Western Australia Soil Acidity Research & Development

1999

Update 1999

Western Australia Soil Acidity Research & Development

Time to Lime

Agriculture
WESTERN AUSTRALIA

FOREWORD

We all know we have to apply lime as part of our farming systems. This means that a huge amount of lime will be applied to soils which have never had lime applied before.

One of the effects of this is that we can now consider thinking about introducing acid-sensitive systems to soils, which previously would have been considered too acid.

The other side of liming is that the pH changes affect many soil properties. There is an element of uncertainty about whether unforeseen side effects will emerge on our fragile soils as a result of this new practice.

The research being conducted by Chris Gazey, some of which is reported in this update, is an essential activity to ensure that we identify opportunities which may come from liming, and that we keep ahead of any issue which might result in "the wheels falling off" the system.

We need to maintain a watchful eye for changes in:

- Nutrient availability;
- Herbicide carry-over;
- Soil borne diseases;
- Soil-borne pests.

If you become aware of an effect of lime that may not be expected – either positive or negative – we are keen to hear about it. Please get in touch with one of the Project Team members.

We are very fortunate to have an advisory committee to help guide the Western Australia Soil Acidity Research Development and Extension (WSARDE) Project. This group of farmers, industry representatives, funders and research and development providers meet twice a year to review progress in the project. These reviews help the team keep focused on delivering outcomes relevant to producers.

On behalf of the team, I would like to thank the members of the committee.

Dr. WM (Bill) Porter
Project Manager

The Western Australia Soil Acidity Research Development and Extension Project wishes to thank the following organisations for their support

Time to Lime

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CONTENTS

Bulletin No. 4505 Soil Acidity Research Development and Extension Update 1997

Bulletin No. 4506 Soil Acidity Research Development and Extension Update 1998

Bulletin No. 4507 Soil Acidity Research Development and Extension Update 1999

Bulletin No. 4508 Soil Acidity Research Development and Extension Update 2000

Bulletin No. 4509 Soil Acidity Research Development and Extension Update 2001

Bulletin No. 4510 Soil Acidity Research Development and Extension Update 2002

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CALCULATED LIME REQUIREMENTS FOR ROTATIONS

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INTRODUCTION

Soil acidification is a serious problem for agriculture in Western Australia. Two thirds of the soils in the agricultural areas of the State are acidic or at risk from soil acidification ($pH_{(CaCl)}$ < 5). The main causes of soil acidification are the removal of alkaline produce, leaching of nitrate and application of acidifying fertilisers. Lime is required to neutralise the acidity associated with agricultural production, but how do the rates vary with different rotations and locations?

In this paper estimated lime requirements are examined for selected rotations growing in the low, medium and high rainfall regions of the State. The information presented here was derived from the Lime and Nutrient calculator, a decision support tool which takes account of the above factors to give an estimate of the total acidification rate, expressed as lime equivalents.

METHODS

The acidification rate, expressed as lime equivalents, was calculated for four cropping rotations in the high, medium and low rainfall zones of WA using the Lime and Nutrient calculator. For the purposes of these calculations, the grain yields in the low, medium and high rainfall zones were assumed to be 1.5, 2.5 and 4 t/ha for wheat; 1, 1.5 and 2 t/ha for canola; 0.8, 1.5 and 2.5 t/ha for lupin; and 0.5, 1.0 and 1.5 t/ha for chickpea.

Nitrogen fertiliser applications were assumed to be 10 kg N/ha (as DAP-based fertiliser), 20 kg N/ha (as DAP-based fertiliser) and 50 kg N/ha (equal quantities of DAP-based fertiliser and urea) for wheat after a legume grown in the low, medium and high rainfall zones respectively. Applications of 20 kg N/ha (as DAP-based fertiliser), 35 kg N/ha (25 kg N as DAP-based fertiliser and 10 kg N as urea) and 60 kg N/ha (equal quantities of DAP-based fertiliser and urea) were assumed for canola and all other wheat crops grown in the low, medium and high rainfall zones respectively.

RESULTS AND DISCUSSION

Lime requirements of the rotations grown on light soil were up to three times higher than for the rotations grown on heavy soil (Table 1). In addition, the lime requirement for each of the rotations increased with increasing rainfall. Nitrate leaching was the main cause of acidification for rotations grown on light soil, while nitrogen fertiliser was the greatest contributing factor on heavy soil (Table 2).

Table 1: Calculated lime requirements (kg lime/ha year) for four rotations in three rainfall zones of the WA agricultural areas using intermediate yields and applications of nitrogen fertiliser.

Rainfall Zone	Rotation*	Soil texture	Lime removed (kg/ha year)
Low	WLWC	light	90
(250 - 325 mm)	WLWL		70
	WChWC	heavy	30
	WWWW		40
Medium	WLWC	light	130
(325 - 450 mm)	WLWL		120
	WChWC	heavy	40
	WWWW		50
High	WLWC	light	170
(450 - 750 mm)	WLWL		150
	WChWC	heavy	70
	WWWW		90

* W = wheat, L = lupin, C = canola, Ch = chickpea

Table 2: The proportion of the calculated lime requirements for four rotations in three rainfall zones of the WA agricultural areas that are attributable to product removal, ammonium-based nitrogen fertilisers and nitrate leaching.

Rainfall Zone	Rotation*	Product removal	Nitrogen fertiliser	Nitrate leaching
Low	WLWC	7%	26%	67%
(250 - 325 mm)	WLWL	10%	14%	76%
	WChWC	18%	82%	0%
	WWWW	13%	88%	0%
Medium	WLWC	7%	23%	70%
(325 - 450 mm)	WLWL	11%	15%	74%
	WChWC	19%	81%	0%
	WWWW	10%	90%	0%
High	WLWC	8%	23%	69%
(450 - 750 mm)	WLWL	13%	15%	72%
	WChWC	16%	54%	30%
	WWWW	11%	61%	28%

* W = wheat, L = lupin, C = canola, Ch = chickpea

The estimated lime requirements reported here are higher than in other reported studies (e.g. Porter, et al. 1995). In these studies the contribution of nitrate leaching to acidification was estimated by difference. However, recent experimental work has indicated that large quantities of nitrate are leached from lightly-textured WA soils

(Anderson, et al. 1998). The estimates of leaching used in the calculator are derived from these latter measurements.

It is important to note that the quantities determined by the calculator represent *maintenance rates* only. If a liming product was applied at a rate equivalent to that determined by the calculator it would only serve to maintain the pH of the soil at its present level. Many of the soils in WA have a pH that is lower than the level required for optimal production and crop selection. Therefore, the information provided by the calculator must be used in conjunction with soil and tissue tests to plan applications of lime (and other nutrients) required to sustain production.

It should also be noted that the lime requirements presented here are examples only. As Table 2 illustrates, the lime requirement for a rotation can vary greatly due to changes in the quantity or type of nitrogen fertiliser used, the amount of leaching and, depending on the crop, the quantity of product harvested. For example, the results presented in Table 1 would be quite different if a more acidifying fertiliser was used in the calculations. The aim of the calculator is to enable individuals to estimate the removal of lime equivalents or other nutrients using their paddock histories or projected production.

REFERENCES

Anderson, G. C., Fillery, I. R. P., Dunin, F. X., Dolling, P. J. and Asseng, S. (1998). *Australian Journal of Agricultural Research* 49:345-361.

