STANDARD SOIL TEST METHODS & GUIDELINES FOR INTERPRETATION OF SOIL RESULTS

These interpretation levels are developed for 0-10 cm surface soils. Subsoil layers can be compared against these calibrations however; critical levels of phosphorus (P), potassium (K), sulphur (S) and trace elements where they occur are relative only to surface levels.

TEXTURE

Method – Assessed using field texturing techniques. The following classes are reported. Note: these lab generated textures are approximate and not as accurate as field described textures by suitable operators.

1	Sand
1.5	Sand - sandy loam
2	Sandy loam - loam
2.5	Loam - clay loam
3	Clay loam - clay
3.5	Clay - heavy clay

NITRATE or NITROGEN (mg/kg)

Method – Extracted with 1:5 soil/1.0M potassium chloride for one hour.

Tentative guide only:
<5 considered low – nitrogen applications should be determined by yield expectations, crop type, soil type, rainfall, past and present management factors etc. Deep soil nitrate testing is the preferred testing as nitrate is highly soluble and can be leached deeper into profiles. Also, nitrate can change quickly with mineralisation.

EXTRACTABLE PHOSPHORUS (Colwell P) (mg/kg)

Method – A 1:100 soil/0.5M sodium bicarbonate extract is shaken for 16 hours and the phosphorus concentration determined by colorimetry.

Criteria

	Crops		Pastures	Potatoes	**Other Vegetables**	Vines/ apples
	Non-calcareous	Calcareous				
Very Low	<10	<15	<10	<20	<40	
Low	10 - 20	15 - 25	10 - 18	20 - 40	40 - 80	
Marginal	20 - 25	25 - 35	18 - 25	40 - 55	80 - 120	
Adequate	25 - 45	35 - 45	25 - 45	55 - 100	120 - 150	>60-80
High	>45	>45	>45	>100	>150	

These figures are a guide only. Actual phosphorus requirements will be based on crop yield, stocking rate and production targets as well as soil phosphorus status. On sandy soils adequate levels can be considerably lower or difficult to establish if on leaching sandy soils. On highly calcareous soils Colwell P is considered less accurate due to high levels of P fixation than on non calcareous soils.

PHOSPHORUS BUFFERING INDEX (PBI)

When applied as granular fertiliser P dissolves rapidly and is then subject to a range of processes including combining with other soil elements (such as iron and aluminium), adsorption to clay and organic carbon particles and leaching. PBI supports Colwell P analysis by providing a measure of "tie up" and leaching potential.

Higher PBI levels (greater than 150-200) indicate a stronger potential for "tie up" and a significant proportion of P applied will be unavailable to plants. A very low PBI (below 40) indicates that there may be potential for phosphorus to leach (these soils generally have low Colwell P levels as well).

Making decisions on P fertiliser

Colwell P, PBI and the forecast needs of the crop for P all need to be taken into account when deciding on fertiliser application. Where PBI levels are low-moderate (40-200) soil P levels detailed in the table is an appropriate benchmark and there may be potential to cut back P applications where levels exceed the recommended minimums. Where PBI levels are greater than 200, Colwell P levels need to be higher than the minimums in the table above. There is also less opportunity to reduce phosphorus applications on these soils as "tie up" of phosphorus will continue to reduce availability.

Also, if aiming to build up soil phosphorus levels higher fertiliser rates above maintenance are required to increase the soil P if your PBI is high.

Critical values for Colwell P when combined with the PBI figures for grazed pastures (from Gourley et. al)

Predicted critical Colwell P soil test values for standard PBI categories, derived from the national data set.

PBI category		Critical value for mid point of PBI category (range)[1]
<15	Extremely low	23 (20 – 24)
15-35	Very very low	26 (24 – 27)
36-70	Very low	29 (27 – 31)
71-140	Low	34 (31 – 36)
141-280	Moderate	40 (36 – 44)
281-840	High	55 (44 – 64)
>840	Very high	n/a[2]

[1] Critical Colwell P value (mg/kg) at the mid-point of PBI category. Values in parenthesis are critical Colwell P values at the lowest and highest PBI values within the category.

[2] Insufficient data to derive a response relationship.

