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CROP NUTRITION FACT SHEET

GRDC Grains Research & Development Corporation
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NORTHERN REGION

SOIL TESTING FOR CROP NUTRITION

Understanding soil nutrient concentrations down the soil profile offers more accurate information to support 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**.
- Fertiliser decisions are in part based on where the **soil test falls** in relation to the **critical range**.
- Critical ranges for combinations of nutrient, crop and soil types are being established.
- Critical ranges are being established for topsoils (0 to 10cm) and subsoils (10 to 30cm in some cases, or to the depth of the crop root zone in others), depending on the nutrient.
- Deeper sampling is considered essential for understanding soil nutritional status and fertiliser requirement in northern cropping systems.

Introduction

Crop nutrition is a major determinant of profitable crop production, with both under and over-fertilisation leading to economic losses.

In northern cropping soils, nutrient deficiencies other than nitrogen (N) are a relatively recent development. Consequently, there has been less nutrient research conducted in these soils and the many crop types grown in northern cropping systems. Most research has been done on N in wheat and barley.

Recent research has highlighted that nitrogen applications can be wasted, even on cropping soils that have low N availability, if the levels of other nutrients such as potassium (K), phosphorus (P) and sulfur (S) are not adequate.

The importance of subsoil layers for nutrients such as P and K is not yet reflected in the limited soil test-crop response data available.

Researchers are currently using rough rules of thumb to help interpret P and K soil tests in terms of likely fertiliser responsiveness on northern region vertosols.

These figures are still 'works in progress' and will be refined as more nutrient information comes to light during this second phase of the More Profit from Crop Nutrition (MPCN) program.

At this stage the soil test values may help answer the question: "Is surface or deep placement of P and K likely to generate a crop yield response under northern cropping conditions?"

These values may not be an accurate reflection of diagnostic criteria for particular combinations of crops, soil types and agronomic management.

Why soil test?

Soils can be tested for a range of factors: to estimate how much water can be stored; to identify the depth of root barriers or subsoil constraints such as boron or salinity; or to quantify the potential occurrence of a soil-borne disease.

This Fact Sheet focuses on soil testing in relation to crop nutrition.

Tests for N and S provide information on nutrient supply, while P and K tests indicate nutrient sufficiency.

If critical nutrient ranges for soil and crop species are available, the soil test information can be used to support decisions about fertiliser rate, timing and placement.

PHOTO: MIKE BELL

A deep placement of P trial being established near Jandowae aims to further clarify the role of subsoil P in northern grains systems. Deeper sampling is considered essential for understanding soil nutritional status and fertiliser requirement in northern cropping systems.

These fertiliser decisions are also influenced by a fertiliser strategy, which can aim to build, maintain or mine the soil reserves of a particular nutrient.

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

Types of soil test

Appropriate soil tests for measuring soil extractable or plant available nutrients in the northern cropping region are:

- bicarbonate extractable P (Colwell-P), to assess easily available soil P;
- acid extractable P (BSES-P), to assess slower release soil P reserves and the build-up of fertiliser residues (not required annually);
- exchangeable K;
- KCl-40 extractable S or MCP-S; and
- 2M KCl extractable mineral N, to provide measurement of nitrate-N and ammonium-N.

PHOTO: MIKE BELL

The value of deeper placed P is clearly seen in the sorghum crop on the left-hand side of the photo compared with commercial practice on the right.

It should be noted that Nitrogen demand is highly influenced by seasonal conditions, mineralisation of N from organic matter between testing and harvest, and crop yield potential (see Major nutrients - Nitrogen section), making soil testing for N in isolation an unreliable indicator of fertiliser N requirements.

Other measurements that aid the interpretation of soil nutrient tests include:

- soil carbon/organic matter content;
- phosphorus buffering index (PBI);
- soil salinity measured as electrical conductivity; and
- chloride and other exchangeable cations including aluminium.

Collecting soil samples for nutrient testing

The greatest source of error in any soil testing service comes from collection of the soil.

Soil sampling does not have a single, definable strategy. The strategy needs to be closely aligned to the reasons for testing.

The most stringent sampling requirement occurs when the reason for sampling is predicting crop response to added fertiliser.

How many cores should be taken to represent an area? The general rule is that the more variable crop growth is in the field the more sub-samples are required to produce a meaningful paddock average.

