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Monitoring and managing soil acidity

Fionnuala Frost, Extension Officer, Northam

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Monitoring and managing soil acidity

By Fionnuala Frost,
Extension Officer, Northam
1. Map soil pH

2. Identify soils on critical pH scale

3. Soil pH below critical pH level for the selected plant variety
   - Minimize acidification rates
   - Change varieties
   - Apply lime

4. Soil pH above critical pH level for the selected plant variety
   - Minimize acidification rates
   - Monitor sites
   - Apply lime to avoid future loss of production

4 Monitoring and managing soil acidity
Introduction

This Bulletin provides information on how to identify acid soils and remedy the problem of excessive acidity. Material in this handbook is suitable for broadscale agricultural systems, and perennial and permanent pastures in the medium and higher rainfall areas of the State.

Acidity of both the surface and subsurface layers of soil is addressed. Each can be important in affecting plant growth and therefore the profitability of the farm.

Advisers and land conservation project officers can discuss any problems or questions that may arise from this Bulletin.

The order of text follows the flow chart opposite.
Mapping acidity

The first step in correcting the problem of acid soils is to map their location on the farm. Information about the current pH levels on the farm may be available from recent soil tests. These data can be plotted on to farm maps.

Produce maps for both surface and subsurface pH. Records from past soil tests may show whether there has been a decline in pH over time. It is likely that there won’t be sufficient data available to produce subsurface pH maps. If this is the case, take additional soil samples. 100 m, collect 30 to 40 pogo samples (0 to 10 cm) of soil. If there is a large area of one soil type in a paddock, take samples from several locations within it.

**Surface sampling**

Identify the major soil types in each paddock. Within a representative area of each type, for example 100 m by 100 m, collect 30 to 40 pogo samples (0 to 10 cm) of soil. If there is a large area of one soil type in a paddock, take samples from several locations within it.

**Subsurface sampling**

Collecting subsurface samples is more time consuming than collecting surface samples, so you may not sample as many areas within the paddock (though ideally you would). The soils to target for subsurface sampling are those with a light to medium texture (loam or lighter) that extends down to 25 cm.

### Soil pH

The pH of a soil is a measure of its acidity or alkalinity. Laboratory measurements are made with a pH meter on suspensions of the soil in water or in calcium chloride (CaCl₂) solution. Most soil pH values (measured in calcium chloride) range from 3.5 for strongly acid soils through 7.0 for neutral soils to 8.5 for strongly alkaline soils.
From a uniform area of soil, take samples from 15 to 25 cm deep in five to ten places. One way to do this is to dig the top 15 cm away with a spade, then take two or three pogo samples from the bottom of the hole. If you don’t have a pogo, use a small garden trowel.

If the samples are intended for analysis by a government or private laboratory, use good quality plastic bags. This will reduce the risk of the bag breaking and the sample being lost.

Ensure the sample is clearly labelled with your trading name, paddock name and sample number. Also include a label in the bag to minimize the risk of losing identification of the sample.

How to check pH

There are several methods available for testing pH. It is important that you know which solution the reading has been taken in. The most common solutions are calcium chloride (CaCl₂) and water. Readings taken in calcium chloride are generally 0.7 to 1.0 units lower than those taken in water.

CSBP used to analyse pH in water; this company now measures soil pH in calcium chloride.

The Department of Agriculture has published most of the results from its research in acidity with the values analysed in calcium chloride.
Readings taken in calcium chloride are less affected by salt levels in the soil, so are far more reliable than those taken in water when determining critical pH levels and deciding whether to lime or not. If pH readings tested in water are low, confirm the result by testing in calcium chloride.

For a quick field assessment, you can use a CSIRO inoculo Field Test Kit. This kit is available at most rural agencies for about $20 and lasts for at least a year. Values measured with these kits are only an indication. For more accurate readings, calcium chloride tests are recommended.

Portable pH meters that look like a pen are also available. These devices have an electrode and digital readout to give precise results. They retail for about $80 and are available from Selby Anax. Analyses can be done at home in either water or calcium chloride.

It is important to calibrate these instruments with standard solutions each time you use them.

