SOIL ACIDIFICATION

FACT SHEET

SOUTHERN REGION
NOVEMBER 2020

Subsurface acidity and stratification:

Recommended recognition and testing practices

KEY POINTS

- Acidity should be addressed early and managed with regular applications of lime.
- Subsurface soil acidity and stratification are emerging as serious constraints to crop production.
- Traditional soil sampling of the 0-10cm layer can lead to misdiagnosis of acidity issues.
- Ideally, growers should test soil in 5cm layers. Testing to a minimum depth of 20cm is recommended.
- Lime can take many years to move through the soil profile without incorporation or physical mixing of the soil.
- In no-till systems, growers may need to consider strategic tillage to increase lime effectiveness.

Photo: Belinda Cay, AgCommunicators

Figure 1. A hardware store pH kit is a useful tool for initial diagnosis of acidification through the soil profile.

Summary

Subsurface acidity refers to a soil pH (measured in calcium chloride) of 5.0 or less, occurring at depths below 10cm from the soil surface. Acid soil stratification can occur anywhere in the soil profile, from as little as 2cm below the surface. Under no-till systems lime applied to the soil surface may move very slowly into soil. Traditional soil testing of the 0-10cm layer is often ineffective in detecting low pH in stratified soils. New techniques for testing at depth must be applied to ensure the best management practices can be implemented.

Introduction

About 4.4 million hectares of South Australia's (SA) 10 million hectares of productive farmland are prone to acidification if not managed appropriately. Almost all agricultural systems where nitrogen fertilisers are used and where grain, hay or animal products are

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exported can increase acidity in the soil. Increasing soil acidity has been a constraint to crop production in Australia for many decades and it is emerging in new areas in South Australia, especially on sandy soils where the pH can drop quickly.

When the soil pH falls below pH 5.0$_{(CaCl)}$ then the productivity of crops and pastures starts to fall; nutrients such as phosphorus, magnesium, calcium and molybdenum become less available; and toxic amounts of aluminium and manganese can occur. In addition, many pulses and their associated rhizobia (required for nitrogen fixation) are highly sensitive to soil acidity.

Between 2015 and 2018, about 100,000 tonnes of lime was applied to acid soils in SA per annum. However, this needs to double to maintain the current soil pH and correct the current rates of acidification generated by our agricultural systems. More importantly, many soils in SA are well below the critical pH level and about three million tonnes of lime are urgently required to raise the pH of these soils to 5.5.

Subsurface acidity

Soil acidity is an unavoidable by-product of good farming practices, but the rate of acidification is increasing due to higher use of nitrogen fertiliser, increased productivity, and greater intensity of cropping and hay production.

Fertiliser nitrogen applications generally accelerate acidification. Sulphate of ammonia (SOA) is three times more acidifying than urea, and one-and-a-half times as acidifying as diammonium phosphate (DAP) when compared per unit of nitrogen.

Acidity in the surface and the subsurface will often vary between soil types or locations and is rarely uniform across a paddock.

Paddocks with a mix of soil types can develop acidity in susceptible soils, even when there are adjacent zones containing calcareous loams or limestone reefs.

If areas of surface acidity are left untreated, this encourages the development of strongly acid layers in the subsurface. Factors like low organic and low clay content mean the soil is less buffered against acid additions, leading to the rapid development of acidic layers.

Under modern no-till farming systems where soil disturbance is minimal, the movement of lime from the surface into the profile is reduced. This means that although the pH of the surface soil can be raised successfully, deeper acid layers may persist.

For example, the top 5cm of soil may be neutral, while an acid layer may be present from a depth of 5-15cm or deeper. In these situations, traditional soil sampling where the 0-10cm layer is collected and mixed before analysis, may produce misleading results that indicate the pH is above the critical level.

Correctly identifying subsurface acid layers requires testing down to a depth of at least 20cm. Sampling to 30cm or to the clay layer is encouraged.

