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EDITORIAL

Highlights of special issue on "Sustainable Phosphorus Use in Agri-Food System"

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Phosphorus (P) is an essential element for plants, and all other life on Earth including humans. However, P is a non-renewable resource with a very uneven distribution in the world. In the agri-food system, P is supplied to agricultural land as chemical P fertilizer and/or animal manure for producing food, feed and fiber, followed by their use or consumption by animals and humans. Despite some returns of P in crop production as organic manure, large amounts of P are released into the environment, severely contributing to pollution or eutrophication (mainly surface waters like rivers, lakes and oceans). Therefore, how to close the P cycle in the agri-food system has become a major challenge for ensuring food and environmental security globally. This special issue focuses on the sustainable use of P in agriculture, and comprises 12 review and research articles covering a wide range of topics on P resources, P use in crop and animal systems, P recycling and eco-environment.

In terms of sustainable use of P in agricultural systems, Shen et al. (https://doi.org/10.15302/J-FASE-2019283) provide an overview of problems and challenges of the whole P supply chain, and propose systemic solutions from mining to dining in different agricultural sectors, including P-fertilizer production, P uptake and utilization by crops, P use by animals and P flow and management at the catchment scale. With a similar idea on management for the whole P supply chain, Müller and Zhang (https://doi.org/10.15302/J-FASE-2019282) describe a recently-established Sino-German international research training group "AMAIZE-P" (Adaptation of Chinese and German maize-based food-feed-energy systems to limited phosphate resources), which was jointly initiated by the University of Hohenheim (Stuttgart, Germany) and China Agricultural University (Beijing, China). Using an interdisciplinary approach, this research group aims to achieve high productivity and high P-use efficiency by adapting P availability and (re-)cycling for the multipurpose use of maize as food, feed and energy. The research group also provides an excellent example of training PhD students from both sides for systemic and interdisciplinary innovation.

For efficient use of P resources in agricultural land, Blackwell et al. (https://doi.org/10.15302/J-FASE-2019274) introduce a combination of approaches to improve P-fertilizer-use efficiency, including development of different P fertilizers that can deal with limited supply of rock P, and the development of plants that can access different P forms in soil. A research article by Li et al. (https://doi.org/10.15302/J-FASE-2019279) investigated variation in plant-available P fractions in different types of manures collected from various regions which can guide manure P use in China regarding P availability for crop production and potential environmental risks. In addition, two review articles by Feng et al. (https://doi.org/10.15302/J-FASE-2019280) and Wang et al. (https://doi.org/10.15302/J-FASE-2019277) introduce several key strategies to improve P-use efficiency in China's crop and vegetable systems, respectively, by the increase of P availability in soil, P-uptake and -utilization efficiency in plants. Ludewig et al. (https://doi.org/10.15302/J-FASE-2019275) further emphasize the importance of root architecture and rhizosphere process for P-uptake efficiency. Furthermore, Li et al. (https://doi.org/10.15302/J-FASE-2019278) summarize the phenotypic, genetic and molecular features of P-efficient maize, and propose a breeding strategy by integrating these favorable characteristics and underlying genes/alleles.

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For the P use in animal systems, Ma et al. (https://doi.org/10.15302/J-FASE-2019276) describe a good example of how to adapt maize-based diets for poultry P nutrition. Maize grain contains little available P because most P is in the form of phytate, which is not available in the absence of phytase activity. Roelcke et al. (https://doi.org/10.15302/J-FASE-2019286) introduce a completed Sino-German research collaboration project (2009–2011) that has developed integrated strategies and solutions for the recycling of organic residues in China. To eliminate the mismatch between centralized animal husbandry and smallholder farming, livestock density and cropland, innovative coupling systems of animal and crop production are urgently required.

Recovery of P from water also helps to close the P cycle in agricultural systems, and minimizes P loss to the environment. Xue et al. (https://doi.org/10.15302/J-FASE-2019287) compare the current situation of P-recycling from P-containing residues, in light of current technologies and policy, between China and Germany, providing valuable experiences and lessons for improving overall P use in the whole chain. Finally, Niño-Savala et al. (https://doi.org/10.15302/J-FASE-2019273) review the problems and challenges of cadmium pollution that are the result of overuse of P fertilizers that contain Cd as a contaminant, and suggest further studies on Cd accumulation within the whole P-based chain.

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Dr. Hans Lambers, distinguished professor of China Agricultural University and emeritus professor of University of Western Australia. He obtained his PhD degree from the University of Groningen, the Netherlands. In the Netherlands and in Australia, he focused on plant mineral nutrition of both crop plants and Australian native species. Since Australian plants evolved in severely P-impoverished landscapes, they have unique adaptations to cope with low-P soils. Some of these are of great interest for future crop cultivars to tighten the P cycle in agroecosystems. He has published more than 450 refereed journal articles and book chapters, and is the lead author of an authoritative textbook, *Plant Physiological Ecology*, *Springer*. He has been the Editor-in-Chief of *Plant and Soil* since 1992.

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