SOIL AND PLANT ANALYSIS AS AN AID TO DETERMINING FERTILIZER NEEDS

Ian Vimpany
Tropical Fruit Research Station
Alstonville

Both soil and plant analysis have been widely used as aids to determine the fertilizer needs of pastures. However, reliable calibration to enable meaningful interpretation of results is generally restricted to the major nutrients, especially under Australian conditions. Rather than being seen as mutually exclusive, with one better than the other, the methods should be seen as complementary, with each having its strong points.

SOIL ANALYSIS

The following analyses are commonly carried out and will be discussed in detail - pH, P, Ca, Mg, K and Al. In addition some laboratories analyse for a range of trace elements but interpretation of these is questionable.

pH - pH is measured in either a soil:water slurry or a soil :0.01M $CaCl_2$ slurry with varying ratios of soil to water. All of these factors influence the result and therefore the interpretation. It is now standard practice to use one part of soil to five parts of either water or calcium chloride. When using calcium chloride the pH will be about 0.8 units lower than if measured in water.

The pH is used to indicate the acidity (or alkalinity) of a soil. The degree of acidity will indicate the possible need for liming and the likelyhood of deficiency or toxicity of a number of elements. Using pH measured in calcium chloride we can rate soils for acidity as follows:

6.0-5.5	mildly acid
5.4-5.0	moderately acid
4.9-4.5	very acid
4.4-4.0	highly acid
< 4.0	extremely acid

At pH ($CaCl_2$) above 5.0, few acid soil problems are likely and most pasture species grow well. For soils with pH ($CaCl_2$) in the range 4.9-4.5 deficiencies of calcium, magnesium and molybdenum may occur and effectiveness of rhizobia is reduced. Toxicity of aluminium may also occur. When the pH ($CaCl_2$) falls below 4.5 toxicity of aluminium is likely together with the deficiencies noted above. At pH ($CaCl_2$) of 4 and below manganese toxicity is also likely.

The pH can thus be seen as a guide to several nutritional problems which are associated with pH's ($CaCl_2$) of below 5. These should then be followed up. While pH *per se* is often used as a guide to lime requirement it does not guarantee an economic response to liming although it is desirable to maintain pH ($CaCl_2$) over 5.0

Extractable phosphorus - This is perhaps the most widely used test on pasture soils as phosphate is the major fertilizer of improved pastures. Considerable research has been carried out to calibrate the three major soil tests used in Australia. These are:

i) Bray 1 - dilute acid - ammonium fluoride - used by NSW Department of Agriculture;

ii) Olsen - pH 8.5 sodium bicarbonate - used by Victorian Department and Pivot;

iii) Modified Olsen or Colwell - as above but longer shake and changed soil-solution ratio - used by AFL, CFL, CSBP, DPI Queensland and WA Department of Agriculture.

The Bray test has the advantage of having a similar critical value for a particular crop across all soils. For non-irrigated pastures on the central and southern tablelands this is about 14 mg kg^{-1}. It is not suitable for use on soils with a pH ($CaCl_2$) greater than 7.0. It is widely used in the USA, India and other countries.

The Olsen test was developed for use on alkaline soils and its use has been extended to acid soils. Soil test values are similar but slightly smaller than those of the Bray test. It is also used in the USA, New Zealand and England.

The Colwell test was developed in Australia but is not used overseas. Because of its extensive commercial use there exists a large data base in NSW. Unfortunately it suffers from one serious drawback. The critical value changes with soil type so that to reliably interpret test values a second test is required to measure either the soils sorption capacity or the reactive iron content. This allows simple adjustment of critical values on different soils.

The following table shows how the Colwell critical values for pastures changes in the central and southern tablelands.

Soil Parent Material	Bray P mg/kg	Colwell P mg/kg
Granite	14	14
Slate/Shale	14	36
Basalt	14	30

On the north coast and old rainforest soils the Colwell equivalent of Bray equal to 10 may be as high as 100mg/kg.

Both Bray and Colwell tests if properly calibrated will provide reliable predictions of the phosphate requirements of pastures.

Work on some very acid soils (pH $CaCl_2$ $\pm$ 4.0) on the tablelands since 1980 has shown that on soils regularly fertilised with phosphate none of the three tests is reliable - all overestimate the phosphorus status due to dissolution of freshly precipitated aluminium phosphates. Dilute calcium chloride as used in the pH test has been tried as an extractant and appears to work satisfactorily, however amounts extracted are very small.

Exchangeable cations - In problem acid soils this determination is perhaps the most important. The nutrients calcium, magnesium and potassium together with toxic aluminium and undesirable sodium are commonly measured. In order to compare these cations on an equal basis their units are expressed as milli-equivalent per 100 g. This has recently been changed to c mol (+)/kg (centimoles of positive charge per kg). The two units are equal.

More important than the absolute amounts of each cation present is the relative percentage of each as a proportion of the total, ie. we total the absolute amounts of all the cations expressed as milli-equivalents and express each as a percentage of the total. On this basis calcium should be 65-80%, magnesium 10-15%, and potassium 1-5% with no aluminium or sodium present.

In problem acid soils the level of calcium is frequently below 60%. This causes poor seed set in subclover and animal health problems especially in lactating animals (milk fever). Frequently the level of calcium in the soil solution is deficient giving rise to damage of the growing root tip. A low percentage of calcium is one reason for liming.

