Western Australia soil acidity research and development update 2000: time to lime

Department of Agriculture and Food, Western Australia
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Western Australia
Soil Acidity
Research & Development
2000

Update 2000

Western Australia Soil Acidity Research & Development

TimetoLime

Agriculture Western Australia
FOREWORD

We have come a long way over the past three or four years in terms of both, the level of understanding and recognition of Soil Acidity as a major land degradation issue for the wheatbelt of Western Australia, and, in our actions to treat the problem.

During 1999 there were three very significant changes relating to acid soils in Western Australia.

- Lime use in WA increased by over 200,000 tonnes from 1998 to 1999 to a record 653,000 tonnes, which was double the amount applied in 1997.

- The Agricultural Lime Industry adopted a voluntary Lime Industry Code of Practice in October 1999, more than 6 months ahead of schedule.

- The Soil Acidity Research and Development team began a program of Agribusiness Training Days to ensure that the latest information was being made available to company agronomists in a coordinated and planned manner.

Each of these milestones, when coupled with the continued progress by all the research and extension projects in soil acidity in Western Australia, demonstrate that the management of acid soils in WA is becoming a reality.

However, we must not become complacent about the success so far. Current lime requirement in Western Australia is estimated to be just over 1 million tonnes annually.

I would like to congratulate the Agricultural Lime Industry in association with the Australian Fertiliser Services Association (WA) (AFSA) on their progress and commitment to the industry through the development of their Code of Practice. Once again, on behalf of the team I thank the members of the Soil Acidity Advisory Committee for their time and input in reviewing our progress and discussions about the future directions.

Finally, I would like to thank all the members of the Soil Acidity Team for their commitment, professionalism and support during the last year.

Mr Chris Gazey
Project Manager
The Western Australia Soil Acidity Research Development and Extension Project wishes to thank the following organisations for their support.

Time to Lime

Grains Research & Development Corporation
NATIONAL LANDCARE PROGRAM
Land & Water Resources Research & Development Corporation
Agriculture Western Australia
CSIRO Australia
The University of Western Australia
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**AGRICULTURAL LIME INDUSTRY ANNUAL LIME USE AND CODE OF PRACTICE**

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**BACKGROUND**

In 1994 there were six registered agricultural lime suppliers in Western Australia. Agricultural lime use was 154,000 tonnes with 1,356 farmers applying lime.

In 1999 there were 45 companies selling lime products (limesand, limestone, dolomite, cement/lime kiln dust, other) from 50 commercial lime pit operations. The Australian Bureau of Statistics reported 653,000 tonnes of lime were used in 1998/1999, with just under 3,000 farmers applying lime at a rate of 1.1 t/ha.

The lime industry in WA is now conservatively worth $20 million per annum. As trucks are the only means of moving product, lime transportation is estimated at $11 million of the total industry value.

**Figure 1 : Agricultural Lime Use Statistics for Western Australia. Information courtesy of the Australian Bureau of Statistics.**
The consequence of this exponential industry growth and consumer use rate was an immature industry with little coordination and, in general, poor product quality control across the industry.

**AGRICULTURAL LIME INDUSTRY CODE OF PRACTICE**

In April 1999 the Australian Fertiliser Services Association (AFSA) in Western Australia embarked upon a targeted and ambitious task of assisting the WA Agricultural Lime Industry to develop and monitor an Industry Code of Practice.

The first meeting of the WA Agricultural Lime Industry was at Katanning in July 1999, it was also the first whole of industry consultation for the first draft of the Code of Practice.

Between July and October 1999, after 14 meetings (6 focus groups) and many one on one and telephone discussions, the Agricultural Lime Industry Code of Practice was developed and launched in WA.

During the focus group process, three key issues arose:

1. Who is going to police this voluntary Code of Practice, and who is going to make sure that the suppliers are following the Code of Practice;

2. The development of new lime quality standards in WA based upon the Victorian standard known as Effective Neutralising Value (ENV);

3. What type of Audit procedure will be undertaken to ensure product quality.

**POLICING THE CODE**

The Agricultural Lime Industry Code of Practice is voluntary and industry driven. The need for strong policing from within the Code has largely been eliminated because of the inclusion of regulatory bodies during the development phase of the document. For instance, the Ministry of Fair Trading under the “Truth in Labelling” laws will help ensure that quality claims are realistic, whilst the Department of Mines, WorkSafe and the Department of Transport will ensure that mining and transport practices are safe and environmentally sound.

A conflict resolution procedure has been written into the Code of Practice to clearly define the pathway of informed complaint via the AFSA to the regulatory bodies.

**LIME QUALITY**

The new lime quality testing in WA is under development. The current testing methodology is as follows:
1. **Initial Sampling and Analysis**

An independent person will undertake the sampling of individual pits once the pit is registered with the Agricultural Lime Industry under the Code of Practice.

The following analysis will be conducted on the initial sample:

- % Calcium (Ca dissolved by 1M HCl)
- % Magnesium (Mg dissolved by 1M HCl)
- % Sodium (Na dissolved by 1M HCl)
- % Moisture (as received at the laboratory)
- % Moisture (maximum, i.e. to field capacity)
- % Moisture (minimum i.e. air dry under standard conditions)
- % Neutralising Value (overall Sample)
- Particle size distribution – 5 fractions, % by weight
  - 100 plus microns
  - 500 – 1000 microns
  - 250 – 500 microns
  - 125 – 250 microns
  - 125 minus microns

Each of the above fractions analysed for:
- % Neutralising Value
- In Soil Solubility Factor

2. **In Soil Solubility Factor**

In Soil Solubility Factor (SSF) is a method that has been devised to capture the relative effectiveness of different sieve fractions for an individual lime. The process is as follows:

1/ **Standard Soil Preparation**

The standard soil in which the test will be undertaken will be a sandy loam subsoil, relatively low in organic matter, of pH 4.2 to 4.5. The test does not require steralised soil.

2/ **Weigh out standard soils**

For each test fraction (five particle size fractions per lime sample) a 1 kg bag of dry standard soil is placed into a plastic bag.

3/ **Add lime fraction to the soil and mix**

For each sieve fraction the equivalent of an application rate of 2 t/ha is added to the standard soil. The bags are shaken to gain lime distribution throughout the soil.
4/ **Controls**
Positive and negative controls are run parallel with each batch of limes being tested. Triplicate negative controls (no lime added) and triplicate positive controls (equivalent of 2 t/ha of analytical grade calcium carbonate powder).

5/ **Test Containers**
The plastic bags of mixed soils are placed into 100mm diameter * 150mm depth containers.

6/ **Field Capacity**
Determine the volume of distilled water required to achieve field capacity, i.e. wet top 1/3 and allow draw down to 2/3, the bottom 1/3 is to remain dry. The containers are not sealed and the surface area of the soil must be allowed to go through “wetting and drying cycles”.

7/ **Storage**
All test containers are to be stored and maintained as one unit under identical conditions. While controlled temperature and humidity are not essential, extremes must be avoided with temperatures preferably being in the range of 15 – 20 degrees C. Care must be taken to eliminate any margin/boundary effects that could bias results.

8/ **Wetting and Drying Cycles**
Monitor moisture levels on a weekly basis. When the soil is approximately 50 per cent dry, add distilled water to restore soil moisture to field capacity. All limes/fractions under the test are to be wet at the same time. Continue wetting and drying cycles for the duration of the test period.

9/ **pH Test Schedule**
Soil pH is to be determined for each sample (including controls) at 2, 4, 8, 16, 32 and 52 weeks.