It is strongly recommended that the soil test results should be discussed with your agronomic consultant or fertiliser supplier when making decisions based on test results.

DGT Phosphorus- An emerging new phosphorus test

Method – Diffusion of available P sources in the soil towards a P sink in the form of a ferrhydrite (Iron Oxide) gel.

This new method of P measurement is being developed through Sean Mason, from the University of Adelaide, and has developed critical levels for 4 crops at this stage - no calibration has been made with pasture species yet! The DGT method measures the soil water available P under the field soil conditions and has a better relationship with yield responses than Colwell P, particularly for non calcareous soils.

Categories by Crop for DGT tests (from Mason) N.B. Levels are still being developed and revised as more information become available

Category	Wheat	Barley	Field and Chick Peas	Canola
Very Low	0-20	0-20	0-20	0-20
Low	20-45	20-45	20-35	
Marginal	45-56	45-73	35-50	20-25
High	56--100	>73	>50	>25
Very High	>100			

EXTRACTABLE POTASSIUM (Colwell P) (mg/kg)

Method – Identical extraction method as used for phosphorus. The concentration of potassium is measured by flame atomic absorption.

	Permanent pastures/ dryland cropping	Potatoes	Other vegetables
Low	<80	<120	<150
Marginal	80 - 120	120 - 250	150 – 250
Adequate	120 - 250	>250	*>250*
High	>250		

Note: some plant species, such as lucerne, have higher demands for potassium

Gourley et al has re-examined pasture sites across Australia and come up with a surface texture by critical value relationship for pastures.

Soil texture	Critical value[1]	Confidence interval[2]	Number of experiments	Equation[3] % maximum yield =
Sand	126	109-142	50	$100 \times (1 - e^{-0.024 \times \text{Colwell K}})$
Sandy loam	139	126-157	122	$100 \times (1 - e^{-0.022 \times \text{Colwell K}})$
Sandy clay loam	143	127-173	75	$100 \times (1 - e^{-0.021 \times \text{Colwell K}})$
Clay loam	161	151-182	194	$100 \times (1 - e^{-0.019 \times \text{Colwell K}})$

[1] Soil test value (mg/kg) at 95% of predicted maximum pasture yield.
[2] 95% chance that this range covers the critical soil test value.
[3] e = Euler's constant (approx 2.71828).

Critical Colwell K at 95% maximum yield (from Gourley et al)

EXTRACTABLE SULPHUR (MG/KG) **(KCl-40)**

Method – Soil sulphur is extracted with 0.25M potassium chloride heated at 40°C for 3 hours. The sulphur concentration is determined using an ICP spectrometer.

Criteria (for permanent pastures and dryland cropping)

Low	<5
Marginal	5 - 10
Adequate	>10

These values are a guide only. Rainfall, soil type, crop type (e.g. canola) and past fertiliser history are important factors to take into consideration when estimating sulphur requirements. Generally this test is much more reliable on sandier soils but will often read low if following long dry periods or excessive leaching. Sandy soils' critical level is around 10 while ironstone soils are closer to 8.

ORGANIC CARBON (%)

(Walkley/Black)

Method – Organic carbon is measured by digestion in strong acid/dichromate solution and the colour development assessed against standard sucrose.

Criteria

Texture	Low	Moderate	High
Sand	<0.5	0.5 - 1.0	>1.0
Sandy loam	<0.7	0.7 - 1.4	>1.4
Loam	<0.9	0.9 - 1.8	>1.8
Clay loam/clay	<1.2	1.2 - 2.0	>2.0

High organic carbon levels are generally good however, can also indicate low levels of biological activity due to acidity or water logging. In the South East organic carbon levels much higher than these standards occur, particularly under long term pasture or blacker soils where water-logging has allowed build up.

CONDUCTIVITY

Method – The electricity conductivity (EC) of the 1:5 soil/water suspension is measured and the results are expressed in decisiemens/metre (dS/m).

The value for EC (1:5 soil/water) is converted to an estimated electrical conductivity of a saturation paste extract (ECe) by multiplying with a texture factor (note: dS/m is the same unit as mS/cm).

