The long term consequences of soil pH management on crop productivity and profitability

Stephen Davies[1], Chris Gazey[2] and David Gartner[2]

Department of Agriculture and Food, Western Australia, www.agric.wa.gov.au
[1] PO Box 110, Geraldton, 6530 Email sdavies@agric.wa.gov.au [2] Northam, Email cgazey@agric.wa.gov.au

Abstract

The investment required to apply lime for the prevention or amelioration of soil acidity can be difficult to justify when farm budgets are tight, as the return on the investment is often not immediate and returns may only be realised gradually over a number of years. Long term lime trials provide an opportunity to examine the consequences of applying or not applying lime and to assess the profitability of liming in the longer term. In 1996 an experiment was established at Bindi Bindi in the wheatbelt of Western Australia with lime sand spread on the soil surface at rates of 0, 1 and 2 t/ha. Yield of wheat was measured in the year the trial was established in 1996 and in three subsequent years, 1998, 2004 and 2007. Grain yield responses of 2t lime compared with the unlimed control were nil in 1996, 13% higher in 1998 (not significant), 28% higher in 2004 (700 kg/ha) and 10% higher in 2007 (270 kg/ha). Using a 3-year average farm gate price for wheat ($250/t) and 2007 lime application costs amortised over 12 years at 8% interest, the cumulative benefit for 2t lime/ha in 1996 is $254/ha for the 4 wheat crops, or $64/ha/year. Soil pH to 30 cm was maintained by the 2 t lime/ha treatment while the pH of the unlimed control soil declined by 0.3–0.4 pH units. The amount of lime required and the cost to correct the acidity, where no lime was applied in 1996, is considerably higher (4–5 t lime/ha over 10 years, estimated to cost $170/ha over 2 applications using 2007 prices) than the lime requirement for the soil which received 2 t lime/ha 12 years previously. In addition, to obtain productivity increases from liming the unlimed soil equivalent to those being obtained fronm the 1996 limed soil would take a number of years. Decisions as to whether to invest or not in liming to manage soil acidification need to consider the benefit of maintaining the soil pH at levels that prevent losses in productivity.

Key Words

Soil acidity, lime, soil pH, investment, return

Introduction

Application of lime and other neutralising soil amendments is the principal strategy to prevent and ameliorate acidification in agricultural soils (Bolan *et al.* 2003). Soil acidification already affects or is likely to affect nearly one-third of the agricultural soils of the south-west Western Australian wheatbelt (Davies *et al.* 2006a). Acidification results in an increase in the amount of aluminium in the soil solution to concentrations that are toxic for the root growth of many agricultural crops and pastures (Tang *et al.* 2001). Research trials run over 25 years by the Department of Agriculture and Food Western Australia, and other research organisations, have shown the value of surface applications of lime to acid soils. Applications of lime at rates of 2–2.5 t/ha, measured for over 50 trial seasons, have given an average wheat grain yield increase of approximately 12% (excluding the year of application) (Davies *et al.* 2006b). Limesand from coastal dune deposits and crushed limestone are the most common liming products available in WA.

Despite the proven benefits of liming to correct or prevent acidity, lime is often one of the first farm practices to be dropped off when the farm budget is tight. While this decision is often justified because of the financial position of the farm business (Trapnell and Malcolm 2004) in other cases this may represent a short-term view of the importance of managing the soil pH. We use the results from a lime experiment established in 1996 to consider the consequences of not liming or liming over the long-term (>10 years) and the implications of this when considering the investment in liming.

Methods

In 1996 limesand was applied at 0, 1 and 2 t/ha to the surface of a sandy gravel soil at Bindi Bindi approximately 150 km north-northeast of Perth, Western Australia. The experiment was sown and managed by the co-operating farmer. Wheat yield response to liming was measured in 4 wheat crops over a 12 season period in 1996, 1998, 2004 and 2007. The paddock is in a wheat-annual pasture rotation. Soil pH_{Ca} was measured in a 1:5 0.01M $CaCl_2$ soil:water extract in 1997 and 2007, and $CaCl_2$ extractable aluminium levels in 2007.