10/ **Sampling for pH tests**
Core samples are to be taken with a 5mm cork borer from the surface of each soil to a depth of 10mm. Five cores are to be taken and are to be pooled and dried. pH will be determined, to two decimal places, in a 1:5 water to calcium chloride (0.01M CaCl2) ratio.

It is anticipated that the results of this testing will be available for the 2000/01 liming season.

**LIME QUALITY AUDIT SAMPLING**
The following is the recommended audit sampling procedure and frequency for Agricultural Lime Suppliers in WA.
During the loading of each and every truck, the loader driver or pit manager, or a person designated to do this task by the pit manager, will take one 250ml cup full of material from either the:

- Loaded truck;
- Bucket of the front end loader whilst in the complete down position and in full view of the driver;
- Outloading face of the deposit or stockpile whilst the loader is not in operation and there is no machinery movement at all;
- The sample is placed into a clean plastic container that has a secure lid, i.e. plastic garbage bin with sealed lid. This sample will be known as the routine sample.

The container will be stable and covered to prevent tipping over and spilling the contents or material blowing into or out of the container. The container will be secured to prevent spilling or vandalism during and after working hours either by locking up or removing into a secure location.

Based upon the pooled routine samples the supplier will provide a representative sub-sample of the truck-by-truck samples to the laboratory for analysis. The frequency of sending samples for analysis will depend upon the volume of supply from a deposit over a 12 month period.

### Table 1: Recommended routine sample testing frequency, on a per pit basis.

<table>
<thead>
<tr>
<th>Annual Production</th>
<th>Recommended Testing Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production less than 500 tonnes annually</td>
<td>Minimum of an annual test</td>
</tr>
<tr>
<td>Production of 501 to 2,000 tonnes annually</td>
<td>Test every 500 tonnes</td>
</tr>
<tr>
<td>Production of 2001 to 10,000 tonnes annually</td>
<td>Test every 1,000 tonnes</td>
</tr>
<tr>
<td>Production of 10,001 to 20,000 tonnes annually</td>
<td>Test every 2,000 tonnes</td>
</tr>
<tr>
<td>Production of over 20,000 tonnes annually</td>
<td>Test every 2,000 tonnes or once per week</td>
</tr>
</tbody>
</table>

**Acknowledgements**

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**Key Words**

Lime use, Code of Practice, Agricultural Lime Industry, Western Australia.
PRELIMINARY RESULTS OF LIME MOVEMENT FIELD TRIAL

Mark Whitten and Andrew Rate
Soil Science and Plant Nutrition, University of WA

KEY MESSAGE
Past lime trials indicate that subsurface acidity can be treated with lime applied to or incorporated into the surface soil, but that subsoil pH increases occur slowly. This is generally attributed to the slow dissolution of lime, but insufficient lime applications or lime loss by wind or water erosion, the short duration of many experiments, and spatial variability in soil pH may have contributed to a perception that subsurface acidity cannot be managed with surface applied lime.

Two lime movement trials established at Kononngorring in 1998 are examining the effects of lime particle size and tillage on amelioration of subsurface soil acidity.

The pre-liming baseline soil measurements from intensive sampling indicate significant spatial variation in pH, and exchangeable calcium and magnesium. Post-liming changes of these parameters are being monitored in each plot rather than comparing limed and unlimed plots.

AIMS
To compare the effects of lime particle size (limesand unprocessed or finely ground), tillage (no-till vs incorporation) and lime application rate on the downward movement of surface applied lime.

METHODS
Limesand which was unprocessed (95% 0.09-0.355 mm diameter) or finely ground (78% < 0.045 mm) was applied in May 1998 at 2.5 or 5 t/ha (Site 1) or 2 or 4 t/ha (Site 2) after collecting baseline soil profiles of each plot. Each lime treatment was split so that half was under no-till and half was cultivated in the first year only with full-cut tynes to incorporate the lime within the top 10 cm. The trial is in a 1:1 wheat lupin rotation seeded with a double-disc seeder to minimise soil disturbance. Crop residues are left ungrazed to minimise windborne losses of lime from both the cultivated and no-till treatments.
RESULTS

Baseline pH profiles

Variation in pre-liming pH between plots designated for different lime treatments ranged by up to 1.6 pH units at Site 1 (Fig. 1), a gradational loamy sand, and by up to 2.8 pH units at Site 2, a duplex soil partly underlain by a calcareous (limey) subsoil. Differences in pH between the means of treatments and controls before liming ranged from about –0.5 to 0.25 pH units at both sites. This illustrates how a simple comparison between limed treatments and the control after liming could result in a false positive or negative for lime movement.

2nd year pH and exchangeable calcium and magnesium

The pH in 1999 at a depth of 0-10 cm had increased more with the higher lime rate for the finely ground limesand than the unprocessed limesand at both sites (Table 1), attaining a maximum pH value of 6.9. Soil pH at 0-10 cm also increased more with the low rate of finely ground limesand than the high rate of unprocessed lime (at Site 1 only; Table 1). Increases in exchangeable calcium at Site 1 corresponded with the pH increases at 0-10 cm, and when converted to the amount of calcium carbonate dissolved, it appears that all the fine lime at 2.5 t/ha had dissolved during the first year. There was no consistent effect of lime on exchangeable magnesium.

Table 1. The change in pH (ΔpH) from 1998 to 1999 at the different rates and particle sizes of lime. Lime rates: Site 1, 2.5 or 5 t/ha; Site 2, 2 or 4 t/ha. LS unprocessed limesand, FL finely ground limesand. Data are means of 4 replicates each consisting of 8 soil cores combined.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Tilled</th>
<th></th>
<th></th>
<th>Tilled</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control LS</td>
<td>FL</td>
<td>Control LS</td>
<td>FL</td>
<td>LSD (p&lt;0.05)</td>
<td>same any lime</td>
<td></td>
</tr>
<tr>
<td>Site 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–10</td>
<td>0.03</td>
<td>0.87</td>
<td>1.67</td>
<td>1.90</td>
<td>2.13</td>
<td>-0.11</td>
<td>1.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.65</td>
<td>2.11</td>
<td>2.40</td>
<td></td>
<td>0.37</td>
<td>0.33</td>
</tr>
<tr>
<td>Site 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–10</td>
<td>-0.16</td>
<td>1.29</td>
<td>2.00</td>
<td>1.91</td>
<td>2.47</td>
<td>-0.18</td>
<td>1.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.58</td>
<td>1.49</td>
<td>1.96</td>
<td></td>
<td>0.36</td>
<td>0.37</td>
</tr>
<tr>
<td>10–20</td>
<td>-0.03</td>
<td>0.04</td>
<td>0.12</td>
<td>0.12</td>
<td>0.21</td>
<td>-0.05</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.07</td>
<td>0.09</td>
<td>0.20</td>
<td></td>
<td>0.11</td>
<td>0.12</td>
</tr>
</tbody>
</table>
At a depth of 10-20 cm, there were significant pH increases of up to 0.2 pH units at Site 2. These occurred in all treatments except the low rate of unprocessed limesand with tillage (Table 1).

Tillage also affected the increase in soil pH ($\Delta$ pH) at 0-10 cm although with opposite effects at each site. At Site 1, $\Delta$ pH at 0-10 cm was higher with no-till at the low rate of unprocessed limesand only, whereas at Site 2 the $\Delta$ pH was significantly lower with no-till at the low rate of finely ground limesand and both rates of unprocessed limesand. This inconsistent tillage effect may be due to the lime being less uniformly distributed without tillage compared to the tilled treatments in which the lime was incorporated with a full-cut tyned cultivator.

