1998

Western Australia soil acidity research and development update 1998 : time to lime

Department of Agriculture and Food, Western Australia

Update 1998

Western Australia

Soil Acidity 1998

Research & Development

Time to Lime

Agriculture
WESTERN AUSTRALIA

Western Australia Soil Acidity Research & Development

FOREWORD

"SOIL ACIDITY R&D TEAM DISSOLVES"

That will be the headline in June 2002.

For the next four years there is a unique opportunity to access this Team of experts.

The integrated soil acidity project is planned to complete its activities in June 2002. If all goes to plan (and all indications are that they are on track) after that date the team members will go on to other activities within their various organisations.

What does this mean?

Make the most of this opportunity.

Every farmer in Western Australia should have considered the issue of soil acidity and made informed decisions about its impact and the action they need to take.

Over the next four years, any uncertainties about soil acidity can be discussed with a member of the Soil Acidity R&D Team. After that, the Team will produce various publications.

Untreated soil acidity is too great a cost, in economic and environmental terms, for individuals and for the community.

It continues to be "Time to Lime".

Dr WM (Bill) Porter
Project Manager - Soil Acidity

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

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SOIL ACIDITY MANAGEMENT COMMITTEE

Dr Bill Porter
Agriculture Western Australia, Northam

The Soil Acidity Research and Extension Program in Western Australia is made up of eleven sub-projects operating in three collaborating organisations (Agriculture WA, The University of WA and CSIRO). By 2002 the project aims to have completed the development of information packages to farmers to manage or reverse acidification throughout the agricultural areas of WA.

To assist the project team achieve this ambitious goal, an advisory committee of key research funders and industry stakeholders has been formed. It consists of:

- **2 landholders:**
  Mr Kim Diamond from Maya, in the North-Eastern Wheatbelt.
  Mr Colin Mills from Brookton, in the Central Wheatbelt/Southern Woolbelt.

- **2 lime industry representative (nominated by Australian Fertiliser Services Association):**
  Mr Grant Andrews (President AFSA)
  Dr Lorelle Lightfoot (Lime Producer)

- **1 agricultural consultant (nominated by Australasian Association of Agricultural Consultants)**
  To be appointed.

- **1 GRDC nominee:**
  Prof. Philip Cocks, GRDC Western Regional Panel.

- **1 Agriculture WA Industry Program Manager:**
  Mr Steve Trevenen, Program Manager, Cereal Industry Program, Agriculture WA.

The committee will meet at least twice a year to review progress of the integrated project, to suggest changes to activities and to provide an independent report to GRDC and other stakeholders on the progress of the project.

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

CANOLA RESPONDS TO LIME

Chris Gazey
Agriculture Western Australia, South Perth

KEY MESSAGE

Recent yield responses by canola where lime has been applied to acidic soils are very encouraging. Two sites have shown that the yield increase in canola after lime was applied in the previous year would have easily paid for the total cost of purchase, transport and application of the lime.

INTRODUCTION

This work was carried out to demonstrate the increased options that are likely to be available once producers are treating or managing soil acidity. Canola is becoming increasingly important as a cash value crop and a break crop allowing wider rotations.

Growers are pushing the limits of canola's tolerance to low soil pH as production packages become more refined. Canola is more sensitive to low pH than crops such as lupins and wheat. However, reasonable crops of 1.0 to 1.2 t/ha are being grown on soil with very low pH (e.g. 4.3 in 0–10 cm and 3.9 in the 10–20 cm, measured in calcium chloride).

METHODS

Three lime trials were established at Varley (south-east of Hyden) on Bruce Hill's property, in 1991, 1994 and 1996 using limesand as the lime source. The paddock had historically been in a wheat – lupin rotation. In 1997 the farmer sowed all trials at the same time as the paddock was sown (16/4/97). The seeding rate was 5 kg/ha Karoo canola and 120 kg/ha Agras. Urea at 70 kg/ha was applied on 21/5/97. The trials were direct harvested on 17/11/97 using a small plot harvester.

A further trial was established at Bill Moore's property at Narrogin in 1996 and was also sown by the farmer. The Narrogin trial was swathed and yield assessment was made using a weigh trailer.

RESULTS

Yield increases in canola were observed at all trials sown in 1997 regardless of the amount of time that the lime had been applied (Table 1). These yield increases were despite the fact that the subsurface pH was still acid. Early growth responses were observed and these persisted during the season for all trials except the lime trial established in 1996 at Varley (96LG7) although significant increases in grain yields were recorded with increasing rates of lime supplied.

Table 1. 1997 Canola grain yields for lime trials.

Lime applied	**Trial (year lime applied)**			
Rate (t/ha)	**91LG71 (1991)**	**94LG17 (1994)**	**96LG7 (1996)***	**96NA3 (1996)**
0.0	1.51 a	1.29 a	1.10 a	1.32 a
0.5		1.42 b		
1.0	1.57 ab	1.55 c	1.30 b	1.46 b
2.0	1.62 b	1.69 d	1.36 c	1.60 c
4.0		1.67 d		

Numbers in the same column with the same letter are not significantly different $p<0.05$).

** Additional lime treatments of Dolomite and G-Lime were also used in trial 96LG7. Dolomite was less effective than G-Lime which was less effective than Limesand. All amendments increased canola grain yield above the unlimed treatment. Neutralising Values of amendments: Lime 97% NV, Dolomite 67% NV, G lime 100% NV. Rates were adjusted to account for the lower NV of Dolomite to allow for a fair comparison.*

The pH results for two of the trials are presented below (Tables 2a, b). Only in the Narrogin trial (96NA3) does there appear to be an increase in soil pH below the zone of incorporation (0–10 cm).

The more acidic site at Varley will have increased lime applied to selected plots in 1998.

Table 2a. pH measured in 0.01M $CaCl_2$ in 1997 for 94LG17, (lime spread in 1994).

Depth	**0 (t/ha lime)**	**1 (t/ha lime)**	**2 (t/ha lime)**	**4 (t/ha lime)**
0-5 cm	4.75	5.48	6.19	6.61
5-10 cm	4.00	4.40	4.78	4.61
10-20 cm	3.93	4.01	4.02	4.08
20-30 cm	4.27	4.41	4.32	4.34
30-40 cm	4.43	4.45	4.51	4.50

Table 2b. pH measured in 0.01M $CaCl_2$ in 1997 for 96NA3, (lime spread in 1996).

Depth	**0 (t/ha lime)**	**1 (t/ha lime)**	**2 (t/ha lime)**
0-10 cm	4.72	5.25	5.75
10-20 cm	4.66	4.80	4.97

CONCLUSION

This work has shown that under the right conditions (physical and climatic) economic returns from applying lime can be made in the short term. However, with the potential yield increases it is essential that the nutrition of crops is adequate. In particular, the availability of micronutrients may be affected by changing the pH of the soil.

Further work will be conducted over the next four years to identify more opportunities from the management of soil acidity.

Acknowledgements
This research is supported by growers through the Grains Research and Development Corporation (GRDC) in partnership with Agriculture Western Australia.

LIME AND LUPINS THE IMPORTANCE OF MANGANESE AND POTASSIUM

Chris Gazey
Agriculture Western Australia, South Perth.

INTRODUCTION

The problem of depressed yield of narrow-leafed lupins after liming of acid soils has been the subject of a now completed GRDC project by Agriculture Western Australia. Initially trials failed to reproduce the depressions, but towards the end of the project evidence of the depressions was becoming available particularly in farmers paddocks.

1997 DEVELOPMENTS

Detailed work was carried out during 1997 on one trial, which showed potential to provide more information on the interaction of narrow-leafed lupins and lime.

Samples of plant tissue were taken from plots in this trial, which had a range of lime applications (both rates of lime and years since lime applied) and nutrient treatments of:

i) a reapplication of lime;
ii) lime;
iii) lime with manganese sprayed at podding;
iv) lime with manganese sprayed at podding and potassium top dressed after sowing;
v) lime application with potassium top dressed after sowing.

A standard application of phosphorus was applied to all treatments.

These treatments were applied because of previous evidence that manganese and potassium were marginal in many paddocks where lime trials were conducted on farmers' properties in 1996. It was observed that farmers were seeing a negative response in their lupin crops after liming, which had not been reproduce in earlier trials.

