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CROP NUTRITION FACT SHEET

GRDC
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SOUTHERN REGION

SOIL TESTING FOR CROP NUTRITION

Updated critical values for soil tests 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 nutrients, crops and soil class.
- A soil test value indicates if there is sufficient nutrient supply to meet the crop's demand.
- Results from more than 2200 trials from south-east Australia have been compiled into a database that can be used to estimate soil test critical values and ranges.
- A value **above** the critical range indicates there is not likely to be a crop yield response to added nutrients.
- A value **below** the critical range indicates there is likely to be a crop yield response to added nutrients.
- Critical ranges for particular crops and soils have been established for 0 to 10cm.
- Soil sampling to greater depth (0 to 60cm) is considered important for more mobile nutrients (N, K and S) as well as for pH, salinity and sodicity.
- Use local data and support services to help integrate soil test data into making profitable fertiliser decisions.

Introduction

In south-eastern Australia profitable grain production depends on applied fertilisers, particularly nitrogen (N), phosphorus (P) and to a lesser extent, potassium (K), sulfur (S), zinc (Zn), manganese (Mn) and copper (Cu).

Fertiliser is a major cost for grain growers, so making careful selections of crop nutrients is a major determinant of profit.

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

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

The values from appropriate soil tests can be compared against critical nutrient values and ranges; these indicate which nutrients are limiting or adequate.

Soil test critical values advise growers if a crop is likely to respond to added fertiliser, but without further information, they do not predict optimum fertiliser rates.

When considered in combination with information about target yield, available soil moisture, 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 reasons. For example, to estimate how much water can be stored, to identify the depth of root barriers or subsoil constraints (such as acidity, high aluminium, high levels of boron 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.

Principal reasons for soil testing for nutrition include:

- monitoring soil fertility levels;
- estimating which nutrients are likely to limit yield;

PHOTO: EMMA LEONARD

Revised soil test critical values have been established. These values advise if the crop is likely to respond to added fertiliser, but without further information, they do not predict optimum fertiliser rates.

- measuring properties such as pH, sodium (sodicity) and salinity, which affect the crop demand as well as the ability to access nutrients;
- zoning paddocks for variable application rates; and
- as a diagnostic tool, to identify reasons for poor plant performance.

Soil test results are part of the information that 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

The soil tests for measuring N, P, K or S in the southern region are:

- bicarbonate extractable P (Colwell-P);
- diffusive gradients in thin-films (DGT) for P;
- bicarbonate extractable K (Colwell-K);
- KCl-40 extractable S; and
- 2 M KCl extractable inorganic N, which provides measurement of nitrate-N and ammonium-N.

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Better Fertiliser Decisions for Crop Nutrition (BFDC)

Through the BFDC project, the results from more than 5000 Australian crop nutrition trials on N, P, K and S have been collated in a single database. Of these, over 2200 trials are from south-eastern Australia.

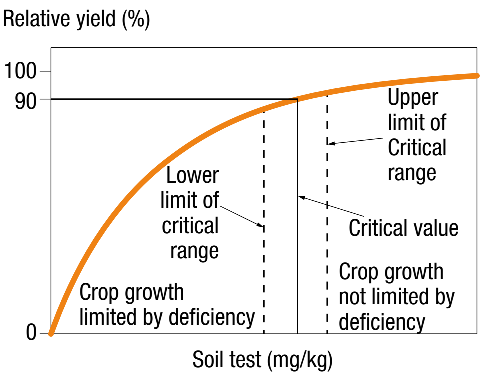
Interrogation of this newly available database has helped establish the reliability of the values used by fertiliser companies and agronomists to support fertiliser decisions. This has allowed soil test critical values and ranges to be established.

Critical values and ranges have been derived for particular crop and soil interactions. Soils are defined using the Australian Soil Classification.These revised values are more relevant to the no-till, stubble-retention systems used by the majority of grain growers.

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

Organisations running statistically valid 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

For determining crop N requirement, soil testing is only part of the picture. Soil nitrogen availability and crop demand for nitrogen are both highly influenced by seasonal conditions (see Major nutrients – Nitrogen section).

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 or PBI), electrical conductivity, chloride and exchangeable cations (CEC) including aluminium.

Collecting soil samples for nutrient testing

Poor sampling is commonly the greatest source of error in a soil test result. Detailed sampling instructions are usually provided in soil test kits.

As a rule, 20 to 30 cores from a uniform soil zone in a paddock should be combined to make a single sample for testing.

Sampling depth

Soil sampling depth for most nutrient analysis is currently 0 to 10 centimetres. For nitrogen and sulfur, which are highly mobile in the soil, 0 to 60cm is recommended.

