NSW DEPARTMENT OF
PRIMARY INDUSTRIES

SOILpak – southern dryland farmers - Readers' Note

This document is part of a larger publication. The remaining parts and full version of the publication can be found at:

http://www.dpi.nsw.gov.au/agriculture/resources/soils/guides/soilpak/south-dryland

Updated versions of this document can also be found at the above web address.

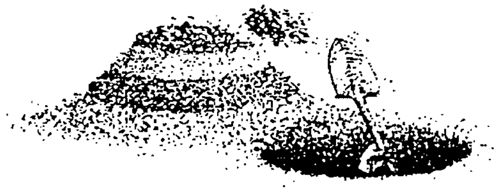
C2. Alternatives to a spade

PURPOSE OF THIS CHAPTER

To show different ways of examining the soil profile

CHAPTER CONTENTS

- using a spade
- using an auger
- using a backhoe



ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- C1. Examining the soil profile

WHERE TO DIG

You are examining the soil profile to make conclusions about soil suitability for crop production or to diagnose any problems. Your conclusions will affect your management decisions, so dig the hole in an area that is typical of the paddock.

Use clues such as yield differences, aerial photos and soil colour as a basis for deciding where to dig a pit. It is useful to look at a site with no apparent problems to appreciate the degree of compaction in poor areas.

Choose an area away from the ends of the field where machines turn (the headlands). Walk in at least 20 m across the direction of water flow.

USING A SPADE

Several soil experts prefer to use a spade when examining soil structure. The great advantage of this technique is that you can carry the spade with you at all times, and it will be available for you to use if questions arise about the current soil structure.

Start by pushing the spade in at approximately 25 cm intervals, parallel to the direction of traffic. (See Figure C2–1.) Note how deep you can push the spade to get an idea of where hard or compacted zones may lie.

If you find hard zones, examine the soil in more detail. Use the spade to scrape away loose soil (moisture will affect how easily the loose soil can be removed) and note the depth and condition of the loose soil.

Look at the top of the hard layer that you have uncovered (you can use your hands to lightly scrape away very loose soil) and take particular notice of the amount of cracking (if the soil is dry), or if there is a smeared layer caused by an implement. If cracks with a spacing of less than 3 cm are visible, plant roots should have little trouble penetrating the soil.

With the top of the firm layer now exposed (note that this firmness is not necessarily compaction) dig out a spadeful of

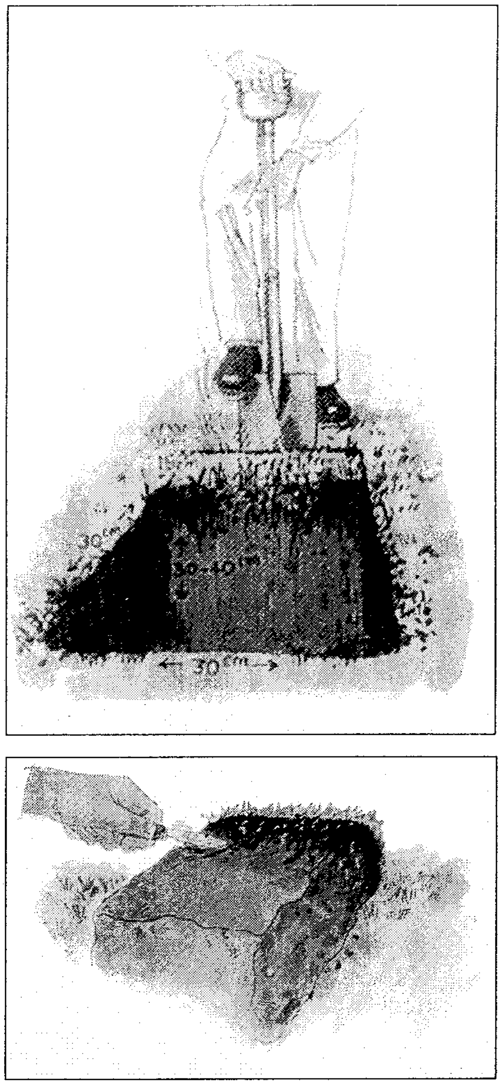


Figure C2-1. Using a spade to help in soil structural diagnosis soil. Keep the soil on the blade of the spade and note the orientation and depth from which it came. Look for natural or platy or massive structures within the spadeful of soil.

In a spadeful of soil dug as described, the natural crack-lines may be expanded, making them easier to see than when they are undisturbed in the face of a backhoe pit.

When you are examining soil structure to depth it will be easier if you dig a small hole first, then take a slice of soil from the side of the hole for examination.

A spade is particularly useful for quickly assessing the impact, either good or bad, of a tillage operation.

You can also use a spade in conjunction with a backhoe pit. Dig down parallel to the edge of the pit until the soil feels firm. Throw the spadeful of loose soil into the pit. Repeat the process along the top edge of the pit. If a hard layer exists it can be more obvious when you use this technique than when you just look at the vertical face of the pit.

Draw the information you collect with the spade method on to SOILpak soil profile description sheets for interpretation and later reference.

Alternatives to a spade are soil augers, coring tubes and backhoes.

Using a soil auger

Soil augers greatly modify the structure of a soil sample. However, they can be used successfully to sample for soil moisture or for chemical analysis. They may also be useful for examination of soil texture and colour. Turn and push in the auger to the depth of tillage, and sample soil from the bottom of the auger for moisture. It is useful to spread a plastic sheet out on the ground and place the samples from different depths in order on the sheet. Use a rule to keep track of the depths of samples.

Using a coring tube

A coring tube takes slightly disturbed soil samples. The tube smears the outside of the core, and there is some distortion of the sample. However, the centre of the core, if large enough, usually retains its structure reasonably well. A soil core shows the soil layers and plant roots.

Backhoe

A backhoe pit provides a good overview of the entire root zone of a crop or pasture. It allows easy sampling of the subsoil and subsurface.

It is important that you have not changed what you will see in the pit by driving the backhoe over the area where the pit will be. Before driving on to the field, decide exactly where you want the pit. Then reverse the backhoe up to the spot so that you can dig in undisturbed ground. (See Figure C2–2.)