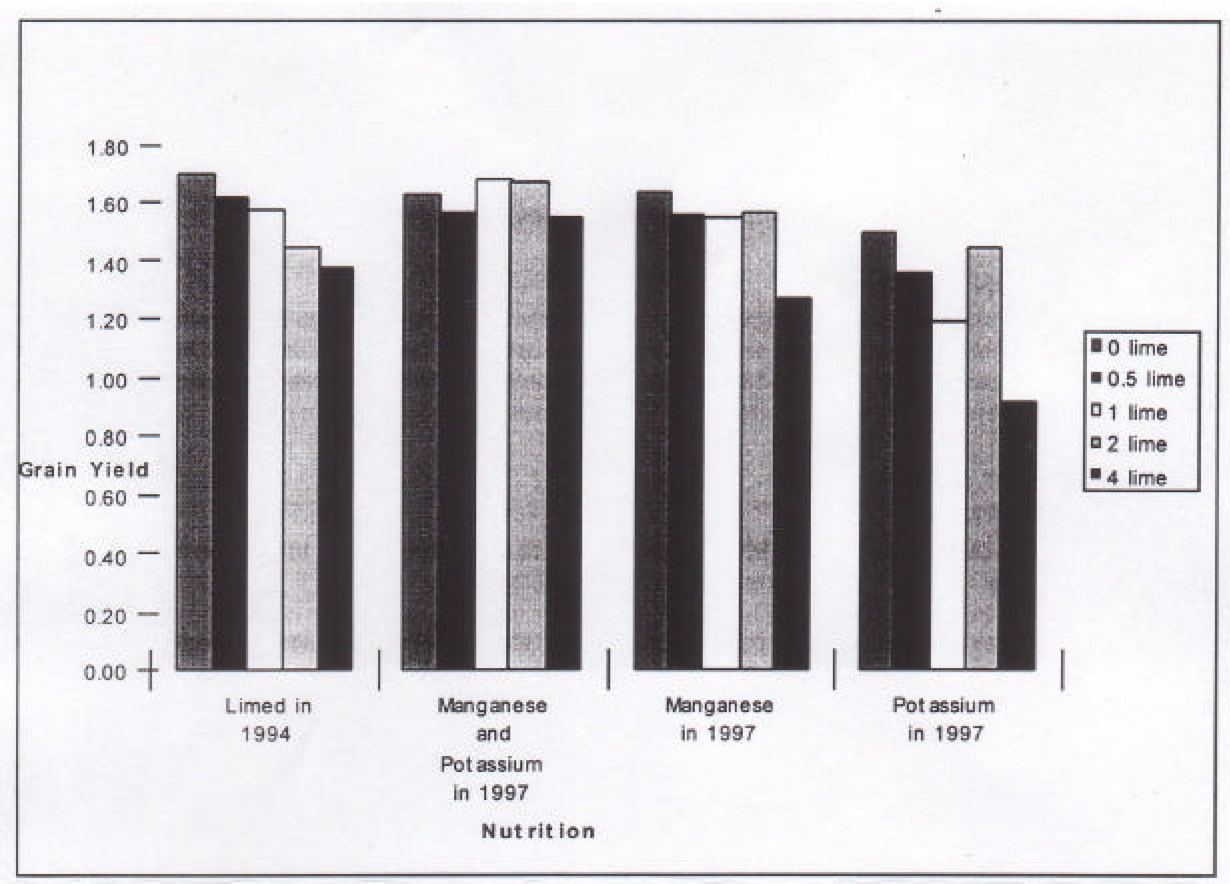
The main difference between the farmer's experience and the trial work was that in trial situations all necessary nutrients had been applied to ensure that the responses that were being examining were attributable to lime.

POTASSIUM AND MANGANESE

The concentrations of nitrogen, potassium, phosphorus, calcium, copper, manganese and zinc in youngest open leaves and whole plant shoots were all significantly affected by some of the treatments used in this trial. Analysis of the results to determine the differences between treatments in plant biomass and plant nutrient status is incomplete at the time of publication.

The following graph shows the 1997 narrow-lupin grain yield from the trial 93AD9 at South Dangin in WA for those plots limed in 1994 only. Additional plots were limed in 1993 and 1995 at this site, however the data presented here illustrates the major findings and further information may be requested from the author if required.

With increasing rates of lime applied, lupin grain yield decreased, this was particularly evident for the treatments without added manganese. Where manganese was applied the effect of lime was reduced and where both manganese and potassium were applied the effect of lime was eliminated (Figure 1). It is particularly important to note where potassium had been applied in the absence of manganese the effect of increasing lime rates on lupin grain yield was greatest. These results confirm earlier observations in this project, which suggested an interaction of several factors was responsible for decreased lupin yields following the application of lime to acidic soils.



Least significant differences: When comparing means with the same level of nutrition lsd=0.31, when comparing between levels of nutrition lsd=0.34.

Figure 1: 1997 narrow-leafed lupin grain yield for trial 93AD9 at South Dangin (1994 limed plots only)

Analysis of seed from this trial has confirmed that manganese was deficient over the entire trial. Furthermore, manganese deficiency, quantified by the proportion of split and shrivelled seed, was exacerbated where potassium had been applied without a manganese treatment. This phenomenon was probably due to an increased yield potential where the potassium deficiency was corrected. A foliar application of manganese reduced the amount of split and shrivelled seed but did not eliminate it.

RECOMMENDATIONS

It is recommended that growers conduct appropriate tissue tests after commencing a liming program and be aware that increasing the soil pH will change the availability of some nutrients. Manganese appears to be particularly important, as narrow-leafed lupins are inefficient at moving this nutrient into its seeds. This effect on nutrient availability is a natural one and it can be argued that, by cropping under very acid conditions some nutrients have been made artificially available.

Acknowledgements

This research is supported by growers through the Grains Research and Development Corporation (GRDC), in partnership with Agriculture Western Australia.

LIME AND NUTRIENT CALCULATOR: TAKING OUT THE GUESSWORK

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[2]*Agriculture Western Australia, South Perth*

SUMMARY

The Lime and Nutrient Calculator is a decision aid that enables farmers to determine the quantities of liming materials and other nutrients that are removed with their rotations. The calculator takes account of losses due to both removal of farm produce and leaching. The "output" from the calculator gives the total amount of lime and nutrients removed per hectare for a specified agricultural product. It can be used to calculate annual losses or for rotations. This information can then be used to plan applications of lime and nutrients.

INTRODUCTION

Soil acidification and the depletion of soil nutrients is a serious problem for agriculture in Australia. Acidification and nutrient depletion are well recognised by producers but are difficult to manage as they occur slowly and are not easily measured. The calculator that has been developed will enable farmers to determine the quantities of liming materials and soil nutrients lost from a paddock following various cropping and pasture practices.

This paper describes the development of the Lime and Nutrient Calculator and highlights its potential uses for consultants, advisers and farmers.

DEVELOPMENT OF THE CALCULATOR

A database of all major plant nutrients in over 13 000 samples of seed and other plant parts was compiled using information from research conducted by Agriculture Western Australia over the past eight years.

These data, in combination with published information was used in the development and verification of the calculator. The average quantities of nutrients in various agricultural products were determined from these sources.

The average quantities of nutrients that are removed is modified by leaching intensity (which takes account of plant species, soil type and rainfall), to give the quantity of the lime or nutrient leached.

Together the quantity of the nutrient removed with produce and the quantity leached give the total amount removed from the system.

The prototype of the calculator was produced in September 1997. This was adapted and improved following comments and suggestions from farmers, consultants, extension personnel and scientists.

At these Crop Updates, the improved version of the Lime and Nutrient Calculator is being presented. Following feedback during the testing of the Calculator last year, the final version will be produced in two forms; a printed version on laminated card for use in the field (or where computers are not practical) and a computer software version. The final product is expected to be ready for distribution in May 1998.

USING THE CALCULATOR

There are three steps in using the Calculator.

1. Look-up the product removal number for the agricultural product and nutrient of interest (Dial 1). There are 13 crops/products to choose from for rotations as well as 10 nutrients/lime that can be investigated.

2. Determine the leaching intensity for each situation and use this to determine the total removal number (Dial 2).

3. Rotate Dial 3 until the total removal number lines up with the amount of production and read off the result in the appropriate window.

This process is repeated for each year of the rotation to determine the total amount of lime or nutrient removed.

The calculator will be an important addition to farmers' "tool kits". The results can be used as the basis for determining the rates of application of lime and other nutrients that are required to maintain current levels of production. Alternatively, different rotations and leaching situations can be compared to examine possible management scenarios.

Acknowledgements
This research is supported by growers through the Grains Research and Development Corporation (GRDC), in partnership with the Centre for Legumes in Mediterranean Agriculture and Agriculture Western Australia.

UNDERSTANDING THE DOWNWARD MOVEMENT OF LIME FOR THE MANAGEMENT OF SUBSURFACE ACIDITY UNDER DIFFERENT FARMING SYSTEMS

Mark Whitten
University of Western Australia, Nedlands

INTRODUCTION

The more acid the surface and subsurface soil the greater the lime requirements for managing subsurface acidity. Monitoring the pH within the depth of lime incorporation is a guide to how much lime remains. Once this has decreased below about pH 6-6.5 in calcium chloride little lime remains and so further increases in subsurface pH are unlikely. On very acid soils, lime at commonly used rates of 1-2 t/ha may be depleted in as little as two years, and re-liming would be necessary if the target subsurface pH has not been reached.

Sites have been located for two replicated field trials to examine how tillage and lime particle size affect the downward movement of lime. During the search for new trial sites, some old lime test strips with good records of cropping history were found. One such site previously had subsurface acidity extending to a depth of 30 cm, and had 2.5 tonnes of lime per hectare applied 13 years ago. This lime application was shown by a preliminary soil analysis to have completely ameliorated the subsurface acidity. Barley yields in 1997 were estimated to have doubled in the limed strips, and yields had increased from 1985 to 1995 in a continuous cropping rotation.

The increased demand for lime in WA, and the high cost of transport from the coastal lime deposits to the wheatbelt, has resulted in recent exploitation of inland lime deposits. These differ markedly from the coastal limes in hardness and mineralogy. Both mineralogy and hardness may affect the rate of dissolution and hence the rate at which subsurface acidity can be ameliorated. A thorough characterisation of limes from a number of Western Australian locations is in progress.

RESEARCH FOR 1998

- To establish new trials on the effects of lime particle size and tillage on lime movement: Two instrumented trials in collaboration with CLIMA/CSIRO ("Sustainable Management of Soil Water and Nutrient in the Medium rainfall Zone of Western Australia") and AgWA soil acidity program; and two test strip trials under farmer management on nearby farms.

- To continue with characterising and comparing different types of lime from WA. This activity will add to existing data (this report) on lime mineralogy, and will include measurement of the following lime properties: neutralising value; particle size distribution; aggregate and particle hardness; dissolution rates under controlled conditions.

- To analyse samples from lime trial soil bank for solid phase sinks for alkalinity, particularly reactive aluminium minerals and their role in long-term pH buffering.

- To commence leaching studies with different lime types. Appropriate lime types will be selected following the extensive characterisation outlined above, with sufficient range of key properties to allow understanding of lime dissolution and movement at a mechanistic level.

RESULTS AND DISCUSSION

LIME REQUIREMENTS

The subsurface pH at the re-limed trials had not increased between the first and second year of liming. At the most acidic site, a decrease in surface pH indicates that most of the lime has been consumed within two years by surface acidity and that little increase in subsurface pH can be expected without additional lime applications. These results indicate that for managing subsurface acidity it is important to monitor the pH in order to determine when lime must be reapplied in order to maintain downward movement of lime.

