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Editorial

Towards a Better Understanding of Agronomic Efficiency of Nitrogen: Assessment and Improvement Strategies

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Abstract: Agronomic N-use efficiency is the basis for economic and environmental efficiency, and an effective agro-ecosystem management practice, improving nutrient use efficiency, is a crucial challenge for a more sustainable production of horticultural, industrial and cereal crops. However, discrepancy between theory and practice still exists, coming from large gaps in knowledge on net-N immobilization/mineralization rates in agro-ecosystems, as well as on the effects of indigenous and applied N to crop response. A more thorough understanding of these topics is essential to improve N management in agricultural systems. To this end, the present Special Issue collects research findings dealing with different aspects of agronomic efficiency of N in different agro-ecosystems, and environmental impact derived from fertilization management practices. In particular, the Special Issue contains selected papers, which concern a wide range of topics, including analyzing tools, options of management, calculation equation and modeling approaches.

Keywords: nitrogen use efficiency; cropping systems; nitrogen management; calculation tool; fertilizer source; nitrate leaching; crop N-status; modeling approach

1. Introduction

Agricultural production would need to increase by 70% (on average) by 2050 to cope with the growth of the world's population [1], which is forecasted to reach about 9.6 billion people [2]. The required crop production increase would be derived from higher yields and enhanced cropping intensity, which, in turn, will raise the demand for agricultural input. However, in this scenario, it is crucial to point out the potential worsening of soil degradation, water resource pollution and atmospheric contamination. Thus, suitable agronomic practices, and particularly fertilization strategies (e.g., organic fertilizers and amendments application), will need to be used.

There is a considerable amount of literature showing that an effective agro-ecosystem management, improving nutrient use efficiency, is a crucial challenge for a more sustainable production of horticultural, industrial and cereal crops. As a matter of fact, as agronomic efficiency (*i.e.*, nutrients recovered within the soil-crop system) improves, economic (farm income is maximized from proper use of nutrient inputs) and environmental efficiency (reduced risk of nutrient losses) will benefit [3].

Nitrogen (N) is a critical element for plant growth, which is also the most complex one considering all of the potential forms and processes involved in its cycle. However, it has been estimated that 50%–70% of the N provided to the soil is lost due to volatilization, runoff, denitrification and

leaching [4]. Improving nitrogen use efficiency (NUE) of cropping systems is essential in order to reduce environmental risks, obtaining, at the same time, a productive agriculture. This result can be achieved by reaching a greater plant uptake efficiency from applied N inputs, and reducing the amount of N lost by soil organic and inorganic N pools. Therefore, there is a need to synchronize crop N demand and the N supply, in time and space, throughout the growing season, not for single crops, but also for a complex crop rotation, including cover crops as an integrated system.

As for the N rate, over- or under-application always results in reduced NUE, yield and crop quality. Moreover, it should be considered that potential nitrate leaching from organic N sources (e.g., green manures, compost, digestates) can be equal to or greater than potential losses from inorganic N fertilizer, when the available N supply exceeds crop demand.

The existing discrepancy between theory and practice comes from large gaps in knowledge on net-N immobilization/mineralization rates in agro-ecosystems, as well as on the effects of indigenous and applied N to crops response. A more thorough understanding of these topics is essential for improving N management in agricultural systems, which should be addressed mainly with: (i) proper fertilizer N management strategies (type of input, time, method and amount of application); (ii) slow-release fertilizers and nitrification inhibitor use; and (iii) diversified crop rotation, including cover crops to capture or recover residual N in the soil, after a main crop harvest.

On the whole, better prediction of soil-available N supplies, crop N, and water needs can improve NUE by tailoring fertilization to the specific conditions of sites, thus optimizing crop performance.

2. Special Issue Overview

This Special Issue collects current research findings dealing with different aspects of the understanding of agronomic efficiency of N in the agro-ecosystems and the environmental impact derived from the adoption of fertilization management practices. In particular, the Special Issue contains seven selected papers, which concern a wide range of topics, including analyzing tools, options of management, calculation equation and modeling approaches. Therefore, in this Editorial, we will briefly introduce the papers published in our Special Issue, entitled "Towards a Better Understanding of Agronomic Efficiency of Nitrogen in Different Agro-Ecosystems".

The papers can be broadly organized into two main subjects: (i) nitrogen efficiency assessment and (ii) nitrogen efficiency improvement strategies, which are hereafter outlined.

