Phosphorus Use Efficiency in *Lotus* spp. under Contrasting Levels of Water Availability: A Comparison of Pot and Field Measurements

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Introduction

The results of the phosphorus (P) use efficiency measurements in pot experiments with soil as subtratum are controversial because they may not be representative of an equivalent situation under field conditions. Under P-stress conditions, strategies for improving phosphorus-use efficiency are: (1) increase the root surface soil contact area by modifying root morphology; (2) increase the effective root area by root symbiosis with arbuscular mycorrhizal fungi; (3) increase nutrient availability through rhizosphere modification. The level of water availability and P supply are of high interest because the water stress, which limits growth more than any other environmental factor, can be minimized by improving the supply of P. P use efficiency (PUE) depends on the internal capacity of individual species to produce more DM from a given amount of P absorbed, and an external efficiency which enables the plant to yield more due to an increased ability to extract P (phosphorus absorption efficiency, PAE) from the soil (Trolove *et al.* 1996).

Because of the deep root of *Lotus* species in may be difficult to evaluate *L. corniculatus* and *L. tenuis* in pots. To examine the value of pot experiments to assess the phosphorus use efficiency of *L. corniculatus* and *L. tenuis* grown in a Vertisol, we compare responses under two contrasting levels of water availability and phosphorus supply, obtained in both pot and field conditions, for their consistency or discrepancy in order to determine the actual value of the pot results.

Methods

The experiments were carried out in the Centro Regional de Investigación Quilamapu INIA, (36°32' S), Biobío Region, Chile. Experiment in pots under cover conducted between October 2007 and March 2008. Treatments corresponded to 24 factorial combinations of the following: (1) Three species: *L. corniculatus* L. cv. Quimey, *L. tenuis* Waldst & Kit. (syn. *L. glaber* Mill), cv. Pampa INTA, and *L. uliginosus* Schkur. (syn. *L. pedunculatus* Cav), cv. Sunrise; (2) Two soils: Andisol (A) and Vertisol (V), 0-20 cm depth; (3) Two soil phosphorus levels: low P soil without P application, and high P with P application of 40 mg P/kg; and (4) Two soil water availability (SWA) levels: 10 and 100%. The experimental design was completely randomized with four replicates.

Experiment in field conditions were conducted between June 2008 and April 2009. The soil was a Vertisol, 0-40 cm depth. The treatments included: (1) Species: *L. corniculatus* cv. Quimey and *L. tenuis* cv. Pampa INTA; (2) P levels: low P - soil without the application of P fertilizers, and high P soil with P application to 40 mg P/kg; and (3) SWA levels corresponded to repositioning of 25 and 100% of pan evaporation accumulated between two successive irrigation dates. A split plot design was used, in which the main plots (1 m x 4 m) were the water treatments and the sub-plots (1 m x 1 m) were all the factorial combinations of the two species by the two levels of P, with four replicates. Soil P (Olsen), DM production and herbage P concentration were measured to calculate P efficiency, for both experiments. The arbuscular mycorrhizal (AM) colonization was also determined.

Results

The values of PAE were higher with the low level of P than with the high one, for all the *Lotus* species (Fig 1 a and b) which is consistent with an increment of AM colonization. At the same time, the efficiency of *L. corniculatus* was lower than *L. tenuis* in pot, but higher in field conditions when P level was low ($P<0.05$). This was due to an increase in PAE by *L. corniculatus* in the field compared with pot whereas for *L. tenuis* there was no difference in PAE under both conditions. These results probably reflect differences in the roots system which is more branched near the surface for *L tenuis*.

The interaction SWA x P (Fig. 1, c and d) showed that PAE was significantly higher at low P level with both levels of SWA in pot and in field conditions. The differences between P levels was higher when SWA was not restrictive reflects the effect of water on P solubility. At low P level, the PAE in the field reached higher values than in pots.