**Crop yields**

Lime or tillage did not affect yields in 1998 or 1999. The 1998 wheat yields (cv Carnamah, which is acid tolerant) averaged 3 t/ha at Site 1 and 2.2 t/ha at Site 2. There was no correlation between yield and subsurface pH in the acidified zone. Lupins (cv Kalya) averaged 1.9 t/ha in 1999 at Site 1, and there were no significant decreases in the leaf concentrations of the lime sensitive trace elements B, Cu, Mn. However, there was a significant decrease in leaf Zn with increasing soil pH at 0-10 cm (measured in the tilled treatments only) even though Zn was applied in both 1999 and in 1998. This may be due to a poor zinc fertiliser history at this site. (Leaf analyses are courtesy of Dr Mike Wong CSIRO Perth, GRDC Project UMU69). As a result of flooding in 1999, Site 2 was re-seeded to sorghum.

**CONCLUSIONS**

Measuring lime movement in field trials requires good baseline data of the pH profile before liming in order to account for spatial variation in pH.

There appears to have been some downward movement of lime beyond a depth of 10 cm at one site, but it is too early in the life of this experiment to expect substantial increases in subsurface pH. The results of the surface pH so far conform with what has been repeatedly demonstrated by research into agricultural liming over most of the 20th century - that the finer the lime the more rapid is the increase in soil pH. It will be interesting to see how much the downward movement of lime is also affected by lime particle size.

It is also of interest that lupin yield in the second year was not affected by soil pH as high as 6.9 at 0-10 cm. The decrease in Zn leaf concentrations in the lupin indicates the importance of maintaining a vigilance for trace element deficiencies after liming.
Figure 1. 1998 pH profiles before liming on gradational loamy sand (Site 1). Joined data points represent 8 cores bulked from each 10 x10 m or 10 x 20 m plots within each 20 x 60 m block.
KEY MESSAGE
Liming and selection of tolerant cultivars provide solutions to the subsoil acidity problem.

INTRODUCTION
Subsoil acidity with high levels of toxic Al is a major limiting factor in crop production in the WA wheatbelt. Liming is a common practice to ameliorate topsoil acidity, but is inefficient in amelioration of subsoil acidity within the time scale and with the economic effectiveness required because of the slow movement of lime down the soil profile.

Subsoil acidity will impair root growth of sensitive crops and hence reduce water and nutrient uptake, particularly in the late part of the season.

Crop cultivars differ in their susceptibility to Al toxicity in acid soils. Selection of tolerant cultivars may provide an alternative way to cope with the subsoil acidity problem. Below is a report on a field trial along with a glasshouse soil column study, which examined the effect of subsoil acidity on the yield of two isogenic wheat genotypes differing only in Al-tolerance.

METHODS
A field trial was conducted on a sand over gravel at Wongan Hills at Peter Sadler, Leahurst Farms - 15 km east of Wongan Hills. The trial used large strips (25 m x 1 km) with lime applied at 0 and 2.5 t/ha in 1984. Two distinct soil acidity profiles had been established under the limed and unlimed strips (Figure 1).
By applying lime (1.5 t/ha in 1999) the topsoil acidity was ameliorated in the portion of the unlimed strip. Hence three soil acidity profiles were created:

- **#1** acid topsoil over shallow subsurface acidity (old unlimed strip),
- **#2** newly limed topsoil over shallow subsurface acidity, and
- **#3** ameliorated topsoil and subsurface acidity (old limed strip).

The two genotypes were sown in five replicates over each of the soil profiles. These genotypes are isogenic (more than 95 per cent similarity in their genome) wheat lines ET8 (Al-tolerant) and ES8 (Al-sensitive), which are almost identical in their genetic background to cv Egret (Egret = Al-sensitive).

The trial was sown on 24 June, and received 150 kg/ha of superphosphate Cu, Mo and Zn, 100 kg/ha of KCl and 100 kg/ha of urea. Due to the late sowing and late maturity of the genotypes, grain filling occurred during the dry part of the season, resulting in decreased yields overall.

**RESULTS**

The average yield of the Al-tolerant genotype (ET8 – 0.99 t/ha) was significantly higher than that of the Al-sensitive genotype (ES8 – 0.87 t/ha) (Table 1). There was an overall 14 per cent yield increase by growing the Al-tolerant genotype, mostly due to much better performance (41 per cent) of ET8 over ES8 in the soil profile with limed topsoil, but acidic subsurface soil. This yield difference also indicates that Al toxicity is a major yield-limiting factor at the trial site because the wheat genotypes ET8 and ES8 differ only in their tolerance to Al toxicity.
The isogenic lines tested here represent the extremely valuable genetic material for identifying potential contribution of Al tolerance to preventing yield losses in an Al-toxic soil. In addition, Al tolerance of modern, well-adapted wheat cultivars (as opposed to old cultivar Egret) can be improved by transferring tolerant genes that exist in ET8.

**Table 1.** Grain yield (t/ha) of Al-sensitive (ES8) and Al-tolerant (ET8) wheat genotypes grown on the field trial site at Wongan Hills in the 1999 season. Values are means ± SE

<table>
<thead>
<tr>
<th>Soil profile</th>
<th>ES8</th>
<th>ET8</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 acid topsoil over shallow subsurface acidity</td>
<td>0.82 ± 0.08</td>
<td>0.85 ± 0.11</td>
</tr>
<tr>
<td>#2 newly limed topsoil over shallow subsurface acidity</td>
<td>0.78 ± 0.05</td>
<td>1.10 ± 0.03</td>
</tr>
<tr>
<td>#3 ameliorated subsurface acidity due to surface applied lime at 2.5 t/ha in 1984</td>
<td>1.02 ± 0.02</td>
<td>1.03 ± 0.06</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>0.87</strong></td>
<td><strong>0.99</strong></td>
</tr>
</tbody>
</table>

The results in Table 1 also showed:

1. The Al-sensitive genotype ES8 did not respond to topsoil liming applied before sowing. By contrast, there was a 29 per cent increase in the grain yield of ET8 due to this lime application.

2. Wheat genotypes produced 21 per cent (ES8) and 24 per cent (ET8) higher yield due to the lime applied 15 years ago. This indicates that the benefits of liming can last at least 15 years after initial application at 2.5 t/ha.

It is interesting to note that there were no differences in the yield between the two wheat genotypes in either the fully acidic soil profile (#1) or in the ameliorated soil profile (#3) (Table 1). This indicates that a) liming is more beneficial than using Al-tolerant wheat genotypes, but b) using Al-tolerant genotypes as opposed to Al-sensitive ones can provide early response to liming (compare #1 and #2) and is beneficial when subsurface acidity is present (compare #1 and #3).

A more detailed glasshouse study using reconstructed soil columns examined the effect of subsoil acidity on the growth of these two wheat genotypes. The soils were collected from the field trial site at Wongan Hill. The reconstructed soil profiles contained the same topsoil (0-10 cm) from the limed strip and different subsoil (below 10 cm): one from 15-25 cm of the unlimed and the other from 15-25 cm of the limed strip. The results showed that subsoil acidity decreased the yield of ES8 (Al-sensitive) by 44 per cent and of ET8 (Al-tolerant) by 12 per cent. The ET8 line proliferated more roots than ES8 in the acid subsoil layer (Figure 2).
CONCLUSION

- Al-tolerant wheat genotype yields higher than Al-sensitive genotype when the topsoil is limed and subsoil acidic.
- Al-tolerant wheat genotype proliferates more roots in the acid subsoil than Al-sensitive genotype.
- The benefits of liming may last at least 15 years after initial application at 2.5 t/ha.

Key Words
Al-tolerance, genotypic variation, root proliferation, subsoil acidity
SOIL ACIDITY IN THE NORTHERN REGION

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BACKGROUND
For this project, the Northern Region is described as the area of Binnu to Moora, west to the coast and east to the end of the broad acre agriculture zone.

