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Growth and DM yield of three *Lotus* spp. (*L. corniculatus* L., *L. glaber* Mill. and *L. uliginosus* Cav.) in clay soils of the Chilean mediterranean zone

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Summary - In the seventh and eighth regions of Chile (35° to 37° south latitude) there is an area of clayey soils where the national rice production is located. This crop uses about a quarter of the land, annually, and high proportion of the available water for irrigation. It has been suggested to use the rest of the land in animal production introducing annual or perennial forage legumes with low irrigation requirements. Among these species, the establishment, growth and DM production of three *Lotus* species (*L. corniculatus* (Lc); *L. glaber* (Lg); and *L. uliginosus* (Lu)) was studied, because of its nutritive value, N-fixation, condensed tannins concentration, which avoid bloat in ruminants. The low temperatures recorded during the sowing period (autumn-winter) negatively affected the germination rate of Lu more than Lg and Lc. The exclusion of P from a complete formula of fertilizer application produced a significant reduction of growth in the early stages of the three species. The number of plant established was higher from 18 days after sowing, when sowing depth was 0.5 or 1.0 cm compared with seeds not buried. Flooded or water saturated soil improved the rate of germination but the growth of seedlings was negatively affected. The cutting frequency of 6 weeks showed better indexes of growth than 8 weeks. The cutting height did not affect growth. The DM yield decreased when cutting height was increased from 3 to 9 cm in Lc and Lg. The total growing season yield were higher for Lc (8 t of DM ha⁻¹) than for Lg and Lu (5 t of DM ha⁻¹). The three species actively fixed N, 200 kg ha⁻¹ season⁻¹ under cutting and 140 and grazing. Low rate of P, K and S application improved DM yield and Lu showed low tolerance to water shortage.

Key-words: forage *Lotus* spp., germination, establishment, growth, yield

Résumé - L'utilisation des sols argileux par des cultures fourragères à base de légumineuse pérennes a été proposée comme une alternative à la culture du riz dans les régions 7 et 8 du Chili. Trois espèces de lotier (*Lotus corniculatus* Lc, *L. glaber* Lg et *L. uliginosus* Lu) ont été comparées pour leur valeur nutritive, la fixation d'azote, et la concentration en tannins. Les basses températures au moment du semis ont plus affecté Lu que Lg ou Lc. L'absence de fertilisation phosphatée a entraîné une réduction de la croissance au stade jeune pour les 3 espèces. Les semences enterrées à 0,5 ou 1 cm se sont mieux installées que celles laissées en surface. L'inondation ou la saturation du sol en eau a amélioré le taux de germination mais a pénalisé la croissance des plantules. La meilleure fréquence de coupe a été toutes les 6 semaines quelle que soit la hauteur de coupe. La production de phytomasse décroît avec l'élévation de la hauteur de coupe de 3 à 9 cm pour Lc et Lg. Lc est plus productif (8t MS/ha) que Lg et Lu (5t). La quantité d'azote fixé est de 200 kg/ha/saison en régime de coupe et de 140 en pâturage. De faibles applications de P, K et S ont significativement amélioré la production mais Lu a présenté une faible tolérance au manque d'eau.

Mots-clés: *Lotus* spp., germination, installation, croissance, rendement

Introduction

Three species of the genus *Lotus* are used in Chile for pasture. *Lotus corniculatus* (Lc) is grown in diverse agroecological conditions. *Lotus glaber* (Lg) and *L. uliginosus* (Lu) are naturalized in the Central and South zones of the country, respectively.

Due to the known good adaptation of *Lotus* species in soil with problems like poor drainage, low levels of available P, K and S, acidity or salinity, water deficiencies etc., it was decided to study these species performance and to develop technologies for using them in the

clayey soils of the Mediterranean zone of Chile. This zone is located, approximately, between 35 to 37 degrees of latitude south. The area holds the total amount of the rice cultivated in the country, the irrigation water is scarce, and a forage legume is required to use the land for the 2 or 3 years between rice crops and to develop animal production systems. The last fact is the main alternative to diversify the agriculture based, today, on rice monoculture. The zone area is 160,000 ha, 30 – 40,000 of which are sown with rice annually.

The main problems to cultivate these species are related with their slow establishment and difficulties to manage, under cutting or grazing, for having good regrowth and persistence.

To accomplish the above a series of experiments were carried out framed within a three years project, with the objectives to develop technologies needed to ensure good establishment, persistence and high levels of production of high quality forage in the conditions of soil, climate and irrigation water availability predominant in the zone.