2.1. Nitrogen Efficiency Assessment

The first paper by Weigh [5] is a Technical Note presenting a calculation tool for analyzing NUE in different varieties of wheat and biomass-willows crops. What is interesting about this study is the potential solution provided for plant mean N content determination during critical crop growth stages, avoiding to perform destructive plant harvests at the exact dates of those stages for all treatments and cultivars. As underlined by the author, a prerequisite for any improvement of NUE of crops grown in different agro-ecosystems is appropriate assessment by using methods that allow for comparisons across crops, varieties, experimental setups and different sites. A feasible application of the tool is the validation of techniques to improve the NUE of different crops.

In Lv *et al.* [6], a methodological tool for a more suitable seasonal fertilization approach is proposed, using a set of calculation equations. Equation application parameters were collected from more than 50 long-term and short-term field tests, being the base of balanced fertilization to properly increase or reduce nutrient rate.

Finally, the paper of Piccini *et al.* [7] deals with assessing nitrate losses in an Italian ryegrass-silage corn crops rotation of a buffalo livestock farm, by using a modeling approach (WinEPIC model) and comparing data trends with NO_3^- concentration, measured into lysimeters. Three scenarios were simulated, with different fertilization rates, showing a beneficial effect on N loss reduction and NUE improvement without any substantial decrease in forage crop yields. Thus, it is suggested that the model proposed by the authors can be used to predict the effect of fertilizing practices.

2.2. Nitrogen Efficiency Improvement Strategies

The first paper of this group, by Nelson *et al.* [8], pointed out that enhanced-efficiency N sources (urea-based fertilizers) can increase wheat profitability. In particular, polymer-coated urea (PCU) or *N*-(*n*-butyl) thiophosphoric triamide (NBPT) treated urea, can increase fertilizer uptake and enhance NUE by reducing N loss. In a four-year field experiment, the authors found that PCU is a viable option for fall application to wheat in poorly-drained soils, whereas, in well-drained soil, fall-applied ammonium nitrate results in greater wheat yields than other N sources. Therefore, the specific pedo-climatic conditions of a site always play a crucial role.

In Agneessens *et al.* [9], two alternative strategies of vegetable crop residues management to reduce nitrate leaching (during winter season) in intensive crop rotations were reviewed: (i) on-field management options and modifications to crop rotations and (ii) removal of crop residues, followed by a useful and profitable application. The conclusion of this complex Review study is that valorization of vegetables crop residues through composting, anaerobic digestion, or ensilage should be promoted, aiming at returning them in a more suitable form to the field, to maintain soil organic matter and nutrient reserves, and also maximizing synchronization between N availability and demand.

The subject of nitrate leaching reduction was also faced by the paper of Herrera *et al.* [10], reporting a study that was conducted by using lysimeters, as in Piccinni *et al.* [7]. The aim was to determine whether three spring wheat genotypes have the potential to minimize nitrate leaching during spring and summer. Unfortunately, the genotypes varied in fertilizer N recovery but not in N losses by leaching, since root growth and N uptake were not well synchronized with nitrate leaching, which occurred before the stage of stem elongation. The paper suggests that the ability to minimize N losses by using spring wheat genotypes differing in N uptake could be site-specific.

Finally, an up to date Review on the different strategies that can be used or developed for increasing NUE in cereals is presented in Herrera *et al.* [11]. This review article also places the focus on the importance of improving NUE using innovative technologies, such as nanofertilizers and endophytic microorganisms. A detailed description of the N sources commonly used in cereals' production is also presented, along with N management practices to optimize source, rate and method of application, and methods used to assess the N status of crops.

3. Conclusions

Agronomic N-use efficiency is the basis for economic and environmental efficiency, and more sustainable agricultural practices are required in farm management for improving crop yield performance and to reduce the environmental risks of farming.

This Special Issue contains different papers, serving as an update on different aspects of knowledge concerning the agronomic efficiency of N in agro-ecosystems, including analyzing tools, options of management, calculation equation and modeling approaches. The aim should be to minimize the discrepancy between theory and practice, coming from large gaps in knowledge on net-N immobilization/mineralization rates in agro-ecosystems, as well as on the effects of indigenous and applied N to crops response.

We are confident that this Special Issue will stimulate further research in the field of agronomic efficiency of N for several agricultural systems.

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Abbreviations

The following abbreviations are used in this manuscript:

N	Nitrogen
NUE	Nitrogen Use Efficiency

PCU	polymer coated urea
NBPT	*N*-(*n*-butyl) thiophosphoric triamide

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