Porter, W. M., McLay, C. D. A. and Dolling, P. J. (1995). Plant-Soil Interactions at Low pH pp. 75-83.

TopCrop Australia (1998). Lime and Nutrient Calculator.

Acknowledgements

The cooperative development of the Lime and Nutrient calculator was supported by the Grains Research and Development Corporation and the Cereals Program of Agriculture Western Australia.

Key Words

Soil acidification, leaching, nitrogen fertiliser, lime and nutrient calculator

WHAT DOES LIME DO TO ACIDIC SOILS - LUPIN NUTRITION

Chris Gazey
Agriculture Western Australia.

KEY MESSAGE

If paddocks have been limed and manganese deficiency is suspected consideration may be given to applying a manganese fertiliser and or monitoring crops closely. Narrow leafed lupins are the most susceptible crops to manganese deficiency in current farming systems.

Check the levels of manganese in lupin seed especially if the seed has come from a limed paddock and ensure that it is above 15 ppm Mn.

Soil tests for manganese can at best only give an indication that Mn deficiency may occur. The best analysis to determine if split seed is likely to occur is a stem test analysis for manganese.

If manganese deficiency is likely in narrow leafed lupins then a foliar application of manganese at podding has been shown to be very effective at reducing the amount of split seed in the harvest sample. Foliar Manganese applications have also been shown to increases the concentration of manganese in the seed.

BACKGROUND

Introducing lime to manage soil acidity is a major change to farming systems in Western Australia. The project "Managing Acidity in Farming Systems" at Agriculture Western Australia aims to identify the benefits and problems that may occur from treating acid soils to raise their pH. Lime is the most commonly used ameliorant and therefore the work has concentrated primarily on the effects and interactions caused by introducing lime into the farming system.

In summary, a series of lime trials and demonstration sites are located throughout the wheat belt. These trials have been in crops or pasture since 1994, while the demonstration sites have been in crops/pastures since 1996. The growth, nutrition and yield of crops at these sites have been monitored and assessed over several years to determine the effects of introducing lime. There have been a range of crops used in the trials and demo's, including wheat, lupins, canola, barley, faba beans, chick peas and durum wheat and a few pastures.

A comprehensive report of the results from the demonstration sites can be found in the Western Australia Soil Acidity Demonstration Site Results Booklet available in late February from the Agriculture Western Australia Office at Northam.

In previous years three major issues relating to liming acid soil have been reported.

- Depressed lupin grain yield associated with the application of lime.
- Positive responses in wheat grain yield to liming over several years following the application of lime.
- More recently, very encouraging early responses of canola to the application of lime have been reported (see also Mike O'Connell & Chris Gazey, " *Case studies of the benefits of lime in WA*", in this booklet).

REASONS FOR DEPRESSED LUPIN YIELD

The conclusions regarding lupin grain yield depressions associated with the application of lime, indicate the occurrence of grain loss was low and was probably due to an induced nutrient deficiency. Additionally, this nutrient deficiency had a strong interaction with seasonal conditions. Therefore if nutrient levels were adequate, depressions were not likely to occur.

This recommendation still stands, but the causes of these grain losses need to be expanded and what can be done to overcome the problem discussed.

In 1998 there were many cases of reduced lupin grain yield. The lupin grain yield losses occurred several years after the application of lime. Well correlated with these depressions was the occurrence of 'split seed', which is the major characteristic of manganese (Mn) deficiency in narrow leafed lupins. Analysis of the harvest samples has confirmed that the concentration of manganese in narrow leafed lupin grain following the application of lime has been reduced.

The concentration of Mn in the seed was often between 8 ppm – 10 ppm which is diagnostic for 'split seed disorder'. In five of the seven trials tested, the level of Mn in seed from the treatments that received 2 t/ha of lime was below 15 ppm. A manganese seed concentration above 15 ppm is recommended in lupin grain which is to be used as seed. The soil type in which no seed Mn responses occurred was a slightly heavier soils. The two trials where the Mn seed concentrations remained adequate were gravel soils.

It has been demonstrated that the availability of manganese is affected by soil pH. Mn is more available at low pH (acid soils) and becomes less available as the pH increases (i.e. after the application of lime). Typically manganese fertiliser has not been used on acidic sandy soils except in areas such as Badgingarra and Esperance, where there are light sandy soils susceptible to Mn deficiency.

The work completed so far in Western Australia on manganese fertilisers has concentrated on slightly acidic deep grey sands and gravelly sands and has not been related to the application of lime. In 1998 Luigi Moreschi from CSBP showed that 100 kg Extra Phos and Manganese (12% P, 8.5% S and 5% Mn) drilled or banded greatly decreased the incidence of split seed in narrow leafed lupins at Badgingarra (pers com).

This confirms earlier work in the mid 1980s by Ross Brennan of Agriculture Western Australia where 30 kg/ha of manganese sulphate drilled with the seed drastically reduced or eliminated the occurrence of split seed on grey sands, gravels and yellow coastal sands north of Perth.

In 1999 investigations will look at the potential to overcome lime induced manganese deficiency by the well placed application of manganese fertilisers on trials where Mn deficiency in lupins is expected.

WHAT CAN PRODUCERS DO THIS YEAR?

- If a paddock has been limed and manganese deficiency is suspected, consider applying a manganese fertiliser and or monitor crops closely. Narrow leafed lupins are the most susceptible crops to manganese deficiency in farming systems.

- Check the levels of manganese in lupin seed especially if the seed has come from a limed paddock and ensure that it is above 15 ppm Mn. This test should be available from plant testing laboratories.

- Soil tests for manganese can at best only give an indication that Mn deficiency may occur. Tissue testing of youngest open leaves or whole shoots of lupins is also not very reliable for manganese. Manganese is relatively immobile in the plants and there is a strong interaction between the expression of manganese deficiency and seasonal conditions. The best analysis to determine if split seed is likely to occur is a stem test analysis for manganese. This test should be available from plant testing laboratories.

- If manganese deficiency is likely in narrow leafed lupins then a foliar application of manganese at podding has been shown to be very effective at reducing the amount of split seed in the harvest sample. Foliar Manganese applications have also been shown to increases the concentration of manganese in the seed (see references).

REFERENCES AND FURTHER READING

Agriculture Western Australia Farmnote No. 70/93. Symptoms of Manganese deficiency (split seed) in narrow leafed lupins. *By Ross Brennan*.

Agriculture Western Australia Farmnote No. 71/93. Treatment of manganese deficiency (split seed) in narrow leafed lupins. *By Ross Brennan*.

Agriculture Western Australia Farmnote No. 16/95. Lupin nutrition. *By Peter Nelson.*

Snowball, K. & Robson, A.D. Symptoms of nutrient deficiencies. Lupins. School of Agriculture, The University of Western Australia. University of Western Australia Press, Nedlands, Western Australia. 6009.

Acknowledgements

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Key Words

lime, lupins, manganese, nutrient, deficiency, canola

CASE STUDIES OF THE BENEFITS OF LIME IN WESTERN AUSTRALIA

Mike O'Connell and Chris Gazey
Agriculture Western Australia

KEY MESSAGE

Economic analysis of long-term lime trials indicates that liming acid soils can be very profitable. When assessing the likely profitability of liming, farmers need to consider the long-term benefits of managing soil acidity. However, farmers must also be aware that it can take several years or more to recover initial costs.