Keep the sides of the pit vertical. Vertical sides make a better profile (depth is easier to measure) and minimise the amount of sideways heave as the backhoe bucket moves in and out of the hole (heave disturbs the soil profile).

Because plant roots often extend well below 1 m, you will need to dig about 1.5 m deep with the backhoe. Do not go deeper than 1.5 m; this is an OH & S requirement. Soil should be piled 1 m away from the pit to prevent cave-ins and falls.

Make the pit length one reach of the backhoe arm. If you are digging a long pit, back it from each end to prevent compaction from backhoe wheels. (See Figure C2–2.)

Important warnings

- Check on the location of underground cables and pipes before digging a backhoe pit. Striking such objects during excavation endangers the backhoe operator, and the cost of damage repair may be great.
- The maximum allowable depth for backhoe pits without special support is 1.5 m. WorkCover has stipulated that it is illegal for people to get into pits that are any deeper, because of the danger of walls collapsing.

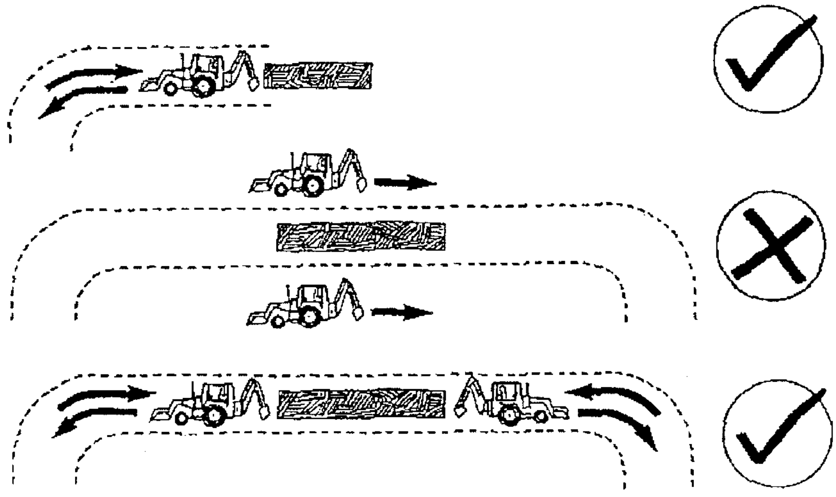


Figure C2-2. Moving a backhoe to and from a pit

- Clean excavating equipment carefully to prevent the spread of serious soil-borne diseases.

If possible, pile the excavated soil on the uphill side of the pit. If it rains heavily, the pile will stop some run-off getting into the pit. Cover the pit face with a plastic sheet if rain is imminent. Fill in the pit soon after inspecting it to allow the soil to settle before planting the next crop.

HOW TO TRIM THE SIDES OF A BACKHOE PIT

Clear away any soil spilled on the soil surface above the face you wish to examine. This is important, as it allows you to locate the original surface as a reference for the depth of features.

Clean an area on the face of the pit to remove soil compacted or smeared by the backhoe bucket. Use a tool such as a chisel, an asparagus cutting knife or a pocket-knife. This will reveal the natural structure and colour.

Work across the pit face. Start from the top and work down the profile so as not to contaminate the profile.

Caution: Do not dig pits in sandy soil, and not deeper than 1.5 metres in any soil or they may cave in.

C3. Soil types and landscapes

PURPOSE OF THIS CHAPTER

This chapter gives an overview of soil types in the mid-Murrumbidgee and mid-Murray catchments.

CHAPTER CONTENTS

- texture contrast soils
- sodic soils
- earth soils
- heavy clays

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- A2. Ideal soil
- C1. Examining the soil profile

SOIL TYPES OF SOUTHERN NEW SOUTH WALES

(For colour photos of the soil types found in this area, see the last page of the field guide in Chapter C1, 'Looking at your soils'. Remember: These are examples of only four soil types found in the area.)

There are more than 22 soil types in the southern dryland farming area of New South Wales. They have been broken up into four major groups on the basis of their management properties. The groups are: 1. non-sodic texture contrast; 2. sodic texture contrast; 3. earth soils and 4. heavy clays. Remember that soil types can vary within a few metres, and that many paddocks have two or three different soil types. It is best if these soils are separated and managed on their individual soil properties. This is not always economic, so it would be best to do a farm plan first. (Contact a Farming for the Future officer with NSW Agriculture or the Department of Land and Water Conservation.)

The southern areas are characterised by many soil chemical imbalances, including acidity, sodicity and salinity, and physical issues like hardsetting, compaction, surface crusting and soil structural decline. All of these issues can be reduced with good soil management. We are aiming for better plant growth at all times.

Figure C3–1 shows a typical soil profile.

Texture contrast soils

Texture contrast indicates that a soil is very old, as it has had time for clay to leach and build up in lower parts of the soil. These soils often have a light-coloured layer at 10 to 20 cm (the A2 horizon).

1. Non-sodic texture contrast soils

Red podzolics (in the new Australian Soils Classification (ASC) known as a chromosols or kurosols)

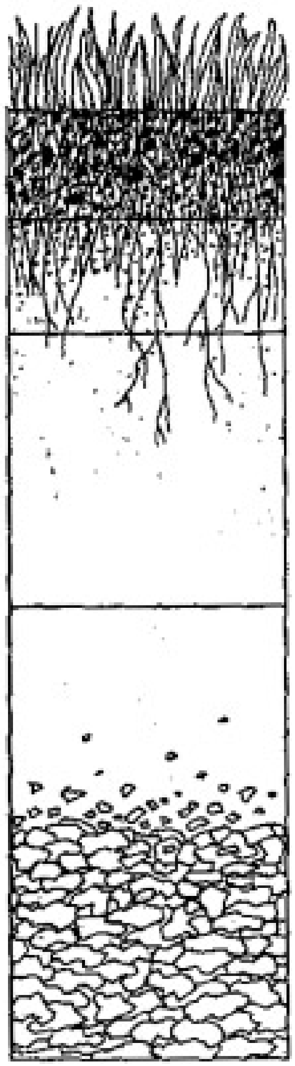


Figure C3-1. *Soil horizons are the different layers of soil seen in cross-section. Not all horizons are present in every soil.*

