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GRDC
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CROP NUTRITION FACT SHEET

WESTERN REGION

SOIL TESTING FOR CROP NUTRITION

Updated critical soil test values will help improve test interpretation to inform better fertiliser decisions.

KEY POINTS

- A range of soil test values used to determine if a nutrient is deficient or adequate is termed a **critical range**.
- Revised critical soil test values and ranges have been established for combinations of nutrients, crops and soil.
- A single database collated more than 1892 trials from Western Australia for different crops.
- Nutrient sufficiency is indicated if the test value is **above** the critical range.
- Where the soil test falls **below** the critical range there is likely to be a crop yield response from added nutrients.
- Critical soil test ranges have been established for 0 to 10cm and 0 to 30cm of soil.
- Soil sampling to greater depth is considered important for more mobile nutrients (N, K and S) as well as for pH and salinity.
- Use local data and support services to help integrate critical soil test data into profitable fertiliser decisions.

Introduction

In Western Australia, profitable grain production depends on applied fertiliser, particularly nitrogen (N) phosphorus (P), potassium (K) and sulfur (S).

Fertiliser is a major variable cost for grain growers. Crop nutrition is also a major determinant of profit.

Both under and over-fertilisation can lead to economic losses due to unrealised potential or wasted inputs.

Before deciding how much fertiliser to apply, it is important to understand the quantities of available nutrients in the soil and where they are located in the soil profile.

It is also important to consider whether the fertiliser strategy aims to build, maintain or mine the soil reserves of a particular nutrient.

Soil test critical values indicate if the crop is likely to respond to added fertiliser, but these figures do not predict optimum fertiliser rates.

Soil test results can be compared against critical nutrient values and ranges, which indicate nutrients that are limiting or adequate.

When considered in combination with information about potential yield, last year's nutrient removal and soil type, soil tests can help in making fertiliser decisions.

Why soil test?

Soils can be tested for a range of factors. For example, to estimate how much water can be stored, to identify the depth of root barriers or subsoil constraints such as acidity, high levels of boron and aluminium or salinity, and to quantify the potential occurrence of a soil-borne disease.

This Fact Sheet focuses on soil testing in relation to crop nutrition. It should be noted that specifications for testing for pH are different (see Useful Resources).

Principal reasons for soil testing for nutrition include:

- monitoring soil fertility levels;
- estimating which nutrients are likely to limit yield;
- measuring properties such as pH, sodium (sodicity) and salinity, which affect the availability of nutrients to crops;
- zoning paddocks for variable application rates;
- comparing areas of varying production; and
- as a diagnostic tool, to identify reasons for poor plant performance.

PHOTO: GAVIN SARRE

Nutrients, even relatively immobile ones such as phosphorus (P), can move down the profile in sandy soil, so testing nutrient reserves to depth can be useful.

Soil testing can help support decisions about fertiliser rate, timing and placement.

To determine micronutrient status, plant tissue testing is usually more reliable. The GRDC has produced a Fact Sheet on micronutrients (see Useful Resources).

Types of test

Appropriate soil tests for measuring soil extractable or plant available nutrients in WA are:

- bicarbonate extractable P (Colwell-P);
- bicarbonate extractable K (Colwell-K);
- KCl-40 extractable S; and
- 2M KCl extractable inorganic N, which provides measurement of nitrate-N and ammonium-N.

For determining crop N requirement, soil testing is unreliable. This is because soil nitrogen availability and crop demand for nitrogen are both highly influenced by seasonal conditions (see Nitrogen section, page 3) .

Other measurements that aid the interpretation of soil nutrient tests include soil pH, percentage of gravel in the soil, soil carbon/organic matter content, P sorption capacity [currently measured as Phosphorus Buffering Index (PBI)], electrical conductivity, chloride and exchangeable cations (CEC) including aluminium.

Depth for nutrient sampling

The Better Fertiliser Decisions for Cropping (BFDC) project has highlighted that deeper soil sampling provides more appropriate critical soil values and ranges for many soil types in WA (see Tables 1 and 2).

Soil sampling depth for nutrient analysis is currently 0 to 10 centimetres. The 0 to 10cm soil layer was originally chosen because nutrients, especially P, and plants roots are concentrated within this layer.

Increasingly, there is evidence of the need to assess production constraints, including acidity, in both the surface soil and subsoil layers.

The importance of subsoil K and S contributions to plant nutrient uptake has also been known for a long time.