From 1996 to 1998 inclusive, this area received heavy input from the “Time to Lime” campaign. The soil types were sandier with higher proportions of acid soils hence the greater potential for the uptake of acid soils technology.

In 1999 and 2000 the project focus moved south to the central, great southern and south coast areas. The result has been a significant decrease in the presence of this project in the Northern Region.

TRIALS
In 1996, eleven demonstration sites were established throughout the Northern Region at Northampton, Mullewa, Bindi Bindi, Morawa, Watheroo, Kalannie, Maya (2 trials), Three Springs, Mingenew and Dandaragan.

In 1999, the Northampton, Mullewa, Kalannie, Dandaragan sites were monitored for grain production, and pH change.

Conclusions from the 1999 work were:

Northampton
• Applying 1 t/ha and 2 t/ha of lime in 1996 (limesand 62%NV and 99% fine) significantly increased soil pH by 0.94 and 1.44 pH units respectively in the 0–10 cm soil depth compared to no lime.

• Screenings in Brookton wheat (sown 20/5/99) were significantly higher where 1 t/ha of lime was applied compared to 0 t/ha and 2 t/ha.

Mullewa
• Applying 1 t/ha of lime in 1996 (limesand 67% NV and 93% fine) significantly increased soil pH at the 0–10 cm, 10–20cm and the 20–30cm soil depths by 0.84, 0.36 and 0.28 pH units respectively compared to applying no lime.
• Applying 2 t/ha of lime in 1996 (limesand 67% NV and 93% fine) significantly increased soil pH at the 0–10 cm, 10–20cm and the 20–30cm soil depths by 1.12, 0.70 and 0.46 pH units respectively compared to applying no lime.

• The yield of Brookton wheat (sown 05/05/99) was significantly decreased by 120kg/ha where 2 t/ha of lime was applied in 1996 compared to applying no lime.

Kalannie
• Applying 1 t/ha and 2 t/ha of lime in 1996 (limesand 93%NV and 98% fine) significantly increased pH in 1999 by 1.36 and 1.72 pH units respectively at the 0–10cm soil depth compared to applying no lime

• Applying 2 t/ha of lime increased the soil pH greater than applying 1 t/ha of lime at the 0–10cm soil depth.

• Lime has changed the concentration of manganese in the soil, therefore, tissue testing should be carried out to avoid any further deficiencies.

Dandaragan
• Applying limesand in 1996 (limesand 93%NV and 99% fine) at 1 t/ha and 2 t/ha, increased soil pH in 1998 and 1999 in the 0–10cm and 10–20cm soil depth.

• The pH in the chalk lime treatments in any of the soil depths did not differ from the unlimed control in 1999.

• More intensive sampling on pasture dry matter production will give a better indication of real differences between the treatments.

LIME PITS
The proliferation of lime deposits since 1994 has had the greatest impact in the Northern Region. In 1999 there were thirteen coastal limesand deposits and three inland dolomite deposits servicing the Region.

Competition for market, price competition between suppliers, product quality (is what the farmer buying what is being advertised), and a developing industry were challenging throughout 1999.

The development of the Australian Fertiliser Services Association, Agricultural Lime Industry Code of Practice was commenced in 1999 and will continue into 2000/01. The code is aimed at improving the professionalism of the industry, giving the consumers better product confidence and enhancing market development within the Agricultural Lime Industry.
LIME USE
Lime use in the Northern Region was not quite so prolific in 1999 with most suppliers reporting a downturn in output.

The Australian Bureau of Statistics 1998/99 Agricultural Commodity Survey figures supported the industry downturn by reporting a decrease in lime usage for the Northern Region of 71,000 tonnes even though the state used a record 653,000 tonnes in 1998/99.

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

Key Words
Northern Region, lime use
SOIL ACIDITY IN THE CENTRAL REGION

Sally-Anne Penny
Development Officer, Dryland Research Institute, Merredin

BACKGROUND
Soil acidity is a major concern in the central/eastern wheatbelt because of the area’s naturally acidic soils and long history of farming. Increasing awareness of the benefits of improving these acid soils has led to an unprecedented interest in lime use.

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

In 1997 a trial was established at West Popanyinning comparing three lime products (crushed limestone, G-lime, and a blend of crushed limesand and G-lime), and a trial 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 lime rates were compared in demonstration trials at Mukinbudin, and South Bodallin.

These trial sites will continue to be monitored in 2000.

LIME PITS
The central/eastern wheatbelt region now has an active dolomite pit at Westonia (50 kms east of Merredin). The dolomite falls within the quality range that currently exists in Western Australian dolomite pits of approximately 40-70% Neutralising Value and 60-80% Fineness.

Apart from the dolomite, all other lime products must be sourced from outside of the area.

LIME USE
Lime tonnage was slightly down in the area for 1999 compared to 1998 with approximately 93,000 tonnes spread. This is possibly due to budget constraints after the devastating frosts in the 1998 season.
Rate of lime use in the region is still low considering the pH of the soils in the area.

The main barrier to lime adoption is the cost of freighting the product. Freight will always be a major cost, however money spent on lime in the short term will be justified by sustainable production achieved in the long term.

Lime usage for the 2000 season is unlikely to be greater than 1999 due to low commodity prices.

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

Key Words
Central region, lime use
SOIL ACIDITY IN THE SOUTH COAST REGION

Andrea Hills
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LIME USE
Soil pH values on the sand plain soils of the south east vary considerably, with topsoil values around 4 pH. Farmers, particularly those growing canola, should be monitoring paddocks and applying lime, as canola has the potential to respond to lime within a few years of application.

Lime use has not increased, although awareness has intensified. One of the main suppliers sold only 2,145 tonnes in 1998/99. One explanation may be the adoption of claying, although it is an expensive process. AGWEST trial results and the experiences of South Australian farmers have shown dramatic increases in grain and pasture production. Claying seems to have taken priority as a soil improvement measure.

DEMONSTRATION SITES
Trial results from the two demonstration sites established in 1998 were limited. The Neridup site was spread with G-lime and local crushed limestone at two rates. This site was in pasture this season and has now been sown to a summer crop of forage sorghum. The other demonstration site was spread with crushed limestone from another pit. It was sown to Cascades wheat, but showed no consistent yield improvement from lime use.

STATE LANDCARE CONFERENCE
The conference was held in Esperance this year. The author presented a paper (which was co-written with Amanda Miller) on the Time to Lime extension campaign’s tools and techniques.

There was also a prominent display linking soil acidity to a host of land degradation issues such as erosion and salinity.
LIME SUPPLIES
A third lime supplier reasonably close to Esperance commenced operations late last summer. While the other two pits are crushed limestone, this one is limesand. The neutralising value of this lime does not appear to be as high as the Lancelin/Dongara limesands which are often 90% +, but it is still adequate for agricultural purposes. The owner is also quite enthusiastic about promoting his product and building up business in the district - and the competition may bring down the price of lime in Esperance, another factor that currently restricts its use.

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

Key Words
South east region, Landcare Conference, lime use
SOIL ACIDITY IN THE GREAT SOUTHERN REGION

Daniel Lamb
Agriculture Western Australia, Lake Grace

BACKGROUND

The undulating country between the major lake chains is a mixture of yellow earths and siliceous sands and lateritic podzolic soils. Although salinity, wind erosion and water erosion are major issues on these soils, acidification through product removal and management practice is becoming more of a problem.

TRIALS

Four lime trials were established in 1994 and 1996 to demonstrate the need for lime in the Great Southern Region.

Trials commencing 1994

In 1994 trials were established on Bruce Hill’s farm at Varley to compare five rates of lime (0, 0.5, 1, 2 and 4 t/ha) additionally each plot received 1.5 t/ha of lime in 1998. Manganese sulphate was also applied at 30 kg/ha (deep banded) on half the trial.

