LEAFLET NO.9

Soil acidity and P deficiency

MANAGEMENT STRATEGIES FOR THE NORTHERN TABLELANDS OF NSW

Productive agricultural soils generally have a pH of between 5 and 8 (measured in calcium chloride). Below pH 5 most crops and pastures are adversely affected by acidity. The extent of this effect is variable and depends on the acid soil tolerance of the plant species grown. In addition, most agricultural soils – many of which are acid – are also phosphorus-deficient or quickly become deficient in the absence of added phosphorus (P) from fertilisers under cropping and grazing activity.

SOIL ACIDITY

Soil acidity affects the growth of pasture and crops in the following ways:

- Aluminium and manganese become more soluble (available) and may reach toxic levels to reduce plant growth below pH 4.8. At or below this pH aluminium will reduce root growth while manganese disrupts photosynthesis and other functions of growth.
- Nitrogen fixation by nodule inhabiting bacteria (*Rhizobia*) located in legume roots is reduced in very acid soils. The effect of the acidity varies for different strains, for example, the Rhizobia associated with lucerne fix most nitrogen at a pH range of 6.3 to 7 whereas the lupin Rhizobia function well at pH 4.0.
- Breakdown of organic matter to release valuable nutrients slows when acidity adversely affects the decomposing organisms. The cycling of organic matter is therefore slower in acid soils, reducing the availability of the major elements, nitrogen, phosphorus and sulfur.
- The important trace element molybdenum (Mo) becomes increasingly less available as pH declines below 5.0. Mo deficiency reduces nitrogen fixation and subsequent pasture quality and bulk.
- Acidity severely restricts plant responses to applications of other nutrients, by reducing either the availability of essential nutrients or the effectiveness of the roots to obtain nutrients and moisture.
- Leaching of acidity into the lower soil layers increases once pH declines below 5.0 leading to an acidified sub soil that cannot be easily corrected.

► *Lucerne is very sensitive to acid soil and responds readily to lime. The pot to the left has received no lime, the pot to the right has been given a small amount of lime and this plant is more vigourous.*

PHOTO: G. CROCKER

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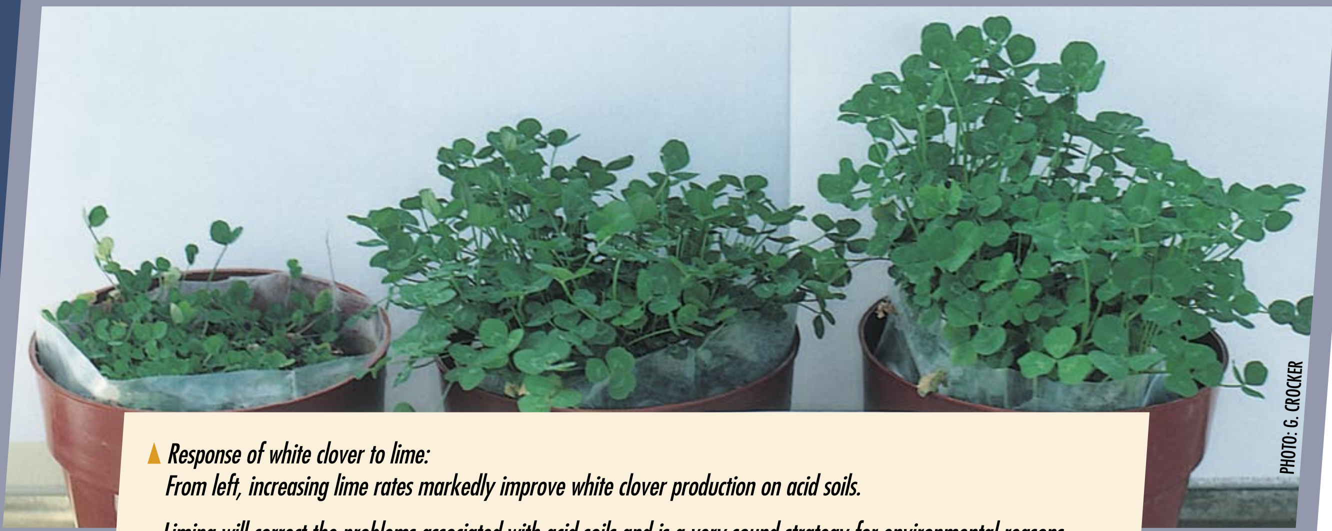

▲ *Response of white clover to lime:*
From left, increasing lime rates markedly improve white clover production on acid soils.

Liming will correct the problems associated with acid soils and is a very sound strategy for environmental reasons.

PHOSPHORUS IN THE SOIL

There are at least four forms (pools) of phosphorus (P) present in soil. P is constantly moving among these pools, but in most soils P is relatively unavailable for plant uptake.

- Two of these pools, organic and inorganic P bound tightly to the soil, are not immediately accessible by plants but depending on many factors including pH, become slowly available to growing plants over time. Between 80% and 90% of soil P is found in these two relatively insoluble, very slowly available forms.
- 10 to 20% is found in an available form, loosely associated with soil particles, with only about 1% in soil solution.
- This 1% is known as the water-soluble form and is the most readily available for plant growth.