Economic analysis

The economic analyses used a 3-year average farm gate grain price of $250/t and an estimated 2007 lime application cost of $38/t/ha amortized over 12 years (1996–2007) at an annual interest rate of 8% to account for the opportunity costs of capital. Estimated cost of applying 2 t of lime at 2007 prices is $76/ha, comprising $11/t for limesand, $17/t for freight (Cervantes to Bindi Bindi) and $20/ha for lime spreading.

Results

Since the experiment was established in 1996 the soil has continued to acidify. Where no lime has been applied the soil pH has declined by between 0.3–0.4 pH units with the biggest decline occurring between 20–30 cm (Fig. 1). Application of 2 t lime/ha initially increased the pH at 0–10 cm to 6.0 (data not shown) but this has subsequently declined and is now slightly less than the starting pH for 0–10 and 10–20 cm depths (Fig. 1). The pH decline was greater in the 20–30 cm depth than in the surface, and decreased by slightly more than 0.1 of a pH unit (Fig. 1). Application of 1 t lime/ha in 1996 maintained the surface soil pH at the same level as the 2 t lime/ha application but the subsoil acidified with a decline of 0.2–0.3 pH units (Fig. 1).

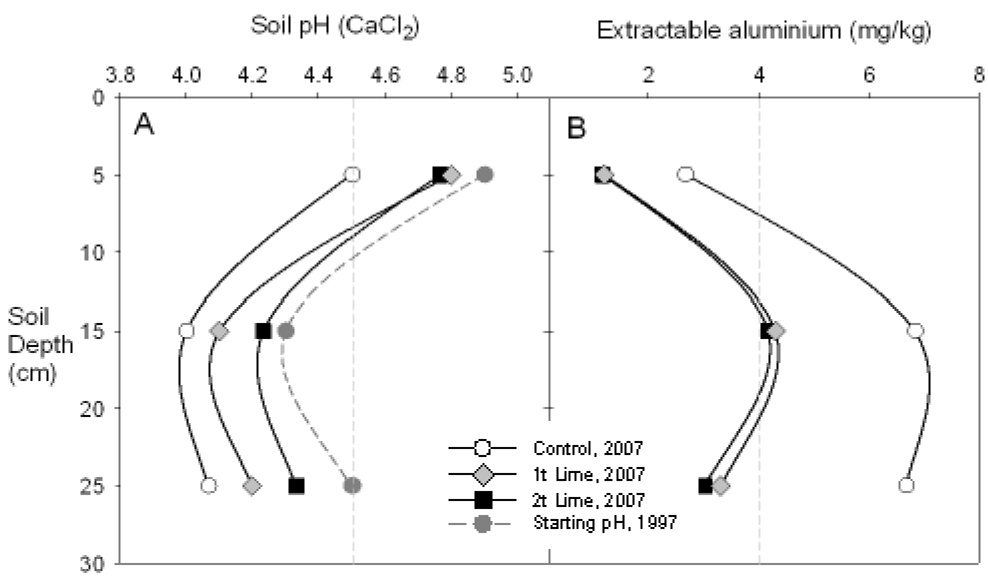

Figure 1. Soil pH_{Ca} (A) and $CaCl_2$ extractable aluminium (B) levels at Bindi Bindi in unlimed soil (control) and soil limed with 1 or 2 t limesand/ha in 1996.

Surface application of lime did not significantly increase wheat grain yield in the year the lime was applied in 1996 (Table 1). In three subsequent wheat crops 3, 9 and 12 seasons after the lime was applied yields were increased by 6–8% where 1t lime/ha had been applied and 10–28% where 2t lime/ha had been applied (Table 1). On average 2 t lime/ha increased wheat yields by 13% (300 kg/ha) over the four wheat crops. The average financial benefit over the 4 cropping years was $31/ha/year from applying 1 t lime/ha and $64/ha/year from applying 2 t lime/ha in 1996 (Table 1).

Table 1. Grain yield responses of wheat to surface applied lime spread in 1996 at Bindi Bindi relative to unlimed grain yield and difference in gross income.

		Yield relative to control (%)		Gross income ($/ha) difference compared with unlimed control*	
Year	Control yield (t/ha)	1 t lime/ha in 1996	2 t lime/ha in 1996	1 t lime/ha in 1996	2 t lime/ha in 1996
1996	2.2	105	100	20	-10
1998	1.6	108	113	27	42
2004	2.5	108	128	45	165
2007	2.6	106	110	32	57

*Farm gate price used for gross income calculations based on 3-year average farm gate price for wheat grain of $250/t less 12-year annualised lime application cost (see details below) and an 8% opportunity cost of capital.

