MAKING SENSE OF SOIL TEST REPORTS

Whether it's improving yields, using fertilisers efficiently or monitoring sustainability, regular soil testing can give you the information you need. ***By Paulette Baumgartl***

Crop health, yield and quality depend not only on the levels of plant nutrients but also how they interact in the soil. Soil testing is a great tool to help you decide how to manage your fertiliser program for crop and soil health. There are several reasons to conduct regular soil testing, including to:

- **Check soil properties** that influence nutrient availability and uptake, such as organic matter, pH, electrical conductivity, and cation exchange capacity (CEC).
- **Determine levels and ratios of nutrients** in the root zone and required interventions.
- **Prepare a nutrient budget** and management plan based on the yield target and the predicted nutrients removed with the crop.
- **Monitor** changes and trends over time.

BEFORE YOU TEST

Having an overview of the soil conditions before planning a soil testing program will help you understand what your test results mean. Specific information you should consider include:

- Site history including cropping and fertiliser and past soil test results.
- Soil type and texture, uniformity, and condition of soil surface.
- How deep is your topsoil and are there any compaction layers?

SOIL TESTING: WHERE, WHAT, WHY, AND WHEN TO TEST

Potatoes are fast growing and high yielding crops, and their demand for nutrients is high. They can remove large quantities of nutrient from the soil, and it is vital to ensure fertiliser applications are adequate to supply the crop requirement.

Soil testing often focuses on the topsoil, i.e., the top 15-30 cm, and doesn't always capture information about the subsoil or deeper crop root zone. It is important to also measure soil properties and nutrient availability at depth, as these factors can influence plant nutrient uptake and crop health. Subsoil sampling is particularly important for minimum or no till systems, where nutrients and pH can be stratified across the soil profile.

Refer to the Soil Wealth website www.soilwealth.com.au for a guide to collecting soil samples for testing.

HOW DO PLANTS TAKE UP NUTRIENTS FROM THE SOIL?

There are three ways that plants can take up nutrients from the soil:

Root interception where growing root system comes into direct contact with nutrients in the soil. This is important for immobile nutrients such as phosphorus.

Mass flow where nutrients move in the soil water to the roots. Good examples are highly soluble nutrients like nitrate and boron.

Diffusion This is where positively

While some soil characteristics can be assessed by sight and feel, soil tests can provide far more detailed information.
- Photo by L. Ketchum

Soil type can vary considerably through the profile

charged nutrients such as potassium (K+), calcium (Ca++), and magnesium (Mg++) diffuse to the soil roots from soil particles.

Laboratory soil tests extract plant available nutrients from the soil. However, understanding the levels of available nutrients is not the complete picture. How well potato plants can use these soil nutrients depends on many factors, including:

- **Soil moisture**: Plants cannot take up nutrients from dry soil, so it is important to keep the soil moist in the entire root zone.
- **Soil properties** such as texture, CEC, and organic matter will impact nutrient uptake.
- **Salinity**: Nutrient uptake and use efficiency is low in salt affected soils, due to negative interactions with nutrients or sodium at high concentrations.
- **Soil-borne disease** can reduce root efficiency and nutrient uptake.

CHEMICAL AND NUTRITION PARAMETERS – WHAT THE NUMBERS MEAN

Soil pH

What: Soil pH is a measure of the acidity or alkalinity of the soil. Soil pH mainly affects the availability of major and trace elements to plants. Highly acidic or alkaline soils can lead to either nutrient deficiencies or toxicities.

How is it measured: Soil pH can be measured in water or in a calcium chloride ($CaCl_2$) solution. When soil pH is measured in water, a level of less than 7 is acidic and greater than 7 is alkaline.

