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EDITORIAL

Rhizobiont for high nutrient use efficiency

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Improving nutrient use efficiency in agriculture is a major challenge for achieving food security and green development, which is necessary to systematically develop the biological potential of soil-crop-microbe systems. Led by Prof. Fusuo Zhang, China Agricultural University has proposed a broadening of the concept of *rhizobiont* and the corresponding working strategies to address this key issue. Aiming at the major scientific questions of rhizosphere interaction and nutrient efficiency, the core of this concept is to develop a systemic theory of the rhizobiont consortium. This is an integrated system consisting of plants, roots, rhizosphere, hypersphere and their associated microbes, and consequently there is a need to decipher the underlying mechanisms of plant-microbe and microbe-microbe interactions that drive high nutrient use efficiency. An understanding of rhizobiont consortia will help to coordinate food security, resource efficiency and environmental sustainability to implement agriculture green development. The objectives of this special issue are to summarize the latest progress on: (1) rhizobiont key interface interactions for high nutrient use efficiency; (2) the mechanisms operating within of rhizobiont consortia that improve nutrient use efficiency and (3) biological management for improving nutrient use efficiency.

Plant roots are crucial for nutrient uptake in soil. Using N as an example, Liu et al. (https://doi.org/10.15302/J-FASE-2024587) summarize how plants sense both local and systemic N signals and transduce them to downstream pathways. They suggest that to fully understand the mechanisms underlying N-dependent root morphogenesis and effectively identify loci associated with an ideotype root system architecture in crops, more attention should be given to non-destructive, in situ phenotyping of root traits, cell-type-specific exploration of gene functions and interactions between root architecture, environment and management in the future.

Plant roots interact with a diverse array of soil microbes, which influence the plant nutrient use efficiency. Xu et al. (https://doi.org/10.15302/J-FASE-2024595) summarize the environmental nutrient conditions and plant nutrient-related genes which have been reported to regulate the composition of root microbiota. They highlight the innovative analytical methods, such as microbiome genome- and microbiome-wide association studies, have advanced understanding of the relationships between plants and root microbiota. These methods systematically reveal the interactions between root microbiota and plant nutrient utilization, providing a theoretical foundation for applying root microbiota in agriculture. He et al. (https://doi.org/10.15302/J-FASE-2024593) summarize the current status of how crop domestication and improvement (heterosis) affected root characteristics and their associated microbiome structure and function. Then they also raise the potential mechanisms how crop domestication and improvement reshaped root-microbiome association through gene regulation, root structure and function and root exudate features.

Mycorrhizal fungi form symbioses with more than two thirds of the terrestrial plants and have emerged as key contributors to the below ground communication between plants. Ma & Limpens (https://doi.org/10.15302/J-FASE-2024578) review the evidence for common mycorrhizal network-based transfer of semiochemicals between plants upon exposure to pathogen infection, herbivory or mechanical damage. Potential transport routes are explored, asking whether the fungi can actively contribute to the distribution of such signals within the network and discussing potential drivers for signal exchange. Duan et al (https://doi.org/10.15302/J-FASE-2024589) analyses the interplay of direct and mycorrhizal pathways for plants to efficiently acquire phosphorus from soil. They show that plants make potential trade-off between direct and mycorrhizal pathways based on C input and P gain. Mycorrhizal fungi sense soil P heterogeneity and release exudates that select for organic P-mineralizing bacteria. Mycorrhizal fungi and soil bacteria develop a C–P mutualistic exchange in organic P patches.

Based on the rhizobiont theory, how to use biological management in future to improve nutrient use efficiency in future is important. Wang et al. (https://doi.org/10.15302/J-FASE-2024575) suggest the soil–plant–microbe interactions in the rhizosphere by incremental amplification induced by localized fertilization. The incremental amplification of root foraging for nutrients induced by localized fertilization through increased absorption area due to altered root morphology, enhanced mobilization capacity underpinned by enhanced root physiological processes, and intensified belowground interactions due to selective stimulation of soil microorganisms. Wang et al. (https://doi.org/10.15302/J-FASE-2023531) find that Proline-2′ -deoxymugineic acid, a phytosiderophore analog, drives beneficial rhizobacterial community formation to promote peanut micronutrition. Liu et al. (https://doi.org/10.15302/J-FASE-2024586) examine the integration of microbial inoculants, nano-fertilizers and biochar, which is demonstrated as a promising strategy to enhance soil health, crop productivity and environmental sustainability. Samago et al. (https://doi.org/10.15302/J-FASE-2024556) find that combined use of rhizobial inoculation and low phosphorus application increased plant growth, root nodulation and grain yield of common bean (*Phaseolus vulgaris*) in Ethiopia. All of those are valuable examples for biological management.

Dr. Lin Zhang is a professor of Plant Nutrition at China Agricultural University. His research mainly focuses on the cross-kingdom interactions of plant–mycorrhizal fungi–bacteria, aiming at using the rhizobiont theory for improving nutrient use efficiency in the plant–soil system. He has published 50 peer-reviewed papers in domestic and international high-profile journals such as *Nature Reviews Microbiology*, *Trends in Plant Science*, *Microbiome*, *The ISME Journal* and *New Phytologist*. He is currently the chair of Soil–Plant Nutrient Professional Committee of Soil Science Society of China and the vice chair of Rhizosphere Nutrition Professional Committee of the Chinese Society of Plant Nutrition and Fertilizer Science.

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