Chapter 7

Field diagnostics

Key points

- Soil texture affects the capacity of the soil to store water and nutrients and can be easily estimated using hand texture analysis.
- pH can be readily measured in the field by using test kits or compact pH meters.
- Salinity can be measured in the field using compact electrical conductivity (EC) meters.
- Sodicity can be estimated in the field by visually assessing dispersion of soil clods in fresh water.
- These basic soil properties provide identification of some common subsoil constraints to crop growth.

Soil texture

The texture of soil is important because it affects the capacity of the soil to store moisture and nutrients. Texture relates to the proportion of clay, silt and sand making up a particular soil, where the upper sizes of these components are 0.002, 0.02 and 2.0 mm respectively. The percentage of clay, silt and sand plotted on the texture triangle allows soils to be classified according to texture (Figure 7.1). The higher the clay composition within a soil the 'heavier' the texture class while the reverse also applies with 'light' soils being mainly of sand and silt. Knowing soil texture is vital to assess the severity of salinity within any particular soil, ie an $EC_{(1:5)}$ of 0.4 dS/m may be deemed moderately saline in a sand, whereas this might be thought of as non-saline in a heavy clay. Soil texture also impacts on pH buffering capacity. Soil texture is an important factor in classifying soil, as it determines whether the profile is uniform, gradational or a duplex.

Field estimation of texture

Although the most accurate way to classify soil texture is using the hydrometer method in a laboratory, soil texture can be reliably assessed in the field using a hand texturing technique.

Figure 7.1 Soil texture triangle.

1. Crumble a sample of soil big enough to fit easily into the palm of your hand.
2. Add small quantities of water to moisten the sample. As you work or squeeze the sample until the soil–water mixture (known as a bolus) just sticks together.
3. Continue to work and moisten the bolus until the feel stops changing (usually 1 – 2 minutes). Notice the resistance when working the bolus, this indicates moisture.
4. Form a ribbon by pushing the soil out from between your thumb and forefinger. The feel of the bolus and the length of the ribbon determine the texture class.

Repeat this procedure a few times to get an average length and refer to Table 7.1 to classify the texture of your soil.

Table 7.1 Description of physical properties for soil texture groups modified after (Northcote 1979).

Texture grade	Behaviour of moist bolus	Clay content (%)
Sand (S)	Coherence nil to very slight; cannot be moulded; single sand grains adhere to fingers	< 10
Sandy loam (SL)	Bolus just coherent but very sandy to touch; will form ribbon of 1.3cm (1/2 in); dominant sand grains are of medium size* and are readily visible.	10-20
Loam (L)	Bolus coherent and rather spongy; smooth feel when manipulated but with no obvious sandiness or 'silkiness'; may be somewhat greasy to the touch if much organic matter present; will form ribbon of about 2.5cm (1in).	20-30
Clay loam (CL)	Coherent plastic bolus; smooth to manipulate; will form ribbon of 3.8cm (1.5in) - 5cm (2in).	30-35
Light clay (LC)	Plastic bolus; smooth to touch; slight resistance to shearing between thumb and forefinger; will form ribbon of 5cm (2in) -7.5cm (3in).	35-45
Heavy clay (HC)	Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; has firm resistance to ribboning shear; will form ribbon of 7.5cm (3in) or more.	>45

Soil pH and salinity

pH testing

Soil pH is readily tested in either the field or the laboratory. When measured in the laboratory, soil pH can be conducted in either water (pH H_2O) or in 0.01 M Calcium Chloride (pH $CaCl_2$). Measurement of pH in water is usually 0.5 – 1.0 pH units higher than those made in Calcium Chloride. The advantage of having measurements done by a laboratory with Calcium Chloride is that the readings are less influenced by the salinity of the soil.