Soil pH in $CaCl_2$ is usually preferred as it is less affected by soil electrolyte concentration, providing a more consistent result. Soil pH in $CaCl_2$ is typically 0.5 to 1 unit lower than pH measured in water. To optimise nutrient availability, soil pH in $CaCl_2$ should be maintained at between 5.8 to 7.5 in the topsoil (top 15cm), and above 4.8 in the subsurface (below 15cm). Potatoes generally prefer slightly acidic soils.

Interventions: Highly acid soils can lead to toxic levels of aluminium, limit nutrient availability and soil biological activity. Acidity is best corrected using lime, which should be applied between potato crops. Note that fresh lime applied before planting may increase the likelihood of common scab.

Moderately alkaline soils (about pH 7.5) can reduce availability of phosphorus and trace elements. These soils can be corrected by applying elemental sulphur or acidifying fertilisers including urea or ammonium. Highly alkaline soils with a pH >8.5 or more are sodic. This can occur naturally or due to high levels of sodium in the irrigation water. These soils are difficult to manage, and tend to form crusts on the soil surface, restricting water infiltration.

Soil texture and Cation Exchange Capacity (CEC)

What: Soil texture refers to the proportion of sand, silt and clay in a soil.

Cation exchange capacity (CEC) is a measure of the capacity of a soil to hold nutrients such as calcium, magnesium and potassium. Clay soils normally have a high CEC, e.g. 25 meq/100g or more and sandy soils have low CECs, often 5 meq/100g or less.

Low CEC soils do not hold nutrients well. Nutrients can easily leach out with rainfall or irrigation. Low CEC soils therefore need smaller quantities of nutrients applied more frequently than heavier loam or clay soils.

How is it measured: CEC is usually expressed as meq/100g or cmol+/kg.

Interventions: Adding organic matter is a good way of increasing or maintaining CEC. Some growers have added clay to sandy soils to increase nutrient (and water) holding capacity.

Organic matter (OM)

What: Soil organic matter (OM) is an essential part of a healthy soil. It is a food source for soil micro-organisms and helps the soil hold water and nutrients.

How is it measured: Although there is no ideal number, soils with less than 2% OM are often regarded as functionally impaired. The organic matter content of soils used for potato production in Australia ranges from very low (less than 2%) in Mallee sands to high (more than 8%) in peaty soils.

Intervention: Planting cover crops, minimising tillage and erosion, spreading organic materials such as composts, manures and crop residues all help to elevate OM levels in soil.

QUICK GUIDE TO ASSESSING A SOIL TEST REPORT

The following checklist a good way to assess your soil test report and identify areas that need attention. A good soil test report should show the following results:

- Soil pH: 5.5-7.5
- Organic matter 3.5-4%
- Nitrate-N: 40-50 mg/kg
- Phosphorus (Colwell): 75-100 ppm
- Potassium: 5% cations or > 0.5 meq/100g
- Sulphur: 10-20 mg/kg
- Calcium: magnesium ratio = 4
- Micronutrients: within recommended ranges
- Salinity: EC < 1/5 dS/m and chloride <200 mg/kg
- Problem cations: Sodium < 6% cations (in a clay soil) and Aluminium less than 1 mg/kg.

PRIMARY CROP NUTRIENTS

Nitrogen (N)

What: Nitrogen (N) is a critical nutrient for crop growth and development of tubers. Too much or too little nitrogen can have a negative impact on yield and quality. Many factors, including the type of N used, when, how much and how often it is applied all need to be considered when determining nitrogen application rates.

How is it measured: Nitrogen levels can be reported as total nitrogen or plant available nitrogen. Total nitrogen is a measure of the total amount of nitrogen in the soil and usually expressed as a % value. Plant available nitrogen is normally expressed as nitrate nitrogen and reported as NO_3-N in mg/kg. Soil nitrate levels alone are guide only and not a reliable indicator of crop nitrogen requirements.

Intervention: Application of fertiliser. The amount and frequency should be based on the soil tests results and knowing the target tuber yield and crop removal rate.

Phosphorus (P)

What: Soil phosphorus (P) is a key essential element for plants, being important in root growth, cell division and tuber initiation.

