Farmnote

Agriculture WESTERN AUSTRALIA

Management of soil acidity in agricultural land

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Farmnote 80/2000

Soil Acidity Series

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Summary

Soil acidity affects two-thirds of Western Australia's Wheatbelt and costs the farming community in excess of $70 million annually through lost production.

Soil acidity is a sleeping monster. It helps increase the spread of salinity by decreasing the water use of agricultural plants. This damages the root structure and changes nutrient availability.

Causes of Soil Acidity

Many light textured soils in Western Australia's cropping areas were slightly acid before they were cleared. The Wodjil soils of the eastern wheatbelt and peaty sands in the south west are naturally very low in pH. However, with the introduction of agriculture all soils are becoming more acid due to:

- leaching of nitrogen from the root zone;
- removal of produce (grain, pasture, meat and wool);
- use of legumes in rotations.

Fertiliser Use

Leaching of nitrogen is acidifying, regardless of whether the nitrogen is from legumes or fertilisers. All ammonium based fertilisers (e.g. Agras and DAP) cause soil acidification whether they are leached or not. Non-ammonium based fertilisers, such as urea only cause soil acidification if the nitrate they are converted to is leached from the root zone. Table 1 shows the acidifying levels of different fertilisers. Superphosphate fertilisers are not directly acidifying, but will indirectly add to soil acidity by improving plant growth. This increases the amount of produce that can be removed and also the amount of legume nitrogen available to leach. Applications of elemental sulphur are also acidifying.

Agricultural Production

Production of all agricultural products causes acidification. The way that plants take up nutrients results in a partitioning of acidity into the soil and alkalinity into the plant as dry matter. If a plant was naturally allowed to die and all parts returned to the soil, there would be no net change in pH. As agriculture removes plant material from a paddock (as grain or pasture), less alkalinity is returned to the soil, and the soil becomes more acidic.

Removing produce from the paddock can be thought of as equivalent to removing lime, leaving the soil more acid. Hay or silage with a high legume content 'contains' the most lime equivalents (up to 80 kg per tonne of feed); cereal silage 'contains' around 45 kg lime per tonne silage; cereal and pasture hay 'contain' around 30 kg of lime per tonne hay; and grains such as wheat, barley and canola 'contain' approximately 2.5 kg of lime per tonne of grain.

Factors Affecting pH Decrease

The rate of decline in soil pH will vary depending upon a number of factors, including the length of time since the land was cleared. Soil type and rainfall affect the rate of nitrogen leaching and also influence productivity. Management decisions on how often legumes are grown, type of fertilisers used, stock grazing techniques and decisions that increase productivity all affect soil acidification rates.

Table 1. The amount of acidity generated by various fertilisers, expressed in terms of the lime equivalent needed to neutralise their addition (Cregan and Helyar 1986, as per Soil Guide, 1998).

Fertiliser	**Lime required to neutralise fertiliser addition (kg CaCO3/kg nutrient N, P, S) When the amount of nutrient leached is:**	
	0 %	**100 %**
Nitrogen fertilisers		
Ammonium sulphate (Agras, MAP)	3.6 (/kg N)	7.1 (/kg N)
Ammonium nitrate (Agran)	0	3.6 (/kg N)
Urea	0	3.6 (/kg N)
DAP	1.8 (/kg N)	5.4 (/kg N)
Potassium nitrate	-3.6 (/kg N)*	0
Sodium nitrate	-3.6 (/kg N)	0

Sulphur fertilisers		
Elemental sulphur	3.1 (/kg N)	-
Gypsum	0	-
Potassium sulphate	0	-

* Negative values indicate a liming effect by the fertiliser.

