A quick guide to understanding the common Summit Fertilizers soil tests

Acidity and salinity

pH H_2O: A measure of the acidity or alkalinity of the soil. In this method, soil is shaken in water. Neutral = pH 7

pH $CaCl_2$: A measure of the acidity or alkalinity of the soil and the most common representative method used in Australia. In this method, soil is shaken in a weak calcium chloride solution, which resembles the natural 'saltiness' of soil water. Neutral = pH 7 but values are lower in acidic soils compared with the pH H_2O method.

Extractable Aluminium: Following pH testing, the solution can be analysed for extractable aluminium. Levels of soil solution aluminium closely follow pH, increasing as pH decreases below 5.5 (H_2O) or 5.0 ($CaCl_2$). It's a very loose test but where extractable aluminium is >2 mg/kg, sensitive species (e.g. barley) begin to be affected and >5 mg/kg more tolerant species will suffer toxicity effects to root growth.

Soil sampling then testing in a dedicated soil laboratory is an essential part of determining crop limiting factors and requirement for added nutrients through fertiliser

Electrical conductivity (EC or $EC_{1:5}$): A measure of the electrical conductivity, which indicates the degree of salinity in the soil. The higher the EC value, the more soluble salts are in the soil. These salts can be of any kind but are regularly dominated by sodium (Na) and Chloride (Cl) in WA soils.

Electrical conductivity is often usefully expressed as an estimation (EC_e) varying the EC for different soil textures. It takes more water to saturate a clay soil than a sand, so the same EC reading for each will have completely different salinity impact for plants. Conversion factors are estimates but they make different soils comparable on a single scale.

Table 1. Interpreting soil salinity in different texture soils using EC or EC_e. Multiplying EC by a conversion factor gives an EC_e value to compare soils on a single scale, but conversion values are rough estimates. (Source: Department of Primary Industries and Regional Development)

Salinity Assessment	$EC_{1:5}$ (dS/m)			EC_e (dS/m)
	Sand	Loam	Clay	All Soils
Non-Saline	0-0.14	0-0.18	0-0.25	0-2
Slightly Saline	0.15-0.28	0.19-0.36	0.26-0.50	2-4
Moderately Saline	0.29-0.57	0.37-0.72	0.51-1.00	4-8
Highly Saline	0.58-1.14	0.73-1.45	1.01-2.00	8-16
Severely Saline	1.15-2.28	1.46-2.90	2.01-4.00	16-32
Extremely Saline	>2.28	>2.90	>4.00	>32

Soil texture	Conversion factor
Sand	15
Sandy loam	12
Loam	10
Clay loam	9
Light-med clay	8
Heavy clay	6

Chloride (Cl^-): Chloride is a negatively charged ion, which means it is generally very mobile and will move out of soil quickly unless it is held on exchange sites like iron and aluminium oxides. However, chloride can have a strong toxic effect on plant roots. Tests for soil chloride can be useful to determine if salinity is due to sodium chloride, and to gauge the impact of chloride salt fertilisers such as muriate of potash (KCl). Soil texture impacts any interpretation, but broad indicator guidelines for Cl^- salinity are shown to the right.

Soil texture	Salinity Cl (mg/kg)
Sand to sandy loam	>120
Loam to clay loam	>180
Clays	>300

Carbon and Organic matter

Organic Carbon: An indicator of the organic matter content in soil. Organic matter aerates the soil and holds onto water and nutrients. Organic matter also feeds soil microbes that make nutrients more plant available.

Organic carbon itself does not 'mineralise' to produce plant available nutrients, however it can be used as an indicator of total organic matter which *does* include all the elements that are a part of organic compounds that can break down to provide nutrients for soil microbes, fungi and plants.

A common conversion factor is *Organic Matter (%) = Total Organic Carbon (%) x 1.72*

Note, however, that the Walkley-Black organic carbon method used to analyse Summit samples only measures readily oxidisable/decomposable carbon, not total soil organic carbon. The method, on average, will measure about 80% of the soil organic carbon. A lab test result of 1-3 % is reasonable for WA agricultural soils but is low on a global scale.

Nitrogen (N)

Nitrate nitrogen (NO_3^-): Nitrate is the form of soil nitrogen that is most readily available for plant uptake. Nitrate levels are highly variable in soils. Nitrate has a negative charge and is highly mobile in the soil. This mobility provides a nitrogen source that moves readily towards plant roots but can also be leached out of reach of the plant root system. Nitrate is used by the plant to make precursors to plant proteins.