How is it measured: Tests measure extractable phosphorus in mg/kg, which roughly indicates how much P is available to plants. Real available P will depend on root distribution as well as soil type as P is not mobile in the soil.

Test results may also show the PBI value (potassium buffering index). PBI is the soil's ability to 'lock up' P so the crop cannot use it. High PBI soils will require higher rates of P fertiliser.

There are several tests offered in Australian laboratories for soil phosphorus:

Colwell P (mg/kg) is the most commonly used test. Results will vary with soil type however levels less than 30 mg/kg are low; levels 70 - 100 mg/kg are generally adequate to high. Colwell P levels should be higher in heavier soils and high yielding crops where a lot of P will be removed.

Olsen P (mg/kg) is the preferred method for soils with a pH above pH 6, and a must for a pH above 7. For potatoes, less than 30 mg/kg is generally considered low, more than 50 mg/kg is high. However, critical values vary considerably with soil texture.

Mehlich 3 (M3) P (mg/kg) is the preferred method for soils below pH 7.5. Less than 30 mg/kg is low, more than 70 mg/kg is high.

Intervention: Fertilisers and/or manures can be used to increase soil P levels. It is important to note that frequent or heavy use of manures can lead to elevated soil P levels and eventually leaching and/or run-off. High P applications reduce zinc uptake and can induce zinc deficiency. However, as zinc helps plants uptake P, a careful balance is required.

AT A GLANCE – COMMON UNITS USED IN SOIL TESTS

Cmol/kg	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 meg/100 g. Adding the concentrations of each cation gives you an estimate of the CEC figure.
% CEC	The proportion of a particular cation to the total cations present in a set volume of soil
meq/100g	Milliequivalents per 100 grams of soil. 1 meq/100g = 1 cmol(+)/kg, where cmol(+)/kg is the abbreviation for centimoles per kilogram.
mg/kg	Milligrams per kilogram - describes concentration of an element in a set volume

Potassium (K)

What: After nitrogen, potassium (K) is the most abundant nutrient in potatoes. As high levels are found in the tubers, it is possible for up to 350kg/ha of K to be removed at harvest. K deficiency can greatly reduce yield and result in plants more susceptible to disease.

How is it measured: Available K (in mg/kg) can be measured using several methods including Colwell, Skene, and Mehlich 3. Heavier soils usually require more K, but as a general guide, K should be present in the range of about 0.5 meq/100g or 5% of cations.

Intervention: If K is too low, it can be applied pre-planting in heavier soils. Foliar applications are more effective in lighter, sandier soils.

Calcium (Ca)

What: Calcium (Ca) strengthens plant cell walls and helps maintain soil structure. In potatoes it helps initiate tuber growth, protects against disorders such as internal brown spot, and improves storage and shelf life of tubers.

How is it measured: Calcium is usually listed as exchangeable calcium which is potentially available to the plant roots. It may also be recorded as a % of the whole CEC. A good value is between 65-80% of total CEC.

Intervention: Calcium is taken up by plants in the xylem (water carrying vessels), so can only move upwards through the plant from the soil. Dry or humid conditions, where transpiration is reduced, limit transport of calcium. Fertilisers with a high soluble calcium content can be used to increase plant access to calcium.

SECONDARY NUTRIENTS

Although plants do not need so much of the secondary nutrients as the primary, these nutrients are just as important for optimal growth and development. Measuring and monitoring their levels in soils is vital.

Sulfur (S)

What: Sulfur (S) aids in the building of proteins in plants, as well as formation of chlorophyll. For potatoes specifically, sulfur helps increase tuber numbers and reduces the risk of Common and Powdery Scab.

How is it measured: Soil test results reveal plant available sulfur in mg/kg. A value of 10-20 mg/kg is adequate; less than 5 mg/kg is low and more than 40 mg/kg is high.