There are instruments that are pushed into the ground to measure pH. These are not accurate, since they are influenced by the wetness of the soil.
Soil pH and plant growth

Critical pH ranges

Test the soil pH and check your selected crop or pasture species with the pH chart.

Soil type, fertilizer history and rainfall determine the effect that pH has on plant productivity.

Different crop and pasture species have specific sensitivities to pH. The critical pH range, shown in Figure 2, indicates the risk of production being limited by pH. At the right hand point of each box there is some risk of productivity being affected, and the left hand point indicates a large risk of

Figure 2. Critical topsoil pH ranges for crops and pastures

Barrel medics (Cyprus, Parabinga, Paraggio)
Polymorpha medics (Circle Valley, Santiago, Serena)
Murex medic (Zodiac)
Subterranean clovers; peas
Serradellas; lupins
Barley; sensitive wheats (Aroona, Cranbrook, Schomburgk, Wilgoyne)
Tolerant wheats
Oats triticale
Cereal rye

pH (calcium chloride)
Have the soil that is collected from your paddock tested for pH in calcium chloride. Using Figure 2, cross check the result with the crop or pasture species intended for seeding. If the pH value is lower than the range given in Figure 2, the potential productivity of the paddock is likely to be reduced.

Productivity being affected by pH. From this information you can assess the species’ capability in the rotation.

For example, if polymorpha medic pastures such as Santiago are not persisting or nodulating well, pH is likely to be the problem if the readings lie below 4.8 (pH in calcium chloride). The advice is to change plant species or lime the soil.

Figure 3, taken from P.J. Dolling's work, shows the deleterious effect of a low topsoil and subsoil pH on the grain yield of barley and Aroona wheat in the medium rainfall region – see Farmnote No. 73/90 'Soil acidity and barley production' (Agdex 114/534).

Subsurface acidity

The deeper layers of some soils are more acid than the surface, so that plant growth is limited by subsurface rather than surface pH. Sometimes both surface and subsurface pH may limit plant production. As a result, testing the pH of the subsurface provides additional information on whether acidity is likely to limit production. Compare the pH of your subsurface soils with the critical pH ranges in Figure 2 as a guide to assess whether subsurface acidity is limiting production.
Aluminium toxicity is a common side effect of low subsurface and surface pH. A test of extractable aluminium in the subsurface soil sample is another indicator of acidity problems.

Aluminium tests

As the soil becomes more acid, aluminium becomes more available to the plant and may reach toxic levels.

Measuring pH is the best guide available at present to determine if productivity of a paddock is being limited by soil pH. However, current research is looking at measuring aluminium concentrations to see if these provide a more reliable indication of productivity losses.

This research has focussed on soils with inherently acid subsoils, the deep yellow sandplain soils known as wodjil soils, in the eastern and northern wheatbelt. The research has reached the point where a 'quick test' to determine the level of aluminium in the soil has been developed.

The 'quick test' is designed to show the level of aluminium in the soil. This figure, taken with the salt level in the soil, gives an estimate of the production potential of the paddock and indicates if the aluminium concentration is likely to be limiting.

Methods of extracting aluminium from soil samples and relating the aluminium concentrations to yields are being developed for the medium and high rainfall zones.

Plant symptoms seen on acid soils

Apart from soil tests, there are other signs that a soil is becoming acid.

As soils become more acid, the availability of various nutrients changes. For example, molybdenum becomes less available to the plants. On an acid soil, plants may be deficient in this nutrient, even though trace elements have been applied recently. The deficiency may be caused by the soil acidity reducing the availability of molybdenum or other nutrients to the plant.

Aluminium becomes increasingly available as the soils become more acid. An abundance of aluminium affects root development. The

Crops that lack vigour, are thin and slightly stunted, and yield lower than expected, may be suffering from the effects of acidification.
Symptoms of pasture affected by acidity are:

- poor nodulation because of poor colonisation by soil rhizobia;
- pale green or red discolouration indicating a nitrogen deficiency;
- poor regeneration;
- slow growth and lack of plant vigour; and
- an increase in grass composition in the paddock.