I.e. ECe estimated = EC1:5 x Texture Conversion Factor #

Note: # use 14 for sand to clayey sand; 9.5 for sandy loam to clay loam; and 6.5 for clay

Criteria	ECe (estimated)
Low salinity	0 - 2
Sensitive plants affected	2 - 4
Many plants affected	4 - 8
Tolerant plants affected	8 - 16
High salinity	>16

Use the salinity fact sheet for the tolerance of various crops and pastures- see attached

pH

Method – There are two standard pH tests in the report. pH (water) is measured in a 1:5 soil/water suspension. pH (calcium chloride) is measured in a 1:5 soil/0.01M calcium chloride suspension.

pH (calcium chloride) is normally 0.7 - 1.2 units lower than pH (water).

Criteria – pH (water)

Strongly acidic	< 5.4	Slightly alkaline	7.1 - 7.5
Moderately acidic	5.5 - 6.4	Moderately alkaline	7.6 - 8.3
Slightly acidic	6.5 - 6.9	Strongly alkaline	> 8.4
Neutral	7.0		

pH (calcium chloride) is generally considered a more accurate test on acid soils and less affected by in-season variation and other salts.

Criteria for liming – using pH (Calcium Chloride) for acid soils

pH Ca	Interpretation	Lime requirement for pastures or dryland crops
<4.8	Strongly acidic	Lime or equivalent required ASAP
4.8-5.2	Moderately high acidic	Lime or equivalent required in near future
5.2-5.5	Moderately acidic	Consider liming as preventative strategy or for highly sensitive crops

ION-EXCHANGE PROPERTIES

Physical and chemical properties of most soils are influenced by their ion-charge characteristics, including the amount and balance of individual ions. Of particular importance are the **exchangeable cations** (calcium, magnesium, sodium, potassium and aluminium) and the **cation exchange capacity**.

Important Note

For alkaline soils it is important to recognise whether your soil is calcareous or not!

See the free lime test results. If calcareous levels are significant over-estimation of exchangeable calcium will occur due to the presence of free lime and the interpretation and ratios below are effectively unreliable for calcareous or highly calcareous soils. Where soils are non calcareous but have alkaline pH the interpretation for Cation Exchange Capacity, Exchangeable Cations and ratios can be used.

CATION EXCHANGE CAPACITY (CEC) (MEQUIV/100)

The CEC is a measure of the soils ability to hold cations. In surface soils the cation exchange capacity is associated with clay content, organic matter and type and retention of cations. The higher the CEC the higher the potential fertility of the soils.

Where total cation exchange capacity is less than 5 this indicates low inherent fertility of the soil. These levels are commonly found in sandy soils and some acidic soils.

The presence of salts, gypsum or carbonate (lime) can lead to over estimation of exchangeable cations and hence CEC. The CEC in this procedure is calculated by adding the 5 cations and as such is the **EFFECTIVE CEC**.

EXCHANGEABLE CATIONS (MEQUIV/100 G)

(calcium, magnesium, sodium, potassium, aluminium)

Method – No pre-treatment for soluble salts. The soil is extracted at a ratio of 1:10 with (0.1M ammonium chloride/0.1M barium chloride) for two hours.

Desirable levels of individual cations vary for crops and soil type. As a general guide for vegetables on loamy soils, adequate levels for exchangeable calcium are 6.0 – 7.5 mequiv/100g and exchangeable magnesium are 1.6 – 2.0 mequiv/100g.

Adequate levels are considerably less for sandier soils, and less intensive crops.

Cation ratios (all calculated ratios are based on figures in mequiv/100g)

Cation ratios are the percentage of the total cation exchange capacity which is attributed to that particular cation. From a plant nutrition perspective provided that there are adequate amounts of calcium, magnesium and potassium the actual ratios are generally not important. However, structural problems may also occur in some soils if the ratio of calcium:magnesium is <2 or there is a high magnesium, sodium and potassium % relative to calcium. In extreme situations similar interactions occur between cations as plant nutrients (e.g. high sodium levels can induce a potassium deficiency). For crops with a high calcium requirement it is good to ensure adequate soil calcium (e.g. apples, some brassicas)

No perfect cation balance exists although Exchangeable aluminium should be <5% to reduce the effects of acidity. In subsurface layers a greater range of ratios can occur without any obvious issue. For example levels of magnesium can be > 50% and still maintain good structure in many South Australian subsoils.