A desirable range of soil nitrate is 15-50 mg/kg. In reality, few agricultural soils in WA will achieve this in dry summer soil testing and even at the high end this is still well short of the full N requirement of almost all crops.

Ammonium Nitrogen (NH_4^+): The positive charged ammonium ion is not very mobile in soil, so tends to not leach, and is an intermediary in the conversion of organic-N to nitrate. High ammonium *relative to nitrate* can indicate REDOX reducing conditions such as waterlogging.

Soil test levels of up to 20 mg/kg are considered desirable yet still do not provide adequate N for most crops.

Phosphorous (P)

Colwell P: A measure of the phosphorus that is available for plant uptake. In the Colwell P method, soil is shaken for 16 hours in a bicarbonate solution before the soluble extract is analysed for phosphorus. The Colwell P result has long been the most commonly used in Australia to determine soil phosphorus status. It is important to note, test values are quite independent of the soil's ability to bind phosphorus, so a Colwell P test *cannot* be interpreted without an associated phosphorus buffering index (PBI). Colwell P of 15-20 mg/kg can be adequate in very low PBI soil whereas 45-50 mg/kg can be deficient in high PBI soil.

Phosphorus Buffering Index (PBI): A measure of the soil's ability to bind and release phosphorus for plant uptake. Soils with a high PBI require more applied phosphorus to achieve an increase in soil phosphorus test value because much of the applied phosphorus becomes bound to the soil particles. Soils with a low PBI need more regular P applications because phosphorus is readily removed. In the PBI test, a phosphate solution of known concentration is added to the soil and shaken for 17 hours. The solution is then analysed to determine how much of the phosphorus has been "bound" by the soil.

DGT Phosphorus (DGT-P): Diffusive Gradients in Thin Films, or DGT, differs from a conventional soil extraction in that it mimics the action of plant roots. An iron oxide gel disc is placed on a saturated soil sample for 16-24 hours. The gel acts as a sink, binding forms of phosphorus that are able to diffuse through the soil and through an additional gel membrane just like a cell membrane in root uptake. The amount of P bound to the gel is then measured after an elution step with dilute acid. An advantage of the DGT test is that the inherent properties that govern phosphorous availability in the soil will determine the test result so testing for a second correcting factor (such as PBI with Colwell P) is not necessary.

Adequate DGT P	
Barley	68-110
Wheat	57-100
Canola	25-44
Field Pea	75-100

Potassium (K)

Colwell K: Soil tests will measure exchangeable potassium or extractable potassium. Colwell K measures extractable potassium (water soluble + exchangeable + some fixed K fractions) so gives a general representation of potassium that is available for plant uptake. The test uses the same extraction as Colwell P, so both are determined simultaneously. Soil type must be taken into account when interpreting potassium results for crops and pastures. Sandy soils regularly show low potassium levels since they have a lower potassium holding capacity than clay soils and K may leach before the plants can use it.

Potassium is one of the most abundant elements in soil. However, it should be noted that much of the potassium occurring in soils is not available to plants and crops, therefore soils containing high levels of K can still be responsive to K fertilisers. Soil Colwell K tests below 45 mg/kg are considered deficient in potassium for most crops (below 30 mg/kg for lupins), but responsiveness has been found to be reasonably common up to 75 mg/kg and occasionally around 100 mg/kg. Clover and medics require higher soil K than other species.

Ammonium Acetate extractable K: As an alternative or complimentary potassium test to Colwell K, ammonium acetate will extract the exchangeable potassium fraction, and can be expressed in terms of mg/kg (conversion to the more common exchangeable cation units cmol(+)/kg can be done by multiplying by 391). Summit Field Research is continuing to investigate key indicator values for ammonium acetate K and how it may contribute to better representative potassium soil test interpretations for crop responsiveness on WA soils.

Sulphur (S)

Sulphur KCl-40: The KCl-40 soil sulphur test uses weak potassium chloride heated to 40°C for three hours to extract sulphur from the soil. It removes most of the sulphur already in the sulphate form *and* releases some organic sulphur. The fraction of sulphur released is loosely approximate to the amount that is available to plants. Values can vary due to seasonal and soil environmental conditions. Recommended ranges are therefore broad for this test at 5-15 mg/kg, and very dependent on soil type and crop to be grown.

Sulphur, like Nitrate N, is affected by soil mineralisation and leaching processes so is one element that may have benefits of measuring to depth.