The re-limed trials are now under farmer management (with buried metal markers so that plots can be relocated). Only one trial was harvested, yielding an average of 3.26 t/ha (wheat cv 'Tammin'). There was no effect of liming in spite of increased subsurface pH, indicating that either the crop was reasonably acid tolerant or that there was little dependence on water and nutrients in the acidified zone.

In the search for new trial sites, preliminary soil analysis in 1997 of a farmer's lime test strips (*c*. 2.5 t/ha in 1984 in two 25 $\times$ 1000 m plots) indicated that subsurface acidity, which extended to a depth of 30 cm had been completely ameliorated. The 1997 barley crop was estimated to have doubled in the lime strips, and yields had increased from 1985 to 1995 in a continuous cropping rotation.

LIME QUALITY

There is considerable diversity in the mineralogical and physical characteristics of limes from different types of deposit in Western Australia. Mineralogy, particle size and hardness can affect the rates of dissolution and hence effectiveness of different lime types for managing subsurface acidity. The rates of dissolution per unit surface area are in the following order: calcite > dolomite > magnesite. Lime particle size distribution, dissolution rates, mineralogy and hardness of these WA limes are being determined.

The results from X-ray diffraction analysis of limes are summarised as follows:

- *Quarried coastal limestones* were predominantly calcite with some aragonite (both calcium carbonate, but differing in crystal structure), and contained variable amounts of quartz;

- *Coastal limesands* were magnesian calcite, again with variable amounts of quartz;

- *Lakeside limes* (loose rock in marl) from around the wheatbelt tended to be predominantly dolomite (calcium-magnesium carbonate) with some magnesite (magnesium carbonate). One calcitic marl with no hard rock was also identified.

- *A pelletised burnt lime by-product* contained calcite and calcium hydroxide, which is more soluble than calcium carbonate but will revert to carbonate if exposed to moisture and air.

Physically, the lime products differed in particle size distribution and hardness. Crushed limestones and dolomites had a wider range of particle sizes than the limesands which are wind-sorted and have low content of the fine (<0.09 mm) and coarse (>0.5 mm) fractions. Differences in particle size distribution can affect rates of dissolution and spreading properties. For example, the fine fraction, which is the most valuable component in terms of reactivity, would be more prone to dispersion by wind. The potential for loss during spreading must be recognised in WA because of the windy climate and popularity of spinning disc spreaders.

Hardness has been shown to affect the rate of lime dissolution. Marl particles and burnt lime pellets are softer than those of limestone or limesand. They could therefore be expected to break apart and expose more surface area during dissolution, and may be more reactive than hard limestone particles of the same size. Thus the “effective neutralising value”, an estimate of reactivity based on the total neutralising value and particle size distribution, may actually be different for marls compared with the limestones and limesands. This hypothesis will be tested in 1998-99 by measuring an index of lime particle hardness and using the resulting data in a mathematical model to predict lime dissolution rates in the laboratory and in the field.

Acknowledgements
This research is supported by growers through the Grains Research and Development Corporation (GRDC), in partnership the University of Western Australia.

LIME USE TARGETS FOR WESTERN AUSTRALIA

Dr Bill Porter & Amanda Miller
Agriculture Western Australia, Northam

INTRODUCTION

If left untreated acid soils would be the largest land degradation issue in Western Australia.

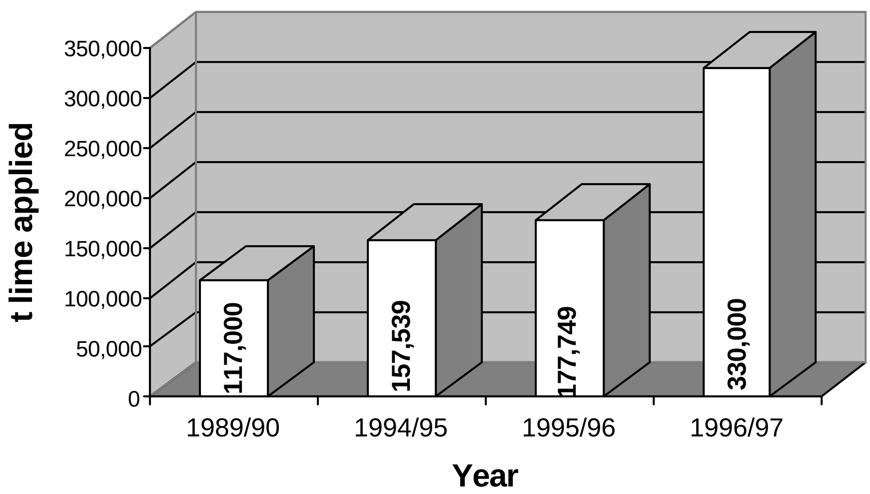
It is estimated that agricultural production will be reduced by soil acidity on more than 10 million hectares of soils within the next 20 years.

Left untreated soil acidity will continue to silently and slowly decrease the potential of agricultural soils causing decreased production and so reduced water use efficiencies of a wide range of crops. This in turn will result in increased water infiltration through the soil profile, causing increasing water tables (and therefore salinity) as well as other off site impacts such as rising water tables affecting infrastructure like roads and culverts.

SITUATION

As a result of the Western Australian integrated soil acidity project, there has been a large increase in the amount of lime applied to acid soils (Figure 1).

Figure 1: Lime use in agriculture in Western Australia.



1989/90data from Porter and McLaughlin (1992). *Other data:* Australian Bureau of Statistics annual farm census.

But, how much more lime is needed before there is confidence that soil acidity is being managed effectively?

Lime use targets (Table 1) were calculated for each shire based on a simple calculation from:

- Area of soil at risk from soil acidification (estimated by Porter and Schultz, 1989, from the Atlas of Australian Soils);
- Rainfall (a typical figure for each shire), which was used to derive an estimate of rate of acidification.

These shire-by-shire lime use targets will allow the "Time To Lime" campaign through district extension officers to target individual shires to determine the barriers to adoption of soil acidity technology and to design methodologies and techniques to overcome the barriers.

Clearly from Table 1 there is a great disproportion of lime usage across the state when compared with the estimated lime use targets. It is interesting to note that the areas that are approaching or are exceeding the lime use targets are generally shires that have lime deposits in close proximity to the shire.

Of the 81 shires, 72 per cent were treated in 1996/97 with less than half the amount of lime required annually to neutralise acidification (Figure 2).

Figure 2: Cumulative frequency distribution of lime use in shires as a percentage of lime use targets for agricultural shires in south west WA.

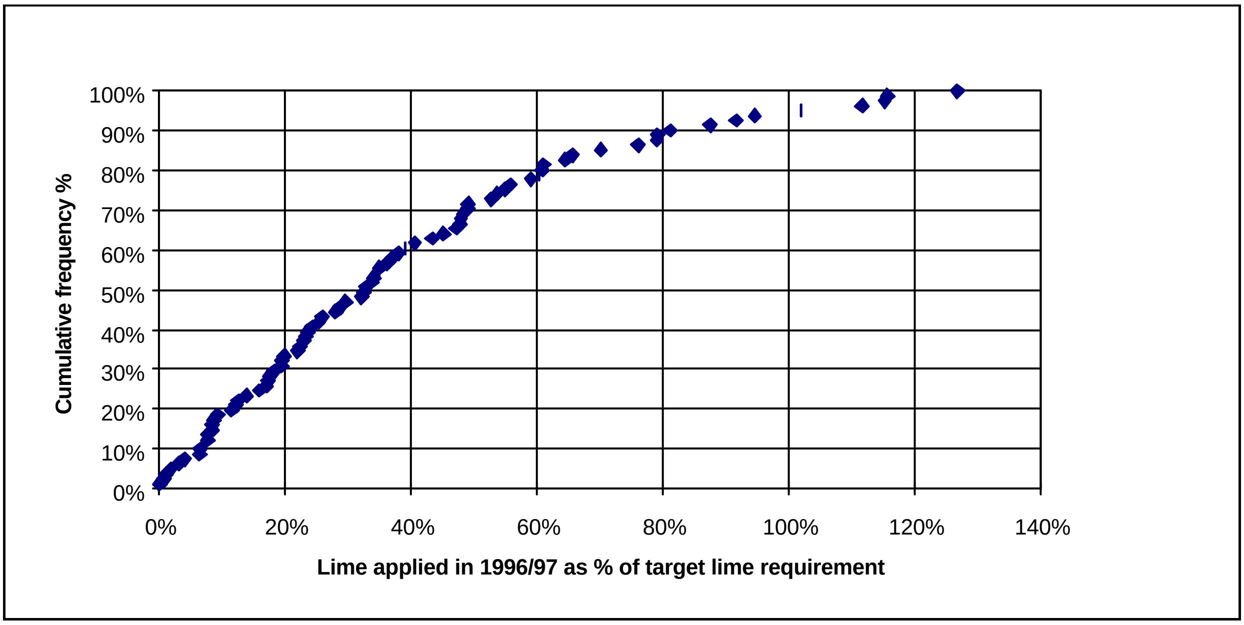


Table 1:Estimated lime targets for key agricultural shires in the south-west land division of Western Australia.