Source: SA Department for Environment & Water

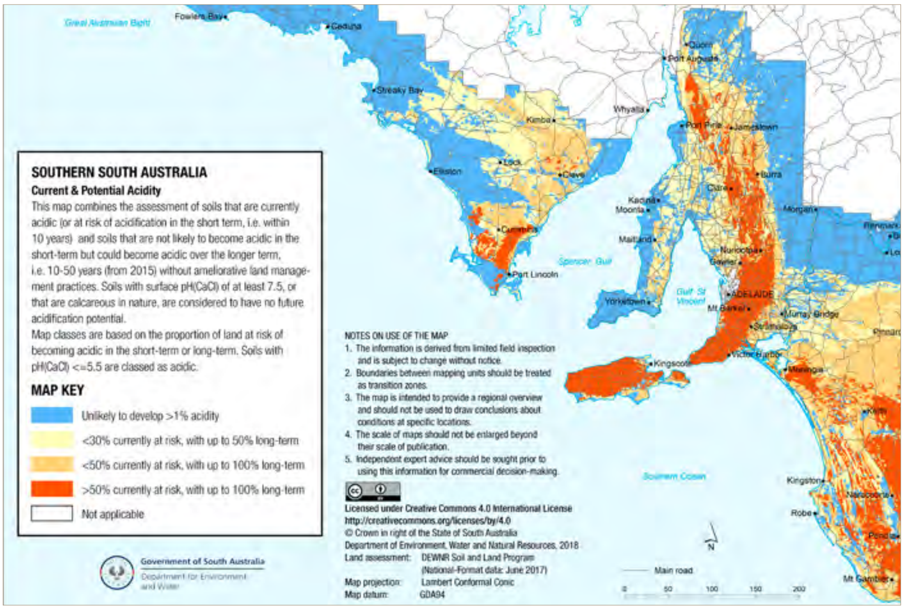

Figure 2. A map of South Australian cropping land showing current acid soils and areas deemed at future risk of acidification. (View original at www.acidsoilssa.com.au under Resources > Maps.)

Source: PRSA

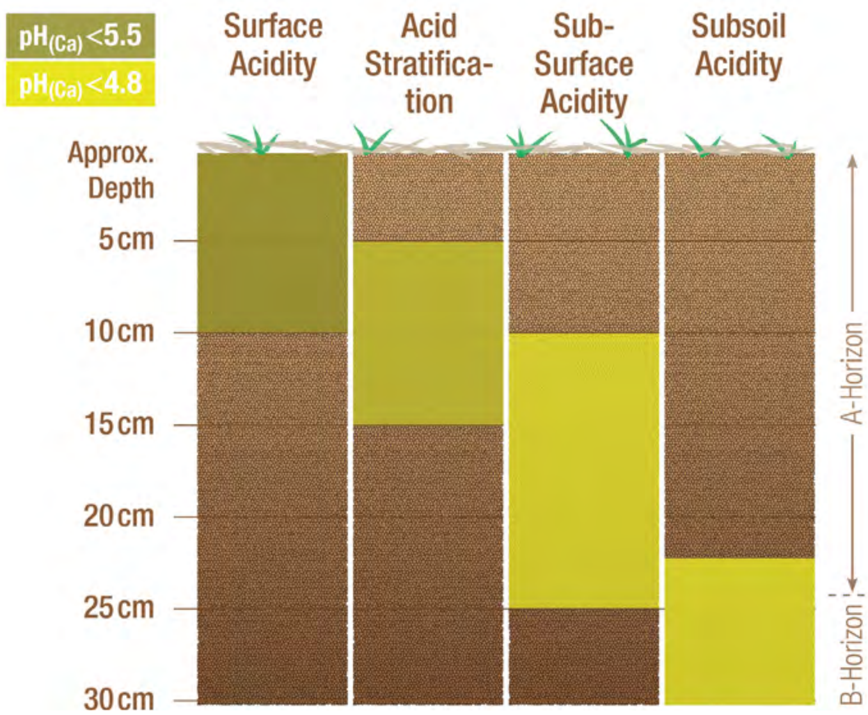

Figure 3. Schematic representation of pH stratification, sub-surface acidity and subsoil acidity.

What to look for

Soil acidity causes a general lack of crop vigour and few specific symptoms can be easily detected. Roots may appear short or stunted, nodulation of legumes may be poor, causing yellowing of the crop.

