Comparing size in lime

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Comparing Extensive research into the management of soil acidity in Western Australia is increasing farmer awareness that lime use can reduce soil acidity and improve crop yields. However, as lime use increases, the question of lime performance and particle size is becoming more critical.

Chris Gazey from the Department of Agriculture is heading up the soil acidity project, with the team comprising members from the department, CSIRO and the University of Western Australia. Mark Whitten reports on project outcomes relating to lime particle size.

Why lime particle size is important
The Department of Agriculture estimates that one million tonnes of lime is needed annually to treat acid soils in Western Australia, which means that the current rate of usage is approximately half of what is required.

While lime use in Western Australia increased from 154,000 tonnes in 1993/94 to 653,000 tonnes in 1998/99, figures from the Australian Bureau of Statistics show that lime use for 1999/00 was 576,000 tonnes.

An immediate option for increasing outcomes from the current rate of usage could be decreasing lime particle sizes, which has been shown to increase lime efficiency. When the average particle size of a given weight of lime is decreased to a finer size, it actually increases the total surface area and therefore increases the rate at which lime will dissolve. This is important to farmers seeking a return on their lime investment, as lime usually dissolves relatively slowly and can take several years to completely dissolve in the soil.

Comparing sizes
Comparing particle size in agricultural limes can be confusing because different products may contain different proportions of 'fine' to 'course' particles.

For example, Lime A and Lime B in Figure 1 have a similar proportion of particles which are less than 0.1 millimetres in diameter, but in Lime A some of the less than 0.1 millimetres
fraction is finer than in Lime B. Lime A also contains a significantly higher proportion of particles greater than 0.5 millimetres.

Particle size efficiency values from the paper by Scott et al. (see Lime particle size research in Australia below) predict that Lime A will have a physical efficiency of 45 to 50 per cent and Lime B about 50 to 60 per cent. Lime A is penalised by its 40 per cent component of particles larger than 0.5 millimetres, despite containing some finer fractions than in Lime B.

In a study related to that by Scott et al., the best of 12 commercial limes was a crushed limestone from New South Wales with a 70 per cent component of finer than 0.075 millimetres particles, and 5 per cent component of particles with a maximum size of 0.25 to 0.5 millimetres. Its physical efficiency was 86 per cent.

**Getting more from lime in WA**

Mark Whitten says that results from field trials over the past three years indicate that reducing the particle size of a widely used lime in Western Australia (Lime B in Figure 1) can substantially increase the lime's effectiveness.

Compared with unprocessed lime at the same application rate, additional grinding resulted in 95 per cent being less than 0.09 millimetres, which increased its efficiency by 22 to 29 per cent at one site and by 37 to 44 per cent at the other (see Figure 2). Even after two years, the increases in surface pH resulting from finely ground lime at lower application rates are approximately the same as increases resulting from double the application rate of the unground lime.

This agrees with the predicted physical efficiency of 98 per cent based on the particle size efficiency values of Scott et al., compared to 50 to 60 per cent for unground lime.

Although, this increase in efficiency does not necessarily mean that less lime will be required in the long-term. Instead, it indicates that responses and benefits can commence earlier by using lime that is finer than most of the limes currently available in Western Australia. It's a question of cost effectiveness. Higher production costs can be off-set by earlier returns and/or lower transport costs.

**Improving lime movement**

Much of the light land in the Western Australian wheatbelt has become sufficiently
Soil samples to a depth of one metre were collected to define the baseline pH profile of each plot before lime was applied — Gabby Quoi Quoi, May 1998 (photo by Mark Whitten).

Acid to affect the root growth of acid sensitive crops below the depth at which lime can be incorporated by normal cultivation.

Therefore, the trials depicted in Figure 2 were established in 1998 on acidic soils in the medium rainfall zone of the Western Australian wheatbelt with the aim of determining the effects of lime rate, lime particle size, and tillage (incorporation versus no-till) on lime movement into the subsurface.

In particular, the trials set out to establish whether top-dressed or surface incorporated lime could prevent subsurface acidification from threatening sustainability.

Three application rates of lime (0, 2 or 2.5 and 4 or 5 tonnes per hectare) were used at each of the trials. Half the trial plots were treated with a commercial lime as it was received, and the other half were treated with the same lime after it had been finely ground by ball-milling.

To examine the effects of tillage, limes were incorporated into half of each plot with a full-cut scarifier, while the remainder was uncultivated (no-till). The crops in both treatments were seeded with a double-disc open no-till implement. This disturbed the soil less than knife point implements which, with long blades, might have buried the lime nearly as much as a conventional scarifier.

The trials showed that compared to unlimed plots, subsurface pH (at 10 to 20 centimetres) on the gradational soil was increased significantly when 5 tonnes per hectare of either grade of the lime was applied. Increases in pH also occurred at this depth after application of 2.5 tonnes per hectare of the finer lime. At 20 to 30 centimetres, there were small pH increases regardless of particle size when lime was applied at 5 tonnes per hectare. These results provided early indications that both lime rate and fineness can influence lime movement because of their effect on surface soil pH — presumably because the higher surface pH means there is more dissolved alkalinity to leach down to the subsurface.

**Barley response greatest with fine lime**

The grain yield in 2000 from the barley treated with finely ground lime increased significantly, while increases from the unground lime were not statistically meaningful.

Subsurface pH also affected yield, as the dry finish to the season most likely caused the crop to depend on subsurface water. Barley is more sensitive to soil acidity than wheat, lupins or canola, and its root growth would be poor where soil pH is below about 4.5 (the Department of Agriculture recommends that pH should not go below 4.8).