Specific Documented Indicator ratios

Grass Tetany (hypomagnesia)

The ratio of $\frac{\text{Exch. potassium}}{\text{Exch. calcium + Exch. magnesium}}$

can be used as an indicator of potential grass tetany. On soils where this ratio is > 0.07 to 0.08 grass tetany may occur. Plant tests need to be used to confirm grass tetany potential and treatment can involve livestock supplements, changing pasture and correcting acid soils.

Exchangeable Sodium Percentage (ESP)

ESP is used to indicate if soils have sodic properties i.e. the cation exchange complex is saturated with too much sodium. Sodic soils are often dispersive with poor structural characteristics.

$$\text{ESP} = \frac{\text{Exchangeable sodium x 100}}{\text{Effective CEC}}$$

Classification: <6% non sodic

6-15% sodic

>15% strongly sodic

If soils are sodic or strongly sodic and disperse, an application of gypsum may improve stability in the short term. If the ECe estimated is >3 the ESP can be overestimated due to the present of significant soluble salt.

In calcareous soils the influence of sodium is reduced as the high level of calcium is a strong influence on soil structure. Therefore high ESP levels on calcareous soils may not lead to dispersion and poor soil structure.

Soil testing interpretation is difficult as critical concentrations vary between soil types and plants. Plant analysis can be used to confirm suspected deficiencies but may also prove unreliable if plants are under stress. Availability of trace elements will vary depending on a range of factors including:

- Amount of carbonate present – manganese, zinc and copper are less available in high pH and calcareous soils, resulting in low values. Even with some fertiliser addition zinc and manganese can become deficient on high pH and calcareous soils. Need to use leaf testing to observe in season variations.
- Iron deficiency- is often observed on calcareous and high pH soils. Can be made worse by poor drainage or wet conditions.
- Soil texture - generally "adequate" levels are lower in sandy soils than loams and clays.
- Soil moisture – dry conditions can result in less movement of nutrients into the plant. Marginal levels of trace elements can result in deficiencies occurring in drier conditions – particularly noted for manganese and copper.

The "ball park" figures below relate to acid and alkaline soils including sandy-loams and clays and are from general experience rather than calibrated trials. The figures are generally described as low levels or high levels rather than adequate due to the lack of calibration.

As a general rule EDTA extracted trace elements are considered more reliable on acid soils while DTPA is considered more reliable on alkaline soils (EDTA and DTPA are very specific trace element soil tests).

TRACE ELEMENTS – EDTA EXTRACTED

(mg/kg) (copper, zinc manganese, iron))

Method- Extracted with 1:5 soil/0.02M EDTA (pH 4.9) for one hour.

EDTA Extractable Copper (mg/kg)

For pastures and crops 0.5 is low and 1 - 2 moderate to high. For intensive crops (e.g. vegetables) 4 is considered moderate to high.

EDTA Extractable Manganese (mg/kg)

As a general guide < 5-10 is low and > 50 high for manganese. No critical concentrations have yet been established.

EDTA Extractable Zinc (mg/kg)

For pastures and crops 0.7 is low and 2 – 2.5 moderate to high. For intensive crops 4 is considered moderate to high.

TRACE ELEMENTS – DTPA EXTRACTED

(mg/kg) (copper, zinc manganese, iron)

Method- Extracted with / method used by CSBP 1:2 soil: DTPA at 0.005M extraction for 2 hrs.

DTPA Extractable Copper (mg/kg)

For pastures and crops 0.1- 0.3 is low and >1 high.

DTPA Extractable Manganese (mg/kg)

As a general guide < 1 is low and > 10 high for manganese. No critical concentrations have yet been established.

DTPA Extractable Zinc (mg/kg)

For pastures and crops 0.3-0.5 is low and >1 high.

DTPA Extractable Iron (mg/kg)

Suggested that 5-10 is low and above 70 is high (less confidence).

EXTRACTABLE ALUMINIUM (MG/KG)

Method- Extracted with 1:5 soil/0.01M calcium chloride solution for one hour.

