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TECHNICAL NOTE

SOIL TESTS & INTERPRETATION

This technical note discusses most of the soil tests used at Hill Laboratories, and gives very general interpretive information for each.

Information for this Technical Note has been taken from Chapter three of the **Field Consultants Guide to Soil & Plant Analysis**.

Hill Laboratories has organised its soil tests into two groups. The first, the Basic Soil test, includes components of significance across all applications:

- pH
- Phosphorus
- The Cations: Calcium, Potassium, Magnesium and Sodium
- Cation Exchange Capacity and Base Saturation
- Volume Weight

The Basic Test can be supplemented by additional tests where extra information is required. Hill Laboratories routinely offers the following:

- sulphate - sulphur
- extractable organic sulphur
- resin P
- organic matter
- soluble salts
- ASC (phosphate retention)
- available nitrogen
- total nitrogen
- total phosphorus
- total sulphur
- boron
- reserve potassium
- reserve magnesium
- aluminium
- trace metals

Selection of these additional tests depends upon the crop under consideration, the cultivation technique and other factors (see Table 1). If in doubt about your exact requirement, or if you require analyses not listed, please do not hesitate to inquire, or talk to your consultant or merchant.

The following information is prepared as a general summary of the range of soil test levels likely to be encountered in New Zealand soils. It is intended as a guide only. **It is crucial to take both the specific crop requirements and local conditions into account when using this summary in conjunction with any analysis results.** Also refer to the appropriate **Crop Guide** for more specific information and to the histogram presentation issued with individual reports.

Sample Preparation

All soils are dried in a forced air convection drier at 35°C. All results are reported on this basis and no correction is made to an oven dried basis (103°C). In-house experiments have determined residual moistures to be typically 5%.

After drying, soils are crushed to pass through a 2mm sieve.

Basic Soil Test

Following is a brief description of the most common tests available. The section also has interpretation data from published[1] references or derived from our own database. Where applicable, cross references to our Technical Notes are also made.

pH

The soil pH is a measure of the acidity or alkalinity of the sample. It is important because of how it influences the chemical and physiological processes in the soil, and the availability of plant nutrients.

Figure 1 shows how pH can affect the availability of nutrients.

Level	Peat	Loam	Sandy
Very Low (acid)	4.0	5.0	5.0
Low	4.5 - 5.0	5.1 - 5.5	5.1 - 5.8
Medium	5.1 - 5.5	5.6 - 6.5	5.9 - 6.8
High	5.6 - 6.0	6.6 - 7.0	6.9 - 7.5
Very High (alkaline)	> 6.0	> 7.0	> 7.5

