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_{water} should be maintained at above 5.5 in the topsoil and 5.2 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 the optimal level to prevent subsoil acidification. Research in Tasmania indicates that the trend for topsoil pH in cropping areas is for increasing pH due to the history of lime applications in these areas, in contrast to large areas of cropping country on mainland Australia. If untreated, acidity will become a problem in the subsurface soils, which are more difficult and expensive to ameliorate.

Acidic soils result in 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_{water} range of 5.5–8.0. Acid soil, particularly in the subsurface, will also restrict root access to water and nutrients.

Aluminium toxicity

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

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. Soils tend to become acidic as a result of (1) rainwater leaching away basic ions (calcium, magnesium, potassium and sodium) (2) carbon dioxide from decomposing organic matter and rain water forming weak organic acids (3) decay of organic matter and ammonium and sulfur fertilisers.

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. To determine the average soil pH of a paddock, it is necessary to collect soil from several locations, combine and thoroughly mix these before taking a subsample for testing. The most accurate method of determining soil pH is by a pH meter. A less accurate result can be obtained using an inexpensive pH test kit available at most nurseries or hardware stores. These test kits generally consist of a test tube, some testing solution and a colour chart. You put a sample of your soil in the tube, add a few drops of test solution, shake it up and leave it for an hour or so to settle. The solution in the tube changes colour according to the pH of your soil. Compare the colour of the sample with the colour chart that came with the kit. Matching colours will tell you the pH of your sample. Soil pH measured in water can read 0.6–1.2 pH units higher than in calcium chloride. 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 6.0 and the subsurface pH above 5.2, only maintenance levels of liming will be required to counter on-going acidification caused by productive agriculture. While many plants can tolerate pH (in water) ranges between 5.2 and 7.8, most plants grow best in mineral soils when soil pH is between 6.0 and 7.0 (slightly acid to neutral). This general rule applies to most of the commonly grown pastures, fruits, vegetables, flowers, trees, and shrubs. Potatoes tolerate a wide range in soil pH. Some noted exceptions include blueberries, azaleas, and rhododendrons (acid loving plants) that require acid conditions between pH 4.5 and 5.2.

Liming

Liming is necessary if the surface pH_{water} is below 5.5. 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.

The key factors in lime quality are neutralising value (NV) 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 more quickly to neutralise acid in the soil, which is beneficial when liming to recover acidic soil.

Agricultural lime is the most commonly used liming material in Tasmania. It consists of limestone crushed to a fine powder and is usually the cheapest material for correcting soil acidity. Dolomite is a naturally occurring rock containing calcium carbonate and magnesium carbonate. Good quality dolomite has a NV of 95–98, and contains 22% calcium and 12% magnesium. It is good for acid soils where supplies of calcium and magnesium are low, but if used constantly may cause a nutrient imbalance. Lime sand, from coastal dunes, is used in the far northwest of Tasmania and on King Island. Lime sand has a lower NV than agricultural lime or dolomite and so more is required to change pH. Hydrated lime (calcium hydroxide) is made by treating burnt lime with water, and is used mainly in mortar and concrete. It is more expensive than agricultural lime.

Rates of lime to apply

As soil acidity increases (the lower the pH), the more lime is needed to ameliorate acidity.

More lime has to be added to clay soils and peaty soils than to sandy soils to achieve the same result because different soil types react in different ways to the application of lime. The amount of lime to apply depends on three main factors; neutralising value, fineness of the lime and soil texture.

It is easier to change pH on a sandy soil than on a clay soil. The estimated pH increases over the upper 10 cm of soil due to the addition of 1 t/ha (1 kg/10 sq metres) of 100%NV product to different soil types are:

Sand	0.5 - 0.7
Loam	0.3 - 0.5
Clay	0.2 - 0.3
Red clay loam (basalt)	0.04 - 0.1

It is best to apply at least 2.5 t/ha to get a good response. The upper limit for one application is 7.5 t/ha.

Lime has to be physically in contact with moist acid soil in order to neutralise acidity. Lime dissolves slowly in the soil, therefore, incorporation in the top 10cm of soil (or deeper if possible) is best to increase the rate of reaction and leaching of lime to a greater depth. Incorporating lime will increase soil pH in the 0-10cm soil depth within 1-3 years.

Further reading and references

Bolland M, Gazey C, Miller A, Gartner D and Roche J (2004) Department of Agriculture and Food, Western Australia Bulletin 4602. (online)

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

NLWRA (2001) 'Australian Agriculture Assessment 2001, Volume 1' (National Land and Water Resources Audit).

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