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Walter Jacob Cox

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Soil and plant analysis—a guide to fertiliser usage

By W. J. Cox, Plant Research Division

Soil and plant analysis can be used to identify problems in soils, diagnose nutrient deficiencies and as a guide to fertiliser usage.

Soil testing is particularly useful where large amounts of phosphorus and potassium are leached or removed from paddocks in hay or silage.

Where these losses are large, soil test values are used as an alternative to fertiliser history. The concepts, advantages and limitations of soil and plant analysis have previously been discussed in detail (1). This article considers the application of soil and plant analysis to the diagnosis of nutrient deficiencies and as a guide to farm fertiliser usage.

Soil testing

Although a number of elements are essential to plant growth (Table 1) and most are deficient on at least some soils in Western Australia, routine soil tests are available only for nitrogen, phosphorus and potassium. In addition pH (a measurement of soil acidity) and salt content can be used to identify problems in soils.

Soil testing can be used to diagnose nutrient problems by comparing the nutrient content of soil in areas of poor growth with that in areas of good growth alongside, for monitoring fertiliser programmes, and as a guide to fertiliser usage.

Farmers mainly use soil testing as a guide to fertiliser usage.

Table 1. Nutrients essential for plant growth

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>N</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
</tr>
<tr>
<td>Sulphur</td>
<td>S</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
</tr>
<tr>
<td>Manganese</td>
<td>Mn</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn</td>
</tr>
<tr>
<td>Boron</td>
<td>B</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Mo</td>
</tr>
<tr>
<td>Sodium*</td>
<td>Na</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
</tr>
<tr>
<td>Cobalt*</td>
<td>Co</td>
</tr>
</tbody>
</table>

* essential for some plants only.
Fertiliser rates for individual paddocks can be recommended without the use of soil testing; in the case of phosphorus through the "Decide" formula used by the Department of Agriculture (5), and with nitrogen using information on cropping history and rainfall (4).

Decide uses superphosphate history as one of the influences on current requirement. Where this information is unavailable, or where leaching or transport losses of phosphorus are large, soil testing can be used as a substitute.

Similarly with potassium large amounts can move out of the soil through leaching or plant uptake. History is therefore of little use in predicting the amount of potassium remaining in the soil, and a soil test is the most effective way of assessing the potassium status.

There are three main steps in soil testing—the collection of a representative soil sample; laboratory analysis, and the interpretation of the analysis to generate a recommendation for fertiliser usage.

**Soil sampling**

Sampling frequently limits the success of a soil test. A hectare to a depth of 10 cm contains about 1 300 tonnes of soil so that a laboratory 10 gram sub-sample from a 10 hectare paddock represents only 1 part in 1 300 million! As a consequence, extreme care is needed to ensure that samples are representative. Nutrient levels in the soil vary as a result of soil type differences and management effects. Most soils in Western Australia are not uniform and many soil types can usually be found in one paddock. Because of this, the soil nutrients will be unevenly spread across the paddock, particularly where leaching is important (6). Even if the paddock has uniform soil, stock can spread soil nutrients unevenly through urine and dung. The management history of the paddock can also concentrate or spread nutrients through clearing, burning and hay cutting. Variation in an apparently uniform area can be overcome by combining many sub-samples into a single sample.

Where differences in soil in a paddock are obvious and where these can be treated differently, it is advisable to sample each area separately.

**Sampling method**

Sample cores are taken across the paddock using a special tool usually equipped with an attachment to regulate the depth of sampling.

*For paddocks, less than 10 ha.*

If the paddock is predominantly of one soil type, 40 cores, each to a depth of 10 cm should be taken in a zig-zag pattern across the paddock. Where there is more than one soil type in the paddock, 20 cores should be taken from each major soil type. The cores from each type should be bulked and thoroughly mixed, and then sub-sampled to provide a 500 g sample of each soil type for forwarding to the laboratory along with the information sheets supplying the necessary details.