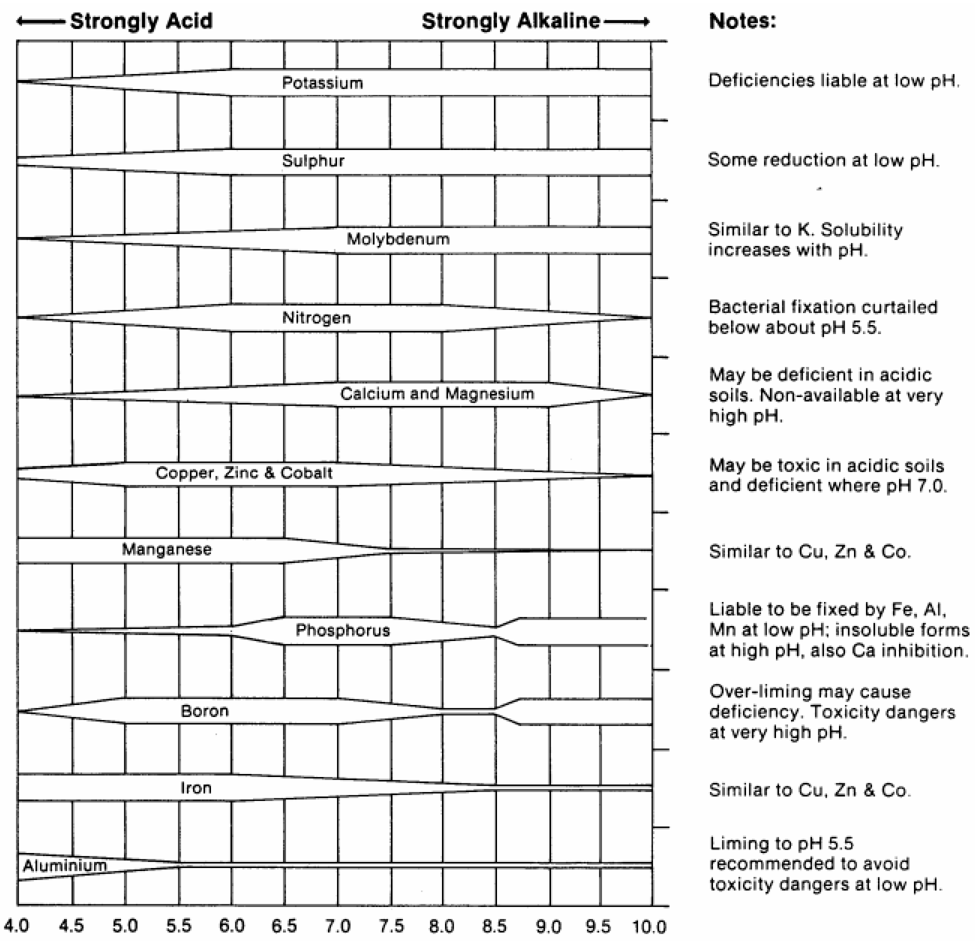

Figure 1: pH affects on plant availability of nutrients[2]

[1] Blakemore, L.C.; Searle, P.L.; Daly, B.K. 1987. Methods for chemical analysis of soils. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 80).

[2] From Truog, 1948

Phosphorus

The Olsen P test is the standard method in New Zealand to assess phosphorus availability to plants. The Resin P test is an alternative test, described later, and is recommended for soils where RPR or other slow release P fertilisers have been used.

The following interpretations apply to autumn sampling of soils in areas with rainfall more than 1000 mm per year.

Level	Ag. Soil (mg/L)	Hort. Soil (mg/L)	G/H Soil (mg/L)
Low	< 20	< 30	< 70
Medium	20 - 30	30 - 80	70 - 150
High	> 30	> 80	> 150

It is recommended that the anion storage capacity/phosphate retention of the soil is considered when interpreting P levels.

Cations and Cation Exchange Capacity

The cations potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) are an important group of nutrients essential for plant growth.

There are two ways to consider cations in the soil:

1. In terms of the actual amounts extracted, which gives an indication of the absolute amount available to plants. Their concentrations are expressed in me/100g. At Hill Laboratories, this is the preferred and recommended way to assess cations.
2. As a proportion of the soil's CEC (see below). This is the cation's Base Saturation level, and is expressed as a percentage.

There are complex interactions that may take place among the cations, affecting the soil's characteristics and their availability to plants. Considering the cations in terms of their Base Saturation as well as absolute concentrations may provide more information than either can do alone.

Crop	K (me/100g)	Ca (me/100g)	Mg (me/100g)	Na (me/100g)
Agricultural	0.5 - 0.8	6 - 12	1 - 3	0.2 - 0.5
Horticultural	0.5 - 1	6 - 12	1 - 3	0 - 0.5
Glasshouse	1 - 3	8 - 15	2 - 4	0.2 - 0.6

For many crops the magnesium level should ideally be twice as much as the potassium. When magnesium is lower than potassium, suppression of magnesium uptake can occur.

Sodium is only of secondary importance in the soil test as its uptake by plants is largely dependent on the plant species involved and the potassium status of the soil, rather than the actual level of sodium extractable from the soil. This element is mainly of interest for animal health and can generally be ignored for cropping and horticultural situations.