Shire	Lime application target (t/year)	Lime applied 1996/97 (t)	1996/97 lime as % of target
Albany	37,616	13,143	35%
Augusta-Margaret River	5,833	6,507	112%
Beverley	9,866	6,355	64%
Boddington	8,289	1,435	17%
Boyup Brook	26,919	1,928	7%
Bridgetown-Greenbushes	8,712	92	1%
Brookton	7,407	2,071	28%
Broomehill	5,734	2,741	48%
Bruce Rock	9,671	5,182	54%
Busselton	10,605	4,998	47%
Capel	3,939	1,928	49%
Carnamah	8,461	5,144	61%
Chapman Valley	27,038	9,796	36%
Chittering	5,866	1,342	23%
Collie	3,002	250	8%
Coorow	17,023	4,391	26%
Corrigin	13,082	4,960	38%
Cranbrook	18,453	1,410	8%
Cuballing	4,906	1,587	32%
Cunderdin	10,075	9,516	94%
Dalwallinu	20,635	9,287	45%
Dandaragan	43,140	5,395	13%
Dardanup	4,023	1,401	35%
Denmark	5,305	4,852	91%
Donnybrook-Balingup	7,682	1,859	24%
Dowerin	8,261	3,348	41%
Dumbleyung	14,396	1,201	8%
Esperance	56,101	405	1%
Gingin	14,620	939	6%
Gnowangerup	9,575	5,255	55%
Goomalling	7,558	4,456	59%
Greenough	22,505	4,346	19%
Harvey	8,021	3,861	48%
Irwin	7,563	2,236	30%
Jerramungup	16,056	2,772	17%
Katanning	7,493	1,448	19%
Kellerberrin	6,070	3,200	53%
Kent	17,097	6,652	39%
Kojonup	23,946	5,236	22%
Kondinin	14,101	5,205	37%
Koorda	1,672	1,320	79%
Kulin	20,518	1,765	9%
Lake Grace	26,305	3,195	12%
Manjimup	11,463	5,613	49%
Merredin	11,038	2,552	23%
Mingenew	9,631	6,308	65%
Moora	25,051	8,210	33%
Morawa	7,641	9,675	127%
Mount Marshall	13,290	1,836	14%
Mukinbudin	2,693	1,285	48%
Mullewa	31,162	4,962	16%
Murray	7,867	2,672	34%
Nannup	4,738	3,320	70%
Narembeen	17,285	3,852	22%
Narrogin	9,702	1,770	18%
Northam	6,599	2,857	43%
Northampton	53,364	13,490	25%
Nungarin	1,751	-	0%
Perenjori	28,325	17,040	60%
Pingelly	6,567	5,737	87%
Plantagenet	28,926	8,297	29%
Quairading	8,778	5,352	61%
Ravensthorpe	22,497	410	2%
Tambellup	5,065	1,706	34%
Tammin	4,980	3,786	76%
Three Springs	11,904	3,816	32%
Toodyay	6,626	1,310	20%
Trayning	4,774	4,859	102%
Victoria Plains	14,131	7,867	56%
Wagin	11,919	777	7%
Wandering	11,173	335	3%
Waroona	2,472	2,002	81%
West Arthur	19,380	757	4%
Westonia	3,207	545	17%
Wickepin	6,148	7,103	116%
Williams	13,883	1,054	8%
Wongan-Ballidu	21,605	17,081	79%
Woodanilling	9,709	1,115	11%
Wyalkatchem	5,615	6,462	115%
Yilgarn	9,985	925	9%

York	9,146	2,150	24%
TOTAL	**1,085,232**	**333,298**	**31%**

EXPECTATIONS FOR SEASON 1997/98

The lime suppliers in the north of the state are reporting increased demand for lime in the 97/98 liming season compared to the 96/97 season. By comparison suppliers in the south of the state are reporting a slower start to the liming season in 97/98. This “slow start” is being attributed to extended harvest season in the south of the state of the 97 crop due to exceptional grain yields and seasonal conditions.

There are 33 commercial lime operations throughout the Port Gregory to Esperance area. The development of new lime deposits at Watheroo (Dolomite), Hopetoun (Limestone) and potentially Esperance (Dolomite) in the 1997/98 season will see lime more readily available than in previous years.

Estimates show that lime usage will increase to in excess of 400,000 tonnes this season. However, these estimates indicate that 1million tonnes of lime are required on an annual basis to combat soil acidification there is no room for complacency.

Now more than ever it is “Time to Lime”.

Acknowledgements
This research is supported by growers through the Grains Research and Development Corporation (GRDC) in partnership with Agriculture Western Australia the National Landcare Program and the “Time to Lime” Campaign.

LIME QUALITY AUDIT 1997
LIME AIN'T LIME

Amanda Miller
Agriculture Western Australia, Northam

INTRODUCTION

As the momentum gathered behind the "Time to Lime" Campaign it became increasingly important for good contact links to be established between the Soil Acidity Integrated Projects and the state suppliers of lime. In the first half of 1997 the "Time to Lime" Campaign identified all lime suppliers throughout the state and began taking a sample from the outloading face of each lime deposit.

This allowed two products to be produced:

1. The establishment of the most comprehensive listing of lime supplier contacts ever to be compiled in Western Australia.

2. The production of a comparative snapshot of the quality of limes being used for agricultural purposes throughout the state.

LIME SUPPLIERS

Currently Western Australia has 33 lime suppliers who operate 39 lime deposits (more than one supplier distributes lime from the same source in some cases). There are currently 11 limesand, 12 limestone, 10 dolomite and 1 cement kiln dust suppliers in Western Australia.

The 1997/98 liming season has already seen the opening of two dolomite deposits at Watheroo. It is proposed that there may be a limestone deposit commencing operation at Hopetoun as well as a dolomite deposit at Esperance later this year.

A current list of lime supplier contact names and numbers follows this paper. Photocopying of this sheet onto an A3 page will assist in easier reading.

LIME QUALITY

The identification of 11 limesand, 12 limestone, 10 dolomite and 1 cement kiln dust suppliers in Western Australia has lead to a need to establish a comparative list of the quality of each lime product. To do this a representative sample from the "outloading face" (i.e. from where the trucks were being loaded) of each supply was taken and analysed for the following characters:

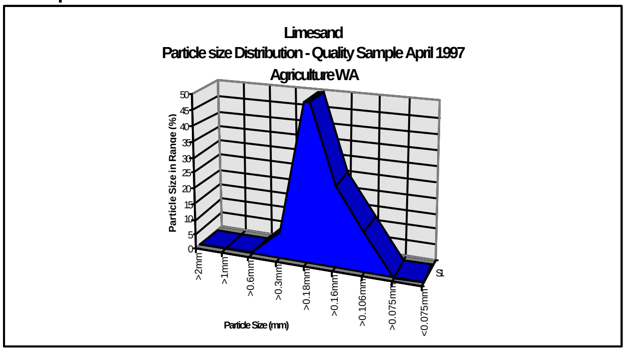
1. Neutralising Value (NV) expressed as a percentage;
2. Particle Size expressed as a percentage (Industry standard = amount of particles passing through a 0.6mm screen);
3. Screening breakdown of particles through >2mm; >1mm;>0.6mm; >0.3mm; >0.18mm; >0.16mm; >0.106mm; >0.075mm; <0.075mm. Each sieve range is expressed as a percentage;
4. Analysis of elements Calcium %; Magnesium %; Sodium %; Potassium (ppm); Sulfur (ppm), Copper (ppm); Iron (ppm); Manganese (ppm) and Zinc (ppm).

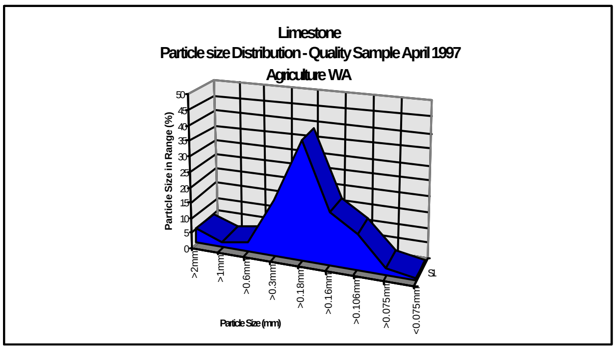
All suppliers have received a copy of the table of comparisons for their product compared to all other products of the same type in the state. Suppliers also received a graph of the particle size profile of their lime supply/s (refer figure 1). Each sample has been identified by a sample number only, to allow for "commercial in confidence" amongst producers. This table has been supplied at the end of this report.

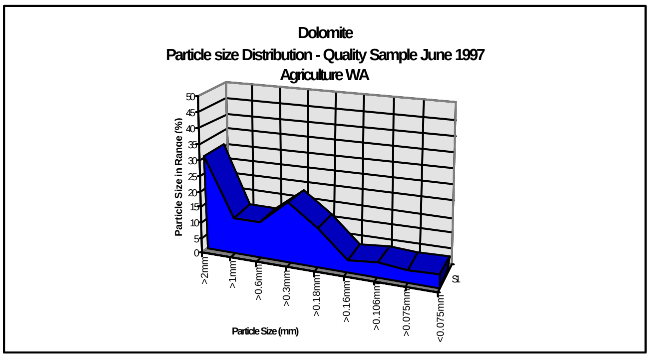
Suppliers are able to provide copies of the report supplied to them by Agriculture Western Australia providing the report is reproduced in full.

As the samples used in this comparison were taken from a localised area they are not a true representation of the average quality of the lime deposit, however the sample does represent a snapshot of the quality of the product at that time.

Figure 1: Examples of a particle size distribution for a typical limesand, limestone and dolomite products.







QUALITY ASSURANCE

All lime suppliers in Western Australia are being encouraged to become members of the Australian Fertiliser Services Association (AFSA), a professional body encompassing suppliers, transporters, spreading and agronomic advice providers in the fertiliser industry (includes, fertiliser, soil ameliorants, organic fertilisers etc.)

The AFSA is currently establishing codes of practice for the fertiliser industry and will be embarking upon a quality assurance system that will encompass HACCP (Hazard Analysis Critical Control Points) and the SQF2000 (Safe Quality Food 2000) system. As part of that quality assurance scheme the lime industry is establishing its own codes of practice and quality control systems that will “feed in” to the AFSA quality control system.

Essentially the quality systems proposed will assist suppliers to provide a quality product at a set standard, and will ensure that users of lime products are assured of receiving a quality product. One of the key elements to the system will be the six monthly independent audit of the quality system.

Agriculture Western Australia supports the AFSA in being the first to set world industry standards for fertilisers. In the future, if a lime supplier is not a member of the AFSA and participating in the Codes of Practice, and the Quality Assurance System, then these suppliers will not receive the support of Agriculture Western Australia and the Lime Industry in general.