For lupins on wheat, the application of lime decreased the availability of manganese in lupins to levels where split seed would be expected. Deep banding of manganese sulphate prior to sowing in 1999 has raised the levels of manganese in stems to levels where split seed would not be expected.

Good responses in wheat and canola on the same site have been observed. After six years pH has increased in the topsoil where lime was applied. However, only the 4 t/ha treatment has increased pH in the 10-20 cm layer.

For wheat on lupins, where lower yields caused by lime-induced Mn deficiencies were observed the previous year, lime had no significant effect on wheat yields. The applications of 1, 2 and 4 t/ha of lime increased pH in the soil down to 20-30 cm.

Demonstration trials commencing 1996

In 1996, trials were established to compare three rates of lime application at 0 t/ha, 1 t/ha, and 2 t/ha as well as plus and minus manganese fertiliser applied at 30 kg/ha. At Newdegate where lupins were growing on wheat stubble, 1 and 2 t/ha applications of lime increased pH in the 0-10 cm layer.
In Varley, 2 t/ha of lime applied in 1996 has increased the soil pH in the 0-10 cm layer, no other differences in pH were statistically different when measured in 1999.

**LIME PITS**

The Great Southern Region currently has three dolomite pits. Two are situated at Lake Magenta and another in the Pingrup area.

**LIME USE**

In the Great Southern Region approximately 150,000 tonnes of limestone, limesand, dolomite and G-lime have been applied over 144,000 hectares by 700 farmers.

Limestone has been sourced from Myalup, Manypeaks, Nannarp and Denmark. Limesand has been sourced from Lancelin and Bornholm. Dolomite has been sourced from Pingrup and Lake Magenta.

Although production losses from frosts in a number of areas have left some farmers with little money to play with, increasing awareness of the benefits of liming has seen a general increase in the practice.

**Acknowledgements**

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

**Key Words**

Great Southern Region, Lime Pits, Lime Use
UNDERSTANDING SUBSOIL ACIDIFICATION

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CLIMA/Soil Science and Plant Nutrition, The University of Western Australia

INTRODUCTION
Subsurface soil acidification under crops has the potential to severely limit crop and pasture production. The application of lime is the usual treatment for surface acidity, but is less effective for the amelioration of subsurface soil acidity. For long-term sustainability, the prevention or minimisation of subsurface soil acidity is important and should be based on sound knowledge of how subsurface acidity occurs.

In this report, the effect of root distribution and excess cation uptake were examined, as well as the nitrogen cycle on acid production in soil profiles under different crop species. The results suggest that increased proton excretion from roots occurs in regions where excess uptake of cations over anions occurs. Nitrogen transformation in and leaching of nitrate from the topsoil are not a cause of subsoil acidification.

METHODS
A reconstructed soil column experiment was conducted in a phytotron room to test the effect of nitrate leaching on the development of subsoil acidity under lupin and subterranean clover. Basal nutrients and calcium nitrate were applied to the top 10 cm layer. Half of the columns received 2 g of calcium nitrate in the top 10 cm layer. Nitrate leaching was achieved by adding excess water to the surface of the columns.

A second soil column experiment examined the effect of nitrogen transformation in the topsoil on subsoil acidification under lupin, subterranean clover and wheat. Basal nutrients were applied uniformly to the entire columns. Plants were grown for 82-105 days. Soil columns in both experiments were sectioned and soil pH, ammonium and nitrate were measured.

A solution culture study using a vertical split-root system examined whether rooting medium acidification by legumes occurs in zones of excess cation uptake. Nodulated lupins were grown in the system with various combinations of full nutrients (minus N) and minimal nutrients in top and bottom chambers (Table 1).
RESULTS

In soil columns where basal nutrients were only applied to the top 10 cm layer, about 60-70 per cent of total root length of lupin and over 50 per cent in case of subterranean clover were distributed in that layer. Growing N₂-fixing plants decreased soil pH in all layers but more significantly in the top 20 cm (by up to 0.7 units).

Where basal nutrients were applied uniformly throughout the column, root length density of lupin and subterranean clover tended to increase with depth. Decrease in pH in soil profiles correlated well with an increased root length density of both species (Fig. 1). The results suggest that the root activity is a significant contributor to soil acidification.

Nitrification and nitrate leaching have been suggested as a major cause of soil acidification. Soil column experiments examined the effect of these processes on subsoil acidification under lupin, clover and wheat. The results showed that leaching of nitrate [added as calcium nitrate] from the topsoil caused less acidification at all the depths of the soil profile compared to the treatment without calcium nitrate. In the second experiment, plants grown with ammonium sulphate in 0-10 cm of the column caused more soil acidification in the top 10 cm but less acidification in 10-50 cm layer than plants grown without ammonium sulphate added (Fig. 2).

It is concluded that nitrogen transformation in the topsoil and nitrate leaching from the topsoil are unlikely to cause subsoil acidification. In contrast, uptake of leached nitrate by the roots in subsoil layers reduces net acid production in these layers.
In the split-root study, average root length, surface area and number of root tips were the same in both chambers across all treatments. There were significant differences in proton excretion, with more acidification occurring in full nutrient solution than in the one with minimal nutrients (Table 1).

These results suggest that greater acidification coincides with greater nutrient uptake. The greater acidity produced in the full-nutrient chamber was related to excess uptake of cations over anions.

Table 1. Proton excretion by lupin plants grown in the split-root system with varied nutrient supplies

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Nutrient supply</th>
<th>Top chamber</th>
<th>Bottom chamber</th>
<th>H⁺ excretion (µmol/m root/day)</th>
<th>Top ± std dev</th>
<th>Bottom ± std dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>full / min</td>
<td>full nutrients</td>
<td>Ca and B only</td>
<td>full nutrients</td>
<td>31 ± 3</td>
<td>23 ± 4</td>
<td></td>
</tr>
<tr>
<td>min / full</td>
<td>Ca and B only</td>
<td>full nutrients</td>
<td>full nutrients</td>
<td>15 ± 1</td>
<td>40 ± 8</td>
<td></td>
</tr>
<tr>
<td>full / full</td>
<td>full nutrients</td>
<td>full nutrients</td>
<td>full nutrients</td>
<td>25 ± 8</td>
<td>43 ± 17</td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSION

- Excess uptake of cations over anions by plant roots is a major cause of subsoil acidification.
- Nitrogen transformation in the topsoil and nitrate leaching from it are unlikely to cause subsoil acidification.
- Plant uptake of nitrate in the subsoil may reduce subsoil acidification.
INCREASING THE VALUE OF A ROTATION BY APPLYING LIME

Chris Gazey and Michael O’Connell
Agriculture Western Australia

KEY MESSAGES
Economic analysis of a long term trial at Holt Rock in Western Australia demonstrates that the application of lime to manage soil acidity has increased average gross margins over the rotation by as much as 30 per cent. However, there was a delay of two seasons before the costs of lime were recovered. This highlights the need to view the investment in lime over the whole rotation and not just for individual crops.

AIMS
A long-term trial was established in 1994 to investigate the effect of lime on the growth and yield of narrow-leafed lupins. Subsequently the trial has followed the farmer’s rotation and has provided information on the effects of lime on a range of crops and their nutrition.

METHOD
An acidic sand over gravel site was selected on Bruce Hill’s farm near Holt Rock, south east of Hyden in the Eastern wheatbelt of Western Australia. Limesand was applied in 1994 at the rates of 0, 1, and 2 t/ha. The plots were sown from 1994 to 1996 using a conventional plot seeder. From 1997 to 1999 they were sown using the farmer’s machinery. The plots were harvested each year using a plot harvester.