Soil organic matter contains between 2% and 3% P, but needs to undergo mineralisation before the P becomes available to the plant. Many factors contribute to mineralisation, including soil temperature, moisture, presence of micro-organisms and pH.

Most plants use between 10% and 20% of the water-soluble P applied in fertiliser during the first growing season after application. Of the remainder, about 30 to 40% becomes available to the plant over the next few years. In most soils the remaining 50% becomes fixed and is effectively lost to the farming system, at least in the short to medium term until P from organic matter gradually moves back into soil solution.

Note the distinction between nitrogen (N) and P fixation. N fixation is the process of converting atmospheric N to a form useable to the plant – a positive result. P fixation is the 'locking-up' of P into forms unavailable to the plant – an unfavourable result.

EFFECT OF PH ON P AVAILABILITY

Research shows that P is most readily available between pH 6 and 7. Availability is governed by solubility and how readily P becomes tied up (fixed) in soils. Fixation onto colloidal iron surfaces at very low pH levels, usually below 4, is **seldom** the dominant P fixation process in most Australian soils. P fixation with aluminium is more commonly seen from pH 4.5 to 6 and results in substantial lock-up of P, while in less acid-to-neutral pH soils calcium phosphate is the more commonly encountered inorganic form of P.

There is a relationship between soil type and pH in terms of P fixation. Soil pH below 5.5 affects solubility (availability) of P in soils characterised by cracking clays, where aluminium and iron dominate. Above this level, calcium and magnesium are the dominant ions and fixation is less permanent.

RELATIONSHIP BETWEEN LIME AND P

Research conducted by NSW Agriculture on improved acid soil pastures in the Northern Tablelands between 1985 and 1990 greatly improved our understanding of the relationship between P and lime under a pasture and grazing system. The following is a brief summary of the significant outcomes from this research.

- Where P was not added, lime increased the availability and plant uptake of P in acid soils where aluminium and manganese toxicities were present.
- P deficiency symptoms are commonly seen on acid soils where root 'pruning' caused by aluminium toxicity restricts nutrient and moisture uptake. These symptoms were, in the short term of two to three years, remedied by lime alone.
- Liming increased P uptake, probably due to improved root growth, although increased mineralisation and subsequent supply of P from organic matter may have also contributed.
- Lime eliminated the need for added P on some P-deficient soils for the three years of the research project by increasing the availability and uptake of native P.
- Lime application rates should be targeted to achieve pH levels of between 5.2 and 5.5. Liming above this pH may induce trace element deficiencies.

LIME, PHOSPHORUS OR BOTH?

The decision whether to use lime, phosphorus or a combination of both to improve pasture production will depend on a number of factors. These include:

- The current pH and P status of the soil
- The acid soil tolerance of the crop or pasture species to be grown
- The presence of aluminium in the topsoil
- Cost: Benefit of applying P where acid tolerant species are present

Liming will correct the problems associated with acid soils and is a very sound strategy for environmental reasons (see ASA leaflets 4, 5 and 6). The economics of liming will vary, at least in the short term, according to commodity prices and seasonal conditions.

There may be some confusion regarding the effect of lime on P availability and plant nutrition, especially in grazed perennial pastures. In addition to reducing aluminium toxicity, lime is likely to correct Mo deficiency. Having reduced toxic levels of aluminium and improved the Mo status further additions of lime, at least in the short term, may not be warranted or provide any economic benefit. At this point, correction of P and sulfur deficiencies will be likely to produce a better overall result.

CONCLUSION

Before commencing a liming program some careful homework is necessary, taking into account the interaction that can occur with a range of soil nutrients.

The first step should be strategic soil sampling to establish the pH and nutrient status of the paddock.

The next step is to establish a four to five-year plan for the paddock. In some cases, it may be of greater benefit to correct major and/or minor nutrient deficiencies in moderately acid soils, where aluminium and manganese do not appear to have reached toxic levels or where the main crop or pasture is relatively tolerant to acidity. This is, however, a short-term approach that ignores the possibility of continued soil acidification and, worse, the more serious problem of the acid layer moving well below the surface. Subsoil acidity is a much more difficult problem to correct and costs significantly more to treat than surface soil acidity (this is explained further in ASA leaflet No.4).

Lime is rarely a long-term substitute for fertilisers. Rather it complements appropriate fertiliser products and in many locations will significantly add to fertiliser effectiveness.

Step three is to establish a regular soil test program that will assist paddock management and provide guidelines for subsequent lime and fertiliser use.

FURTHER READING

1. Acid Soil Action leaflets available from NSW Agriculture.
2. Crocker, GJ and Holford, ICR (1994), 'Long-term effects of lime on pasture yields and responses to phosphate fertilisers on 8 acidic soils', *Aust. Journal of Agricultural Research*, 45: 1051-62.

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