O horizon (surface organic litter): *This is the layer of organic matter on top of the soil.*

A horizon (topsoil): *This is the surface soil, referred to as topsoil. It has the most organic matter and biological activity of any part of the horizon. The decaying organic matter darkens the soil colour.*

A2 horizon (subsurface soil): *This layer is not always present. It is often paler than the A1 and B horizons. The paler colour is due to the leaching of clays and organic matter, and may indicate poor drainage.*

B horizons (subsoil): *This horizon, known as the subsoil, usually has more clay than the topsoil, is denser and holds more moisture, but is less fertile. The B horizon has a stronger colour and is better structured then the topsoil.*

C horizon (weathering rock): *The C horizon is made up of weathering parent rock, so is full of gravel, rocks and boulders.*

D horizon (bedrock): *This horizon is known as bedrock, which is unweathered rock.*

Red podzolic soils occur mainly on the upper slopes of hills grading into shallow soils (lithosols) on hill tops. These soils are found south (including Mangoplah) and north-east of Wagga Wagga (including Tarcutta), where they are on undulating to steep hilly country. Red texture contrast soils are also found on a plateau around Tumbarumba and pockets in the red earths and the red-brown earth soils. (See further in this chapter.) In the Murray valley, red podzolic soils are confined to metamorphic rock (sedimentary rock that has been exposed to extreme temperatures and pressures, for example, slate) about Woomargama, Mullengandra and the hill areas around west of Albury, Jindera and Burrumbuttock.

Red podzolic soils have a strong textural difference: the A horizon (topsoil) is usually loamy, and the A2 horizon (lower topsoil) is sporadically bleached (or randomly pale). The A horizon has a medium to coarse particle size overlaying a predominantly red B horizon (subsoil), which has a higher clay content. The soils are often more acidic in the surface than at depth. The boundaries between the soil layers are gradual to clear.

These soils are inherently infertile and commonly deficient in phosphorus, nitrogen and molybdenum. They are highly erodable and suffer from sheet erosion and moderate to severe gully erosion. (See Figure C3–2.)

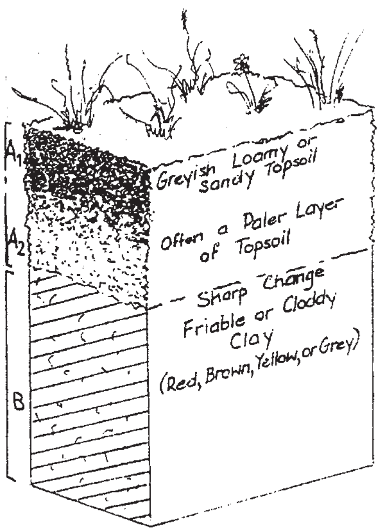


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***Figure C3-2.** Texture contrast soils can be red or brown or yellow or grey podzolic, depending on the subsoil colour.*

Neutral red podzolics

Neutral red podzolic soils are found in the area west of Young and Cootamundra on sedimentary and metamorphic rock outcrops. These are relatively shallow soils, less than 1 m deep, and often less than 0.5 m.

These shallow red soils have a hardsetting A horizon, often bleached in the A2 (light grey to white). Some of these soils have gradual changes and well-structured B horizons. Red texture contrast soils are relatively infertile. If they are mismanaged the soil structure deteriorates and the surface soil seals, becoming highly erodable. These soils have a neutral pH in the surface soil and in the subsoil.

See Chapter D4 for more information on soil structure.

Yellow podzolics (chromosols in the ASC)

These are predominantly acidic soils occurring in poorly drained areas such as footslopes (lower slopes) and depressions. They are usually deep, and are dispersible and highly erodable.

The topsoil is a sandy loam, which can have a platy (compacted) structure and can set hard. The subsurface is a fine sandy loam that is bleached and dispersible. The subsoil is a medium to heavy clay, yellow, and often with mottles (blotches of other colours).

This soil is infertile, and plant growth responds to fertiliser application. The soil is highly erodable and is more acidic in the surface than subsoil.

Neutral yellow podzolic soils (chromosols in the ASC)

Also found around Young are yellow texture contrast soils with a neutral pH down the soil profile. The soil is reasonably fertile, although plants respond well to fertiliser. These soils often waterlog, so these are mostly used for grazing.

Red brown earths (chromosols in ASC)

Red brown earths have a gradual colour boundary between the A2 and B (subsoil) horizons, although they have a texture contrast between the A and B horizon (Figure C3–3).

They have a grey-brown to red-brown loamy A horizon, weakly structured to massive (see C1—Examining the soil profile) and can be quite deep. They have a brighter brown to red clay B horizon that has a blocky structure. There is often a weakly developed A2 horizon of a lighter colour.

Red brown earths are found north-east of Cootamundra, north and north-west of Wagga Wagga, north-west Albury and in pockets around areas of red earths and red texture contrast soils.

Red brown earths can erode if there is a long slope, or if the soil is low in organic matter or soil structure. In some areas it is prone to sheet erosion.

For maximum production in these soils, fertiliser is required, especially phosphorus. The clayey subsoils (B horizon) have a high water holding capacity but are still easily penetrated by roots.

Red brown earths are often hardsetting and surface crusting. Some have sodic B horizons.

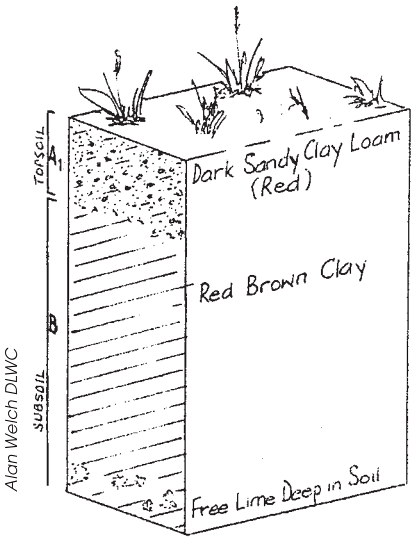

Figure C3-3. Red brown earths

2. Sodic texture contrast soils

Sodic soils are commonly found in our area. A sodic soil contains clay that swells and disperses when wet due to its high levels of sodium (Na). A sodic soil has an exchangeable sodium percentage (ESP) of greater than 6%. An ESP is a measure of the amount of sodium (Na) that exchanges with other cations (calcium, potassium, aluminium and magnesium) in the soil.