Acknowledgements
This research is supported by growers through the National Landcare Program in partnership with Agriculture Western Australia the Grains Research and Development Corporation (GRDC) and the “Time to Lime” Campaign.

LIME DEMONSTRATION TRIALS PARTICIPATIVE RESEARCH AND DEVELOPMENT

[1]Amanda Miller & [2]Dave Gartner
[1]*Agriculture Western Australia, Northam*
[2]*Agriculture Western Australia, Moora*

INTRODUCTION

In 1995 it was recognised that many farmers were aware of the soil acidity issue, however, farmers in Western Australia lacked experience in the use of lime and this highlighted the necessity to stimulate more farmers to work through the issues and to accept lime as part of a sustainable farming system.

Additionally, it was recognised that the Soil Acidity Integrated Project required a more intensive way of identifying the issues, which should be addressed in the research and extension of soil acidity management.

The demonstration sites were designed to allow farmers to make decisions on acid soil management on a small area, and share the decision making process with groups of neighbours and others.

There are currently 19 demonstration sites throughout the state with another three sites to be established in the Jerramungup and Esperance districts in the 1998 season. In general each site has three rates of lime (0,1 and 2 t/ha) replicated three times, and each plot is approximately 1 hectare in size. Therefore each trial covers approximately 9 hectares and is totally managed as part of the whole paddock by the host farmer.

Variations such as different sources of lime, different tillage treatments, different pasture species sown across plots, different species (i.e. half the plot in narrow leaf lupins and half the plot in yellow lupins), and the use of foliar sprays have all been initiated by the host group in consultation with their local District Development Officer and the Soil Acidity Team.

PRINCIPLES

- The sites were established in partnership with a farmer group (catchment or farm improvement group) which had shown a high level of interest in soil acidity as an issue and which was willing to put time and resources into managing the site, as well as a willingness to allow field day access by different groups i.e. Consultancy groups, commercial merchandiser groups, etc.

- A Development Officer from the closest local office of Agriculture Western Australia manages the relationship between Agriculture Western Australia and the host farmer.

- The Soil Acidity Team supports the District Development Officer and the host farmer and host group with scheduling for sampling, monitoring procedures, the analysis of sampling (soil, plant and grain/pasture) and the interpretation of results.

- At any time that the potential exists for more intensive sampling of a site i.e. Chris Gazey's work with the interaction between lime and plant nutrition, the District Development Officer and the host farmer are informed of the request for sampling and in some cases assist with the additional research.

- The aim of the sites is not to demonstrate positive response to lime. It is important that the District Development Officers and farmers do not enter this process with the understanding that a large visual response will be seen in the first year or two of liming. The process is to promote lime applications as an essential tool for maintaining production in the longer term and as an investment in the future of sustainable farming practice. The demonstration sites provide a focus point for the discussion of these concepts.

- The sites offer an opportunity to act as a focus for research. As issues that need researching are identified (in partnership with farmer groups), it makes sense to conduct research with the same group. This provides the researchers with a clear context for the problem they are researching. It also gives them the opportunity to interact with people who see the need for the research and who will benefit from the research. The end result is a quality feedback system from farmer to researcher.

DEMONSTRATION SITE LOCATIONS

Trial No.	Location	Host Farmer	District Officer Contact	District Officer Contact
96GE7	Northampton	Daryl Reynolds	Nancye Gannaway AgWA Geraldton	08 9956 8501
96GE8	Mullewa	Alan Desmond	Kylie Jensen Mullewa Community Landcare Centre	08 99611388
96TS2	Latham	Kim Diamond	Adrian Cox Morawa Community Agricultural Centre	08 99711438
96TS3	Latham	Kim Diamond	Adrian Cox Morawa Community Agricultural Centre	08 99711438

96TS4	Three Springs	Neil Reid	Jason Brady AgWA Three Springs	08 9954 1004
96MO5	Bindi Bindi	Mal King	Dave Gartner AgWA Moora	08 9651 1302
96MO6	Watheroo	Doug Butcher	Dave Gartner AgWA Moora	08 9651 1302
96MO7	Kalannie	Don Stanley	Amanda Falconer Wongan Hills Community Agricultural Centre	08 96711661
96MO8	Dandaragan	Clive Moore	Tim Wiley Jurien Bay Community Agricultural Centre	08 96522225
96WH142	Kalannie	Robert Nixon	Amanda Falconer Wongan Hills Community Agricultural Centre	08 96711661
96AD6	Southern Brook	John Dwyer	Meg Howe Community Landcare Coordinator Northam	08 96221099
96AD7	Tammin	Packham Family	Tony Clark AgWA Northam	08 96902000
96AD110	Brookton	Colin Mills	Colin Holt AgWA Narrogin	08 9881 0233
96NA3	Narrogin	Bill Moore	Darren Morris AgWA Narrogin	08 9881 0222
96NA4	Narrogin	Peter Wharton	Darren Morris AgWA Narrogin	08 9881 0222
96NA6	Wickepin	Steve Rose	Jenny Crisp AgWA Narrogin	08 9881 0231
97NA1	West Popanyinning	Rod Wiles	Eliza Dowling AgWA Narrogin	08 9881 0222
96LG8	Varley	Chris Henderson	Daniel Hester AgWA Lake Grace	08 9865 1205
96LG9	Newdegate	Geoff Cugley	Daniel Hester AgWA Lake Grace	08 9865 1205

NOTE : Consultants, Company Agronomists, Farmer Groups, Catchment Groups etc are encouraged to visit these sites during the growing seasons and to request information on sites relevant to your location. Please contact the development officer for more information.

RESULTS

As there are 19 trials under this initiative it is impossible to discuss all trials in this report. The following gives an indication to the types of information determined from these trials and the format by which it is reported. At the time of printing this article a separate comprehensive report dealing with demonstration sites is being produced for distribution to all collaborators. Copies of this report may be requested from the author.

Activity #: 96LG8

Start-Date: 1996

Finish-Date: 1999

Personnel: Daniel Hester (Lake Grace), D. Gartner (Moora), A. Miller (Northam)

Location: GW Henderson & Co., Lake Varley

Treatment

Three levels of lime (0, 1, and 2 t/ha), replicated three times.

Plot size: 50 m wide by 200 m long = 0.48 ha
Plots: 3 levels of lime by 3 replications = 9 plots
Total size: 450 m by 200 m = 9 ha

Protocol 1996

1. SAT to discuss the trials with local DOs and farmer groups.
2. Select sites (DOs with SAT and Group). Bury metal markers at the corners of the trial site for detection with metal detector in the future
3. Soil sample sites (DO & Group). Soil samples sent to David Gartner, Moora, who will process and send the samples for analysis.
4. Spread lime (DO with SAT help). Year of initiation of the trial only.
5. Plant crop (Host Farmer).
6. Dave Gartner to visit all sites and spray out a 30cm strip around the trial and between plots using a shielded sprayer. This process allows for easy identification of the trial and the plots for sampling, field days and for harvesting.
7. Collect plant samples at 6 to 8 weeks after sowing for analysis (DO & Group): (a) whole tops (b) youngest fully expanded leaves (YEB)

8. Send the samples to David Gartner who will process the samples and send them for analysis.
9. Harvest plots, using a weigh trailer, and collect samples of grain from each plot for analysis (DO & Host Farmer). Send harvest results and grain samples to Amanda Miller, Northam. Field days, if desired by farmer groups, local DOs or SAT. To be organised by DO, with SAT help is desired.
10. Data analysis and report (Amanda Miller, Northam). The report will be sent to all collaborators.

Note: SAT = Soil Acidity Team, DO = District Officer

Plan

Plot No.	1	2	3	4	5	6	7	8	9
Replicate	1	1	1	2	2	2	3	3	3
t/ha lime	2	1	0	2	1	0	2	1	0

Plot 1 western end

Results

Soil pH Analysis 1996

CO-OPERATOR	Henderson, Chris	**OFFICER**	Daniel Hester
TRIAL REGISTRATION NUMBER	96LG8	**GROUP**	Holt Rock Spray Group
LOCATION	Varley		

Plot Number	Lime (t/ha)	Sample Depth	ADAC Soil Bank No.	Soil pH (Pre liming)	ADAC Soil Bank No.	Soil pH (Mid Season 96)
1	2	0-10 cm	44298	4.3	48087	5.5
1	2	10-20 cm	44299	4.3	48088	4.2
1	2	20-30cm	Not Sampled	Not Sampled	48089	4.9
2	1	0-10 cm	44300	4.3	48090	5.2
2	1	10-20 cm	44301	4.4	48091	4.4
2	1	20-30cm	Not Sampled	Not Sampled	48092	5.0
3	0	0-10 cm	44302	4.3	48093	4.4
3	0	10-20 cm	44303	4.2	48094	4.2
3	0	20-30cm	Not Sampled	Not Sampled	48095	4.8
4	2	0-10 cm	44304	4.2	48096	5.4

4	2	10-20 cm	44305	4.0	48097	4.1
4	2	20-30cm	Not Sampled	Not Sampled	48098	4.6
5	1	0-10 cm	44306	4.4	48099	4.6
5	1	10-20 cm	44307	4.2	48100	4.2
5	1	20-30cm	Not Sampled	Not Sampled	48101	4.7
6	0	0-10 cm	44308	4.3	48102	4.7
6	0	10-20 cm	44309	4.2	48103	4.0
6	0	20-30cm	Not Sampled	Not Sampled	48104	4.6
7	2	0-10 cm	44310	4.4	48105	5.6
7	2	10-20 cm	44311	4.4	48106	4.5
7	2	20-30cm	Not Sampled	Not Sampled	48107	5.5
8	1	0-10 cm	44312	4.5	48108	4.9
8	1	10-20 cm	44313	4.6	48109	4.9
8	1	20-30cm	Not Sampled	Not Sampled	48110	5.3
9	0	0-10 cm	44314	4.3	48111	4.4
9	0	10-20 cm	44315	4.6	48112	4.4
9	0	20-30cm	Not Sampled	Not Sampled	48113	5.4

