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Response to Phosphorus, Potassium and Sulphur application on the productivity of *Lotus* spp. in two soil groups of central Chile

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Introduction

The *Lotus* forage species, *L. corniculatus* (Lc) , *L. glaber* (Lg) and *L. uliginosus* (Lu), have several valuable characteristics for agriculture, among which is that they are adapted to poorly drained soils with low pH and fertility. In high fertility soils they are replaced by more productive species like white clover or lucerne. They respond to fertilizer application at low rates. The higher yield of Lc is reached with phosphorus and potassium application (Russelle, 1991). Another important element in *Lotus* nutrition is sulphur (Lowther, 1980).

In general legumes increase nodulation, N-fixation and growth when phosphorus availability in the soil increases, by phosphorus fertilizer applications or arbuscular mycorrhiza. The nodulating rhizobia genera for Lc and Lg is *Mesorhizobium* and for Lu *Bradyrhizobium.* Some authors propose using these species for "low input" production systems, where more productive species would not be successful. This performance is attributable to efficient soil phosphorus uptake by their large root systems (Blummenthal *et al.*, 1993). Hart *et al.* (1981) found that phosphorus concentration in Lu tissues is lower than the concentration in white clover tissues when both species grow under similar soil fertility conditions.

Experimental

Chilean research about the effects of mineral fertilizer applications on *Lotus* spp. is scarce. Two experiments were carried out in soils originating from volcanic ash, fixing phosphorus, medium texture and well drainage. One considered different levels of phosphorus application on Lc (Acuña, 1996) and the other studied the comparative response of phosphorus applications on Lc, Lg and two white clover cvs. (Acuña, 1998). Three experiments were carried out in poorly drained clay soil of a rice growing area, one per each species, to study phosphorus, potassium and sulphur application rates combined with three levels of soil water availability (Acuña *et al.*, 1998). Dry matter yield, availability of soil P, K, S and others elements, concentration of these elements on herbage and, in some cases, growth variables, such as the number of growing points and rhizomes or stolons, per unit area (Lu) and dimensions and appearance rates of leaves were measured.The dry matter yield (DM), soil nutrient availability and concentrations of phosphorus and other elements in herbage are reviewed in this paper.

Results and discussion

In the Lc experiment on volcanic soil (4 mg/kg of P; 123 mg/kg of K; 13.2 mg/kg of S- SO4; pH 6.0) there was no phosphorus response despite very low soil phosphorus availability. Phosphorus applications of 0, 5, 10 and 15 kg/ha, as triple superphosphate, were compared. DM yield was recorded for three growing seasons. Because of the high soil potassium availability, there was also no response to this element. Figure 1 shows the sulphur effects on DM production of total and pure *Lotus* under generous application of phosphorus and potassium. DM yields increased when sulphur application rates were increased, despite high initial levels of soil sulphur availability. Soil sulphur increased from 13.2 to 17.1 mg/kg when 60 kg/ha was applied and to 22.4 mg/kg when 120 kg/ha was applied.

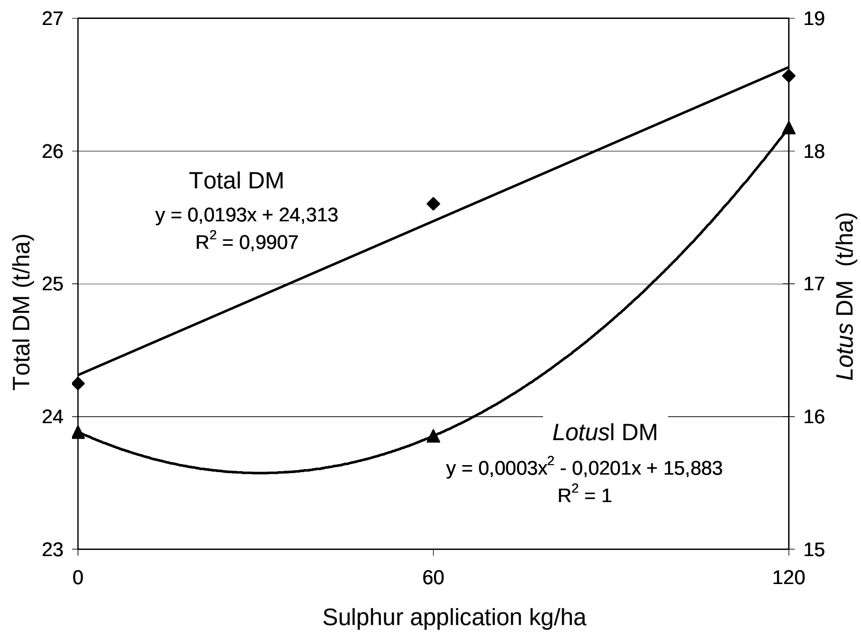

Figure 1. *Lotus corniculatus* cv. Quimey response to sulphur application in volcanic soils. Accumulated DM production in three growing seasons (t/ha).

When the response to P application of two *Lotus* species (*L. corniculatus* and *L. glaber*) and two *T. repens* cvs. (Ladino Italia and Huia) were compared in a volcanic soil, Lc reached high production levels (Table 1) with 7.5 kg/ha/year. The control without P yielded significantly less than 7.5, but it maintained the high level of production, 11.5 t/ha/year. Lg yielded 50% less than Lc, but its yields, including those with zero P treatment, were higher than those of white clover cvs. These results confirm that *Lotus* spp. are able to absorb phosphorus in a more efficient way than other forage legumes when soil phosphorus is available in small amounts. Table 2 shows a significant fall of soil P, after two years of production, in *Lotus* spp. treatments compared to clover cvs. treatments, due to greater *Lotus* P uptake as a result of its higher DM yield, given that the herbage P concentration differences between lotus and clovers do not explain this level of P extraction (Table 3). Phosphorus concentration in Lc was significantly less than white clover in all levels of P application except 7.5 kg/ha; according to Hart *et al.* (1981) its performance would be similar to Lu. The Lg herbage P concentration values were higher than Lc concentrations.