Materials and methods

Pot experiments were carried out during 1995, with the three species, in soil taken from 0-15 cm depth strata. The effects of application of P, K, S, Ca, Mg and microelements, seed depth at sowing (0.0, 0.5, 1.0 cm), and soil water content (flooded, saturated, field capacity (FC), and 50 % available moisture (AM)), on germination, establishment and nodulation were measured. To study the competitive capacity of *Lotus* spp., each species was sown in mixture with *Lolium multiflorum* and the results were analyzed according to the Replace Series Model developed by De Wit (1960).

Field experiments to study the effects of 3, 6 and 9 cm of height of cut, under cutting, and two grazing intensities (with Hereford steers of 300 kg, approximately), combined with 6 and 8 weeks of utilization frequencies, were carried out. At the same time, P and K, with and without S, fertilizer application experiments, combined with three levels of irrigation water reposition (50, 100 and 150 % of pan evaporation) each lasting 10 days, were also carried out.

The N-fixation assessments by the acetilen reduction method, modified by Hoglund and Brock (1978), were done in the cutting height experiment.

Results and discussion

Figure 1 shows accumulated germination per species. The differences would be explained because of the low temperatures recorded during the experimental period (daily means < 10° C, autumn-winter). Some authors, Hill and Luck (1991) and Blumenthal *et al.* (1996), reported that at these temperatures the germination rates decrease, and that Lu is more affected than Lc and Lg. Also, these results could be associated with the higher seed size of Lc compared to Lu and Lg.

The negative effect on growth of P exclusion of the complete formula of fertilizer application is shown in Figure 2. This result is consistent with the low level of available P in soil (2 ppm, Olsen). The same effect was found in dry weight of roots and nodules.

The accumulated germination was higher when seeds were placed on surface until 18 days after sowing. In the following days, 0.5 and 1.0 cm of sowing depth showed higher values (Table 1). The accumulated percentages of germination seeds and plants with the first true leaf expanded, from 25 days after sowing, were higher in the flooded treatment compared to saturated, and the latter higher than the treatment with soil at FC (Table 1). However, the herbage dry weight was affected negatively by higher levels of water content in the soil. The described effect would be related to water functions on processes to break the seed hardness which, according to Blumenthal *et al.* (1993), have not been studied.

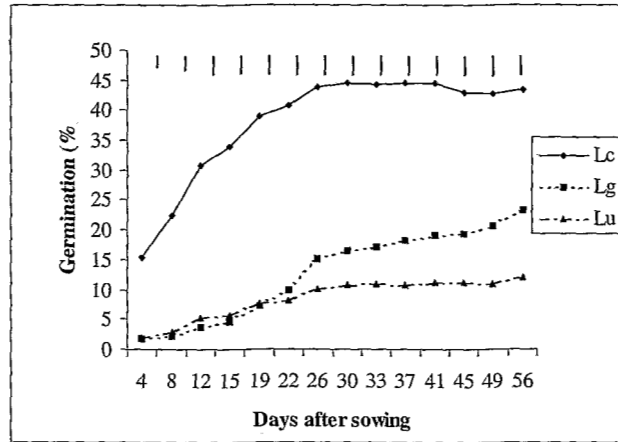


Figure 1. Accumulated germination per species, until 55 days after sowing (% transformed Arcosen $(\%)^{1/2}$). Vertical bars LSD (0.05).

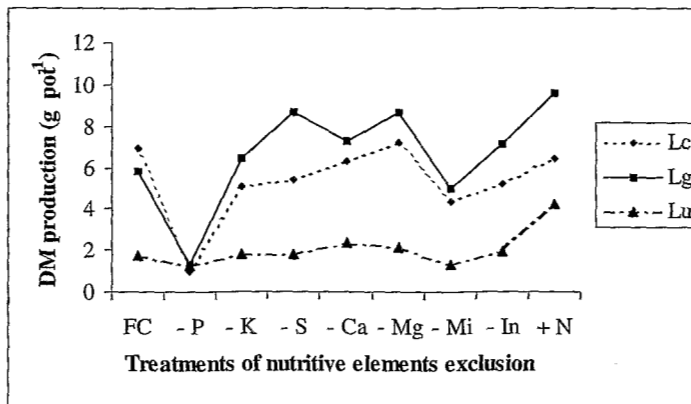


Figure 2. Effect of nutritive element exclusion from a complete formula (FC) of fertilizer application on DM production (g plot^{-1}) 86 days after sowing. Vertical bars LSD (0.05) for comparing FC with each treatment within each species.