Indications of subsurface acidification can include:

- Patchy or uneven crop growth and yellowing, especially in susceptible legumes such as lentils and faba beans.
- Crops which look fine early but are unable to access moisture in deeper soil layers and do not reach their yield potential.

Grain yield maps and/or mid-season normalised difference vegetation index (NDVI) images, particularly for acid sensitive crop such as lentils, beans or barley, can help identify areas of poor plant growth to be targeted for soil sampling.

The number of sites to be soil sampled will depend on the variability within the paddock and its overall size. Precision soil sampling such as grid-based or on-the-go Veris® pH mapping can provide more detailed data on surface pH variations and help identify areas of potential subsurface acidity.

PHoto: © Chris Davey, YP Ag

Figure 4. A healthy pulse crop on the Yorke Peninsula (left) indicating a zone of 'good'soil, and a patch of poorly performing crop (right) indicating the possibility of low soil pH.

How to test

Checking rooting depth, soil moisture and other constraints such as compaction can be useful for assessing the possibility of subsurface acidity. If the roots are stunted and if there are only a few nodules on legumes, then soil pH testing is recommended.

A soil pH indicator kit available from most hardware shops or plant nurseries will quickly and cheaply indicate whether soil acidity is affecting plant growth:

1. Dig a few holes to a depth of at least 20cm in each location (using a spade, loader or backhoe) to leave a smooth, vertical face through the soil profile.
2. Alternatively, use a 'Dig Stick' soil probe to take an intact soil core. A probe makes soil testing viable in standing crops without causing major damage.
3. Apply the pH testing liquid onto the profile (or core) from the surface down to at least 20cm, then apply the indicator powder and let the colour develop (refer to pH kit instructions for details). Testing to 30cm or the B Horizon is recommended for deeper topsoils.
4. Use the pH colour indicator card supplied with the kit to determine the soil pH down through the profile. Any acid layers will turn the pH indicator light green to yellow.
5. With a tape measure, identify the position of any pH changes and acid layers.
6. Finally, record its location.

While focusing on zones of poor crop growth, it is a good idea to also test at least one area of good growth. If the soil pH in these areas is higher than the poor areas, this is a strong indicator that acidity is the limiting factor.

If subsurface acid layers are detected using a soil pH indicator kit, careful soil sampling and more accurate laboratory testing is recommended before developing a liming program. PIRSA can provide a list of accredited soil laboratories on request. See 'More Information' below.

Alternatively, on-the-go Veris® testing or grid sampling can also be useful, especially in highly variable paddocks.

PhotO: © Chris Davey, YP Ag

Figure 5. Dig at least 20cm through the soil profile to test pH to depth. Apply pH test fluid and indicator powder down the soil face to highlight soil strata with low pH.

More precise testing

While careful soil sampling and accurate laboratory testing are time consuming and add expense, it is worthwhile investing in this procedure to ensure your liming program targets the most acidic areas and that you get the best return on every tonne of lime that is applied. The collection of soil samples for laboratory testing will depend on the position of the acid layer:

- Sampling from depths of 0-5cm, 5-10cm and 10-20cm is generally recommended. Sampling from 20-30cm may also be useful in deeper, often sandier soils.
- However, if the acid layer ranges from 5-15cm, for example, then depths of 0-5cm, 5-15cm and 15-25 cm may be more appropriate.

Depending upon the paddock size and variability you may want to divide the paddock into zones representing areas of poor to intermediate crop growth, plus one or two good areas. Alternatively, you may wish to sample by soil type.

To understand the variability in acidity across a paddock, the aim is to collect soil samples from each depth within each zone, rather than trying to estimate an average for the whole paddock. But if the paddock and crop growth are uniform or paddock is small, then one sampling zone may be sufficient.

Within each zone, find a representative area of about 20-30 square metres and dig three to four holes, combining the soil samples from each depth layer into a clean and clearly labelled bucket. This is best done with a soil corer where the depths can be accurately separated.

Thoroughly mix the composite soil samples in each bucket and place a representative sub-sample in a clearly labelled plastic bag provided by the laboratory. Repeat this process for each zone within the paddock.

