Identification and treatment of sub-surface soil acidity

Surface soil acidification is relatively well–known but sub-surface soil acidity that refers to acidification below the normal depth of cultivation (10-20 cm) is less well understood and is becoming an increasing problem.

Surface and sub-surface soil acidification can greatly affect the potential production of crops and pastures.

Recent soil sampling across the Lower Eyre Peninsula, Northern and Yorke, Mount Lofty Ranges, Kangaroo Island and the South East showed that sub-surface acidity is a problem in all regions with Kangaroo Island, Mount Lofty Ranges and the South East being the most affected.

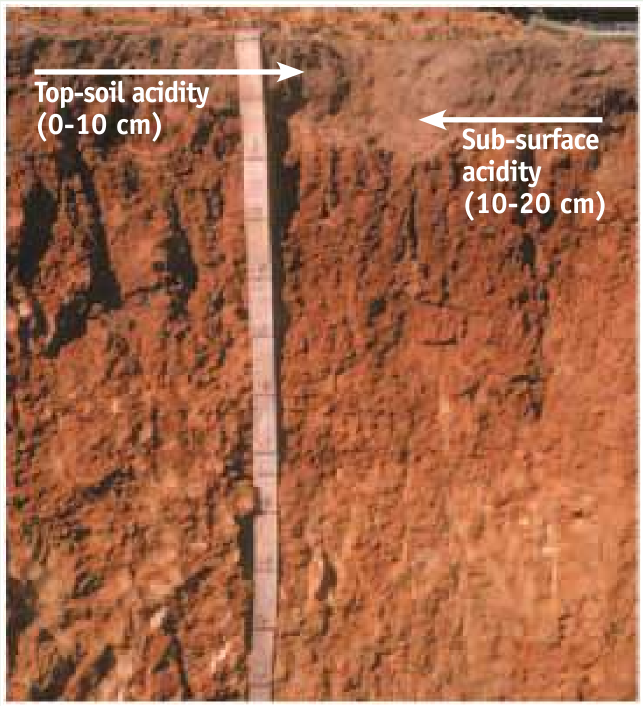

Figure 1: A soil profile showing area where sub-surface acidity occurs. Source: DENR

Sub-surface acidity has the same basic causes and treatments as surface soil acidity but it is more difficult to detect and much more expensive to treat.

The depth to which sub-surface (10–20 cm) and sub-soil (>20 cm) acidity can reach depends on the type of soil and the rate at which acidification takes place.

Causes

The causes of sub-surface acidification are natural processes but are greatly accelerated by farming practices. It is caused by an accumulation of acid hydrogen ions in the soil through: the acid production by plant roots particularly legume-based plants; the addition of nitrogen fertilisers and leaching of nitrates; and the removal of alkaline materials in farm produce such as hay and grain.

When the soil pH ($CaCl_2$) falls below 5.0 then toxic amounts of aluminium and manganese can be released into the soil solution. Aluminium solubility increases markedly as the soil pH ($CaCl_2$) drops below 5.0 and goes from having a negligible effect on plants to having a large effect. Soluble aluminium is toxic to roots of sensitive plants, it reduces root growth and therefore limits their access to soil, water and nutrients.

At a low soil pH, nutrients such as phosphorus, magnesium, calcium and molybdenum become less available.

Symptoms

The symptoms of surface and sub-surface acidification are not easy to identify but may show up as un-even crop and pasture growth, yellowing of crops, poor nodulation of legumes and stunted root growth. Sensitive plants such as lucerne, lentils, medic, faba beans, canola and barley will be first affected.

If soil acidification is allowed to continue then it is likely that it will further decrease productivity and limit plant options to acid tolerant crops and pastures.

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Sampling and measuring sub-surface pH

Field sampling

Measuring sub-surface acidity requires soil samples to be taken from 10-20 cm.

Soil samples can be taken with either a spade, soil auger or a soil corer. Samples should be collected from the same soil type and land use. Sample along a fixed transect that can be re-sampled in the future. Collect 10 to 30 samples: the more cores taken, the more reliable the sample. Thoroughly mix the soil and take out a sample to send to the laboratory.

Measurements

Soil pH can be measured either in the field or in the laboratory. Field pH testing kits are available at most agricultural stores. These kits provide a useful guide of soil pH levels, with the result approximating a pH measured in a water solution.