Gross margins for the limed and unlimed plots have been calculated for each year of the rotation. The cost of spreading lime was assumed to be $32 and $60 /ha for 1 and 2 t/ha respectively, while the grain prices used reflect the prices that would have been received in each of the years.

In 1999 an additional treatment of manganese fertiliser was applied to some of the limed plots. A cost of $36 /ha was allowed for the deep banding of this fertiliser. Other variable costs (sprays, seed, fuel etc.) were assumed to be $100, $130 and $160 /ha for lupin, wheat and canola.
RESULTS

Grain yields for the trial are presented in Table 1. The very low wheat yield in 1998 was caused by the severe frost events in that year. Reductions in lupin grain yield following the application of lime reflect the marginal manganese status of this site created by the increase in the soil pH.

Table 1. Grain Yield (t/ha) for trial 94LG17, Holt Rock, Western Australia.

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
<th>Unlimed</th>
<th>1 t/ha lime in 1994</th>
<th>1 t/ha lime in 1994 plus manganese in 1999</th>
<th>2 t/ha lime in 1994</th>
<th>2 t/ha lime in 1994 plus manganese in 1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>Lupin</td>
<td>0.61</td>
<td>0.64</td>
<td></td>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>Wheat</td>
<td>1.49</td>
<td>1.83</td>
<td></td>
<td>1.98</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>Lupin</td>
<td>1.22</td>
<td>1.10</td>
<td></td>
<td>1.19</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>Canola</td>
<td>1.29</td>
<td>1.55</td>
<td></td>
<td>1.69</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Wheat</td>
<td>0.11</td>
<td>0.11</td>
<td></td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>Lupin</td>
<td>1.64</td>
<td>1.67</td>
<td>1.74</td>
<td>1.54</td>
<td>1.64</td>
</tr>
</tbody>
</table>

Gross margins for each crop and lime treatment are shown in Table 2. All dollar values are nominal - that is they reflect the actual cashflow for each year and have not been adjusted for inflation, time value or opportunity cost of alternative investments. However, the analysis was repeated using an investment appraisal approach (not shown here) and the conclusions remain unchanged.

Good prices for wheat in 1995 and canola in 1997 helped to capitalise on the yield benefits of liming, though even with poorer prices the lime would have been a worthwhile investment. Manganese applied in 1999 has had little negative impact on average profitability and, like the lime, will provide benefits for several years to come. It must be remembered that the expression of lime induced manganese deficiency is very seasonally dependent. Given the good conditions at the end of the 1999 growing season at Holt Rock, split seed and reduced lupin yields were unlikely.
### Table 2. Gross margins for trial 94LG17 at Holt Rock

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
<th>Gross Margins ($/ha)</th>
<th>Unlimed</th>
<th>1 t/ha lime in 1994</th>
<th>1 t/ha lime in 1994 plus manganese in 1999</th>
<th>2 t/ha lime in 1994</th>
<th>2 t/ha lime in 1994 plus manganese in 1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>Lupin</td>
<td>-15</td>
<td>-42</td>
<td>-72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>Wheat</td>
<td>183</td>
<td>254</td>
<td>286</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>Lupin</td>
<td>126</td>
<td>104</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>Canola</td>
<td>259</td>
<td>344</td>
<td>389</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Wheat</td>
<td>-115</td>
<td>-115</td>
<td>-115</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>Lupin</td>
<td>80</td>
<td>84</td>
<td>55</td>
<td>69</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average gross margin (nominal $/ha)</td>
<td>87</td>
<td>105</td>
<td>100</td>
<td>113</td>
<td>109</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% Increase compared to unlimed</td>
<td>21</td>
<td>15</td>
<td>30</td>
<td>25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### CONCLUSION

The yield responses in this trial have been among the best of all the medium to long term lime trials that have been conducted in Western Australia, and clearly demonstrate the potential long term profitability of liming to manage soil acidity. The trial also shows that the application of additional costs such as manganese fertiliser can be absorbed.

The application of 1 t/ha of lime has resulted in an increase in average gross margins of between $13 and $18/ha over the six years of this trial. Due to the significant response in wheat in the second year of the trial the cost of the application of lime was recovered after two seasons. Similar analyses from other trials have shown that it may take several years more than this for the cost of lime to be recovered but the benefits are long lasting. It is important that growers recognise this and budget accordingly. However, there is now clear evidence that a liming program for acidic soils should be implemented as soon as possible, especially in those situations where lime is required to leach down to correct a sub-surface acidity problem. Appropriate management will ensure that any lime-induced changes can be overcome.

### Acknowledgements

Thanks to the Newdegate Research Support Unit (AGWEST) for maintaining the trial for the first few years and also to Mr Bruce Hill who has provided the site, trial seeding and maintenance, valuable discussions and freely given farm data over the years.
THE PROFITABILITY OF LIMING ACID SOILS

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Western Australian farmers are currently treating 653,000 hectares of agricultural soil annually for low pH, and although this is four times that of 1994, it is barely stabilising the soil pH decline.

Since 1994 numerous long-term lime trials have been conducted at many locations across the state. These trials have helped to highlight the potential benefits of liming.

RESPONSES TO LIMING

In some trials, yields from crops like wheat, barley and canola increased over 20 per cent within three years of liming acid soils. These yield responses mean the cost of liming can be recovered within a few years of application, with benefits continuing for up to ten years or more. Under these circumstances liming represents a very attractive investment.

For example, Table 1 shows the yields from a lime trial at Holt Rock in the south eastern wheatbelt of WA. The soil type at this site is a yellow sandplain with initial pH of 4.9 at 0 – 5 cm depth, 4.4 at 5 – 10 cm, and 4.0 at 10 – 20 cm (all measured in calcium chloride). The application of 1 t/ha of lime has resulted in an increase in average gross margins of $15/ha over the seven years of this trial. The significant response in wheat in the second year meant that the cost of liming was recovered after two seasons. Further benefits are likely to accumulate in future years, leading to continued gains from liming.

Table 1. Responses to lime at Holt Rock, WA. Lime was applied in 1994 at 1 t/ha.

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
<th>Grain without lime (t/ha)</th>
<th>Grain with lime (t/ha)</th>
<th>Change in yield with lime</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>Lupins</td>
<td>0.61</td>
<td>0.64</td>
<td>5%</td>
</tr>
<tr>
<td>1995</td>
<td>Wheat</td>
<td>1.49</td>
<td>1.83</td>
<td>23%</td>
</tr>
<tr>
<td>1996</td>
<td>Lupins</td>
<td>1.22</td>
<td>1.10</td>
<td>-10%*</td>
</tr>
<tr>
<td>1997</td>
<td>Canola</td>
<td>1.29</td>
<td>1.55</td>
<td>20%</td>
</tr>
<tr>
<td>1998</td>
<td>Wheat (frosted)</td>
<td>0.11</td>
<td>0.11</td>
<td>0%</td>
</tr>
<tr>
<td>1999</td>
<td>Lupins</td>
<td>1.64</td>
<td>1.74</td>
<td>6%</td>
</tr>
<tr>
<td>2000</td>
<td>Wheat</td>
<td>3.22</td>
<td>3.38</td>
<td>5%</td>
</tr>
</tbody>
</table>
*Note: The lupin yield suppression in 1996 was a result of a deliberate attempt to induce a nutrient deficiency in that crop. Results from this trial have provided valuable information on the management of nutrients when liming. With adequate nutrition management, growers should be able to minimise the risk of yield suppressions.