See Chapter D3 for information on managing sodicity.

Solodic soils (sodosols in the ASC)

Solodic soils occur on residual hills to low ridges and slopes. They occur on various types of sedimentary and metamorphic material, often presenting the appearance of layering within the soil itself.

Solodic soils therefore have strong textural contrast, with a clear to abrupt boundary (occurring over 2 to 5 cm) between the surface and the subsoil. The topsoil is usually loamy in texture, with the subsurface sporadically bleached (or blotchy) (Figure C3–4). Soil profiles vary in depth.

This soil is prone to sheet erosion, as topsoil is thin and highly dispersible and compacts when dry before setting hard. This causes increased run-off and can result in severe gully erosion.

Solodic soils are generally infertile, but respond well to applications of molybdenised superphosphate. They are best under pasture.

Sodic soils are found below The Rock towards Milbrolong (where the Ca:Mg ratio is greater than 2:1). They occur in sections of major creek lines at Haulighans, Burkes, Kyeamba and Tarcutta Creeks and tributaries. There are also areas of solodic soils at Burrumbuttock, Mangoplah and NE of Albury.

See Chapter C5 for more information on Ca: Mg ratios.

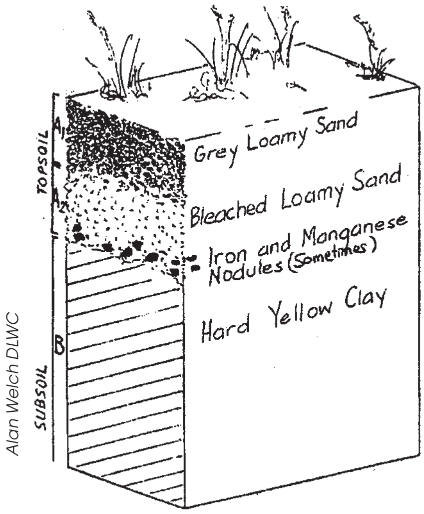

Figure C3-4. Yellow solodic soil

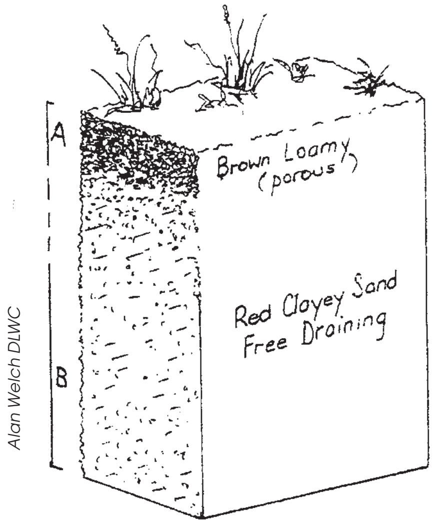

Figure C3-5. Red earth

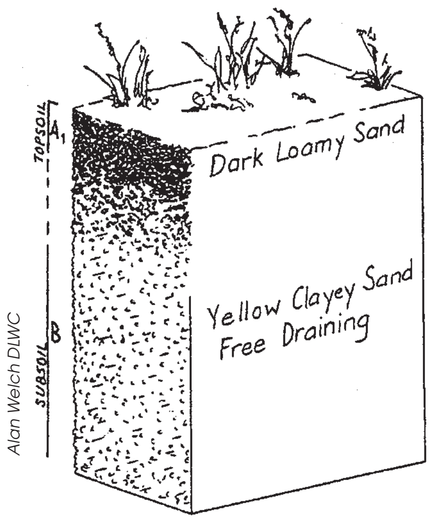

Figure C3-6. Yellow earth

Solonised solonetzics (sodosols in the ASC).

These soils have a strong texture differentation, with a very abrupt boundary between the topsoil and subsoil. The topsoil is usually loamy and often has a well developed bleached subsurface. The subsoil is clayey, with a strong, coarse, columnar blocky structure. There is often mottling in the subsoil, as well as shiny-faced peds.

These soils are inherently infertile, with severe deficiencies of nitrogen and phosphorus, and they may lack calcium and trace elements. The use of fertilisers and legumes is necessary to obtain satisfactory pasture and crop growth.

Generally the surface soil sets hard and the infiltration rate is low. The subsoil, when wet, expands, filling the cracks so that the subsoil becomes very impermeable. These soils are highly erodable, developing severe gullies, and can often be saline. The pH ranges from neutral to alkaline in the subsoil.

However, around Balldale, these soils are non-hardsetting and therefore slightly more fertile then described. They still respond well to phosphorus and nitrogen.

3. Earths

Red earths (kandosols in the ASC)

Red earths have gradational texture profiles. Gradational texture profiles become gradually more clayey with depth. Red earths are fairly well structured, but are still prone to hardsetting and surface crusting. Red earths (C3–5) are more freely drained than yellow earths (Figure C3–6).

In red earths excess nutrients are washed deeper down the profile. Therefore, only deep-rooted plants can reach or gain access to these nutrients. These soils are high in iron, often having black (iron) nodules.

These soils are some of the more fertile ones in the region, but they can have deficiencies in phosphorus and nitrogen. Erosion is not a major problem, except where soils are crusted or hard set.

Yellow earths (kandosols in the ASC)

These soils are similar to the red earths but are predominantly yellow. They are not as well drained as the red earths. They are weakly structured and often massive (with no structure) (Figure C3–6).

See Chapter C1 for more information on examining the soil structure in a profile.

The A horizon is often darkened by organic matter. It is rather compact and hard when dry, although it is friable when wet. The topsoil is acidic to neutral, ranging from pH 5.5 to 7.