*For paddocks of more than 10 ha.*

Even in apparently uniform paddocks, some estimate of the variation should be obtained by

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**Table 2. Laboratories for soil and plant analysis**

<table>
<thead>
<tr>
<th>Laboratory Name</th>
<th>Address</th>
<th>Soil tests</th>
<th>Plant tests</th>
<th>Cost of analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agro Nutritional Research Laboratories</td>
<td>2C Main Street, OSBORNE PARK</td>
<td>pH, Electrical conductivity (salt), P, K, Na, initial and potential NO₃ nitrogen, Cu, Zn, Mn</td>
<td>N, P, K, Na, Ca, Mg, Cu, Zn, Mn, B, Mo, S</td>
<td>$20 per composite sample</td>
</tr>
<tr>
<td>CSBP</td>
<td>105 St George’s Tce, PERTH</td>
<td>pH, Cl (salt), P, K, initial and potential NO₃ nitrogen.</td>
<td>N, P, K, Cu, Zn, Mn</td>
<td>$28 per 6 samples</td>
</tr>
<tr>
<td>Government Chemical Laboratories</td>
<td>30 Plain Street, PERTH 6000</td>
<td>pH, Electrical conductivity (salt), P, K</td>
<td>N, P, K, S, Cu, Zn, Mn, Fe, Mo, B, Cu, Mg, Cl</td>
<td>Fees are available on application.</td>
</tr>
</tbody>
</table>

Note: Plant analysis samples are normally accepted only on the advice of Department of Agriculture advisers. Recommendations for rates of applications for fertilisers are given only through the Department of Agriculture.
collecting at least four separate samples each of 20 cores from separate parts of the paddock. Where differences in soil are obvious 20 cores should be collected from each major type.

Short cuts in sampling such as taking only one or two cores, a handful, or a spade-full of soil will give quite misleading results.

It is important to avoid contaminating the sample and equipment with fertilisers.

Depth of sampling
Ideally the whole root zone should be sampled. However, in most soils the nutrients are concentrated in the plough layer, so that only the top 10 cm is sampled.

For mobile nutrients such as nitrogen, and for potassium and phosphorus in leaching situations, sampling only the top 10 cm will not accurately assess nutrient availability.

Depth of sampling must be controlled, as in most soils the concentration of phosphorus and potassium decreases rapidly down the profile.

Time of sampling
The amount of nutrients which can be extracted from the soil varies markedly during the season as a result of plant accumulation, decomposition and changes in soil moisture. When soil samples are collected in spring therefore, a large proportion of available nutrients are still in the plant, and do not return to the soil until after decomposition when the amount available to subsequent crop or pasture increases. Most comparisons are based on midsummer (January to March) sampling when the soil is dry.

Analysis
The analysis of soil samples in the laboratory is very accurate. Errors in the soil test are mainly caused by poor paddock sampling techniques or in the interpretation of the analysis.

When the soil samples arrive in the laboratory they are dried, sieved to remove gravel and organic matter, sub-sampled and then analysed. The result of the technique used for analysis gives an index of nutrient availability to the plants, and this has a good relationship with yield.

The same test (0.5M NaHCO₃ extractable) is often used to measure both available phosphorus and potassium.

Another test estimates the amount of nitrogen that may be released during crop growth. However, because of the marked effect of rainfall and temperature on mineralisation and the release of nitrogen, and the effect of rainfall on leaching, nitrogen soil tests have generally been of little use in predicting nitrogen fertiliser requirement.

Analytical services
A number of laboratories handle routine soil testing and plant analysis and these are listed in Table 2. The Government Chemical Laboratories analyse a wide range of substances including soil samples. They offer no interpretation or recommendations and these would have to be obtained from advisers of the Department of Agriculture. The other organisations interpret the results and suggest fertiliser programmes.