ANALYSIS

Pre Liming	**pH**
Average 0-10cm	4.3
Average10-20cm	4.3

LIME SOURCE	**NEUTRALISING VALUE**	**PARTICLE SIZE**
Limestone	78%	85%

Lime 2 tonnes/ha	**Pre Liming**	**Mid Season 96**	**Change**
Average 0-10cm	4.3	5.5	1.2
Average 10-20cm	4.2	4.3	0.0
Average 20-30cm	Not Sampled	5.0	N/A

Lime 1 tonne/ha	**Pre Liming**	**Mid Season 96**	**Change**
Average 0-10cm	4.4	4.9	0.5
Average 10-20cm	4.4	4.5	0.1
Average 20-30cm	Not Sampled	5.0	N/A

No Lime	**Pre Liming**	**Mid Season 96**	**Change**
Average 0-10cm	4.3	4.5	0.2
Average 10-20cm	4.3	4.2	-0.1
Average 20-30cm	Not Sampled	5.0	N/A

Yield & Quality Analysis 1996

CO-OPERATOR	Henderson, Chris	**OFFICER**	Ken Bradley
TRIAL REGISTRATION NUMBER	96LG8	**GROUP**	Holt Rock Spray Group
LOCATION	Varley		Spear Wheat

Plot Number	Treatment	Yield t/ha	Hectolitre grams	Hectolitre Weight	Screen-ings grams	Screen-ing %	Protein %
1	2 t/ha Limesand	3.04	425	85.0	15.0	3.53	11.0
2	1 t/ha Limesand	3.05	425	85.0	13.0	3.06	11.0
3	0 t/ha Limesand	3.37	425	85.0	9.0	2.12	11.2
4	2 t/ha Limesand	3.67	427	85.4	14.0	3.28	11.3
5	1 t/ha Limesand	3.54	428	85.6	13.0	3.04	11.0
6	0 t/ha Limesand	3.64	419	83.8	12.0	2.86	11.4
7	2 t/ha Limesand	3.23	422	84.4	7.0	1.66	N/A
8	1 t/ha Limesand	3.43	427	85.4	7.0	1.64	11.2
9	0 t/ha Limesand	3.55	428	85.6	6.0	1.40	10.8

ANALYSIS

Yield Averages	Tonnes / hectare
0 t/ha Limesand	3.5
1 t/ha Limesand	3.3
2 t/ha Limesand	3.3

LSD (95%) 0.27

Hectolitre Averages	Weight
0 t/ha Limesand	84.8
1 t/ha Limesand	85.3

2 t/ha Limesand	84.9

LSD (95%) 1.7

Screenings Averages	**Screenings %**	
0 t/ha Limesand	2.1	
1 t/ha Limesand	2.6	
2 t/ha Limesand	2.8	**LSD (95%) 0.7**

Protein Averages	**Protein %**	
0 t/ha Limesand	11.1	
1 t/ha Limesand	11.1	
2 t/ha Limesand	11.2	**LSD (95%) n/a**

Acknowledgements
This research is supported by growers through the National Landcare Program in partnership with Agriculture Western Australia the Grains Research and Development Corporation (GRDC) and the “Time to Lime” Campaign.

WHY ARE OUR SOILS ACIDIFYING?

Perry Dolling
Agriculture Western Australia, Katanning.

BACKGROUND

This report summarises the 1996 data from two rotation experiments, which were established in 1994 at Kojonup (300 km south of Perth) on a loamy sand over a sandy clay at a depth of 30-40 cm and at Moora (200 km north of Perth) on a deep yellow sand. The rotations under study include one year of lupins-one year of wheat, two years of annual pasture-one year of wheat, continuous annual pasture and perennial grass pasture (only at Kojonup, phalaris and tall fescue).

This project is run jointly with a team from CSIRO (Dr Ian Fillery and Dr Geoff Anderson) based in Perth.

Acidification is determined by measuring the amount of nitrate leached and the alkalinity removed in produce. The amount of nitrate leached was determined by the difference at Kojonup i.e. nitrate leached = change in nitrate and ammonium content over time + nitrogen added via the breakdown of organic matter - nitrogen uptake by the plant. At Moora greater instrumentation by CSIRO has determined the drainage of water through the soil so the amount leached = drainage multiplied by the nitrate concentration.

RESULTS AND DISCUSSION

Results from both sites indicate that acidification soon after the break of season is mainly caused by leaching of nitrogen. At this time, nitrate levels are high due to mineralisation at the break of season or before if there has been summer/autumn rain. Also rainfall is generally high after the break of season and plants are not growing quickly resulting in drainage, which carries nitrate with it.

The amount of nitrate leached does vary between rotations, indicating that changes in agronomic management could result in lower acidification rates. Wheat after either pasture or lupins is most prone to leaching due to relatively high nitrate within the soil at the break of season following legumes and the low utilisation of nitrate by the wheat crop. Mixed species pasture (clover, capeweed and grass) was less prone to nitrate leaching compared to wheat as grass and especially capeweed are large sinks for soil nitrogen. The wheat – lupin rotation is more acidifying than wheat and two or more years of pasture rotations because of the greater frequency of the wheat phase and generally the greater utilisation of soil nitrogen in pastures compared to lupins.

In 1996 at Moora there was lower drainage compared to 1995, which resulted in lower nitrate leaching and therefore less acidification (Table 1). There was less drainage in 1996 because the season was shorter and the rainfall was less than in 1995. In 1996 total rainfall for the year was 438 mm compared to 703 mm in 1995.

Table 1. The lime required (kg/ha per year), for different rotations to neutralise the acidity produced as a result of nitrate leaching at Moora.

Rotation	**Lime (kg/ha/year)**
1995	
2nd year pasture after wheat	61
Wheat after lupins	212
Lupins after wheat	126
1996	
2nd year pasture after wheat	101
Wheat after lupins	151
Lupins after wheat	83
Wheat after 2 years pasture	155

At Kojonup in 1996, acidification was higher than in 1995 due to high plant available nitrogen at the break of season and heavy rainfall (330 mm) over nine weeks after the break of the season. The high nitrogen at the break of the season was due to early summer rain and the good legume season in 1995. Analyses of soil and plant samples are still being completed before estimating the amount of acidification.

The late spring and early summer rains in 1996 suited the growth of lupins and the perennial pasture at Kojonup (Table 2).

In the case of the perennial pasture this extra growth late in the season had important implications for water use. Just before the start of the 1997 growing season the amount of water in the soil profile to 1 m under perennials was 20 to 29 per cent (35 to 55 mm) lower than the annual pasture or crop treatments (Table 2). Also the amount of soil water in the profile was not related to dry matter production.

It appears that soil evaporation in annual systems over summer plays a larger part in soil water loss than previously thought. The lower soil water content under the perennials is important because going into the 1997 growing season the soil needs a greater amount of water to fill up the profile. When the profile is full drainage will occur, if drainage occurs then it will carry nitrogen with it. So depending on the season, if perennials get sufficient spring and summer rain, there will be reduced drainage and acidification the following year.

Table 2. Cumulative dry matter at the end of 1996 and the soil water content to a depth of 1m on the 12th May 1997 at Kojonup.

Rotation	Total dry matter (t/ha)	Soil water content (mm)
Perennial pasture	8.6	136
Annual pasture	5.6	191
Wheat after lupins	5.4	171
Lupins after wheat	9.7	181
Wheat after 2 years pasture	7.1	174

Acidification in the wheat - lupin rotation also occurred due to the removal of alkaline produce from the plots, the acidification was however small in comparison to acidification due to nitrate leaching. In 1996 at Moora wheat after lupins yielded 2.4 t/ha, equivalent to removing 4 kg lime/ha (based on ash alkalinity measurements) and the lupin yielded 1.7 t/ha, equivalent to removing 16 kg lime/ha. At Kojonup the wheat yielded 2.4 t/ha, equivalent to removing 4 kg lime/ha and the lupin yielded 2.1 t/ha, equivalent to removing 20 kg lime/ha.

Acknowledgements
This research is supported through the Land and Water Resources Research and Development Corporation (LWRRDC) in partnership with Agriculture Western Australia and CSIRO.

SUSTAINABLE MANAGEMENT OF SOIL WATER AND NUTRIENTS IN THE MEDIUM RAINFALL ZONE OF WESTERN AUSTRALIA

Dr Ian Fillery
CSIRO Plant Industry, Perth

BACKGROUND

Field experiments are being established that will monitor the hydrological and nitrogen cycles for a suite of annual and perennial crops with the aim to evaluate the strategies for better management of soil water and nitrogen by incorporating deep-rooted species into existing rotations. Research being undertaken will improve understanding of the fate of symbiotic nitrogen, and other nutrients applied to both legumes and cereals, and investigate the linkages between leaching of anions and cations and soil acidification. The project will provide invaluable data for continued progress on the modelling of the consequences of rotations on the use of water, and the fate of nutrients.

SPECIFIC AIMS

- To determine the effect of annual and perennial species on drainage, the input, turnover and fate of legume-fixed nitrogen, anion and cation leaching, and soil acidification, for a soil in the 400 mm rainfall zone.
- To use information on nutrient and water balances to validate wheat/grain legume growth models, to test soil water movement models, and to test predictions of lime movement and lime requirement.
- To devise pasture/crop rotations for improving efficiency of use of water and nutrients.

The instrumented site will also serve a number of GRDC-funded projects:

- Soil acidity management in Western Australia - an integrated project, including the sub projects “Understanding the downward movement of lime for the management of subsurface acidity under different farming systems” and “Quantifying yield losses due to subsoil acidity”
- Biological activity and organic matter in no-tillage systems and their contribution to crop production (GRDC Project CSP 245).

The instrumented site will be located in the Gabby Qoi Qoi Valley, immediately east of the Goomalling-Wongan Hills Road, ~20 km south of Wongan Hills. This area has a prominent Landcare Group.