The PUE results showed that *L. corniculatus* was more efficient than *L. tenuis* under both pot and field conditions which is most like due to the genetic differences between both species. An improvement of PUE, under restricted soil P availability was observed in pot (Fig. 2, a and b), but there is no apparent explanation for the effect of soil P availability on the internal P efficiency. In the pot experiment, when the level of P was high the PUE was not affected by SWA, but when the P level was low the water stressed conditions showed a tendency ($P<0.05$) to decrease the efficiency. In the field experiment there were no responses to P and SWA ($P>0.05$) (Fig. 2, c and d).

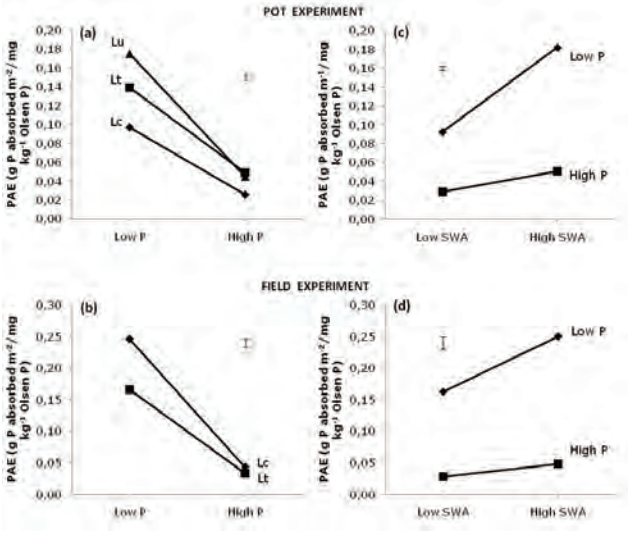

Figure 1. Phosphorus absorption efficiency (PAE) on pot and field experiments. Interactions: species x P levels (a and b) and SWA x P levels (c and d). Lc, *Lotus corniculatus*; Lt, *Lotus tenuis*; Lu, *Lotus uliginosus*. Vertical bars show s.e.m. to compare the interaction means.

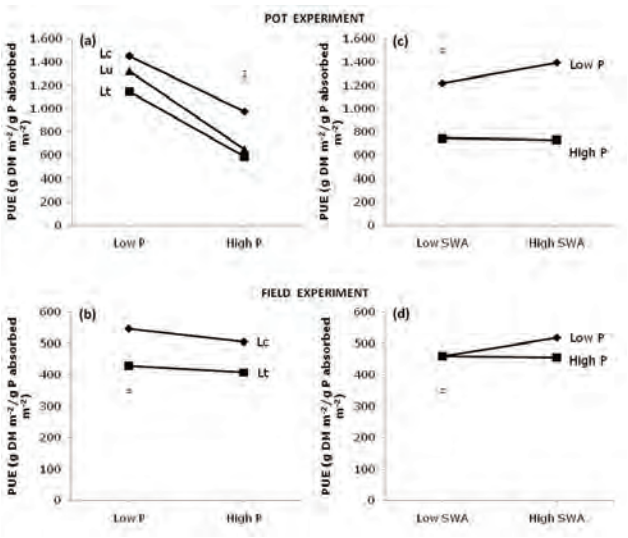

Figure 2. Phosphorus utilization efficiency (PUE) on pot and field experiments. Interactions: species x P levels (a and b) and SWA x P levels (c and d). Lc, *Lotus corniculatus*; Lt, *Lotus tenuis*; Lu, *Lotus uliginosus*. Vertical bars show s.e.m. to compare the interaction means.

Conclusion

The absolute values of PAE for *L. tenuis* were similar in pot and in field conditions whereas the *L. corniculatus* PAE was higher in field, therefore the pot measurements of PAE should be taken with caution when these results are used to predict field performance because there are differences between species and probably between different genotypes within a particular species. The absolute values of PUE were higher in pot compared with field conditions for both species, particularly when soil P availability was low. In spite of this, the effects of P and SWA on the internal P efficiency, comparing pot and field conditions, were lower than the effects on P external efficiency, and the PUE pot results represent the field performance of *Lotus* spp.

References

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