INTRODUCTION

A barrier to the adoption of lime for managing soil acidity in Western Australia has been the perception that liming represents an increased cost to production without an obvious increase in returns. This perception stems largely from a lack of data showing either yield responses to increasing soil pH with lime or yield losses due to acidity.

To accurately assess the profitability of liming it is necessary to account for the long-term benefits that are likely to occur. This requires data from long-term trials. Alternatively, bio-economic modeling can be used. In this paper case studies of two long-term lime trials in Western Australia are reported. This kind of information has previously been lacking due to the small number of long-term lime trials in the state.

CASE STUDY 1: Agriculture Western Australia trial at Varley

This trial (94LG17) was established in 1994 at Varley (Bruce Hill's property), approx. 350 km SE of Perth. Limesand (NV 95%) was spread at 0, 1, or 2 t/ha. The unlimed soil pH ($CaCl_2$) was 4.3 in the 0–10 cm layer and 3.9 in the 10–20 cm layer. $CaCl_2$ extractable aluminium in the 10–20 cm layer was 96 µM. In 1997, 2 t/ha of lime had raised the surface pH (0–10 cm) to 5.5 and the subsurface pH (10–20 cm) slightly to 4.0. Aluminium was reduced to 65 µM in the 10 - 20 cm layer.

Recent yield responses by canola where lime has been applied to acidic soils are very encouraging and have increased the profitability of managing acidity in Western Australia. In this trial there were positive effects of lime on wheat yields in 1995 and canola yields in 1997. Yields and gross margins (nominal dollars) are presented in Table 1.

Table 1. Yields and gross margins for lime case study at Varley.

		Crop Yields (t/ha)			Gross Margins ($/ha)		
Year	Lime Rate	0 t/ha	1 t/ha	2 t/ha	0 t/ha	1 t/ha	2 t/ha
1994	Lupin	0.61	0.64	0.63	17	-6	-36
1995	Wheat	1.49	1.83	1.98	133	191	217
1996	Lupin	1.22	1.10	1.19	124	103	118
1997	Canola	1.29	1.55	1.69	282	369	416
1998		crops destroyed by frost					

The low gross margins for all treatments in 1994 are due to poor seasonal conditions. In the case of the limed treatments, the cost of applying 1 or 2 t/ha ($28 and $56/ha) was higher than the returns from lupins, resulting in negative gross margins. Despite these losses, the benefits realised from applying 1 or 2 t/ha of lime outweighed the initial cost within two years.

In 1996, and more recently 1998, there was evidence of yield depressions in lupins grown on the limed soil at this site. Research in W A has shown that depressions in lupin grain yield after liming can be attributed to induced nutrient deficiencies. Future losses should be avoidable with the application of additional nutrients, particularly manganese.

CASE STUDY 2: Farmer test strips at Wongan Hills

This second case study is from a farmer's trial near Wongan Hills (Whitten, M. and Diatloff, E., unpublished data). Lime test strips were spread at 2.5 t/ha in 1984. The initial pH and lime quality is unknown. In 1998 the unlimed soil pH ($CaCl_2$) was 4.8 in the topsoil (0 - 10 cm) and 4.1 in the subsoil (10 - 20 cm). On limed soil, the pH in 1998 was 5.0 in the topsoil and 5.1 in the subsoil. A summary of the yields and gross margins (nominal) from this trial are presented in Table 2.

Table 2. Yields and gross margins for lime case study at Wongan Hills.

		Crop Yields (t/ha)		Gross Margins ($/ha)	
Year	Lime Rate	0 t/ha	2.5 t/ha	0 t/ha	2.5 t/ha
1984	Wheat	2.50	2.45	305	247
1985	Pasture	no data	no data	no data	no data
1986	Wheat	2.30	2.60	271	322
1987	Lupins	2.00	2.00	260	260
1988	Wheat	2.00	3.20	220	424
1989	Lupins	1.60	1.60	190	190
1990	Wheat	2.80	3.40	356	458
1991	Lupins	1.80	1.80	225	225
1992	Wheat	2.70	3.10	339	407
1993	Lupins	1.90	1.90	243	243
1994	Wheat	2.00	2.30	220	271
1995	Lupins	1.80	1.80	225	225
1996	Wheat	3.00	3.50	390	475
1997	Barley	1.50	3.00	98	315
1998		no data	no data	no data	no data

Consistent yield responses to lime have been observed in all crops except lupins. Consequently, gross margins from the limed soil have been equal to or greater than the unlimed soil except in the year that the lime was applied. Despite these consistent responses, the benefits realised from liming did not outweigh the initial cost until 1988.

RECOMMENDATIONS

Analysis of long-term trial data shows that liming can increase profitability on acidic soils. There is evidence that in some cases the benefits of lime can last for well over ten years. Despite the benefits, growers need to be aware that it may take several years or more to recover the initial costs of applying lime. Where canola is grown the costs of lime may be recovered more quickly.

Acknowledgements
The research is supported by growers through the Grains Research and Development Corporation in partnership with the Cereals Program and the Pulse and Oilseed Program of Agriculture Western Australia.

Key Words
lime, lime trial, profitability, gross margin

THE RH LIME REACTIVITY TEST AND RH OF TYPICAL WA LIMES

Mark Whitten and Andrew Rate
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KEY MESSAGE

Lime Quality

With increased demand for agricultural lime in WA there is a new emphasis on lime quality. For example, values from the RH (relative hardness) test of lime reactivity have recently appeared in lime advertisements although this is not a standard method for assessing lime quality in WA.

Neutralising value (NV) and particle size are well-established criteria for evaluating lime quality. NV determines both per-weight effectiveness and costs of transport and spreading. Particle size is important because it affects the surface area and hence the rate of dissolution. Particle shape and porosity can also influence surface area.

Hardness has been identified as a less important factor than particle size in determining the rate of lime dissolution, but may be related to particle size by affecting crushability.

The mineral form of carbonate can also affect its rate of dissolution. For equal surface area and purity, rates of dissolution decrease in the order aragonite > calcite > dolomite > magnesite. All of these minerals have been identified in different limes from WA.

AIMS

To evaluate the RH (relative hardness) lime reactivity test and to compare the RH values of representative types of lime from WA which differ in mineralogy and/or hardness.

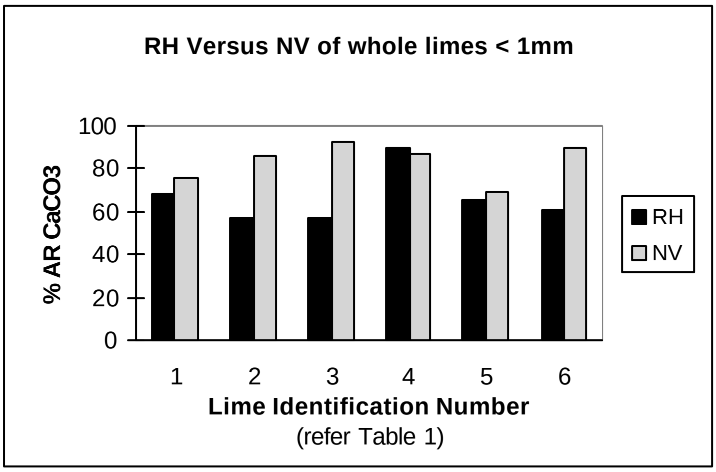
METHODS

The RH values of six different WA limes were measured (Table 1) and their particle size fractions by the resin suspension method of Folscher and Bornman (1985) using BDH analytical reagent calcium carbonate as a reference. Lime surface area was measured by BET nitrogen adsorption.