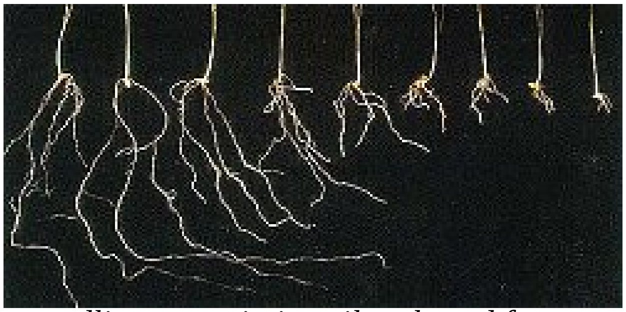

Figure 1. Ten day old wheat seedlings growin in soils selected for a range of extracted aluminium. Low aluminium on the left, high aluminium on the right with stunted roots with few branches. Photograph courtesy of Dr. Steve Carr.

Figure 2. Subclover response to pH. Plant on the left was grown in an acid soil and has a much poorer root system with less root mass and fewer nodules. The plant on the right was grown in a high pH and has a much greater root mass with many nodules.

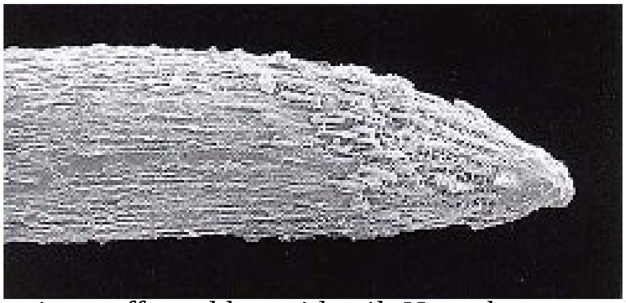

Figure 3. Root tip unaffected by acid soil. Note the tapered appearance. Photograph courtesy of CSIRO.

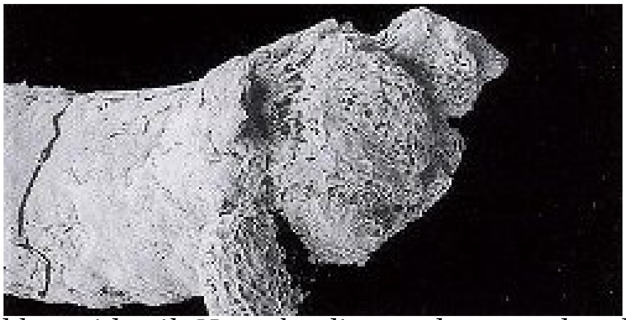

Figure 4. Root tip affected by acid soil. Note the distorted root end and the thickening of the root itself.
Photograph courtesy of CSIRO.

Why are acid soils a problem?

Acid soils affect plant growth by creating toxicities and nutrient deficiencies, reducing plant root growth and decreasing legume nodulation.

The most significant toxicity found in WA acid soils is aluminium. Most soluble forms of aluminium are toxic to plants, and only trace amounts are needed to affect the growth of most plants. Insoluble forms of aluminium start to dissolve at pH 5.5 and there is another noticeable increase in solubility at pH 4.5.

Root growth is directly restricted by contact with soluble aluminium. Roots are shorter and thickened with fewer fine roots (see Figure 1.). Shorter roots mean the plant may have difficulty getting adequate moisture during spring, while a reduction in the number of root hairs lowers the plants capacity to take up nutrients, particularly trace elements. pH measures Hydrogen ions (H^+), but H^+ ions do not directly affect the growth of non-legumes until the soil pH is below 3.4. Legumes are more sensitive to hydrogen ions, although it is actually the rhizobia that are affected rather than the plant itself. Manganese toxicity is a problem in acid soils in the eastern states, but has not been observed in WA.

The availability of molybdenum, nitrogen, sulphur, phosphorus, calcium and magnesium decreases at low soil pH so deficiencies in these nutrients may be seen. Molybdenum in particular is strongly adsorbed by soil when pH is below 4.2.

Acid soils indirectly affect legume growth by decreasing the growth and survival of rhizobia in soil. Disruption of the complex process of nodule formation and function on legumes also occurs at low soil pH. Any of these can reduce the growth of legumes and the amount of nitrogen fixed - legumes may even show symptoms of nitrogen deficiency.