Trace Elements

DTPA trace elements (Zn, Cu, Mn): Trace elements commonly extracted using a diethylenetriaminepentaacetic acid solution – hence, why we call it DTPA. Although only required in small amounts, minor nutrients (micronutrients or trace elements) are essential for plant growth. Soil level requirements for trace elements will vary between soil types and plants. Look for soil levels below 3 (Mn), 0.3 (Cu) and 0.2 mg/kg (Zn) as being indicatively low, but be aware that (a) pH will significantly affect availability of all three metal elements, plant uptake being much higher as pH decreases, and (b) relationships between soil extraction levels and plant growth are not robust. Soil testing for trace elements can be a guide but confirmation or investigation through plant tissue sampling is always recommended.

Extractable Boron: Boron is quite often present in subsoil layers, this needs to be considered when interpreting Boron results in the 0-10 layer. Boron deficiency is more common in horticultural crops, in particularly on acid soils. Deficiencies are seen less in broad acre crops and pastures.

Boron toxicity may occur in sensitive crops when >5. Soil boron levels >12 are generally considered toxic for dry land cereals and are typically associated with alkaline (pH >8) and sodic clay subsoils.

Exchangeable Cations

Exchangeable Ca, Mg, Na, K, Al and H: Calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}) are base cations (nutrients) held and released by the soil to plants. Aluminium (Al^{3+}) and hydrogen (H^{+}) are acidic cations and are only usually only reported if the soil is acidic because non-acidic soils have low levels.

Exchangeable Ca should make up the majority of the cations (desirable range 65% - 80%) and exchangeable Mg should ideally comprise 10% - 20%.

Exchangeable cations are positively charged particles, and it is the electrostatic charge that attracts them to soil particles and other soil components. Hence, they are usually expressed in units (centimoles) of positive charge, cmol(+)/kg soil.

Cation exchange capacity (CEC): An indicator of the soils ability to hold and make plant nutrients available to plants. It influences soil structure stability, nutrient availability, soil pH and the soil's reaction to fertiliser and ameliorants. CEC is calculated as the sum of the exchangeable base cations Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}. Most clays have a higher CEC than sands because they hold more cations. The CEC of soils varies according to the clay %, the type of clay, soil pH and amount of organic matter.

Effective Cation Exchange Capacity (ECEC): The sum of the exchangeable bases *plus* exchangeable acid cations (H^{+} and Al^{3+}). ECEC is an indication of the actual cation exchange capacity of acid to neutral soils because in acidic soil traditional exchangeable bases can be replaced or "swamped" by H^{+}, Al^{3+} and sometimes Mn^{2+}.

A CEC or ECEC (below) less than 5 cmol(+)/kg is indicative of a soil with low fertility. Desirable range is 5-25.

Cation ratios

The concept of soil cations in an "ideal" balance ratio - sometimes known as Base Cation Saturation Rate – was found to have flaws and has been largely surpassed by soil science consensus that that amounts of nutrients, not ratios, are of critical importance for nutrient interpretation, fertiliser management and advice for crop performance.

Nonetheless, some exchangeable cation ratios can provide useful indicators of things such as soil structure and potential stock health management issues.

Exchangeable Sodium Percentage (ESP): Calculating the percentage of the total CEC made up by sodium (Na^{+}) is used to indicate if soils have sodic properties. Sodicity means the cation exchange complex is saturated with sodium. Sodic soils are often dispersive with poor structural characteristics and may require gypsum or organic matter amendments.

Sodicity	ESP
Non sodic	<6%
Sodic	6-15%
Strongly sodic	>15%

Ca:Mg: A calculation of the Exchangeable Calcium to Exchangeable Magnesium ratio after extraction of these exchangeable base cations (above).

Ca:Mg provides a guide to a soil's structure, which influences soil drainage, root development and plant growth. Well-structured soils have a Ca:Mg greater than 2:1, meaning the amount of calcium cations is more than two times greater than the amount of magnesium cations.

A Ca:Mg ratio of greater than 10:1 can indicate potential for Mg deficiency in cattle. Grass tetany, or hypomagnesaemia, is a highly fatal disorder in cattle associated with low blood magnesium levels.

Mg:K: A calculation of the Exchangeable Magnesium to Exchangeable Potassium ratio.

A Mg:K ratio of less 1.5:1 can also contribute to the occurrence of grass tetany.

SUMMIT inSITE

Soil testing data, soil nutrient status interpretations and scientific modelling of optimum fertiliser rates can be accessed through Summit's inSITE platform and SummitConnect.

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