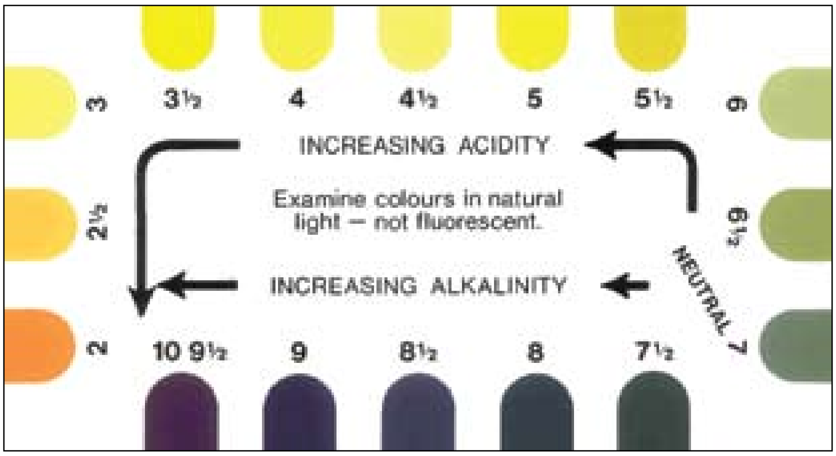

Figure 7.3: Colour chart used for estimating soil pH.

Soil pH test kits usually cost around $25 from a nursery, hardware or agricultural supply outlet. They are accurate to within half a pH unit.

Method

1. Place a crumbed half teaspoon sample of soil onto the plastic card and mix into a paste with 2 drops of blue indicator solution using a clean plastic teaspoon or spatula.
2. Dust the soil paste with the white powder (barium sulphate).
3. Match the colour of the powder with the colour chart to determine the soil pH (Figure 7.3) which approximates values determined by pH $_{(H2O)}$.

Hand-held pH meters are more accurate than pH test kits and cost around $170. Combined pH and EC meters are also available.

Note 1: You can use the same 1:5 soil solution extract to test for soil pH, Sodium and EC using hand held meters for each analysis.

Note 2: Laboratory pH and EC analyses are made on soil solutions diluted at a ratio of 1 part (by weight) of air dry soil to 5 parts of distilled water. When taking measurements in the field, it may not be possible to air dry the soil and accurate scales may not be available. The method described below will give a result that approximates laboratory measurements and will give an indication of whether pH or EC is likely to be limiting to plant growth.

Method

1. Check that the meter is calibrated and then rinse pH meter in distilled (or rain) water.
2. Take a sample from the soil profile and leave to air dry (if possible).
3. Break down the clods and aggregates with a hammer or rolling pin on top of a wooden block, removing any stones or plant debris at the same time.

4. Weigh out 20 g of crushed, air-dry soil and add 100 mL of distilled (or rain) water, or add one scoop of soil and five scoops of distilled or rainwater.
5. Screw the lid on the jar and shake the container for three minutes.
6. Allow the mixture to settle for at least 1 minute before measuring the pH with the pH meter.
7. Place the meter in the suspension (not in the soil at the bottom) and take a reading.
8. **If you now wish to test the salinity with an EC meter, you can use the same soil solution.**

Salinity (EC) testing

Soil salinity can be measured by determining the Electrical Conductivity (EC) of a solution – obtained by saturating or diluting a soil sample with water as described in solution preparation for soil pH. The EC reading increases as the salinity increases and is generally measured in deciSiemens per metre (dS/m).

Method

1. Check that the meter is calibrated (usually with 1.413 dS/m solution) and then rinse the EC meter in distilled water (tap water contains ions which will interfere with EC measurements).
2. Use the EC meter to determine the EC of the soil solution prepared for pH measurement.
3. This measurement is $EC_{1:5}$. To convert this to EC_e, which takes soil texture into account, the multiplication factors given in Table 4.2 are used. The two values are differentiated by the subscript 1:5 and e.