There is also increasing evidence of the value of assessing soil-based physicochemical constraints to production, including sodicity, salinity and acidity/ aluminium, from both the surface and subsoil layers.

In some regions there is evidence to suggest that deep soil samples should be analysed for nutrients other than N. This is still not fully supported in the soils in the southern region. However, occasional deep sampling for K and S to the depth of any root barriers may help indicate depletion of subsoil nutrient reserves.

To ensure that a sample is representative:

- check that the soil type and plant growth is typical of the whole zone or paddock;
- 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;
- shortcuts in sampling such as taking only one or two cores, a handful, or a spadeful of soil will give misleading results; and
- avoid contaminating the sample, the sampling equipment and the sample storage bag with fertilisers or other sources of nutrients such as sunscreen, which can contain 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 that single value. The narrower the range the more reliable the data (see Table 1).

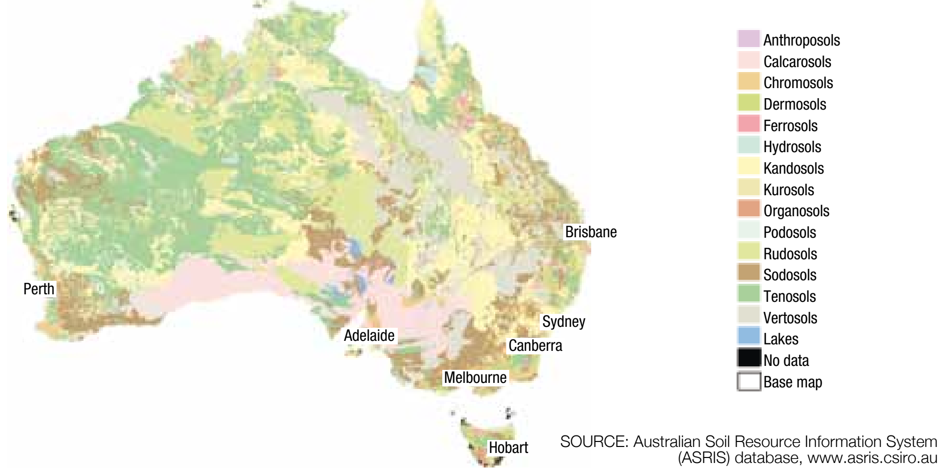
The critical value indicates if nutrient supply is likely to result in a crop yield response (see Figure 1).

The values used to determine the soil test and crop response relationship have been derived from fertiliser rate trials, where various fertilliser rates were applied and the crop yield response measured. With many of these experiments, soil test values and crop responses can be graphed.

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

For values within the range there is less certainty about whether a response will occur. If a response does occur, it is

FIGURE 2 ASRIS Australian Soil Classification soil order, level 3 map.



SOURCE: Australian Soil Resource Information System (ASRIS) database, www.asris.csiro.au likely to be small. Growers must 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 **must be applied** to maintain soil levels or to lower the risk of encountering deficiency.

Major nutrients

Nitrogen (N)

Predicting N supply to crops is complex.

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

There is generally a poor relationship between pre-sowing soil test N and wheat and canola yield response to applied N. This is usually due to the effect of stored water and in-season rainfall.

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, in-crop mineralisation, rate of nitrate leaching, rotation history and presence of yield limitations (such as root disease) and abiotic constraints (such as salinity and sodicity).

TABLE 1 Critical values (mg/kg) and critical ranges for the 0 to 10cm sampling layer for 90 per cent of relative yield.

Soil test	Crop	Soil type*	Critical values (mg/kg)	Critical range (mg/kg)
Colwell-P**	Wheat and barley	Vertosol	17	12–25
		Chromosol/sodosol	22	17–28
		Brown/red chromosol	25	18–35
		Calcarosol	34	26–44
	Barley	Ferrosols	76	46–130
	Canola	All soils	18	16–19
	Field pea	All soils	24	21–28
Colwell-K	Wheat	Chromosols	40	35–45
		Brown ferrosols	64	57–70
		Kandosols	49	45–52
		Tenosols	41	32–52
	Canola	All soils	45	43–47
	Lupin	Tenosols (WA data)	24	22–27
KCl-40 S+	Wheat	Chromosols/kandosols/ sodosols/tenosols/ vertosols	4.5	3.2–6.4
	Canola	NSW data (0 to 15cm)	8.6	4.8–15.0
		NSW data (0 to 60cm)	31	25–39

* Soil types are based on the Australian Soil Classification.
** Currently insufficient data to provide similar calibration criteria for DGT-P. Check BFDC Interrogator for DGT-P.
+ There was insufficient S data to measure 0 to 10cm

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. Surrogate measurements of crop N using canopy sensors are a better alternative.

