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SOIL ACIDITY

Key points

- Soil pH is a measure of the concentration of hydrogen ions in the soil solution. The lower the pH of soil, the greater the acidity.
- pH should be maintained at above 5.5 in the topsoil and 4.8 in the subsurface.
- A well maintained soil pH will maintain the value of the soil resource, maximise crop and pasture choice and avoid production losses due to low pH.

Background

Soil acidity is a major environmental and economic concern. Approximately 50% of Australian agricultural land or 50 million ha have surface pH values less than or equal to 5.5 which is below the optimal level to prevent subsoil acidification. If untreated, acidity will become a problem in the subsurface soils, which are more difficult and expensive to ameliorate. Subsurface acidity is already a major problem for large areas of Western Australia and New South Wales. It is estimated that 12 to 24 million ha is extremely to highly acidic with pH values less than or equal to 4.8 (NLWRA, 2001).

Acidic soils cause significant losses in production and where the choice of crops is restricted to acid tolerant species and varieties, profitable market opportunities may be reduced. In pastures grown on acidic soils, production will be reduced and some legume species may fail to persist.

Degradation of the soil resource is also of wider concern and off-site impacts must be considered. Off-site impacts mainly result from reduced plant growth. Deep-rooted species required to increase water usage may not thrive, increasing the risk of salinity. Increased run-off and subsequent erosion has detrimental impacts on streams and water quality. Increased nutrient leaching may pollute ground water.

Soil pH

Soil acidity is measured in pH units. Soil pH is a measure of the concentration of hydrogen ions in the soil solution. The lower the pH of soil, the greater the acidity. pH is measured on a logarithmic scale from 1 to 14, with 7 being neutral. A soil with a pH of 4 has 10 times more acid than a soil with a pH of 5 and 100 times more acid than a soil with a pH of 6.

Effects of soil acidity

Plant growth and most soil processes, including nutrient availability and microbial activity, are favoured by a soil pH range of 5.5–8. Acid soil, particularly in the subsurface, will also restrict root access to water and nutrients.

Aluminium toxicity

When soil pH drops, aluminium becomes soluble. A small drop in pH can result in a large increase in soluble aluminium (figure 1). In this form, aluminium retards root growth, restricting access to water and nutrients (figure 2).

Poor crop and pasture growth, yield reduction and smaller grain size occur as a result of inadequate water and nutrition. The effects of aluminium toxicity on crops are usually most noticeable in seasons with a dry finish as plants have restricted access to stored subsoil water for grain filling.

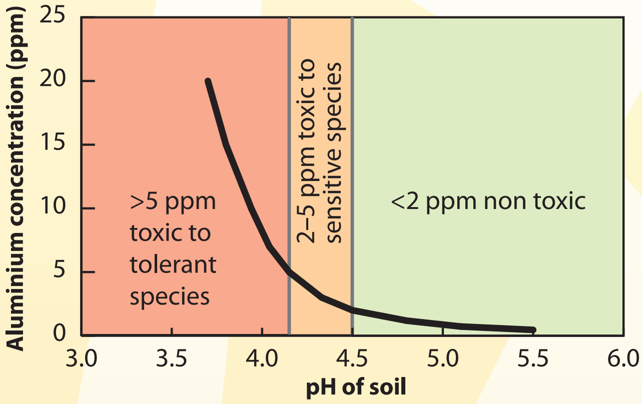

Figure 1: *Al & pH graph with Rule of thumb Al toxicity.*

Figure 2: *Roots of barley grown in acidic subsurface soil are shortened by aluminium toxicity.*

Nutrient availability

In very acid soils, all the major plant nutrients (nitrogen, phosphorous, potassium, sulfur, calcium, manganese and also the trace element molybdenum) may be unavailable, or only available in insufficient quantities. Plants can show deficiency symptoms despite adequate fertiliser application.

Microbial activity

Low pH in topsoils may affect microbial activity, most notably decreasing legume nodulation. The resulting nitrogen deficiency may be indicated by reddening of stems and petioles on pasture legumes, or yellowing and death of oldest leaves on grain legumes. Rhizobia bacteria are greatly reduced in acid soils. Some pasture legumes may fail to persist due to the inability of reduced Rhizobia populations to successfully nodulate roots and form a functioning symbiosis.