Calibration and interpretation
The chemical analysis gives the concentration of extractable nutrient. To relate this to fertiliser needs requires a comprehensive field experimental programme relating soil test values to crop and pasture fertiliser needs. This information is available for phosphorus on wheat and pastures (2), for potassium on pastures (3) and is being investigated for nitrogen on wheat.

The actual amount of fertiliser needed is modified by method and time of placement, type of crop or pasture and economic considerations such as cost of fertiliser and the value of the product. As the Decide
method of phosphorus recommendation incorporates these factors soil testing used with Decide will give the best estimate for phosphorus usage.

Potassium fertiliser recommendations can be derived along similar lines.

Routine soil testing for copper, zinc, molybdenum, manganese, iron, calcium, magnesium and boron is not feasible as insufficient local data are available to interpret results.

A limited test to determine if copper has previously been applied is available through the Department of Agriculture by sampling and analysing soil from the paddock and a nearby virgin area of comparable soil type. It will not however, indicate the copper status or the need for re-application.

Soil pH affects the availability of a number of plant nutrients. Soils with pH values of 5.5 or less are considered to be strongly acid. These soils, and especially those with pH values of less than five are characterised by relatively high concentrations of manganese and aluminium which may reduce plant growth.

pH measurements can indicate such problem soils, but they cannot be used to determine the amount of lime required. W.A. soils with low pH include the peaty sands along the south coast.

Liming of soils of higher pH may induce a number of nutrient deficiencies including iron and manganese.

**PLANT ANALYSIS**

Plant analysis is based on the concept that plant growth, yield, and quality are related to the concentration of nutrient in the plant. This relationship is illustrated in Figure 1 and indicates that growth increases as the concentration within the plant increases until adequate concentrations are reached. At very high levels yields may be depressed as a result of toxicities.

At very low concentrations of a nutrient, the depression in growth is often accompanied by specific symptoms that can be used to diagnose the deficiency. Often the symptoms are not clearly defined or are complicated by insect damage, disease and other nutrient deficiencies which make plant analysis necessary to verify or determine the cause of specific symptoms.

Plant analysis is also useful in cases of sub-clinical deficiency, often called “hidden-hunger” where there are no gross symptoms but where the addition of fertiliser supplying the deficient nutrient will increase yield.

Diagnosis of nutrient deficiencies of crops and pastures relies very heavily on the use of critical levels (Fig. 1). This level is often defined as the concentration of the nutrient that gives 90 per cent of maximum yield. The “critical level” for a nutrient, differentiates between plants in which growth is being restricted by the nutrient and those in which growth is not being limited.

However, this critical level varies with species, stage of growth and a number of other factors and must be used with caution. Although some overseas research on critical levels can be extrapolated for use in Western Australia, extensive local research is required to derive these levels for crops and pastures.

The need for information from extensive research on critical levels and standardisation of these at different stages of maturity can be partly overcome by sampling plants from healthy and affected areas and comparing the nutrient content of each.

**Use of plant analysis**

Plant analysis can be used to identify or verify deficiency symptoms as well as to explain nutritional problems of crops and pastures. It can also be used to monitor nutrient levels in long term crops such as apples or citrus for adjustment of fertiliser rates.

Plant analysis by itself is of little use in predicting fertiliser requirements. However in conjunction with soil tests, fertiliser history and the experience of an adviser, it can provide some guide to the type and rate of fertiliser needed to overcome a problem.

If the analysis indicates toxicities, it is possible to recommend reduced rates of application of the problem nutrient or management techniques to minimise the effects.

**Sampling**

As with soil analysis the method of sampling determines the usefulness
of plant analysis results. The major aim in sampling is to collect a truly representative sample.

When sampling for plant analysis, material is collected from the affected area or plant parts to compare with material collected from unaffected areas or plant parts. Plants sampled must be of comparable age and stage of growth.

