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Soil and plant analysis for mineral deficiencies

By M. D. Carroll, Research Officer, Plant Research Division

Soil and plant analysis (testing) has its supporters and its critics. Some of the differences are resolved if the distinction is made between the concept and the practice. Most people would agree with the concept of soil and plant analysis but the practice, or service offered, in any agricultural situation can be subject to valid criticism.

This article defines some of the principles involved and illustrates some of the problems, to provide a better understanding of the usefulness and the limitations of soil and plant analysis as a diagnostic aid in plant and animal nutrition.

Soil analysis and plant nutrition

The aim of soil analysis is to provide a guide for fertiliser management, using experimentally determined relationships between soil chemical properties and crop growth. For practical purposes, this relationship must be sufficiently broad to apply to many situations (paddocks), yet specific enough to apply to an individual situation (paddock).

The soil testing process has four major components—sampling, chemical analysis, interpretation and recommendation.

Sampling

Soil testing assumes a paddock can be sampled so that the results of the analyses represent the whole paddock and reflect its true nutrient status. This does not mean that all samples from the same paddock will give the same result—this would be highly unlikely, but the results of all the samples must reflect the variations in the nutrient status of the paddock. A single sample cannot show this variation.

Ideally, sampling intensity—the number of samples per unit area—should vary with the inherent paddock variability; the more variable the paddock, the more samples are needed. New light land in Western Australia tends to be uniformly low in available nutrients and the natural variability will not be important. In any case the initial fertiliser requirements have been fairly well established by field experiments.

As the fertiliser history builds up, important variations will develop within a paddock. Some areas of the paddock may be cropped differently to others using different fertiliser applications, corners worked out will receive extra fertiliser, spinner topdressing may apply fertiliser unevenly, and different soil types within the paddock will have different influences on nutrient leaching and fixation, leading to differences in nutrient availability for plants; and some of the nutrient will be evenly distributed by the animal in dung and urine.

Finally, when soil nutrient levels are built up to the stage where there is no current requirement—for superphosphate, many paddocks in
Copper deficiency in a black-woolled sheep showing as a grey band in the fleece.

W.A. which have received well over a ton of superphosphate are in this category—the variation in extractable nutrient will still exist but it will be uniformly high and now unimportant since the whole paddock requires no fertiliser or only a bare maintenance dressing.

In practice, sampling intensity is determined largely by what is commercially feasible. The limited sampling must still be done without bias in a way which best represents the whole paddock, and preferably using a sampling tool to ensure samples of uniform diameter and depth.

For some tests, time of sampling, soil moisture and sample handling and storage conditions are important and should be advised by the testing laboratory.

Chemical analysis

With modern instrumentation, chemical analysis is the most reliable aspect of soil testing. The total quantity of an element in the soil is not a reliable indication of its availability to plants and the soil test uses a chemical to remove a particular fraction of the nutrient from the soil. The extractable nutrient must be related to plant response but is not necessarily the actual nutrient fraction available to the plant.

There is sometimes a difference of opinion between laboratories on the best extractant to use for a particular nutrient. Different extractants may be suited to different classes of soils. Usually the testing service has to settle for only one extractant for each nutrient and often the one extractant is used for several nutrients.

Interpretation

Laboratory analysis gives the concentration of extractable nutrient in each soil sample. How is this value interpreted in terms of crop requirements?

It has already been pointed out that extractable nutrient values have no absolute meaning of their own in this context—only as they relate to variations in plant response. The soil test must be calibrated by field experimentation to relate the soil test values to the degree of crop response to additional fertiliser. A separate calibration is usually required for different crops and for different soil types.

A sound interpretation depends almost entirely on the thoroughness and quality of the background studies to establish these relationships. Soil testing programmes have often been started without adequate local research. Analytical methods can be transferred from one country to another but the calibrations cannot.

Interpretation problems are not simply removed by carrying out a large number of calibration experiments. The level of a particular nutrient in the soil is only one factor governing yield. Other factors may alter the relationships between soil test and yield response. For example, the level of other nutrients which may be limiting and climate, particularly rainfall and the length of the growing season. To ignore these other factors is to seriously reduce the validity and accuracy of the interpretation.

Recommendation

The recommendation to the farmer takes into account the level of deficiency indicated by each soil test and the variation within the paddock indicated by differences between samples. It also gives the value of the expected increase in yield relative to the cost of the extra fertiliser recommended.