RESULTS

Using the RH method

The RH test compares the rate of dissolution of limes with analytical grade calcium carbonate under controlled conditions. This work indicates that RH-values are not absolute and will vary according to the rate of dissolution of the reference calcium carbonate, which itself may not dissolve completely. It is also sensitive to variation in technique, and without rigorous standardisation, would be reliable only for comparisons within the same laboratory and with the same reference calcium carbonate. Unacceptable variability was also found in replicated measurements of a single lime with a wide particle size distribution typical of crushed limestones and marls in WA. Variability of individual particle size fractions of the same lime was lower, which indicates that sub-samples of the whole lime had differed in particle size content.



RH-values of selected WA limes

The mean RH-values of the whole screened limes (<1mm) ranged from about 55 per cent to 65 per cent in the limesand (3), crushed limestones (1 & 2) and dolomitic marls (5 & 6), while the highest value of about 90 per cent occurred in the calcitic marl (4) (refer to figure 1). The ranges of the replicate values for limes 2, 3 and 6 overlapped. Overall the correlation between RH and NV was poor.

Figure 1. The RH-values and neutralising values of the 6 limes in Table 1.

The best single predictor of RH was the content (%w/w) of particles less than 90 µm, which explained about 65 per cent of the variation in RH between the lime types. The BET surface area explained an additional 25 per cent of the variation in RH between the lime types. In other words, the higher surface areas in all particle size ranges of the marls, and their greater proportions of very fine particles, compensated for the lower reactivities of the dolomite and magnesite in the products tested here.

Table 1. The types of lime, the predominant form of carbonate, the particle size distribution and BET surface area of a fine and coarse size fraction and the whole lime (< 1mm)

	Lime Type Identification					
Lime ID Number	1	2	3	4	5	6
Deposit	Crushed Limestone		Limesand	Marls		
Mineral	Calcite	Calcite	Magnesian Calcite	Calcite	Dolomite	Dolomite & Magnesite
Sieve Screen Size	Particle Size % w/w					
2.000	8.8	10.3	0.0	0.0	0.0	0.0
1.000	10.1	6.8	0.1	9.2	32.9	25.5
0.710	7.0	2.8	0.7	6.7	11.2	11.9
0.500	16.1	5.2	4.5	9.3	11.2	12.1
0.355	13.1	8.8	11.4	8.9	8.3	8.8
0.250	11.3	17.3	23.0	9.4	7.3	7.5
0.180	13.2	26.0	36.9	11.3	7.2	6.7
0.090	13.6	17.2	23.0	15.5	8.8	9.3
0.063	2.2	2.1	0.3	7.7	3.5	4.6
0.045	1.3	1.0	0.0	4.9	1.9	3.0
<.045	3.2	2.1	0.0	16.1	5.9	10.1
	BET Surface Area M^2/g					
63-90 µM	4.3	2.9	1.3	12.6	58.3	114.5
500-710 µM	1.9	1.4	0.7	12.1	39.6	43.2
WHOLE < 1MM	2.6	2.1	1.2	12.0	45.0	59.4

RH-values of the particle size fractions

From this work it has been demonstrated that RH is affected more by particle size than by the type of lime. Within the same lime sample, RH decreased by a factor of 2 to 6 as particle size increased from <45µm to 1-2 mm. The greatest differences between limes of the same size fraction ranged from about 20 per cent in the finest fraction to a factor of 2 to 4 in the coarse fractions (Fig. 2).

In the fine fractions (<180 µm) the limestones and limesand were more reactive than the dolomitic marls, but this reversed as particle size increased.

There was a trend of decreasing RH of the marls which followed the order of reactivity of calcite > dolomite > magnesite. Differences between the limestones and limesand were smaller and less consistent.

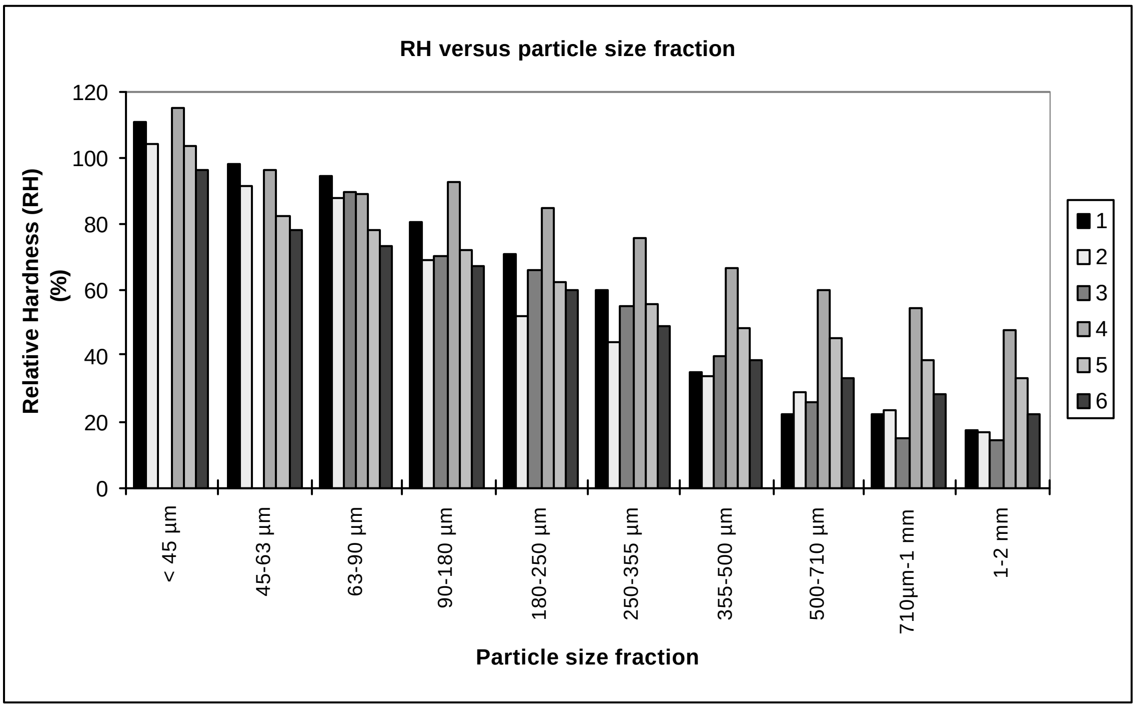


Figure 2. The RH values of individual particle size fractions of the six limes in Table 1.

The similar RH of the coarse calcite marl and finer fractions of limestone or limesand does not mean that they will be equally effective in the soil. This is because the finer lies would be mixed more evenly in the soil than an equal weight of coarse material.

CONCLUSIONS

Differences between the relative hardness (RH) of lime types in the fine fractions were much less than the differences between fine and coarse fractions of the same lime. The percentage of fines was therefore the most important factor in determining the reactivity of these representative and diverse types of WA lime with NV's of 70-90 per cent.

The high surface area of the marls appears to compensate for the lower reactivity of dolomite and magnesite.

The RH test is a useful research tool, which has demonstrated that particle size distribution and NV of WA limes are adequate indexes of quality for comparing the cost effectiveness of different lime sources.

