Nitrogen

Editorial

Soil Nitrogen Supply: Linking Plant Available N to Ecosystem Functions and Productivity

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Nitrogen (N), a common chemical element in the atmosphere (78% of our atmosphere) yet less common within the Earth's crust (less than 2%), is a crucial nutrient for life. It is an essential constituent of many cells, such as amino acids, proteins, chlorophyll, and even DNA, and is involved in various processes, such as photosynthesis, energy transfer, growth and reproduction. Up to 90% of the N in surface soils is organic in nature and is contained in soil organic matter (SOM). N cycling is complex, with numerous interacting controlling factors. Scientists around the world have been working for many decades now to understand, model and predict the soil's capacity to supply N to plants in different ecosystems, whether agricultural, forest, grassland or urban. Plant available nitrogen (PAN) is a pillar of the functioning and productivity of any ecosystem.

There is no exact definition for PAN. Sometimes considered as a pool of inorganic N, sometimes referred to as an amount related to plant uptake during a growing season, PAN is now generally viewed as a continuum of soluble inorganic and organic N, with the latter composed of molecules of varied structural complexity, which cycles continuously in a dynamic way. The transient nature of available forms of N has led them to be defined in many models as pools and rates, and they continue to be the focus of numerous research studies.

Efforts to gain a better understanding of the soil N supply and PAN are oriented towards optimizing N cycling. In this context, optimization is related to improving the synchronicity between the soil N supply and plant demand and reducing N losses to the atmosphere or water, which can have environmental and economic consequences. Improving the productivity of ecosystems necessarily involves optimizing the N cycle. Higher productivity implies that the many ecosystem-related functions will also improve, notably biomass production and carbon sequestration.

Developing models that can more accurately predict N mineralization will contribute to optimizing N cycling. In this regard, Morvan et al. [1] present an original experimental design aimed at quantifying and modeling the net mineralization of organic nitrogen in the field using generalized additive models. The innovative aspect of their model is the inclusion of a cropping system indicator that increases the accuracy of the mineralization predictions. Although the final accuracy of the model remained relatively moderate, the results evidenced that N mineralization cannot be predicted from a single test but instead requires a combination of site-specific information, including land use, basic soil properties, and chemical and biological indicators. New knowledge based on machine learning algorithms might be the next step towards improving soil N supply predictions and optimizing N cycling.

N cycling, supply and availability to plants are all influenced by management practices, such as tillage, cover crops, crop residues and soil amendment. In a laboratory lysimeter experiment comparing the effect of autumn inversion tillage (AuT) against no-till (NT) on the reduction of N loss through leaching, with volunteer winter rye as a cover crop, Miranda-Vélez and Vogeler [2] observed that the presence of the cover crop significantly reduced leaching. They thus propose that fall tillage be avoided in order to take advantage of the cover crop effect.

Citation: Dessureault-Rompré, J. Soil Nitrogen Supply: Linking Plant Available N to Ecosystem Functions and Productivity. *Nitrogen* **2022**, *3*, 455–457. https://doi.org/10.3390/nitrogen3030030

Received: 22 July 2022
Accepted: 6 August 2022
Published: 10 August 2022

In addition to protecting against soil erosion and nutrient leaching, cover crops have the potential to improve soil health. In the particular context of a barley cash crop for malt production, Siller et al. [3] investigated how the use of summer cover crops, namely sunn hemp and crimson clover, alone or in a mixture, might improve barley crop production the following winter. Their results showed an increase in nitrate content under sunn hemp as compared to no cover crop. Although no improvements in the quality parameters of the barley crop were observed, the authors concluded that barley can be successfully integrated into crop rotations with leguminous plants without negative impacts on barley growth, yield or grain quality.