High sodium levels may occur in low lying coastal areas, or in glasshouse soils irrigated with water high in sodium. If this situation is suspected, a soluble salts test may be useful.

The Cation Exchange Capacity (CEC) of a soil is a measure of it's capacity to hold cations[3]; in particular, potassium, calcium, magnesium and sodium. The larger the value of the CEC, the higher the soil's capacity for cation nutrients. Fine textured soils and those with high organic matter and clay content have higher CECs.

Soils may contain cations in the form of soluble salts that are not part of the exchangeable pool. Concentrations of exchangeable cations can be overestimated if soluble salts are high. Our CEC measurement assumes negligible free soluble salts.

Typical CEC values for different soils are given below.

Level	CEC (me/100g)	Soil Description
Low	5 - 12	Sandy or low in organic matter
Medium	12 - 25	Average, silty or clay soils with medium to low organic matter level
High	25 - 40	High fertility silt or clay soils with high or medium organic matter level
Very High	> 40	Clay soils with high organic matter levels or peat soils

Sometimes requests are made to convert our cation results from me/100g units to mg/mL or MAF units. This can be done according to the formula in the table below, provided the testing procedures are known to be similar, which is normally the case with results from New Zealand laboratories.

me/100g to µg/mL:	Potassium Calcium Magnesium Sodium	me/100g x 391 x VW = µg/mL me/100g x 200 x VW = µg/mL me/100g x 122 x VW = µg/mL me/100g x 230 x VW = µg/mL
me/100g to MAF units	Potassium Calcium Magnesium Sodium	me/100g x 20.8 x VW = MAF K me/100g x 1.29 x VW = MAF Ca me/100g x 23.3 x VW = MAF Mg me/100g x 53 x VW = MAF Na
Note:	for results on a weight basis: for results on a volume basis: For results on a per hectare basis (7.5 cm sample)	µg/g = mg/kg = ppm µg/mL = mg/L = ppm µg/mL x 0.75 = kg/ha

Base Saturation

As discussed above, the individual cations can be considered as proportions of the CEC. This approach may give interesting information about the balance among the nutrients. Desirable Base Saturation levels are given in the table below.

Crop	K (%)	Ca (%)	Mg (%)	Na (%)
Agricultural	2 - 5	50 - 75	5 - 15	1 - 2
Horticultural	3 - 6	50 - 75	7 - 15	1 - 2
Glasshouse	6 - 12	50 - 75	7 - 15	1 - 2

The proportion of the soil's total capacity for cations that is actually occupied by these nutrients, the Total Base Saturation, is calculated by summing together the levels of calcium, magnesium, potassium and sodium found in the soil and expressing this sum as a percentage of the CEC value.

There is a correlation between Total Base Saturation and soil pH, with increasing Total Base Saturation being associated with increasing soil pH. This can give another perspective on the soils requirement for lime.

[3] Refer to KB3188: Cation Exchange Capacity and Base Saturation.

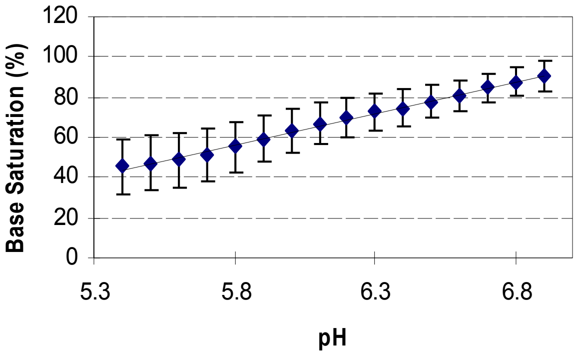

Figure 2: Relationship between pH and Base Saturation4

Volume Weight (Bulk Density)

The Volume Weight is the weight of a known volume of air-dried and ground soil. This figure gives an indication of the soil's physical characteristics, as well as allowing the conversion of test results to other units if necessary.

