LUCERNE DECLINE: THE ROLE OF SOIL ACIDIFICATION

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ABSTRACT
Paddock surveys and preliminary glasshouse experiments have identified acidification of the surface soil layers as a contributing factor to the problem of declining lucerne yields occurring in the mid north region of South Australia. In a field experiment, lime application at rates of 2 t/ha and 4 t/ha significantly improved the growth of lucerne in a soil with an acidic topsoil and alkaline subsoil. Lime incorporated into the soil had an initial short term advantage of improving lucerne production over lime applied to the soil surface. By the end of the first season there was no benefit of incorporated lime application over surface application. High levels of manganese associated with this soil were significantly reduced with the application of lime. Whilst liming produced lucerne growth responses, there was no response to inoculation with *Rhizobium meliloti* strain CC169, regardless of liming treatment, and the initial low levels of *Rhizobium meliloti* in this soil were not improved.

KEYWORDS
Lucerne, *Medicago sativa*, soil acidification, lime, *Rhizobium meliloti*

INTRODUCTION
In recent years, soil acidification has become an increasing problem in the mid north region of South Australia. Results of a survey conducted in the region (Koopman *et al*., 1993) show that a significant part of the decline in lucerne (*Medicago sativa*) yields experienced in the past 10-15 years has been associated with a reduction in soil pH where lucerne has been grown. Surface soil pH(w) in the region varies from 6.3 in areas where lucerne has not been grown, to as low as 5.0 where lucerne has been grown. Soil below 30cm remains alkaline. The survey also showed that the populations of *Rhizobium meliloti* were very low in all paddocks sampled.

Preliminary glasshouse experiments, using the surface soil layers 2-15cm (pH (w) 5.0) have shown a positive response by lucerne to lime application. A response to nitrogen however indicated a low level of nitrogen fixation. Following the initial findings, the field experiment reported in this paper was established in the region to evaluate the response of lucerne growth and nitrogen fixation to lime application and rhizobial inoculation.

MATERIALS AND METHODS
The experiment was established in 1992. The treatments applied were 3 rates of lime (0, 2, and 4t/ha), 2 methods of lime application (surface applied and incorporated to 20cm), 2 levels of rhizobial inoculation (with and without), with four replications in a randomised block design.

The site was established at Marrabel in the mid north region of South Australia (34°09'S. 138° 53'E.). The soil was a hard setting red brown earth, with a sandy loam texture (clay 11%, silt 40%, sand 49%). The average annual rainfall at the site is 500mm, falling mainly in winter and spring (April - November).

The oat stubble from the previous season was burnt to provide an even and easily workable site for cultivation. After the break of the season the site was cultivated and sprayed with 1 L/ha of Trifluralin for weed control prior to sowing. Lucerne cv Siriver was sown on May 24 at 4kg/ha. The seed was inoculated with Group A commercial lucerne peat inoculant (strain CC169). Lucerne shoots were harvested for measurement of dry matter production five times per year over the four years duration of the experiment. Soil pH (1:5, soil-water) was measured annually in autumn at 10cm intervals to 60cm. From 1993 the soil was also sampled annually in early winter to determine the number of *Rhizobium meliloti* present [MPN technique, using 5 fold dilution series with *M. sativa* cv. Siriver as the test host (Brockwell, 1980)]. The 0-10cm soil layer was analysed for available manganese in 1995.

Data were analysed by analysis of variance and treatment means compared at the 95% (P=0.05) probability level.

RESULTS AND DISCUSSION
There were positive responses ($P<0.05$) to lime and the method of lime application on shoot drymatter production (Table 1). In the year of application (1992) lime applied at 4t/ha significantly outyielded the nil lime treatments. By the summer harvest the 2t/ha and the 4t/ha lime treatments produced significantly higher levels of drymatter than the control treatments. At the spring harvest there was a trend for the incorporated lime treatments to improve lucerne growth compared to the control treatments. This was associated with a trend for the incorporated lime treatments to have caused a significant increase in pH. By the summer harvest the advantage of incorporating lime was no longer evident. In the first year after lime application there was no change in soil pH below the 0-10cm layer, which indicates the incorporated lime treatments were not as effective in getting lime into the soil profile as expected. Within two years after the application of lime, there was a significant increase in soil pH in the 10-20cm layers due to liming. The pH of the incorporated 4t/ha lime treatment was significantly higher than the other lime treatments.

Through the 1993 and 1994 seasons the benefits of lime application continued in the improved lucerne growth. There was no clear benefit of applying lime at 4 t/ha over 2 t/ha.

