Chapter D3. Chemical tests

PURPOSE OF THIS CHAPTER

To describe how various chemical tests can help you find out more about your soil

CHAPTER CONTENTS

- pH
- organic matter
- salinity
- exhangeable cations and clay dispersion

ASSOCIATED CHAPTERS

- A3 ‘Features of soil’
- B5 ‘Does my soil need lime’
- B7 ‘Managing saline soils’
- B8 ‘Dispersion’
- D4 ‘Slaking and dispersion’
- D5 ‘Sodic soil management’

CHEMICAL SOIL TESTS

Several commercial laboratories offer soil chemical testing services that describe the nutrient status of soil and give fertiliser recommendations. These services usually do not include direct measurements of soil structure. However, chemical testing, as well as providing valuable information about the chemical fertility of the soil, can also give some indirect information about a soil’s physical condition. This can help you to decide how to manage it (Figure D3–1).

Figure D3–1.

Deep rippers, hillers and ‘dammer dykers’ assembled on one tool frame. The deep rippers help break up the sodic subsoil in clays. (Ben Rose)

SOIL PH

The standard method of measuring soil pH is with a suspension of 1 part air-dry soil by weight to 5 parts liquid by volume. The recommended liquid is 0.01M $CaCl_2$ (calcium chloride). Results in this case are reported as pH ($CaCl_2$). Distilled water is sometimes used in place of calcium chloride, in which case results are reported as pH (water). Soil tested in $CaCl_2$ solution gives pH values about 0.5–0.8 lower than the same soil tested in water.

Interpreting soil pH

The pH ($CaCl_2$) of many vegetable-growing soils can vary down the profile and between sites, from strongly acid (less than 5) through to strongly alkaline (greater than 8). Values of pH between 5 and 8 are very common.

A low pH (less than 5) is detrimental to plant growth, not because of the acidity itself, but because of imbalances in nutrient levels. Phosphate is poorly available, and aluminium and/or manganese may be present in toxic concentrations. Lime is needed to raise the pH.

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See Chapter B5 for more information on the effect of pH on vegetable production.

A pH greater than 8 indicates possible high levels of exchangeable sodium or magnesium, and therefore a tendency for the clay to disperse (producing poor soil structure). Phosphate, iron, zinc and manganese are poorly available.

A desirable pH ($CaCl_2$) range for plant production is 5.5 to 7.5.

ORGANIC MATTER

Changes in organic matter levels over time (several years) will indicate the effects of a management system on soil condition. A high level of organic matter generally indicates better soil structure. In cracking clays, organic matter may not be quite as important to soil structure as it is in other soils. Be wary of reported organic matter contents that do not state the method used.

Converting organic matter values

The average carbon content of soil organic matter is approximately 57%. Multiply the values for the organic carbon % by 1.75 to convert to organic matter %.

Interpreting organic matter values

Most soils in Australia, even in their natural state, are low in organic matter compared with soils in other parts of the world. Cultivation history, sample depth and soil type affect organic levels markedly. The following ranges are only a guide, and individual values could lie outside these ranges.

A virgin grey or brown cracking clay could have an organic matter content anywhere between 1.4% and 4.0% in the surface 0.1 m.

Typically, the red brown earths have organic matter levels of about 1.75% in the topsoil.

In the broad context of various soil types, regard an organic matter below 1% as very low, 1%–2% as low, 2%–4% generally satisfactory, and greater than 4% as high. As with much soil data, information on organic matter content becomes more useful when compared over different locations, management histories and times.

SALINITY – ELECTRICAL CONDUCTIVITY

Electrical conductivity (EC) is a measure of the ability of a liquid to pass an electric current. EC increases as the salinity (salt concentration) of the liquid increases. The units are dS/m (deciSiemens/metre)

EC_e is the electrical conductivity of a saturated soil-water extract. The water is removed from a just-saturated soil sample by a centrifuge or vacuum pump, and the electrical conductivity of the water extract is tested. EC_e is the preferred method of estimating soil salinity, because it best reflects how salinity will affect plant growth. However, it is very time consuming and is not a routine method.

$EC_{1:5}$ is the electrical conductivity of a suspension of one part air-dry soil by weight to five parts water by weight, as for pH (water). This is the most common method because it is easy to do. However, it is difficult to interpret. $EC_{1:5}$ values need to be converted to EC_e values so they can be interpreted.

Total soluble salts (TSS) used to be a popular way of expressing soil salinity and is still used by a few laboratories. TSS is not recommended, because it cannot be easily related to plant growth.

Converting EC values

Tables of salt tolerance use values of EC_e. If your result sheet shows TSS, first convert the values to $EC_{1:5}$ and then to EC_e.

Interpreting EC_e

Conventionally, saline soils are defined as those with an EC_e value greater than 4 dS/m. However, much lower levels of salinity than this can affect the growth and yield of sensitive plants such as maize, most legumes (beans, peas, clovers and, to some degree, lucerne) and some grasses

Saline soils are often friable, because the high salt concentration allows the clay particles to flocculate (form clusters) even when the soil has a high exchangeable sodium percentage.

Step 1

Convert TSS to $EC_{1:5}$ if necessary:

TSS units are mg kg^{-1} (ppm) or g/100 g (%). The following two formulae approximately relate $EC_{1:5}$ and TSS:

$EC_{1:5}$ (dS/m) = TSS (mg kg^{-1}) x 0.00031

$EC_{1:5}$ (dS/m) = TSS (g/100g) x 3.1

Example: TSS % of 0.015 g/100 g:

$EC_{1:5}$ = 0.015 x 3.1

= 0.047 (dS/m) (approx.)