To obtain more comprehensive soil data, including nutrient data, sampling to 30cm should be considered, providing there are no subsoil constraints.

PHOTO: PRECISION SOILTECH

Soil test results can be compared to critical values, which indicate if a crop will respond to added fertiliser.

Collecting deeper soil samples does raise issues of logistics and cost, which should be discussed with soil test providers. One suggested approach is to run a comprehensive suite of soil tests on all 0 to 10cm samples and only test for N, K, S and salinity in 10 to 30cm samples. On sands, P can also be tested for at depth.

Note that pH samples need to be taken at 10cm increments to depth. If sampling to 30cm, the 0 to 10cm, 10 to 20cm and 20 to 30cm soil layer samples should be tested for pH so that soil acidity can be better understood.

Collecting soil samples for nutrient testing

The greatest source of error in any soil test comes from the soil sample.

Detailed sampling instructions are usually provided in soil test kits. The following information is provided as a reference only.

When sampling the 0 to 10cm soil layer, 20 to 30 cores per site are required, while for the 10 to 30cm soil layer, 8 to 10 cores per site are required. Cores per sample from a uniform zone should be bulked, mixed and sub-sampled for testing.

For pH, it is often more useful to see how the figures vary within the paddock or across soil types – therefore sampling will always be less than ideal. For pH, 8 to 10 cores bulked from six locations in a paddock is usually adequate.

To ensure that a sample is representative:

- check that the soil type and plant growth where the sample is collected are typical of the whole area;
- avoid areas such as stock camps, old fence lines and headlands;
- ensure that each sub-sample is taken to the full sampling depth;
- do not sample in very wet conditions;
- avoid shortcuts in sampling such as taking only one or two cores, a handful or a spadeful of soil; and
- avoid contaminating the sample, the sampling equipment and the sample storage bag with fertilisers or other sources of nutrients such as sunscreen, containing zinc.

Critical values and ranges

A soil test critical value is the soil test value required to achieve 90 per cent of crop yield potential.

The critical range around the critical value indicates the reliability of the test. The narrower the range the more reliable the data (Table 1).

The critical value indicates if a nutrient is likely to limit crop yield based on whether the value is greater than or less than the upper or lower critical range value (see Figure 1).

If the soil test value is less than the lower limit, the site is likely to respond to an application of the nutrient.

For values within the range there is less certainty about whether a response will occur. In this case, growers have to exercise judgement about the costs and benefits of adding fertiliser in the forthcoming season, versus those associated with not applying.

If the soil test is above the critical range, fertiliser is applied only to maintain soil levels

Better Fertiliser Decisions for Crop Nutrition (BFDC)

Through the BFDC project, the results from more than 5000 Australian crop nutrition trials have been collated in a single database. Of these, 1892 trials are from Western Australia.

Interrogation of this newly available database has helped establish the validity of many values used by fertiliser companies and agronomists to support fertiliser decisions.

In some cases modified soil test critical values and ranges have been established. Data analysis of post-1995 experiments was used to generate these new critical values and ranges because they are more relevant to the no-till, stubble-retention systems used by the majority of grain growers. Where data exists, critical values and ranges have been produced that relate to crop and soil type interactions.

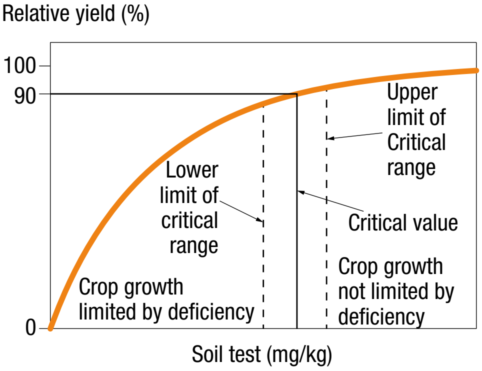
For example, in WA 67 per cent of soil experiments included soil pH measurements. Of these, 82 per cent have soil pH in the 0 to 10cm layer of less than 5.5. Hence, WA critical values have been defined for acidic soils.

In cases where soils have very low pH (less than 4.3), or soil acidity has a greater limitation on crop production than nutrition, the sites were removed from the analysis.

The BFDC project also identified gaps where crop response and nutrient data were lacking. A new phase of GRDC research investment has started to plug the more important gaps.

Organisations running statistically validated trials are encouraged to add their results to the database (see Useful Resources). ***www.bfdc.com.au***

FIGURE 1 Generalised soil test response calculation curve.