Soil Type	VW (g/mL)
Sandy	1.0
Clay	0.8
Peat	0.5

In the past, this test was called Bulk Density, but the name was changed in 1997 to avoid confusion with the Field Bulk Density property.

Lime Requirement

Lime requirement is a calculation that estimates the amount of lime ($CaCO_3$, 90% pure) necessary to achieve a target total base saturation for a particular crop[5]. The default target is 70%. Other targets range from 35% for peat soils to 80% for some horticulture crops.

The formula for 15 cm core samples is:

Lime Req. (t / ha)= (Target%BS – Soil%BS) x CEC x VW x 0.0083

The formula for 7.5 cm core samples is:

Lime Req. (t / ha)= (Target%BS – Soil%BS) x CEC x VW x 0.0083 ÷ 2

[4] *Soils with 0.60≤VW≥0.90 and 17≤CEC≥35 selected from Hill Laboratories database.*

[5] *Theoretically derived from first principles.*

An alternative formula to calculate Lime Requirement for pastoral soils, based on New Zealand field trials[6] using pH and CEC, is:

$$\textit{Lime Req. (t / ha)} = 26.2 - (4.4 \times pH) + (0.007 \times CEC)$$

Additional Soil Tests

There is a range of additional tests available. Which to choose can depend primarily on the crop being grown. Refer to Table 1 to help select the appropriate tests.

Sulphate-Sulphur

This test measures readily available sulphur in the form of dissolved plus absorbed sulphate. Sulphur testing is important where low sulphur or sulphur-free fertilisers are used, such as high analysis NPK fertilisers. Retention of sulphate-sulphur by the soil is related to its phosphate retention, with high leaching losses of sulphate being associated with low phosphate retention soils. This should also be taken into account when considering sulphur fertiliser options.

Level	Sulphate-Sulphur (mg/kg)
Very Low	< 4
Low	4 - 10
Medium	10 - 20
High	20 - 50
Very High	> 50

Extractable Organic Sulphur

Most of the soil's sulphur (95%) is in organic forms. This pool of S is in a slow equilibrium with the plant available, inorganic form of S. Being a natural source of S, it is useful to have a means of assessing this component, especially where the sulphate-S test indicates low levels of the readily plant available form. This test measures the readily soluble fraction of the organic S pool.

Level	Extractable Organic Sulphur (mg/kg)
Very Low	< 5
Low	5 - 11
Medium	12 - 20
High	> 20

[6]Edmeades, D.C.; Wheeler, D.M.;Waller, J.E. (1984).

Comparison of methods for determining lime requirements of New Zealand soils. *New Zealand Journal of Agricultural Research* 28: 93-100.

Resin P

As with the Olsen P test, the Resin P test[7] also gives an indication of plant available phosphorus in the soil. The Olsen P test is considered to have a poorer correlation with pasture growth than the Resin P test where there is a history of slow release phosphorus fertiliser use (i.e. RPR, PAPR or Longlife Super). There is also evidence that the Resin P test may have some advantages, particularly when interpreting results from a variety of soil types and pHs. However, as interpretation data for the Resin P test is limited, this test is offered as an additional test rather than a replacement for the Olsen P test.

Level	Dairy Soil (mg/kg)	Dry Stock Soil (mg/kg)
Low	< 50	< 40
Medium	50 - 100	40 - 75
High	> 100	> 75

Soluble Salts

This test monitors the level of soluble salts in the soil. The 1:5 water extraction is used for field soils and the 1:2.5 calcium sulphate extraction for glasshouse soils.

Some common reasons for this determination are:

- Heavy application of fertilisers under conditions of intensive cropping (particularly in glasshouses) where plant growth may be affected by salt stress.
- For specific investigations of irrigation and ground waters.
- Soils recently affected by seawater are perhaps too salty to support some crops or pasture species.