If the objective of soil sampling is monitoring trends in paddock fertility or problem solving, the number of cores representing an area can be substantially reduced.

To ensure that a sample is representative:

- check that the soil type and plant growth from where the sample is collected are typical of the whole area to be treated;
- avoid areas such as stock camps, old fence lines and headlands where nutrient concentrations are often significantly higher than the rest of the paddock;
- 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 or a handful or a spadeful of soil, which will give misleading results; and
- avoid contaminating the sample, the sampling equipment and the sample storage bag with fertilisers, other sources of nutrients or organic materials such as oils used to lubricate deep probes.

Sampling depth

The most common soil sampling depth for nutrient analysis is 0 to 10 centimetres for broadacre crops. This layer was chosen because nutrients, especially P, and plant roots are concentrated within this layer.

To obtain more comprehensive soil data, including nutrient data, sampling below 10cm should be considered for some nutrients.

Suggested sampling increments for key nutrients and salinity for northern cropping regions are:

- 0 to 10cm (N, P, K and S);
- 10 to 30cm (N, P, K and S);
- 30 to 60cm (N and S, salinity);
- 60 to 90cm (N, salinity); and
- 90 to 120cm (optional) (N, salinity).

Deeper sampling does raise issues of logistics and cost, which should be discussed with soil test providers. However, the additional information provides a clearer insight into nutrient status in the crop root zone.

Critical values and ranges

A soil test critical value is the soil test value required to achieve 90 per cent of maximum potential crop yield, while the critical range reflects the degree of uncertainty around the critical value. The narrower the range, the more reliable the prediction of a fertiliser response from the available data (see Tables 1 to 3).

The critical range determines if a nutrient is likely to be deficient for crops based on whether the soil test 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 resulting in higher crop yields.

For values within the range there is less certainty about whether a response will occur. Growers have to exercise judgement about the cost benefit of adding fertiliser in the coming season.

If the soil test is above the critical range, fertiliser may be applied to maintain existing soil levels or a controlled rundown of nutrient reserves can be conducted until fertiliser applications become viable.

Critical values for nitrate and mineral nitrogen are mostly supplied by laboratories as milligrams per kilogram and sometimes kg per hectare. To convert mg N/kg to kg N/ha the soil test value in each sampling layer is multiplied by the depth of the soil sample (millimetres), then multiplied by the bulk density and divided by 100, i.e.

soil N (kg/ha) = nitrate (mg/kg) x bulk density x test depth/10.

As an example, a soil test result of 10.0mg nitrate-N/kg from a 10cm soil core in a vertosol soil (bulk density 1.1g/cm^3) would represent about 11kg N/ha. If that same concentration was found in a sample from the 10 to 30cm layer (bulk density 1.3g/cm^3) it would represent about 26kg N/ha.

Soil bulk density changes with texture and gravel content. As a rule, the bulk density of vertosols can range from 1.1 to 1.3 grams/cm^3. The SoilMapp app provides details of soil bulk densities across Australia (see Useful Resources).

Soil test–crop response relationship

The soil test–crop response relationship allows growers to determine if grain yield increases are likely in response to nutrient application, based on the soil test value.

The values used to determine the soil test and crop response relationship are derived from fertiliser rate trials, where extra fertiliser is added and the crop yield response measured. With many of these experiments, soil test values and crop responses can be graphed (Figure 1).

Major nutrients

Nitrogen (N)

Predicting N supply to crops is complex.

Nitrogen demand by the crop is related to actual yield, which, in the north, is often determined by water availability in the north (see Table 1).

Soil tests for mineral N alone – even to a depth of 90cm to measure total soil profile N – do not necessarily tell the whole story.

The ability of the soil to meet the N demand of non-legume crops depends on a range of variables, including inorganic and organic N content of the soil, mineralisation, rate of nitrate leaching or denitrification and rotation history.

Greater sampling depths may be necessary, especially before sowing winter cereals, to account for significant quantities of mineral-N that can be moved deep into the subsoil when excessive rainfall is received during fallow periods.

However, soil mineral N will only be available if roots can reach these deeper reserves. Lack of soil moisture, salinity, aluminum, chloride and boron toxicity and high bulk density can all limit root growth and associated nutrient uptake.