As an average of the different tillage treatments used, the yield increased from 1.44 tonnes per hectare where no lime was applied, to 1.79 tonnes per hectare where finely ground lime was applied at 2.5 tonnes per hectare, and to 1.96 tonnes per hectare where finely ground lime was applied at 5 tonnes per hectare, representing gains of 24 per cent and 36 per cent respectively.

Assuming that the farm gate price for barley is $145 per tonne, the yield increases with the finely ground lime would represent improved returns of about $50 per hectare at 2.5 tonnes per hectare and $75 per hectare at 5 tonnes per hectare. The total cost of spreading lime at this location would be approximately $25 to $30 per tonne for lime and transported approximately
150 kilometres (this is not meant as an endorsement of a particular lime product).

In terms of pH, these yield responses at $145 per tonne would represent an increased return of about $22 per hectare per unit increase in pH from 4.3 to 6.8 at a depth of 0 to 10 centimetres, and about $109 per hectare per unit increase in pH from about 4 to 5 at a depth of 20 to 30 centimetres.

A rapid response to liming is always desirable, particularly in acid soils with little or no lime history. This is often the case in situations where short season barley, such as Unicorn, is added to the rotation as part of a strategy for controlling herbicide tolerant annual ryegrass.

Producing more effective limes could therefore be beneficial to both the lime industry and Western Australian farmers. These results show the quality of Western Australian limes can be significantly improved by decreasing the particle size.

**Lime particle size research in Australia**

Work first started in Australia in 1986 to compare the effectiveness of different sized lime particles. To obtain a realistic comparison, limestone was crushed to meet the specification of six different sieve sizes, the smallest being less than 0.075 millimetres and the largest 2 to 5 millimetres.


"The six particle size fractions were derived from a 98% pure calcitic limestone from the Marulan Quarry in New South Wales. At a given rate of application, the finer the particle size, the greater the increase in pH. This trend applies even at the 10 t/ha application rate where we expected the fineness would be of less importance."

This was one of the few trials that compared the same product crushed to different fractions of fineness.

The greater increases in pH with finer lime lasted for at least three years and were highlighted by increased yields. Coarse fractions were relatively ineffective, demonstrating the fallacy of a commonly held belief that the larger lime particles impart a longer benefit because they dissolve more slowly.

**Lime movement trials**

To complement and expand on the field trial research, the rates of dissolution of different limes under more controlled conditions are being examined.

To date, a number of representative Western Australian limes have been characterised by mineralogy, neutralising value (NV), specific surface area, and relative rates of dissolution in laboratory tests. These tests are suited to narrow particle size ranges because of their

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**Estimating the physical efficiency of lime from particle size data.**

The physical effectiveness (PE) can be estimated from the particle size of a lime using calibrations from field trials, which were conducted in New South Wales from 1986 using lime of different particle sizes (reference: Scott and Conyers 1992 above). The improvement with grinding the Western Australian lime (see Figure 2 above) was consistent with this method for estimating lime effectiveness.

To calculate the PE of a lime sample, multiply the percentage weight of each particle size by the PE factor given in the table below and divide by 100. Adding these values from each particle size gives the physical efficiency of the lime. NB: Sizes down to less than 0.075 millimetres must be measured.

For total efficiency, the PE of particle size is multiplied by the neutralising value (NV) of each size. As an approximation, the total PE value can be multiplied by the NV of the whole lime if the individual NVs are not known

<table>
<thead>
<tr>
<th>Size mm</th>
<th>PE factor (%)</th>
<th>Lime A</th>
<th>Lime B</th>
<th>NSW Best product 1986*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%wt</td>
<td>PE</td>
<td>%wt</td>
<td>PE</td>
</tr>
<tr>
<td>&lt;0.075</td>
<td>100</td>
<td>7</td>
<td>7</td>
<td>0</td>
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<td>58</td>
<td>14</td>
<td>8</td>
<td>28</td>
</tr>
<tr>
<td>0.15-0.25</td>
<td>52</td>
<td>13</td>
<td>7</td>
<td>38</td>
</tr>
<tr>
<td>0.25-0.5</td>
<td>47</td>
<td>24</td>
<td>11</td>
<td>31</td>
</tr>
<tr>
<td>0.5-1</td>
<td>34</td>
<td>33</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>1-2</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>45</td>
<td>52</td>
<td>100</td>
</tr>
</tbody>
</table>

Worked examples for estimating the physical efficiency (PE) of limes A and B, and the best crushed commercial limestone from New South Wales trials in 1986**: PE value in column two is based on application rate of 2.5 tonnes per hectare.
The Grains Research and Development Corporation is funding the current trials as part of a Soil Acidity Research Development and Extension Program in Western Australia. The field trials are a joint project between The University of Western Australia, CSIRO and the Department of Agriculture.

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Soft limes have been a problem as they fragment when stirred, and are likely to dissolve more rapidly in the tests than would be the case in the soil, particularly where cultivation is minimal. Therefore, in order to compare lime reactivity in undisturbed conditions, leaching experiments are being used to examine the effect of lime particle size, rate and type, and crop residues on the downward movement of alkalinity through the soil profile.

Six limes from Western Australia are being tested, including the lime used in field trials, and these results will be compared with the field data. Reference to the calcitic lime from the New South Wales research has also been included, as it will enable the results on lime movement to be linked with other published research on lime particle size.

The results from this experiment will be available early in 2002.

References