Extractable aluminium closely follows the pH of the soil and becomes a problem when the pH (water) is less than 5.5 (in soils which contain significant aluminium). Where extractable aluminium is > 2, sensitive plants will be affected. Agricultural lime which raises pH will therefore reduce high extractable aluminium.

EXTRACTABLE BORON (mg/kg)

Method – Extracted with 1:2 soil/0.01M calcium chloride solution, refluxed for 10 minutes.

Boron deficiencies may occur if extractable boron concentrations are <0.5 in most crops or <1.0 in crops with very high boron requirements e.g. some brassicas (vegetables). Some crops can tolerate quite low levels. Boron toxicity may occur in sensitive crops if > 5. Toxic layers frequently occur at depth. For cereal crops the most reliable indicator for boron toxicity is analysis of the grain. Soil levels >15 are generally considered toxic for dryland cereals.

CHLORIDE (MG/KG)

Method- Extracted with 1:5 soil/water for one hour.

Critical levels for salinity are:

120 sands to sandy loam

180 loam to clay loam

300 clays

Above these figures salinity damage may occur depending on soil drainage and plant tolerance

FREE LIME

Method – 1 N hydrochloric acid is added to the soil and the degree of effervescence is evaluated. The following categories are defined.

NIL SLIGHT	Non-calcareous
MODERATE HIGH VERY HIGH	Calcareous

References Used in this Document

Gourley, C, Melland, A, Waller, R, Awty, I, Smith, A, Peverill, K, and Hannah, M (2007) Making Better Fertiliser Decisions for Grazed Pasture in Australia. Vic DPI

Mason, S (2012) DGT Fact Sheet. Univ of Adelaide

Hughes, B, Jacka, J, Lewis, D, Prance, T and other PIRSA and SARDI staff (1996) Soil Test Methods and Guidelines for Interpretation of Soil Results

Agricultural Bureaus of SA (2010) Interpretation Guides for the Comprehensive acid and alkaline soil tests

For further info please go to our website: www.naturalresources.sa.gov.au/southeast or contact our Land Management Adviser on 08 87351177

APPENDIX 1- RELATIVE TOLERANCE OF PLANTS TO SOIL SALINITY

Soil salinity ECe (dS/m)	Grain crops	Pastures	Vegetables	Fruit Crops
16				
		Puccinellia		
15				
		Saltbush (selected species)		
10	Barley	Tall wheat grass		
9				
	Canola			
8	Cereal rye			
	Triticale			
	Wheat	Barley hay		
7		Perennial ryegrass		Date palm
6	Safflower	Kikuyu		
		Tall fescue		
		Phalaris	Zucchini	
	Oats			
5	Sorghum		Beetroot	
		Strawberry clover		
		Oaten hay		
4	Germinating cereals		Broccoli	
		Vetch		
		Burr medic		Fig, olive
		Lucerne	Tomato	
		Cocksfoot	Cucumber	
		Maize	Pea	
3	Peas, lupins		Broad bean	
	Faba beans		Sweetcorn	
		Annual medic	Potato	Walnut, grape
		Annual clover	Lettuce	Citrus, pome
2			Carrot, onion	Peach, plum
			Green bean	Apricot, almond
1				Strawberry

HOW TO USE THIS CHART

Use the "ECe (est.)" figure from the results sheet, not the "EC (1:5)" figure. In the chart, plant names are positioned at the soil salinity figure, which will cause a 10% yield reduction. Compare your soil test with the figure indicated for a particular plant. Higher soil salinities than those shown will cause greater yield losses for that plant.

Germinating plants will suffer more from salt than indicated by this chart. Water logging will also increase salinity effects. Relative salt tolerances are approximate and are based on limited information. For further advice, contact your local Primary Industries SA office.

References: Ayers (1977), Mass and Hoffman (1977), VIRASC (1969) and Shaw *et.al* (1987). Compiled by T Hermann and A Solomon, Primary Industries SA, December 1994.

Authors Brian Hughes, David Davenport and Lyn Dohle
RSSA

Agricultural Bureau of South Australia Inc.
PATHWAY TO IMPROVEMENT

RURAL SOLUTIONS SA

Natural Resources South East

Government of South Australia