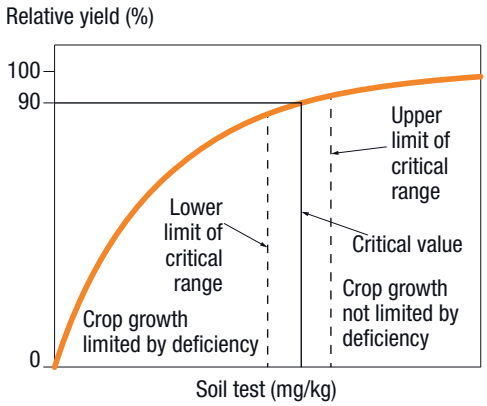
Nitrate-N data from soil tests is one value used in a range of commercial and publically available N models that help predict in-crop nitrogen requirement, for example, NBudget Calculator (see Useful Resources).

Phosphorus (P)

In vertosol soils, it has been discovered that pathways of P availability can be represented by different tests depending on speed of release.

Colwell-P measures the labile, readily available P pool, while BSES-P measures this labile pool and also a slowly released P pool.

FIGURE 1 Generalised soil test response calculation curve.



A generalised soil test–crop response relationship defining the relationship between soil test value and percent grain yield increase 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 percent of maximum yield is used to define the critical value but in critical values and ranges at 70 percent and 95 percent of maximum yield can also be produced.

SOURCE: DAFWA AND MURDOCH UNIVERSITY

TABLE 1 Summary of the effect of crop yield potential on the critical nitrate-N values (kg/ha) and critical ranges for the 0 to 60cm sampling layer for 90 per cent of relative yield. The wider critical ranges at high yield potentials reflect a lack of trial data in those yield classes.

Nutrient	Crop	Region	Maximum yields with N fertiliser (t/ha)	Critical values (kg/ha)	Critical range (kg/ha)
N	Wheat	All	<1	NA	NA
			1–2	32	27–39
			2–3	43	38–48
			3–4	56	48–64
			4–5	79	56–110
			>5	110	84–130

TABLE 2 Critical P values used to determine likely response or drivers of P availability in northern vertosols.

	Surface (0 to 10cm)		Subsoil (10 to 30cm)	
Colwell-P	<20 to 25mg/kg	Likely to get a response to starter P	<10mg/kg	Likely to get a response to deep P placements, unless BSES P high
	>60mg/kg	Ensure good ground cover to limit erosion risk and to avoid nutrient loss in runoff	>100mg/kg	Unlikely to see P deficiency in your lifetime
BSES P	<25mg/kg	Limited evidence of residual fertiliser accumulation	<30mg/kg	Limited reserves of slowly available P. Consider replacement of removed P once every five years.
	>100mg/kg	High residual fertiliser load; slowly available to surface roots	>100mg/kg	Potential to slowly replace Colwell-P reserves and support crop growth in large soil volumes

TABLE 3 Critical K values used to determine likely response or drivers of K availability in northern vertosols.

	Surface (0 to 10cm)		Subsoil (10 to 30cm)	
Cation exchange capacity (CEC)	ExK (cmol/kg)	High Mg (>30% CEC) or Na (>6% CEC)	ExK (cmol/kg)	High Mg (>30% CEC) or Na (>6% CEC)
<30 cmol/kg	0.2	0.3	0.1	0.2
>60 cmol/kg	0.4	0.5	0.2	0.3

Concentrations of cations are expressed in centimoles of positive charge per kilogram of soil (cmol(+)/kg). This measurement is equivalent to the previously used unit me/100g.

SOURCE: GUPPY ET AL., GRDC UPDATE 2012

Where present at reasonable concentrations, the Colwell-P pool represents the main source of crop P uptake. BSES-P measures sources of P that were once considered unavailable.

When reserves of BSES-P are present in the subsoil root zone, the small amounts of P released per unit volume of soil collectively make a major contribution to crop P uptake in the later stages of crop growth.

The Colwell-P soil test needs to be interpreted in association with the PBI, which helps define the availability of soil P.

The higher the PBI value the more difficult it is for a plant to access P, so soils with a high PBI will have a higher critical value and range than those where PBI is low.

Generally, a PBI value of less than 300 indicates that soil P, as assessed by Colwell-P, is readily available.