Acknowledgements
The research is supported by Growers through the Grains Research and Development Corporation (GRDC) in partnership with The University of Western Australia.

Key Words
Relative hardness, lime, RH, lime quality

DEFINITIONS

MARL - I a calcareous mudstone, which has formed in lakes, estuaries, or under the ocean and is a sediment of microscopic shells (as well as clays) held together by carbonate cementing.

LIMESTONES - Coastal limestones can be still mainly shell with carbonate cementing or a precipitate from leaching of surface deposits (i.e like the Pinnacles). Look in the coarse fraction for little discs, which are the opercula (caps) of sea snails etc. which they pull over their opening for protection.

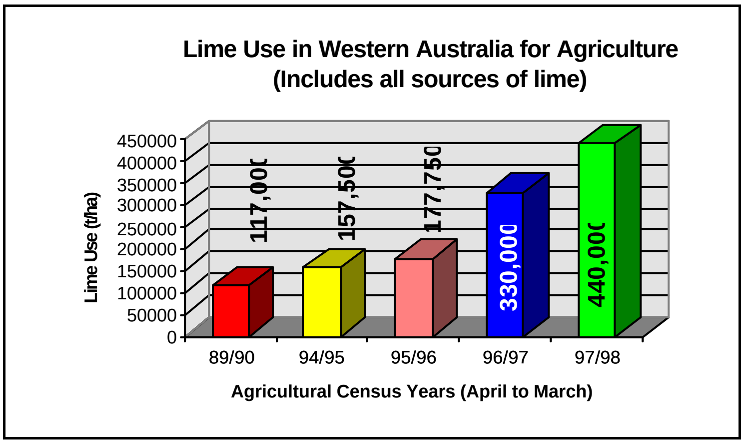
LIMESANDS - Limesands are remnants of shell and coral.

LIME USE INCREASES BY 75 PER CENT IN 1997/98 ½ MILLION TONNES FORECAST FOR 1998/99

Amanda Miller
Agriculture Western Australia, Northam

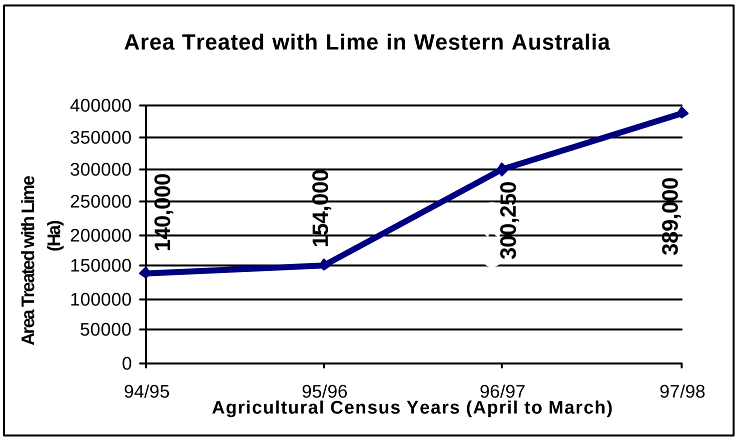
LIME USE

The 1997/98 the Australian Bureau of Statistics (ABS) preliminary figures report that lime usage has increased statewide by 110,000 tonnes since 1996/97 to 440,000 tonnes in 1997/98. It is anticipated that in 1998/99 growers will use in excess of 500,000 tonnes of lime. The projected increase in lime use in the face of a difficult 1998 with growers suffering from frost and a growing incidence of root diseases, will largely come from the increase in the area sown to canola, and growers in the higher rainfall zones diversifying from their traditional grazing systems.



LIME AREA

The ABS census figures are also demonstrating a significant increase in the number of farmers using lime. While the area being treated by lime has climbed to 389,000 hectares up from 300,250 hectares in 1996/97.



LIME USE PER HECTARE

Lime use has consistently hovered around 1.1 to 1.2 tonnes per hectare in the last three to four years. With the advent of the Lime and Nutrient calculator it is anticipated that we will see lime use tonnage per hectare increase as growers strive to account for the net alkalinity export from the property over their rotation (i.e. account for the acidity from fertiliser, leaching and product removal).

FUTURE

Based upon soil types and an estimation of soil acidification rates, lime usage for Western Australia will need to increase even further to prevent greater soil degradation from taking place

Over $70 million is lost annually due to the lower production caused by low soil pH.

It is estimated that between 1 and 2 million tonnes of lime will be required on 13,500 farms annually to maintain soil pH in Western Australia for the future.

At present we are only applying 30 per cent of the amount of lime that should be used, and only 17 per cent of farmers who need to be applying lime are doing so.

Applying lime is an investment in the future of farms. For the cost of about $4.00/ha annually in lime, farming systems can be strengthened and sustainability improved.

So now it's *TIME TO LIME* because *LIME TAKES TIME!!*

Acknowledgements
The extension work is supported by growers through the Natural Heritage Trust, the Grains Research Development Corporation and the Cereals Program and the Pulse and Oilseed Program of Agriculture Western Australia.

Key Words
lime use, lime area, soil acidification, Lime and Nutrient Calculator

SOIL ACIDITY IN THE NORTHERN REGION

Amanda Miller
Agriculture Western Australia, Northam

BACKGROUND

Soil acidity in the Northern wheatbelt has become a major management issue in the last four to five years. When lime usage by shire is compared, there is no definitive area within this region that has adopted liming as part of the sustainable farming system any more than another area. It is however prudent to say that this Northern region has largely embraced soil acidity technology as a whole more quickly than the Central and the South East. There are probably three reasons for this observation.

1. Large areas of the soils classified as high risk i.e. sandy soils with low buffering capacity, good rainfall (adequate for growing quality crops), high use of high analysis nitrogen fertilisers and consistent average to above average yields in this area.

2. Good quality lime is available in relatively close proximity (largely) when compared to the Central and the South East.

3. A focus of the "Time to Lime" campaign and active lime company marketing in the area North of the Great Eastern Highway (1996 - 1998). This work has aimed to increase general awareness and to foster a high uptake of the systems application of soil acidity technology by consultants and company agronomists.

TRIALS

Eleven major lime demonstration trials were established in 1996 at a Northampton, Maya (2), Kalannie, Three Springs, Mullewa, Bindi Bindi, Watheroo, Dandaragan and Moora (2) to look at different levels of lime applied, some looking at different lime sources i.e. Chalk lime vs Limesand. A comprehensive report on all of the lime demonstration sites will be available by late February from the Agriculture WA Northam office.

At the same time (1994 - 1998), Chris Gazey has undertaken heavy trial work in the "Lime on Lupins" and "Managing soil acidity in the farming system" projects in the Northern region.

A long-term site at Ninan Farms at Moora has been looking at "Sustainable and profitable rotations through efficient use of nutrients and lime". This is a co-operative research site involving all of the organisations involved in the integrated soil acidity project (Agriculture WA, CSIRO, CLIMA and the University of Western Australia).

In 1998 a similar intensively managed site was developed in the Gabby Qoi Qoi Catchment at Konnongorring. These "paired" sites at Konnongorring will contribute to the greater understanding of nutrient movement (leaching) in the soil for a range of nutrients.

All of these trial sites will continue to be monitored in 1999.

LIME PITS & LIME USAGE

There are now 19 lime suppliers providing lime to the Northern Region. Only four or five years ago this number was less than five.

