

Editorial

# Soil Fertility Management for Better Crop Production

John Havlin <sup>1,\*</sup> and Ron Heiniger <sup>2,\*</sup>

<sup>1</sup> Department of Crop Soil Sciences, North Carolina State University, Raleigh, NC 27695, USA

<sup>2</sup> Department of Crop Soil Sciences, North Carolina State University, Plymouth, NC 27962, USA

\* Correspondence: jlhavlin@ncsu.edu (J.H.); rheinig@ncsu.edu (R.H.)

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**Abstract:** Increasing crop productivity per unit of land area to meet future food and fiber demand increases both soil nutrient removal and the importance of replenishing soil fertility through efficient nutrient management practices. Significant progress in enhancing nutrient-use efficiency in production agriculture requires improved estimates of plant-available nutrients in the root zone, enhanced crop response to applied nutrients, and reduced offsite nutrient transport. This special issue, Soil Fertility Management for Better Crop Production, presents 15 manuscripts that advance our knowledge of interrelated soil, plant, and management factors important to increasing the nutrient availability and crop recovery of applied nutrients.

**Keywords:** nutrient use efficiency; nutrient management; rhizosphere; soil fertility; nutrient cycling; soil testing; plant analysis

## 1. Introduction

Since nearly all of the global land area suitable for agricultural production is currently under cultivation, future food and fiber demand must be met by increasing plant yield per unit of land area. With over 50% of global soils degraded, and with some regions approaching 70%, anthropogenic land degradation threatens our ability to meet food and fiber demand in the 21st century [1,2]. Only about 11% of the global land surface is Class I-III arable land, which must support an estimated 50% increase in agricultural production to feed approximately 9.5 billion people in 2050 [3]. Land degradation effects include both onsite (e.g., erosion) and offsite (sediment deposition) degradation. Onsite land degradation effects on agricultural productivity include physical (crusting, compaction, erosion, desertification), chemical (acidification, leaching, salinization, fertility depletion), and biological (carbon oxidation/loss, microbial biodiversity) processes [4]. Offsite effects are related to the eutrophication of surface water, groundwater contamination, and trace gas emissions (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, NO<sub>x</sub>) to the atmosphere.

Many of the same biological, chemical, and physical soil properties affected by onsite soil degrading processes also impact soil fertility and nutrient availability to plants. Understanding these processes and interactions is essential to optimizing plant nutrient availability and minimizing nutrient losses to the environment. As plants are removed from a field or soil sediments are transported offsite, nutrients in the soil are depleted [5]. Native soil nutrient supply depends on the soils' ability to buffer nutrient loss through crop removal. Therefore, to optimize nutrient supply to crops and minimize the environmental risk of nutrient use, it is essential to understand nutrient reactions and processes in soils (soil fertility) and to efficiently manage inorganic and organic nutrient inputs (nutrient management) to ensure adequate soil nutrient supply. Agricultural producers must take advantage of soil- and plant-management technologies that increase plant productivity and minimize soil productivity loss through runoff, leaching, and nutrient depletion.

With increasing demand for fertilizer (>food demand), increasing the crop recovery of applied nutrients while reducing nutrient depletion due to offsite transport is crucial [6,7]. Therefore,

increasing nutrient availability and nutrient use efficiency requires enhanced research to (1) quantify nutrient supplying capacity in soils; (2) improve plant genetics and crop-management practices; and (3) improve nutrient-management technologies to include nutrient sources, rates, timing, and placement. The following sections briefly summarize 15 manuscripts focused on soil, plant, and management factors important to increasing the nutrient availability and crop recovery of applied nutrients.

## 2. Plant Factors

Improving nutrient use efficiency will include enhancing the ability of plants to acquire nutrients from the soil through improvements of plant genetics primarily related to plant root architecture, root exudate effects on rhizosphere biochemistry, and enhanced nutrient metabolism in the plant [8]. For example, genetic variation between and within plant species in root exudation of organic acids has been demonstrated to enhance solubility and mobilization of soil P, thus increasing P use efficiency [9]. In addition, phytase enzyme exudation by plant roots is genetically controlled; therefore, development of transgenic plants that increase phytase concentration in the rhizosphere can increase P mineralization and P uptake [10].

In this special issue, Pellegrino et al. [11] demonstrated that soil inoculated with *Rhizophagus irregularis* at planting increased micronutrient uptake in wheat grain, although there was significant variability between wheat genotypes. Lisuma et al. [12] reported that under tobacco production, soil P, K, Mg, and S decreased while N and Ca increased, likely due to an increase in nicotine deposition in the rhizosphere. Oo et al. [13] assessed the effect of dipping rice seedlings in a P-enriched solution before transplanting. Their results indicated a potential for increased seedling P uptake and biomass.