The subsoil is yellow to yellow brown, often with mottling in the lower subsoil. It has a neutral pH, and there are usually iron nodules present.

These soils are found in pockets around Young, Cootamundra, Harden and Albury. Sandy yellow earths are found around Rosewood, Tumbarumba and North of Jingellic.

4. Heavy clays

Grey cracking clays (vertosols in the ASC)

These soils are grey or brown, have relatively uniform high clay contents (45%–70%) throughout, and have deep vertical cracks from the surface to depth when dry (Figure C3–7).

The surface may be loose and self-mulching, but it is often firm and has a platy crust.

Lime nodules and soft lime are common throughout the profile.

These soils are found in low-lying areas with poor drainage, and often are associated with gilgai humps and hollows. The clay contains a high proportion of smectite (a type of clay mineral that swells and absorbs water as it wets). This accounts for the cracking on drying. These clays can absorb large amounts of water, but release it only slowly. Heavy rain is needed to wet the soil enough for plant growth, but when wet these soils can be very productive.

The main limitation of cracking clays is their propensity to winter waterlogging. This is due to the flatness of the country in which they occur, but it may be made worse by sodicity.

Drainage and gypsum are the keys to productivity on these soils.

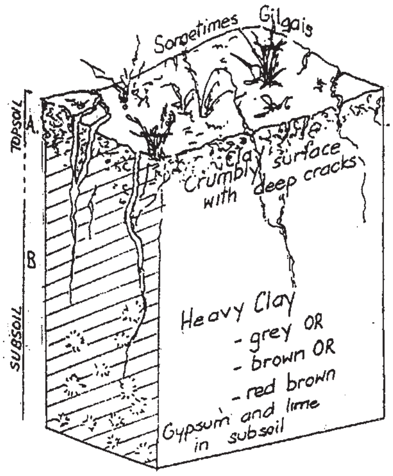

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Figure C3-7. Heavy clay

Minor soil types

Alluvial

These soils are formed from the deposition of material during floods. They are found along the flood plains and river terraces of the Murrumbidgee, especially around Wagga Wagga, Yass and the Murray Valley. They have a thick, dark A horizon, varying from loam to light clay in texture (Figure C3–8).

The B horizon has a higher clay content and some structure. The A horizon is moderately acidic, while the B horizon is alkaline.

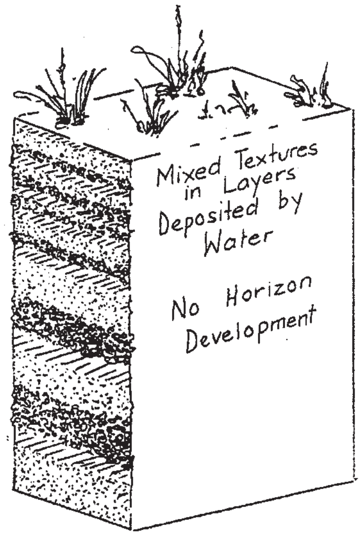

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Figure C3-8. Alluvial soil

Euchrozems

Euchrozems are found around Wallendbeen, Tumbarumba, Tumut and Batlow. They are dark red, strongly structured, clayey soils with weak horizon differentiation. They have a near-neutral pH to depth (Figure C–9).

The soils are clayey throughout, with a weak profile differentiation and a gradual boundary between the A and B horizons, which grade into weathered rock. They are red throughout, and darker at the top due to organic matter accumulation.

These soils are well structured and drained. They require only small inputs of phosphorus and nitrogen fertilisers. In the natural state they may not require fertiliser. They are highly permeable, and therefore there are large amounts of water available to plants.

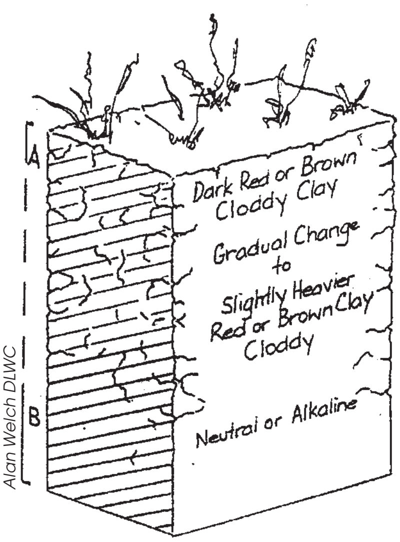

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Figure C3-9. Euchrozem

Lithosols

Lithosols are essentially stony or gravelly soils lacking horizon development. The A horizon is usually darker due to organic matter accumulation (Figure C3–10).

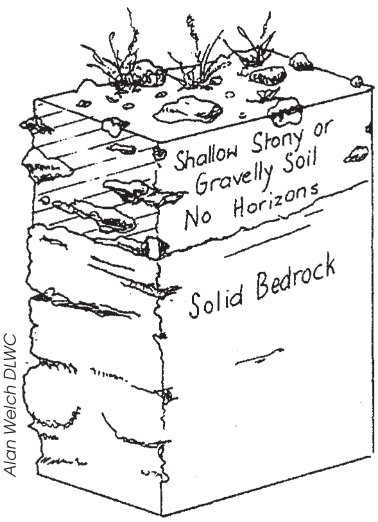

Figure C3-10. Lithosol

They have shallow sandy to sandy loam topsoil, and a clayey sand subsoil formed in situ or formed from colluvial material (soil washed off hilltops).

They occur mostly in the north-east of the Murrumbidgee catchment on ridges and close to drainage lines.

These soils are usually highly dispersible (clay particles separate and erode); when wet they can become semi-liquid and when dry they set very hard. Areas with lithosols around Binalong can repel water, therefore increasing run-off and erosion. These soils are slightly acidic.

In most cases these soils should be left under native timber.

C4. Examining plant roots

PURPOSE OF THIS CHAPTER

To identify if plant roots are affected by a chemical, physical or biological soil problem

CHAPTER CONTENTS

- root disease
- field examination
- identifying root diseases
- flow chart

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- B2. Is my soil acid? Does it need lime?
- C1. Examining the soil profile
- C5. Chemical soil tests
- D1. Acidity
- D3. Sodicity
- D4. Maintaining and improving soil structure
- D8. Improving soil chemical fertility

ROOT DISEASE

Many plant diseases can be recognised by the damage caused to plants. Any abnormal growth, premature death or other deviation from normal growth could be caused by a disease.