Critical soil P concentrations differ according to crop type and different soil layers are important as sources of P during different growth stages in those crops (Table 2).

For example, the critical Colwell-P in the 0 to 10cm layer for maize and wheat is between 25 and 30mg P/kg, while for peanuts the critical range is 12 to 15mg P/kg with limited responses above these concentrations.

Cereals including wheat, barley and sorghum require a high P concentration in the seedling root zone in the early stages of crop growth, when grain number is established.

Typically, less than 10 per cent of total crop P uptake occurs during this early growth period. Yet this shallow soil P requirement forms the basis of the starter P strategies because it ensures that the P concentration in the plant tissue is high enough not to limit the formation of vital yield factors such as number of tillers per plant and grain number per head.

Later in the season and in dry years starter fertiliser and P reserves in the topsoil become less important as roots access P from deeper soil layers.

As root systems develop and crop P accumulates to support biomass and grain yield, so too does the total crop P demand. For these reasons sampling to at least 30cm is suggested.

Potassium (K)

Table 3 summarises current thinking for rules of thumb on K availability. The main modifier of critical range at this stage is cation exchange capacity (CEC). This is mostly a reflection of the quantity and type of clay present and the organic matter content of the main cropping soils of this region. More research is required in this area.

However, other factors indicative of relatively poor structure and restricted K supply rates to roots, such as high sodium (Na) and/or magnesium (Mg), may also affect critical range.

At present there is no commercial equivalent of the BSES-P test to identify the presence of slow release K reserves, which can be present in some soils.

While presence of these reserves is not necessarily linked to a particular soil type or mineralogy, they are commonly found in alluvial soils derived from a variety of parent materials.

Work on developing and commercialising a potentially useful test is continuing.

Sulfur (S)

Historically, adequate S has been supplied by mineralisation from organic matter, from co-application as a nutrient in N and P fertilisers (sulfate of ammonia and superphosphate) or via the presence of calcium sulfate layers in root-accessible layers of the subsoil.

However, with the increased use of high analysis N and P fertilisers low in S, deficiency in crops is increasing, especially in wet years, due to leaching.

S deficiency appears to be a complex interaction between the seasonal conditions, crop species and plant availability of subsoil S, which impacts on the ability of the soil S test to predict plant available S. Deficiencies may be more evident in wet yeras due to S leaching.

The critical wheat soil S test value measured in the 0 to 10 cm soil layer is poorly defined.

In contrast, the critical wheat soil S test value measured in the 0 to 30cm soil layer is 4.6 (4 to 5.3) mgS/kg for all soils to achieve 90 per cent of maximum yield. However, there is currently no data from northern soils and climate conditions on which to test these relationships.

Research into S nutrition of other species has generally been conducted on crops not suited to northern cropping systems, with the exception of canola. The critical soil S test value for canola is 7.1 (6.0 to 7.7) mg S/kg in the 0 to 30cm layer to meet crop demand.

A sampling depth of at least 0 to 30cm is recommended for S soil tests, possibly extending even to 60cm to indicate presence of subsoil reserves available in later crop growth stages.

Work on refining the S soil tests for key species are currently being conducted in MPCN II.

MORE INFORMATION

Mike Bell, QAAFI
07 4160 0730
m.bell4@uq.edu.au

Chris Dowling, Back Paddock Company
0407 692 251
cdowling@backpaddock.com.au

Chris Guppy, UNE
02 6773 3567
cguppy@une.edu.au

Kaara Klepper, DEEDI
07 4639 8870
kaara.klepper@daff.qld.gov.au

Simon Speirs, NSW DPI
0428 647 787
simon.speirs@dpi.nsw.gov.au

USEFUL RESOURCES

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

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

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

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

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

Cropmate
http://cropmate.agriculture.nsw.gov.au

Nitrogen Fertiliser Calculator
(DAFF (Queensland) – Business Information Centre)
13 25 23

WhopperCropper
www.yieldprophet.com.au

NBudget Calculator (part of Managing legume and fertiliser N for northern grains cropping)
www.grdc.com.au/GRDC-Booklet-ManagingFertiliserN

GRDC Radio Northern Update 20
www.grdc.com.au/Media-Centre/GRDC-Podcasts/Northern-Weekly-Update/2013/11/20-north

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