Two experimental sites will be used; one with 80 cm of yellow sand over clay that is positioned high in landscape of the valley, and a duplex soil with 40 to 50 cm sand over permeable clay that is close to the Gabby Qoi Qoi creek (low landscape position).

TREATMENTS

- Lupin-wheat rotation, both phases present. Three tillage sub treatments will be imposed on the lupin-wheat treatment and six lime sub treatments (lime particle size by tillage) will be imposed on the wheat-lupin treatments. One lime treatment and one tillage treatment will be common over both phases.
- Perennial legume, represented by lucerne, with and without lime. Lime sub treatments will include surface lime, and surface lime plus banded lime.
- Subterranean-based clover plus a mixture of perennial grasses including phalaris, tall fescue and tall wheat grass.
- Serradella-based pasture.
- Subterranean based pasture as control.

None of the pasture treatments will have a concurrent wheat phase, wheat will follow two or three years of each pasture treatment.

OVERVIEW OF ACTIVITIES

Each site is to be established in March/April 1998. Time domain reflectrometry equipment will be installed in a lucerne, a pasture, a wheat and a grain legume plot to measure volumetric water content. Neutron access wells will be installed in each plot to survey changes in water content over all treatments. Detailed information on the soil hydraulic conductivity-soil water relationship and the soil water content-suction relation will be collected.

A micrometeorological procedure will be used to measure evapo-transpiration from soil and crop in selected treatments equipped with TDR (pasture, grain legume or wheat), to provide accurate estimates of evapo-transpiration for computation of the water balance, and for model validation. Rainfall, radiation, wind speed, wind direction and air and soil temperatures will be monitored on an hourly basis. Drainage (D) of water will be calculated using $D = R - ET - \Delta S$; where R is rainfall, ET is evapo-transpiration and ΔS is the change in soil water content in the soil profile.

Lime is to be applied before the break of season. Wheat, lupin, annual pasture (duplex site) and perennial grasses will be seeded soon after the break of season, while serradella, and lucerne will be seeded during July.

Nitrogen fixation by lucerne, lupin and serradella will be estimated using ^{15}N natural abundance techniques and appropriate reference plants. These measurements will be concurrent with measurements of nitrogen content in pasture, grain legume and wheat plants.

Net mineralisation of soil organic N will be determined using a microplot method developed in the CSIRO Perth laboratories. Soil under lucerne, pasture, grain legume and wheat will be sampled to 2 metres at the break of season and at critical crop growth stages, to determine the content of ammonium, nitrate, sulphate, phosphate, potassium and other cations.

The concentration of nitrate and sulphate in soil solutions in soil profiles will be determined at two weekly intervals during periods of drainage, by extracting soil solution using ceramic and teflon cup samplers. Quantities of cations in soil solutions will be ascertained using only teflon cup samplers. Anion-cation budgets will be produced for soil layers, and the contribution of anion-cation movement to soil acidification will be assessed. Bromide will be used as a tracer of anion movement to complement measurements on nitrate movement described above. A rainfall simulator will be used in some treatments to enable control over water input and to facilitate measurement of water fluxes during and immediately after specific rainfall events.

Acknowledgements

This research is supported by growers through the Grains Research Development Corporation (GRDC) in partnership with CSIRO, Agriculture Western Australia, the University of Western Australia and the Centre for Legumes in Mediterranean Agriculture (CLIMA)

SUBSOIL ACIDIFICATION AND LEGUMES

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INTRODUCTION

Introducing legumes in farming systems improves soil fertility. Legumes are well known for their role of increasing plant-available nitrogen and soil organic matter, however a negative aspect of the introduction of legumes is the increase in soil acidification. Increased soil acidification has been observed under clover pasture and lupin-cereal rotations. Lime can ameliorate acidity in topsoil; however, subsurface soil acidification under legumes is of particular concern due to the greater cost and difficulty of amelioration.

ACID PRODUCTION BY LEGUMES

N_2-fixing legume plants take up more cations than anions and produce acid, resulting in decreases in rhizosphere pH and eventually in bulk soil pH. The amount of acidity produced by the plant is equivalent to the content of excess cations or ash alkalinity of the plant. It has been demonstrated that the content of excess cations in various pasture legume species was nearly a 1:1 relationship with their proton excretion from legume roots to nutrient solution.

Legume species differ in their ability to produce acid. In general, among grain legumes, chickpea and narrow-leafed lupins have a greater acidifying ability than other lupin species and faba beans, which in turn acidify soil more than field pea. Among pasture legumes, woolly clover and sub clover generally have greater acidifying ability than serradella and biserrula. The species variation in soil acidification is related to the difference in the excess uptake of cations.

The form and amount of nitrogen in the soil profile has a prominent influence on acid production by plants. Ammonium uptake would increase acidification but decrease non-N excess cations or ash alkalinity, and the reverse is true for nitrate.

Deficiencies of nutrients may affect acid production directly, or indirectly through affecting N_2 fixation. Phosphorus deficiency in some legume species can induce rhizosphere acidification. This has been suggested to be due to the imbalance of cation and anion uptake and increases in organic acid excretion.

This study has shown that increasing phosphorus supply to a moderately deficient level can increase the amount of acid production per unit shoot biomass of narrow-leafed lupin,

clover and white lupin, and further increasing phosphorus levels can decrease acid production by these species.
Application of potassium sulfate to a K-deficient soils decreased the amount of acid produced per unit biomass of narrow-leafed lupin and sub clover. The acid production correlated with concentrations of excess cations, ash alkalinity and calcium but not with potassium concentrations in the plant.

SOIL ACIDIFICATION UNDER LEGUMES

Acid production by various N_2-fixing legumes grown in the glasshouse is variable but generally considerable (20-265 cmol H^+ per kg biomass produced). However, the acidity developed under legumes in the field also depends on:

1. total biomass production;
2. on whether all or only part of the crop is removed at harvest;
3. on nitrate leaching after residue decomposition ;
4. on the percentage of legume-N fixed or the proportion of N absorbed in ammonium and nitrate forms.

For grain legumes, only the seeds are harvested. Seeds have much lower ash alkalinity than shoots. The removal of seeds at the production sites would contribute to the development of soil acidity to a lesser extent than the removal of shoots.

For pasture legumes, if plant materials are removed, such as hay, the acid produced by the roots will remain in the soil. A pasture legume under animal grazing may have less acidifying effect than when the legume is cut, however freely grazing animals return the alkalinity unevenly (i.e. sheep camps).

Application of legume residues to acid soils increases soil pH. The magnitude of alkalinity production in soil depends on type and rate of plant materials added and initial pH of the soil. Alkalinity production in soil is positively correlated with the concentration of ash alkalinity (excess cations) in the residues and negatively with initial soil pH. However, the residue returned will largely be decomposed in the topsoil so that the acidity produced by the roots in sub-surface layers persists, leading to subsoil acidification.

Nitrate leaching under legumes is a major cause of topsoil acidification. In contrast, nitrate uptake by the plant is a de-acidifying process. Thus the uptake of nitrate by plant roots in deeper layers during the downward movement of nitrate may reduce subsoil acidification. Legume species differ in their ability to intercept nitrate in soil profiles. In the pot experiment with eight nodulated grain legume species, increasing nitrate supply up to 57 mg N/kg soil increased plant nitrate uptake by nodulated plants by 40 to 77 per cent. The nitrate uptake increase was greatest in the grasspea and least in white lupins. Correspondingly plant acid production declined by 45 to 100 per cent, with the greatest decrease being under grasspea and least under chickpea.

SUBSOIL ACIDIFICATION

The following factors may be related to the development of subsoil acidification.

1. Legumes produce acid along their roots due to excess uptake of cations over anions during their N_2 fixation. In soil columns under lupin and sub clover, it was observed that the decrease in pH of a soil layer was proportional to root length density in that layer. Grain legumes usually have deeper root systems than pasture legumes and will acidify deeper soil layers.

2. The return and decomposition of plant shoot residues will neutralise the acidity produced by the growing plant in the topsoil. However, root residues have little "liming" effect and will not neutralise the acidity along the roots.

3. Mineralisation and nitrification of plant N mainly occurs in the topsoil. The acid produced in the nitrification process may be neutralised by the process of plant nitrate uptake in that layer. However, if nitrate is leached, soil acidification occurs in the topsoil layer. In contrast, the uptake of nitrate by plant roots in subsurface layers may reduce subsoil acidification.

4. The downward movement of H^+ and soluble Al may contribute to the development of subsoil acidification but the magnitude of the acid movement is unknown.

CONCLUSION

Soil acidification under legumes appears to be greater than under non-legume crops. This has mainly been attributed to the large excess uptake of cations over anions by legume roots during N_2 fixation, and the great potential for leaching of nitrate once organic nitrogen is decomposed.

The incorporation of legume residues to the soil is unlikely to cause soil acidification. By contrast, the decomposition of the residues can increase soil pH.

Subsoil acidification is of great concern under legumes, especially under grain legumes, which have deep root systems. Acid production along the root due to the imbalance in uptake of cations and anions is probably a major cause of subsoil acidification.

Legume species differ considerably in their ability to produce acid and in their ability to up nitrate from the soil profile. Selection of species and genotypes, which produce acid to the smallest extent and utilise soil nitrate to the greatest extent may help to minimise soil acidification in legume-based agriculture.

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MODELLING YIELD LOSSES DUE TO SUBSURFACE ACIDITY

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INTRODUCTION

Many soils of the WA wheatbelt are poorly buffered and prone to subsurface acidification in the current agricultural production systems. Such acidification poses various stresses on root growth and metabolism, either directly by increasing the concentration of H^+ and of toxic elements such as aluminium (Al), or indirectly by decreasing the plant availability of various mineral nutrients.

Plants with impaired root growth are unable to fully explore soil in search of water and nutrients, and reduced yields can result depending on plant species, location and time.