In 2007 grain protein was increased by 1.2% where 1 or 2 t lime/ha had been applied (Table 2). This may be indicative of not only improved root growth and access to soil nitrogen but also of greater nitrogen supply coming from the pasture years. Pasture biomass has been observed to be much greater where the lime had been applied and a single pasture biomass measurement in September 2005 showed that total biomass was 70% greater (2.9 t/ha) where there had been 2 t lime/ha compared with the control (1.7 t/ha). There was a trend towards lower screenings where lime had been applied (Table 2).

Table 2. Grain yield and quality of wheat grown at Bindi Bindi in 2007.

Treatment	Yield (t/ha)	Protein (%)	Screenings (%)	Hectolitre Weight (kg/hL)
No Lime	2.64	11.6	3.1	80.6
1t/ha Surface Lime	2.79	12.8	2.9	80.1
2t/ha Surface Lime	2.91	12.8	2.4	80.7
LSD (5%)	0.23	0.5	ns	ns

Conclusion

Over 10 years the soil pH at the Bindi Bindi site has continued to acidify under a wheat-annual pasture rotation where no lime has been applied. Consequently the soil pH is acid, pH_{Ca} 4.5, in the surface 10 cm and strongly acid at depth with a pH 4.1 or less at 10–30 cm. It is estimated that this soil would now require the application of 4–5 t/ha of high quality lime over the next 10 years to correct both the topsoil and subsoil acidity. Two applications of 2.5 t lime/ha would cost approximately $170/ha at 2007 prices. Additional costs as a result of ongoing productivity losses that would still be incurred while the acid soil is ameliorated have not been taken into account. By comparison where 2 t lime/ha was applied in 1996 the soil pH in 2007 is similar to that measured in 1997. Grain yields have been on average 13 % higher (300 kg/ha) than the unlimed control yields over 4 wheat crops. An additional 2–3 t/ha of lime is required over the next 10 years to continue to maintain and increase the soil pH at an estimated cost of $75–104/ha at 2007 prices. There was a large benefit in the long term from applying lime in 1996 to maintain the soil pH and crop and pasture productivity. Lost productivity and future cost of pH amelioration need to be considered in the medium to long-term when making decisions about investing in liming.

Acknowledgements

Thanks to Mal and Justin King of Bindi Bindi. We acknowledge the technical support of Adam Clune and Breanne Best (DAFWA Northam) and advice of Rob Grima (DAFWA Geraldton) and Joel Andrew (Precision SoilTech). Funding for this research was provided by the Grains Research and Development Corporation and the Avon Catchment Council with investment from the State and Federal Governments.

References

Bolan NS, Adriano DC and Curtin D (2003). Soil acidification and liming interactions with nutrient and heavy metal transformation and bioavailability. Advances in Agronomy 78, 215–272.

Davies SL, Gazey C, Bowden JW, Van Gool D, Gartner D, Liaghati T and Gilkes R (2006a). Acidification of Western Australia's agricultural soils and their management. Proceedings of the 13th Australian Agronomy Conference, Perth, WA. Australian Society of Agronomy. www.regional.org.au/au/asa/2006/concurrent/soil/4555_daviess.htm. Accessed 28 April 2008.

Davies SL, Gazey C, Tozer P (2006b). Long-term productivity and economic benefits of subsurface acidity management from surface and subsurface liming. 2006 Agribusiness Crop Updates, Perth, WA. WA Department of Agriculture and Food. www.agric.wa.gov.au/content/FCP/FarmingSystems2006.htm. Accessed 28 April 2008.

Tang C, Asseng S, Diatloff E and Rengel Z (2001). Growth response to subsurface soil acidity of wheat genotypes differing in aluminium tolerance. Plant and Soil 236, 1–10.

Trapnell L and Malcolm B (2004). Net benefits from liming acid soils. Proceedings of the AFBMNetwork Conference "Profit in an uncertain environment", Orange, NSW. Australian Farm Business Management Network. www.csu.edu.au/faculty/science/saws/afbmnetwork/conferences/2004/proceedings/index.htm. Accessed 8 May 2008.