



## **Phosphatase activity and phosphorus depletion in the rhizosphere of blue lupin (*Lupinus angustifolius*) assessed with 2D imaging**

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The widespread phosphorus (P) deficiency in agricultural soils is reflected in a dependency on external P fertilizer inputs. Agronomically, lupins are interesting due to their ability to associate with nitrogen fixing bacteria and mobilize P from organic and inorganic pools in soils. Plant and microbial P mobilization processes include acidification, exudation of organic anions and enzymes. Understanding the functionality of phosphatase enzymes and how they are linked to the organic P dynamics and bioavailability is crucial to improve our understanding of how plant-soil-microbial interactions affect plant nutrition. Recently, innovative non-destructive 2D imaging methods such as zymography and diffusive gradients in thin films (DGT) have been developed to assess the distribution of phosphatase activity and labile solutes at the root-soil interface. Here we demonstrate for the first time the combination of these two powerful techniques to improve our comprehension of root-soil-microbiota interactions in P mobilization. The objective was to study and quantify the localized mechanisms of P mobilization and associated phosphatase activity in the rhizosphere of blue lupin (*Lupinus angustifolius*) in two soils from New Zealand differing in P and organic carbon content. Blue lupins were grown in rhizotrons in glasshouse conditions for 45 days. Zymography based on 4-methylumbelliferylphosphate (4-MUP) for acid phosphatase activity mapping and Diffusive Gradients in Thin Films (DGT) gels capable of binding labile P were applied to visualize P mobilization and depletion in the rhizosphere of blue lupin.

Irrespective of the soil investigated, acid phosphatase activity was evidently higher in the rhizosphere and co-occurred with P-depletion zones around the roots. Lateral root profiles showed that elevated acid phosphatase activity as well as P-depletion extended up to 2 mm from the root center into the rhizosphere, suggesting rapid uptake of inorganic P after mineralisation by phosphatases. Despite higher total and higher organic P pools in soil B, phosphatase activity in the bulk soil was lower and P was less plant available (DGT labile P) than in soil A. Lupins grown on soil A had twice the biomass of soil B grown plants. Even though the phosphatase activity was comparable in the rhizosphere in both soils (up to  $300 \text{ nmol mm}^{-2} \text{ s}^{-1}$ ), these results suggest that the efficiency of acid phosphatases to mobilize P for plant growth was limited and initially available P determined blue lupin growth more than phosphatase activity.