Phosphorus bioavailability – nothing but a rhizosphere story

Claude Plassard, Elodie Betencourt, Nicolas Devau, Marek Duputel, Frédéric Gérard, Benoît Jaillard, Edith Le Cadre, Philippe Hinsinger

INRA, UMR Eco&Sols (INRA-IRD-SupAgro), Montpellier, France
plassard@supagro.inra.fr

A major challenge in the coming decades is to achieve the necessary ecological intensification of agroecosystems in order to keep the pace of a growing pupulation while decreasing agricultural inputs such as fertilisers. The Millennium Ecosystem Assessment underlined that the cycles of nutrients, especially nitrogen (N) and phosphorus (P), were among the most affected ecosystem services, leading to a massive and fast-increasing eutrophication of aquatic ecosystems, as a direct consequence of the considerable increase in agricultural inputs alongside of a steady decrease of their efficiency. For P, at the current rate of consumption of P fertilisers, the fast exhaustion of high grade phosphate ores worldwide clearly challenges the sustainability of current P fertiliser use in developed countries in the coming decades. This rather short deadline which may be further extended by using lower quality resources and paying a greater cost clearly requires a major shift in P fertiliser use (Cordell et al. 2009). A better understanding of the processes governing P bioavailability to plants is thus needed. This review will stress the importance of rhizosphere biogeochemistry, which is currently ignored in most models of plant nutrition. Indeed, their central hypothesis is that the driving force of nutrient acquisition it the absorption process which results in a decrease in nutrient concentration at the surface of the root, leading to a diffusion gradient in the rhizosphere. Experimental evidence for nutrient depletion occurring in the rhizosphere is especially documented for poorly mobile, major nutrients such as P (Hinsinger 2001). Recent measurements conducted after sampling the rhizosphere *in situ* in various field-grown plant species have further shown that depletion of P may not be a general rule in low P input conditions. Such findings invalidate classical models of nutrient acquisition. While nutrient uptake models adequately predict P uptake by crops grown under non-limiting conditions, they most often largely underestimate the actual P uptake in low P soils. This suggests that processes that are not accounted for in such models play a key role in determining P bioavailability. Among these, root-induced pH changes as well as changes of ionic (e.g. carboxylates, calcium) concentrations have been shown to be major drivers of changes of inorganic P availability in the rhizosphere (Casarin et al. 2004; Devau et al. 2010; Hinsinger 2001). In addition, the fate of organic P may also be altered by rhizosphere processes involving microbial communities and mycorrhizae. Better understanding the impact of such processes on P bioavailability shall help designing more P efficient plants and agroecosystems.

Casarin, V., C. Plassard, P. Hinsinger, and J.C. Arvieu. 2004. Quantification of ectomycorrhizal fungal effects on the bioavailability and mobilisation of soil P in the rhizosphere of *Pinus pinaster*. New Phytol. 163:177–185.

Cordell, D., J.-O. Drangert, and S. White. 2009. The story of phosphorus: Global food security and food for thought. Global Environ. Change 19:292–305.

Devau, N., E. Le Cadre, P. Hinsinger, and F. Gérard 2010. A mechanistic model for understanding root-induced chemical changes controlling phosphorus availability. Ann. Bot. 105:1183–1197.

Hinsinger, P. 2001. Bioavailability of soil inorganic P in the rhizosphere as affected by root-induced chemical changes: a review. Plant Soil 237:173–195.