Competition experiments showed that Lc and Lg increased significantly plant height, number of leaves and herbage dry weight when the proportion of *Lolium* in the mixtures was decreased. No effects were observed in Lu.

Table 1. Effect of sowing depth and soil water content on accumulated percentages (transformed values Arcosen $(\%)^{1/2}$) of germination and seedling with the first true leaf expanded and dry weight of herbage 130 days after sowing.

(cm)	Sowing depth			Levels	Soil water content		
	Germ. 23 days	T. leaf 64 days	DM $\text{g} \cdot \text{pot}^{-1}$		Germ. 25 days	T. leaf 66 days	DM $\text{g} \cdot \text{pot}^{-1}$
0,0	22	36	2.8	Flooded	28	55	2.5
0,5	28	60	3.5	Saturated	20	50	3.2
1,0	29	53	3.5	FC	21	40	3.9
				50 % AM	22	38	3.7
LSD	4.6	8.3	0.68	LSD	4.7	6.8	0.95

Defoliation every 6 weeks produced bigger leaves in Lc and Lg, higher leaf specific weight in Lg and Lu, and higher leaf appearance rates in Lg and Lu, compared to defoliation each 8 weeks. The height of cut did not affect significantly the growth variables studied, except in Lu where hard grazing produced higher growing points density than lenient grazing.

Table 2. Effect of cutting frequency (6 and 8 weeks) on some growth variables in the cutting experiment (1996/97). Means of three cutting heights.

Variable	Species	<i>L.corniculatus</i>		<i>L.glaber</i>		<i>L.uliginosus</i>		s.e.*
	Frequency	6	8	6	8	6	8	
Length of central leaflet (mm)		13.96	13.27	12.02	10.49	11.85	11.3	0.293
Width of central leaflet (mm)		6.38	5.05	3.91	3.08	6.05	5.88	0.170
Leaf area index		2.78	3.15	2.23	2.42	3.03	2.65	0.180
Dry weight of lamina (mg * cm ⁻²)		9.69	7.62	7.89	7.70	12.59	7.60	0.569
Leaf appearance rate (N° * weeks ⁻¹)		2.22	2.47	1.79	1.12	1.72	0.85	0.122
Growing points (N° * 0,1m ⁻²)		318	242	413	300	396	411	4.628
Dry weight of rizomes and stolons (g * 0, 1m ⁻²)		-	-	-	-	19.58	26.74	3.865
Length of rizomes and stolons (m * m ⁻²)		-	-	-	-	84.87	77.43	7.090

(*) s.e. for comparing means of frequency within each species.

The DM yield (Figure 3), at the second growing season of the experiments (1996/97), decreased when the height of cut was increased in Lc and Lu. No effects of cutting height were observed in Lg. Four and five cuts were done in the season for the six and eight weeks frequencies, respectively, from October 23, 1996, to April 9, 1997.

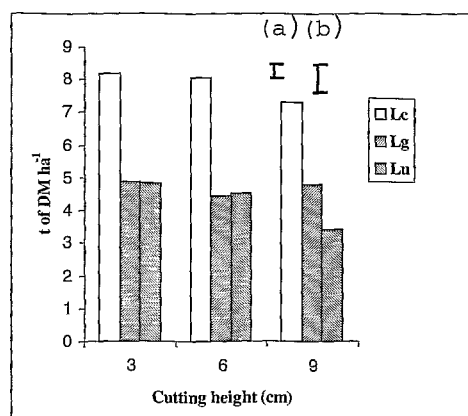


Figure 3. Effect of cutting height on DM yield (t ha⁻¹) in 1996/97. Means of two cutting frequencies. Vertical bars=s.e. for comparing cutting height means within species (a) and means of the species within each cutting height (b).

The total DM yield per growing season (1996/97) was higher for Lc (8 t ha⁻¹) than for Lg and Lu (5 t ha⁻¹). The distribution of the DM production throughout the growing season was concentrated in spring for Lg and Lu, while Lc produced 40 %, approximately, of the total season yield in the summer-autumn period.

The simbiotic N-fixation during the growing season (7 months) was around 181 and 219 kg ha⁻¹ in the plots under cutting, and 112 and 173 kg ha⁻¹ in plots under grazing. The lowest height of cut (3 cm) showed higher N-fixation than the treatments cut at 6 or 9 cm height.

The P, K and S application, at low rates, increased the DM yield in the three species, Lu showed low tolerance to irrigation water shortage.

Conclusions

The results of the project allowed the development of the practical recommendations needed for using these species in the zone. The specific conditions of the farms or of the production systems should be taken into account for choosing the species to grow.

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