Root damage caused by disease can show up as poor growth, distortion, stunting, multi-branching or rotting. This damage results in stunting or premature death of above-ground growth, often with symptoms of nutrient deficiencies. Premature death of heads or plant death during pod fill in broadleafed crops can sometimes result from root diseases. This is usually the time when plants are drawing heavily on soil moisture and nutrient reserves as the plant strives to reproduce.

Plants with damaged root systems are often unable to take up water and nutrients from the soil adequately for normal plant growth. Therefore, affected plants may appear stressed for moisture (for example, with wilting or yellowing) or may show signs of nutrient deficiency.

FIELD EXAMINATION

This involves the identification of the patches within the paddock that are not growing to their full potential.

In order to diagnose any plant disease it is vital to observe symptoms on affected plants and compare these to the appearance of healthy plants.

IDENTIFYING ROOT DISEASE PROBLEMS

- Dig up plants from apparent healthy areas and from areas where plants are growing poorly. Remember to keep the roots as intact as possible. This may require large portions of soil to remain on roots that can later be washed off.
- Wash out roots by soaking them and the soil in water, then agitate to remove the soil. Heavier soil types may require a longer soaking time.
- Once you have removed the soil from the roots, observe the root growth of healthy and unhealthy plants. Healthy roots appear white, while diseased roots may be entirely darkened or have areas of darkened tissue present. Normal roots grow extensively through the upper layers of the soil, and some grow to deeper layers. A deviation from this pattern could indicate such things as acid soil, compacted soil, herbicide residues, nematodes, insect damage and fungal attack.

The flow chart in Figure C4–1 will help you to decide whether or not the problem is likely to be caused by a root disease. Ultimately the diagnosis is best confirmed by an agronomist. In the flow chart, the shaded boxes require observations and decisions by you. The clear boxes give possible causes of the problems; these causes must be confirmed by soil tests or agronomic advice.

If the problem is caused by a root disease, the solution may involve a spray or, more likely, the selection of an appropriate crop-pasture rotation to break the disease cycle. As with confirmation of the diagnosis, this decision is best made with a local agronomist. If the problem is due to a soil chemical or physical condition, see the management sections of this manual for a solution.

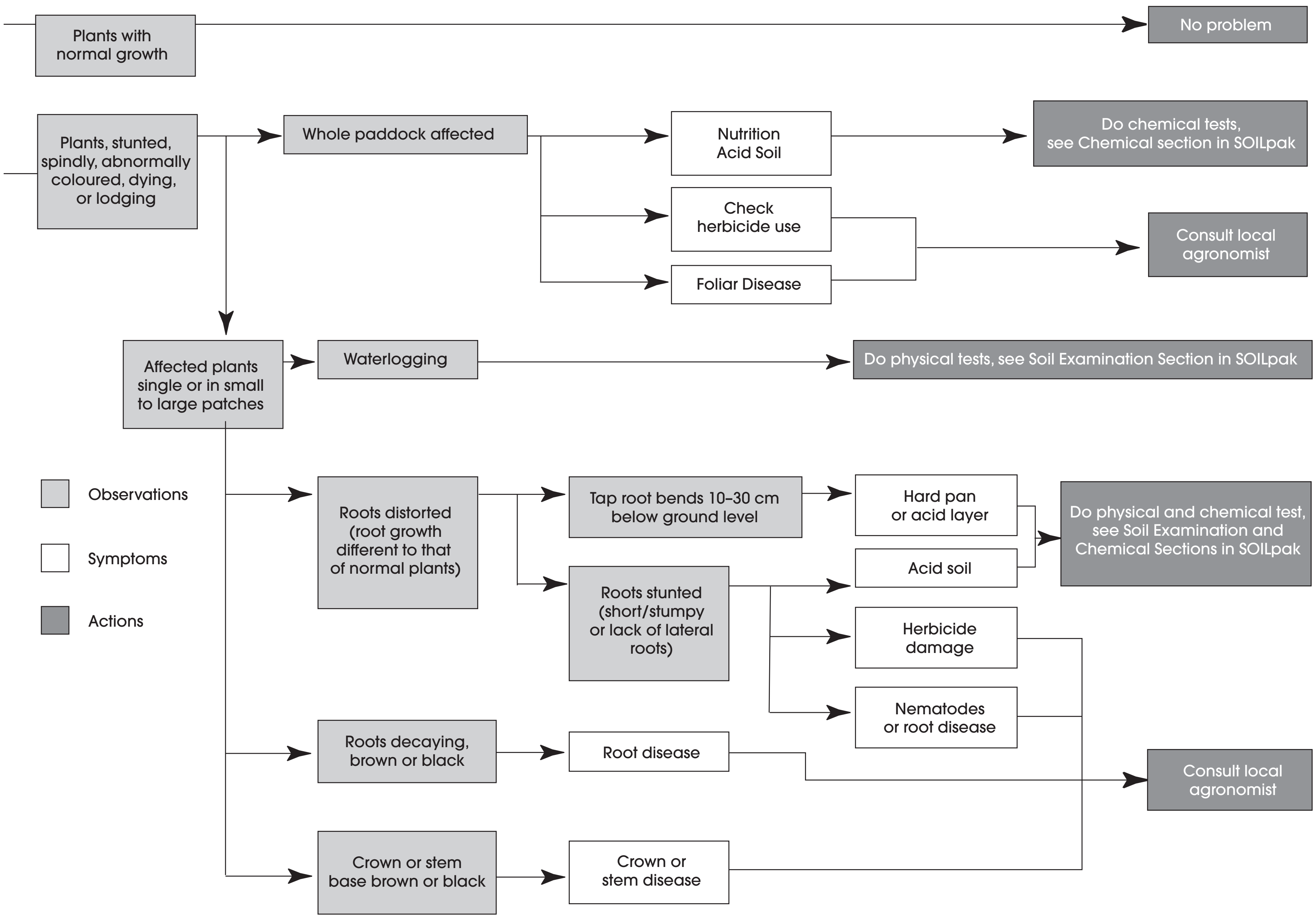

Figure C4-1. Action plan for diagnosing and solving plant problems

C5. Chemical soil tests

PURPOSE OF THIS CHAPTER

This chapter explains how to interpret the results of some chemical soil tests.