Low pH also reduces the growth and survival of soil microbes that mineralise nitrogen from plant residues such as stubble, so less nitrogen is available to plants from this source.

The application of lime is the simplest way to overcome soil acidity.

Tackling Soil Acidity

Know the pH of your topsoil and subsoil.

To decide when a liming program should be started, it is essential to know the topsoil and subsoil pH of each paddock. The topsoil is from 0 - 10 cm depth while the subsurface is from 10 - 20 cm. Testing for pH deeper in the soil is also useful, for instance deep sands often have their most acid layer below 20 cm.

Soil testing for pH can be done through private laboratories or by purchasing your own pH meter (meters are around $100 or $200 for the kit). Each paddock should be pH tested as differences in paddock management and productivity affect the rate of soil acidification. Having your own pH meter is convenient and inexpensive and excellent for monitoring. All decisions on using lime should be made based on a laboratory test. These tests cost about $5 per sample but the results are extremely accurate. Both tests rely on good soil sampling methods to get a representative sample of each soil type in a paddock.

Know the critical pH of the species grown.

Consider what species of plants you grow. The pH of your topsoil and subsoil should be above the critical pH of the most acid sensitive crop you grow otherwise pH will limit production. If pH is limiting production, then liming is likely to be a profitable option.

Different plants have different tolerances to acidity. Plant growth is affected at a certain soil pH, this is called the critical pH and is often given as a range. Below the critical pH, plants do not take up soil nutrients efficiently and will suffer yield penalties. Different varieties of the same species may be more tolerant of acidity and therefore have a lower critical pH. Soil pH may initially fall into the critical pH range with no obvious loss of yield, but crops may be using fertiliser less efficiently, relying on weaker root systems to get through the season and nodulating less (if legumes).

Acidity is insidious, yield penalties of 20 - 30 per cent build up gradually and may not be noticed if agronomy is improved in other ways. See Figure 5 for the critical topsoil pH points of WA crops, but note that some crops such as pulses need a higher subsoil pH.

