Acid soils: what have we learned from research?

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Introduction

Naturally acidic soils and acidifying soils generally occur in areas where rainfall exceeds 450 mm/year, affecting some of the most productive agricultural land in Australia. Estimates suggest that 33 million hectares of land have a pH_{Ca} of less than 4.8, with approximately half of these soils occurring in New South Wales and Victoria. The most strongly acidic soils occur in permanent pasture areas where rainfall exceeds 600 mm/year, typical of central and southern New South Wales and northeastern Victoria. The capacity of grazing enterprises to pay for amendment by lime application is a major constraint in long-term pasture areas. This has led to poor adoption of liming by graziers. In addition, soil acidification is likely to have substantial off-site effects on water quantity and quality and, as a result, on dryland salinity. However, there is a paucity of scientific evidence to link soil acidity and dryland salinity in this way.

Soil acidification is not as easily recognised as other land degradation problems, such as salinity and erosion. Symptoms are less visible; production declines are gradual; and these production declines are often ascribed to other factors, such as season.

Management

Topdressing lime

The application of limestone is intended to alter the chemistry of a large proportion of the soil volume, rather than to add a particular nutrient. Limestone application is of little value if it does not ameliorate a significant proportion of the soil in the root zone, hence the importance of lime incorporation or the movement of the lime effects into the soil. The movement of the lime effect into the soil from surface application (topdressing) is suggested as a major factor in controlling lime responses by plants.

Responses by subterranean-clover–based pastures to incorporated lime (at 0 to 10 cm depth) have been reported on the southwest slopes of New South Wales by Hochman *et al*. (1990) and Scott and Cullis (1992), on the southern tablelands by Horsnell (1985) and Helyar and Anderson (1971), and in Victoria by Ridley and Coventry (1992) and Burnett *et al*. (1994).

There is limited evidence of plant responses to surface-applied lime. Peoples *et al*. (1995) reported increased dry matter yield of a subterranean-clover–based pasture in an undisturbed soil by surface liming at 2.5 t/ha. The responses were apparent 1 year after surface liming at Bungendore and 2 years after surface liming at two of three sites (Bungendore and Braidwood). When high phosphorus (P) inputs were applied, these responses were 56%, 25%, and 49%. These responses to surface-applied lime were as large as those observed for incorporated lime in other studies, despite the lime effect being confined to the surface 5 cm of the soil (Smith *et al*., 1994). These results are encouraging, but there are few reported instances of topdressed lime on undisturbed soil giving clear yield increases in subterranean clover pasture.

MASTER: Managing Acid Soils Through Efficient Rotations (MASTER) is a long-term experiment commenced in 1992 on an acidic soil 40 km southeast of Wagga Wagga, New South Wales, in a 650-mm rainfall zone. The objectives of the experiment were to (1) test whether perennial pasture systems are less acidifying than annual systems; (2) ameliorate subsoil acidity by topdressing lime; (3) demonstrate the crop, pasture, and animal responses to lime; and (4) assess the economics of lime use. Further detail is available in White et al. (2000).

Sufficient lime was applied and incorporated in 1992 to maintain pH_{Ca} at 0 to 10 cm depth at an average of 5.3 over the first 6 years. After 6 years, further lime (relime) was surface applied to maintain pH_{Ca} at 0 to 10 cm depth at an average of 5.5. The pH_{Ca} at 15 to 20 cm depth increased by 0.05 pH unit per year, and the aluminium dropped from 42% in 1992 to 11% in 2002. This indicated that the effect of lime was moving downward into the soil profile and beyond the depth of the initial lime incorporation.

Pasture responses to lime were shown on feed quality and quantity. In this experiment, stocking rates were adjusted according to sheep liveweight and available feed. As a result, limed pastures carried 24% more stock (up to 4 DSE/ha more) than unlimed pastures while maintaining identical liveweights. In the pasture/crop rotations, the crop responses to lime were large except for lupins (Table 1).