Unfortunately, none of these symptoms on plants can be linked only to acidity. Soil testing is essential to be confident acidity is causing poor plant growth.

Soils at risk

Lighter textured soils have a high risk of acidification. Those with the highest risk are:

- light soils supporting productive lupin/wheat rotations;
• light soils supporting strong subterranean clover pastures (legumes add acid to the soil); and

• light soils with a history of heavy nitrogen fertilizing.

Other soils at risk are the medium-textured soils growing productive medic pastures. Medics are acid-sensitive.

These areas, particularly the lighter textured soils, are the parts of the farm at risk of acidifying to problem levels within the next 20 years.

Heavier soils are at less risk of acidification because the higher clay percentage can buffer or resist the change in pH for a longer period. This is termed the soil's 'buffering capacity'.

**Effects of soil acidity on plant growth**

Increasing acidity in Western Australia will induce:
- aluminium toxicity,
- nodulation failure.

Increasing acidity in Western Australia will reduce the availability of:
- molybdenum,
- nitrogen,
- phosphorus,
- calcium, and
- magnesium

Increasing acidity will suppress take-all (*Gaeumannomyces graminis*)

Ten day old wheat seedlings grown in soils selected for a range of extracted aluminium: Low aluminium on right; high aluminium on left, showing stunted roots with few branches
Managing soils at or below the critical pH

Minimize acidification rates

The nitrogen cycle

Most of the nitrogen that accumulates in our soils comes from the fixing of nitrogen by legumes.

It is not the nitrogen fixation itself that is acidifying. When the plant dies and breaks down in the soil, the nitrogen that was converted to a form usable by the plant is now converted to nitrate and acid is produced. This process is known as the Nitrogen Cycle (see the diagram opposite).

The conversion of organic nitrogen (in plant material) to nitrate releases hydrogen ions (H⁺) into the soil. The resulting acid may be reincorporated into plant material if the nitrate is absorbed by plants or soil organisms. However, if the nitrate is leached out of that soil layer, the accumulated acidity will persist.

The phosphate in DAP has a neutralizing effect on soils that have a pH less than 6.0. That is, it balances some of the acidity produced by the nitrogen in the fertilizer.

Product removal

Nitrogen fertilizers have variable effects on the acidification of the soil. The nitrogen in Agras, DAP and half the nitrogen in Agran is the highly acidifying ammonium form. The nitrogen in urea is similar to the nitrogen fixed by legumes. If the nitrate is allowed to leach, the free hydrogen ions (H⁺) will accumulate and acidify the soil.

The removal of produce from a paddock can be thought of as the equivalent of removing lime. When plants take up nutrients, they excrete acidity from their roots.
Plants take up more positively charged elements such as calcium, potassium and magnesium. The positively charged hydrogen ($H^+$) is then excreted by the roots to balance the electrical charges in the plant cells. The net result is that the plant becomes alkaline and the soil becomes acid.

Because at least some of each plant is either harvested or eaten, not all of this alkaline plant material is returned to the soil. As a result, there is an accumulation of acidity in the soil.

Legumes excrete more $H^+$ into the soil than cereals do—see Table 1. Leguminous hay acidifies the soil rapidly, since the alkaline tops are generally fed elsewhere on the property or sold.

**Perennial pastures**

Perennial pastures are a management option to reduce acidification where the rainfall is adequate—over 450 mm—particularly on paddocks with long pasture phases.

Because perennial pastures absorb nutrients during more of the growing season, the amount of nitrate leached is less than under annual pastures.

Perennial pastures are also valuable because of their water use potential.