The 1996/96 Agricultural Census figures show that the Northern Region (Avon, Campion, Moore & Greenough ABS areas) consumes approximately 60 per cent of the lime used in agriculture.

Lime quality is generally high, and the mining of dolomite has given producers a choice of products to consider. The cleanliness of lime supplies from debris (sticks and logs) is an ongoing debate, and it is proposed that the new Lime Suppliers Code of Practice and Quality Assurance Programs that will be developed in 1999 will help alleviate these types of problems.

LIME AND NUTRIENT CALCULATOR

The release of the Lime and Nutrient Calculator in 1998 was well received in the northern region with Train the Trainer workshops being held in Geraldton for AAAC Consultants, and at the Moora District Office of Agriculture WA.

The "Man Size" calculator was also on display at the Dowerin Machinery Field Days (Launched at Dowerin), and the Mingenew Expo.

Responses to the calculator as a decision support tool to help growers analyse their rotations for lime removal has helped growers make that important decision of "how much lime do I need to apply". Consultants and farmers alike have heralded the calculator as a success, citing the calculators as the "bit that has been missing". Growers have been saying they have the soil and tissue tests to tell them what they have, but no tool to help them know how much (including leaching) they were taking out.

1999 IN FOCUS

With a largely incident free year in 1998 (compared to the frosts of the Great Southern), reports of high quality and above average yields for a majority of the Northern Region in 1998, and an anticipated increase in canola planting's again in 1999, we would expect lime usage to increase in 1999.

It is predicted that lime usage in Western Australia will increase beyond half a million tonnes in 1999 compared with 440,000 tonnes in 1998. Long-term usage of lime however needs to be between 1 and 2 million tonnes per annum to maintain soil pH in Western Australia.

Acknowledgements
The extension work is supported by growers through the Natural Heritage Trust, the Grains Research Development Corporation and the Cereals Program and the Pulse and Oilseed Program of Agriculture Western Australia.

Key Words
Northern region, lime use, lime quality, Lime & Nutrient calculator

SOIL ACIDITY IN THE CENTRAL REGION

Sally-Anne Penny
Dryland Research Institute, Merredin

BACKGROUND

Soil acidity is a major concern in the central/eastern wheatbelt, due to the area's naturally acidic soils and long history of farming. This has resulted in an exceedingly high interest in lime to increase soil pH.

TRIALS

Major lime trials were established in 1996 at Tammin, Southern Brook, Narrogin, and Wickepin to look at three levels of lime, which were applied at 0t/ha, 1t/ha, and 2t/ha.

In 1997 a trial was established at West Popanyinning to compare three lime products (crushed limestone, G-lime, and a blend of crushed limesand and G-lime), and a second trial was established at Brookton looking at the direct drilling of limesand through an airseeder.

For the 1998 season, five lime products were compared at Beverley and two demonstration sites at Mukinbudin, and South Bodallin compared lime rates.

All of these trial sites will continue to be monitored in 1999.

LIME PITS

No lime pits are located in the central region due to geological unsuitability for lime, and there are no active dolomite deposits in the area (closest is at Newdegate and Watheroo). Therefore all lime products must be sourced from outside of the area.

Potentially a depot is to be established in Merredin with the lime product sourced from Kalgoorlie. If this comes to fruition, it should decrease landed lime costs in the eastern wheatbelt.

LIME AND NUTRIENT CALCULATOR

The release of the Lime and Nutrient Calculator in 1998 was well received in the central area.

The calculator opened a few eyes in how much lime is removed in a rotation, and that lime should be considered earlier rather than later especially if it is to increase pH and not just to provide maintenance of pH levels.

LIME USE

Average wheat prices and yield in 1997 led to lime tonnage in the area being slightly down in 1998 compared to 1997.

The start of 1998 looked promising for an increase in lime usage especially after the Lime & Nutrient calculator release and various soil acidity workshops held in the area. However the devastating 1998 frosts will result in lime usage unlikely to be greater in 1999 than compared to 1998.

The main barrier to lime adoption in the central particularly eastern area is the cost of freighting the product. Freight will always be a major cost, however in the long-term, outlaying money for lime now will be an insignificant cost compared to the productivity and sustainability of the land (see article "What impact does transport cost have on the profitability of liming").

Acknowledgements
The extension work is supported by growers the Cereals Program and the Pulse and Oilseed Program of Agriculture Western Australia.

Key Words
Central region, lime use, Lime & Nutrient calculator

SOIL ACIDITY IN THE SOUTH EASTERN REGION

Andrea Hills,
Agriculture Western Australia, Esperance

BACKGROUND

The south east agricultural region of Esperance is split into two roughly equal areas. The northern area is mallee - characterised by its alkaline soils. The other is the sandplain, where soils are generally either a duplex of sand over clay or deep sands. Wind erosion and non-wetting are the most obvious ongoing battles, but soil acidity is becoming an issue.

TRIALS

In 1998 two lime trial sites were set up. These trial plots are large, 'farmer size' strips which are replicated. The first site is in the Neridup area (north east of Esperance) where a nil and two rates each of G-lime (0.5 t/ha, 1.5 t/ha) and crushed limestone (1.5 t/ha, 3 t/ha) were compared. The paddock was sown to Cascades wheat. The lowest pH at this site was 4.4 and the paddock is a medium depth sand. Yield results were mixed.

The second lime trial is at Munglinup (west of Esperance). Here three rates of crushed limestone (0, 1.5 t/ha, 3 t/ha) were used. Initially, the lowest pH at this site was 4.5. The paddock is a duplex soil of sand over tight clay. Gungurru lupins were sown and grew well throughout the season. Unfortunately excessive rains in early January led to the lupin grain sprouting, and the lupin swaths could not be harvested.

In 1999 both trial sites will continue to be soil sampled and harvested if in crop.

LIME PITS

The Esperance region now has two lime pits, one east of Esperance town and another at Hopetoun. Both are limestone of respectable quality (around 85 per cent neutralising value). Another potential pit of dolomite (at Norseman) is under Native Title Claim but may become more accessible soon.

LIME USE

Lime and Nutrient Calculator
The new calculator was presented to Esperance AgWA and private industry staff at a workshop in October. It has great potential as a tool when working with farmers on liming issues.

The rate of lime use in the region is still low, far lower than it should be considering the pH of many of our sandplain soils and the area grown to canola (one of the most sensitive plants to soil acidity and a high return crop).

Sandplain farmers have embraced claying their non-wetting sands which is costly (rates start at about $100 /ha), probably at the expensive of liming (which at least looks much cheaper in comparison).

A reasonable number of farmers have commenced liming programs and I expect this to be the beginning of a growing trend.

Acknowledgements

The extension work is supported by growers the Cereals Program and the Pulse and Oilseed Program of Agriculture Western Australia.

Key Words

South Eastern region, lime use, Lime & Nutrient calculator

PERENNIAL PASTURES REDUCE RECHARGE AND ACIDIFICATION

Perry Dolling
Agriculture WA, Katanning

KEY MESSAGE

During the last three years, herbaceous perennial pastures near Kojonup have showed great potential in reducing the soil water content over summer and autumn. Since 1995 the soil water content to a depth of 1m has been 20-60 mm lower than the soil water content under annual crops or pastures at the end of the growing season. The perennial pastures have also reduced acidification.