Plants vary considerably in their tolerance to soluble salts. In outdoor situations, soluble salts should ideally be at a low level.

Level	Glasshouse Soils (%)	Field Soils (%)
Low	< 0.10	<0.05
Normal	0.10 - 0.20	0.05 - 0.30
High	0.20 - 0.40	0.30 - 0.70
Very High	> 0.40	> 0.7

[7]Refer to KB3192: The Resin P Soil Test.

Anion Storage Capacity (Phosphate Retention)

Anion storage capacity or ASC (previously termed phosphate retention) refers to the phosphorus immobilisation property of the soil. Although high ASC soils may require between two to three times the amount of phosphorus as capital or maintenance fertiliser than low ASC soils, it is important to realise that an ASC/phosphate retention of 90% does not mean that 90% of the applied P is rendered unavailable to plants.

ASC should be included with any initial soil test to establish the value for that soil type. This value is an inherent property of the soil and does not change.

Level	ASC/Phosphate Retention (%)
Very Low	< 10
Low	10 - 30
Medium	30 - 60
High	60 - 80
Very High	> 80

Organic Matter

The Organic Matter (OM) level in the soil is strongly correlated to the soil's CEC, and is a source of many plant nutrients, particularly nitrogen. Organic matter also plays a major role in determining soil physical characteristics; soils with medium to high OM levels would generally be expected to have good structure, moisture retention and water infiltration.

The quantity and nature of organic matter[8] is highly dependent upon farming practices and climatic conditions and is found as both chemically stable humus (or passive OM) and partially decomposed plants, microbes and animal residues (or active OM).

It is Organic Carbon (as Total Carbon) that is directly measured in the laboratory, and OM is calculated from this using a standard factor derived for soils.

Organic Matter (%) = Organic Carbon (%) x 1.72

Level	Organic C (%)	Organic Matter (%)
Very Low	< 2	< 3
Low	2 – 4	3 - 7
Medium	4 – 10	7 - 17
High	10 – 20	17 - 35
Very High	> 20	> 35

Available Nitrogen (also known as Anaerobically Mineralisable N)

This test provides an indication of the quantities of nitrogen that can be readily mineralised from soil organic matter under ideal soil conditions. The actual amounts of nitrogen that will mineralise in the field will depend on factors such as soil temperature and moisture, which are impossible to emulate or predict in the laboratory. This test must therefore be interpreted with caution, realising that it is a measure of nitrogen mineralised under specific laboratory conditions.

The test measures the potential of soil to provide nitrogen to growing plants. It has been widely used for arable soils, but has not been widely used for pasture soils. Pasture soils usually show high levels with this test, but may still benefit from strategic use of nitrogen fertiliser because of unfavourable conditions for the mineralisation of these soil reserves at certain times of the year.

Level	Anaerobically Mineralisable N ug/g	Available nitrogen kg/ha
Very Low	<35	< 50
Low	35 – 50	50 - 150
Medium	50 – 80	150 - 250
High	80 – 240	250 - 350
Very High	>240	> 350

[8]Refer KB 10151 Assessing Soil Quality—the Organic Soil Profile

During the last few years, researchers have shown that the anaerobically mineralisable nitrogen (AMN) is a good indicator of biological activity and is closely related to microbial biomass.

Total Nitrogen

This test determines the total nitrogen (TN) content of the soil including that present as both chemically stable humus (or passive) and partially decomposed plant and animal residues (or active) organic matter fractions. The test gives some indication of the N supplying power of a soil, but it's primary use is to enable the expression of other, related parameters (Organic C, AMN) relative to this property.

Level	Total Nitrogen (%)
Very Low	< 0.1
Low	0.1 - 0.2
Medium	0.2 - 0.5
High	0.5 - 1.0
Very High	> 1.0

Carbon: Nitrogen Ratio

The ratio of total organic carbon and total nitrogen is the traditional guide to the nature of the organic matter present in the soil.