Intervention: If additional sulfur is required, add a sulfate fertiliser to soils.

Magnesium (Mg)

What: Magnesium (Mg) generally assists photosynthesis, and the regulation of other elements.

How is it measured: Soil tests measure the amount of magnesium that is potentially available to the plant. This can be listed as mg/kg of exchangeable magnesium or %CEC. Magnesium present in the range 10-20 % of total CEC is adequate.

Intervention: Low magnesium can be corrected via a range of fertilisers applied to soils or as foliar products.

MICRONUTRIENTS/TRACE ELEMENTS

Boron (B), Manganese and Zinc (Mn, Zn), Copper, Iron and Molybdenum (Cu, Fe, Mo)

Adequate trace element nutrition is just as important for vigorous and profitable crops and pastures as the primary and secondary nutrients.

Critical levels for trace elements vary with soil texture and crop. Levels are lower in sandy soils than in loams or clays. Soil testing for trace elements can only be a guide; further investigation through plant testing is recommended.

GETTING THE TESTING RIGHT

A few simple measures will ensure the test is accurate, reliable and the best reflection of your soil conditions.

- Ensure the lab is using a testing strategy good for potatoes, and make sure you nominate potatoes as the crop type on submitted samples.
- Don't mix samples from different soil types.
- Use the same soil testing laboratory each year to reduce confusion and conflicting recommendations.
- Consider using precision soil sampling approaches to derive zone-based recommendations, enabling variable rate fertiliser spreading technology to be used.
- Use in-crop soil and petiole testing to confirm that your nutrient management strategies are adequately meeting your crop needs.

Table 1: Plant nutrients and soil properties: desirable ranges

MEASUREMENT	UNITS	VERY LOW	LOW	TARGET RANGE	HIGH
Soil properties					
pH (in water)		5	5.5	6.5 – 7.0	8
pH (in $CaCl_2$)		4.5	5	6	7.5
Cation Exchange (CEC)*	meq/100g	<5	<10	10 – 20	>20
Organic matter	%	<1.0	2	3.5 - 4	>5
Nutrients					
Nitrate – Nitrogen (topsoil)**	mg/kg	<10	20	40 - 50	>60
Phosphorus (Colwell)	mg/kg	<20	30-60	70 - 100	>100
Phosphorus (Ohlsen)	mg/kg	<20	<30	30 - 50	> 50
Phosphorus (Mehlich)	mg/kg	<20	<30	30 - 70	> 70
Potassium (meq/100g)	meq/100g	0.2	0.3	0.5 - 0.7	1
Potassium (%)	% of CEC	<1	3	5	>8
Calcium	% of CEC	50	65	75	>80
Magnesium	% of CEC	<5	<10	10-20	>20
Aluminum***	% of CEC	<0.1	<0.5	<1	>1
Ca/Mg Ratio		<2	3	4	>5
Sulfur	mg/kg	2	5	10 - 20	40
Copper	mg/kg	<0.3	<2	2 - 20	>50
Zinc	mg/kg		<1	1 - 20	>20
Manganese	mg/kg		<5	10 - 20	>50 (toxic)
Iron	mg/kg		<10	10 - 200	>200
Boron	mg/kg	0.1	0.4	0.5 - 4	>5
Molybdenum	mg/kg	0.5	1	2	>2
Salinity					
Conductivity	dS/m	EC 1:5 dS/m			
Sodium***	% of CEC	<1	<3	<4	>6
Chloride	mg/kg	50	100	<200	>200

Note: The units meq/100g, meq% and cmol+/kg are all the same

* CEC is a property of the soil type (clay and organic matter)

** Nitrogen application rates should be based on crop nitrogen levels (e.g. sap), potato variety, fertiliser history and crop performance from the farm or block. Soil nitrate levels alone are **not a reliable indicator of crop nitrogen requirement**.

*** For sodium and aluminium, the lower the better

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Scott, B (E E Muirs and sons) for providing technical information