The farmer's attitude to change must be considered. He may reject the recommendation if it differs greatly from his expectations based on fertiliser history or experience. If the test shows widely differing requirements for different parts of the same paddock he may decide on an average fertiliser rate for the whole paddock rather than treat each area separately—and thus largely defeat the purpose of soil testing.

Briefly, the quality of a soil testing programme depends on the quality of the component parts.
There are sources of error in all the components but the most serious errors occur when interpretation is made from inadequate research information. The success of a soil testing programme is directly proportional to its research backing.

With some elementary information it may be possible to use a soil test to help decide whether a soil is likely to be deficient in a particular nutrient and whether some crop response is likely. As research data accumulates and existing information is refined and added to, the precision of the recommendation can be increased to recommend quantities of fertiliser, usually as a range of rates. Considering the uncontracevable and unpredictable environmental factors which influence yield response, current soil tests cannot confidently predict specific rates of application.

Soil analysis and animal nutrition

An animal may become deficient in an essential mineral nutrient when it is grazing pasture growing on a soil which does not supply enough of that nutrient to the plant to satisfy the animal’s intake requirement.

Plants and animals have different requirements for the same nutrients. For example, with phosphorus, both plants and animals may be deficient at the same time; with copper, the plant may get enough yet the animal may be deficient; with potassium it is usually the other way around; and the plant has no requirement for selenium but the animal does.

Soil testing calibrations for the major plant nutrients (phosphorus, nitrogen, potassium) are still at a fairly early stage and there is almost no experimental information for the trace elements (copper, zinc, manganese, molybdenum) and the animal nutrients (such as cobalt and selenium).

In this context, the most useful soil analysis may be the simple test for soil pH (acidity-alkalinity) which can give an indication of the likely availability of some nutrients. Other useful information can be obtained without analysis—from fertiliser records and experience. How much fertiliser has been applied? When was the last application? Have trace elements or lime been applied? When and at what rate?

From observation and experience, on this soil type, in this area with this class of stock, can we expect cobalt or some other deficiency?

Soil testing for animal nutrition is not appealing since the soil is two steps away from the animal. The mineral deficiency in the diet comes from an inadequate concentration in the grazed pasture; so plant analysis seems more logical than soil analysis.

Plant analysis for plant nutrition

Because other factors besides the availability of the particular nutrient under test may limit plant nutrient uptake and yield, advocates of plant analysis say that deficiencies are better diagnosed in the plant, since all other factors are integrated in the plant’s growth. As a diagnostic procedure, it “asks” the plant about its nutrient problems.

Plant analysis has the same components as soil analysis and much the same problems.

Sampling

How many plants should be sampled to represent the crop or pasture? As with soils, the variation in nutrient content must be covered and cannot be represented by one sample. Establishing the required sampling intensity must be part of the background research. In practice the intensity of plant sampling will be largely determined by commercial restrictions. Three composite samples, each comprising a number of plants collected at random, would be a minimum requirement.

A further complication with plant sampling arises because different parts of the plant may have very different concentrations of the nutrient. For example, molybdenum levels are much higher in the stems of sub. clover than in the leaves. With copper it is the reverse.

The distribution of nutrients within the plant under deficiency conditions is often determined by their “mobility”. Under deficiency conditions mobile elements such as nitrogen and phosphorus can move from older tissues (leaves) to support new developing tissues (young leaves and growing points). An immobile nutrient such as calcium will not move out of old leaves and hence the young leaves and growing points become deficient and eventually collapse.

These differences in mineral distribution in the plant part make some plant parts more sensitive indicators of deficiency than others. In practice, this sensitivity is usually lost since the quickest sampling method is usually to take the whole of the plant top.

The time of sampling must also be considered. The concentration of most nutrients declines during the season. Values obtained early in the season will usually be higher than those from older plants later in the season.

Contamination of plant samples from soil or from fertiliser or spray residues can be a serious source of error, particularly for trace elements where small amounts of soil contamination can give entirely erroneous results.

Chemical analysis

As with soil testing, chemical analysis is the least troublesome part. Plant samples can usually be processed faster than soil samples and unlike soil testing, it is usually the total concentration of the nutrient which is measured although some fractions such as nitrate-nitrogen and sulphate-sulphur are more useful for some purposes.

Interpretation

An important concept in plant analysis is that of the “critical concentration” - that concentration of a nutrient within the plant below which plant growth begins to decline. The critical concentration is estimated experimentally by growing plants in a deficient soil with increasing amounts of the nutrient added to the soil.