The C:N ratio is readily calculated as follows:

$$\textit{Carbon:Nitrogen Ratio} = \frac{\textit{Organic Carbon (\%)}}{\textit{Total Nitrogen (\%)}}$$

The basic premise behind this ratio is that organic carbon is the primary source of energy for soil microbes, but these also require nitrogen to multiply and utilise this energy. The microbes utilise soil carbon via respiration, with the consequent loss of carbon dioxide from the soil. As the *active fraction* of the OM is thus degraded, the C:N ratio drops until a steady state (the *passive fraction*) is finally attained.

Interpreting this ratio is complicated, as it also depends on the nature of the OM.

The *passive fraction* of the OM can have a C:N ratio that is 'medium'. Consequently, medium C:N ratio soils can have a wide variation in mineralisable N status, and this is a limitation when considering the C:N ratio in isolation.

Level	C/N Ratio
Very Low	< 8
Low	8 – 10
Medium	10 – 15
High	15 – 25
Very High	> 25

A ratio of 10-12 is normal for an arable soil with a good rate of organic matter decomposition, 15-20 indicates slow decomposition of the organic matter. Ratios greater than 25 suggest that the organic matter is not decomposing.

Exchangeable Aluminium

Aluminium (Al) is not present in a plant available form in soils with a pH above 5.5 and therefore tests for extractable aluminium need only be done on distinctly acid soils. In New Zealand, soils with a pH range of 4.5 - 5.5 are those most likely to be affected by aluminium toxicity. Up until recently, Hill Laboratories has reported Al measured from a 1M KCl extract. A recent change means the 0.02M $CaCl_2$ extractable method is now in use, with this lower ionic strength extractant giving different interpretive levels.

Level	1M KCl Exchangeable Aluminium (me/100g)	0.02M $CaCl_2$ Exchangeable Aluminium (mg/kg)
Low	< 0.5	<1
Medium	0.5 - 1.0	1.0 - 3.0
High	1.0 - 2.5	3.0 – 10.0
Very High	> 2.5	> 10.0

Extractable Boron (Hot Water Soluble Boron)

Boron is an essential plant nutrient, but many crops are also susceptible to boron toxicity. The difference between adequate levels and toxic levels can be quite small.

The following guidelines may be used, although be aware of different crops' tolerance to boron. For example, avocado has a high boron requirement, but kiwifruit is sensitive to boron toxicity. This should be considered, especially when changing from one crop to another.

Level	Boron (mg/kg)
Low	< 1
Medium	1 - 2
High	2 - 5
Very High	> 5

Reserve Magnesium

Reserve magnesium is used to estimate long-term magnesium reserves in the soil and is predominantly used in research investigations.

The difference between the slow, long term available magnesium and the exchangeable magnesium of the soil is called the Reserve Magnesium. Because the total magnesium content of soils is often very large, and the maintenance requirements of pasture and crops are relatively small, it is likely that slow weathering of magnesium containing minerals and clays can supply an appreciable proportion of plant requirements.

Level	Reserve Magnesium (me/100g)
Very Low	< 3
Low	3 - 7
Medium	7 - 15
High	15 - 30
Very High	> 30

Reserve Potassium and TBK

The amount of slowly released potassium is often more significant than the amount of immediately available exchangeable potassium. The "Reserve Potassium "test is used to estimate the long term potassium supplying potential of the soil, and appears to be unaffected by short term treatments. An alternative test known as "TBK " (modified from the original Jackson test) has now largely been adopted in NZ laboratories. This test gives similar information about the long-term supply of reserve potassium.

Level	Reserve Potassium (me/100g)	TBK (me/100g)
Very Low	< 0.10	< 0.40
Low	0.10 - 0.20	0.40 - 0.80
Medium	0.20 - 0.35	0.8 – 1.2
High	0.35 - 0.50	1.2 – 1.8
Very High	> 0.50	> 1.8

Trace Elements

Soil trace element tests[9] are available although Hill Laboratories consider that plant tissue analysis is the best approach to determining the trace element status of plants. Soil trace element tests can be used to identify best treatment options such as soil application or foliar application of nutrients for plant nutrition by giving a general indication of soil nutrient status.