The Australian Soil Classification (see Figure 2)

The Australian Soil Classification (ASC) was developed more than 20 years ago to better define the properties of our soils. It relies on soil chemical properties as well as texture, depth, organic matter and profile types.

Soil test critical values and ranges produced by the BFDC Interrogator use the ASC. This classification system is detailed in the application SoilMapp, which can be used to identify soil classifications for individual paddocks (see Useful Resources).

***Calcarosols:** soils that are usually calcareous throughout the soil profile (often highly calcareous); 30 per cent of cropping soils in south-east Australia are calcarosols.*

***Chromosols:** soils with a strong texture contrast between the topsoil and subsoil. Subsoils are not strongly acid and are not sodic. Seven per cent of cropping soils in south-east Australia are chromosols.*

***Dermosols:** soils with structured subsoils that lack a strong textural contrast between the topsoil and subsoils; three per cent of cropping soils in south-east Australia are dermosols.*

***Ferrosols:** soils with subsoils that contain a high content of free iron oxide and which lack a strong texture contrast between the topsoil and subsoil. They are only a minor cropping soil in south-east Australia.*

***Sodosols:** soils with strong texture contrast between topsoil and subsoil horizons. These soils are not strongly acid but are sodic; 32 per cent of cropping soils in south-east Australia are sodosols.*

***Tenosols:** generally sandy soils with generally weak pedological organisation in the subsoil; nine per cent of cropping soils in south-east Australia are tenosols.*

***Vertosols**: clay soils with shrink-swell properties that exhibit strong cracking when dry. Some of these soils also show gilgai microrelief. Ten per cent of cropping soils in south-east Australia are vertosols.*

N fertiliser recommendations are generally based around a budgeting approach using a series of relatively simple, well-developed equations that estimate plant demand for N and the soil's capacity to supply N.

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) (see Useful Resources).

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

Phosphorus (P)

Phosphorus is relatively immobile in soils and P applied to the 0 to 10cm layer generally remains in that layer, especially in no-till systems.

In most of our cropping systems, the Colwell-P soil test is still the benchmark soil P test used in Australia. The critical values differ between soil types, and the values given are expressed for the major soil types in south-eastern Australia.

Phosphorus buffering index (PBI) could not be directly related to the critical soil test value using the BFDC Interrogator, although other published data indicate that critical Colwell-P increases with PBI. Note that most trials were conducted prior to the PBI test being available.

Soil critical P test value is not affected by wheat yield except where yields are very low (less than one tonne per hectare).

On the highly calcareous soils (calcarosols), the DGT-P soil test provides a better prediction of crop response to fertiliser than Colwell-P.

Critical values for canola were similar to wheat, feed and malting barley. There were no clear soil type effects for canola.

There are currently not enough experiments to determine critical values for chickpeas, faba beans, lupins or lentils.

Potassium (K)

Generally, in the southern region cropping soils are unresponsive to additions of K. However, as crops continue to mine K from soils, this may change in the future.

Potassium deficiency is more likely to occur on light soils and with high rainfall, especially where hay is cut and removed regularly.

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

The critical values for Colwell-K in wheat vary with soil type from about 40 milligrams per kilogram on chromosols, to about 49mg/kg on kandosols and about 64mg/kg on brown ferrosols.

There was some evidence in the BFDC analysis that critical values increased with increasing crop yield and on soils with no acidity constraints to root growth.

Canola and lupin values were derived from experiments grown mainly on tenosols in Western Australia. The critical range in this soil classification was similar for wheat and canola, but for lupins the critical range was 22 to 27mg K/kg.

Sulfur (S)

Historically, S has been adequate for crop growth because S is supplied in superphosphate, in rainfall in coastal areas and some from gypsum. In the southern region sulfur-responsive soils are uncommon in cereals, but can be seen in canola.

Sulfur inputs to cropping systems have declined with the use of TSP, MAP and DAP which are low in S. Sulfur is also subject to leaching and in wet seasons may move beyond the root zone.

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

Interrogation of wheat trial data in the BFDC database found that the critical soil S test value (measured in the 0 to 10cm soil layer) is poorly defined when considered across all soil types. Results in Table 1 are for specified soil types.

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

KCl-40 S soil tests taken from deeper sampling provide a more reliable prediction of S response in canola.

There is little data from south-east Australia on the response of pulse crops – including lupins – to S.

MORE INFORMATION

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Undertaken as part of GRDC's More Profit from Crop Nutrition initiative.

USEFUL RESOURCES

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

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

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

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

Find an ASPAC-certified laboratory
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

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

SoilMapp
www.csiro.au/soilmapp

Yield and N Calculators
www.clw.csiro.au/products/ncalc/index.html

Yield Prophet
www.yieldprophet.com.au

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