Example

If we had a light clay with an $EC_{1:5}$ of 0.6 dS/m, we would multiply 0.6 × 7.0 to get an EC_e of 4.2 dS/m.

Estimating type of salts contributing to salinity

As described in Chapter 4, a range of ions typically make up the salts causing salinity. In alkaline soils the ions are dominated by Sodium (Na^+) salts, which are highly soluble. Gypsum salts (Ca^{2+}) can also occur in varying amounts in soil and are less soluble. Compared with Ca^{2+} salts, Na^+ salts are more destructive of soil structure although both contribute to osmotic stress in plants.

Due to the difference in solubility of Sodium and Gypsum salts, the amount of gypsum present in the soil can be estimated using the following methodology, after Kelly & Rengasamy 2006.

1. Measure $EC_{1:2}$ using a suspension of soil and water in the ratio 1:2 i.e. for 100ml of water add 50 grams of soil (A).
2. Measure $EC_{1:5}$ using a suspension of soil and water in the ratio 1:5 i.e. for 100ml of water add 50 grams of soil (B).

Interpretation of results

(1) If EC1:2/ $EC_{1:5}$ (A/B) is less than 1.3, the salt in the soil is mainly Gypsum.

(2) If A/B is greater than 1.75, the salt in the soil is dominated by Sodium.

(3) If A/B is between 1.3 – 1.75 then the salt in the soil is a mixture of Gypsum and Sodium salt.

Units of salinity

Salinity can be expressed using a large range of different units, which can be confusing. Table 4.3 gives the conversion factors for a range of units used.

Interpretation of results

Electrical conductivity gives an indication of the amount of soluble salt in the soil, but it gives no information about the type of salt in the soil. Differentiating between the types of salt is important because, in terms of plant growth, at a given EC, sodium chloride has more deleterious effects than gypsum. In most alkaline soils within south-eastern Australia, the primary salt is NaCl.

Gypsum may be visible in the profile as white crystalline nodules. Gypsum (Calcium Sulphate) can be differentiated from lime (Calcium Carbonate) by using dilute Hydrochloric Acid (HCl). Several drops of HCl will cause lime to fizz, whereas gypsum will not.

Testing for sodicity in the field

Slaking & dispersion

Soils high in clay usually disperse when they are low in organic matter and have excessive Sodium bound to the clay particles. A simple test can determine if the soil is sodic and should benefit from Gypsum application. The test involves placing a soil aggregate (5 – 10 mm) gently into a saucer of distilled water or rain water and observing its response to wetting. The various responses of aggregates are outlined and their associated remedial management is as follows.

1. The aggregate remains intact over a 24-hour period and shows no signs of breaking down. This indicates that it is water-stable and no immediate remedial attention is required.
2. The aggregate spontaneously appears to fall apart into smaller sub units. This relates to the macroaggregate breaking down into microaggregates (Figure 7.4 a). The water surrounding the sample should remain clear. This process is called **slaking**.

The disruptive forces which drive the slaking process are derived from air trying to escape from the pores within the aggregate and non-linear expansion. Slaking occurs because there is insufficient organic matter in the form of fine roots and fungal hyphae to hold the macroaggregate together.

A soil that slakes does not require Gypsum. It does, however, require organic matter to help hold the microaggregates together. Minimum tillage systems, stubble retention and pasture phases are all management options that help to maintain and boost soil organic matter.

3. The aggregate slakes, and over a period of 24 hours starts to produce cloudiness in the water. This cloudiness is representative of microaggregates breaking down into clay domains (Figure 7.4 b). Because the domains are so fine they remain suspended in water. This process is **dispersion**. A soil will tend to be dispersive if the Exchangeable Sodium Percentage (ESP) is greater than six percent. The ESP can be calculated using results from soil tests, if exchangeable cations have been determined (see *Salinity & sodicity*, Chapter 4).