If the plant analysis shows the nutrient level in a crop or pasture to be below the established critical concentration, the plants are presumed to be deficient and an appropriate fertiliser is recommended.

Although the critical concentration can be readily established for one particular set of circumstances, it can vary with plant species and variety, with plant part, stage of growth, level of other nutrients and with environmental conditions.

Once determined with sufficient calibration, some of the values for
critical concentration have been shown to have wide and useful application, provided sampling procedures and other conditions are rigidly observed. This has usually been for intensive crops such as pineapples, sugar cane, sugar beet and fruit trees where the close control of a valuable crop has warranted the massive research effort required.

In summary, plant analysis can often be used to confirm an acute deficiency (or toxicity) already suspected from visual signs, fertiliser history and experience. However, for most nutrients, plants can be suffering from a deficiency restricting production without showing obvious signs. It is in this area that one hopefully looks to plant analysis for a confident diagnosis. Unfortunately, for most nutrients in most situations, particularly in W.A., there is insufficient information on critical concentrations to identify borderline deficiencies.

**Plant analysis for animal nutrition**

The advocates of plant analysis for the diagnosis of mineral deficiencies in animals would say that the deficiency in the animal must be due to an inadequate intake in the feed, therefore an analysis of the feed will show if a deficiency is present or likely to develop.

This approach raises some further problems with plant sampling. Not only must there be an adequate sampling intensity, but also an adequate sampling of the different species which comprise the pasture, together with an estimate of their relative proportion in the pasture. More importantly their proportion in the animal diet must be estimated; since, except at very high stocking rates, there is probably some degree of selective grazing. For a good example of the effects of pasture species on mineral intake see Research Round-up.

Since nutrient concentration varies with the plant part, the plant parts sampled should represent those being grazed. For example, cattle will tend to take a higher proportion of leaf to stem than sheep, which usually graze much closer to ground level.

Time of sampling is again important. The nutrient concentration in the plant often declines with age of the plant and a sample taken at one point in time does not necessarily represent the animal’s level of intake in a previous period. Animals can often accumulate mineral reserves during periods of luxury intake which can be drawn on when intake falls below requirements, so that deficiency in the animal may not coincide with the indications from plant analysis.

Bearing these difficulties in mind, what standards are available to determine the adequacy of the nutrient content in the pasture?

Again the research information is very meagre. As with plants, it is often possible to confirm acute symptoms of mineral deficiencies, but within the range where animals suffer production losses from mineral deficiencies without showing obvious signs, plant analysis is of little help.

It has been shown in particular cases that animals need, for example, 0.08 parts per million (ppm) of cobalt, 6 ppm of copper or 0.03 ppm of selenium in the diet. Yet it is known that other animals in other areas at other times are quite healthy on pastures with lower levels than these.

A commonly used set of standards has been published under the auspices of the British Agricultural Research Council. This gives estimated requirements for the major elements (phosphorus, calcium, magnesium, potassium, sodium and chlorine) determined by a method based on theoretical requirements for growth, pregnancy, lactation and excretion, divided by the availability of the mineral in the diet and checked against the experimental data available.

There was not enough data to use the same method for the trace elements (copper, zinc, molybdenum, cobalt, selenium, iodine) and the standards for these are based on a very limited number of feeding trials.

The publication emphasises the paucity of the information available on mineral requirements and points out that for countries outside the U.K. with different breeds, feeds, management systems and climatic conditions, some of the suggested standards would almost certainly have to be modified.

Separate standards have not been established for W.A. and the conclusion might be, in this situation, that the best place to diagnose a mineral deficiency in an animal is not in the soil or the plant but in the animal itself.

If the deficiency is acute, clinical signs can often help. These signs may be exaggerated by using a sensitive indicator such as running a few black sheep to detect copper deficiency. Chemical analysis of body tissues can often indicate the status of mineral reserves, and some standards are available for these. Certain diagnostic techniques, such as the vitamin B12 assay for cobalt deficiency, are useful in specific cases. In this area, too, much still needs to be done.

To conclude, soil and plant analyses have an established place in modern agriculture and animal husbandry. But their usefulness depends almost entirely on the local research and development on which they are based. In W.A. this information is very limited, but, taken in conjunction with other supporting information and fully realising its limitations, testing can be a useful aid in helping to diagnose mineral deficiencies in plants and animals. On their own, soil and plant analyses can be quite misleading.