CHAPTER CONTENTS

- do’s and don’ts of soil sampling
- pH
- organic matter
- soil nitrogen
- electrical conductivity
- exchangeable cations
- converting units
- phosphorus

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- C1. Examining the soil profile
- C4. Examining plant roots
- D1. Acidity
- D2. Salinity
- D3. Sodicity
- Handout: Interpreting soil test results

DO’S AND DON’TS OF SOIL SAMPLING

Your soil tests are only as good as your sampling procedure. It will save you money if you sample correctly.

Do’s

- know what you are sampling for
- wait at least one year after liming and two months after the last fertiliser application
- take 30 core samples of the major soil type in the paddock
- take samples randomly
- take samples of the topsoil (0 to 10 cm) and, for mineral N, the subsurface soil (10 to 60 cm)
- remove excess plant material before sampling
- mix sample well
- collect a sub-sample of about 0.5 to 1 kg of soil
- send to lab on day of sampling or air-dry soil on newspaper
- label bag immediately, on outside, in permanent pen. Include your name, address and paddock name or number.

For 10 to 60 cm sampling

- take 10- to 60-cm samples when measuring mineral nitrogen. You must keep the sample cold or air-dry it. If the sample is left in warm, moist conditions the bacteria start breaking down the organic nitrogen, giving an inaccurate result.
- be careful not to get any topsoil in the sample.

Don'ts

- avoid sampling along fence lines and in headlands, stock camps, gateways, wet areas, troughs or fertiliser dumps, on tracks, under trees, near buildings and in areas where timber has been stacked and burnt. Such areas will have different fertility to the majority of the paddock and will influence the result
- avoid areas of poor growth or excessively good growth, for example, urine and dung patches
- avoid leaving samples in a hot car or the back of a ute
- avoid handling soil, as perspiration from hands can affect the sample.

CHEMICAL TESTS

Several commercial laboratories offer soil chemical testing services that measure the nutrient status of your soil. The results can be used to make fertiliser recommendations. Chemical testing, as well as providing valuable information about the chemical fertility of the soil, can also give some indirect information about your soil's physical condition.

Soil pH

The standard method of measuring soil pH is with a suspension of 1 part air-dried soil by weight to 5 parts liquid by volume. The recommended liquid for soils in southern New South Wales is 0.01 M $CaCl_2$ (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 to 0.8 lower than the same soil tested in water.

Interpreting soil pH

The pH ($CaCl_2$) of soils can change with the depth into the soil, and from place to place within a paddock. This is why proper soil sampling is important if you want a meaningful soil test from the laboratory.

A low pH (less than 5) can be detrimental to plant growth, not because of the acidity itself, but because of the toxicities and deficiencies it induces. Aluminium and/or manganese can be present in toxic concentrations. Phosphate availability can be poor. The only practical way to raise soil pH is with a liming material.

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, copper and manganese are poorly available at high pH.

A pH value between 4 and 8 is very common. A desirable pH ($CaCl_2$) range for plant production is 5.0 to 6.5, depending on the species and cultivar.

Organic matter

Changes in organic matter levels with time (over several years) will indicate the effects of a management system on soil condition. A high level of organic matter generally indicates good soil structure and nutrient supply. In cracking clays, organic matter may not be quite as important to soil structure as it is in other soils.

Laboratory methods for estimating soil organic matter first measure the carbon content of the soil. (Some of these methods may also measure the carbon from charcoal and from lime; this is not very helpful. Reputable labs will tell you the method they use so you can interpret the results more easily.)

Converting organic matter values

The average carbon content of soil organic matter is approximately 57%. Multiply values for total organic carbon % by 1.75 to convert to organic matter %. If the organic carbon % was measured by the Walkley-Black method, multiply by 2.3 to convert to organic matter. Reported organic matter contents should state the chemical and calculation methods used.

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. The cultivation history, sample depth and soil type affect organic matter levels markedly. In the broad context of various soil types, regard values below 1% organic matter as very low, 1% to 2% as low, 2% to 4% as generally satisfactory, and greater than 4% as high. As with much soil data, information on organic matter content becomes more useful when compared among different management histories and over time.

Soil nitrogen

Total nitrogen

Soil nitrogen occurs in many forms. Total nitrogen is a measure of the organic and ammonium forms, and sometimes includes the nitrate form as well. The ammonium and nitrate forms are available to plants. The organic forms, which make up most of the total N, become available only as organic matter is mineralised; they are a measure of the soil's potential long-term chemical fertility. Total nitrogen, in % by weight, varies from less than 0.05 (very low), to 0.05 to 0.10 (low), to 0.10 to 0.20 (normal for cropping country), to greater than 0.2% in permanent pastures.

Nitrate

Nitrate is the main form of nitrogen that is immediately available to plants. The nitrate content of soil varies during the year. Because nitrate is water soluble, it can move below the normal depth of soil sampling after substantial rain. This is why soil sampling to 30 or 60 cm is generally recommended, so as to avoid underestimating the potential supply of N in the soil. However, even a perfect soil sample can only tell you how much nitrate is in the soil at that time. The soil test cannot tell you how much N is subsequently lost due to deep leaching, or to denitrification (lost as gas). Nor can it tell you how much more N will subsequently mineralise from the breakdown of organic matter. There are various models available to help you make these guesstimates.

See Chapter D8 for more information on nitrogen use.

Each unit of N in the soil test, in mg/kg or ug/g, is equal to about 1.3 kg N/ha as fertiliser.

Electrical conductivity (salinity)

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).

ECe is the electrical conductivity of a saturated soil-water extract. The water is removed from a just-saturated soil sample by centrifuge or vacuum pump and the water extract is tested for its electrical conductivity. ECe 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 used routinely.