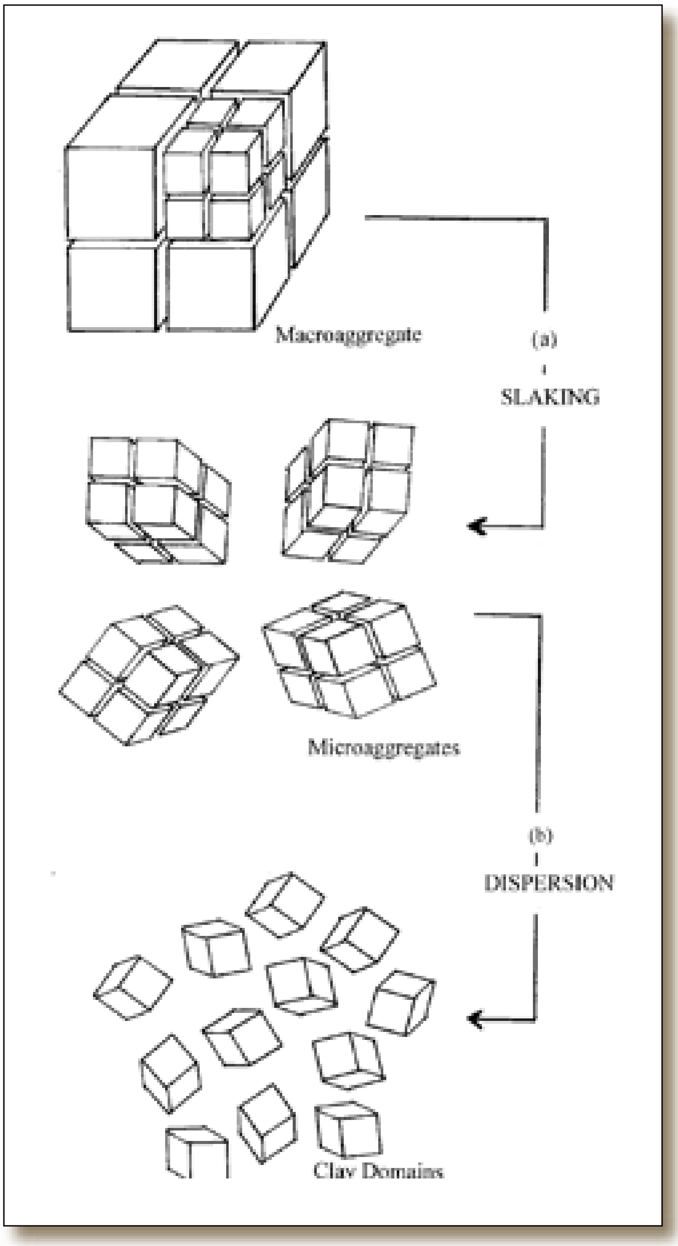

Figure 7.4: The degenerative pathway taken by a macroaggregate (clod) as it breaks down into smaller units, these being microaggregates (a) or clay domains (b). These processes are termed slaking and dispersion respectively.

Dispersion occurs when the proportion of Sodium in the soil compared with Potassium, Magnesium and Calcium is high, causing the clay component to disperse, triggering aggregate breakdown. Under these circumstances soils would be Gypsum responsive, where the addition of Calcium, (through Gypsum or lime), will induce clay flocculation. This will also reduce the relative proportion of Sodium in the soil solution. The aim is to reduce the ESP to under 6% so clay particles maintain structure when wet.

The assessment of the soil clod is based on the modification of a scheme for assessing the structural status and stability of soils (Emerson 1991). The stability class is based on the rate of dispersion (Table 7.2 & Figure 7.5).

Table 7.2 Dispersion classification key

1 severe	2 slight	nil (rework)		
		↓		
		3a severe	3b slight	4 nil

If after 24 hours the dispersion is severe, the stability is severe and rated 1. If dispersion is moderate to slight, it is given a rating of 2. Under circumstances where there is no apparent dispersion, the sample is reworked to form a bolus and again immersed in water. If after 24 hours dispersion is severe then it is classed as 3a. If dispersion is moderate to slight, it is classed as 3b. If there is nil dispersion, then it is classed as 4, non dispersive.