By 1995, the benefit of applying lime was still apparent but lime at 4 t/ha produced higher yields than 2 t/ha. Soil pH in both the 0-10cm and the 10-20cm soil layers had increased significantly in the time since lime was applied to a level more suitable for lucerne, just below the recommended pH range for lucerne of 6.5 - 8.0 (Bolton, 1962). Associated with the increase in soil pH was a decrease in the level of manganese in the soil to less than 25 mg/kg, well below the toxic levels for lucerne (Figure 1). In the nil lime treatment the manganese concentration was as high as 150 mg/kg which is very close to toxic levels (Reuter and Robinson, 1986). Over the duration of the experiment there were no significant changes in the soil pH below 20cm. A further application of lime may enable lime to move into the 20-30cm soil layer and increase the soil pH of this acidified layer. The results show no response to the inoculation of seed with *Rhizobium meliloti*. The most probable number counts of *Rhizobium meliloti* show very low R. *meliloti* populations in the soil, which suggests that the reintroduction of R. *meliloti* to this soil even after the application of lime was ineffective. No definite explanation can be offered for the lack of response to inoculation, even with liming, although it may be related to the poor symbiotic effectiveness of strain CC169 with the cultivar Siriver (Koopman *et al*., 1995). Liming has provided a simple solution to the problem of acidification of the 0-20cm layers. This gives the opportunity to investigate other aspects of the apparently complex problem of low lucerne yields, including the reason for low Rhizobium populations.

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Figure 1
The relationship between soil pH and extractable manganese concentration

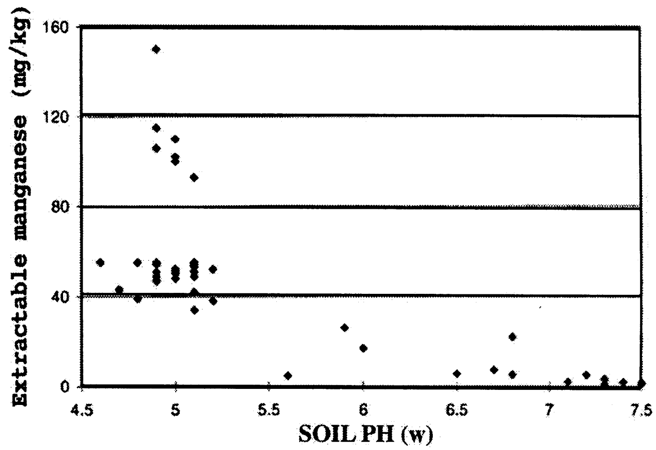

Table 1 Lucerne shoot dry weights and associated soil pH measurements for 1992 -1995.

Year	Lime treatment	Lucerne shoot dry weights (g/m^2)		Soil pH measurement	
		Spring Harvest	Summer Harvest	0-10cm	10-20cm
1992	0t/ha	50.50	56.03	5.0	5.4
	2t/ha surface applied	71.13	70.00	5.4	5.5
	2t/ha incorporated	76.77	78.88	5.6	5.4
	4t/ha surface applied	77.25	98.82	5.3	5.4
	4t/ha incorporated	83.09	97.29	5.8	5.4
	Tukey(5%)	5.733	9.821	0.33	NS
1993	0t/ha	69.90	42.32	5.1	5.3
	2t/ha surface applied	120.15	99.06	5.4	5.4
	2t/ha incorporated	113.72	104.57	5.7	5.5
	4t/ha surface applied	147.66	107.92	5.5	5.5
	4t/ha incorporated	142.98	106.88	5.8	5.5
	Tukey (5%)	21.372	7.930	0.31	NS
1994	0t/ha	47.12	82.00	5.0	5.4
	2t/ha surface applied	117.33	178.56	5.6	5.6
	2t/ha incorporated	109.86	150.01	5.7	5.6
	4t/ha surface applied	111.27	132.93	5.9	5.6
	4t/ha incorporated	104.03	126.31	5.9	5.8
	Tukey (5%)	6.862	6.414	0.19	0.15
1995	0t/ha	48.99	70.08	5.1	5.5
	2t/ha surface applied	102.75	126.49	5.8	5.6
	2t/ha incorporated	84.62	109.16	5.7	5.7
	4t/ha surface applied	110.23	117.28	6.0	5.6
	4t/ha incorporated	119.84	124.52	6.1	5.9
	Tukey(5%)	5.855	10.371	0.18	0.16

Within harvests, values associated with the same letter are not significantly different.