For assessing the nutrient status of crops and pastures it is important to sample the whole area, selecting plants of comparable age. Sampling methods for a number of crops and pastures have been summarised in Table 3.

Analysis is best done during the active growth stage for both crops and pastures—generally six to 12 weeks after germination. Post-heading and post-flowering sampling and analysis is less reliable.

When sampling, obvious dung and urine patches should be avoided. Similarly, sampling is not recommended when the plant part is soil or dust covered, damaged by insects, mechanically injured or diseased.

Samples may be forwarded to a number of laboratories for analysis and these and the types of analyses they conduct are summarised in Table 2. Each laboratory requires that the samples be accompanied by information sheets listing type of sample, fertiliser history and other details which are used in interpreting the results.

Samples should be forwarded immediately and if delays may occur the samples should be oven dried at 70 to 80°C. If analysis of moist samples is delayed they can decompose during transport and give misleading results.

If a deficiency is diagnosed, its correction depends on how early in the plant growth cycle the problem is diagnosed, the degree of deficiency, mobility of the nutrient and the season. In some case it may not be economic to correct the problem the same season, as the increased returns may not cover the cost of treatment.

When diagnosis is made late in the season, correction may not be possible that season but the results can be used to decide the following year’s fertiliser programme. Crops found to be deficient early in the season can benefit from additional fertiliser the same year. This applies particularly to the mobile nutrients which may be topdressed—nitrogen, potassium and sulphur and to some of the trace elements which may be sprayed—copper, zinc, iron and manganese.

Conclusion

Soil and plant analysis can be used to diagnose problems and monitor the effect of fertiliser programmes. Actual rates of fertiliser can only be recommended from soil testing and only in conjunction with additional biological and economic information.

For both soil and plant analysis extreme care must be taken to collect representative samples.

Further information on soil and plant analysis as well as sampling methods is available from regional advisers of the Department of Agriculture as well as companies operating soil and plant analysis services.

Further reading


Table 3. Sampling methods for common crops and pastures

<table>
<thead>
<tr>
<th>Crop or Pasture</th>
<th>Nutrient</th>
<th>Plant Part</th>
<th>Number required for:</th>
<th>Stage of Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Diagnosis</td>
<td>Monitoring</td>
</tr>
<tr>
<td>Clover</td>
<td>All</td>
<td>Whole plant</td>
<td>20 healthy and 20 affected</td>
<td>40</td>
</tr>
<tr>
<td>Lucerne</td>
<td>All</td>
<td>Whole plant</td>
<td>20 healthy and 20 affected</td>
<td>40</td>
</tr>
<tr>
<td>Medic</td>
<td>All</td>
<td>Whole plant</td>
<td>20 healthy and 20 affected</td>
<td>40</td>
</tr>
<tr>
<td>Cereals</td>
<td>All</td>
<td>Whole plant</td>
<td>10 healthy and 10 affected</td>
<td>20</td>
</tr>
<tr>
<td>Cereals</td>
<td>Copper</td>
<td>Youngest fully expanded leaf</td>
<td>10 healthy and 10 affected</td>
<td>20</td>
</tr>
<tr>
<td>Citrus</td>
<td>All</td>
<td>Leaves from non fruiting growth</td>
<td>50 healthy and 50 affected</td>
<td>20 leaves from each of 5 trees</td>
</tr>
<tr>
<td>Pome fruits</td>
<td>All</td>
<td>Recently matured leaves</td>
<td>50 healthy and 50 affected</td>
<td>20 leaves from each of 5 trees</td>
</tr>
<tr>
<td>Grapevines</td>
<td>All</td>
<td>Recently matured leaves</td>
<td>20 healthy and 20 affected</td>
<td>40</td>
</tr>
</tbody>
</table>

6 weeks to mid flowering
6 weeks to mid flowering
6 weeks to mid flowering
Up to flowering
Before flowering
4 months after formation
Midsummer
December to January, 2 leaves per vine close to the fruit bunch