EC1:5 is the electrical conductivity of a suspension of 1 part air-dried soil by weight to 5 parts water by volume, as for pH (water). This is the most common method because it is easy to use. However, it is difficult to interpret: EC1:5 values need to be converted to ECe values to allow interpretation. (See below.)

A measure of total soluble salts (TSS) used to be a popular way of expressing soil salinity, and it 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 ECe. If your result sheet shows TSS, first convert the values to EC1:5 and then to ECe.

Step 1. Convert TSS to EC1:5 if necessary. TSS units are mg/kg (ppm) or g/100 (%). The following two formulae approximately relate EC1:5 and TSS:

EC1:5 (dS/m) = TSS (mg/kg) x 0.00031
EC1:5 (dS/m) = TSS (g/100 g) x 3.1
Example: TSS % of 0.015 g/100 g:
EC1:5 = 0.015 x 3.1
= 0.047 (dS/m) (approx).

Step 2. Convert EC1:5 to ECe. To obtain an approximate value for ECe, multiply EC1:5 by a factor that depends on the soil texture. (See Table B3–1.)

Miscellaneous units for electrical conductivity

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

Interpreting EC_e

Conventionally, saline soils are defined as those having 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.

Exchangeable cations

A few laboratories report exchangeable cations as mg/kg (ppm). It is more useful to express them as centimoles of positive charge per kilogram of soil (cmol(+)/kg), numerically equal to milliequivalents per 100 g of soil (me/100 g or meq/100 g). This takes into account the different valencies and atomic weights of each cation.

Step 1. Convert mg/kg to cmol(+)/kg, if necessary.
1 cmol(+)/kg of Ca = 200 mg/kg; Mg = 121 mg/kg; K = 391 mg/kg; Na = 230 mg/kg; Al = 90 mg/kg and Mn = 275 mg/kg.

Step 2. Calculate the cation exchange capacity. Add the cation concentrations to give an approximate value for the effective cation exchange capacity (the ECEC). Express each cation as a % of the ECEC, as in the example in Table C5–1.

Table C5–1. *Example of expressing cations as a percentage of the ECEC*

Cation	cmol(+)/kg	% of ECEC
Calcium (Ca)	3.3	3.3/6.6 x 100 = 50%
Magnesium (Mg)	0.7	0.7/6.6 x 100 = 10.6%
Potassium (K)	1.1	1.1/6.6 x 100 = 16.7%
Sodium (Na)	0.5	0.5/6.6 x 100 = 7.6%
Aluminium (Al)	0.8	0.8/6.6 x 100 = 12.1%
Manganese (Mn)	0.2	0.2/6.6 x 100 = 3%
ECEC	6.6	100%

Caution 1: Never add values expressed as mg/kg or ppm. The result is meaningless.

Caution 2: Free lime or gypsum can give false values for exchangeable calcium (overestimated by as much as 50%) so don't retest your soil within the first year after applying lime or gypsum.

Other cations (iron, copper and zinc) are usually present in only trace amounts, so they do not contribute significantly to the total.

In addition, soils with pH (CaCl2) above 5 contain very little exchangeable aluminium or manganese, so the effective CEC is the sum of that of the four cations: calcium, magnesium, potassium and sodium.

Step 3. Note the Na% (ESP). The exchangeable sodium percentage (ESP) in the above example is 7.6%. This value gives a guide to the potential for clay dispersion. A clay soil with an ESP greater than 6% is prone to dispersion on wetting if its salinity is low.

Step 4. Note the Al%. The exchangeable aluminium percentage in the above example is 12.1%. This value gives a guide to the potential for aluminium toxicity. A soil with values greater than 5% will affect the yield of sensitive crops such as barley, canola and lucerne. Values greater than 30% will cause even tolerant crops species, such as oats, triticale, lupins, subclover and cocksfoot, to lose yield.

Step 5. Calculate the Ca:Mg ratio. Calculate the ratio of exchangeable calcium to exchangeable magnesium (Ca:Mg ratio), with their units in cmol(+)/kg.

Using the example in Table C5–1:

Ca:Mg ratio = 3.3/0.7 = 4.7 (no units).

A Ca:Mg ratio of less than 2 (particularly, less than 1) also indicates a tendency towards dispersion for clay soils which are high in sodium. The soil in the example above has a Ca:Mg ratio of 4.7, so it is not at risk from this index of dispersion.

Step 6. Some cations are best interpreted in terms of their absolute value rather than their percentage of the ECEC. For example, the potassium (K) value should be greater than 0.2 to 0.25 cmol(+)/kg for intensive pasture production. Take care using K fertilisers if you are in a risk area for grass tetany.

Magnesium (Mg) deficiency is difficult to predict, because so many of our soils have large reserves in the subsoil.

We sometimes get confused between magnesium and manganese (Mn). Mn is an essential nutrient, but in high concentrations it can be toxic. Values greater than 0.3 cmol(+)/kg are of concern, but Mn toxicity is generally of a transient nature. The high values we get from soil tests taken before sowing generally decrease within a month after the break of season.

Exchangeable cations and clay dispersion

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

See Chapters C1, D3 and D11 for more information on clay dispersion.

In general, non-saline soils with an exchangeable sodium percentage (ESP) above 6 are liable to disperse in water. A Ca:Mg ratio less than 2 may aggravate the tendency of a high sodium soil to disperse.

Phosphorus

Phosphorus is the most controversial issue in soil testing. Phosphorus exists in soils in a range of forms with varying degrees of availability. In general, the order of availability is: soluble > adsorbed > organic > mineral forms, but there is a large amount of overlap between the various sources within these general forms.

Common soil tests extract the soluble P plus some proportion of the adsorbed P, sometimes including a little organic P. The Colwell test extracts a large proportion of the adsorbed P. The ‘critical value’ for Colwell P is about 30 to 35 mg/kg for our soils. The Olsen and Bray tests extract less of the adsorbed P and have lower ‘critical values’, typically 15 to 20 mg/kg for our soils.

See Chapter D8 for more information on soil chemical fertility.