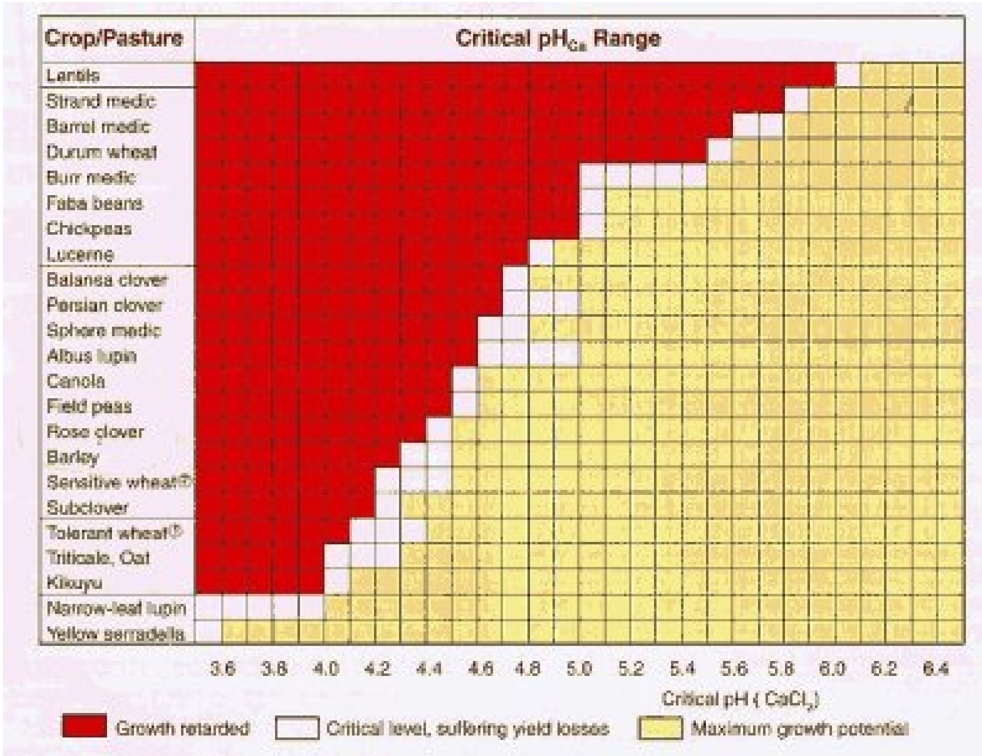

Figure 5. Critical pH ranges (topsoil pH in $CaCl_2$) of some WA crops and pastures.

Legend for Figure 5.
1. Tolerant wheats include the varieties Ajana, Arrino, Westonia.
2. Sensitive wheats include the varieties Aroona, Cascades, Cranbrook, Janz, Schomburgk, Stretton and Wilgoyne. Note that Cascades can be considered tolerant where aluminium levels are low (eg. south coast sandy duplex soils).

Management Options For Soil Acidity

Options for the management of soil acidity are:

1. Do nothing;
2. Reduce acidification;
3. Grow more tolerant species;
4. Apply more nutrients;
5. Ameliorate acidity.

The management strategy used must be the most profitable, but in the medium to long term, the majority of WA soils will have to be treated for soil acidity if the land is to be productive.

Do Nothing.

Continue current practices and monitor pH regularly. Eventually pH will fall to levels where other options are more profitable.

Reduce Acidification

A change in management practices will reduce the rate of acidification, but ultimately will not stop it.

- Reduce the level of "lime removal"from the paddock by changing paddock use e.g. less hay cutting. Use the Lime and Nutrient Calculator to work out less acidifying rotations.
- Use of less acidifying nitrogen and elemental sulphur fertilisers.
- Reduce leaching of nitrogen by use of split applications of fertiliser, sowing crops early, perennial rather than annual pastures, fewer legumes in rotation.
- Return plant material to the paddock e.g. retain crop stubble, feed stock on the same paddock from which hay was cut, rotation grazing rather than set stock.

Grow More Tolerant Species

Some plants are quite acid tolerant (see Figure 5.). The tolerance of these varieties can be used to avoid yield losses from soil acidity, but this is a short term solution - pH will continue to fall and eventually all plant species will be affected by soil acidity.

Some tolerant crops can be used to increase returns while acidity is being corrected, because they can respond to the lime and the acidity.

Apply More Nutrients

To compensate for fewer available nutrients and a retarded root system, more fertiliser can be used to maintain production levels. As pH continues to fall more fertiliser will be needed and molybdenum will need to be applied regularly to avoid a deficiency.

Ameliorate Acidity

Lime is the easiest solution to soil acidity, and should be viewed as a medium term investment. Best production responses to lime have been seen where topsoil pH is very low (less than 4.5) and while mildly acidic soils generally show little yield response, this is not the rule. In trials at Narrogin yield responses in canola were seen in the first year after liming. At the Narrogin site, topsoil pH was 4.72 while subsoil (10-20 cm) was at 4.66 before liming (See 1998 Soil Acidity Update Report).

Table 2. 1997 Canola grain yield for lime trial 96NA3 at Narrogin.

Lime Rate (t/ha)	Grain Yield (t/ha)
0	1.32 a
1.0	1.46 b
2.0	1.60 c

Note: Numbers in the same column with different letters are significantly different ($p<0.05$).

While there may be no net gain in liming soils close to critical pH levels (cost of liming = gain in production), big yield responses to lime indicate that previous crops may have experienced yield penalties from soil acidity. Liming is ultimately the only profitable and sustainable option for acidic agricultural soils.

Applying Lime

Lime is applied by topdressing the paddock. Rates of 1 - 2 t/ha can be applied depending upon lime quality and required pH rise.