AIMS/METHODS

The perennial pastures along with the rest of the trial were established in 1994 and consisted of the perennial grasses phalaris and tall fescue, subterranean clover and annual grasses. The trial was established to examine mechanisms of acidification under different rotations

RESULTS

In the first six months of 1998 the soil water content under the perennials was 30 to 40 mm lower than under the annual crops and pastures (see Graph). This result is surprising since the spring in 1997 and the 1997/98 summer was very dry. The perennials are using soil water to a maximum depth of 1 m in comparison with the annuals, which only use soil water to a depth of 0.6 of a metre.

Drying out the soil profile is important in reducing recharge as recharge occurs once the profile is saturated. In the case of the perennials, at the start of the 1998, growing season an additional 30 to 40 mm of rain was required before the profile was saturated. Winter rainfall brought the soil water contents together under all treatments but at the end of 1998 the soil water content under perennials was again 30 mm lower than the annuals (see Graph). There was no difference in the soil water content between any of the annual crops or pastures. There does not appear to be a strong relationship between soil water content and plant biomass as all of the treatments produced a similar amount of dry matter at the end of the year (see Table 1).

Table 1 - Plant available soil nitrogen and plant biomass for pastures and crops in 1998

Parameter	Day	Perennial	Annual pasture	Pasture/Wheat
Soil N (kg N/ha)	17th Dec 1997	49	53	63
	31st Mar 1998	146	122	107
	18th May	102	73	164
	6th July	43	37	89
Plant biomass (DM t/ha)	6th July	2.9	2.9	0.2
	26th Oct	10.0	8.4	9.8 (2.7)[A]

[A] Grain yield

Another aspect of the trial at Kojonup has been to examine leaching of nitrate, which is one of the main causes of soil acidification. The results since 1994 have shown that pastures have the ability to reduce leaching of nitrate and therefore cause less acidification compared to crops, 1998 again confirmed these results.

In March the area received 74 mm of rain, which resulted in the germination of the pastures and the mineralisation of 40 to 100 kg N/ha (see Table 1). Although plant deaths did occur in the pastures by the 18th of May, the soil N levels had decreased by 40 to 50 kg N/ha compared to a 60 kg N/ha increase in the wheat after pasture treatment (see Table 1). Plant uptake contributed most to the decrease of N in the pastures.

In the wheat after pasture treatment, weeds were controlled in the wheat phase resulting in very little uptake of N early in the season. High levels of N under wheat is beneficial to plant growth, however it also means that the N is at risk of being leached. The decrease in soil N levels in the wheat on the 6th July compared to May is mostly due to immobilisation of N by microbes (34 kg N/ha) and leaching (30 kg N/ha). Plant uptake contributed only a small amount (10 kg N/ha) to the decrease as indicated by the low plant biomass (see Table 1).

Under pasture the soil N levels also fell in July but the fall is mainly due to plant uptake, with the cumulative plant biomass being 3 t/ha.

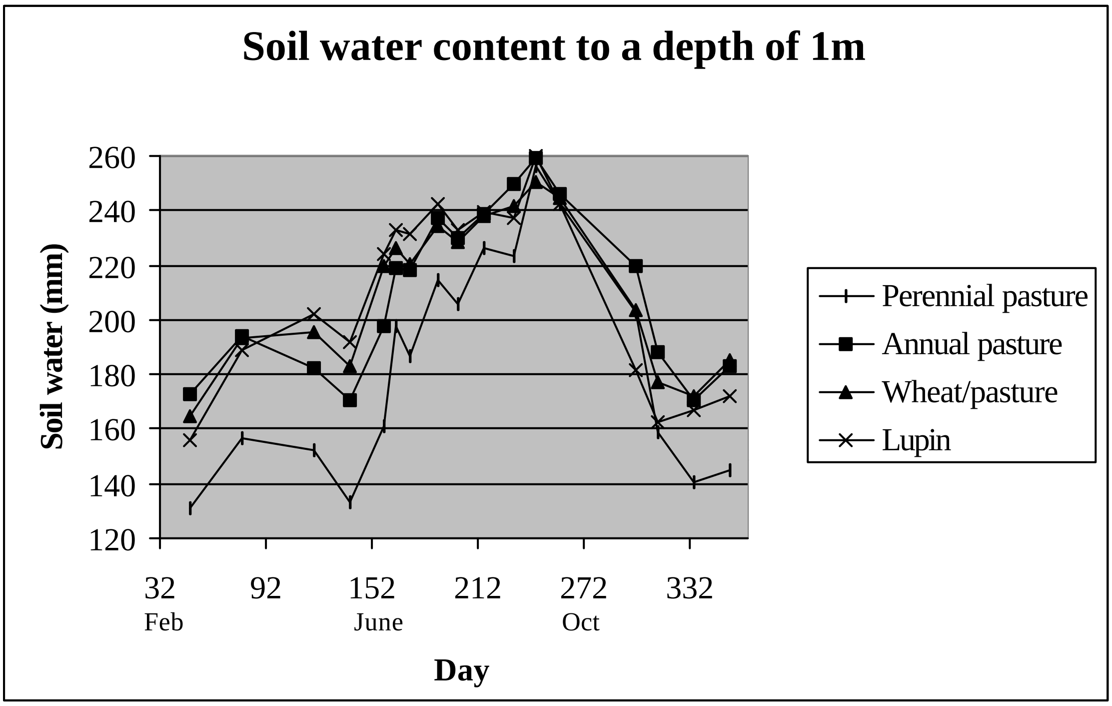


Figure 1 - Soil water content readings to a depth of 1 meter in 4 different rotations in 1998.

CONCLUSION

Perennial pastures and to a less extent annual pastures need to become part of the agricultural system to increase the sustainability of rotations. The increased sustainability comes from less input of water into water tables and reduced acidification.

Acknowledgements

The research is supported by growers through the Land and Water Resources Research Development Corporation in partnership with the Cereals Program and the Pulse and Oilseed Program of Agriculture Western Australia.

Key Words

perennial pastures, soil acidification, recharge, soil water content

WHAT IMPACT DOES TRANSPORT COST HAVE ON THE PROFITABILITY OF LIMING?

Mike O'Connell and Andrew Bathgate
Agriculture Western Australia

KEY MESSAGE

Lime transport costs, although high, do not have a large impact on the profitability of applying lime to acid soils. This is because the benefits of lime are potentially large and long lasting, whereas costs are incurred infrequently.

BACKGROUND

Transporting lime from the pit to the farm accounts for a large part of the cost of a liming program. Farmers are often concerned by this, when considering applying lime, especially if they are unsure if the benefits of applying lime will outweigh the costs. For this reason, the impact of transport costs on the profitability of applying lime needs to be determined so that farmers can make informed decisions about soil acidity management.

It is important to address the impact of transport costs from a long-term point of view. There are two reasons for this:

1. The benefits of liming are not always immediately apparent; and
2. The benefits of liming usually last for many year.

In this analysis a 30 year cashflow is used.

Returns to liming were estimated for paddocks 50, 150, 250 and 350 kilometres from the nearest source of industry standard lime (neutralising value of at least 75 per cent and at least 80 per cent of particles able to pass through a 0.6 mm sieve). Three scenarios in different parts of the agricultural region were investigated. These are outlined in Table 1. The soil pH values used are common for soils on which lime is being applied, and the subsoil was assumed to be moderately aluminium toxic (aluminium levels high enough to cause a yield loss in sensitive crops). For each scenario, the impact of transport cost on the profitability of applying 1 t/ha of lime every ten years was estimated.