Send the samples to the laboratory for pH, organic carbon percentage, aluminium and soil texture analysis. You may also wish to include measurements of nutrients to inform fertiliser programs.

Apply lime to target acidity

Source: PIRSA

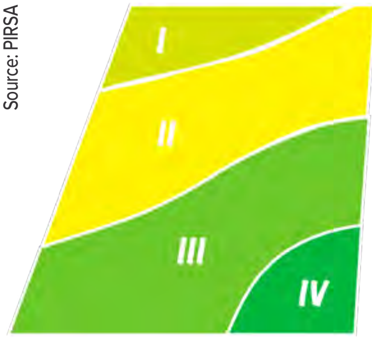

Figure 6. An example of a schematic paddock pH map, indicating zones with different lime requirements based on soil pH test results.

Soil pH maps can be generated based on pH testing data and used to identify zones where lime application rates should be varied. Your agronomist or consultant may be able to help with this approach.

Spreaders equipped with variable rate technology provide growers with the opportunity to tailor lime rates to target zones of the paddock based on pH, soil texture and organic carbon. These properties influence the soil's pH buffering capacity, the likely change in pH with lime additions, and the rate at which lime moves down through the soil.

This variable rate method is used in place of a blanket application across the paddock to target lime applications where they are most needed, avoid lime where it is not required, and optimise the overall lime investment.

Photo: Brian Hughes, PIRSA

Figure 7. A soil probe and soil pH test kit provide a convenient means of testing soil pH to depth. This test shows: from 0 to 5cm, pH 7-8; from 5 to 20cm, pH 4-5; from 20cm, pH 7.

Soil pH should be checked two to three years after the lime application, when the lime has fully dissolved and done its job. Experience suggests topsoil pH must be 5.5 or more to encourage lime to move deeper into the profile. If the topsoil pH is below 5.5, the lime application may be used up in neutralising the surface acidity and no movement into the subsoil will occur.

No-till farm systems

Lime has low solubility, so it dissolves and moves through the soil very slowly, even in high rainfall zones. Lime movement will be even slower in low to medium rainfall areas, as the topsoil is not moist for very long and leaching is less likely.

In the absence of tillage, evidence suggests that lime applications will move slowly into the soil at rates up to 2cm per year on sandy soils in high rainfall zones, down to 1cm or less per year on loamier soils in medium rainfall zones. So it could take five years or more for lime to penetrate below 10cm.

Strategic tillage as a 'one off' operation can be used to help mix the lime deeper and break up acid layers mechanically. While frequent tillage can be detrimental to soil fertility, strategic tillage every eight to 10 years will increase the return on lime applications and may have other benefits.

A new GRDC invested research project has begun exploring options for treating subsurface acid stratification in no-till farming systems in SA. This study will trial different types of lime; mixing lime with other products (such as gypsum, composts and manure); applying more soluble alkaline materials and incorporation; and possibly whether improved soil biology helps increase lime effectiveness.

Photo: GRDC

Figure 8. Applying lime with a variable rate spreader can be a more effective and economical way of remediating acidification in different soil types across each paddock.

Treat acid soils early

- If soil pH (in calcium chloride) is less than 5.0 in the surface or less than 4.8 in the subsoils, lime should be applied **at the earliest opportunity.**
- If pH is in the 5.5–5.0 range lime should be applied **within the next few years.**
- When the soil pH (in calcium chloride) falls below 4.8
  - root growth and the uptake of water and nutrients are reduced
  - nodulation in pulses is compromised significantly
  - the productivity of crops and pastures starts to fall
  - nutrients such as phosphorus magnesium, calcium and molybdenum become less available
  - toxic amounts of aluminium and manganese can occur.
- Precise soil testing to depth is required to identify subsurface acidity or stratification.
- Many legume crops including lentils, chickpeas, faba beans and their associated rhizobia (required for nitrogen fixing) are highly sensitive to acid soils.
- Lime is the most effective and economical method for treating acid soils but it moves slowly down the soil profile in no-till systems.

Address acidification early

Soil acidity develops slowly, and by the time crops show symptoms, yields may have already been compromised for several years.