In other trials there has been a lag of three to five years before yield responses occur. A range of factors might cause this to happen. For example, it may take several years for lime to leach into an acid subsoil; or a run of good seasons might allow crops to yield well because they don’t have to rely on extracting water from an acid subsoil.

Using lime over the longer term can be an attractive investment on acid soils, although where a time lag occurs, it will be several more years before farmers recover the costs associated with applying the lime.

Figure 1 shows the cumulative effect of liming on cash flow from a long-term lime trial at Wongan Hills, north east of Perth. Lime was applied in the mid 1980s at 2.5 t/ha. The site is sand over gravel, with the unlimed pH of 4.6 at 0 – 10 cm, 4.1 at 10 – 20 cm and 4.2 at 20 – 30 cm. It took about four years to recover the costs of liming, yet substantial yield benefits have continued for over ten years at this site making the lime a very good investment.

![Figure 1. Returns to liming from a long-term trial at Wongan Hills, WA.](chart.png)
THE LIMING DECISION

There are several important criteria that should be met if liming is to be profitable. Those listed here are general and it is recommended that growers consult local agronomists for specific recommendations.

Soil pH

The starting pH of the soil should be 4.5 to 5.0 or less (measured in calcium chloride), depending on rotation. Profitable responses are unlikely in less acid soils (higher pH). It is important for farmers to also assess pH in the subsoil, as a good topsoil pH is no guarantee that the subsoil isn’t acidic.

Of the major crops wheat, oats, narrow leaf lupins and triticale tend to be more acid tolerant than barley, canola and alternative grain legumes (although there are acid sensitive wheat varieties). Sub-clover and serradella pastures are more acid tolerant than medics and lucerne. So an economic response to lime would be more likely in a rotation that includes canola and barley than in a continuous wheat - lupin system.

Figure 2 shows results from WA based modeling. In this example, the profitability of liming a wheat - lupin rotation is compared with wheat - canola - barley - lupins. Lime has been applied at 1 t/ha in the first year to a deep sand with topsoil pH of 4.7 and subsoil pH of 4.5. Dollar values have been discounted at 7 per cent per annum.

![Figure 2. Comparison of expected returns to liming under two different rotations.](image-url)
The results demonstrate the impact of rotation selection on the potential returns to liming, and show the importance of prioritising lime application to acid sensitive crops and pastures. Under the wheat-lupin rotation, returns from liming are modest, and it takes seven to eight years to recover the cost of lime. With barley and canola included in the rotation, the application of lime is much more attractive with cost recovery within three years (in this particular example).

**Lime test strips**

Despite its importance, pH has generally not been a good predictor of yield response in WA lime trials. For example, excellent responses were observed at a site near Narrogin where the starting pH (measured in calcium chloride) was 4.7 in the topsoil and 4.6 in the subsoil, while other more acid sites have taken longer to respond to lime. This variability in response to liming means that it can be a good idea for growers to conduct lime test strips before embarking on a large scale liming operation, especially if there is a lack of local trial data. A simple measure of soil pH will not necessarily be a good predictor of yield response.

Test strips will need to be monitored for several years, as it may take some time before a response occurs. Also, when liming a paddock, leave a strip of untreated land for future comparison, otherwise it will be difficult to tell if the lime has increased yields.

The benefits of using lime are long term whilst costs are incurred occasionally so only small yield responses are required to break even. For example, in a wheat-lupin rotation a yield increase in the wheat crops of 3 - 10 per cent over a ten year period will generally cover the cost of applying lime at 1 t/ha. Yield potential of the site and frequency of acid sensitive crops will largely determine break even yield responses.

**Nutrient management**

Applying lime can change the availability of some plant nutrients, especially manganese, copper and zinc. If these nutrients have been allowed to decline to marginal status, then a deficiency may occur following liming. For this reason, nutrient levels must be adequately maintained. In particular, manganese in lupins should be monitored. This is critical. In WA poor manganese nutrition has led to yield reductions in excess of 30 per cent in narrow leaf lupins.

Assuming a farm gate price of $120/t and a potential lupin yield of 1.5 t/ha, this could equate to a loss of $50/ha or more. A lupin stem test at flowering is a more reliable indicator of the nutrient deficiency than a soil test.

Farmers should also be aware that herbicide residues, which require acidic conditions to break down (e.g. sulfonylureas or “SUs”), will remain in limed soil longer. This can cause damage to future crops that are sensitive to these herbicides. The risk of this occurring is minimised when lime is incorporated into the topsoil and relevant herbicide rates are adjusted.
Lime rate and quality

It is common practice in WA to apply lime at about 1 t/ha at intervals of seven to ten years, regardless of the situation. A higher rate may be required in some circumstances. For example, soils that are heavier, or have large amounts of organic matter will require more lime than sandy soils with low organic matter.

Increased rates will also be necessary if lime is required to leach down to an acid subsoil, if there are large amounts of soluble aluminium in the soil, or if acid sensitive species are to be grown.

Growers should keep in mind that the total benefits of liming are likely to be larger if they apply a low rate of lime over a larger area, rather than a high rate over a small area.

The neutralising value of lime varies considerably depending on the product and this means that growers may need to adjust their application rates accordingly. As a general rule of thumb, the higher the neutralising value the quicker the response time, especially when the product is incorporated into the soil. A grower’s decision on which lime to use should be based on neutralising value and the costs of purchasing, transporting and spreading the product.

CONCLUSION

The introduction of lime to previously unlimed farming systems requires management changes for it to be successful, although these changes are not necessarily costly. Nutrient management is particularly important, and there may be implications for the use of some herbicides.

The potential returns that growers can expect will depend largely on the choice of crop rotation and the severity of acidity. But there is little doubt that integrating the use of lime into acid farm systems offers growers the opportunity for higher crop yields. In some cases benefits can last for well over ten years, making liming an attractive long-term investment.
SUSTAINABLE MANAGEMENT OF SOIL WATER AND NUTRIENTS IN THE MEDIUM RAINFALL ZONE OF WESTERN AUSTRALIA

Ian Fillary
C.S.I.R.O.

TRIALS

Two field research sites 18km south of Wongan Hills were established in 1998. The aim of the trials was to study the effect of annual crops (lupin and wheat), subterranean clover-based pasture, lucerne, long-season annuals (serradella and biserulla) and perennial grass-annual legume pastures on water use, nutrient flows and soil acidification. The trials were located in the 400 mm rainfall zone of the Western Australian wheatbelt.

One site has deep sand grading into a clay at 1.2 to 1.5 m and is at a high elevation in the Gabby Quoi Quoi catchment. The second site is close to the Gabby Quoi Quoi creek and has duplex soil with 30-50 cm sand over clay with the water table at 2.5 to 3 m.

Most other studies of the effect of crop and pasture species on drainage and nutrient flows have been undertaken in the higher rainfall zones of Western Australia closer to the coast.

The effect of lime rate and lime fineness on the amelioration of subsoil acidity under conventional and minimum tillage, are additional subplot treatments in lupin-wheat plots. Both sites have been intensively instrumented to enable daily assessments of drainage below the rooting zone of annuals and perennials. Use of deep soil water outside of periods of drainage is being evaluated using networks of neutron access wells.

NUTRIENT

Nutrient flows have been determined by traditional soil coring techniques, the application of suction cups to sample soil solution, the *in situ* incubation of soil in net mineralisation apparatus (to measure N and S inputs) and the analysis of nutrient uptake by pasture and crop species.
Lucerne sown in June 1998 survived a dry spring and summer in 1998/99 even though soil at 0.2 m was strongly acid (pH 4 to 4.2 in 0.01 M Ca Cl\(_2\)). On the other hand, perennial grasses (tall wheat grass, phalaris and tall fescue) did not persist on a deep sand soil and only small densities established on a duplex soil (water table within 3 m).