Selecting a Lime

When choosing between lime sources, look carefully at percentage Neutralising Value (NV) and cartage costs (see example below and the Farmnote 69/2000 "Looking at Liming - comparing lime sources"). There are four main types of lime available in WA; limestone (%NV ranges from 50 - 85%), limesand (%NV ranges from 50 - 95%), dolomite (%NV ranges from 40 - 110%), and industrial limes such as lime or cement kiln dust (%NV around 70 - 110%). Particle size of lime is also important since it is not very soluble in the soil solution - lime particles that are greater than 2 mm in diameter dissolve very slowly and therefore are far less effective against soil acidity.

Table 3. Compare the lime sources of different neutralising values and different prices.

Cost of lime at the pit ($/t) + Cost of transport to the paddock ($/t) + Cost of spreading ($/t) ÷ Neutralising
Value (%)* = Cost of pure lime equivalent ($/t)

5.00 + 10.00 + 10.00 ÷ 0.80 = 31.28

7.00 + 10.00 + 10.00 ÷ 0.95 = 28.42

* Divide the neutralising value (%) by 100.

Rates of Lime

Lime rates above 2.5t/ha in broadacre cropping should not be applied since trace elements such as manganese and zinc may be tied up. Application of lime has led to crops such as lupins, which have a high manganese demand (especially towards the end of the season), becoming deficient in that nutrient when grown after liming. Nutrient deficiencies can be overcome through fertiliser or foliar trace element applications. In the year after liming plant tissue testing is recommended for all crops to ensure that adequate levels of trace elements are present.

Expected pH Rise

The rise in soil pH after liming will vary depending on lime quality, degree of mixing through the soil (combining after topdressing is beneficial), depth of incorporation, the buffering capacity of the soil, the initial pH and rainfall (lime is only active in moist soil). Generally, in the medium rainfall zone, 1 t/ha of lime will lift the topsoil pH of a sandy loam soil (pH 4.5) 0.5 - 0.7 pH units in the first year.

Raising subsoil pH is more difficult than raising topsoil pH and takes considerably longer - hence the value in monitoring subsoil pH. Topdressed lime must dissolve and work its way down the profile to where it is needed and this may take four to seven years. However, before the lime is available to move down the profile, it must first neutralise the topsoil acidity that it is in contact with, leaving less available to react in the subsoil and thus smaller changes in pH.

How often does lime need to be applied?

Lime programs will vary depending on your current soil pH, your plans for future production, anticipated fertiliser use and the "optimum"point you are seeking. You also need to establish if you are liming to maintain or lift your pH in the topsoil (0-10 cm) or subsoil (10-20 cm).

If started early enough, a liming program may be used to maintain soil pH, but if pH is quite low relative to your most sensitive species or if your soil type is heavy, two applications over three to five years may be required to lift pH into the desired range.

Once the target pH is reached, repeat applications of lime will maintain soil pH at the required level. The amount of lime that is removed from your soil over a rotation can be calculated using the Lime and Nutrient Calculator, which takes into account factors such as the fertiliser used, soil type and rainfall. The amount of lime removed by your rotation can be replaced about every five to seven years, and usually works out to around 1-1.5 t/ha of lime.

Acknowledgements

The WA soil acidity project is an integrated project of work being completed by Agriculture Western Australia, the University of Western Australia, and CSIRO. We would like to thank Chris Gazey (AGWEST), Mark Whitten (UWA), and contributors to the publication "Soil Acidity - A Reference Manual"edited by Linda Leonard and Mike Bolland 1995 for their contributions to this farmnote.

Further Reading

- Farmnote No. 68/2000 "Looking at Liming - test strips'
- Farmnote No. 70/00 "Looking at Liming - consider the rate"
- Farmnote No. 67/00 "Looking at Liming - quality"
- Farmnote No. 69/00 "Looking at Liming - comparing lime sources"
- Farmnote No. 78/00 "The importance of soil pH"
- Farmnote No. 79/00 "Soil Acidity and Barley Production"
- Bulletin No. 4343 "Soil Guide - A Handbook for Understanding and Managing Agricultural Soils".

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