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**Management Options to Minimize Acidification**

- Sow crops early, to use up nitrogen before it is leached.
- Strategically time the application of nitrogen, so that most of the nitrogen is used by the crop.
- Retain stubble, to encourage organisms to use nitrogen during summer and autumn.
- Feed hay on paddocks the hay was cut from.
- Manage grazing so as to minimize the concentration of dung and urine in animal camps.
- Grow perennial pastures, since less nitrogen is leached early in the season.
Table 1. Amounts of alkalinity accumulated by a range of species

<table>
<thead>
<tr>
<th>Species</th>
<th>Plants parts</th>
<th>Alkalinity, as kg lime/t plant dry matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subterranean clover</td>
<td>Whole tops</td>
<td>40</td>
</tr>
<tr>
<td>Lucerne</td>
<td>Whole tops</td>
<td>60</td>
</tr>
<tr>
<td>Lupins</td>
<td>Whole tops</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Grain</td>
<td>20</td>
</tr>
<tr>
<td>Ryegrass</td>
<td>Whole tops</td>
<td>30</td>
</tr>
<tr>
<td>Cereals</td>
<td>Whole tops</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Grain</td>
<td>5</td>
</tr>
</tbody>
</table>

Changing varieties

The pH at which there is a risk of acidity reducing production depends on the crop or pasture variety being grown. If the soil pH is below the critical pH and you are not going to apply lime, don't grow varieties that are likely to be limited by the pH.

For example, if the pH is less than 4.5 (in calcium chloride), Aroona, Cranbrook and Wilgoyne wheats and all barley varieties will almost certainly have their yield reduced by the acidity.

Liming

Lime incorporated by cultivation will reduce acidity in the top 10 cm of soil. It is estimated that 1 t of lime will adjust pH by up to 0.7 per hectare on light soil and 0.3 on heavier soil.

Topdressed lime is expected to take a longer time to be effective in the medium and low rainfall areas, since the alkaline component in the lime is only slowly leached from the surface of the soil. Topdressing lime is probably...
Lime quality

When buying lime consider:

- price,
- Neutralizing value (NV),
- particle size (analysis measured using a 0.6 mm sieve),
- cartage and spreading costs,
- the rate of lime required, and
- soil type.

Lime granules greater than 2 mm will take over ten years to neutralize the pH even if the product has a high neutralizing value.

<table>
<thead>
<tr>
<th>Particle size</th>
<th>Reaction time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 0.6 mm</td>
<td>Less than 1 year</td>
</tr>
<tr>
<td>More than 2 mm</td>
<td>Many years (over 10?)</td>
</tr>
</tbody>
</table>

Higher rates of lime will be required to compensate for a low neutralizing value. The suppliers should be able to provide this information to you before you buy any lime.

The rates of lime to use are also determined by the amount of clay in the soil. More lime is required to shift the pH by 0.5 unit in a heavy soil than in a sandy soil.

Lime can be applied at any time of the year when the soil is not in an erodible state, that is, when the lime will not blow or wash away.

only a management option on permanent pastures in the high rainfall areas of the south-west.

Acid subsoils may restrict a plant’s response to lime. A plant may respond to the top-soil application of lime, but once the roots reach the acid subsoil, any initial response to the lime may be reduced, particularly with acid sensitive varieties.

Monitor and managing soil acidity

18
Approximate costs (1991 prices)

Limesand and crushed limestone - $7-$12/t ex pit (check quality)

G-lime - $23/t ex Perth (check quality) $33/t ex Harvey

Cartage - 10c/t km

Spreading - $5/t to $8/t for 1 to 2.5 t/ha.

To apply 1 tonne of limesand or crushed limestone per hectare, work on a budget of between $25 and $30 per hectare.

Table 2 shows how to compare lime sources.

If you would like to analyse your lime for neutralising value and particle size,

<table>
<thead>
<tr>
<th>Cost of lime at the pit, $/t</th>
<th>Cost of transport to the paddock, $/t</th>
<th>Cost of spreading, $/t</th>
<th>Neutralizing Value (%/100)</th>
<th>Cost of pure lime equivalent $/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.00</td>
<td>10.00</td>
<td>8.00</td>
<td>0.80</td>
<td>31.25</td>
</tr>
<tr>
<td>10.00</td>
<td>10.00</td>
<td>8.00</td>
<td>0.95</td>
<td>29.47</td>
</tr>
</tbody>
</table>
(09)325 5544 for advice on submitting samples for analysis.

**Measuring a lime response**

Different rates of lime may also be applied to the paddock, for example, 0 t/ha, 1 t/ha and 2.5 t/ha. You may wish to include a 5t/ha treatment to assess whether overliming is likely to be a problem.