Step 2

Convert $EC_{1:5}$ to EC_e:

To obtain an approximate value for EC_e multiply the $EC_{1:5}$ by a factor that depends on the soil texture (Table D3–1).

Table D3–1. Multipliers for converting $EC_{1:5}$ (dS/m) to an approximate value of EC_e (dS/m).

Soil texture	Multiply $EC_{1:5}$ (dS/m) by this number
Sand, loamy sand, clayey sand	23
Sandy loam, fine sandy loam, light sandy clay loam	14
Loan, fine sandy loam, silt loam, sandy clay loam	9.5
Clay loam, silty clay loam, fine sandy clay loam, sandy clay, silty clay, light clay, light medium clay	8.6
Medium clay	7.5
Heavy clay	5.8

Example: if a sample of medium clay has an $EC_{1:5}$ of 0.4 dS/m, then:

EC_e = 0.4 x 7.5 dS/m

= 3 dS/m (approx.)

Miscellaneous units for electrical conductivity

1 dS/m (deciSiemens/metre) equals
1 mS/cm (milliSiemens/centimetre)
or
1 mmho/cm (millimho/centimetre)

EXCHANGEABLE CATIONS

A few laboratories report exchangeable cations as mg kg^{-1} (ppm). It is more useful to express them as centimoles of positive charge per kilogram of soil (cmol (+) kg^{-1}), numerically equal to milliequivalents per 100 g of soil (me/100g). This takes account of the different valencies and atomic weights of different cations. Use the numbers in Table D3–2 to convert the units.

Table D3–2. Converting mg kg^{-1} to cmol (+) kg^{-1}.

Cation	Divide mg kg^{-1} by this number
Calcium (Ca)	200
Magnesium (Mg)	120
Potassium (K)	390
Sodium (Na)	230
Aluminium (Al)	90

Step 1

Convert mg kg^{-1} to cmol (+) kg^{-1}, **if necessary**

Step 2

Calculate the cation exchange capacity:

After converting the cation concentrations to cmol (+) kg^{-1}, add them to give an approximate value for the cation exchange capacity (the 'effective' CEC). Express each cation as a % of the effective CEC, as in the example (Table D3–3).

Caution: Never add values expressed as mg kg^{-1} or ppm. The result is meaningless.

Table D3–3. Example of calculating exchangeable cations as % of effective CEC.

Cation	mg kg^{-1}	cmol (+) kg^{-1}	% of effective CEC
Calcium (Ca)	3000	3000/200=15.0	100 x 15.0/34.9=43.0
Magnesium (Mg)	2020	2020/120=16.8	100 x 16.8/34.9=48.1
Potassium (K)	351	351/390=16.8	100 x 0.9/34.9=2.6
Sodium (Na)	512	512/230=2.2	100 x 2.2/34.9=6.3
Aluminium (Al)	nil	0	0
Total (effective CEC)		34.90	

Other cations (manganese, iron, copper and zinc) are usually present in only trace amounts and so do not contribute significantly to the total. In addition, soils with pH ($CaCl_2$) above 5 contain very little exchangeable aluminium, and so the effective CEC is the sum of the four cations calcium, magnesium, potassium and sodium. In the example, the effective CEC is 34.9.

Step 3

Note the ESP:

The exchangeable sodium percentage (ESP) in the above example is 6.3. This value gives a guide to the potential for clay dispersion. A clay soil with an ESP greater than 5 is prone to dispersion on wetting if its salinity is low.

Step 4

Calculate the Ca:Mg ratio:

Calculate the ratio of exchangeable calcium to exchangeable magnesium (Ca:Mg ratio) after converting the units to cmol (+) kg^{-1}.

Using the example in Table D3–3:

Ca:Mg ratio = 15.0/16.8 = 0.89 (no units)

EXCHANGEABLE CATIONS AND CLAY DISPERSION

The balance between the various exchangeable cations and the concentration of total salts (salinity, as measured by electrical conductivity) determines whether clay will disperse in water.

In general, non-saline soils with an exchangeable sodium percentage (ESP) above 5 are liable to disperse in water. The soil in the example in Table D3–3 has an ESP of 6.3 and may disperse.

A Ca:Mg ratio of less than 2 (particularly, less than 1) also indicates a tendency to disperse. The soil in the example in Table D3–3 has a Ca:Mg ratio of 0.89. Considering this and its ESP of 6.3, it is likely that such a soil would disperse if it were non-saline.

Free lime or gypsum can give false values for exchangeable calcium (overestimated by as much as 50%). Laboratories should use the Tucker method for exchangeable cations to minimise this error. This method uses an ammonium chloride leaching solution at pH 8.5, and measurement of the sulfate and carbonate content.

In clay soils the higher the Ca:Mg ratio, and the lower the Na %, the higher the likelihood of the soil being self-mulching. Self-mulching clays usually have Ca:Mg ratios of 2 to 4, and a Na % of 3% or less. Non-self-mulching clays generally have Ca:Mg ratios of about one, with the Na % usually exceeding 5%.

Therefore, the Ca:Mg ratio and the exchangeable sodium percentage (Na %) are important indicators of the soil structural stability and land-use potential of clay soils.

Methods for testing exchangeable cations used by some laboratories can give false values for exchangeable sodium, if the soil is saline. Where the electrical conductivity (1:5 soil/water) exceeds 0.3 dS/m, the soil should be treated to remove soluble salt. If not pre-treated, such soils will produce inflated test values for exchangeable sodium, over-estimating ESP and indicating a need for gypsum where none may be needed.