Table 1. Response in crops to lime application at MASTER.

Crop	Lime+	Lime-	Lime response
Wheat (1992–2001)	3.24	1.44	126%
Oats (1993–1996)	2.48	1.96	27%
Triticale (1997–2001	3.48	2.32	50%
Canola (1998–2001)	1.66	1.12	49%
Lupins (1996–2001)	1.64	1.71	-4%

Source: G. Li *et al.* (unpublished).

If no lime was used, permanent pastures tended to give higher returns than pasture/crop rotations, although it depended on prices. Liming permanent pastures is profitable when the clean wool price is over 700c/kg. Grazing without cropping is more profitable if the clean wool price is over 900c/kg and the wheat price is $180/t or lower.

Economic gains from liming are greater in pasture/cropping systems than in pasture-only systems. Rotations with crops are more profitable if the clean wool price is below 900c/kg and the wheat price is $180/t or higher.

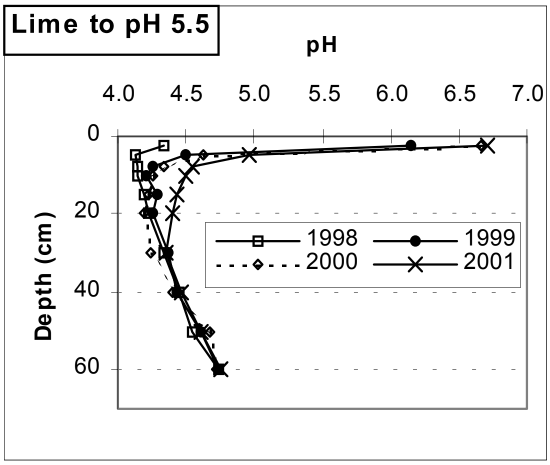
Perennial systems had less deep drainage and less nitrate leaching in wet years. However, no significant difference was detected in terms of soil pH_{Ca} and maintenance lime between perennial and annual systems.

Sutton: A replicated grazing experiment was established on the southern tablelands of New South Wales in 1998. Treatments were two rates of superphosphate (125 and 250 kg/ha/year: P1, P2) and three rates of topdressed lime (nil, lime to increase pH to 5, and lime to increase pH to 5.5: L0, L1, L2). Lime rates were calculated as the amount of lime to raise soil pH to the target levels averaged over a 6-year period. The experimental site was dominated by native perennial and naturalised annual grasses; but a mixture of phalaris, cocksfoot, ryegrass, and subclover was sown over the whole area by direct drilling in May 1998. Pastures were grazed by Merino wethers, with the same animals being maintained on plots throughout the experiment. In this experiment, stocking rates were adjusted according to wether performance and available feed

Average soil pH_{Ca} in the top 10 cm has remained at 4.2 without lime (average exchangeable aluminium, 1.5 cmol(+)/kg[1]; 32% of effective cation exchange capacity). In the first 2 years of the experiment, there was little movement of lime below the soil surface. However, at the lower lime rate, pH_{Ca} reached 4.5 at a depth of 5 cm in spring 2000 and at a depth of 7.5 cm in spring 2001. At the higher lime rate, pH_{Ca} reached 4.5 at a depth of 5 cm in 1999, at a depth of 7.5 cm in 2000, and at a depth of 10 cm in 2001 (Figure 1).

