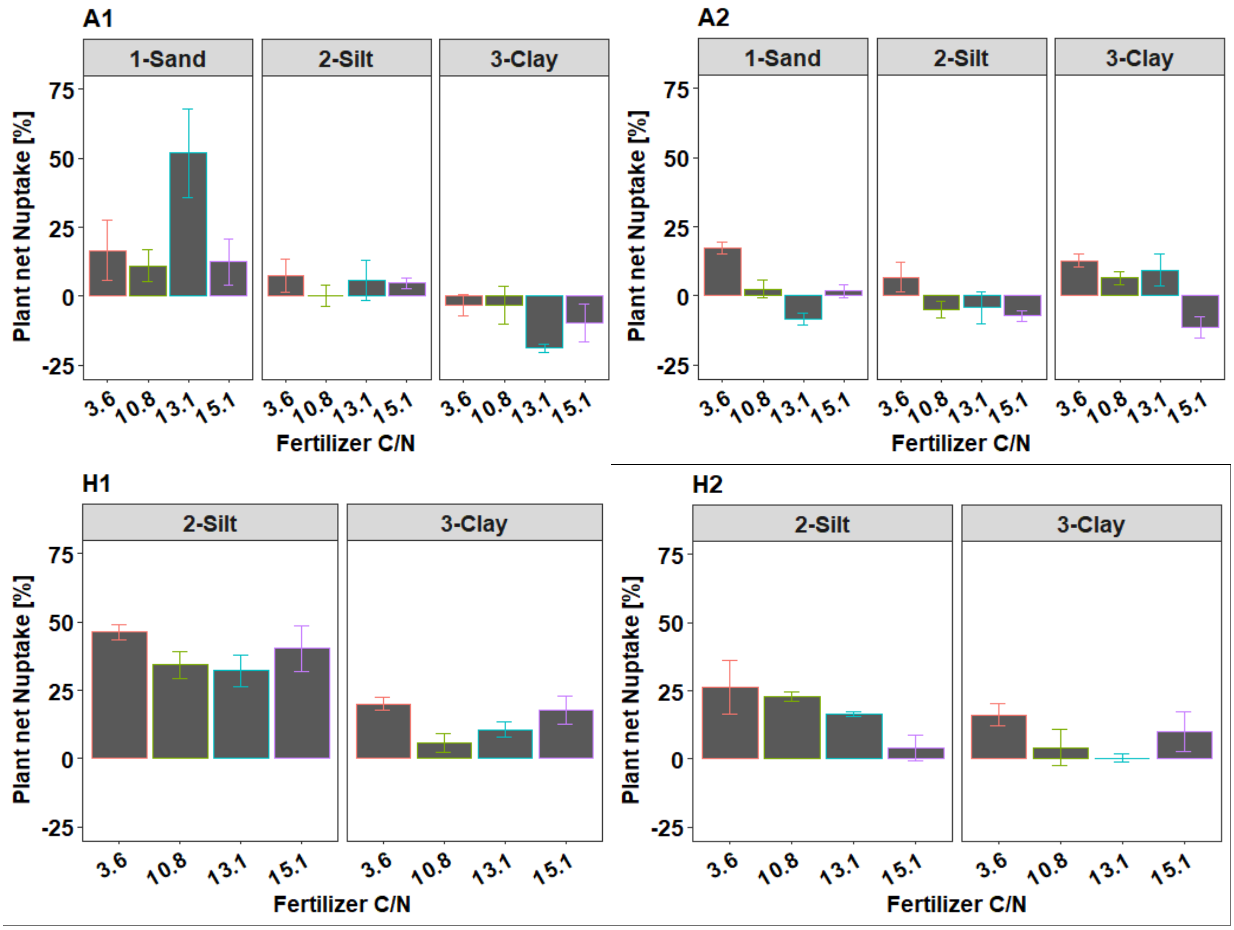

Figure 4: Fertilized plant net N uptake (42d) per farm (A1, A2, H1, H2), clay content (~14 % / sandy loam: „sand“, ~22 % / silt loam: „silt“, ~31 % / clay loam: „clay“) and fertilizer C/N ratio (3.6 = hair pellets; 10.8 = field bean meal; 13.1 = clover pellets und 15.1 = sunflower seeds press cake)

However, across all farms no significant interaction between clay content and fertilizer could be found. In horticultural soils, plants took up relatively more N through fertilization than in agricultural soils, where even negative fertilization effects occurred (N immobilization, smaller plants, less N uptake). The additional N uptake through fertilization was overall lower on clay soils, while individual fertilizer effects varied by farm and interaction of fertilizer and clay content. Laber (2001) reported variable effects of different fertilizers on vegetable crops across several trials (varied locations/soils), including yield reductions due to legume seed meals and, in some cases, high yields in unfertilized controls, attributed to residual soil N or prior green manuring. The significant variation observed here, influenced by soil type and prior management history, may support these findings. However, the causes for these effects require further investigation to be effectively integrated into fertilization planning.

Conclusions and Outlook

The N release from organic fertilizers varies by farm, clay content, and management system. Clay content influenced both the amount and pattern of N release, though this effect was inconsistent across farms. The wider the C/N ratio of the fertilizer, the lower the N release, with variations in both magnitude and timing, as well as differences by farm. Fertilizers with a C/N ratio >10 were found to be only partially suitable for rapid fertilization effects in organic vegetable farming. The results underscore the importance of specifically investigating management history to further understand and improve fertilization efficiency.

References

1. LABER, H. (2001). Organische Handelsdünger für den ökologischen Gemüsebau. In: ÖKOmenischer Gärtnerrundbrief (1/2001), S. 27–29.
2. LABER, H. (2013). Zügiger Umsatz bei vielen der im Brutversuch getesteten organischen Handelsdünger. In: Versuche im Deutschen Gartenbau.
3. STADLER, D. AND HEUWINKEL, H. (2008). Vegetabile N-Dünger im Ökologischen Gemüsebau. - Schule und Beratung. Heft I-2/08, III-8-11.