The plots need to be at least 10 m wide to allow for the multisreader. Plot length should be approximately 50 m. Short plot lengths may be inadequate for measuring crop yields and very long plots may cross several soil types.

It is also important that the vehicle does a run up the nil plot to ensure that any possible variability with the wheel tracks is accounted for.

Farmers on the south coast particularly may use strips of lime to test the alleviation of a non-wetting soil problem. The approach and measurements for each plot again must be the same. Higher rates of lime are often needed to ameliorate water repellance, so be sure to look out for possible overliming effects.

To interpret a response to lime you will need to record paddock details. This will include:

- rotations,
- current yields
- soil data (type, pH),
- fertilizer use (types and rates),
- herbicides used,
- seeding date, and
- rates and type of lime used.

Take samples for tissue tests and soil tests from each treatment, that is, from both the plus and minus lime treatments. This allows you to decide if a nutrient deficiency is restricting potential yield, or if lime has caused a problem.

Lime can increase the amount of nutrients (particularly nitrogen released from
soil organic matter. This effect may only be short-lived (1 to 2 years).

To adequately measure a response, keep records over a ten year period. Lime may improve yields in the first year, but the responses may be greater or less in following years.

Compare crop responses by weighing header samples from each treatment. Weighing trailers are available through the Department of Agriculture, or a private consultant can help.

Consultants and advisers will be able to interpret the results to see if changing the pH has altered nutrient status. The test for molybdenum deficiency is expensive, but well worth doing if there is a risk of molybdenum deficiency. Coating cereal grain with sodium molybdate will temporarily alleviate molybdenum deficiencies on extremely acidic soils.

**Broadscale liming**

On sands, or sandy loams, 1 t lime/ha can be expected to raise the pH by 0.3 to 0.7 units. On loams, up to 2 t lime/ha may be required for this pH change. The higher rates of lime will have a longer residual value.

**How to apply lime**

Multispreaders are the usual way to apply lime. Combines are not suitable for spreading lime, unless low maintenance rates are applied regularly. The Kondinin Farm Improvement Group has carried out a survey on spreaders – see Kondinin Group Talk, Fertilizer Spreader Report, October 1990 and Yearbook, 1990 (January 1991).

**Overliming**

There is a danger of overliming.

Do not apply more than 2.5 t/ha on lighter soils, except in trial strips.

Overliming can occur:

- when large amounts of lime are applied in one operation - for example, 4 t/ha; or
- when lower rates are repeated within a short time, for example, 2 t/ha of lime in one year and another 2 t/ha a year later.

The lighter the soil is, the less lime is required to change the pH.

If you overlime, you risk losing yield because of zinc deficiency or manganese deficiency (split seed in lupins), or because of the crop disease take-all. The take-all fungus is suppressed by acidity.
Managing soils just above the critical pH

To find out at what rate your soil is acidifying and how close it is to the critical pH, long term monitoring is essential. It is very useful to set up a long term monitoring site on a paddock or paddocks that are at risk of acidification. This will provide the information needed when you are making a management decision about the acidity problem in a paddock.

Monitoring sites

Sampling

Collect soil samples using the same technique as described at the beginning of this Bulletin.

The most important point is to map the site carefully, so that you sample the same sites each time. Samples should be analysed in calcium chloride so that reliable comparisons of pH changes can be made.

Time of sampling

It does not matter when you take the samples, provided that when you resample the site it is at the same time of the year as the previous sample. This is to ensure a fair comparison between pH readings. Samples are preferably collected over summer; however, if the soil is hard, winter or spring sampling is adequate.

If wet samples have been collected, dry them as soon as possible after sampling before they are analysed.
Recording the data

A graph and recording sheet are included in this Bulletin for your use. Either or both methods may be used - it is a matter of choice. If you choose to use the graph, ensure that you include a legend to illustrate what each line means. Examples of how to record the data by each of these methods are shown in the forms on pages 24 and 25, and in Figure 4. Larger copies of these forms for your use are available from district offices of the Department of Agriculture.