The type of crop residue and its management can also have a significant impact on N mineralization processes and therefore on PAN. In an interesting incubation experiment, Alghamdi et al. [4] investigated changes in N mineralization under successive surface applications of crop residues (simulating the no-till system). They observed that in the long term, corn, wheat and soybean crop residues reduced available N as compared to pea or forage radish residues. Although their study did not take into account the contribution of the root system to PAN, the results showed that the long-term accumulation of certain types of crop residues might negatively impact the soil's capacity to supply N to plants. For their part, Tanjila et al. [5] observed in a laboratory incubation experiment that soil respiration was higher under decomposing high-N corn residue and that the effect was exacerbated by fertilization. N and C cycling are intimately linked, and excessive N fertilization could potentially lead to soil C depletion, even in no-till systems.

Organic soil amendments are known to have a positive impact on many soil properties, including N pools and cycling. In a two-year field experiment, Omara et al. [6] showed that biochar applied in combination with inorganic N can improve N availability and potentially increase crop N uptake in coarse-textured soils. Furthermore, Dessureault-Rompré et al. [7] showed that cultivated peatland amended with miscanthus straw or willow wood chips contained less available N, offering opportunities to improve N sequestration in these highly mineralizing soils that are prone to N loss through leaching and denitrification. Phillips et al. [8] investigated N loss by runoff and N-use efficiency using a combination of inorganic N and organic soil amendment. They observed that the inorganic-organic amendment combination doubled N-use efficiency as compared to mineral fertilizer alone and significantly reduced N runoff, allowing for better synchronization between N availability and plant uptake.

Numerous studies have focused on the use of urease or nitrification inhibitors to reduce N losses through volatilization, denitrification or leaching. Lasisi and Akinremi [9] showed that urease and nitrification inhibitors can be combined without impairing their individual effects and that soil pH is an important factor for the persistence and efficacy of urease inhibitors. Furthermore, Guo et al. [10] showed that the efficacy of nitrification inhibitors is highly dependent on soil texture, but when the right combination is used, these inhibitors can reduce N_2O loss by up to 88% and CO_2 loss by up to 73%.

N supply and availability are a concern in urban landscapes as well. Bukomba and Lusk [11] investigated the small-scale variability of soil nitrogen (N) properties in a single urban landscape featuring distinctly different patches or types of cover. They found that N mineralization varied widely over just a few meters. Future studies should focus on the mechanisms that act on the soil N supply and PAN in such landscapes, which are commonly fertilized and irrigated, and are at risk of N loss.

Besides soil, climate and management, plant root traits and functions have a straightforward, often neglected, impact on soil N cycling. Because root traits and functions vary between crops, and between cultivars of a same crop, their influence on N cycling, including N capture, also varies. Kupcsik et al. [12] evaluated 55 modern winter oilseed rape cultivars for their ability to use nitrogen. They observed that root biomass production and morphological traits could be positive indicators of above-ground biomass production and that N uptake capacity was, to some extent, root morphology-dependent. These results have major implications with regard to improving oilseed rape production and optimizing

N cycling under this crop. While N-fixing bacteria are directly involved in N cycling and plant nutrition, the N-contributing efficacy of rhizobia varies widely. *Sandhu* et al. [13] evaluated how *Bradyrhizobium* growth is affected by a soil nutrient environment as compared to more traditional growth media, such as mineral salts or arabinose. They observed marked differences in nodulation efficiency in the soil nutrient environment and propose that the nodulation efficiency of *Bradyrhizobium* be evaluated in soils from specific sites prior to planting soybeans. Better knowledge of leguminous crop symbiosis is another key component of strategies aimed at optimizing N cycling.

In conclusion, this Special Issue, Soil Nitrogen Supply: Linking Plant Available N to Ecosystem Functions and Productivity, presents insightful new research papers that advance our understanding of this relevant topic. Modeling, cover cropping, crop residues, soil amendment, root traits and functions, and the symbiotic N-fixation capacity of leguminous crops and rhizobium bacteria are discussed. Further research on soil nitrogen supply should go beyond investigating mineral forms of N and focus more on the rhizosphere environment and on the interconnection between C and N cycling.

Funding: This research received no external funding.

Conflicts of Interest: The author declares no conflict of interest.

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