For a more precise pH test, soil samples can be sent to an accredited laboratory. In the laboratory, soil pH is tested by two methods, either by pH water or pH calcium chloride ($CaCl_2$). Calcium chloride is the preferred method for measuring acid to neutral pH soils.

Figure 2: Field testing pH kit

The difference between the calcium chloride and the water test can be about 0.5 to 1.2 pH units. It is important to know which test was used when interpreting results.

pH variability

Surface soil pH and the sub-surface pH can vary within the same soil type and the same paddock. The diagrams below show the variation in soil pH that occurs in a paddock with red-brown earth soils in the mid north of SA. Each sample point is 100 metres apart.

The more samples taken and tested will provide a better guide to the variation of soil pH across the paddock and then the paddock can be zoned according to similar pH levels. Once paddocks are zoned then various rates of lime can be applied on the surface in each zone to raise the soil pH with the use of variable rate technology.

Prevention and treatment of sub-surface acidity

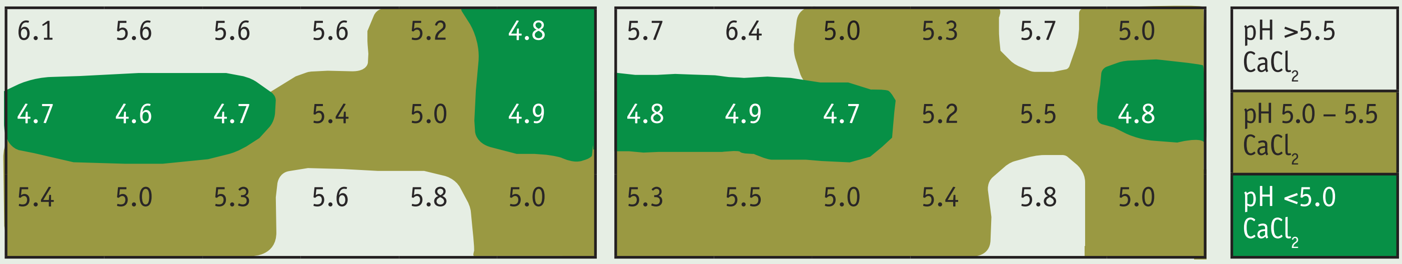
The cause of sub-surface acidity is essentially the same as for surface soil acidity and the treatments are the same in principle, usually involving liming. The difficulty is in applying lime below the surface and mixing it to maximise its effectiveness. Lime has a very low solubility and is very slow to move down through the soil.

The cheapest and most effective control method is to prevent sub-surface soil from becoming a problem. Maintaining the top-soil pH at or above 5.5 ($CaCl_2$) will help to reduce the likelihood of developing a sub-surface soil acidity problem. If the sub-surface has developed an acidity problem then there a number of treatment options available. These are outlined below.

Application of surface lime

Lime (calcium carbonate) is used to treat surface acidity by raising the soil pH and decreasing the concentration of toxic aluminium ions. This then allows plant roots to explore a greater volume of soil for nutrients and moisture.

Research has shown that lime will generally only move into the sub-surface soil when the surface pH is maintained above ph 5.5 ($CaCl_2$). If the pH is below this then all the lime is used up neutralising the acidity within the top-soil. It may take several applications of lime to achieve and build up the top-soil pH to



Sandy loam top-soil (0-10 cm)

Sandy loam sub-surface (10–20 cm)

Figure 3: Soil pH variability across a paddock (one sample point represents one hectare)

5.5 ($CaCl_2$) extending the time until lime will move downward. This approach may take decades to raise sub-soil pH.

Zoning the paddock as shown in Figure 3 will enable application of lime where it is most needed. Varying the rates of lime rather than applying a set amount across the paddock will be more efficient and effective. Applying lime at various rates on the surface will help to achieve the target pH of 5.5 ($CaCl_2$) across the whole paddock. The white areas (0-10 cm) would require no lime; the olive areas (0-10 cm) would require 0.5-1.5 t/ha of lime and the green areas (0-10 cm) would require about 1.5 – 3.0 t/ha, which will also help to influence sub-surface acidity.