Liming to avoid future productivity losses

The economic and biological question is, should you lime at point A or point B (see Figure 5)?

Some growers lime before the pH levels in the paddock reach the critical levels for the crop or pasture species that they intend to grow. This is to avoid yield losses from acidity.

For example, a paddock pH may be 4.7 (in calcium chloride). If the rate of pH decline is a high 0.1 unit per year, then within the next 2 or 3 years, the pH will be critical for several crops and pasture species.

However, if the paddock is limed when the pH is 4.7, it is likely that pH will increase to about 5.5. This will avoid yield losses from acidity for about 10 years.
<table>
<thead>
<tr>
<th>Date sampled</th>
<th>Site no.</th>
<th>Topsoil</th>
<th>Subsoil</th>
<th>Management</th>
<th>Yield</th>
<th>Tissue test done</th>
</tr>
</thead>
</table>

* Nominate which solution - for example, field kit, calcium chloride or water - and depth

24 Monitoring and managing soil acidity
<table>
<thead>
<tr>
<th>Date sampled</th>
<th>Site no.</th>
<th>Topsoil (\text{Calcium Chloride})</th>
<th>Subsoil (\text{Calcium Chloride})</th>
<th>Management</th>
<th>Yield</th>
<th>Tissue test done</th>
</tr>
</thead>
<tbody>
<tr>
<td>13/6/89</td>
<td>1</td>
<td>5.4</td>
<td>4.8</td>
<td>WHEAT</td>
<td></td>
<td>NO</td>
</tr>
<tr>
<td>13/6/89</td>
<td>2</td>
<td>5.0</td>
<td>4.8</td>
<td>WHEAT</td>
<td></td>
<td>NO</td>
</tr>
<tr>
<td>14/6/90</td>
<td>1</td>
<td>5.2</td>
<td>4.8</td>
<td>LUPINS</td>
<td></td>
<td>NO</td>
</tr>
<tr>
<td>14/6/90</td>
<td>2</td>
<td>4.9</td>
<td>4.7</td>
<td>LUPINS</td>
<td></td>
<td>NO</td>
</tr>
<tr>
<td>15/6/91</td>
<td>1</td>
<td>5.1</td>
<td>4.7</td>
<td>WHEAT</td>
<td></td>
<td>YES</td>
</tr>
<tr>
<td>15/6/91</td>
<td>2</td>
<td>4.9</td>
<td>4.7</td>
<td>WHEAT</td>
<td></td>
<td>YES</td>
</tr>
</tbody>
</table>

* Nominate which solution - for example, field kit, calcium chloride or water – and depth

Monitoring and managing soil acidity 25
Key points

- The lighter textured productive soils are acidifying fastest.

- Compare the paddock pH with the critical pH values for the crop and pasture species you intend to grow.

- Aroona, Cranbrook and Wilgoyne are acid sensitive wheat varieties.

- All barley varieties are sensitive to acidity.

- Medics are very sensitive to acidity.

- Subterranean clover growth may be limited on soils with a pH less than 4.5.

- When sampling for acidity collect both topsoil and subsoil samples for analysis.

- pH analysis can be done in calcium chloride or water. Inoculo Field Kits are available at all rural traders.

- Lime reduces acidity.

- When buying lime assess the price, rate of application, cartage costs, neutralising value and particle size.

- Work on a budget of between $25 and $30 per hectare for 1 tonne of limesand or crushed limestone per hectare.
Note: Mention of trade names does not imply endorsement of, or preference for, any company's product or services by the Department of agriculture, and any omission of a trade name is unintentional. Recommendations are current at the time of printing.

Acknowledgements

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Further Information

- Farmnote No. 68/84 'Soil acidity' (Agdex 534)
- Farmnote No. 84/86 'Liming of sub. clover pastures on acid soils in the high and medium rainfall areas of W. A.' (Agdex 137/534)
- Farmnote No. 3/89 'Management of topsoil acidity in cropland (Agdex 534)
- Farmnote No. 73/90 'Soil acidity and barley production' (Agdex 114/534)

870/6/92 — 7,000

Monitoring and managing soil acidity 27