A stability score of 1 or 2 indicates that a soil will spontaneously tend to disperse in the field and become 'soupy' when wet and hard setting on drying. Under these circumstances Gypsum is recommended to assist in the chemical stabilisation of these soils.

A score of 3a or 3b indicates that the soil in the field will be likely to have reasonable structure if left undisturbed, however excessive impact by raindrops or disruption by tillage or stock traffic will be likely to cause structural deterioration. Under these situations, using minimum tillage and applying Gypsum will assist in preserving soil structure.

A score of 4 indicates that despite disruption through tillage or stock traffic, the soil retains its friability, resisting aggregate breakdown i.e. it is a well-structured soil.

Aggregate stability in water test (ASWAT)

The aggregate stability in water test is an alternative field test used to estimate a soil's dispersive potential. This is a modification of the Loveday and Pyle dispersion test. This test takes several hours and thus is best performed at home rather than in the field.

Figure 7.5 Estimating the dispersion (nil, slight and severe) of a soil clod 24 hours after it is placed in distilled (rain) water.

Method

1. Pour distilled water into the number of shallow dishes (for example, petri dish) required for different soil depths to be scored for slaking and dispersion. You need to have the water at least 6 mm deep, to cover the 5 mm soil aggregates.
2. Carefully place several small (3 – 5 mm diameter) air-dry soil aggregates in the dishes – Do not use moist soil.
3. Cover the dishes to help prevent wind disturbing the water.
4. Make a visual assessment of the degree of slaking (Table 7.3) after 5 minutes and dispersion (Table 7.4) after 10 minutes and again after 2 hours.
5. Add the 10-minute and 2-hour scores together (giving a range of values between 0 and 8).
6. If the clods scored 0, determine the amount of dispersion after remoulding by mixing soil with distilled water until it becomes plastic. Form several small balls (less than 5-mm diameter) and carefully place in a dish of distilled water. Assess dispersion on wetting after 10 minutes and 2 hours. Add these two scores together.
7. For air-dried clods that disperse, add 8 to the sum of the scores for the 10-minute and 2-hour assessments, giving a range of values between 9 – 16.

Examples

Example 1: A soil that shows no dispersion after 10 minutes scores 0 and if it is still not dispersed after 2 hours it scores another 0, equally a total of 0. Proceed to a dispersion test with pieces of soil that have been remoulded (small pieces of the ball of soil from the texture test is ideal). Add the 10-minute and 2-hour scores for the remoulded dispersion to the total for the spontaneous dispersion, giving the ASWAT score.

Example 2: A soil that shows slight dispersion after 10 minutes scores a 1. If it is moderately dispersed after 2 hours, it scores an additional 2, giving a total of 3. We assume that a soil showing any spontaneous dispersion would disperse completely after remoulding, so we do not carry out the remoulded test. Just add 8 to the total score. Therefore, in this example the ASWAT score is 3 + 8 = 11.

Example 3: A soil that disperses completely in 10 minutes scores a 4, and if it is still completely dispersed after 2 hours it scores another 4, giving a total of 8. Again, assume complete dispersion on remoulding and add another 8. ASWAT score is 8 + 8 = 16.

Management options that may be appropriate for a range of ASWAT test data are given in Table 7.5. These values are derived by adding the score (0 – 4) assessed after 10 minutes and the score assessed after 2 hours plus a score for a remoulded clod.

Treating sodic soil

If a soil is dispersive (sodic), it can be treated using Gypsum. Usually growers apply an arbitrary rate (ca 2.5 t/ha) periodically, based on experience as a maintenance strategy to keep the seed bed friable. Alternatively, Gypsum requirement can be calculated. This may be useful, especially if you need to treat sodicity in the subsoil. Gypsum requirement can only be calculated if the soil has been analysed for exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}). The following is an example of calculating Gypsum requirement (Figure 7.6).