Table 1. Scenario investigated

Rainfall zone / region	Soil	Initial Topsoil pH (CaC1$_2$)	Initial Subsoil pH (CaC1$_2$)	Production type
Low (Eastern Wheatbelt)	Duplex	4.75	4.25	4PWCWLWLW
Medium (Northern Wheatbelt)	Good Sandplain	4.75	4.25	7PWCWLWLW
High (Great Southern)	Duplex	4.75	4.25	10PWCBLW

W = wheat, C = canola, B = barley, L = lupins (angustifolius), and 4P = 4 years of pasture (sub clover based)

Results

Results are presented in Table 2. These results are examples of typical returns from liming acid soils.

Tale 2. The effect of lime transport cost on the profitability of liming.

Transport distance (km)	Cost of transport ($/t)	Average long-term gross margins ($/ha/year) Low rainfall (Eastern Wheatbelt)	Medium rainfall (Northern Wheatbelt)	High rainfall (Great Southern)
50	5	83	120	110
150	15	82	119	108
250	25	81	118	107
350	35	80	117	106
No Lime	0	75	103	95

It is important to note that the results are estimates of average gross margins over the long term (expressed as annuities). The results indicate that increasing transport costs have a small impact on the profitability of liming. This is because even though high transport costs will cause a decrease in gross margins in the year that lime is applied, this cost is incurred infrequently (for example, once every ten years). On the other hand, it is likely that the benefits of liming will last for many years after application.

Under these circumstances the total benefits from liming over time are likely to outweigh the costs. For example, in this analysis, average gross margins were always higher in limed than unlimed paddocks, even with the longest transport distances. For the scenarios outlined here, transport distances would have to be in excess of 700 km before liming became unprofitable.

RECOMMENDATIONS

If planning a liming strategy, the immediate impact of lime transport costs on the farm business must be considered. However, also remember that the benefits of applying lime to acidic soils where yield loss is occurring are likely to be long term. Trials have shown large yield benefits more than ten years after liming. Provided that yield reducing levels of acidity are correctly identified and an appropriate strategy is adopted, liming is likely to be profitable even if transport costs are high.

Acknowledgements
The research is supported by growers through the Grains Research and Development Corporation in partnership with the Cereals Program and the Pulse and Oilseed Program of Agriculture Western Australia.

Key Words
Lime, transport cost, transport distance, profitability

LIME INDUSTRY MOVES TO QUALITY ASSURANCE

Amanda Miller
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BACKGROUND

The professional body representing the Lime Industry in Western Australia is the Australian Fertiliser Services Association (AFSA).

This association has operated at a national level for 26 years and has had a Western Australian Branch for the last six years.

The AFSA represents individuals and industries involved in the manufacture/supply, transport/distribution and spreading plus agronomic advice on fertilisers (including soil ameliorants like lime) throughout Australia.

In 1995 the AFSA made the decision to further promote the activities and image of the fertiliser industry as a professional and caring organisation by undertaking the development of an industry Code of Practice.

In a joint venture agreement with the National Landcare Program in 1997, the AFSA developed the fertiliser industry Code of Practice with the aim of maximising economic returns for members and clients, whilst at the same time minimising the negative environmental impact associated with the use of fertilisers.

Recently the AFSA completed the four modules of the Code of Practice, which includes modules on Storage; Transport; Spreading and Agronomic Advice (developed in conjunction with the Fertiliser Industry Federation of Australia).

The spreading module was the first to be completed and is complemented with the “AccuSpread” protocol. AccuSpread provides operators with a system to accurately measure spread patterns, and a means of accrediting spreaders on a regular basis by an independent auditor to improve the quality of spreader operation.

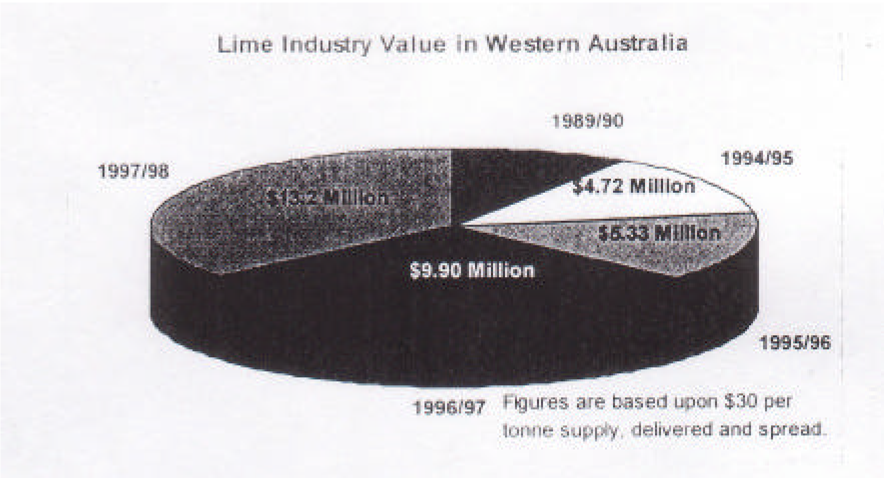
The AFSA Calibration Trailer commissioned in February 1999 will permit AFSA members to test spreader calibration patterns to assist with passing “AccuSpread” accreditation. This can only assist the lime industry as it is anticipated that many machines are not giving even spread pattern with the various sources of lime, or that spreader operators are spreading on too wide a bout width.

The AFSA in WA has been charged with developing the Quality Assurance System for the fertiliser industry and has formed an alliance with AgWest Trade and Development to use the Safe Quality Food (SQF) 2000 quality assurance system. To date eight member of the AFSA nationally have received the required Hazard Analysis and Quality Control Point (HACCP) and SQF 2000 training with another six members to complete this training by the end of February.

QUALITY ASSURANCE IN THE LIME INDUSTRY

Quality Assurance in the lime industry in WA is of high importance as we have seen this industry surge from a $3.51 million industry in 1989/90 to an industry worth in excess of $13.2 million in 1997/98.

Farmers, lime industry, and conservation/community groups alike acknowledge that there is a real need to ensure that lime supply, transport, spreading and the agronomic advice on lime is quality controlled.



The Lime Industry Taskforce has been established by the Western Australian State Government to specifically deal with the special needs of this industry. Issues such as lime use for the future and the development of safe routes of transport are priorities of this group.

At the same time the lime industry recognises its need to establish a Code of Practice and Quality Assurance System.

Issues the lime industry will be addressing will be areas such as quality audit sampling, product free from contamination, truth in labelling, safety issues with lime pits, and the rehabilitation of extraction site.

Within 12 months, the AFSA Quality Assured Lime Suppliers, while the first AFSA Quality Assured transport and spreader operators will be operating by mid 1999.

FURTHER INFORMATION

For further information on AFSA Quality Assurance please contact Grant Andrews (Chairman of the AFSA) Quality Assurance Committee) on 08 9796 0587 or mobile 0418 931 116

Acknowledgements
The extension work is supported by growers through the natural Heritage Trust, the Grains Research Development Corporation and the Cereals Program ane the Pulse and Oilseed Program of Agriculture Western Australia and the Australian Fertiliser Services Association.

Key Words
Quality assurance, code of practice, lime, lime industry.

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