A generalised soil test–crop response relationship defining the relationship between soil test value and per cent grain yield expected. A critical value and critical range are defined from this relationship. The relative yield is the unfertilised yield divided by maximum yield, expressed as a percentage. The BFDC Interrogator fits these curves and estimates critical value and critical range. Normally 90 per cent of maximum yield is used to define the critical value but critical values and ranges at 80 per cent and 95 per cent of maximum yield can also be produced.

SOURCE: DAFWA AND MURDOCH UNIVERSITY

or to lower the risk of encountering deficiency. The larger the range around the critical value, the lower the accuracy of the critical value.

Soil test–crop response relationship

The soil test–crop response relationship allows growers to determine whether crop grain yield is likely to respond to nutrient application, based on the soil test value.

The values used to establish the soil test and crop response relationship are determined by fertiliser rate trials, where extra fertiliser is added and the crop yield response measured (see Figure 1).

The BFDC Interrogator fits these curves and estimates the critical value and critical range. Normally 90 per cent of maximum yield is used to define the critical value but critical values and ranges at 80 per cent and 95 per cent of maximum yield can also be produced.

Major nutrients

Nitrogen (N)

Crop nitrogen demand is related to actual yield, which is determined by seasonal conditions including the amount and timing of growing season rainfall.

As the water-holding capacity of WA soils fluctuates, N crop use efficiency is highly variable also. There has generally been a poor relationship between pre-sowing soil test N and wheat and canola yield response.

For non-legume crops, crop N requirement and the ability of the soil to supply N depends on a range of variables, including inorganic and organic N content of the soil, sowing date, mineralisation, rate of nitrate leaching and rotation history.

The pattern of crop demand for N during the growing season also has to be considered. The highest demand is when the crop is growing most rapidly.

In-crop soil sampling can help identify how much nitrogen is being mineralised but this is generally not practical. Surrogate measurements of crop nitrogen using crop sensors are a more practical alternative. Consequently, predicting N supply to crops is complex.

In WA, N fertiliser recommendations are based around a budgeting approach using a series of relatively simple, well-developed equations. These equations attempt to predict the soil processes of mineralisation, immobilisation, leaching, volatilisation, denitrification and plant uptake. They are built into models such as Yield Prophet and Select Your Nitrogen (SYN).

Yield Prophet requires a detailed characterisation of the physical and chemical properties of the soil profile explored by roots.

Phosphorus (P)

The soil P test needs to be interpreted in association with the soil's P sorption capacity, which is estimated by the PBI. The higher the PBI value the more difficult it is for a plant to access P.

Phosphorus is relatively immobile in soils and P applied to the 0 to 10cm layer tends to remain in that layer, especially in no-till systems. This is the case for loams, duplexes and red and yellow sands. However, grey sands have low P sorption capacity and P can leach from the 0 to 10cm soil layer and accumulate in the layers below 10cm.

Soil P test critical values for wheat are 14 milligrams P per kilogram for grey sands and 23mg P/kg for other soils for 0 to 10cm (see Table 1 for critical ranges). However, a single critical value of 11mg P/kg is suitable for wheat on all soil types when testing 0 to 30cm.

The canola soil P test critical value was defined as 19mg P/kg for sand, gravels, duplexes and loams in the 0 to 10cm layer and has not been established for 0 to 30cm.

For lupins grown in the northern agricultural region of WA, critical values are 8mg P/kg for grey sands and 22mg P/kg for yellow sands (both 0 to 10cm).

For lupins grown in the central and southern agricultural regions, critical

TABLE 1 Summary table of critical values (mg/kg) and critical ranges for the 0 to 10cm sampling layer.

Nutrient	Crop	Soil types	Critical values (mg/kg)	Critical range (mg/kg)
P	Wheat	Grey sands	14	13–16
		Other soils	23	22–24
	Lupins	Grey sands in Northern Region	9	6–12
		Yellow sands in Northern Region	22	21–23
		Grey sands in Southern Region	12	10–15
		Yellow sands in Southern Region	30	25–37
	Canola	All	19	17–25
K	Wheat	All	41	39–45
		Yellow sands	44	34–57
		Loams	49	45–52
		Duplexes	41	37–44
	Lupins	Grey sands	25	22–28
	Canola	All	44	42–45
S	Wheat	All	4.5	3.5–5.9
	Lupins	All	n/a	N/A
	Canola	All	6.8	6.0–7.7

N/A = NOT AVAILABLE SOURCE: DAFWA

TABLE 2 Summary table of critical values (mg/kg and kg/ha) and critical ranges for the 0 to 30cm sampling layer.