Table 7.3. Slaking score

Score	Slaking description
0	The lump remains intact indicating the soil is stable to wetting.
1	The lump collapses around the edges but remains mainly intact. Typical of pasture soils rich in organic matter. No action needed.
2	The lump collapses into angular pieces. Typical of self-mulching soils. They form a loose granular surface layer sometimes with a thin, fragile crust. If stable to dispersion, no action is needed.
3	The lump collapses into small (less than 2 mm) rounded pieces, forming a cone. Soil may form a crust. Reduce tillage, maintaining stubble, and apply gypsum.
4	The lump collapses into single grains. Soils may crust or set hard. Soil needs organic matter.

Table 7.4. Scoring dispersion

Score	Dispersion description
0	Indicates no dispersion (marked by cloudiness). Unlikely to form crusts or hard blocks after drying.
1	Slight dispersion, recognised by a slight milkiness or cloudiness of water adjacent to the clod. Unlikely to form crusts or hard blocks on drying.
2	Moderate dispersion with obvious milkiness. Gypsum may help stabilise any muddiness.
3	Strong dispersion with considerable milkiness and about half the original volume dispersed outwards. Soil disperses easily and will form crusts and set hard. Gypsum application will help reduce clay dispersion and improve structure.
4	Complete dispersion, leaving only sand grains in a cloud of clay. Soil disperses easily and will form crusts and set hard. Gypsum application will help reduce clay dispersion and improve structure.

Table 7.5. Response to the soil structural stability diagnosis (McKenzie 1998)

ASWAT score critical limits	Severity of dispersion	Management options
7–16	Serious dispersion	Apply gypsum (and/or lime for pH of < 5.5) and organic matter.
2–6	Moderate dispersion if the soil is remoulded	Avoid working the soil when it is moist (also applies to the category above).
0–1	Negligible	Protect soil from dispersion by reducing impact of raindrops eg. Retaining stubble cover (also applies to the above two categories).

A soil with a CEC of 40 cmol (+)/kg and an ESP (0-10 cm) = 25%

Our desired ESP in the upper 10 cm soil = 5%

(1) Calculate the amount of Na to be replaced

= CEC × (current ESP – desired ESP)

= 40 cmol (+)/kg × 0.20 = 8 cmol (+)/kg

(2) Calculate the amount of Ca^{2+} required

Soil-Na + $CaSO_4.2H_2O$ ⟷ Soil-Ca +Na_2SO_4 +$2H_2O$

Divide by 2 because Ca has 2+ charges and Na only 1+charge, therefore 1 Ca^{2+} displaces 2 Na^+ molecules

= 4 cmol (+)/kg of Ca^{2+} needed to replace 8 cmol (+)/kg of Na^+

(3) Calculate the weight of gypsum needed to provide the Ca^{2+}

1 cmol (Ca^{2+})/kg = 200 mg/kg

4 cmol (Ca^{2+})/kg = 800 mg/kg

Molecular weight of $CaSO_4.2H_2O$ = 172 g/mol, but only a percentage of the mass of gypsum is due to Ca (40 g/mol)

= 800 mg/kg × (172 g/mol ÷ 40 g/mol) = 3.44 g gypsum per kg soil

(4) Calculate the weight of soil that has to be treated

Weight of top 10 cm soil/ha = 10000 cm × 10000 cm × 10cm × 1.3 g/cm^3

(assuming a bulk density of 1.3 g/cm^3) = 1.3 ×109 g/ha = 1.3×106 kg/ha

(5) Amount of gypsum/ha = 1.3×106 kg/ha × 3.44 g/kg = 4.47 tons/ha

Figure 7.6 Calculating gypsum requirement.

References and further reading

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