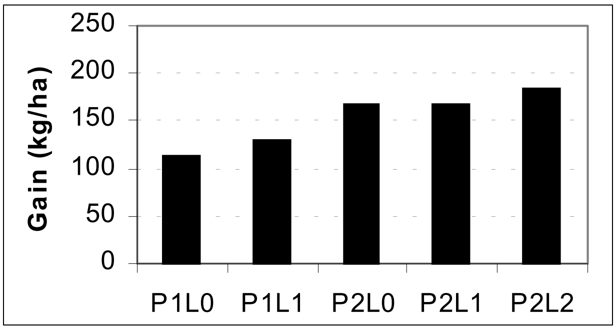
Survival of phalaris and cocksfoot was improved with lime, but cocksfoot declined dramatically under dry conditions. Figure 2 shows total liveweight gain/ha during the period March 1999 to March 2002. The main influence on liveweight gain/ha was phosphorus, with all high P treatments having higher liveweight gains than low P treatments. Performance of wethers on limed treatments has been better than that on unlimed treatments throughout the dry period from October 2001 to June 2002. This was the first impact of lime on animal performance and occurred 3 to 4 years after lime application.

Other: NSW Agriculture, under the Acid Soil Action initiative, has established nine sites where lime has been topdressed onto plots that are grazed. At most of these sites, lime was surface applied onto established pasture. Lime movement down the soil profile has been monitored; but to date, no consistent response to lime application has been measured in either sheep or cattle (S. Glover et al., unpublished).



D. Garden *et al.* (unpublished).

Figure 1. The movement of the effect of surface topdressed lime downward into the soil profile at a site near Sutton, New South Wales.



D. Garden *et al.* (unpublished).

Figure 2. **Effect of phosphorus and lime treatments on total liveweight gain per hectare from March 1999 to March 2002 at a site near Sutton, New South Wales.**

Cropping and lime application

There has been recent interest in cropping in the high-rainfall, long-term pasture areas using reduced tillage, with the aim of diversifying enterprises and improving farmer income. Our interest has been to use cropping as a vehicle for the recovery of liming costs while preparing to re-establish pasture. Incorporation during cropping avoids the time delay inherent with the movement of lime that has been topdressed. However, the soils are fragile; and a range of tillage practices (lime incorporation methods) has been used. A short-duration cropping phase has been successful in the red earth soils south of Orange (see Neville in Table 2), but grain yield and lime response have been poor on a shallow acid soil near Yass (see Oolong in Table 2). We (Peter Dowling and David Michalk, Orange) are currently determining the residual benefit to subsequent pastures of lime applied to these short-duration (1- to 3-year) crop phases.

[1] Centimetres of positive charge per kilogram of soil.

Table 2. Dry matter and grain yield of winter crops (wheat, canola, and Faba beans) following the application of lime at Oolong and Neville, New South Wales.

Lime quantity	Dry matter (kg/ha)						Grain yield (t/ha)					
	Wheat			Canola		Beans	Wheat			Canola		Beans
	1998	1999	2000	1998	1999	1999	1998	1999	2000	1998	1999	1999
Oolong												
Unlimed	386	2,260	1,120	480	1,160	1,580	1.08	3.57	3.15	0.26	1.77	1.29
2.2 t/ha	392	2,440	1,640	460	1,920	1,280	0.97	3.16	3.59	0.40	1.97	2.12
4.4 t/ha	482	2,720	1,720	420	2,020	1,300	0.93	3.03	3.46	0.49	2.18	2.35
Neville												
Unlimed	1,136	309	250	1256	1,660	994	2.93	2.54	0.45	1.69	0.43	1.06
2.2 t/ha	1,580	611	1,408	1826	3,520	1,312	3.90	6.35	2.06	2.29	1.09	3.22
4.4 t/ha	1,514	576	1,702	1746	3,800	1,392	3.96	6.78	2.33	2.43	1.10	3.79

Source: A. Mead *et al.* (unpublished).

Conclusions

- There is extensive soil acidity in central and southern New South Wales and northeastern Victoria.
- There is a need for more evidence of the benefits of topdressed lime in non-arable soils before producers are likely to adopt the practice.
- High subsurface acidity in many soils is a major limitation to the range of species that can be grown. In the longer term, the use of lime may remove constraints on the use of productive species, such as lucerne.
- Short-duration cropping or pasture/crop rotation systems offer an opportunity to recover the cost of lime application.

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