Liming can readily ameliorate such root growth constraints in the topsoil and hence their penalties on yield assessed. In contrast, such constraints in the subsurface are more difficult to ameliorate in the field and hence their contribution to yield depression is also difficult to determine. In addition, the extent to which crops are reliant on subsurface moisture and nutrients will determine the magnitude of the effect of subsurface acidity on yield.

To predict how such variables as nutrient and water availability may affect yield losses due to subsurface acidity, the computer model APSIM (**A**gricultural **P**roduction **S**ystems S**IM**ulator) has been used. This computer model has been recently used successfully to simulate wheat yields in WA using recorded meteorological data along with soil water and soil nitrogen (N) data.

APSIM has a subroutine that enables the root growth of the simulated crop to be varied throughout the soil profile. In the simulations described below, root growth profiles were selected to reflect various levels of subsurface acidity and plant tolerance to acidity. Simulations were conducted to examine the interaction of water availability, N application and acidity on wheat yields.

ROOT GROWTH PROFILES

1. Levels of soil acidity

Root growth profiles of wheat were selected based on the available literature to represent those of plants grown in soils with a range of acidity levels (Figure 1).

a) Severe acidity

The Wodjil soil (eastern yellow sandplain soil from Carrabin) was chosen as an example of extreme soil acidity. This soil can be viewed as the worst-case scenario of what might occur if the soils of the main WA wheatbelt are allowed to continue acidifying over time. Root growth in this soil was calculated from the measured concentration of Al in each soil depth and the relationship between the Al concentration and root growth of an Al sensitive wheat cultivar ("Aroona").

b) Twenty-five per cent of severe acidity

This profile represents root growth association with Al concentrations one-quarter of those measured in the Wodjil soil.

c) Mild subsurface acidity

This soil is found at the Moora experimental site where there is cooperative research currently being conducted (UWA, AgWA, CSIRO). This soil has been identified as having soil compaction in the surface and acidity in the subsurface soil. The root growth profile in this soil has been calculated by Dr. Senthold Asseng (CSIRO) from field observations and, when incorporated into the APSIM model, has been shown to accurately predict observed wheat yields for this Moora site. Such a result suggests that these root growth parameters may closely reflect root growth at the Moora site.

d) Control

The subsurface acidity (10-30 cm) constraint in the Moora soil has been removed, thus simulating the situation where subsurface acidity would be ameliorated.

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Figure 1: Profiles of root growth* in WA soils with varying levels of soil acidity. These predicated profiles are calculated from the concentration of Al in each soil depth and the

relationship between Al concentration and root growth (* = Al sensitive wheat cultivar *Aroona")

2. Al-tolerant wheat cultivars

Root growth profiles were generated comparing Al-sensitive and Al-tolerant wheat cultivates grown on soils with extreme acidity and 25 per cent of extreme acidity (Figure 2). These profiles were calculated from the measured concentration of Al in each soil depth and the relationships between Al concentration and root growth of Al-sensitive and Al-tolerant wheat cultivars.

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Figure 2: Profiles of root growth of Al-sensitive and Al-tolerant wheat cultivates on soils with severe acidity and 25 per cent of severe acidity. These predicted profiles are calculated from the concentration of Al in each soil depth and the relationship between Al concentration and root growth of Al-tolerant and Al-sensitive wheat cultivars.

Simulations

The root growth profiles described above were used as input data for the simulation model APSIM. The effects of root growth profiles on the yield of wheat were simulated using the recorded meteorological data (rainfall, temperature, evaporation, etc.) for 80 years (1911 – 1990) for Moora (high rainfall – annual average 460 mm) and Merredin (low rainfall – annual average 310 mm). The effect of nitrogen fertilisation prior to planting (0 and 30 kg N/ha) was also simulated.

RESULTS AND DISCUSSION

Amelioration of subsurface acidity

The soil at Moora has been identified to contain the root growth constraints of surface compaction and subsurface acidity. In this relatively high rainfall area, improving root growth by amelioration of subsurface increased wheat yields by 7 per cent (about 100 kg/ha) (Figure 3).

This yield increase could also be achieved by the addition of 30 kg N/ha, even with the acidity-related root growth constraint remaining in the subsurface soil. However, in low rainfall areas, the amelioration of subsurface acidity resulted in predicted yield might have occurred. The APSIM simulations suggest that if root growth cannot be improved in the acidic subsurface, then N application may offset yield losses incurred due to subsurface acidity (or yields can be maintained in the presence of subsurface acidity).

Exacerbation of mild soil acidity

If the soil acidity at Moora is allowed to increase, it is expected that in the future root growth profiles similar to those shown in the severe acidity scenarios will be observed. In the case of severe acidity with high rainfall, 30 kg N/ha, a decrease in yield of 44 per cent (700 hg/ha) could be expected (Figure 3). Even if the soil acidity in the most severe situation could be decreased to 25 per cent only, yield decreases of 20 per cent are still predicted. These simulations, producing the large detrimental effect of continued acidification on yields in the future, emphasise the importance of attempting to arrest current soil acidification, or at least provide options for farmers to maintain yields whilst other ameliorative measures are examined.

Al-tolerant wheat cultivars
There are potentially three ways to deal with soil degradation due to acidity:

1. correcting the acidity by lime application;
2. introduction of non-acidifying farming systems;
3. use of more acid (Al) tolerant cultivars

Plant tolerance is viewed as a short-term option, as even the most acid tolerant cultivars will be affected as soils continue to acidify. However, acid-tolerant cultivars can help farms to maintain production, while other ameliorative measures are implemented.

The benefits of using Al-tolerant wheat cultivars in WA are currently not known. The APSIM simulations showed that Al-tolerant wheat cultivars would out-yield Al-sensitive ones

(Figure 4). In the presence of severe acidity in high rainfall areas (460 mm) a yield increase of approx. 30 per cent (300 kg/ha) could occur. Similarly, in low rainfall areas (310 mm) a 30 per cent increase in yield could occur, but due to the lower overall yields the increase could be about 200 kg/ha.

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Figure 3: Predicted wheat yields from soils with varying levels of soil acidity. The simulations predicted the effect of nitrogen fertilisation (0 and 30 kg N/ha) and rainfall (high – Moora (460 mm) and low – Merredin (310 mm)). Vertical bars represent the predicted yield range of 80% of the years simulated. Numbers adjacent to the vertical bars are yields predicted to occur in 50% of the years simulated.

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Figure 4: Predicted wheat yields of Al-sensitive and Al-tolerant cultivars from soils with acidity. The simulations predicted the effect of nitrogen fertilisation (0 and 30 kg N/ha) and rainfall (high – Moora (460 mm) and low – Merredin (310 mm)) on wheat yields from soils with varying levels of soil acidity. Vertical bars represent the predicted yield range of 80% of the years simulated. Numbers adjacent to the vertical bars are yields predicted to occur in 50% of the years simulated.

When grown in soils with less acidity (25 per cent of severe acidity), yield increases of approximately 20 per cent (300 kg/ha) were predicted to occur with Al-tolerant compared to the Al-sensitive cultivars. Nitrogen application had little or no effect on the 50 per cent yield probability, but increased the range of yields that might be achieved.

CONCLUSIONS

The APSIM simulations suggest that amelioration of mild subsurface acidity could increase wheat yields by 100 kg/ha. If root growth cannot be improved in the acidic subsurface, then N application at 30 kg/ha may offset yield loss due to acidity.

If soil acidification is allowed to proceed, then future yield losses could range from 20 – 44 per cent (up to 700 kg/ha). The use of Al-tolerant wheat cultivars was predicted to result in a yield benefit of approximately 30 per cent. The absolute yield increases corresponding to this percentage varied depending on severity of soil acidity and rainfall, with N fertilisation having little or no effect. Under severe acidity in low rainfall areas, a 200 kg/ha yield benefit could occur due to the use of Al-tolerant cultivars. In high rainfall areas with less severe acidity, the 20 per cent yield increases corresponding to 300 kg/ha grain.

IMPLICATIONS FOR FUTURE WORK

The APSIM simulations suggest that water availability (rainfall), Al-tolerant cultivars and N fertilisation can have an influence on overcoming some of the wheat yield losses due to soil acidity. Based on these predictions, glasshouse experiments will be conducted to examine the interactions between water availability and Al-tolerance on plant growth in the presence of subsurface acidity.

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ECONOMIC OPTIMISATION OF SOIL ACIDITY MANAGEMENT

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INTRODUCTION

Soil acidity research is valuable to farmers only to the extent that it contributes to improved profitability in the long term. This sub project is aimed at identifying those components of the research, which are likely to lead to better management decisions by farmers, and to determine the potential increase in profit resulting from the work. This will be done using benefit cost analysis.

In addition, this sub project will determine the profitability of managing soil acidity in different regions of the State, under different pasture and crop rotations.

Project aims are as follows:

- To evaluate proposed activities within the soil acidity project to help researchers decide how best to achieve project objectives;
- To provide analysis of the profitability of managing acid soils, for extension purposes;
- To document analyses.

RESULTS FOR 1997

Optlime has been reviewed as a tool for providing economic information to conduct benefit cost analyses of the soil acidity research program. A number of refinements to the model were required to make it a suitable tool. Pasture and several crops were added to the model and the number of possible rotations that could be analysed was extended from 4 to 35. The inclusion of 31 new rotations increases the flexibility of the model so that it can be used for a number of regions of the State.

PLANS FOR 1998

The main aim for the coming year is to complete a comprehensive benefit cost analysis of the soil acidity research program being undertaken jointly by AgWA, UWA and CLIMA. The uncertainty of the impact of the research on farmers management decisions make it appropriate to employ a Baysian framework to determine the value of information that is being generated by acidity research in Western Australia.

The diverse range of research being undertaken requires that each component of the project be assessed individually, rather than conducting one analysis for the whole project.

The process of undertaking the analysis will provide insight into the economic importance of improved information on different aspects of the acidity problem. This may then be used to refine and redirect the research effort with the aim of maximising the impact of farmers' profitability.

In addition to the benefit cost analysis, it is planned to investigate the profitability of managing soil acidity under different crop and pasture rotations.

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