Soil TE tests can also be used to monitor changes in levels of elements that accumulate in horticultural soils due to long term application of fungicides.

Mehlich 3 profile[10]:	P, Ca, Mg, K, Na, Mn, Zn, Cu, Co, Fe, B, Al
EDTA profile:	Mn, Zn, Cu, Co, Fe
Total element tests:	Mo, Se, S, P, Ca, Cd, Cu, Co

Total Element Tests

Total (acid-recoverable) element tests[11] are available for several elements. The main use of these tests is for comparison with 'plant available' nutrient tests and monitoring the long-term effects of fertiliser application to soils.

Others

There are several tests available from Hill Laboratories that have not been described in this section. Please contact the laboratory to discuss your requirements.

[9] Refer to KB3185: New Calibration Data for Soil Trace Element Tests in NZ.

[10] Refer to KB5565: The Mehlich 3 Soil Test

[11] Refer to KB23107: Soil Total Nutrients – Analysis & Interpretation

Table 1: Soil test selection guide by enterprise description

Pasture	Crop	Tree Crop	Field Crop	Glass House	Forestry	Sports Turf	Test/Comments
✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	**Basic Soil**
✓✓	✓	✓	✓	✓	✓	-	**Sulphate Sulphur** – where sulphur is likely to be lost by leaching ie sedimentary soils or if sulphur is not included in the fertiliser programme on a regular basis.
✓	✓	-	✓	-	-	-	**Organic Sulphur** – where sulphate sulphur status is low and there is a requirement for more information on soil sulphur status.
✓✓	✓✓	✹	✹	-	✹	-	**Resin Phosphorus** – where RPR or similar slow release P fertilisers have been used.
-	-	-	-	✓✓	-	-	**Soluble Salts** – In glasshouse soils where high fertiliser application rates and high evapo-transpiration rates often cause a build up of salts which may harm sensitive crops.
✹	✹	✹	✓	-	-	✓	**Soluble Salts -(field)** where high salt levels due to fertiliser, irrigation water content, sea water contamination or other factors is suspected.
✓	✓	✓	✓	-	-	-	**Anion Storage Capacity/Phosphate Retention** – where capital application of P fertiliser is contemplated. The P retention value will influence the required application rate to reach a target level.
✹	✓	✓	✓	✓	✓	✹	**Organic Matter** – gives an indication of nutrient reserve, soil structure and moisture retention characteristics. Normally on cropping soils or in development situations.
-	✓✓	✓	✓✓	-	-	✓	**Available Nitrogen –** test is designed to estimate N status of cultivated soil. (Also known as Anaerobic Mineralisable N)
-	✓	-	✓✓	-	-	-	**Mineral N –** immediately available NO3-N and NH4-N
✹	-	-	-	-	✹	-	**Exchangeable Aluminium –** where soil pH is low and the economics of lime application to counter Al toxicity is being investigated.
✹	✹	✓	✹	✓	✓	-	**Boron –** where the soil boron status is required, normally in horticultural cropping situations where crops have a known requirement for this nutrient.
✹	✹	✹	✹	-	✹	-	**Total Nitrogen** – used in conjunction with Organic Matter to determine C:N ratio as a measure of biological activity in the soil.
✓	✹	✹	✓	-	✓	-	**Reserve Potassium** – where the soils capacity to provide slow release/long term potassium to pasture or crops is required.
✹	✓	✓	✓	-	✓	-	**Reserve Magnesium** – where the soils capacity to provide slow release/long term magnesium to pasture or crops is required.

✓✓	Recommended	✹	For specific investigations only
✓	Optional	-	Not normally requested