Nutrient	Crop	Critical values (mg/kg)	Critical range (mg/kg)
P	Wheat	11	10–11
	Lupins	9	8–10
	Canola	N/A	N/A
K	Wheat	N/A	N/A
	Lupins	N/A	N/A
	Canola	31	28–34
S	Wheat	4.6	4.0–5.3
	Lupins	N/A	N/A
	Canola	7.1	6.7–7.5

N/A = NOT AVAILABLE SOURCE: DAFWA & MURDOCH UNIVERSITY values are 9mg P/kg for grey sands and 30mg P/kg for yellow sands (0 to 10cm).

However, a single critical value of 9mg P/kg is suitable for all soil types and regions when a sampling layer of 0 to 30cm is used.

Potassium (K)

Factors such as soil acidity, soil compaction and waterlogging will modify root growth and the ability of wheat to extract subsoil K.

Consequently, interrogation of results across all soil types has identified a poor relationship between the soil test for K and crop yield response for wheat.

However, the critical value (0 to 10cm) for K is defined across all soil types as 41mg K/kg to achieve a relative yield of 90 per cent for wheat.

When interrogating by soil type, loams have a higher critical value of 49mg K/kg.

The critical soil K test value for lupins grown on grey sands is 25mg K/kg (0 to 10cm) to achieve 90 per cent of maximum yield.

For canola the critical value measured in the 0 to 10cm soil layer is 44mg K/kg for all soils to achieve 90 per cent of maximum yield.

When sampled from 0 to 30cm the critical value for canola reduces to 31mg K/kg for all soils.

Sulfur (S)

Historically, S has been adequate for crop growth because S was supplied in superphosphate.

Sulfur deficiency occurs when growers use high analysis N and P fertilisers that are low in S and in wet growing seasons due to leaching of S.

Occurrence of S deficiency appears to be a complex interaction between the seasonal conditions, crop species and plant availability of subsoil S. As with N these factors impact on the ability of the soil S test to predict plant available S.

Interrogation of the trial data in the BFDC database found that for wheat the critical soil S test value, measured in the 0 to 10cm soil layer, is poorly defined.

In contrast, the critical wheat soil S test value measured in the 0 to 30 cm soil layer is 4.6mg S/kg for all soils to achieve 90 per cent of maximum yield.

Similarly, for canola the critical soil S test (0 to 10cm) was poorly defined.

For the 0 to 30cm layer the critical soil S test value for canola is defined as 6.8mg S/kg.

Research into S nutrition of lupins has been limited due to its lower requirement rather than other crops.

A sampling depth of 0 to 30cm is recommended for canola and wheat S soil tests compared to a sampling layer of 0 to 10cm.

MORE INFORMATION

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USEFUL RESOURCES

Better fertiliser decisions for crop nutrition Fact Sheet
www.grdc.com.au/GRDC-FS-BFDCN

Phosphorus Fact Sheet
www.grdc.com.au/GRDC-FS-PhosphorusManagement

Nitrogen fixation of crop legumes: basic principles and practical management Fact Sheet
www.grdc.com.au/GRDC-FS-NFixation-Legumes

Micronutrients Fact Sheet
www.grdc.com.au/GRDC-FS-CropNutrition-Micronutrients

Find a laboratory with comprehensive ASPAC certification
www.aspac-australasia.com/index.php?Itemid=128

Soil analysis: an interpretation manual
www.publish.csiro.au/pid/1998.htm

Australian soil fertility manual
www.publish.csiro.au/pid/5338.htm

Interpreting soil test results: what the numbers mean
www.publish.csiro.au/pid/5352.htm

Soil acidity: diagnosis, treatment and prevention
www.agric.wa.gov.au

Get to know your soils deeper workshop notes
www.agrci.wa.gov.au

Better Fertiliser Decisions for Cropping Systems in Australia
www.bfdc.com.au

SoilMapp
www.csiro.au/soilmapp

Select Your Nitrogen (SYN)
www.climatekelpie.com.au

Crop Phosphorus model
www.agric.wa.gov.au/PC_94422.html

Crop Potassium Model
www.agric.wa.gov.au/PC_94089.html

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