Hence, it is important to monitor and address topsoil and subsurface acidity as early as possible.

Careful monitoring of soil pH and appropriate management can produce significant cost savings for growers in the short and medium term.

If acidity is evident on the farm, then the best approach is to maintain a regular soil testing program where the topsoil of each paddock is tested every three to five years. The test samples can also be used to monitor soil nutrient levels and guide fertiliser recommendations.

Soil $pH_{(CaCl)}$ should be at least 5.5 in the top 10cm of soil and 5.0 or higher in the 10-20cm layer.

Liming is generally recommended once the topsoil $pH_{(CaCl)}$ falls below 5.5 or sub-surface $pH_{(CaCl)}$ falls below 5.0.

In paddocks that are vulnerable to acid stratification including no-till systems and sandy soils, regular pH testing at 0-5cm, 5-10cm and 10-20cm is generally recommended. pH testing at 20-30cm may also be useful in deeper, often sandier soils.

USEFUL RESOURCES

Acid Soils SA
www.acidsoilssa.com.au

Latest strategies for treatment of soil acidification
https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/02/latest-strategies-for-treatment-of-soil-acidification

Liming acid soils
www.youtube.com/watch?v=0bUfCwpfBxo

Legumes in acidic soils
https://grdc.com.au/legumes-in-acidic-soils

Treat soil acidity early to prevent yield decline
https://grdc.com.au/news-and-media/news-and-media-releases/south/2020/march/treat-soil-acidity-early-to-prevent-yield-decline

FREQUENTLY ASKED QUESTIONS

How do I determine the rate of lime to apply?

The rate of lime required to achieve a target pH is affected by the buffering capacity of the soil, which is largely a factor of soil texture and organic matter content.

As an approximate guide, changing soil pH by one unit for each 10cm of depth requires 2t/ha of lime for sandy soil, 3t/ha for sandy loam and 4t/ha for loam/clay loam. These rates can be reduced where the soil organic content is low, such as in subsurface layers and low rainfall areas.

Growers can access a range of tools to help with lime management, including:

- **Acid Cost Calculator**
  Estimates the loss of crop and pasture production caused by acid soils.
- **Maintenance Lime Rate Calculator**
  Estimates the replacement lime required to counteract the annual acidification of the surface soil layer.
- **Lime Cheque**
  Estimates the lime application rates for acidic soils and calculates the most cost-effective source of lime.

These resources are available via the **Acid Soils SA** website.

What form of lime should I use?

Agricultural lime is available in numerous forms including lime sand or limestone, dolomite and magnesite.

- Limestone contains mostly calcium carbonate but can also contain a small amount of magnesium carbonate.
- Lime sand is fine lime that contains a high calcium carbonate content and does not require crushing like limestone.
- Dolomite contains both calcium and magnesium carbonate and is generally defined as having a minimum magnesium carbonate content of 28 per cent and a minimum calcium carbonate content of 35% (Victorian Limestone Producers Association).
- Magnesite is mostly magnesium carbonate.

Other sources of lime include burnt lime (calcium oxide) and hydrated lime (calcium hydroxide).

The ability of lime to dissolve, move through the soil and raise pH is due to its effective neutralising value (ENV). ENV is derived from the neutralising value (i.e. the calcium carbonate purity) and the particle size, which influences how effectively the lime will neutralise soil acidity.

Where should I buy lime?

Several suppliers are currently registered to sell lime as an agricultural source in South Australia.

For more information on lime types and sources, see **Current and potential lime sources** on the Acid Soils SA website.

When can I expect to see results?

In no-till farming systems, correcting subsurface acidity through lime application is a slow process and crop responses can be expected after 1-3 years. Recent research in SA found that fine lime broadcast at 3t/ha or 6t/ha without soil incorporation moved 7- 10cm into the soil over a four-year period, while coarser lime moved 5cm in the same time.[1]

Lime quality, soil type, and rainfall will all affect the time required for top-dressed lime to mitigate subsurface acidity.

MORE INFORMATION

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REFERENCES

1. Harding, A and Hughes, B (2018) Current and potential lime sources in South Australia. Viewed online at https://acidsoilssa.com.au/index.php/home/resources/

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