## 3. Nutrient-Management Factors

### 3.1. Nutrient Rates—Recommendations

Effective nutrient management requires the quantification of crop nutrient requirements and the nutrient-supplying capacity of the soil through soil testing. Nutrients applied in excess of crop requirements increase residual nutrient reserves that, if not utilized or recovered in subsequent crops, may result in offsite transport and contribute to degradation of environmental quality [14]. This is especially important for continual animal- or other waste applications based on crop N requirements, where the P and nutrients applied in the form of waste often exceed crop demand [15]. Nutrient recommendations based on soil testing are well established and reliable [5]. Nutrient recommendation models should be continually re-evaluated to reflect advances in plant genetics and soil-/crop-management technologies that affect crop nutrient requirements.

Using the QUEFTS model (Quantitative Evaluation of the Fertility of Tropical Soils), Xie et al. [16] demonstrated a linear accumulation of nutrients with increasing yield. Nutrient accumulation decreased slightly after yields reached ~60% to 70% of the potential yield. Reliable tools able to quantify nutrient demand will significantly enhance nutrient use efficiency by minimizing overapplication errors. Li et al. [17] conducted a meta-analysis of nearly 300 nutrient-response studies of fruit crops conducted over four decades. While the results showed increased yields over time, they also showed slightly reduced agronomic efficiency and partial factor productivity for NPK due to increased soil nutrient supply. These data suggest that NPK rates can be reduced while maintaining productivity.

Dupre et al. [18] used local and published soil analysis data (~1200 samples) to successfully establish soil-test interpretation ranges (low, medium, high) for hot-water- and Mehlich-3 extractable B. These results significantly enhance our ability to quantify B deficiencies and minimize B-toxicity potential. For many crops, plant-nutrient analysis is a valuable tool to assess nutrient requirements and improve the reliability and accuracy of nutrient recommendations. Using field data, Song et al. [19]

developed greatly improved leaf-dry-matter-N concentration curves that enhanced the accurate diagnosis of N nutrition of rice.

### 3.2. Nutrient Sources

The development of biofertilizers containing organic waste material has been demonstrated to enhance nutrient availability to plants [20]. Vanneckhaute et al. [21] reported that biofertilizers represent promising alternatives to inorganic P fertilizers in enhancing P use efficiency. A recent literature review reported 8–22% increased crop response to bio-based fertilizers [22].

With increasing global population, animal and biosolid wastes provide substantial resources for nutrient recycling in agriculture. For example, struvite ( $\text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}$ ) has been successfully produced from diverse wastes and provides a valuable slow-release P fertilizer [23]. In addition, composted plant residues and animal waste materials mixed with rock phosphate have been demonstrated to enhance P availability and P use efficiency compared to rock phosphate alone on severely acid soils [24].

Wang et al. [25] compared supergranules containing NPK and organically enhanced N fertilizer and found little difference between nutrient sources in corn-grain quality parameters. Although not formally considered an essential plant nutrient, Gad et al. [26] demonstrated that application of Co, especially in combination with animal wastes, increased *Moringa oleifera* Lam growth, yield, and plant Co in plants grown in semi-arid soils. Wang et al. [27] showed that applying slow-release fertilizer resulted in reduced NPK rates being needed for optimum production, while increasing yield and net return for fertilization of chives. Aslam et al. [28] demonstrated increased wheat yield and yield components with application of NPK + vermicompost compared to NPK alone.

Głowacka et al. [29] reported significantly increased soil pH, organic matter, cation exchange capacity, and switchgrass yield with application of biogas digestate applied with recommended nutrients. These results suggest that recycling waste organic materials improves soil physicochemical properties to enhance nutrient availability and crop productivity. Han et al. [30] reported significant increases in soil OM and many other related parameters when all corn and rice residues were returned to the soil, which resulted in increased yields in a corn–rice rotation after several years.

Wang et al. [31] conducted a meta-analysis of 169 field studies to assess mulching effects on potato yield and nitrogen use efficiency (NUE) in arid climates. The results demonstrated that mulching significantly increased yield and NUE; however, combining organic fertilizers with mulching substantially reduced NPK fertilizer input without affecting potato yield or NUE.

While not directly related to nutrient application, ensuring that soil chemical properties are maintained at levels suitable for optimum production is critical. For example, Sakai et al. [32] used low-quality coal combined with organic waste materials applied to sodic soils to substantially reduce exchangeable Na percent and soil pH while increasing exchangeable  $\text{Ca}^{+2}$  and, ultimately, corn yield.

## 4. Conclusions

Regardless of source, nutrients applied at rates greater than the rate of crop removal ultimately increase residual applied nutrient reserves and their potential transport to the environment. Improved nutrient management requires understanding numerous site-specific interactions between nutrient rate, source, application timing, and placement. The 15 manuscripts in the Soil Fertility Management for Better Crop Production special issue communicate results of soil- and nutrient-management research that advance our ability to quantify soil nutrient reserves, enhance nutrient availability, and maximize soil and crop productivity.

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