Table 1. Comparison of two *Lotus* species and two white clover cvs. in volcanic soils. Dry matter yield (kg/ha) of pure *Lotus* in the second growing season.

	Annual rate of phosphorus application (kg of P/ha)			
cvs.	**0**	**7.5**	**15**	**22.5**
Huia	390	994	1602	1200
Italia	421	539	1864	2188
Quimey	11536	14749	12685	12552
Toba	3884	3589	4709	4756

120.3 s.e. for comparing P means within each cv.
399.3 s.e. for comparing cv. means within each P level or within different P levels (P x cv. means).

Table 2. Comparison of two *Lotus* species and two white clover cvs. in volcanic soils. Effects of *Lotus* spp. or white clover cv. on soil P changes (0- 10 cm).

	Phosphurus in soil (mg/kg)	
cv.	**Second season**	**Third season**
Huia	3.6	3.1
Italia	4.2	3.7
Quimey	3.5	2.6
Toba	3.4	2.6
s.e.	0.26	0.25

Table 3. Comparison of two *Lotus* species and two white clover cvs. in volcanic soils. Effects of P application on concentration of P in herbage (% in DM), in the second growing season.

	Annual rate of phosphorus application (kg of P /ha)			
cv.	**0**	**7.5**	**15**	**22.5**
Huia	0.170	0.200	0.222	0.235
Italia	0.172	0.180	0.225	0.225
Quimey	0.165	0.182	0.192	0.200
Toba	0.182	0.197	0.232	0.217

0.0033 s.e. for comparing cvs. within the same P level.
0.0022 s.e. for comparing P levels within the same cv..

The experiments in clay soils (5.4 mg/kg of P; 70.4 mg/kg of K; 1.73 mg/kg of S–SO4; pH 5.5) tested 2 levels of P application at sowing, 10 and 20 kg/ha, plus annual applications, which reached 50 and 100 kg/ha by the third year, combined with 2 levels of K application at sowing, 20 and 40 kg/ha, plus annual rates, which by the third year totaled 60 and 120 kg/ha and combined with 3 levels of water availability, replenishing the soil with 50,100,150% of water evaporation (Class A evaporimeter) every ten days. Sulphur was applied (120 kg/ha) to all plots except to a control without S at higher levels of P, K and water. Phosphorus increased DM production at the 3 levels of water availability (Table 4), contrary to the literature which reports positive effects of phosphorus only at low application rates. Phosphorus herbage concentration increased significantly ($P < 0.001$) in the three species when P application was increased (Table 5). Lc shows the lower values and Lu the higher. There is no response of K application, except in the case of Lc, which increased yield in the first and third growing seasons. Potassium herbage concentrations of Lu doubled the concentration of Lg and Lc (Table 6). Calcium and magnesium herbage concentrations in Lc were significantly higher than Lg and Lu. There was no response to application in any of the three species.

Table 4. Phosphorus and potassium applications at three levels of soil water availability. Effects of P application x soil water availability interaction on DM production (t/ha) in the third growing season.

	Soil water availability (% of evaporation replenishing each ten days)						
	50		**100**		**150**		
Species	**Low P**	**High P**	**Low P**	**High P**	**Low P**	**High P**	**s.e.**
Lc	6.08	8.85	7.28	8.71	7.48	9.51	0.293
Lg	3.54	5.35	4.70	6.51	5.77	6.55	0.245
Lu	3.58	5.05	4.24	5.67	2.86	5.50	0.171

Table 5. Phosphorus and potassium application at three levels of water availability in clay soils. Effects of P application on the concentration of P in herbage (% in DM) in the three *Lotus* spp. (second growing season).

	Phosphorus levels		
Species	**Low**	**High**	**s.e.**
Lc	0.193	0.222	0.0018
Lg	0.236	0.273	0.0020
Lu	0.284	0.317	0.0016

Table 6. Phosphorus and potassium application at three levels of water availability in clay soils. Effects of P application on K, Ca and Mg concentration in herbage (% in DM)in the three *Lotus* spp. (second growing season).

	Levels of phosphorus application								
	Low			**High**			**s.e.**		
	Lc	**Lg**	**Lu**	**Lc**	**Lg**	**Lu**	**Lc**	**Lg**	**Lu**
K	0.60	0.67	1.71	0.62	0.70	1.70	0.008	0.019	0.053
Ca	0.60	0.37	0.32	0.59	0.40	0.30	0.010	0.007	0.007
Mg	1.50	1.13	0.73	1.59	1.20	0.70	0.037	0.033	0.016

Conclusions

The *Lotus* spp. response to P application was more evident in clay soils even though the soil P availability in both environments was equally low. This response was notably inferior to that of the clover, but the production levels reached by *Lotus* without P were very high compared to that of the clover under the same conditions. For that reason, the *Lotus* P uptake is very high compared to clover uptake, although the P concentration in *Lotus* herbage would be slightly lower or similar. There were no effects of K in DM production, contrary to the expectation in cutting experiments on soils with low K availability. Sulphur application improved the productivity in volcanic soils with high S availability; there were no S application effects on clay soils.

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