Excellent production was obtained from serradella treatments in 1998, but this treatment produced less biomass than subterranean clover-based pasture in 1999, chiefly because of lower densities of self-regenerating seedlings in the serradella pastures.

**RAINFALL**

Rainfall in 1998 was lower than the long-term average for the area and as a result only 30 mm of drainage occurred below 1.5 m in all treatments. Cyclonic rainfall in March 1999 and in late May 1999 recharged soil water in all treatments and caused ~100 mm of soil water to drain below 1.4 m by 1 June.

Subsequent winter rainfall resulted in an additional 60-80 mm of drainage below 1.5 m by 1 September.

Low amounts of nitrate were in the soil under all pasture treatments before the onset of drainage in late May whereas in excess of 100 kg nitrate N was in the soil to 1.5 m in wheat plots following lupin at the same date. As a result the potential for nitrate leaching and surface soil acidification was appreciably lower in pasture treatments than for wheat following lupin.

Soil water to 2.5 m was essentially the same for both annual and perennial pasture treatments in late July. Thereafter lucerne progressively extracted more water from soil between 1 to 3.5 m than subterranean clover based pastures.

**CONCLUSION**

Research undertaken has highlighted the ability of lucerne to establish and grow on soils with acidic sub soils, and to withstand periods of water deficit over summer, constraints that are prevalent in the Western Australian wheatbelt.

Key Words

Wongan Hill, nutrient, rainfall
ZERO TO END PRODUCT IN 6 MONTHS
The Agricultural Lime Industry Code of Practice

Amanda Miller
State Development Officer – Soil Acidity,
Agriculture Western Australia, Lake Grace

ABSTRACT STATEMENT
The Agricultural Lime Industry in Western Australia has grown from six suppliers in 1994/95 to 45 suppliers operating 50 commercial locations in 1999. Nearly 3,000 farmers in WA now use 653,000 tonnes of lime (limesand, limestone, dolomite, lime/cement kiln dust), over an area of 454,000 hectares. The product is transported over 2.5 million kilometres.

In April 1999 the Australian Fertiliser Services Association approved an Agricultural Lime Industry Sub-Committee to help achieve a voluntary Code of Practice. The final Code of Practice was released in October 1999.

PROJECT BACKGROUND
Approximately half of the agricultural soils already require the application of lime, and two thirds of the agricultural soils require changes in management practices to address soil acidity.

The Agricultural Lime Industry in Western Australia has grown from six suppliers in 1994/95 to 45 suppliers operating 50 locations in 1999.

Farmer adoption of acid soil management has risen from less than 1,000 farmers to just under 3,000 farmers in 1998/99 (Australian Bureau of Statistics, 1995 and 1999 preliminary).

Lime use has risen from 154,000 tonnes in 1993/94 to 653,000 tonnes of lime (limesand, limestone, dolomite, lime/cement kiln dust) in 1998/99. The area treated has risen to over 454,000 hectares during this four year period and the product is transported over 2.5 million kilometres (Australian Bureau of Statistics, 1995 and 1999 preliminary).

This massive increase in agricultural lime usage has brought with it associated problems including product quality, product consistency, product supply, disputes, safety, mining, conservation and local government issues. In order to preserve and enhance the agricultural lime industry’s image, increase lime sales, improve buyer perceptions and to ensure the long-term sustainable extraction of lime for the future,
the Australian Fertiliser Services Association (WA) embarked upon establishing an industry driven Code of Practice.

The AFSA worked closely with the lime industry, Mines and Energy, Ministry of Fair Trading, Local Government, Department of Environmental Protection, Environmental Protection Authority and Agriculture Western Australia, to produce the Code of Practice.

THE PLAN

The AFSA is the peak industry body for suppliers, transporters, spreaders and agronomic advice providers for fertiliser and soil ameliorant products (including lime).

In April 1999 the AFSA WA branch approved an Agricultural Lime Industry Sub-Committee to help the Industry achieve a voluntary Code of Practice.

The project, funded by the Natural Heritage Trust and named “Transferring responsibility for management of soil acidification to industry”, includes $15,000 to be matched by direct and in kind support by the AFSA to assist with the Code’s development and ultimately a Quality Assurance program.

After six months, six technical meetings, four focus group meetings, two industry meetings and many additional hours, the Agricultural Lime Industry achieved the production of a “live” Code of Practice in October 1999. This document is undergoing constant development, and members receive updated pages and sections as the document evolves.

THE PROCESS

At the establishment meeting the names of persons considered to have the greatest knowledge in this area were put forward. These people where then contacted to obtain their agreement to forming the technical committee that would drive this whole process.

In 1996 five AFSA members developed a solid outline and this initial work formed the foundation of the Code of Practice that was released.

Industry people worked cohesively on the document, mindful that its contents would form “Best Practice” and become a reference that regulatory institutions would rely on. The blend of people that formed the committee, their position within the industry and their variety of experience, proved to be the strongest point of the development process.
Industry Meetings & Focus Groups

Industry Meeting – Initial

The meetings were used to develop relationships and mutual respect, as many of the stakeholders in this rapidly expanding industry that covers a large geographical area (Geraldton to Esperance) had never met others from the same industry.

At the first full meeting held at Katanning, 48 people attended representing suppliers, transporters and spreaders. Of the 48 attendees there were 17 lime suppliers representing 80 per cent of the volume of the State’s agricultural lime supply. The level of support was enormous, and the willingness to work with each other towards a common goal was very encouraging, and gave the industry its first glimpse at what its future may hold.

Focus Groups

In this process the focus groups consisted of Agricultural Lime suppliers only. The meetings were held North and South of the Great Eastern Highway in locations in low and high rainfall zones.

The aim of the meetings was to ask 8 – 10 key questions, to discuss issues that had arisen from the Code of Practice and to address any proposed future changes. These groups allowed more members to “have their say” in a smaller forum. This process fostered greater understanding and reversed the opinions of five suppliers who initially opposed the Code of Practice as unnecessary, time consuming and expensive, to ultimately voting for and being adamant supporters of the end product.

Industry Meeting - Ratification

The proof is in the support. Twenty-one people attended the ratification meeting with proxy votes accepted from those unable to attend. Thirteen suppliers voted in favour of the Western Australian Agricultural Lime Industry Code of Practice, an impressive 70 per cent of agricultural lime production within the State.

THE RESULT

At the September meeting it was discovered that the whole Code of Practice could not be accepted as complete, and it was necessary to work on one section through November 1999 to February 2000. The Administration of the Code of Practice is also still under “construction”.

Critical feedback on the Code by farmers has been extremely encouraging, and requests have been received from local government to use this Code of Practice for other commodities such as sand and gravel. The Interdepartmental Lime Steering Committee established by the State Environment Minister the Honourable Cheryl
Edwardes is using the Code of Practice to establish a State Lime Supply Strategy. The first dolomite supplier in Western Australia to achieve SQF2000 (Safe Quality Food 2000) has used the Code of Practice as a support and reference document in the development of Hazard Analysis Critical Control Points (HACCP).

The Agricultural Lime Industry and the Australian Fertiliser Services Association are justifiably proud of what they have achieved. They have put in place a document they can conform to, a system that allows amendments and a document that can flex and adapt to suit the changing needs of the industry.

REFERENCES


Acknowledgements
Australian Fertiliser Services Association - Agricultural Lime Industry Technical Committee.
Grant Andrews National Acid Soils Committee
Lorelle Lightfoot Aglime of Australia
John Lightfoot Aglime of Australia
Ross Armstrong Greenhead Sands
Ray Levin Lime Industries
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## LIME SUPPLIERS PARTICIPATING IN CODE OF PRACTICE

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