In acid soils magnesium is often low and farmers may use magnesite ($MgCO_3$) in addition to lime. It is suspected that hypomagnesemia is related to low magnesium levels in the soil. Responses of pastures to magnesium have not been demonstrated in NSW, perhaps because many subsoils are high in magnesium, but on the deep sands of Western Australia responses have been obtained. High levels of potassium may induce magnesium deficiency, especially in horticultural crops where magnesium deficiency frequently occurs.

Potassium deficiency is common in soils on the coast used for dairying and dryland and irrigated pastures used for haymaking. This is because large amounts of potassium are removed in herbage, and in the case of dairy cows deposited elsewhere. Strip grazing is especially severe in removal and redistribution.

On tableland pastures potassium deficiency is rare and is usually associated with old cultivation or haymaking areas.

Both the absolute level of potassium (below 0.2 c mol(+)/kg) and relative percentages of potassium (<2%) are good indicators of deficiency. A second measure of the solubility of mineral reserves is also a useful guide. This applies particularly to alluvial soils.

Since the mid 1970's many laboratories have provided estimates of exchangeable aluminium. This is either the amount extracted at the same time as the other cations or that removed in a separate extract such as 1M KCl. This amount when expressed as a percentage of the exchangeable cations has proved a useful indicator of the growth and lime response of a large number of sensitive species. The following table is commonly used:

Al level (%)	Species affected
1-5	Lucerne, barley, rape
5-10	Wheat, phalaris, red clover
10-15	Some oats
15-20	Some oats, ryegrass
>20	Triticale, subclover, white clover, cocksfoot, tropical legumes

For the sensitive species this has worked well and provided a good guide to liming. A formula to calculate the lime required to reduce Al to a predetermined level has also been developed and successfully used.

More recently, doubts as to the adequacy of the so called exchangeable aluminium to predict plant responses to lime for most clover and more tolerant species have been raised. My own trials on the tablelands have not shown clover responses at levels of aluminium saturation as high as 35%.

If we follow the release of exchangeable cations in a leaching process such as that used at Rydalmere we find that after 50-80 ml of leachate, all the calcium, magnesium and potassium is removed, but after 200 ml aluminium is still being released, often at a constant rate. This fraction is clearly not a definable exchangeable cation and is best referred to as "salt extractable".

Recent research has shown that to accurately estimate the likely damage to growing roots it is necessary to either measure or estimate the actual amount of monomeric aluminium in the soil solution and then calculate its activity. The amount of aluminium in the soil solution is more affected by the concentration of the soil solution - the stronger the concentration the more aluminium is dissolved with a rapid increase in the amount solubilised as concentration increases. Any extraction with solutions of a concentration greater than the soil solution will obviously overestimate aluminium toxicity. At the present time it would appear that extraction with $CaCl_2$ (0.002M) may be appropriate but research in this area is currently under way.

Exchangeable sodium is not normally a problem except in western areas where levels greater than 5% indicate the need for gypsum.

In summary, the pH is a useful indicator, extractable phosphorus can be a reliable guide and exchangeable cations can indicate the need for lime and potassium.

PLANT ANALYSIS

The principle behind plant analysis relies on the fact that if the roots have taken up a sufficiency of any element, then the soil is adequately supplied. The major drawback is that in many cases diagnosis of a deficiency is too late to permit remedial action for the season in hand, especially with annual species.

This is particularly the case with subclover and phosphate application which is the major fertiliser of improved pastures. In general a properly calibrated soil test is the best guide for phosphate application for pastures.

It is important for plant analysis that certain plant parts are sampled at particular growth stages. These are determined by calibration studies and vary for different plants. Care should be taken to understand nutrient interactions. The toxic levels of aluminium may limit root growth which in turn restricts the uptake of other nutrients. The deficiency of one nutrient may restrict the size of a plant so that concentrations of other nutrients may be high. Very rapid growth may also lead to dilution effects of nutrients.

Nitrogen - Nitrogen analysis of clovers is a useful guide to the efficiency of nodules fix nitrogen. Poor fixation is usually due to a molybdenum deficiency or soil acidity. Plant analysis is seldom used to determine fertilizer nitrogen use except as a topdressing of ryegrass pastures.

Sulphur - Plant analysis is the major tool for diagnosis of sulphur deficiency. There are no reliable soil tests for this nutrient because sulphate is produced by microbial breakdown of organic matter and this cannot be predicted.

Potassium - Plant analysis is a useful and reliable indicator of potassium deficiency and, since potassium fertilisers are water soluble, topdressing a pasture during a growing season is a viable option. Whether soil or plant analysis is used will depend largely on personal preference and when the sample is taken, ie. before or after pasture is sown.

Calcium and Magnesium - Deficiences of these elements are usually associated with problem acid soils and therefore soil analyses to define other acid soil problems are usually preferable. However plant analysis for these elements is well established and is a reliable guide to deficiency.

Trace elements - Plant analyses for the trace elements including boron, copper, zinc, iron, manganese and molybdenum is well calibrated for the important pasture species and can be confidently used in preference to the unreliable soil analyses.

While plant analysis can be reliably used to detect deficiencies, it cannot be used to determine fertiliser rates as can be the case with several soil analyses.