Causes of soil acidity

Soil acidification is a natural process accelerated by agriculture. Soil acidifies because the concentration of hydrogen ions in the soil increases. The main cause of soil acidification is inefficient use of nitrogen, followed by the export of alkalinity in produce.

Ammonium based fertilisers are major contributors to soil acidification. Ammonium nitrogen is readily converted to nitrate and hydrogen ions in the soil. If nitrate is not taken-up by plants, it can leach away from the root zone leaving behind hydrogen ions thereby increasing soil acidity.

Most plant material is slightly alkaline and removal by grazing or harvest leaves residual hydrogen ions in the soil. Over time, as this process is repeated, the soil becomes acidic. Major contributors are hay, especially lucerne hay and legume crops. Alkalinity removed in animal products is low, however, concentration of dung in stock camps adds to the total alkalinity exported in animal production.

Management of acidic soils

Soil testing

Knowledge of how soil pH profiles and acidification rates vary across the farm will assist effective soil acidity management.

Ideally, soil samples should be taken when soils are dry and have minimal biological activity. It is standard to measure pH using one part soil to five parts 0.01 M $CaCl_2$. Soils with low total salts show large seasonal variation in pH if it is measured in water. pH measured in water can read 0.6–1.2 pH units higher than in calcium chloride (Moore *et al*., 1998).

Soil sampling should take paddock variability into consideration. For example, clays have greater capacity to resist pH change (buffering) than loams, which are better buffered than sands. Samples should be taken at the surface and in the subsurface to determine a soil pH profile. This will detect subsurface acidity, which may underlie topsoils with an optimal pH.

Samples need to be properly located (e.g. GPS) to allow monitoring. Sampling should be repeated every 3–4 years to detect changes and allow adjustment of management practices.

Interpreting pH results

Depending on soil pH test results, agricultural lime may need to be applied to maintain pH, or to recover pH to an appropriate level. If the topsoil pH is above 5.5 and the subsurface pH above 4.8, only maintenance levels of liming will be required to counter on-going acidification caused by productive agriculture.

If the topsoil pH is below 5.5, recovery liming is recommended. Keeping the topsoil above 5.5 will treat the on-going acidification due to farming and ensure sufficient alkalinity can move down and treat subsurface acidity.

Liming is necessary if the subsurface pH is below 4.8, whether or not the topsoil is acidic. If the 10–20 cm layer is below 4.8 but the 20–30 cm layer above 4.8, liming is still required. In this case the band of acidic soil will restrict root access to the more suitable soil below.

Liming

Liming is the most economical method of ameliorating soil acidity. The amount of lime required will depend on the soil pH profile, lime quality, soil type, farming system and rainfall.

Limesand, from coastal dunes, crushed limestone and dolomitic limestone are the main sources of agricultural lime. Carbonate from calcium carbonate and magnesium carbonate is the component in all of these sources that neutralises acid in soil.

The key factors in lime quality are neutralising value and particle size. The neutralising value of the lime is expressed as a percentage of pure calcium carbonate which is given a value of 100%. With a higher neutralising value, less lime can be used, or more area treated, for the same pH change. Lime with a higher proportion of small particles will react quicker to neutralise acid in the soil, which is beneficial when liming to recover acidic soil.

Complimentary management strategies

If soil pH is low, using tolerant species/varieties of crops and pasture can reduce the impact of soil acidity. This is not a permanent solution because the soil will continue to acidify without liming treatment.

A number of management practices can reduce the rate of soil acidification. Management of nitrogen fertiliser input to reduce nitrate leaching is most important in high rainfall areas. Product export can be reduced by feeding hay back onto paddocks from where it has been cut. Less acidifying options in rotations will also help, e.g. replace legume hay with a less acidifying crop or pasture.

Further reading and references

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Lime Comparison Calculator, www.soilquality.org.au/calculator.

Moore G, Dolling P, Porter B and Leonard L (1998) Soil Acidity. In 'Soilguide. A handbook for understanding and managing agricultural soils'. (Ed. G Moore) Agriculture Western Australia Bulletin No. 4343.

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