An investigation was carried out on two adjacent sandy paddocks in the Mount Lofty Ranges to demonstrate what happens to the distribution of lime in the soil. Lime was spread on one paddock approximately every four years with about 12 tonnes of lime over 17 years. The other paddock had no lime.

Over the 17 years, lime moved down the soil profile and improved the soil pH to about 40 cm depth.

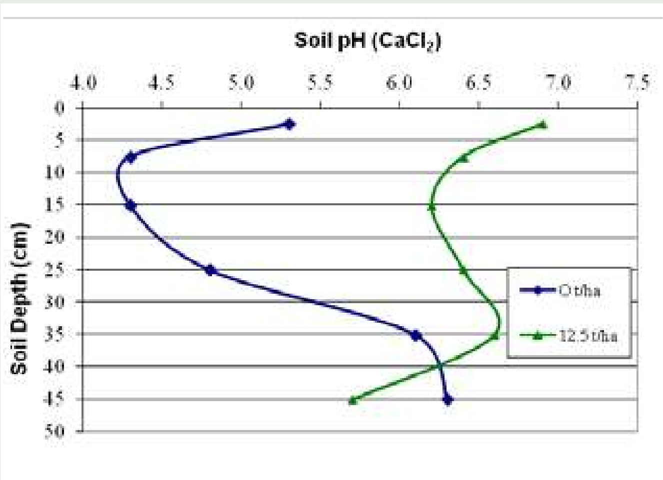


Figure 4: Soil pH down the profile with and without lime over 17 years

High rates of lime applied on the surface at one time (more than three tonnes of lime on sandy soils) can induce trace element deficiencies such as manganese, particularly on light textured soils.

There has been little work in SA on the economics of treating sub-surface acidity with applications of surface applied lime however, work in WA has shown that this practice is profitable over the long term and contributes to the sustainability of the farming system.

Incorporating lime into the sub-surface

Incorporating lime into the sub-surface has a much quicker effect and has been carried out using specialised machinery such as a Yeoman's plough, deep rippers and slotters. This has been used for small areas of high value crops and in some cases has been effective, but for most broad-acre crops is too expensive.

Figure 5: Incorporation of lime using Yeoman's plough

Delving / spading

Delving or spading can be effective options for improving the sub-surface pH. Delving drags clay from the sub-soil and mixes it through the upper soil profile. This has been shown to help to raise the sub-surface soil pH and improve conditions for plant growth, but is only effective when the underlying clay is less acid than the soil being treated. The pH of the sub-soil clay should be checked before using this method.

If the top-soil pH is above 5.5 ($CaCl_2$) and the sub-surface has a lower soil pH then liming the top-soil and spading will help to mix the top-soil layer and lime with the sub-surface layer. A Spader is like a large rotary hoe that can mix the upper soil layers to a depth of 30 to 40 cm and help improve soil pH and conditions for plant growth.

There is a high cost associated with delving or spading and they should only be considered if there are other benefits for improving soils such as overcoming water repellent sands.

Figure 6: Delving

Figure 7: Spading

Non-acidifying fertilisers

Fertilisers such as urea and ammonium nitrate can acidify the soil whereas calcium nitrate and potassium nitrate do not acidify the soil and can have a slight alkalising effect. These are increasingly been used on horticultural crops such as apples, vines and citrus. They not only supply nutrients to crops but can also treat soil acidity

These fertilisers are highly soluble and are therefore suited to fertigation, foliar sprays or banded or broadcast on the surface. Due to their cost they are largely restricted to high value crops.

Other options

There are a number of other options such as animal manures, bio-solids, plant residues and biochar that could prevent or treat sub-surface acidity. These require further investigations to evaluate their effectiveness and cost.

Conclusions and recommendations

Surface and sub-surface acidity is becoming an increasing problem and can adversely affect plant growth and yield.

Both surface and sub-surface soils should be monitored on a regular basis every five years to determine the soil pH. If soil acidity has been detected then this should be treated. The problem becomes increasingly more difficult and expensive to overcome if acidification is left untreated.

Monitoring your paddocks and having a pro-active approach to preventing acidity is the cheapest and most cost-effective method of control.

Figure 8: Spreading lime on the surface. The cheapest and most effective control method to prevent sub-surface acidity from becoming a problem is to maintain the top-soil at or above pH 5.5 ($CaCl_2$).

For further information contact your local Rural Solutions SA consultants

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